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August 11, 2021

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MSE 411 Final Report for the Ztriker: A Smart Combat-Oriented Fitness Device

Dear Dr. Golnaraghi:

The attached document is the final report for the Ztriker: A Smart Combat-Oriented Fitness Device that is intended to assist martial artists with training. The report details the modifications completed to ensure the completion of a working first-iteration prototype.

Throughout this project, Dr. Marzouk from the Mechatronic Systems Engineering program at Simon Fraser University will provided guidance and technical insight into the iterative process as the project supervisor.

Sincerely,

Cheng Jie Huang
Team Lead
Team Sibulus

Final Report for Ztriker: A Smart, Combat-Oriented Fitness Device

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Submitted to:

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Executive Summary

This proposal for Ztriker: A Smart, Combat-Oriented Fitness (SCF) Device. The SCF Device is constructed to tackle the lack of data-driven feedback in the martial art industry by providing a consistent empirical analysis of user performance and biometrics in a portable package that martial arts practitioners of all skill levels can use.

The project began with problem discovery, which was undergone through interviews with experts in the field. From there, a set of primary goals and objectives was formed and weighted for a risk-benefit analysis. Concepts were then developed to best address the issue to solve, and the final concept was determined using a decision matrix, based on how well the concept met the functional specifications as put forward by the potential user. After the final concept was selected a set of design specifications was made to outline the requirements that the prototype device would have. A comprehensive budget and timeline was formed to guide project development towards a functional prototype, of which both budget and timeline constraints have been met. The functional prototype shares similarities to the concept but differs in key areas. However, all key functional requirements have been met, and any changes between the concept and functional prototype have been explained. There are currently no future plans for this project, but any potential future updates have been addressed, including the potential expansion towards other sports disciplines.

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Glossary

SCF	Smart, Combat-Oriented Fitness
TEB	Total Error Band
MTBF	Mean Time Between Failure
ANSI	American National Standards Institute
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
EN	European Standards
CSA	Canadian Standards Association
CGSB	Canadian General Standards Board
SpO2	Peripheral Capillary Oxygen Saturation, it is an estimate of the amount of oxygen in the blood.

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Supporting Documents

Supporting documents are as follows and have been included in the Appendices for reference.

- *Functional Specifications for the Smart, Combat-Oriented Fitness Device*
- *Design Specification for the Smart, Combat-Oriented Fitness Device*
- *Sibulus Ztriker User and Technical Support Manual*

1. Introduction

Practice makes perfect conveys the message that persistent and regular exercise of an activity or skill is the way to gain proficiency in a subject. Conventional martial art practice comes in the form of guided sessions with expert instructors along with the self-practice of fundamental movements. While self-practice can provide crucial improvements in a martial artist's skill and physical abilities, it lacks qualitative feedback to ensure consistency in performance increases. This shortcoming of conventional martial arts practice has been exacerbated by the COVID pandemic, where martial arts as a close-quarters sport have been severely limited in terms of instructorship capabilities; leaving many students without the essential guidance needed to progress their skills which can lead to dissatisfaction with progress, injury due to faulty form, and ultimately burn out and drop out.

1.1. Justification for Solution

Through interviews with experts in the martial arts industry, common pain points have been identified to form the basis of the community user profile, which is used to form the project objective. These pain points include the lack of feedback during self-training without direct expert supervision, a lack of consistent, standardized performance metrics used to gauge changes in performances, as well as the worry of potential injuries due to faulty form during high-intensity practice.

1.2. Target Audience

An ideal solution would be generalized for applications by all skill levels, improve accessibility to martial arts, and improve the skills and techniques on a per-user basis. From interviews and field research, we discovered that many beginners to martial arts train incorrectly during unsupervised learning, which leads to a lack of consistency in their progress, an unstable foundation, and sometimes injury. A personal trainer is usually the most effective way to help a beginner learn the correct way. However, access to skilled personnel for supervised learning is not feasible for most people. Therefore, we would like to create a solution that will help learners of all skill levels practice martial arts with proper form. The product will be useful in a gym environment or anywhere with enough space for the user to exercise.

2. Project Expectations

2.1. Project Goals

The primary goal of this project is to help martial artist practitioners of all skill levels overcome their performance plateau by providing data-driven performance analysis and feedback, which can be broken down into the following sub-goals:

1) Provide empirical data for martial art training sessions,
2) Establish a reference of comparison for changes in performance,
3) Reduce the likelihood of injury occurrence.

2.2. Primary Objectives and Desired Outcomes

The project's primary objectives and desired outcomes are as follows:

1) The solution should achieve accurate measurement of desired performance metrics such as:
    a. Average strike acceleration,
    b. Average strike force,
    c. Maximum strike velocity,

    With a total error band (TEB) within 10% deviation from actual values to provide users with a consistent comparison of performance progress during training.
2) The solution should achieve accurate measurement of desired biometrics such as:
    a. SpO2,
    b. Heart rate,

    With a total error band (TEB) within 10% deviation from actual values to provide the user with a consistent comparison of wellbeing during training.
3) The solution should provide data storage capability and allow for on-demand user reference of historical data.
4) The solution should provide a warning for actions that may lead to potential injury.

2.3. Secondary Objectives and Desired Outcomes

Secondary objectives of the project which are non-crucial include:

1) Limiting form factor of the solution to provide a compact solution,

2) Interfacing analytical data with companion application service to provide on-the-go user history.

2.4. Risks and Benefits

The risks and benefits associated with the creation of the Smart Combat-Oriented Device are weighted to determine the solution's impact on the end-user.

2.4.1. Risks

Based on the constraints placed upon this project through the limitation of resources, foreseeable risks encounterable includes:

- Potential injury to the user resulting from misuse.
- Data security liability through the usage of wireless communication protocols.

2.4.2. Benefits

Successful implementation of this project can result in:

- Improved mental and physical health because of reaffirmed changes to performance.
- Better self-awareness of user capabilities.
- Reduced likelihood of injury occurrences.
- Automated bookkeeping for progress updates.

3. Prototype Design

Design concepts for satisfying the project objectives included variations of wearable devices, smart striking targets, and a vision system which are then ranked using significant metrics decided upon the functional and design requirements.

3.1. Key Functional Specifications

The creation of Key functional requirements as detailed in *Functional Specifications for the Smart, Combat-Oriented Fitness Device* is considered in the design selection process for the solution [1]. The solution will be able to record and transmit biometrics and performance sensor data to the backend companion for post-sessional processing to determine historic quantitative changes in training quality. The solution will be usable with a wall supply of 110V/120V at 60Hz AC to ensure compatibility with standard North American consumer electrical outlets and conform to ANSI, IEC, ISO, EN, CSA, and CGSB standards. The solution should have a duty cycle of no less than 1,000,000 cycles and achieve a Mean Time Between Failure (MTBF) of no less than 5000 hours to ensure reliability during day-to-day operation. The solution should respond to user inputs within 500ms and be capable of communicating recorded user data with five minutes as a minimum acceptable threshold for response and communication rate. The solution should report measurement of the primary indicators mentioned in section 2.2 with an acceptable TEB of 10% deviation.

3.2. Design Matrix

By establishing important metrics of consideration for the project development cycle, a decision matrix, listed in Table I, is created to rank the design concepts considered to satisfy the functional requirements. The wearable device is chosen as the main implementation due to its portability and wide application range in comparison to smart targets and vision systems which are more rigid and immobile in practice.

Table I. SCF Device Design Matrix

		Wearables			Targets			Vision System
Metrics	**Weights**	Smart Band	Sleeve with padding and wrist position tracking	Sleeve without padding and wrist position tracking	Free-Standing Target	Wall-mount target	Handheld target	Motion Tracking for form monitoring
Cost	4	4	3	3	1	1	5	3
Manufacturability	3	4	3	4	2	2	4	5
Safety	5	1	5	4	1	1	1	5
Reliability	4	4	3	4	2	2	3	4
Portability	4	5	5	5	1	1	4	2
Visual Appeal	3	3	4	3	2	2	1	1
Usefulness	5	3	5	4	4	4	3	4
Innovativeness	2	1	3	2	2	2	4	1
Compatibility	4	4	2	4	5	5	5	4
	Weighted Score	111	129	129	77	77	111	117
	Rank	3	1	1	5	5	4	2

3.3. Design Usage

The preliminary prototype is intended for use and testing by members of team Sibulus as a proof-of-concept model to iteratively progress functional solution capability through collaboration with potential stakeholders to achieve a market-ready product for the public.

3.4. Design Specifications

Detailed design implementation methods are described in *Design Specifications for the Smart, Combat-Oriented Fitness Device* to meet the functional requirements set out for the project which can be broken down into the mechatronic subsystems of mechanical, electrical, and software [2].

3.4.1. Concept Mechanical Design Specifications

The physical format of the SCF device is a wearable that is constrained to the user's forearm and is comprised of three main components: the measurement unit that houses the battery, processor, and main performance sensors; the sleeve that secures the measurement unit to the arm, and the flex sensor for monitoring the position of the user's wrist. The layout for the proof-of-concept SCF device is shown in Fig.1. For the concept device, the measurement unit has external dimensions of 5 x 6.5 x 18 cm, while the sleeve has a length of 16 cm; these values are below the maximum determined values as present in the *Design Specifications for the Smart, Combat-Oriented Fitness Device* of 5 x 10 x 2 cm for the measurement unit and a length of 20 cm for the sleeve, allowing for expansion in future iterations. The sleeve of the SCF device has a nominal circumference of 13 cm and is intended to be flexible and expand to snugly fit the user's arm.

The proposed material for the measurement unit is ABS plastic, as ABS is easily acquired and formed, and has relatively high durability and good chemical compatibility depending on the manufacturing process. The sleeve will be made of a polyester blend due to the moisture-wicking properties of polyester and high abrasion resistance. Further details regarding the mechanical design can be found in Appendix 1: Concept Mechanical Design Details.

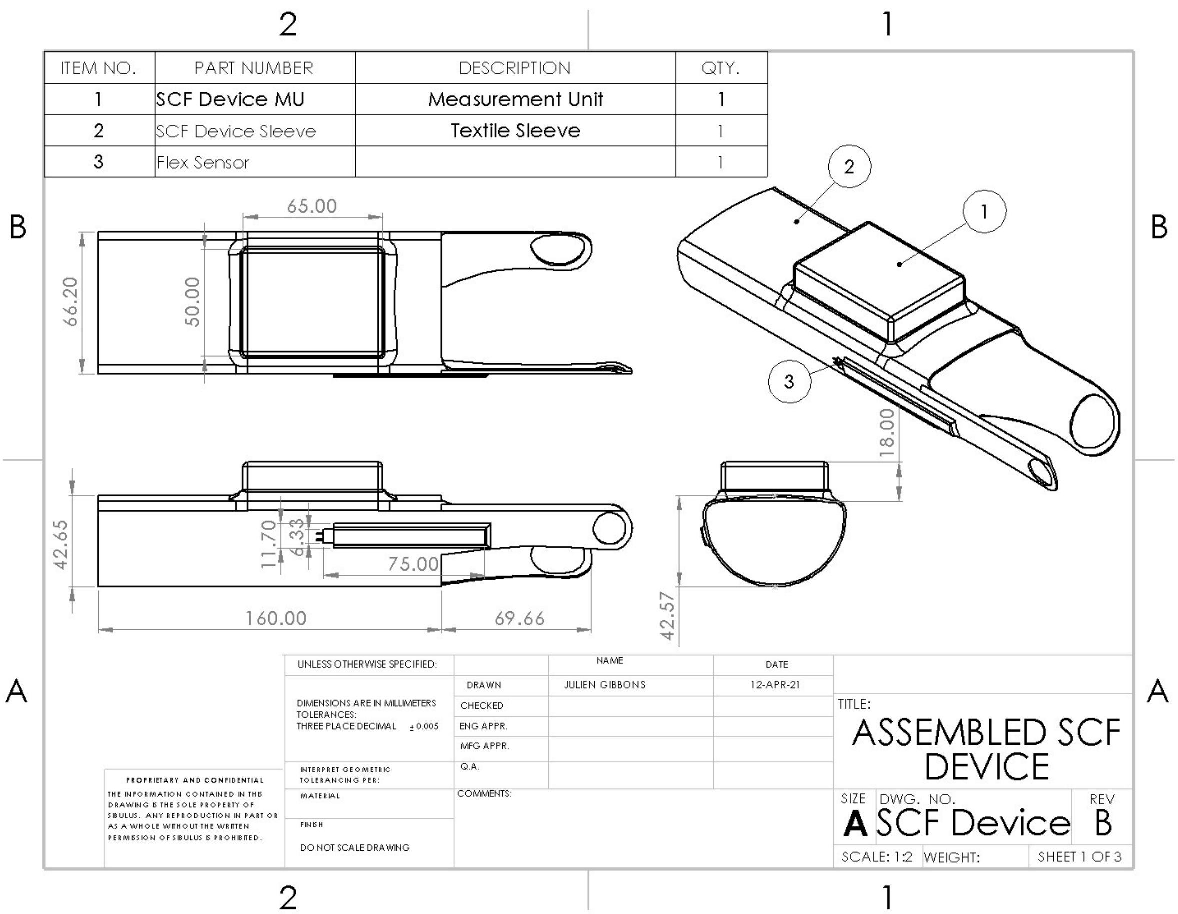


Figure 1. The physical layout of the proof-of-concept SCF device

3.4.2. Concept Electrical Design Specifications

The electrical design of the device consists of the selection of modules to provide the desired functionality and compatibility within the entire circuit design. The Arduino Nano 33 IOT is when combined with the desired peripheral components enables fast implementation, support resources, and desired features. Included in the Arduino IoT subsystem is an LSM6DS3 6-axis gyroscope and accelerometer. The LSM6DS3 meets functional specification requirements of 16g acceleration measurements, SPI/I2C interface, and data sampling rate of 1kHz which enables accurate plotting and analysis of each impact. The Arduino Nano 33 IOT also comes with built-in u-Blox NINA-W102 Bluetooth/Wi-Fi module and an ATECC608A CryptoAuthentication™ Device to ensure wireless communication safety.

The Arduino nano IoT board is connected to a resistive flex sensor, heart rate sensor, an SPO2 sensor, and a li-ion battery. The FS-L-0055-253-ST flex sensor from Spectra Symbol was chosen as the flex sensor due to its durability, a suitable length of measurement for wrist angles, and low nominal resistance of 25 kΩ with a maximum resistance of 100 kΩ. The selection for heart rate and SPO2 sensor is the MAX86140 version B. The MAX86140 performs heart rate and oxygen saturation measurements from the wrist and transfers data to the MAX32664 biometric sensor hub. The MAX32664 performs algorithmic calculations such as digital filtering, pressure/position compensation, and R-wave detection to measure pulse rate in bpm. With automatic gain control, power usage is minimized. Additional features are embedded to provide a high signal-to-noise ratio and ambient light rejection suitable for outdoor use. The battery was chosen to meet the system voltage and total runtime requirements of 3.3V and 500mAh enabling an ideal minimum single charge runtime of 72 hours. The systematic integration of electrical components will enable processing and wireless transmission of biometric and kinematic data to a smartphone or computer. Further electrical design details including a full schematic of the device and component specifications are included in Appendix 2: Concept Electrical Design Specifications.

Table II. Electrical Components

Electrical components	
Controller	SAMD21 Cortex M0+
Radio Module	u-Blox NINA-W102
Secure Element	ATECC608A
IMU	LSM6DS3
Flex Sensor	FS-L-0055-253-ST
Heart Rate SPO2	MAX32664
Biometric Processor	MAX86141
Battery	3.7 V nominal, 500mAh

3.4.3. Concept Software Design Specifications

The software subsystem is responsible for interfacing the data provided by the electronic subsystem, facilitating data transfer and data analysis, and reporting the key data features to the end-user. An overview of the data flow is shown in Figure 2. Various raw sensor signals will be filtered, recorded, and transferred from the measurement unit to the companion device for analysis. Injury warning functionality will be implemented using a form detection algorithm on-board the measurement unit to limit overhead communication between devices. Upon receiving the transferred training data, the companion device software will process the data using signal processing methods such as normalization and data smoothing before applying time domain and frequency domain analysis along with Machine Learning to facilitate key feature extractions of the primary objective variables such as strike acceleration, velocity, and force. The resulting interpreted data will then be stored locally on the device and be readily available for user review.

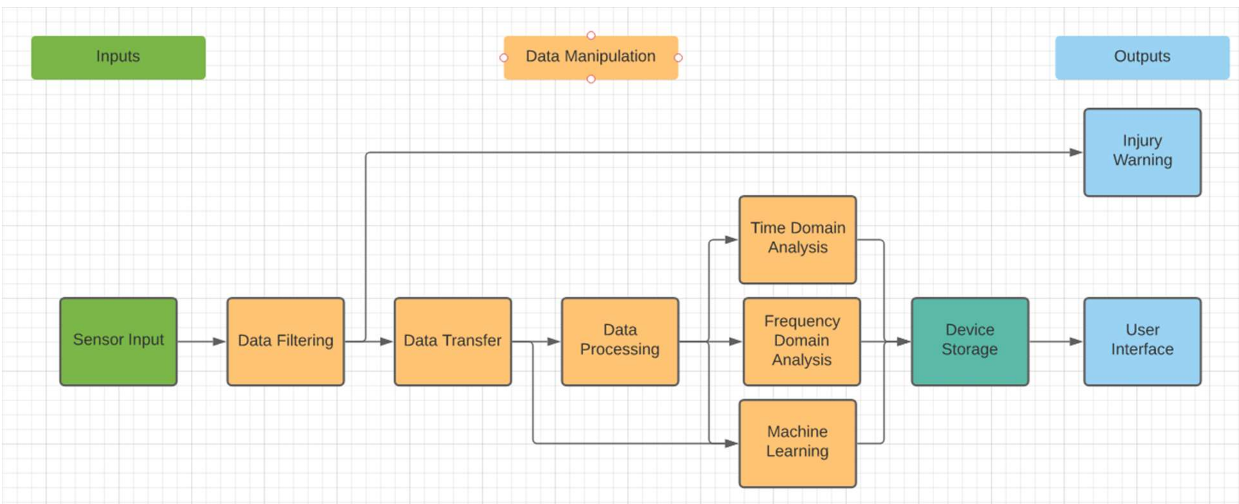


Figure 2. Data Flow Block Diagram

3.5. Functional Prototype Design Specifications

The functional prototype for the Ztriker is very similar to the concept prototype electrically, with minor changes such as a smaller 110 mAh instead of the proposed 400 mAh, and a different battery charger given that during testing the previously selected battery charger was damaged. Mechanically however the functional prototype differs greatly from the concept in that the dimensions have changed, as has the layout and selected materials. The new prototype layout is shown and described in Figure 3 and Table III respectively.

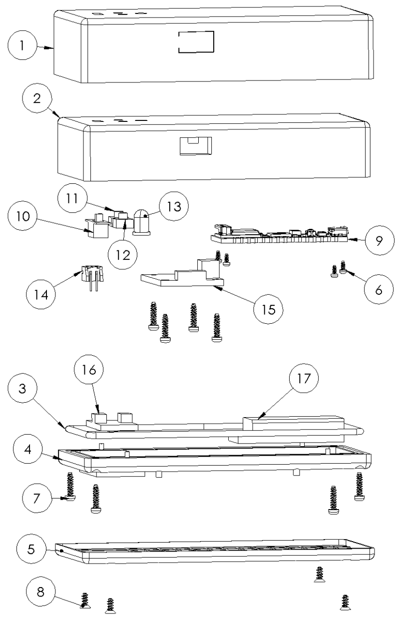


Figure 3. Functional prototype measurement unit layout

Table III. Functional prototype measurement unit components

#	Item	#	Item
1	Dust Cover	10	Power Switch
2	Measurement Unit Upper Case	11	Sync Button
3	O-Ring	12	Record Button
4	Measurement Unit Lower Case	13	Status LED
5	Attachment Plate	14	Injury Detection Sensor Connector
6	3mm M1.4 Torx Head Thread Forming Screw	15	Battery Charging and Monitoring Module
7	8mm M2 Torx Head Thread Forming Screw	16	Heartrate and SpO2 Sensor
8	5mm M2 Phillips Head Thread Forming Screw	17	Battery
9	Primary Processing and Radio Module		

While the initial concept had dimensions of 5 x 6.5 x 18 cm with a sleeve length of 20 cm with a circumference of 13 cm, the functional prototype has dimensions of 5 x 10 x 2.4 cm with a sleeve length of 20 cm and a circumference of 18 cm. The increased size of the functional prototype was due in part to a change in layout to make the prototype easier to remove but was also due to the electrical components being larger than initially anticipated. To account for the increase in sleeve circumference Velcro straps were added to allow for adjustable tightness. The change in material was mainly due to the availability of materials locally. The material for the measurement unit was changed from ABS to PETG as on further research it was determined that PETG is cheaper and easier to work with, while having similar mechanical properties and better biocompatibility. The material for the device sleeve was changed from a polyester blend to a merino wool-spandex blend, as that is what was available locally, and satisfied many of our design requirements. The assembled functional prototype is shown in Figure 4. Due to issues with manufacturing and time constraints, the silicone rubber dust cover and gasket were unable to be implemented at this time.

Figure 4. Assembled functional prototype

The digital dashboard for the functional prototype was made using the Arduino IoT cloud (see Figure 5), as it allowed for us to test the wireless capabilities of the functional prototype quickly and easily.

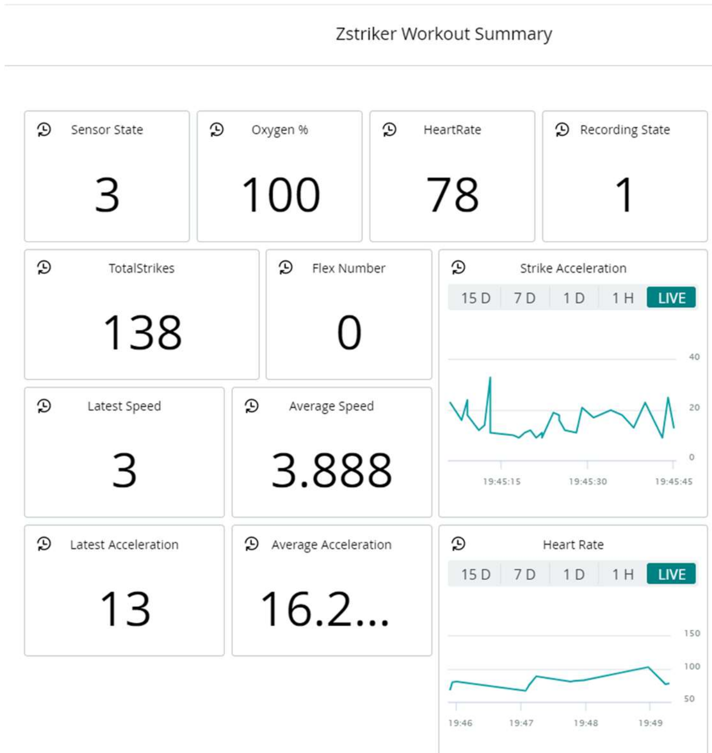
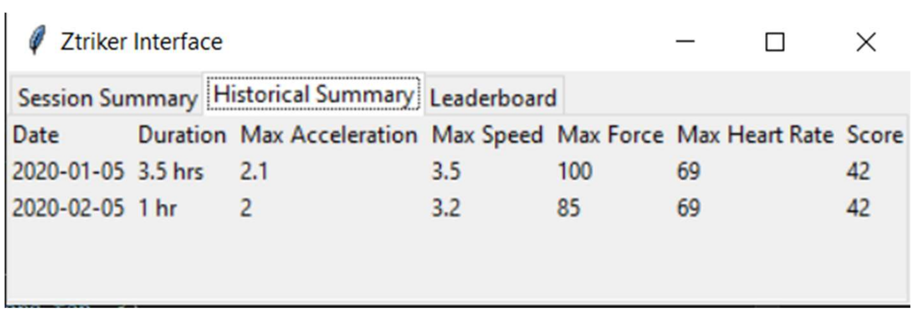


Figure 5. Functional prototype Arduino IoT digital dashboard

A custom user interface (shown in Figure 6) was also designed but was not implemented given time constraints.



Date	Duration	Max Acceleration	Max Speed	Max Force	Max Heart Rate	Score
2020-01-05	3.5 hrs	2.1	3.5	100	69	42
2020-02-05	1 hr	2	3.2	85	69	42

Figure 6. Custom functional prototype user interface

Additional design details are included in Appendix 3. Functional Prototype Design Details.

4. Technical Challenges

Foreseeable technical challenges include:

1) The solution's ability to withstand repetitive striking without deformation, which will be addressed through unit testing of the device to ensure the reliability of the final marketed device.
2) Accurate sampling of striking data, which will be ensured through comparison of measured data from the prototype to a known reference to evaluate accuracy.
3) Scalability of product to ensure end-users at all skill levels will be optimized through iterative design improvements accomplished with the feedback of a wide variety of potential stakeholders and end-users.
4) Achieving pseudo-real-time sampling, and data analytic capabilities by setting a reasonable response rate for the system to be adhered to throughout the software development cycle.

4.1. Design Constraints

4.1.1. Budget

To keep development costs within a reasonable limit we were allocated a total budget of CAD 2000.

4.1.2. Material limitation

The selected materials for the SCF device are required to meet five key requirements:

- Durability
- Weight
- Chemical compatibility
- Biocompatibility
- Ease of manufacture

The selected materials must be durable enough to withstand prolonged daily use at mid to high-intensity training sessions while having a low enough weight that the total weight of the device is not noticeable during use. The materials selected must also be compatible with a range of chemicals for cleaning purposes and be safe for human contact. Finally, the selected materials must have a high ease of manufacture to keep production costs and time as low as possible.

4.1.3. Compatibility

The physical design of the SCF device should have a low enough profile that it is compatible with existing equipment used for martial arts training. The software design of the SCF device should be compatible with a range of platforms.

5. Project Development Timeline and Expenses

The project development timeline and phase one wearable budget are listed in Figure 7 and Table IV respectively. Market research took place during the first three months of the development process, followed by the technical implementation of prototype components which took place in the following three months. The final two months were then reserved for iterative updates to prototyping functionality. While the first four months of project development were plagued with setbacks that delayed technical progress, the last four months have been relatively unscathed, allowing us to accomplish most if not all of our key required tasks. Currently, the first iteration prototype is completed and ready for alpha testing with potential partners in the martial arts industry to gain vital insight prior to initiating phase two of development. All in all, we only ended up using half of our total allocated budget, with the vast majority of the costs spent towards the electrical components required to implement the functional prototype. The budget lists the components needed to implement the wearable prototype with the described functionalities, with the remaining budget available for potential expansion into phase two using a deep vision system. Due to component failures during testing, replacement components were required to be purchased.

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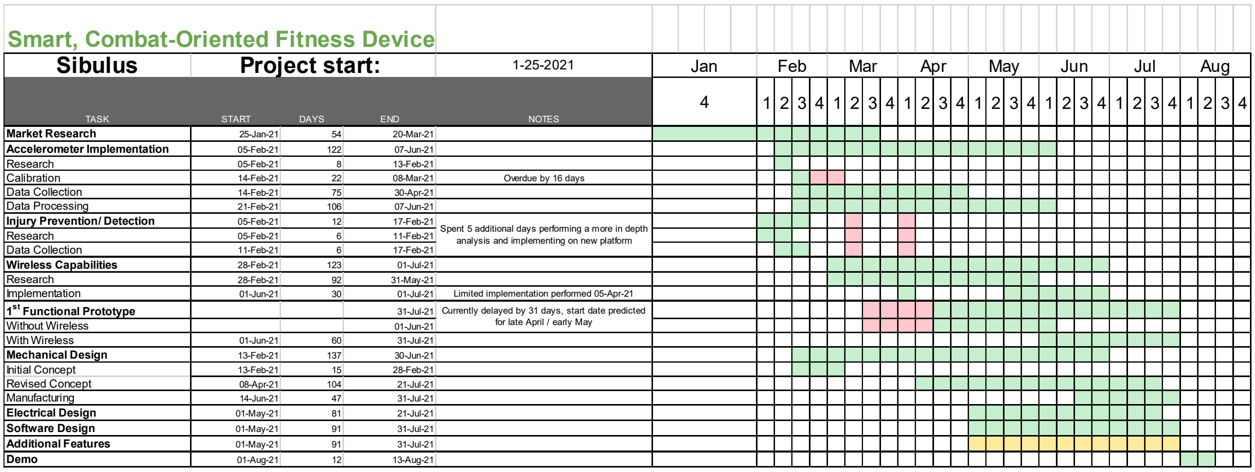


Figure 7. Development Timeline

Table IV. Phase one wearable budget

Purchaser	Description	Supplier	Price	Quantity	Taxes	Shipping	Cost
Julien	Pressure Sensor	Amazon	$16.79	2	$0.00	$0.00	$33.58
	Electrical Components	Amazon	$20.99	1	$0.00	$0.00	$20.99
	ADC Converter	Amazon	$15.99	1	$0.00	$0.00	$15.99
	Flex Sensor	Amazon	$17.56	1	$0.00	$5.99	$23.55
	Arduino nano 33 IOT	Amazon	$29.00	2	$6.96	$5.99	$70.95
	Female Clincher Connector	Digikey	$2.41	2	$2.15	$8.00	$14.97
	Male Clincher Connector	Digikey	$2.67	2	$0.00	$0.00	$5.34
	2 Circuit OpAmp	Digikey	$0.76	2	$0.00	$0.00	$1.52
	4 Circuit OpAmp	Digikey	$1.84	2	$0.00	$0.00	$3.68
	2 Wire JST Jumper	Digikey	$1.27	2	$0.00	$0.00	$2.54
	Fabric, Needles and Thread	The Stichery	$14.85	1	$1.30	$0.00	$16.15
	Assembly Hardware Screws	McMaster-Carr	$31.61	1	$3.28	$50.50	$85.39
	Silicone Mold Making Kit	Amazon	$39.99	2	$0.00	$0.00	$79.98

Chris	Sparkfun SPO2/heart rate	Sparkfun	$39.95	1	$0.00	$3.37	$43.32
	Arduino nano 33 IOT	Amazon	$29.00	2	$6.96	$5.99	$70.95
	Li-ion Battery	Adafruit	$12.50	2	$0.00	$0.00	$25.00
	DC/DC charger	Adafruit	$14.95	1	$0.00	$0.00	$14.95
	ESP32 feather	Adafruit	$51.30	1	$22.85	$23.67	$97.82
	BLE Sense	Amazon	$39.50	1	$0.00	$5.05	$44.55
	DK-42688-P -ND	Digikey	$193.17	1	$23.18	$0.00	$216.35
	LAUNCHXL-CC2640R2	TI	$51.96	1	$7.31	$9.00	$68.27
	Push Buttons and LED's	Lee's elec	$9.90	1	$0.69	$0.50	$11.09
Michael	MPU6050	Amazon	$12.98	1	$0.00	$0.00	$12.98
	Konect Adapter	Amazon	$14.99	1	$0.00	$0.00	$14.99
	3D Filament	Amazon	$38.18	1	$0.00	$0.00	$38.18
	Smart Bluetooth Adapter	Amazon	$31.32	1	4.09	7.61	$43.02
					Total Cost		$1,076.10
					Remaining Budget		$924

6. Team Member Biographies

6.1. Michael Huang

As a senior Mechatronic Systems Engineering Student with experience in software integration, artificial intelligence, and innovative design, Michael is the software lead. Having achieved an overall ranking of black stripe in taekwondo, Michael hopes to advocate for martial arts as a constructive method to help individuals overcome performance plateaus.

6.2. Julien Gibbons

Julien is a senior Mechatronic Systems engineering student, who is the acting mechanical lead, with experience in CAD design, 3D printing, and prototype development. Julien was formally a taekwondo instructor and has firsthand knowledge of the difficulties experienced by martial arts practitioners at all levels.

6.3. Chris Vattathichirayil

Chris is a fourth-year Mechatronic Systems Engineering student with an interest in hardware and RC hobbies. Previously, Chris has assisted in the research of additive manufacturing and customer service. Chris has an interest in martial arts.

7. Future Plans

Currently there are no plans to continue with Sibulus, given a lack of progress on the business side of operations. Future technical updates would have included a reduction in the footprint of the device due to a custom PCB drastically shrinking the space required for the electrical components, updates to the materials to more closely align with our proposed materials, and the development of a custom method of monitoring the wrist of the user, which would increase reliability and durability. The future design concept is shown in Figure 8.

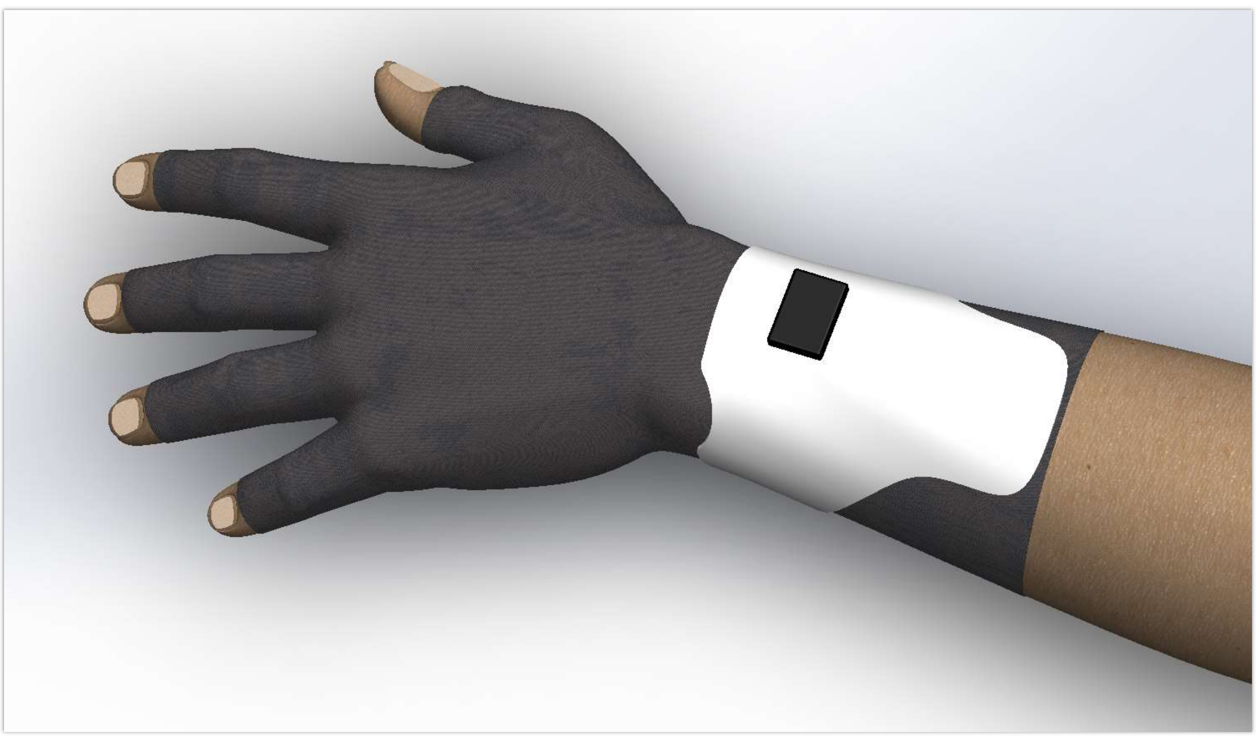


Figure 8. Future design concept

Potential software updates would have been the implementation of the custom user interface, inclusion of a deep vision system for increased monitoring of technique, and development of a mobile app.

There is potential for the selected technology in sports disciplines outside of martial arts, and that would have been the next logical step if we had planned to continue Sibulus: the expansion towards a system of devices that provide tailored, useful information to an athlete based on their sport of choice.

8. Conclusion

Despite numerous difficulties and setbacks, the functional prototype for the Ztriker was completed on time, under budget, and accomplishes the key objectives as set forth by team Sibulus. The Ztriker is a portable, wearable device that records and displays performance metrics such as strike speed and frequency, health metrics such as heartrate and SpO2, and monitors the position of the user’s wrist to warn of potential injury. Not implemented at this moment are the secondary objectives as set forth by team Sibulus, instead these objectives have been included as part of the potential future updates to the Ztriker.

8. References

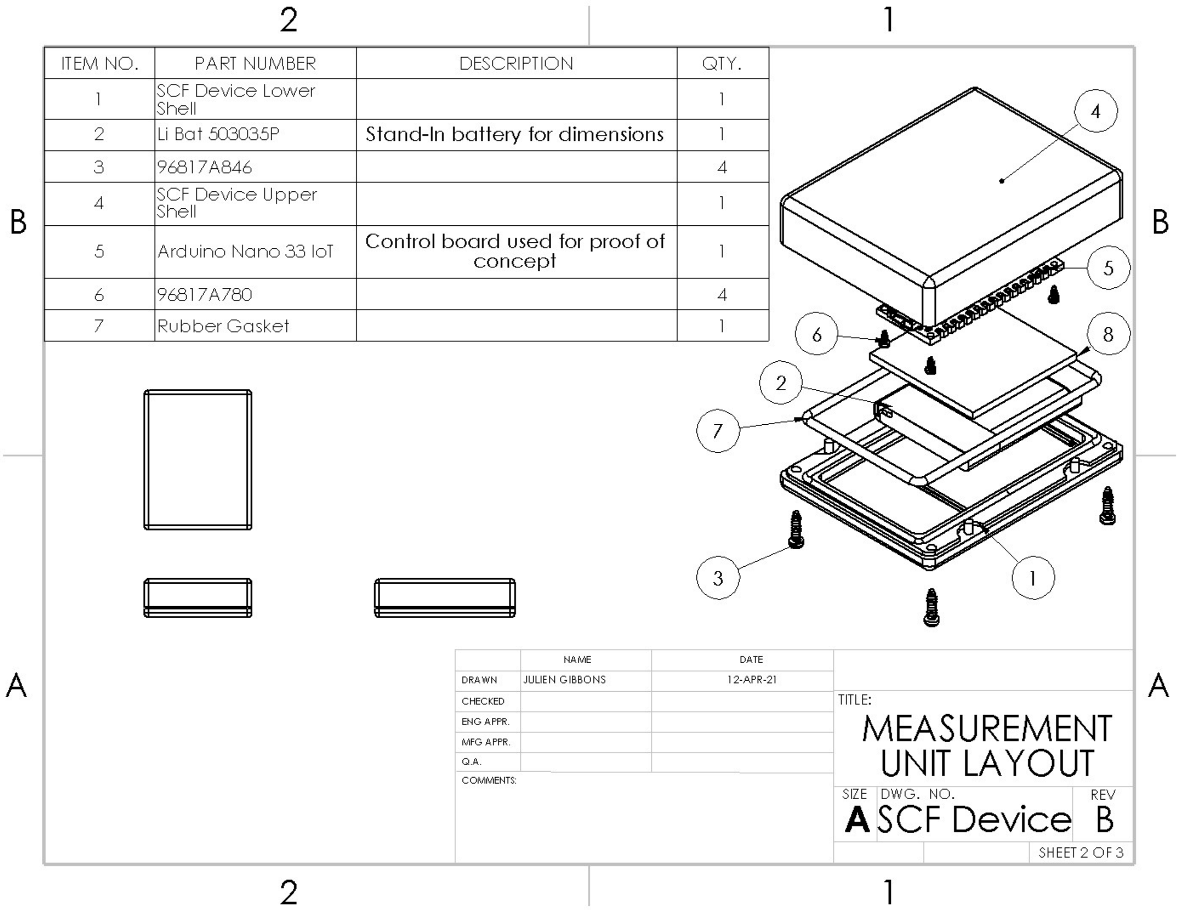
[1] J. Gibbons, C. J. Huang and C. Kurian, "Functional Specifications for the Smart, Combat-Oriented Fitness Device," Sibulus, Surrey, 2020.

[2] J. Gibbons, C. J. Huang and C. Kurian, "Design Specifications for the Smart, Combat-Oriented Fitness Device," Sibulus, Surrey, 2021.

[3] Dielectric Manufacturing, "ABS Characteristics," 24 March 2020. [Online]. Available: https://dielectricmfg.com/knowledge-base/abs/. [Accessed 14 April 2021].

9.Appendices

Appendix 1. Concept Mechanical Design Details



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	SCF Device Lower Shell		1
2	Li Bat 503035P	Stand-In battery for dimensions	1
3	96817A846		4
4	SCF Device Upper Shell		1
5	Arduino Nano 33 IoT	Control board used for proof of concept	1
6	96817A780		4
7	Rubber Gasket		1

Figure 9. Internal layout of the measurement unit

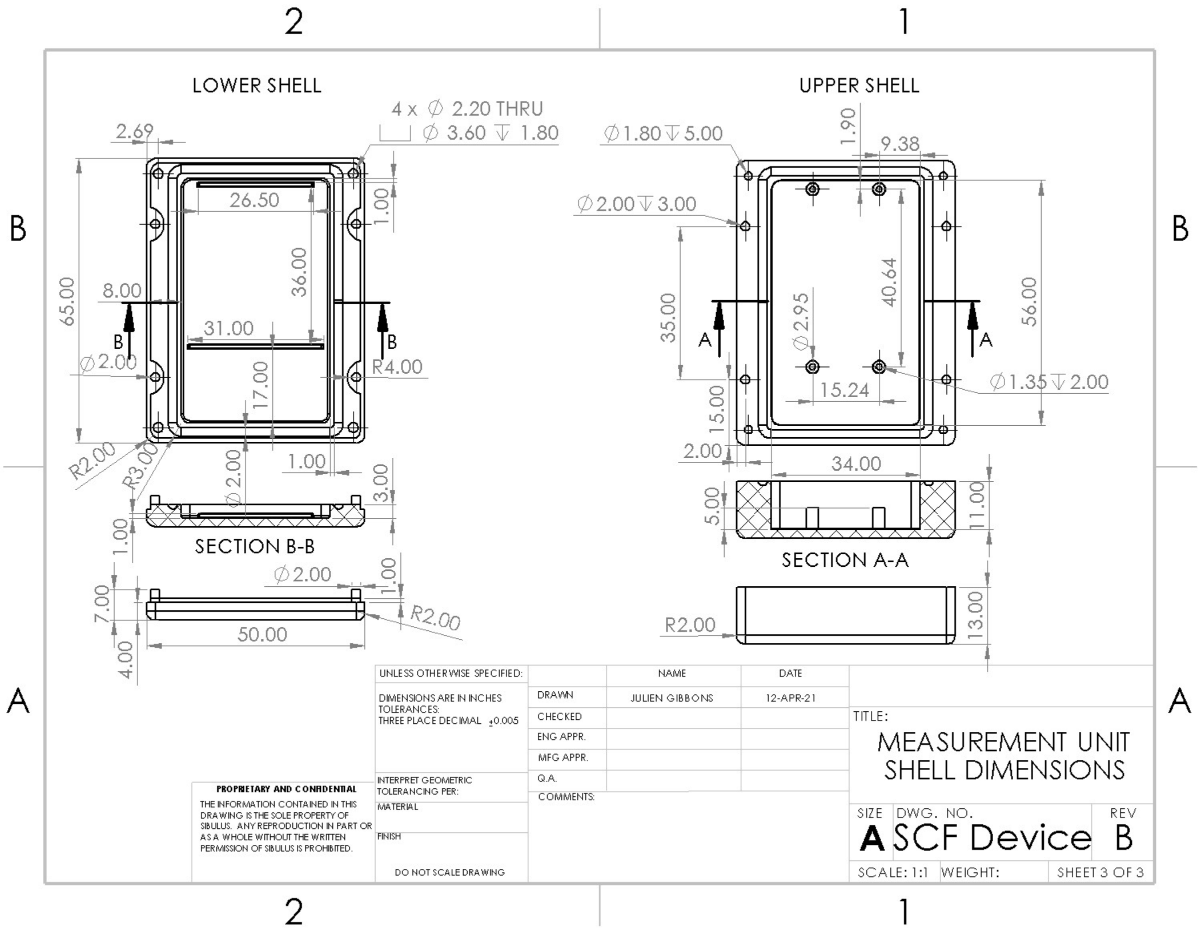


Figure 10. Measurement unit dimensions

Table V. Material Characteristics of ABS [3]

Property	Value
Density (kg/m^3)	1.01e3 – 1.21e3
Young's Modulus (Pa)	1.19e9 – 2.9e9
Tensile Strength (Pa)	2.76e7 – 5.52e7
Yield Strength (Pa)	1.85e7 – 5.1e7
Fracture Toughness ($Pa * m^{\frac{1}{2}}$)	1.19e6 – 4.29e6

Appendix 2. Concept Electrical Design Details

Table VI. Arduino Nano 33 IOT parameters

Arduino Nano 33 IOT	
Controller	SAMD21 Cortex®-M0+ 32bit low power ARM MCU @ 48 MHz
Radio Module	u-blox NINA-W102
Operating Voltage	3.3 V
Memory	256 KB (Flash), 32 KB (SRAM)
GPIO	23
Dimensions	18 x 45 mm @ 5g

Inertial measurement Unit:

Table VII. LSM6DS3 Parameters

LSM6DS3	
Max Power Draw	1.25 mA
FIFO	8 kB
Accelerometer Range	±2/±4/±8/±16 g
Gyroscope Range	±125/±250/±500/±1000/±2000 dps
Interface	SPI/I^2C
Sampling Rate	1.6 kHz (Gyroscope) / 6.66 kHz (Accelerometer)

Flex Sensor:

Table VIII. FS-L-0055-253-ST Parameters

FS-L-0055-253-ST	
Flat Resistance	25K Ohms
Resistance Tolerance	± 30 %
Bend Resistance Range	45K to 125K Ohms
Power Rating	0.50 Watts continuous
Cycle life	> 1 million cycles
Height	0.43mm
Temperature Range	-35°c to +80°c

Heart Rate and SPO2 sensor:

Table IX. MAX32664 and MAX86141 parameters.

MAX32664 and MAX86141 Parameters

Power Supply Voltage (VDD)	1.7-2.0 V
LED Supply Voltage (VLED)	3.1-5.0 V
Supply Current (IDD)	600 µA
Supply Current in Shutdown	0.7 µA
ADC resolution	18 bits
ADC output data rate	50-3200 sps
Communication	I2C, SPI

Battery:

Table X. Potential Battery Parameters

Dimensions	29mm x 36mm x 4.75mm
Weight	10.5g
Capacity	500 mAh nominal
Voltage	3.7 V nominal
Cycle life	> 300 cycles

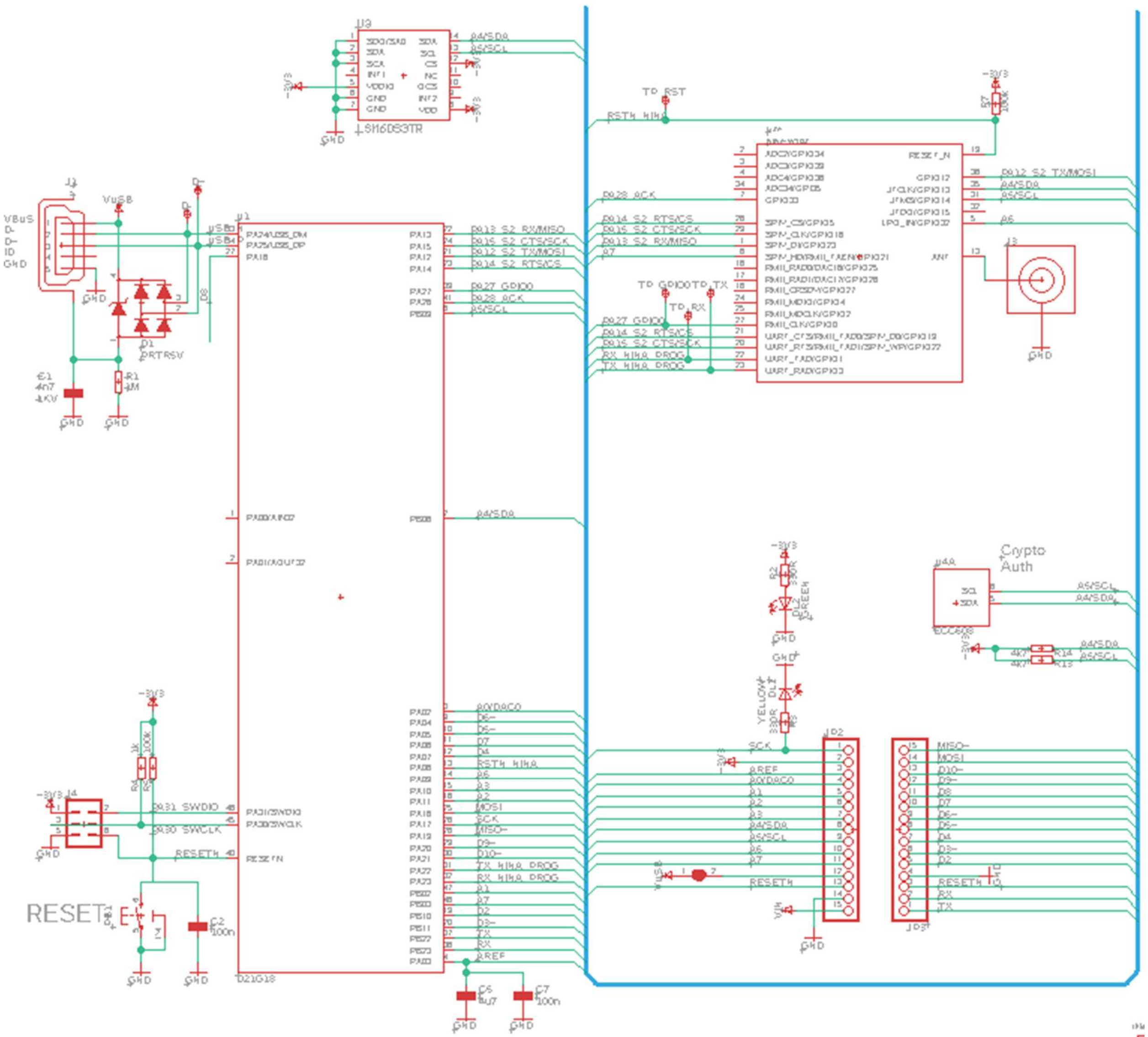


Figure 6. Schematic Design Arduino Nano IoT

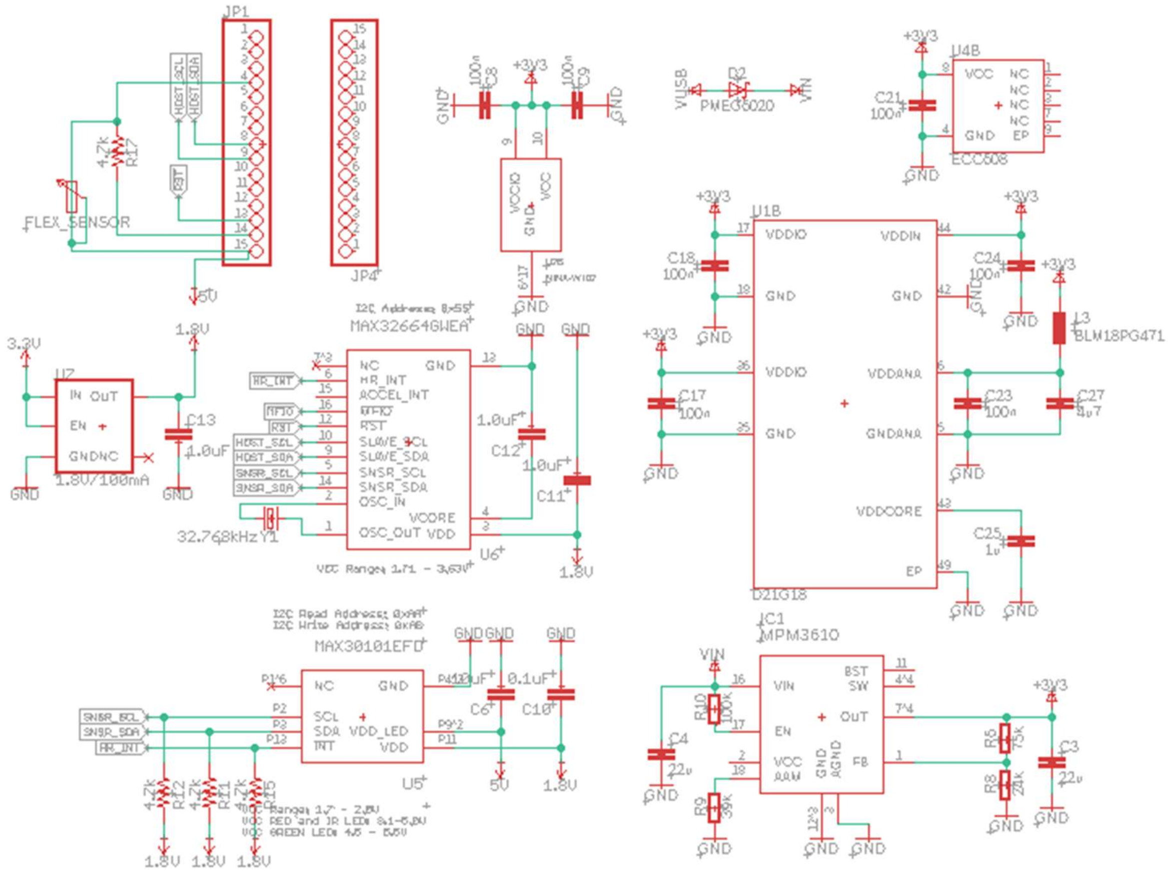


Figure 7. Schematic Design Arduino Nano IoT

Appendix 3. Functional Prototype Design Details

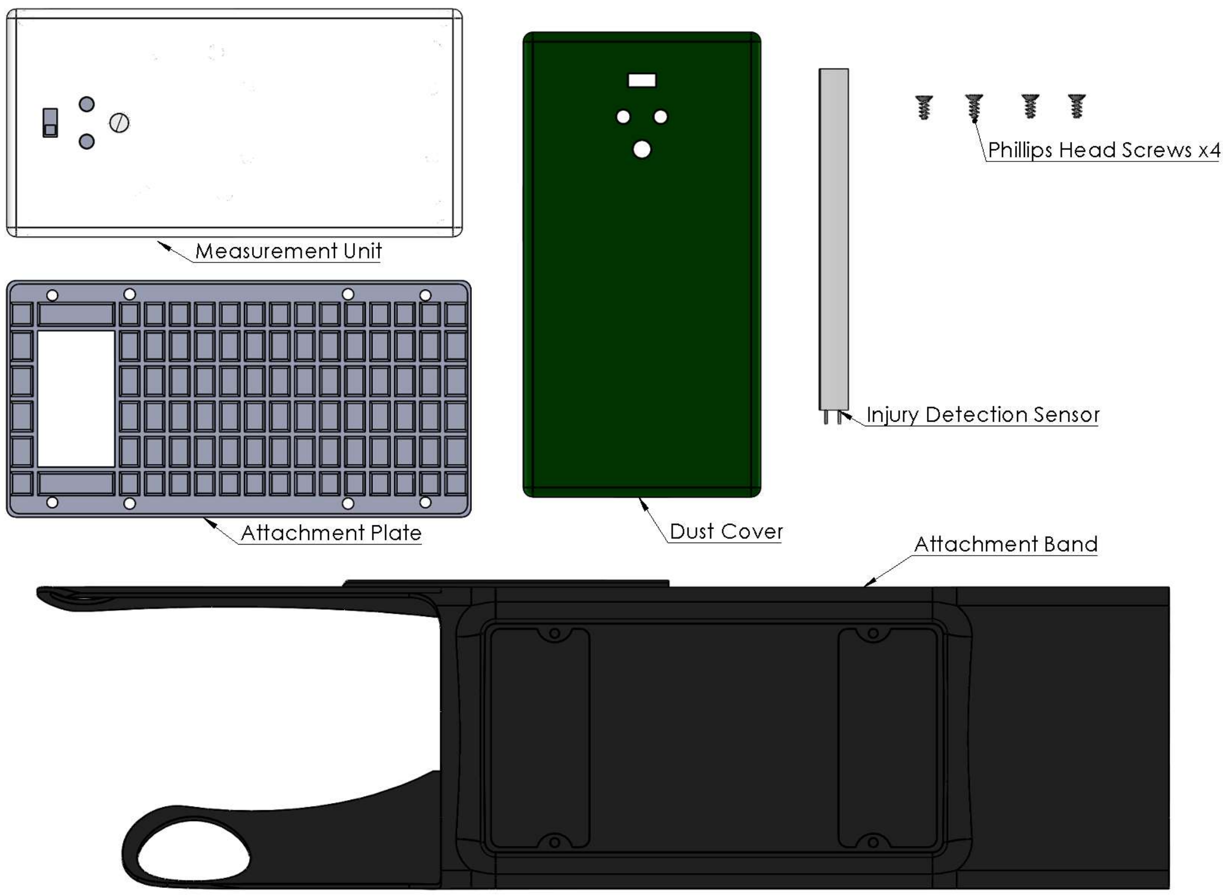


Figure 11. Functional prototype exterior components

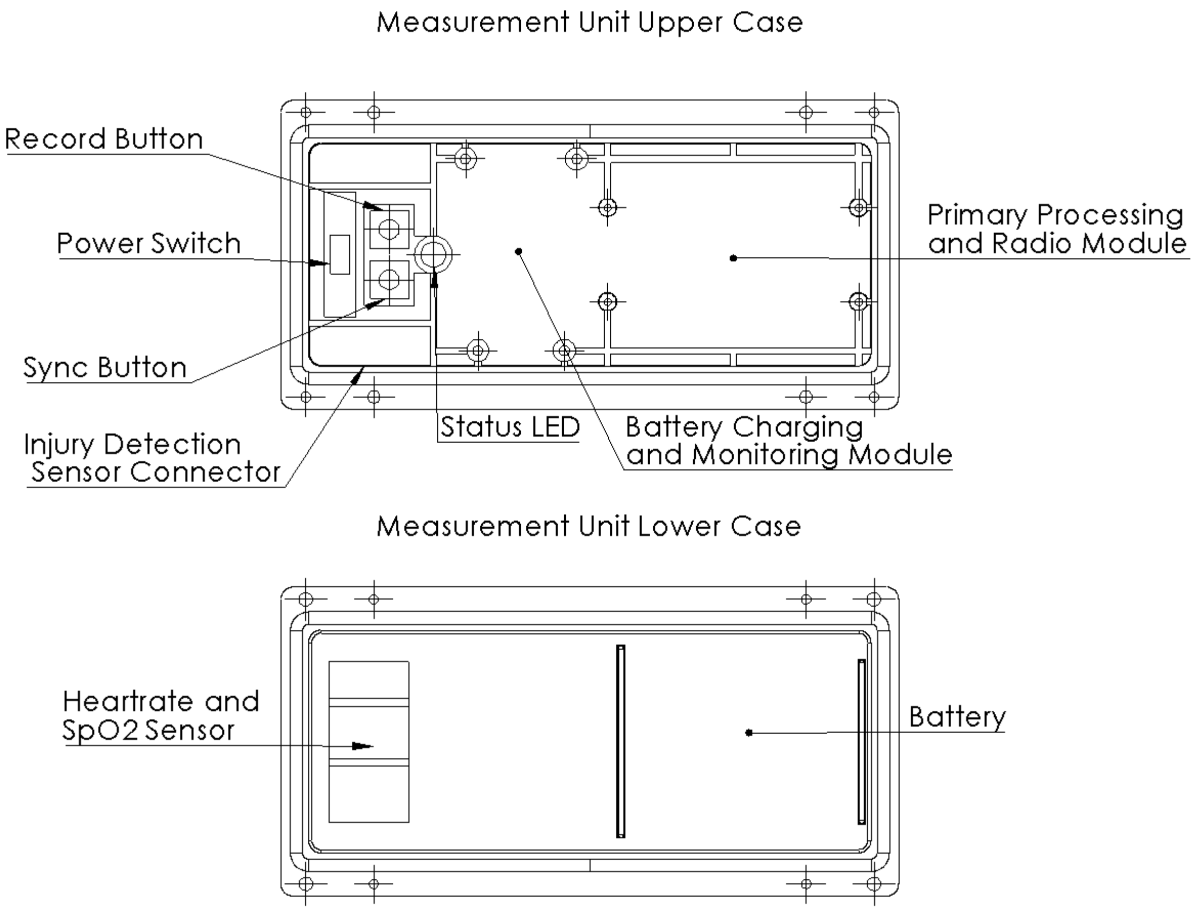


Figure 12. Functional prototype measurement unit interior layout

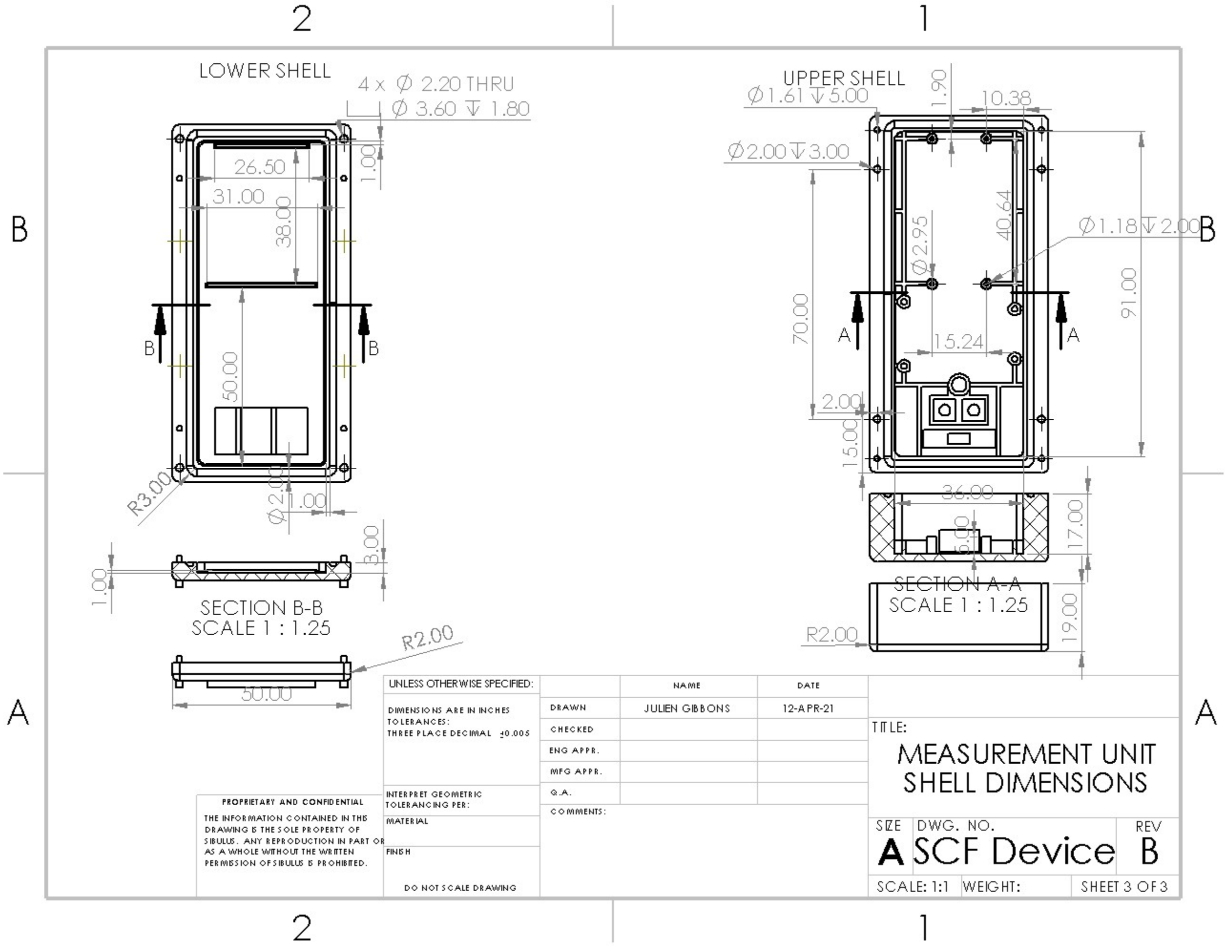


Figure 13. Functional prototype measurement unit dimensions

Functional Specifications for the Smart, Combat-Oriented Fitness Device

February 22nd, 2021

Dr. Farid Golnaraghi
Professor
School of Mechatronic Systems Engineering
Simon Fraser University
13450 102 Ave #250
Surrey, BC V3T 0A3

RE: MSE 410 Functional Specifications for Smart Combat-Orientated Fitness Device

Dear Dr. Golnaraghi,

The attached document is the functional specification report for the Smart Combat-Orientated Fitness Device designed to improve user striking martial art performance. The product will provide quantitative feedback and injury warning to the user. This report is a technical guideline and applies to the proof-of-concept prototype, as well as our final design.

Our functional specification provides a high-level overview of the intended solution functionality throughout the development cycle. Our project manager, design engineers, and test engineers will reference this document throughout the duration of research and development.

We would like to thank Dr. Marzouk as well as the other Co-champions of Technology Entrepreneurship for their mentorship and support. We look forward to providing the next generation of data-driven martial art accessory. Your consideration of our proposal is greatly appreciated.

Sincerely,

Cheng Jie ("Michael") Huang
President
Sibulus

Executive Summary

Attached to this document is a proposal that describes the functional specifications for the Smart Combat-Oriented Fitness Device by Sibulus, an organization dedicated to driving forward the world of martial arts with data. While the sports and fitness industry has seen an explosive incorporation of smart technology applications to aid athletic development in recent years, the martial art industry has remained stagnant and opted for traditional practices.

Sibulus' mission is *"to deliver a device that will help martial artists and combat-sport based fitness practitioners of all skill levels to overcome their performance plateaus by providing data driven performance analytics and feedback, as well as promote positive mental health."* With the restrictions placed upon the world due to the COVID-19 pandemic, the need for data-supported progress is more apparent than ever. Through the application of motion tracking, biometric scanning, as well as artificial intelligence, Sibulus will create a comprehensive wearable that can provide users the data they need to consistently outperform themselves.

The functionality of the Smart Combat-Oriented Fitness Device can be broken down into two major segments: prototype, and marketable product. The functional constraints for each iteration as well as a general overview of the system functionality will be detailed in the following report along with any additional information required to provide users an understanding of the solution offered, and the production team the necessary guidance for developing the solution.

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Glossary

ANSI	American National Standards Institute
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
EN	European Standards
CSA	Canadian Standards Association
CGSB	Canadian General Standards Board
SpO2	Peripheral Capillary Oxygen Saturation. Is an estimate of the amount of oxygen in the blood.
Mean Time Between Failure (MTBF)	The average time required for a failure to occur in a system during normal operation.

1. Introduction

COVID19 has placed many restrictions upon the martial art world including the limitation of instructorship and guidance for martial art practitioners to receive proper feedback. The Smart Combat-Oriented Fitness (SCF) Device is a wearable device that will provide quantitative data to striking based martial arts practitioners, and combat sports enthusiasts while preventing injuries. The requirements for the SCF Device, as proposed by Sibulus, are described in this functional specification.

Explosive power, agility, and endurance are core components of every martial art practice [1]. As such, the improvement of these areas is vital in dictating the performance for martial artists. Through analyzing the biometric parameters and movement of the practitioners during practice, better feedback can be generated based on the gathered quantitative data to provide details to be improved upon for the user to overcome their plateau. As a result, key features identified for extraction includes force, frequency, and biometric values during operational periods.

9.1. Scope

This document describes the function requirements that must be met by a functional SCF Device. This set of requirements fully describes the proof-of-concept-device and partially describes the production device. The listed requirements will drive the design of the SCF Device and will be traceable in future design documents.

9.2. Target Audience

The functional specification document (FSD) is intended for use by all members of Sibulus. The project manager shall refer to the FSD as a concrete measure of progress throughout the development stage. The design engineers shall refer to the requirements present in the FSD as overall design goals to keep in mind from the product design stage to the product implementation stage. Test engineers shall use this document to assess the similarity in function of the completed system with the function described in this document.

9.3. Classification

Throughout this document the following shall be used to denote functional requirements and at which stage of development they should be implemented:

[Rn-x] A functional requirement.

Where **n** is the number of the functional requirement, and **x** is at which stage in the developmental process the requirement applies to.

A The product requirement applies to the proof-of-concept device only.

B The product requirement applies to both the proof-of-concept and final device.

C The product requirement applies only to the final device.

2. System Requirements

Functional requirements pertaining to the SCF Device as a complete system are presented in this section.

2.1 System Overview

The SCF device is a system that can be modeled at a high-level as shown in Figure 1.

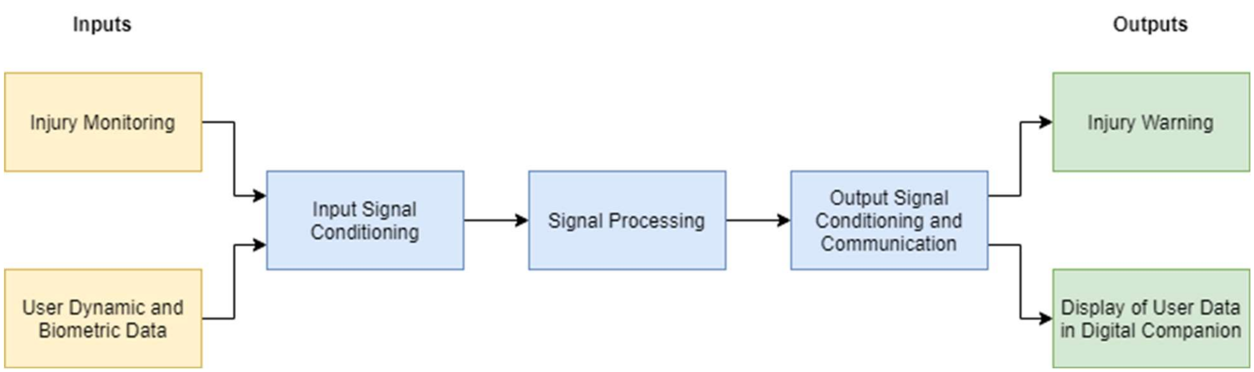

Figure 14. SCF Device System High-Level Block Diagram

The SCF Device system is intended to record user performance metrics and reduce the risk of injury caused by improper form. As a system the SCF can be further broken down into three distinct parts; The Protector/Sleeve that is in direct contact with the user's body; the Measurement Unit that will record and communicate user data metrics; and the User Interface, which is how the user will interact with the system both physically and digitally. Due to time and budget constraints the number of features implemented during early stages of development will be limited, and the system will only record metrics from the upper body. Key performance metrics to record include:

- Strike Speed
- Strike Acceleration
- Strike Frequency

- Strike Force

As well as biometrics to record:

- Heart rate
- SpO2

The device will work to reduce the risk of injury due to improper form by monitoring the wrist angle of the user and informing the user if the angle exceeds a predefined amount.

All signal processing of the recorded data is intended to be done with the measurement unit. Once the signal has been processed it will be wirelessly communicated to a digital companion interface. Inside the digital companion interface, the user will be able to see the data from the latest session, as well as a history of data over time to determine how their performance has varied, either showing improvement or deterioration. in-depth data analysis, feedback, and visualization will ideally be implemented to provide intuitive tips for the user to improve their performance.

Since the SCF Device is intended for those who practice martial arts or combat sports, the device must be able to withstand a certain degree of shock and vibration without suffering damage to the sensitive electronic components. The device must also be able to resist several environmental factors such as pressure, temperature, dust, and moisture.

2.2 General Requirements

[R1-C] The Final retail price of the system shall be under CAD$500.
[R2-B] The system shall be simple and intuitive to use.
[R3-B] Each individual component of the system shall be self contained.
[R4-C] The system shall be scalable.

2.3 Physical Requirements

[R5-B] The system shall fit body dimensions between the 95^{th} percentile female and the 95^{th} percentile male.
[R6-B] The length of the system shall not exceed 20 cm.
[R7-C] The system shall be minimally intrusive to the user.
[R8-B] The system shall not interfere with user range of motion.
[R9-C] The system shall be visually appealing.

2.4 Electrical Requirements

[R10-C] The internal power supply shall be able to adequately provide power for up to 6 hours.

[R11-C] The internal power supply shall be able to be charged from a charging dock.
[R12-C] The charging dock will be usable with a wall supply of 11V/120V at 60 Hz AC, which is typical of North American wall outlets.
[R13-C] The internal power supply shall last for a minimum of at least 2 years, or 300 charge cycles, whichever comes first. [2]
[R14-B] The system shall power down for power saving after 15 minutes of inactivity.
[R15-B] Key voltage nodes shall be easily accessible for troubleshooting and debugging.

2.5 Mechanical Requirements

[R16-B] All system components must be securely connected during intended use.

2.6 Environmental Requirements

[R17-C] The system shall operate normally at elevations from sea level to 2500 m above sea level. [3]
[R18-B] The system shall operate normally at temperatures ranging from 4 °C to 45 °C. [4]
[R19-C] The system shall be fit for use both indoors and outdoors.
[R20-B] The system shall be resistant to dust and moisture.

2.7 Standards

[R21-C] The system shall conform to ANSI standards. [5]
[R22-C] The system shall conform to IEC standards.
[R23-C] The system shall conform to ISO standards.
[R24-C] The system shall conform to EN standards.
[R25-C] The system shall conform to CSA standards.
[R26-C] The system shall conform to CGSB standards.

2.8 Reliability Requirements

[R27-B] The system shall be able to withstand day-to-day physical treatment.
[R28-B] The system shall be resistant to breakage under normal operating conditions.
[R29-C] All device interfaces shall have a duty cycle of no less than 1,000,000 cycles.
[R30-C] The system shall be serviceable by trained technicians, or in some cases the user.

2.9 Safety Requirements

[R31-B] The system shall not actively cause harm to the user, or anyone the user is interacting with.
[R32-C] The electronic and mechanical components and power connections of the system shall be enclosed.

[R33-B] The electronic components of the chair shall not cause interference with other devices.
[R34-B] The internal power supply must not be charging while in use.
[R35-C] The system will be able to detect any failure in the internal power supply and alert the user in such a case. The system will then enter an error mode and will not function until the system has been resolved.
[R36-C] Upon power on the system will perform diagnostics. If a previous error is detected the system will enter an enter an error mode and will not function until the system has been resolved.
[R37-B] The system shall not spontaneously combust.

2.10 Performance Requirements

[R38-B] The system shall respond to user inputs within 500 ms.
[R39-B] The system shall communicate recorded user data within 5 minutes.
[R40-C] The system shall indicate that it is on within 500 ms of power on.
[R41-C] If the system is in a shutdown sequence it shall communicate the most recently recorded user data before powering down.
[R42-B] The system shall inform the user If they have performed a motion that could have potentially resulted in injury within 200ms.

2.11 Usability Requirements

[R43-B] The system will perform measurements assuming that it is being worn correctly.
[R44-B] The system will perform measurements assuming that it has been correctly calibrated by the user before use.
[R45-C] The systems firmware shall be upgradable through a digital application by the user.
[R46-C] The recorded data shall be communicated to and displayed by a digital application.
[R47-B] The system shall have an interface to an external connection for diagnostic purposes.

3. Protector/Sleeve

[R48-C] The protector/sleeve shall be breathable.
[R49-C] The protector/sleeve shall be washable.
[R50-B] The protector/sleeve shall be flexible.
[R51-B] The protector/sleeve shall incorporate a means of determining if the user would have caused themselves injury.
[R52-B] The protector/sleeve shall have a mounting point for the measurement unit.
[R53-B] The protector/sleeve shall offer the wearer some level of protection, or else be low enough profile to fit beneath current protective gear.

4. Measurement Unit

[R54-B] The measurement unit shall be resistant to impact.
[R55-C] The mass of the measurement unit shall be less than 200 g.
[R56-B] The measurement unit shall measure acceleration.
[R57-B] The measurement unit shall measure velocity.
[R58-B] The measurement unit shall measure force.
[R59-C] The measurement unit shall measure heart rate.
[R60-C] The measurement unit shall measure SpO2.
[R61-B] The measurement unit shall measure strike frequency.
[R62-B] The measurement unit shall communicate wirelessly.
[R63-B] The measurement unit shall be removable from the protector/sleeve.
[R64-B] The measurement unit shall be able to isolate the correct motions from the recorded data.
[R65-C] The Mean Time Between Failure (MTBF) of the measurement unit shall be no less than 5000 hours.

5. User Interface

[R66-B] The primary means of physical user input shall be through a set of push buttons and/or switches.
[R67-B] The physical user interface shall have a series of LEDs to inform the user of power status, remaining battery life, and error codes.
[R68-C] The digital user interface shall be accessible from several platforms.

6. User Documentation

[R69-C] The user documentation shall be presented through the digital companion and will include a general and technical support manual, as well as a user manual, both written in English.
[R70-C] The user manual shall be written for an audience with minimal knowledge of electromechanical devices.
[R71-C] User documentation shall be provided in French, Spanish, German, Traditional Chinese, Simplified Chinese, and Japanese to satisfy product language requirements for international markets.
[R72-C] A detailed service manual for technicians and vendors shall be created.

7. Conclusion

The functional specification clearly defines the capabilities and requirements of the SCF Device. Development of the final production device will take place in two distinct phases. The proof-of-concept model is currently in development and it is confidently expected that all functional requirements outlined above applying to the proof-of-concept model (marked with A or B) will be completed by the target date of March 25, 2021.

References

[1] E. MMA, "7 Critical Elements That Every Martial Artist Must Work On," Evolve Mixed Martial Arts, 23 November 2014. [Online]. Available: https://evolve-mma.com/blog/7-critical-elements-every-martial-artist-must-work/. [Accessed 22 February 2021].

[2] Tektronix, *Lithium-Ion Battery Maintenance Guidlines,* Beaverton: Tektronix, p. 1.

[3] J. E. Cohen and C. Small, "Hypsographic demography: The distribution of human population by altitude," PNAS, 1998.

[4] NASA Earth Observations, "Land Surface Temperature," NASA, December 2020. [Online]. Available: https://earthobservatory.nasa.gov/global-maps/MOD_LSTD_M. [Accessed 21 February 2021].

[5] UL, "Wearable Technology Testing and Certification," [Online]. Available: https://www.ul.com/services/wearable-technology-testing-and-certification. [Accessed 13 February 2021].

Design Specification for the Smart, Combat-Oriented Fitness Device

March 22nd, 2021

Dr. Farid Golnaraghi
Professor
School of Mechatronic Systems Engineering
Simon Fraser University
13450 102 Ave #250
Surrey, BC V3T 0A3

RE: MSE 410 Design Specifications for Smart Combat-Orientated Fitness Device

Dear Dr. Golnaraghi,

The attached document from Sibulus is a document that outlines a set of technical guidelines for the design of the Smart, Combat-Orientated Fitness (SCF) Device. The SCF Device is a wearable aimed at striking based martial arts and combat sports athletes that will provide quantitative performance feedback and injury warning to the user.

The design specifications described in this document apply to the proof-of-concept model only. Design improvements for future iterations of the SCF Device are discussed briefly but will not be implemented at this stage of development.

We would like to thank Dr. Marzouk as well as the other Co-champions of Technology Entrepreneurship for their mentorship and support. We look forward to providing the next generation of data-driven martial arts accessories.

Sincerely,

Cheng Jie ("Michael") Huang
President
Sibulus

Executive Summary

The following document dictates the design specification for the Smart Combat-Oriented Fitness Device by team Sibulus, an organization dedicated to driving forward the world of martial arts with data. While the sports and fitness industry has seen an explosive incorporation of smart technology applications to aid athletic development in recent years, the martial art industry has remained stagnant and opted for traditional practices.

Sibulus' mission is to deliver a device that will help martial artists and combat-sport based fitness practitioners of all skill levels to overcome their performance plateaus by providing data driven performance analytics and feedback, as well as promote positive mental health. With the restrictions placed upon the world due to the COVID-19 pandemic, the need for data-supported progress is more apparent than ever. Through the application of motion tracking, biometric scanning, as well as artificial intelligence, Sibulus will create a comprehensive wearable that can provide users the data they need to consistently outperform themselves.

The design specification lists the design selection process of team Sibulus' engineers in meeting the functional requirements as listed in *Functional Specifications for the Smart, Combat-Oriented Fitness Device* [1]. The overall functionality of the device is first introduced, followed by the system design process which describes the decision process behind the selection process of various mechanical and electronic components, as well as the general software implementation process. The complete system test plan is provided to guarantee the full range functionality of the prototyped device.

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Acronyms

MACSA	Martial Arts and Combat Sports Athlete
SCF	Smart, Combat-Oriented Fitness
HMI	Human Machine Interface
LED	Light-Emitting diode
BLE	Bluetooth Low Energy

1. Introduction

The Smart, Combat-Orientated Fitness (SCF) Device is a wearable aimed at striking based martial arts and combat sports athletes (MACSA) that will provide quantitative performance feedback and injury warning to the user. Key performance metrics such as strike speed, power, frequency, and biometric values due to the importance of explosive power, agility, and endurance in martial arts practice [2]. Our aim is to create a device that presents quantitative data to the athlete in a meaningful way such that they can avoid or overcome performance plateaus that would otherwise be detrimental to both their physical and mental health.

• Scope

This document specifies the design of the SCF Device and explains how the design meets the functional requirements as described in *Functional Specifications for the Smart, Combat-Oriented Fitness Device* [1]. The design specifications include all requirements for a proof-of-concept system and a partial set of requirements for a production model. As the focus is on the proof-of-concept system, only requirements marked A or B will be explicitly discussed.

• Target Audience

The design specification document is intended for use by all members of Sibulus. Design engineers shall refer to the specifications as overall design guidelines to ensure all requirements are met in the final product. Test engineers shall use this document to implement the test plan and to confirm the correct behaviour of the SCF Device.

2. System Specifications

The SCF Device will record data generated during training sessions, analyze the received data, and report end point metrics that provide meaningful performance interpretation. Data collection begins with the pressing of the start/end button. Bluetooth connectivity through button activation will allow for device pairing to transfer analyzed data to the Human Machine Interface (HMI) for visual representation to the end user. Light-emitting diodes (LEDs) will be used to display connectivity and battery status of the device.

• Synthesis

To meet the goal of helping MACSA overcome performance plateaus through providing data driven feedback, three major methods of implementations are considered in Table I. The wearable category provided clear benefits in terms of portability and application as compared to the smart target and deep vision approaches and is therefore chosen as the main implementation to meet the functional specifications, whereas the deep vision system is noted to provide more comprehensive data and may be considered as a supplement to the main implementation.

Table XI. SCF Device Design Matrix

		Wearables			**Targets**			**Vision System**
Metrics	**Weights**	Smart Band	Sleeve with padding and wrist position tracking	Sleeve without padding and wrist position tracking	Free-Standing Target	Wall-mount target	Handheld target	Motion Tracking for form monitoring
Cost	4	4	3	3	1	1	5	3
Manufacturability	3	4	3	4	2	2	4	5
Safety	5	1	5	4	1	1	1	5
Reliability	4	4	3	4	2	2	3	4
Portability	4	5	5	5	1	1	4	2
Visual Appeal	3	3	4	3	2	2	1	1
Usefulness	5	3	5	4	4	4	3	4
Innovativeness	2	1	3	2	2	2	4	1
Compatibility	4	4	2	4	5	5	5	4
	Weighted Score	111	129	129	77	77	111	117

	Rank	3	1	1	5	5	4	2

2 Overall System Design

This section provides a high-level overview of the SCF Device design. The electromechanical system of the SCF Device includes the securing mechanical structure that will withstand the high impact of MACSA usage, the various sensors used to measure MACSA performance, as well as the data processing, interpretation, communication, and interface process of the device.

• Mechanical Design

The mechanical design of the system is to be such that all requirements put forth in the *Functional Specifications for the Smart, Combat-Oriented Fitness Device* that pertain to the physical and mechanical aspects of the SCF Device are met. Key factors involved in the mechanical design are resistance to impact, reduction of vibrations, and sealing against environmental factors. An initial design concept of the SCF Device is shown in Fig. 1.

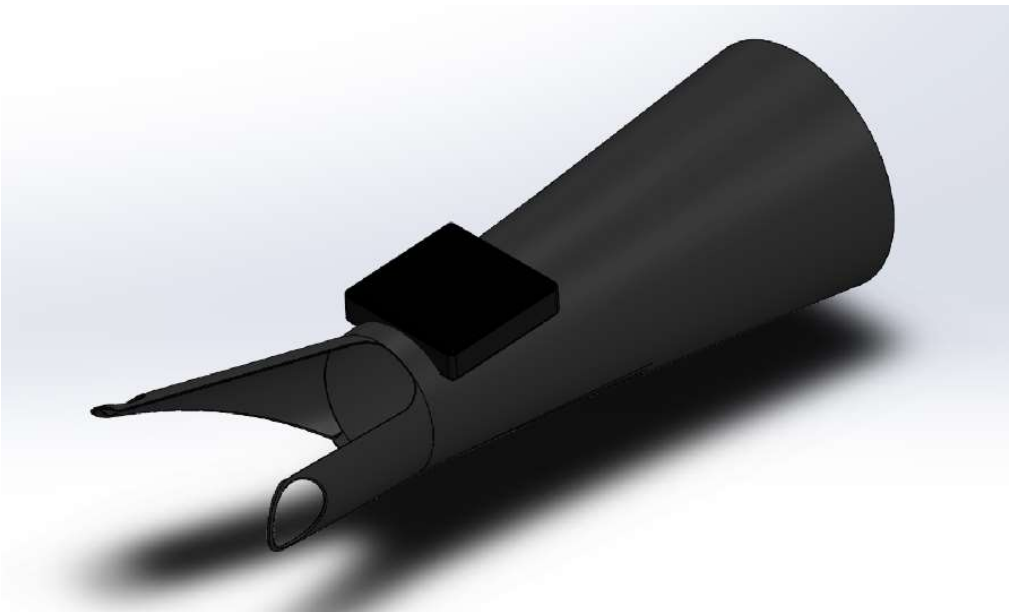


Figure 15. Initial Wearable SCF Device Concept

The SCF has two primary components: the sleeve that is in direct contact with the wearer, and the measurement unit that records and transmits the collected data. Rather than having a single component, a two-component system was selected to be as cost effective and convenient for the end user as possible.

By using a two-component system if any single component fails it can be easily swapped out for a functional component. Furthermore, a two-component system allows for upgradability and backwards compatibility without the need to purchase an entirely new system.

Sleeve Design

While designing the sleeve of the SCF device the required dimensions and the materials to be used were the primary concern. The SCF device must be constrained to the forearm of the user, requiring compatibility with a range of arm sizes. Using anthropometric data, it was determined that the average wrist circumference is determined by height, and ranges from a minimum average circumference of 14 cm for women, to a maximum average circumference of 19 cm for men [3]. To account for a range of wrist circumferences a circumference of 13 cm was chosen as the minimum circumference of the SCF device sleeve, with the ability to expand to accommodate larger sizes. The length of the sleeve is also a constraint that must be considered, as the average length of the forearm is reported as 25 cm for women, and 29 cm for men [4]. Using these constraints, a maximum from-wrist length of 20 cm was determined to allow for adequate mounting space for the measurement unit while avoiding interference with the elbow. To prevent shifting while in use the sleeve will make use of two loops that go around the thumb and little finger, respectively.

To withstand daily use by a MACSA, the material to be used for the sleeve must be durable and abrasion resistant, all while being breathable, elastic, and moisture wicking. Textiles are divided into two main classes based on the type of material used to manufacture: natural textiles have fibers that are directly derived from living organisms, while synthetic textiles have fibers that are produced through chemical synthesis [5]. Both natural and synthetic textiles are applicable for use in an active environment, while having certain pros and cons. Natural textiles tend to resist odors and are biodegradable, however, they are usually very poor at repelling moisture. Synthetic textiles have greater durability and elasticity than natural textiles, are excellent at repelling moisture, and are stain resistant; however, synthetic textiles have poor odor resistance. Four textiles that were considered as the material for the SCF device sleeve are presented in Table II.

Table XII. Considered Materials for the SCF Device

Textile Type	Natural		Synthetic	
Material	Bamboo	Merino Wool	Nylon + Spandex	Polyester + Spandex
Odor Repellent	X [6]	X [7]		
Breathable	X	X	X	X
Moisture Repellent	X	X	X	X

UPF Rating	50+	20+	X	X
Stain Resistant				X
Time to Degrade	1 year [8]	1 year	30 – 40 years [9]	> 200 years [10]

Of the four considered materials, both bamboo and merino wool have the lowest environmental impact as they are both derived from sustainable sources, while also breaking down within a year of being discarded. However, both materials are quite expensive, and merino wool is more suited for outdoor focused activities due to the material's excellent thermal insulation [11]. Given the requirements of a MACSA, the synthetic textiles are a more appropriate choice, as they offer greater durability, breathability, UPF ratings, and moisture repelling properties, in exchange for having a much larger environmental impact. To combat the lack of odor resistance inherent to synthetic textiles, modern synthetics are often treated with chemicals to fight bacterial growth, and in some cases are also woven with silver mixed in [6], [12]. The ideal choice of material would be a blend of both natural and synthetic textiles, as is commonly done. If a blend of material was not available for an appropriate cost, then polyester and spandex would be the second-best choice of material due to the excellent durability of polyester, and the unrivalled elasticity of spandex.

The SCF Device's last sleeve component is the pocket that will house the soft sensor used to determine if the MACSA has their wrist in a position which could potentially lead to injury. As impact on the MACSA's range of motion is to be minimized, the placement of the soft sensor is crucial. The chosen placement of the soft sensor is shown in Fig. 2.

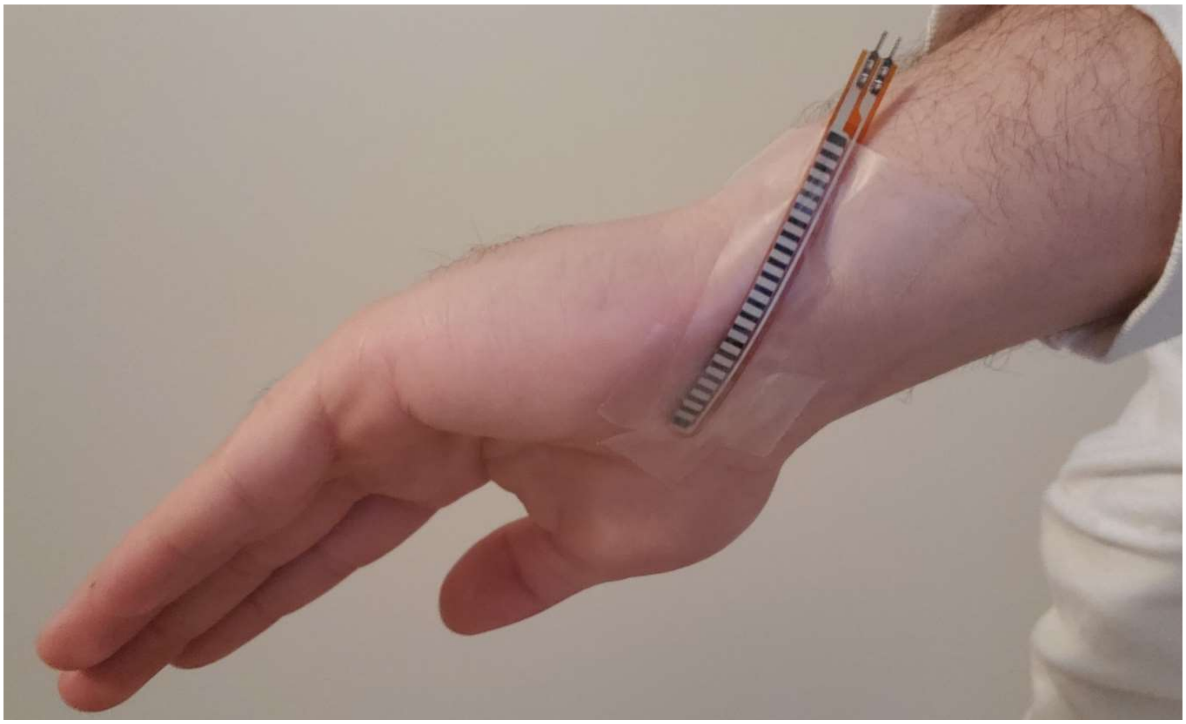


Figure 16. Chosen location for the placement of the soft sensor.

The soft sensor was placed as shown in Fig. 2 to allow for the MACSA to maintain full range of motion of the wrist, while allowing for the sensor to bend in all required planes, allowing for the determination of wrist position in two planes using only a single sensor. To prevent damage to the sensor during intended use, a strain relief will be attached to the end of the sensor where the electrical contacts are present.

Measurement Unit Design

The measurement unit of the SCF Device will house all electrical components required for functional operation, minus the soft sensor. The electrical components include the IMU, the processor unit, the battery, and the heartrate/SpO2 sensor which will be implemented in future iterations. The first iteration of the measurement unit design will be a single, sealed unit, with future iterations being implemented as a modular unit in which the IMU, the processor, and the battery are sealed in a separate, removable housing. The dimensions for the measurement unit design are largely dependent on the selected electrical components for the final design, with the maximum dimensions as 5 x 10 x 2 cm (w x l x h). A single, sealed unit was selected for the initial concept design for simplicity of implementation, while allows for excellent durability and sealing against the environment. As previously stated, future iterations of the measurement unit will allow for the removal of core electronic components to improve ease of cleaning, charging, and hot swap capabilities. The removable core unit will sit in a shell that is permanently attached to the sleeve, and will be held in place by a hinged, latching lid that will prevent unwanted button presses and ejection of the core unit.

The material of the measurement unit housing must be durable enough to resist failure due to accidental contact during MACSA training. Metals such as aluminum and magnesium were considered due to their current applications as smart watch housings but were dismissed considering three key characteristics: cost, ease of manufacture, and electrical conductivity. Polymers such as ABS and polycarbonate were also considered. A decision matrix for the material selection process is shown in table III.

Table XIII. Materials for the Measurement Unit Housing

Material	Aluminum	Magnesium	ABS	Polycarbonate
Cost	2	1	5	4
Ease of Manufacture	1	1	5	4
Weight	2	3	5	5
Electrical Insulation	1	1	3	5
Chemical Resistance	2	1	3	4
Recyclability	4	4	5	3
Total	12	11	26	25

ABS was chosen as the material for manufacturing the measurement unit housing primarily due to how easy it is to manufacture parts from ABS; ABS can be used in injection molding for mass production and is a very common material for 3D printing. ABS is also very cost effective at only $0.76 CAD/kg, opposed to the cost of polycarbonate at $1.28 CAD/kg [13]. While ABS is less durable than polycarbonate, it is durable enough to be used as a substitute for metal automotive components [14]. The key mechanical properties of ABS are an Izod Impact strength of 215 J/m and a Young's modulus in the range of 1.79 – 3.2 GPa depending on the blend of polymers used. Depending on how the ABS housing performs in real world conditions, the material for the housing could shift to either an ABS/polycarbonate blend or pure polycarbonate.

Rubber will also be used throughout the design of the SCF Device. The top portion of the measurement unit will be covered with molded rubber to absorb impacts and reduce vibrations, reducing the risk of injury due to accidental contact during training and reducing the risk of damage to the polymer shell. To seal against environmental factors, rubber seals will be used to prevent against dust and moisture from contacting the electrical components. Rubber vibration mounts will also be used to reduce vibration experienced by the electrical components.

• Electrical Design

Electrical components are selected based on the functional specifications and cross compatibility between each system. Total run time for the device powered on will need to be above six hours. The current consumption of the sensors and processor together is 7.1mA if we process the data on the device using the MCU. Assuming optimal conditions, the device can be powered by a 500mAh battery for three days, much higher than the functional specification target of six hours. The MCU can also be programmed to turn off due to inactivity to further prolong battery life.

The devices will be interfaced using the relevant evaluation boards and testing software for prototyping which will then be referenced for circuit board printing to create a compact device. The device will collect data at the specified sampling rates, apply data filtering, and wirelessly communicate the data to be analyzed on an end device where the user can monitor performance and gather key insights from the data. useful insights from training sets will be extracted and summarized for the user on their devices.

Microcontroller Unit

Selection for the microcontroller unit (MCU) is based on a few key parameters and features. The MCU will need to have 2.4 GHz wireless Bluetooth communication, I2C and SPI communication ports for connection with the IMU and other sensors. A design matrix for potential MCUs is presented in Table IV.

Table XIV. Potential MCUs for the SCF Device

Controller	Arduino Nano 33 IOT	Raspberry Pi Zero W	TI CC2640R2F
Bluetooth	4	4	5
Ease of Implementation	4	3	2
Memory	3	5	4
Interfaces	3	4	5
Size	5	5	3
Cost	4	2	2
Additional Features	5	3	3
Total	28	26	24

While the Arduino and the Raspberry Pi are tied in total score, the Arduino was ultimately chosen due to the increased ease of implementation and support resources, lower associated cost, and useful additional features that are included. The Arduino Nano 33 IOT not only comes with a built in Bluetooth 4.2 LE module, but also a LSM6DS3 6-axis IM which reduce interfacing requirements and compatibility satisfaction. Other relevant parameters are presented below in Table V. Data Sheets and parameters for the other considered MCU are included in Appendix 1: Controllers.

Table XV. Arduino Nano 33 IOT parameters

Arduino Nano 33 IOT	
Controller	SAMD21 Cortex®-M0+ 32bit low power ARM MCU @ 48 MHz
Radio Module	u-blox NINA-W102
Operating Voltage	3.3 V
Memory	256 KB (Flash), 32 KB (SRAM)
GPIO	23
Dimensions	18 x 45 mm @ 5g

One issue that the Arduino has is the lack of included connection for a battery, which is fine for the prototyping stage as we plan to use an external power source, but must be accounted for with a MCU, preferably an Arduino to allow for easy migration of existing software infrastructure, that has a battery connection in the production stage model of the device. These boards do exist, but unfortunately do not come with a built in IMU, requiring us to choose an external one.

Inertial Measurement Unit

The inertial measurement unit will encompass a 6-axis gyroscope and accelerometer. Functional specification requirements show that a force of 16g acceleration must be reliably measured. The data sampling rate for both the accelerometer and gyro will be one kHz for accurate plotting and analysis of each impact. Communication protocol will be either SPI or I2C for compatibility with the microprocessor. As stated in the previous section, the controller board that we have selected has a built in LSM6DS3 6-axis IMU. The LSM6DS3 meets all our requirements for the SCF Device as it can read up to 16g of acceleration and has a maximum data sampling rate of 6.66 kHz when only the accelerometer is in use, or 1.6 kHz when both the accelerometer and gyroscope are enabled. External IMUs such as the ICM-42688-P and the ICM-20649 Wide-Range 6-DOF IMU were also considered and could be implemented if the LSM6DS3 proves inadequate for our intended application. The specifications for both the ICM-42688-P and the ICM-20649 are included in Appendix 1: IMUs. Parameters for the LSM6DS3 are presented below in Table VI.

Table XVI. LSM6DS3 Parameters

LSM6DS3	
Max Power Draw	1.25 mA
FIFO	8 kB
Accelerometer Range	±2/±4/±8/±16 g
Gyroscope Range	±125/±250/±500/±1000/±2000 dps
Interface	SPI/I^{2}C
Sampling Rate	1.6 kHz (Gyroscope) / 6.66 kHz (Accelerometer)

Soft Sensor

A soft resistive sensor was chosen to be implemented to measure the position of the user's wrist. This sensor can either be read digitally through a capacitor's charge value to signify high or low and determining time between value polarity changes or can be read directly using an analog-to-digital (ADC) converter. Pressure-sensitive conductive sheets were considered for use as the soft sensor but were discarded due to a lack of robustness. Ultimately, the FS-L-0055-253-ST flex sensor from Spectra Symbol was chosen as the soft sensor due to its short length, long lifespan, and low nominal resistance of 25 kΩ with a maximum resistance of 100 kΩ. For a production version of the SCF device a custom soft sensor made from flexible rubber and a conductive filament will serve as a viable replacement for off the shelf components [15], [16]. A basic circuit for measuring the soft sensor value is shown below in Fig. 3 with the parameters of the FS-L-0055-253-ST presented in Table VII. The Op-Amp shown in Fig.3 is not required for our design as the intended application does not require a precise value, only changes in value polarity.

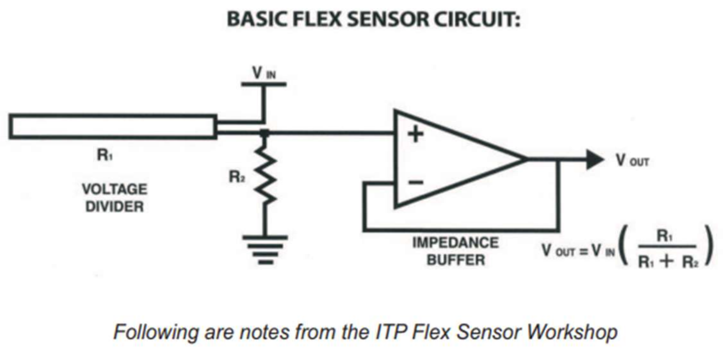


Figure 17. Basic circuit for measuring the value of a variable resistive sensor.

Table XVII. FS-L-0055-253-ST Parameters

FS-L-0055-253-ST	
Flat Resistance	25K Ohms
Resistance Tolerance	± 30 %
Bend Resistance Range	45K to 125K Ohms
Power Rating	0.50 Watts continuous
Cycle life	> 1 million cycles
Height	0.43mm
Temperature Range	-35°c to +80°c

Battery

Due to the size constraint of the SCF Device the size of the battery is a considerable limiting factor on the provided capacity. However, since our chosen sensors and MCU have relatively low current draws, the capacity of the battery is of less importance than its physical dimensions, output voltage, and durability against vibrations. Parameters of a potential battery are shown below in Table VIII.

Table XVIII. Potential Battery Parameters

Dimensions	29mm x 36mm x 4.75mm
Weight	10.5g
Capacity	500 mAh nominal
Voltage	3.7 V nominal

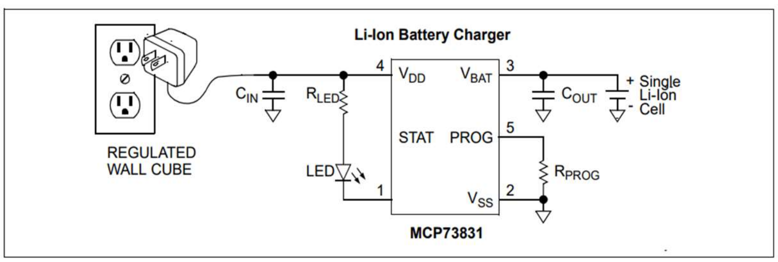
Cycle life	> 300 cycles

As the currently chosen MCU does not come with a battery connection, the potential battery is intended for the final proof-of-concept model than the current prototypes.

Battery Charger

Once the battery is implemented, a means for reliably charging the battery will be required. An external charger such as the MCP73831 would provide the preferred charge algorithm for Lithium-Ion and Lithium-Polymer cells at a constant current followed by a constant voltage. Figure 4 depicts a typical stand-alone application circuit along with the accompanying charge profile. The parameters of the MCP73831 are presented below in Table IX for reference of suitable charger specifications.

Figure 18. Typical application circuit (left) and charge profile of a 1000 mAh battery.



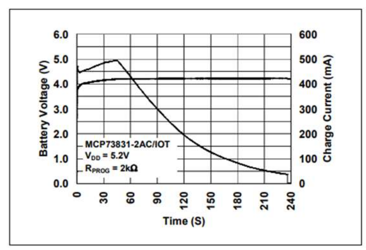


Table XIX. MCP73831 Parameters

MCP73831	
Supply Voltage	3.75-6 V
Supply Current	510-1500 µA
Constant voltage mode	4.20 V
Fast Charge Constant-Current Mode	100 mA

Another option for charging the selected battery would be an internal battery charger, such as those present on Arduino boards with battery capabilities.

Heart rate Sensor and SP02 Sensor

The MAX32664 Version B communicates with MAX86140 via SPI communication to perform heart rate and oxygen saturation measurements from the wrist. The the MAX32664 embedded algorithm performs digital filtering, pressure/position compensation, and R-wave detection to measure pulse rate in bpm. With automatic gain control, power usage is minimized. Additional features are embedded to provide high signal to noise ratio and ambient light rejection. An accelerometer can be used as shown in Fig. 5 as an additional sensor.

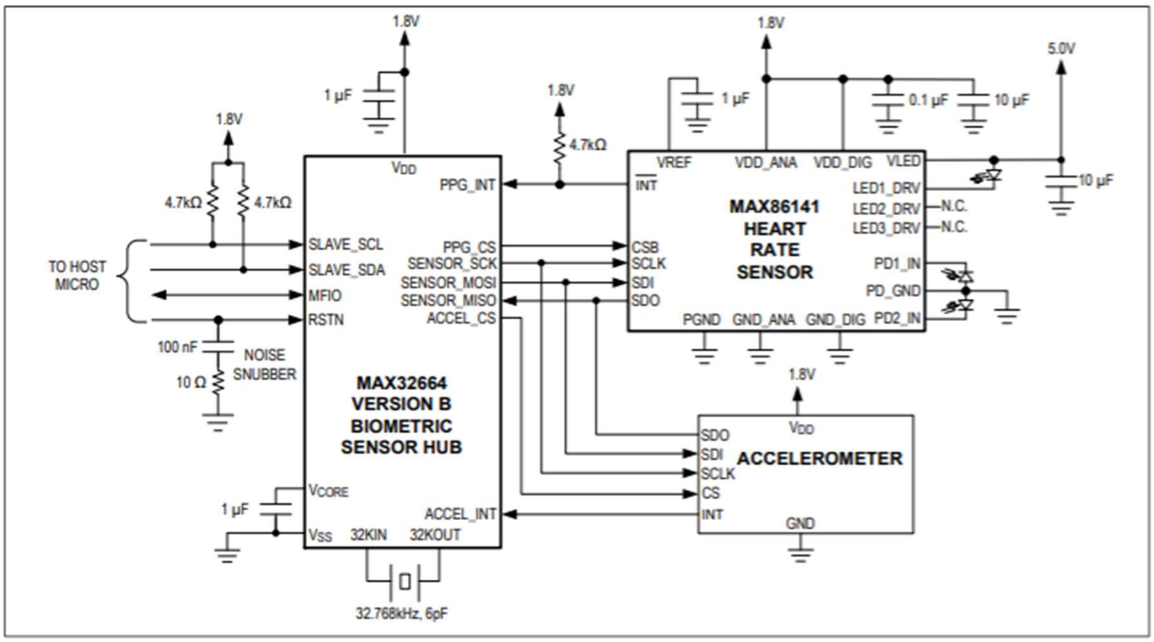


Figure 19. Maxim Integrated Heartrate and SpO2 sensor with additional Accelerometer

Show below in Table X are the parameters of the Maxim Integrated MAX32664 and MAX86141.

Table XX. MAX32664 and MAX86141 parameters.

MAX32664 and MAX86141 Parameters	
Power Supply Voltage (VDD)	1.7-2.0 V
LED Supply Voltage (VLED)	3.1-5.0 V
Supply Current (IDD)	600 µA
Supply Current in Shutdown	0.7 µA
ADC resolution	18 bits
ADC output data rate	50-3200 sps
Communication	I2C, SPI

Additional Electrical Components

To facilitate feedback capabilities for user interfacing, the SCF will include a push button for power, connection purposes, a LED for status indication, and a mini vibrating disk motor for warning capabilities.

Software Design

Provided with the data generated from the various SCF Device sensors, the software architecture will then be responsible for providing the data transfer, processing, and output capabilities.

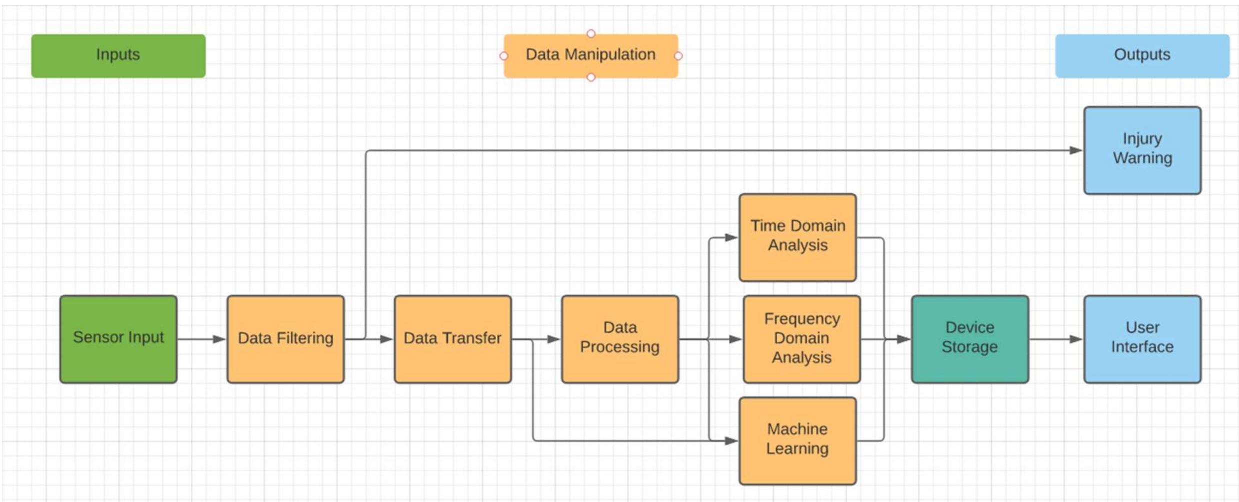


Figure 20. Data Flow Chart

Data Processing

The SCF Device software will gather various filtered sensor values to create a dataset of relevant information per activity session. Data transfer will be facilitated between the SCF Device and the end user interface, where the dataset will then be processed through feature extraction in the time domain and the frequency domain to output meaningful data interpretations that will provide the user with the end point statistics such as punch speed, frequency, acceleration, and force to be used to reference user performance. This information will be stored locally to allow for user reference of performance. By limiting the data processing workload on the SCF Device and minimizing memory requirements, we can further minimize the form factor of the product wearable device. Given the large quantity of data expected from the device operation, the application of machine learning will be explored in interpreting strike statistics.

Data Transfer

As the SCF device is limited in form factor, power efficiency, and must include wireless capabilities, the Bluetooth Low Energy (BLE) is chosen as the optimal form of data transfer between the wearable device and the end point display due to the low power consumption, overall ease of interface, and low-cost implementation as seen through comparison in Table XI.

Table XXI: Decision Matrix for Data Transfer Method

	BLE	Zigbee	Z-Wave	6LoWPAN	LAN
Power Consumption	1	2	1	1	3
Cost	1	2	3	3	3
Speed	2	3	4	3	1
Ease of Interface	1	3	3	3	1
Score	5	10	11	10	8

User Interface

The various performance metrics and biometrics will be outputted to the end user through mobile, or PC application display due to the widespread availability of such devices. The user interface program will allow the user to navigate between the various statistics made available by the SCF Device such as historical performance data per session, historical biometrics per session, and interpretation of punch statistics. The software will also notify the user of disconnects, low battery, and misaligned joint positioning for the purpose of injury prevention during training through vibrational feedback of the device.

3 System Test Plan

• General Testing Procedure

1. Set aside a separate batch with a minimum of 10 units for each test procedure classified as destructive, (*i.e.,* mechanical, and environmental testing). Also, set aside a minimum batch size of 30 units for accelerated aging as per 4.7 Accelerated Aging.
2. Disable the sleep timer when performing tests requiring the device be active, unless explicitly testing the sleep timer as per 4.6.3 Sleep Mode Timer.
3. Enter test results directly into the corresponding digital form. Results must be directly entered and not copied from external documents. If a test result is entered in a physical format rather than digitally, the physical document must be scanned into the file system for accurate bookkeeping.

• Physical

Sleeve dimensions

1. Measure the length of the SCF device sleeve from the wrist opening to the distal tip. Expected value is less than 20 cm.
2. Place the sleeve on each of three cylindrical objects each with maximum circumferences of 12.9 cm, 13.0 cm, and 13.1 cm. Expected results are minimal or no visual stretch of the material.

Measurement unit dimensions

1. Using a calibrated caliper measure the width of the measurement unit housing. Expected value is less than 5 cm.
2. Using a calibrated caliper measure the length of the measurement unit. Expected value is less than 10 cm.
3. Using a calibrated caliper measure the thickness of the measurement unit. Expected value is less than 2 cm.
4. Using a calibrated scale ensure that the total weight of the measurement unit including the electronic components is less than 200 g.

Color and markings

Visually inspect the measurement unit and sleeve for discoloration, ensuring that all markings are present and in the correct locations.

• Mechanical

Sleeve

1. Place the sleeve into the cyclic testing apparatus that is set up to expand the circumference from 13 cm up to 20 cm and then return to 13 cm. Set up to run for 500 cycles. When the set number of cycles have completed remove from the testing apparatus and determine nominal circumference as per 4.1.2.1.
2. Place the sleeve into the static testing apparatus that is set to hold the sleeve circumference at 20 cm. Leave for a minimum of 50 hours, then remove from the testing apparatus and determine nominal circumference as per 4.1.2.1.

Measurement Unit

1. Using an abrasive surface of known roughness, lightly score the surface of the measurement device housing 10 times. Increase abrasiveness if required and note down at which level and cycle scoring becomes easily detectable by visual inspection.
2. Place the measurement unit housing on a hard, flat surface. From a height of 1 m above the measurement unit drop a calibrated 5 kg mass. Visually inspect for damage. If no damage is

visually apparent increase the mass in 10 kg increments up to 55 kg. Note down at which mass damage is easily seen by visual inspection.

• Environmental Testing

High Temperature Testing

Place the SCF device into an environmental testing chamber and set the internal temperature to 50 °C at 50% relative humidity. Run for 6 hours, then remove device from the chamber and let sit for a minimum of 2 hours. After a minimum of 2 hours have passed ensure that the device functions as intended before continuing with further testing.

Low Temperature Testing

Place the SCF device into an environmental testing chamber and set the internal temperature to 0 °C at 50% relative humidity. Run for 6 hours, then remove device from the chamber and let sit for a minimum of 2 hours. After a minimum of 2 hours have passed ensure that the device functions as intended before continuing with further testing.

High Humidity Testing

Place the SCF device into an environmental testing chamber and set the internal temperature to 25 °C at 80% relative humidity. Run for 6 hours, then remove device from the chamber and let sit for a minimum of 2 hours. After a minimum of 2 hours have passed ensure that the device functions as intended before continuing with further testing.

High Pressure Testing

Place the SCF device into a pressure testing chamber and set the internal pressure to 110 kPa. Run for 30 minutes, ensuring that the device functions as intended for the entire duration.

Low Pressure Testing

Place the SCF device into a pressure testing chamber and set the internal pressure to 75 kPa. Run for 30 minutes, ensuring that the device functions as intended for the entire duration.

• Electrical

Accelerometer Full Scale Range (FSR)

Using a pendulum that has a known mass at the end, strike a plate that has the SCF device mounted to the opposite side. Increase the angle of the pendulum until the accelerometer records the minimum required acceleration value of 16g. Note the angle at which this value was recorded. Repeat for the remining two axis.

Sampling Rate

Enable data logging and run for 5 seconds. Open the corresponding logged data and ensure that there is a minimum of 5000 samples, repeat 5 times per unit. Take the average number of recorded samples to determine if the sampling rate meets the minimum required sampling rate of 1 kHz.

Battery Operating Time

Power on a SCF Device with a fully charged battery and start a calibrated stopwatch. Note down at which time the battery low warning indication is illuminated and stop the timer when the device shuts down, noting the time. Ensure that operating time is over 6 hours.

Time to Charge

Plug in a SCF Device that has a completely drained battery and start a calibrated stopwatch. Stop the timer when the battery charge indication turns on. Note down the time taken. Expected charge time should be less than 2 hours.

• Software

Normal Run Time

Enable data logging and run the SCF device for three hours with regular motion throughout. Check user interface for updates on transferred data at specified intervals.

Max Run Time Application

Start data logging on an SCF Device with a fully charged battery and run until battery is completely drained, with continual motion throughout. Check user interface for updates on transferred data at specified intervals, ensuring that data is transferred throughout the entire run time of the SCF Device.

Sleep Mode Timer

Start data logging on an SCF Device and do not disturb the device for a minimum of 20 minutes. After 15 minutes the device should enter sleep mode for power saving and stop transmitting data at regular intervals. Upon detecting motion, the device should reset the sleep timer and become active if currently in sleep mode. If no motion is detected for 30 minutes that device will power off to preserve battery.

User Interface

Ensure that all components of the user interface function as intended as described in the user interface documentation. This includes all required features and visuals.

• Accelerated Aging

To simulate 1 year of the SCF Device's shelf life, place 30 units into a temperature chamber set to 50 °C for 73 days. These values were determined using the Arrhenius equation for the temperature dependency of reaction rates.

Arrhenius Equation $$k = Ae^{-\frac{E_a}{RT}} \quad (1)$$

Using (1) it can be approximated that for every 10 °C increase in temperature the reaction rate increases by a factor of 2 or 3 [17]. Once 73 days have elapsed remove units from the temperature chamber and allow to sit for a minimum of 2 hours. After 2 hours have passed proceed with test plan as normal.

4 Conclusion

The design specifications clearly define the decision process and justification that leads to the development of the SCF device based on the system requirements outlined in the *Functional Specifications for the Smart, Combat-Oriented Fitness Device* [1]. The test cases have been designed to ensure the expected functionality of the SCF device. Functionalities listed for A, B iterations of the prototype are accounted for, with C iteration features discussed for future reference.

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Appendices

Appendix 1: Electrical Design

	Electronic Components and Design Requirements				
	MCU	IMU	Heartrate and SP02	Battery	Battery Charger
Features					
Total runtime on full charge	1.45mA Current Draw	0.88mA Current Draw	0.6mA Current Draw	500mAh 2.93mA Runtime 170 Hours	Full charge in < 5 hours
Standard battery charging via USB charging dock	1.8 to 3.8 V	1.71-3.6 V	1.7-2.0 V	3.7 V	MCP73831 3.75-6 V
Voltage Testing nodes	Evaluation board ports	Evaluation board ports	Evaluation board ports	Terminals	Input Output Terminals
Charge cycles >300	Battery monitoring	Embedded programming	N/A	Yes	Built in lithium Polymer charging algorithm
Configurable power off and power on conditions	Embedded programming	Embedded programming	Programmable switch from MCU	Program Switch from MCU	Automatic shutoff after full charge
Wireless range	≥ 10 meters	N/A	N/A	N/A	N/A
Communication protocol	SPI, I2C, Bluetooth LE	SPI, I2C	SPI, I2C	N/A	N/A

Data Sampling rate	48-MHz clock speed	≥ 1000 Hz	≥ 50 sps	N/A	N/A
Data processing	Embedded programming Machine learning	Embedded programming	Unprocessed Data Transmission	N/A	Built in CCCV LiPo Charging Algorithm
Data display	Bluetooth transmission to display device	SPI transmission to MCU	I2C transmission to MCU	Battery monitoring connection to MCU	Built in LED status indicator
Vibrational robustness	≥ 300g	≥ 20,000g	≥ 300g	≥ 300g	≥ 300g
Manufacturers	Texas Instruments, Microchip, U-Blox	TDK Invensense, ST, Bosch	Maxim Integrated	TinyCircuits	Texas Instruments, Microchip, Analog Devices
Part	CC2640R2F	*ICM-42688-P*	MAX32664 and MAX86141	ASR00035	MCP73831
Cost	$170	$250	$60	$10	$20

Controllers

Texas Instruments CC2640R2F MCU

[CC2640R2F SimpleLink™ Bluetooth® low energy Wireless MCU datasheet (Rev. C) (ti.com)]

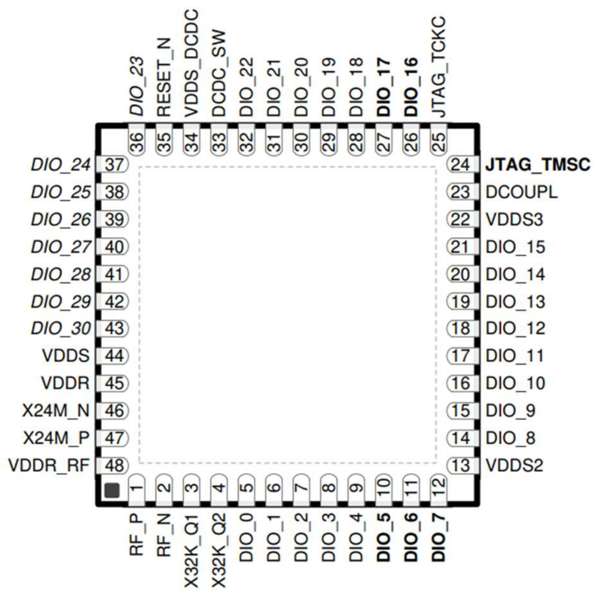


Figure 7-1. RGZ Package 48-Pin VQFN (7-mm × 7-mm) Pinout, 0.5-mm Pitch

Texas Instruments CC2640R2F MCU Parameters

Power	1.8 to 3.8 V 0.4mA + 8.2 µA/MHz
CPU	CC2640R2F 2.4 GHz wireless microcontroller (MCU) 48-MHz clock speed 32-bit Arm Cortex-M3
Memory	128kB Flash 275kB ROM 20kB SRAM
Software configurable power modes (current draw)	Active- Normal operation (1.45 mA) Idle- Active peripherals, waiting for interrupt to turn on active mode (650 µA) Standby- AON domain is active, GPIO's latched (1 µA)

	Shutdown- I/O's latched to value before shutdown and flash memory saved (0.15 µA)
General peripherals and modules	Synchronous serial interface supports master and slave up to 4 Mhz UART (Universal asynchronous receiver/transmitter function) max baud rate 3Mbps I2C connection at 100-kHz and 400-kHz operation Battery monitor Up to 32 channels Watchdog Timer Four general purpose timer modules (GPTM) 32 kHz RC oscillator True random number generator Supports up to eight capacitive sensing buttons Sensor controller Proprietary power optimized CPU Analog sensors using integrated ADC Digital sensors using GPIO's, I2C, SPI 12 bit ADC 200 ksamples/s
Software Tools	Smart RF studio 7 - Evaluate RF performance SensorControlStudio- Development environment for the CC26xx Sensor Controller Code Composer Studio IDE IAR embedded workbench
Radio Frequency	2.4-GHz RF transceiver compatible with Bluetooth® Low Energy 5.1 and earlier LE specifications Compliance with worldwide radio frequency regulations FCC CFR47 Part 15 (US)

SAMD21 Cortex®-M0+ 32bit low power ARM MCU
https://content.arduino.cc/assets/mkr-microchip_samd21_family_full_datasheet-ds40001882d.pdf

IMUs

ICM-42688-P

[DS-000347-ICM-42688-P-v1.3.pdf (netdna-ssl.com)]

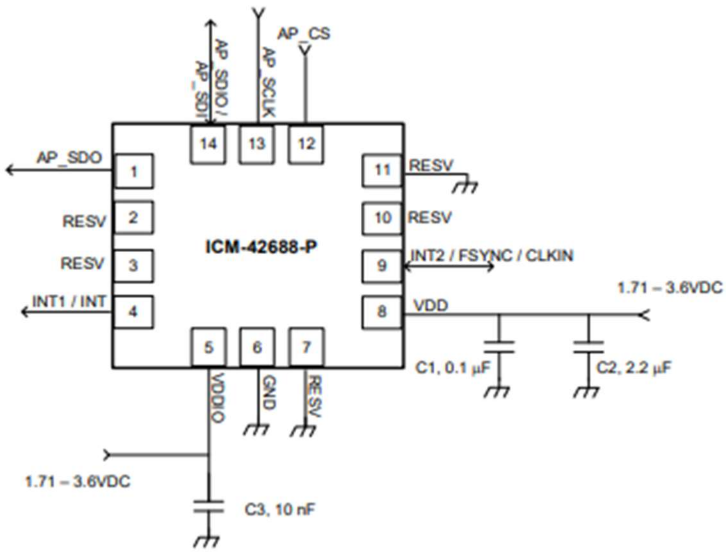


Figure 6. ICM-42688-P Application Schematic (SPI Interface to Host)

ICM-42688-P Sensor Parameters

ODR & Sample Synch	32kHz; RTC
GYRO Noise (mdps/rt-Hz)	2.8
GYRO Offset Temp Stability (mdps/°C)	±5
GYRO Range & Resolution	±2000dps; 16/19-bits
GYRO Sampling rate	1000
ACCEL Noise (µg/rt-Hz)	AXY: 65; AZ: 70
ACCEL Range & Resolution	±16g; 16/18-bits
ACCEL sampling rate	1000 Hz
Communication Protocol	SPI, I2C
Current Consumption	0.88 mA
VDD	1.71-3.6V
VDDIO	1.71-3.6V

ICM20649

https://www.infinity-component.hk/datasheet/8f-ICM-20649.pdf

ICM20649	
Max Power Draw	> 3.2 mA
FIFO	512 B
Accelerometer Range	±2/±4/±8/±16/±30 g
Gyroscope Range	±125/±250/±500/±1000/±2000/±4000 dps
Interface	SPI/I^2C
Sampling Rate	562.5 Hz

LSM6DS3

https://content.arduino.cc/assets/st_imu_lsm6ds3_datasheet.pdf

Other Datasheets and External Utility Links

Heart rate and spo2

https://datasheets.maximintegrated.com/en/ds/MAX86140-MAX86141.pdf

https://datasheets.maximintegrated.com/en/ds/MAX32664.pdf

Battery

Dongguan Large Electronics Co (adafruit.com)

Battery Charger

https://cdn-shop.adafruit.com/datasheets/MCP73831.pdf

Soft sensor

FLEX SENSOR DATA SHEET '10 (SPARKFUN KIT).ai (mouser.ca)

Battery Runtime calculator

Battery run-time calculator from PowerStream, how long will a battery last calculator

Part I: User Manual

Table of Contents

List of figures and tables

1. Preface

The purpose of this document is to familiarize users with the general functionality, usage, and care-taking process of the *Ztriker* devices. *Ztriker* is a martial arts tailored fitness tracker designed to elevate martial artists who are striving towards the next level, the device is capable of providing historical comparison of strike speed, power, acceleration, as well as biometrics for a comprehensive overview of progress variations between training sessions.

2. Glossary

Term	Description
LED	Light emitting diodes
IC	Industry Canada
RSS GEN	General Requirements for Compliance of Radio Apparatus
Pulse Oximetry	Method of determining the amount of oxygen in the blood
Sternum	Center of the chest
Groin	Lowest part of the body, located between the legs

3. Health and Safety

3.1. Conventions Used in This Manual

⚠ DANGER	These warning mean that it is certain or highly probable that death or severe injuries **will** occur if no precautions are taken.
⚠ WARNING	These warnings mean that death or severe injuries **may** occur if no precautions are taken.
⚠ CAUTION	These warnings mean that minor injuries **may** occur if no precautions are taken.
NOTICE	These warnings mean that damage to property **may** occur if no precautions are taken.

4. Warranty, Liabilities, and Legal Statements

4.1. Disclaimers

Sibulus makes no representations or warranties with respect to this manual and reserves the right to make changes to the specifications of the Ztrker product without notice and without obligation to notify of such revisions.

4.2. IC Notice to Users in accordance with current issue of RSS GEN

This device complies with Industry Canada license exempt RSS standard(s).

Operation is subject to the following two conditions:

1. This device may not cause harmful interference and
2. This device must accept any interference, including interference that may cause undesired operation of the device.

4.3. FCC Warning

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

4.4. Limited Warranty

Sibulus hereby warrants its products solely to the immediate purchaser of the Ztriker product, and to no others in the line of commerce; all other personnel involved with this product are expressly excluded from this warranty. The Ztriker product is warranted for fitness activities as described in this manual and is guaranteed to be free from defects in material, workmanship, and title. Sibulus warrants that the device manufactured will deliver the functionality promised through our product descriptors if and only if the product is properly cared for and operated under normal operating conditions. The warranty is valid for a period of one year from the date of shipment.

4.5. Service Under Warranty

Contact Sibulus through the methods described under Customer Support to request for warranted inspections of experienced technical problems with the product.

4.6. Service Out of Warranty

If the device purchased is out of warranty, follow the same procedure as listed in Service Under Warranty. You will be responsible for all fees incurred due to the shipment, replacement, parts, and services required to ensure the correct functionality of your device.

5. Introduction

5.1. QuickStart

1. Remove *Ztriker* device from packaging and power on. Physical device interfaces are shown at the end of the QuickStart section in Fig. 1.
2. Download the app from the iTunes App Store or the Google Play store & create a profile.
3. Enable Bluetooth on your Android or Apple Smartphone.
4. Press the sync button on the Ztriker and find the *Ztriker* device in your smartphone's Bluetooth connectivity section and initiate connection.
5. Put on the *Ztriker*, ensuring that a snug fit is achieved. Turn on the *Ztriker* and hold your wrist straight as the device calibrates.
6. Press the record button and Start punching. User interface will show the acceleration and speed of each punch as well as the biometric data. To stop recording, hold the record button and release.

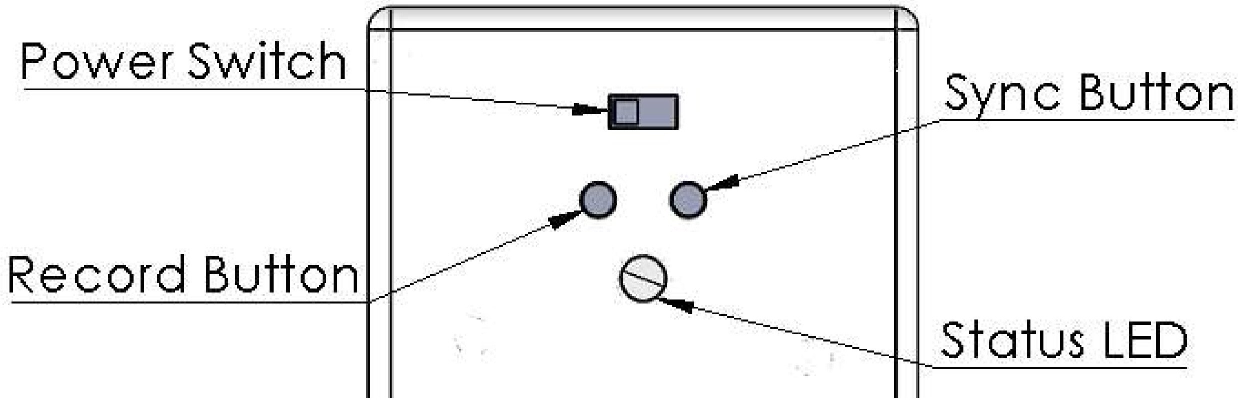


Figure 21. Physical user interface

5.2. How to Use

1. Download the Sibulus App from the iTunes App Store or the Google Play store & create a profile.
2. Ensure that Bluetooth is enabled on your smartphone.
3. Ensure that the battery level of the device is above operational threshold. Before using the *Ztriker* Device, you will need to charge it for approximately 30 minutes using a micro-USB cable attached to your computer or standard micro-USB phone charger.

LED Colour	Charging status
Solid Red	Low charge
Solid Orange	Connected to an adapter and charging
Solid Green	Fully charged

Warning! Prevent the USB charger port and the small end of the charger from contacting conductive materials, such as liquids, dust, metal powders, and pencil leads.

Battery charging Precautions:
If the battery is completely discharged, the Ztriker cannot be turned on immediately after being connected to the charger. Allow a depleted battery to charge for a few minutes before turning on the Ztriker.

4. Wake up the sensors by:
   4.1. Toggling the power button to the on position and hold your wrist straight as the device calibrates.
   4.2. Once the power led indicates that the device is powered on, press the connect button to initiate connection with the app. Only connect one set of devices at a time.
   4.3. Sensor states
   The LED indicator light on the device shows the status of the device once powered on:

LED Colour	Device status
Flashing Red	Searching for Wi-Fi
Flashing Blue	Connected to Wi-Fi, not recording
Flashing Green	Connected to Wi-Fi, recording

5. Training

When training using the *Ztriker* device, ensure that you are well hydrated and that you follow all health advice as put forth by a medical professional. When striking targets ensure that contact is made with only the first knuckles on the index and middle fingers, and that those two knuckles form a straight line with your arm. Doing so will help to prevent injuries. For additional training recommendations please refer to section 8: Training Guides.

6. Updates and checking the current firmware version.

The current firmware and software versions can be checked inside the Sibulus app. Firmware updates are done over the air, when updating device firmware please ensure that the *Ztriker* remains on and connected during the update process. Software updates for the app can be downloaded from the respective app store.

7. Cleaning, Troubleshooting, Maintenance

   For maintenance instructions, please refer to section 7.

8. Others

   For additional support, refer to the FAQ section or contact customer support.

6. Device Overview

The *Ztriker* is made up of five main components; The Measurement Unit, the Attachment plate, the Dust Cover, the Injury Detection Sensor, and the Attachment Band; and is secured together using four Phillips head screws. All main components are shown below in Fig. 2.

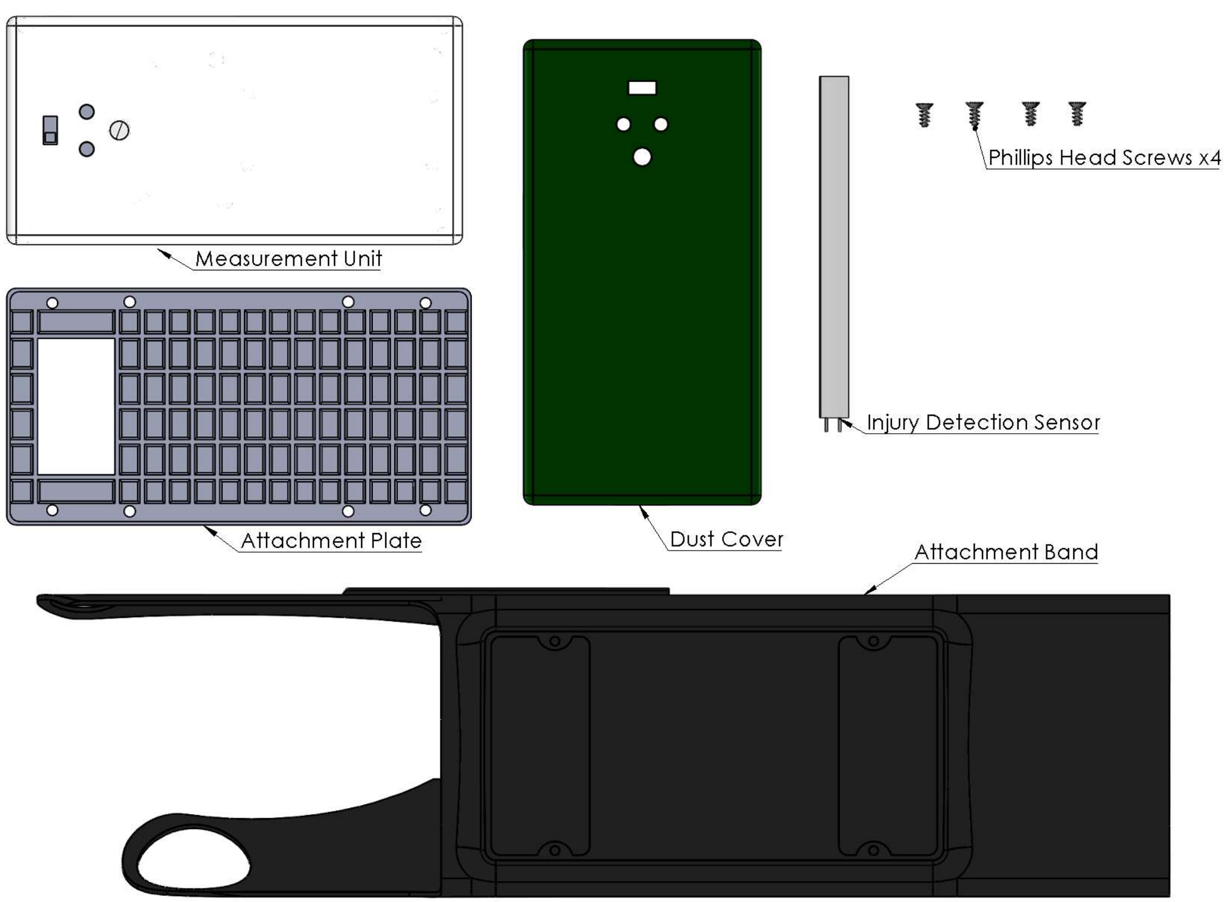


Figure 22. Main Ztriker components

WARNING! Choking hazard: small parts. Keep away from children and pets.

6.1. Measurement Unit

The Measurement Unit houses all the main electrical components of the *Ztriker*. On the main face of the Measurement Unit are the power switch for the *Ztriker*, the wireless sync and data recording buttons, and the status LED. When the sync button is pressed the wireless connection will be enabled the status LED will flash blue. When the record button is pressed performance recording is enabled and the status LED will flash green. To stop the recording, hold and release the record button. The stoppage of performance recording is indicated by the status LED flashing blue. Around the sides of the Measurement Unit are the access ports for charging, service diagnostics, and connecting the Injury Detection Sensor. The bottom face of the Measurement Unit provides access to the heartrate and pulse oximetry sensor. For ease of assembly the Measurement Unit features guideposts to assist with alignment of the Attachment Band first and the Attachment Plate second. The layout of the Measurement Unit is shown in Fig. 3.

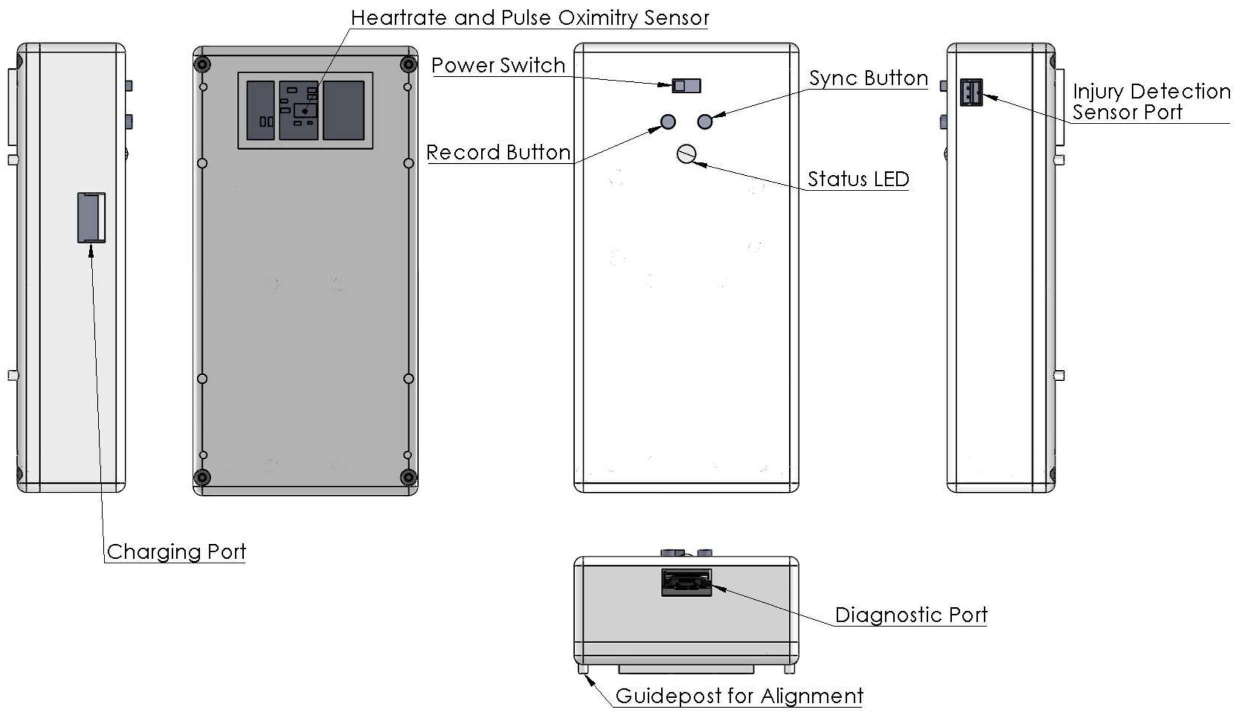


Figure 23. Measurement Unit layout

When using the *Ztriker* ensure that the Dust Cover is installed over the Measurement Unit to prevent intrusion of dust and moisture during use as shown in Fig. 4.

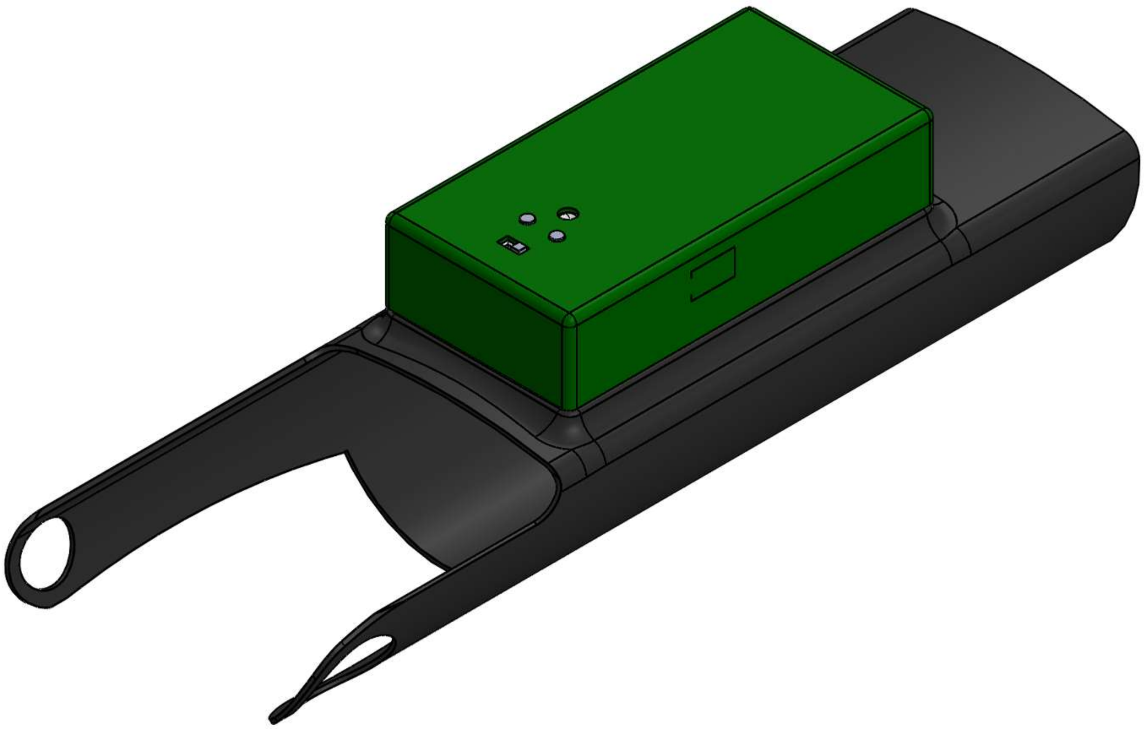


Figure 24. Ztriker with the Dust Cover installed

6.2. Attachment Band

The Attachment Band secures the Measurement Unit in place when wearing the *Ztriker*. To ensure alignment and proper fit, make sure that the guideposts on the Measurement Unit pass through the alignment holes on the Attachment Band. The Attachment Band pocket is where the Injury Prevention Sensor is inserted. The Attachment Band is shown below in Fig. 5.

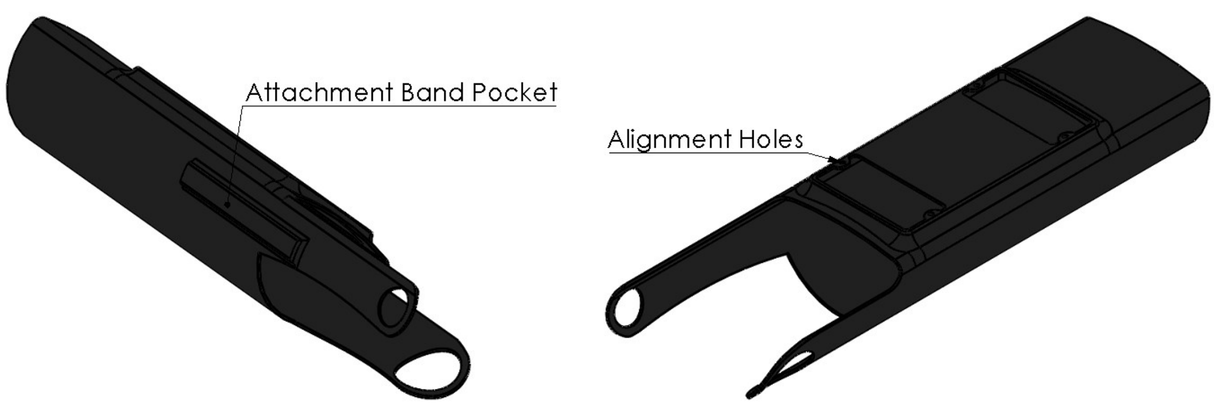


Figure 25. Attachment Band overview

6.3. Attachment Plate

The Attachment Plate secures the Measurement Unit to the Attachment Band using the included Phillips screws. To ensure alignment and proper fit, make sure that the guideposts on the Measurement Unit pass through the alignment holes on the Attachment Plate. The assembled configuration of the Measurement Unit and the Attachment Plate is shown below in Fig. 6 (The Attachment Band is omitted from Fig. 6 for clarity).

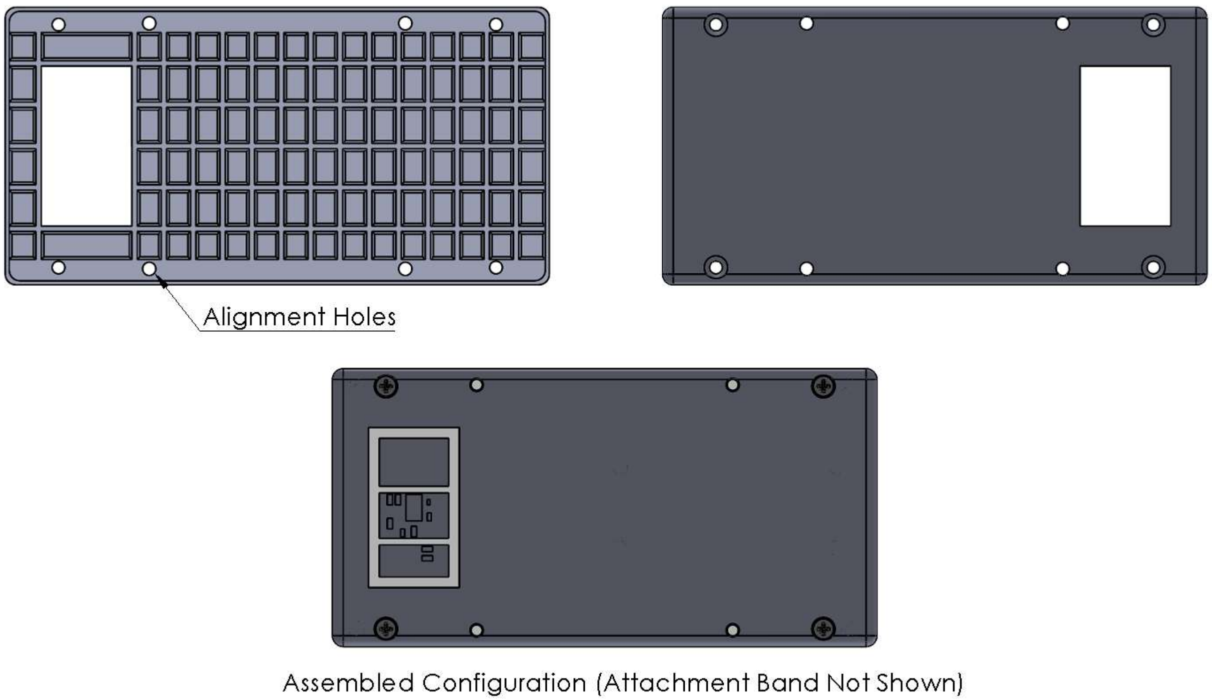


Figure 26. Attachment Plate overview and assembled Measurement Unit configuration

6.4. Injury Detection Sensor

The Injury Detection Sensor is inserted into the Attachment Band pocket to monitor wrist position during use of the *Ztriker* and will detect when your wrist has bent at an angle that may result in an injury occurring.

7. User Interface

The home screen will run on the central device application window (either computer or smartphone). Measurements that are updated real time are shown in the widgets as displayed below. These metrics include:

1. Instantaneous Heart Rate, Status, Oxygen Saturation
2. Instantaneous X, Y, Z acceleration
3. Total strikes during recording session
4. Average striking acceleration
5. Average striking velocity
6. Flex sensor values

The home screen is shown below:

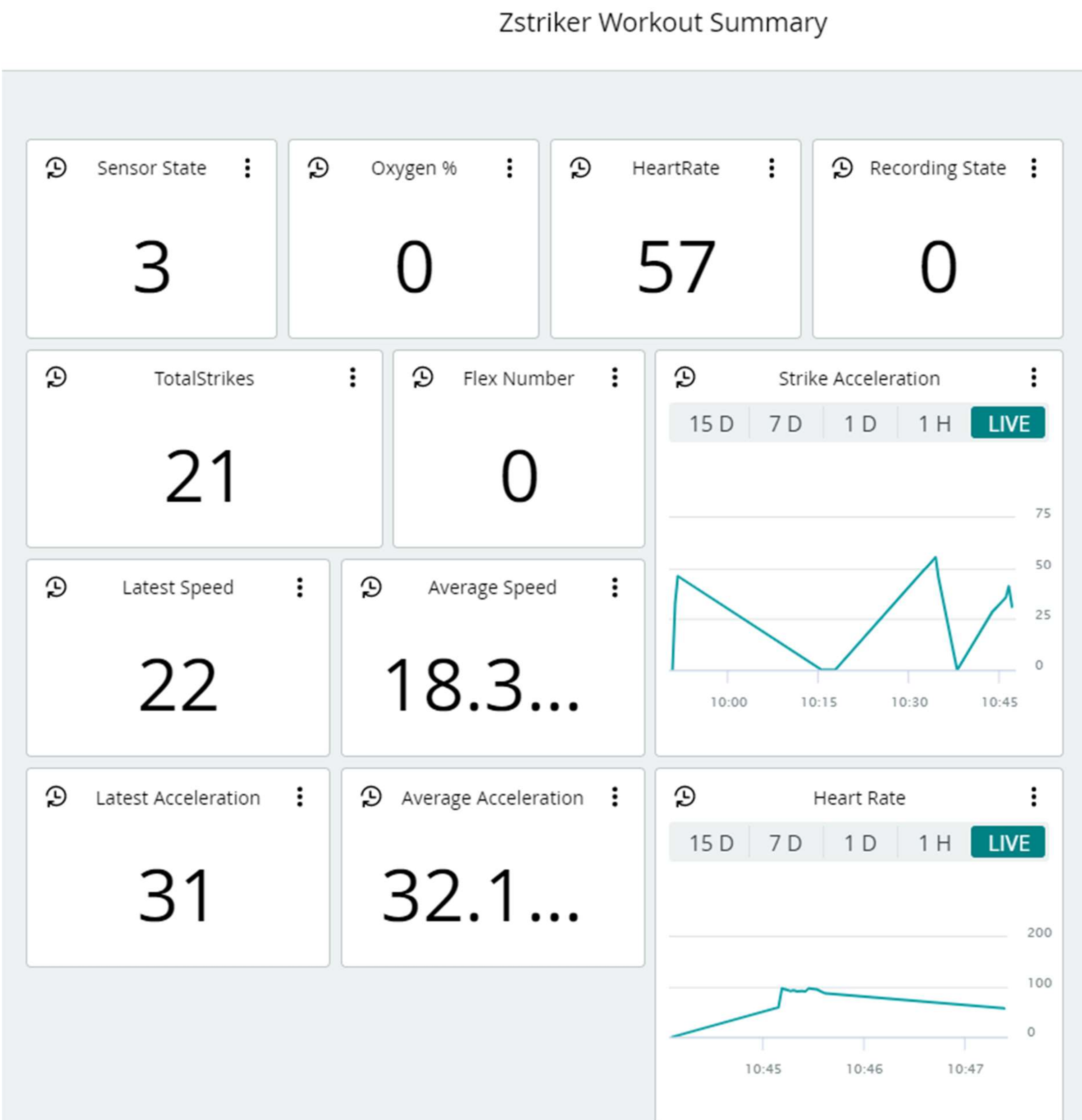


Figure 27. Digital user interface home screen

Table XXII. Sensor states and recorded data

Recording State	0 - Recording 1 - Not Recording
Sensor State	0 – Wrist not detected 1 – Body detected 2 – Wrist Detected, unstable signal 3 – Wrist Detected, Recording
Heart Rate	Units - Beats per minute
Oxygen	Percentage Oxygen

Total Strikes	Number of Strikes since Recording
Average Strike Speed	Average speed in m/s
Latest Strike Speed	Latest speed in m/s
Average Strike Acceleration	Average acceleration in m/s^2
Latest Strike Acceleration	Latest acceleration in m/s^2

8. Training Guides

CAUTION! Failure to use the device in ways other than intended may cause injuries.

The key to improving is consistency: consistent training, consistent diet, and consistent rest. As you progress through your training journey you will need to adapt your training program accordingly based on what benefits you wish to get out of it. As such there is no one perfect training guide for all persons. Listed below are a few exercises that are time proven to be effective at improving performance. A wider list of exercises along with images and videos is available in the Sibulus app.
Make sure when training to stay hydrated and always listen to your body, stopping if an injury occurs, and not resuming training at a high intensity until fully recovered. Always make sure to choose an appropriate weight or resistance for your strength level and the exercise at hand, and make sure that resistance bands are in good working order (no damage) and are firmly secured before use. Exercises can be performed either for repetitions or for time elapsed and is mostly down to personal preference.

Warning! High intensity training is not for everyone and can lead to injury and the worsening of health conditions. If you have a history of health conditions in your family or suspect that you may have an undiagnosed health condition, please consult with your primary care physician before proceeding.

8.1. Warmup and Stretching

A key component to preventing injury while training is a good warmup. A warmup is generally a group of exercises that targets to primary muscle groups you want to work. Often a warmup includes the exercises you have planned to do, with the exercises performed at a lower intensity. Warming up and dynamic stretching go hand in hand. Dynamic stretching is usually performed as part of the warmup procedure and helps to loosen up the joints and muscles. Dynamic stretching is not performed with intensity and is not intended to help improve flexibility, static stretching on the other hand is. Static stretching is performed after a workout has finished, as now that the muscles are warm, they allow for a much deeper stretch with a lower chance of injury. Static stretching also helps to reduce muscle soreness after a workout. For the best stretching results, perform static stretching as soon as you can after a workout, and then repeat the stretches within a 1-hour period.

8.2. Proper Technique

Technique is key to getting the most out of your training and preventing injuries from occurring. When either striking targets or shadow sparring the strike technique can be broken down into three parts: stance, delivery, and impact.

The stance is the same throughout all hand based striking techniques. To get into the proper stance step back with the same leg as your dominant hand until your feet are shoulder width apart. Make sure that your heels are offset by a hand width, instead of being in a straight line. Have your feet pointed diagonally, matching the orientation of your body. The final step to get into the proper stance is to raise both hands to chin level. Once in a proper stance, take care not to be flat footed. This will delay your actions and negatively effect your training. Instead, try to bounce on the balls of your feet, this will ensure that you are always ready to act.

Delivery will vary depending on what strike is intended. The basic Jab is a direct punch with the foremost arm. When extending your arm make sure to pivot your hip to turn your body away from the punch, this will allow you to extend your reach and generate more power. The Reverse or Straight punch is a direct punch with the rearmost arm. As you extend your arm lift your rear heal off the ground as you turn your body away from the punch. The hook is an indirect punch that follows a horizontal path and can be performed with either the foremost or rearmost arm. When performing the hook your arm does not completely extend. As you initiate the hook you lift and pivot on the heel that is the same side as the strike. This will allow you to turn your hip and generate more power and reach. The uppercut is the vertical version of the hook. The upper cut is a more defensive strike and is only intended to be used in close quarters. When performing an uppercut lean back slightly as you turn the body way from the strike. Like the hook, the uppercut is performed without fully extending your arm, as fully extending your arm will leave you off balance and open for a retaliatory strike.

Impact is where the effectiveness of your strikes is determined, and injuries are most likely to occur. Usually strikes are aimed at three main locations: below the nose, the below the sternum, and the groin. When impacting targets ensure that the fist is tightly closed, that only the first knuckles on the index and middle fingers make contact, and that the index and middle finger knuckles are in line with the forearm. Opening up your body by turning away from the strike will allow you to follow through with your strike by extending your range. Following through is very important in effectively transferring your power to a target. The importance of follow through is why having a proper striking distance is greatly emphasized; being too close to the target will not allow you the generate enough power before impact, while being too far away from the target will either result in shallow impact or no impact at all. The sweet spot is the distance at which you can hit the target without turning your body.

Caution! Striking targets with improper form may result in injuries to your hand and wrist, including sprains and broken bones.

8.3. Upper Body

Working the upper body is going to be the primary focus of anyone looking to improve the speed and power of their strikes. The primary muscle groups of focus are going the be the chest muscles (pectoralis), the arm muscles (biceps and triceps), shoulder muscles (deltoids), and the upper back muscles (trapezius and latissimus).

Push-ups

Required Equipment: None
Good for: Strength, Speed
Push-ups are perhaps the most versatile of all body weight exercises, with an almost infinite number of variations. Push-ups primarily work the upper body muscles but are a compound exercise that works the

entire body. How you perform push-ups should be tailored to your strength and skill level starting from the basic starting position, for beginners push-ups can be performed against a wall and as your strength improves you can transition to a kneeling push-up, before transitioning to a full push-up.
Hand position and elbow position are key to deciding which muscle groups and what part of the muscle group are the primary focus of the exercise. Having your hands closer to the center of your body allows for greater engagement of the pectoralis, allowing you to target the inner chest, while having your hands further apart shifts the focus to the outer chest and the shoulders. Moving your hands towards your head will shift the focus towards the upper chest while moving your hands towards your feet will shift the focus towards the lower chest. Having your elbows close to your body shift the focus away from your chest to your arms, primarily your triceps. Ideally your elbows should make an angle of less than 15° with your body for arm focused push-ups, and between 15° and 45° for chest focused push-ups. Angles between the body and elbows of greater than 45° are not recommended as there is a high chance of injury occurring.
Basic Push-up steps

1. Choose the starting position.
    a. Wall push-ups: Stand a shoulder width distance away from the wall, place hands shoulder width apart at shoulder height on the wall.
    b. Kneeling and Full push-ups: Kneel and place your hands on the ground in front of you directly below your shoulders. For Full push-ups extend your legs behind you until your knees are off the ground and your weight is supported by the balls of your feet. Once in position your back should be straight from your shoulders to the point of contact with the floor.
2. Push your heels as far back as possible, then squeeze your glutes and engage your core.
3. Breath in while lowering yourself until your chest is in line with your elbows, keeping your back straight through the entire motion.
4. Exhale while pushing yourself back towards your starting position, keeping your back straight through the entire motion.

Variations: Incline push-ups, decline push-ups, Spiderman push-ups, archer push-ups, clapping push-ups, pike push-ups, dive bomber push ups, knuckle push-ups etc.

Tricep Extensions/Tricep Kickbacks

Required Equipment: dumbbells, curl bar, or resistance bands (flat or adjustable bench optional)
Good for: Speed
Tricep exercises are a great isolation exercise to tone your arms and increase the speed of your direct strikes. Dumbbells can be used to perform tricep extensions, tricep kickbacks, and skull crushers, a curl bar can be used to perform tricep extensions and skull crushers, resistance bands can be used to perform tricep extensions and kickbacks. Where your palm is facing while performing the motion will change which part of the tricep is targeted and can be varied for more advanced exercises.
Tricep Extension steps

1. Using an appropriate weight or resistance raise your arm(s) above your head.
2. Breath in while bending your arm(s) until your forearm is parallel to the ground.
3. Exhale as you straighten your arm(s) back to their starting position.

Tricep Kickback steps

1. Using an appropriate weight or resistance band over with your arm fully curled and your elbow close to your body.
2. Exhale as you extend your arm behind your body.
3. Inhale as you return to the starting position.

Using a bench for tricep kickbacks can help as a bench can be used to proved support. A bench can also allow you to work both arms at the same time more easily.

Skull-Crusher steps

1. Using an appropriate weight lie on your back with your arms pointing straight up.
2. Inhale as you bend your arms until the make a 90° angle.
3. Exhale as you straighten your arms and return to the starting position.

Bicep/Hammer Curls

Required Equipment: dumbbells, curl bar, or resistance bands

Good for: Strength, Speed

Curls primarily work the biceps brachii, more commonly known as the biceps, and help to increase the speed and strength of indirect strikes such as uppercuts and hooks. Bicep curls and hammer curls are very similar exercises, with the main difference being the direction your palm is facing as the motion is performed. Bicep curls however are more versatile in what equipment can be used to perform them. Curls with the palm facing up are bicep curls, while curls with the palm facing in are hammer curls.

Bicep/Hammer Curl steps

1. Using an appropriate weight or resistance band over with your arm pointing down and your elbow close to your body.
2. Exhale as you bend your arm as much as possible, engaging the muscles the entire time.
3. Inhale as you slowly straighten your arm with a controlled motion to the starting position.

Variations: Bicep curls with supination, reverse curls

Pull-Ups

Required Equipment: Stable horizontal bar or ledge (a makeshift bar can be made using two chairs and a broomstick)

Good for: Strength, Speed

Next to push-ups pull-ups are one of the most effective body weight exercises. Pull-ups engage the shoulders, the back, the core, and the arms. Pull ups can be quite challenging for beginners, but the difficulty can be scaled down to an appropriate level. Choosing a lower bar that allows you to keep your feet on the ground is a good choice for beginners looking to build up strength, from there assisted pull-ups using bands are the next difficulty progression. Performing negatives in which the body starts in the up position and is slowly lowered before letting go of the bar and repeating are an alternative difficulty progression. Once you feel that your strength has progressed enough move on to hanging pull-ups without assistance. For greater challenge one armed or weighted pull-ups can also be attempted. A static hang is a good method of training pull-ups without dynamic movements, as long as the shoulders and back are engaged.

Pull-up steps

1. Grab the bar with your hands approximately shoulder width apart.
2. Engage your shoulders and back by pulling your shoulders towards the center of your back.
3. Exhale as your pull your body towards the bar, aiming to get your chin at, or higher than the bar.
4. Inhale as you lower your body back towards the starting position.

Finger Extensions

Required Equipment: None

Good For: Injury Prevention, Impact Transfer

One body part that is often neglected from training are the forearms. The forearm muscles help to stabilize the wrist and control grip strength. Having a higher grip strength will allow you to form a tighter fist, creating a more solid impact point allowing for more of your power to be transferred into the target. Start by making as tight of a fist as you can, then completely straighten all of your fingers before tightening them back into a fist and repeating. Changing the speed of the movement, having your arms bent, and if your arms are raised to your side, raised in front, or raised straight above your head all affect the effectiveness of the motion.

8.4. Lower Body

One might ask “How is the lower body connected to my punches?” and the answer is quite simple, without a stable base from which to start the motion your strikes will have no power. You begin by pushing off from the ground, pivoting your legs and turning your hips before your upper body begins to do any work. Calves, quads, hamstrings, and glutes are all muscle groups associated with the lower body, and all help to transfer power from the ground into your strikes and maintain balance.

Squat

Required Equipment: None

Good For: Strength, Stability

The mighty squat, a staple of lower body exercise routines everywhere. Squats primarily target the quads and the glutes. While squats can be performed without any equipment, difficulty progression can be achieved using resistance bands or weights. Changing how far apart your feet are as well as which direction your toes are facing effects which areas of the muscle groups are targeted.

Squat Steps

1. Place your feet approximately shoulder width apart with your toes pointing slightly outward.
2. Shoot your hips backward, keep your back straight, and you lower your body as if you were sitting down on a small chair with your weight spread evenly across your feet. As your hips go back bend your body forward, using your arms for balance if needed. (When using resistance bands or weights you will be unable to use your arms for balance)
3. Inhale as you lower yourself until your hips are level with your knees. This will help to stabilize your body and tighten up your core.
4. Exhale as you return to the starting position.

Variations: Jump Squat, Pistol Squat, Zercher Squat, Front Squat, Sumo Squat, Sissy Squat, Buddhist Squat, etc.

Deadlift

Required Equipment: None

Good For: Strength, Stability

The deadlift, like the squat, is a staple of lower body routines everywhere. Deadlift target the hamstrings, the glutes, and the lower back. While deadlifts can be performed without any equipment, it can be easier to visualize the correct motion and increase the difficulty using resistance bands or weights such as dumbbells and barbells.

Deadlift steps

1. Start with your feet shoulder width apart and your toes pointed slightly outward.

2. With your weight spread out evenly across your feet stick your hips back and bend over while keeping your back straight.
3. Grab the barbell if required (dumbbells and resistance bands should already be in your hands) and keep it as close to your legs as possible.
4. Inhale to stabilize your body and tighten up your core.
5. Exhale as you Raise the weight in a vertical line, making sure that your knees **Do Not** cross in front of your toes during the motion.
6. As you raise the weight your shoulders and hips should move at the same time.
7. The movement is finished when your legs are straight, and your hips are fully forward.

Variations: Romanian deadlift, Single leg deadlift, Sumo deadlift

Caution! Deadlifts with high weight and improper form will result in injury. Recommended to perform this movement under supervision of an experienced professional.

Glute Bridge/Hip Thrust

Required Equipment: None
Good For: Stability, Balance

The glutes are a key muscle group to target when improving stability and balance. The glute bridge and hip thrust are effective at targeting the hamstrings and glutes and are static and dynamic versions of each other respectively.

Glute Bridge/Hip Thrust steps

1. Lie on your back with feet flat on the floor.
2. Raise your hips off the floor until your body forms a straight line from your knees to your shoulders.
    a. For hip thrusts hold at the top and squeeze your glutes for 1-2 seconds.
    b. For glute bridges hold the position for as long as possible, or until your set exercise time expires.
3. Lower your hips back down and repeat.

Variations: Single leg glute bridge/hip thrust, elevated glute bridge/hip thrust, reverse plank glute bridge/hip thrust

Calve Raise

Required Equipment: None
Good For: Stability, Balance, Speed, Injury Prevention

Your calves are the final muscle group of the lower body and are key for explosive movements. Your calves control your feet, and thus are responsible for the initial transfer of power as you push off from the ground. Having strong calves will also strengthen your ankles and help to prevent injury. The direction that your toes are facing when performing the motion will change which area of the calves are targeted.

Calve Raise steps

1. Start with your feet should width apart.
2. Slowly raise your body onto the balls of your feet.
3. Hold at the top for 1-2 seconds.
4. Slowly lower yourself until your heels are touching the floor.

8.5. Core

Your core is perhaps the most important muscle group for any sport or activity. Your core is key to balance and stability and is required to effectively transfer power from your lower body to your upper body. The core is comprised of the abs, the obliques, and the lower back.

Plank

Required Equipment: None

Good For: Balance, Stability

Love it or hate it the plank is a classic core exercise. Planks are the static form of push-ups and can be used to help progress your push-ups if done in the full push-up position. The further your body is from the floor the more difficult the plank becomes.

Plank steps

1. Assume a push-up position with your forearms flat on the ground and your elbows beneath your shoulders.
2. Push your heels as far back as possible, then squeeze your glutes and engage your core.
3. Maintain a steady breathing rate as you hold the position for as long as possible, or until your goal time is met.

Variations: Push-up plank, one armed plank, side plank, single leg and arm plank

V-up

Required Equipment: None

Good For: Balance, Coordination

The V-up is a dynamic core exercise that targets the entire length of the abs. To progress the difficulty of V-ups resistance bands or weights can be added. Another way of progressing the difficulty of V-ups is to not lie completely flat between reps, and instead hold your hands and feet above the floor, the lower you can get without touching the greater the effect.

V-up steps

1. Lie on your back with your legs straight and your hands above your head.
2. Exhale as you engage your core and raise your upper and lower body at the same time, touching fingers to toes at the top.
3. Inhale as you lower yourself back to your starting position.

Variations: Cross body V-up, 1-2-3s

Russian Twist

Required Equipment: None

Good For: Balance, Stability

The Russian Twist is a dynamic core exercise that targets the obliques. Difficulty can be progressed by starting with your feet on the ground, balancing with your feet in the air, and then adding weight or resistance.

Russian Twist steps

1. Sit down on the floor and then with either your feet elevated or planted elevate your upper body.
2. Inhale as you twist your upper body to the side, reaching behind you.
   a. If your feet are elevated, try to keep them in the same position throughout the entire movement.
3. Exhale as you twist towards the other side.

Superman

Required Equipment: None

Good For: Stability, Impact Transfer

Supermans are an exercise that targets the lower back. The lower back is one of the primary stabilizing muscle groups and a strong lower back will allow for an effective transfer of power at the point of impact.

Superman steps

1. Lie down flat on your stomach with your hands above your head.
2. Inhale and lift your upper body and legs off the ground.
3. Hold for 1-2 seconds.
4. Exhale and lower your upper body and legs back down.

8.6. Cardio

Cardio, we know that no one really wants to do it, but it is a key part of a healthy, high performing body. Think of it this way, a body that has no cardio is like a car with bad fuel economy; it does not matter how fast or powerful the car is, once the fuel runs out the car stops.

Running/Jogging

Required Equipment: None
Good For: Coordination, Balance
Running and Jogging are the classic cardio exercises and can be performed without any equipment, and in any weather. The key to running or jogging is to make sure that your body moves in sync and that you find a rhythm for your movements. Try to land towards the center of your foot, and keep in mind that the faster you move your arms the faster your legs will move. One tip is to lean forward just a little bit, that way your body will think that it is falling and will try to get your legs under you even faster. Aside from working the lower body, running also activates the core to stabilize the upper body and prevent it from flopping all over the place.

Jump Rope

Required Equipment: Jump Rope
Good For: Timing, Coordination
Jump Rope is an excellent substitute for running as a cardio building exercise. Not only does jump rope make use of the entire body, but it also requires a great deal of coordination and timing to keep a constant rhythm. Normal jump ropes are widely available, and weighted jump ropes can be substituted

in for an increase in difficulty. Variations to increase the difficulty can include switching up the direction of the jump, increasing the height of the jump, single leg jumps, and mixing up the rhythm throughout the exercise.

9. Care and Maintenance

9.1. Cleaning

9.1.1. Cleaning the *Ztriker* Measurement Unit

The *Ztriker* Measurement Unit can be cleaned using an alcohol-based solution or IPA (Isopropyl Alcohol) and a soft cloth. Do not apply the solution directly to the *Ztriker* Measurement unit, instead dampen the cloth with the solution wipe down and the entire surface of the Measurement Unit. Let the Measurement Unit dry completely before using the *Ztriker*.

9.1.2. Cleaning the *Ztriker* Attachment Band

The *Ztriker* Attachment Band can be cleaned by hand washing in warm water using a mild detergent solution. When cleaning the Attachment Band, the Measurement Unit **MUST** be removed before cleaning, or else risk the chance of electric shock and damage to the *Ztriker* Measurement Unit.

Steps to separate the Attachment Band from the Measurement Unit:

Step 1. Ensure that the *Ztriker* is in the powered down state.
Step 2. Remove the Injury Detection Sensor from the Attachment Band Pocket.
Step 2. Undo the 4 Phillips head screws and remove the *Ztriker* Attachment Plate.
Step 3. Remove the Attachment band for cleaning.

Steps to join the Attachment Band to the Measurement Unit:

Step 1. Ensure that the Attachment Band is completely dry.
Step 2. Align the alignment holes on the Attachment Band with the guideposts on the Measurement Unit.
Step 3. Replace the Attachment plate and tighten the 4 Phillips head screws that were removed when the Attachment Band and Measurement Unit were initially separated.

NOTICE

Note: Do not overtighten the Phillips head screws as this may lead to damage to the *Ztriker* device.

Step 4. Insert the Injury Detection Sensor into the Attachment Band pocket.

9.2. Troubleshooting

⚠CAUTION

CAUTION! Electrical shock risk. Do not touch exposed wiring or bring device near liquid sources.

DANGER! Device includes lithium-ion battery which may present a serious fire hazard if damaged, defective, or improperly used.

The following are intended to help diagnose problems with the *Ztriker* unit. If the following issues occur and are unable to be resolved, please contact customer support for additional resources.

The *Ztriker* will not turn on.

Determine if the *Ztriker* is receiving power. Connect the *Ztriker* to the included charger and allow for the battery to charge for a minimum of 30 minutes. After charging the *Ztriker* for a minimum of 30 minutes try powering the *Ztriker* on again. If still unable to power the *Ztriker* on the problem may lie with an electrical fault. Discontinue use immediately and contact customer support to seek out service from a trained service technician.

Unable to find the *Ztriker* on a mobile device.

Power cycle (turn the *Ztriker* off then on again) the *Ztriker* and check on your mobile device to see if the *Ztriker* is now discoverable. If the *Ztriker* can still not be found, remove the current saved connection (if any) from your mobile device and proceed through the pairing process.

Injury Detection Sensor not responding/too many false readings.

Check the physical connection between the Measurement Unit and the Injury Detection Sensor. If the Injury Detection Sensor is inserted all the way, inspect the sensor for kinks or damage. Replace with a new sensor if any damage is found.

9.3. User Applicable Maintenance

9.3.1. Replacing a Damaged Injury Detection Sensor

Step 1. Ensure that the *Ztriker* is in the powered down state.

Step 2. Remove the dust cover from the *Ztriker* casing.

Step 3. Unplug the Injury Detection Sensor and remove from the Attachment Band pocket

Step 4. Insert the new Injury Detection Sensor into the Attachment Band pocket and insert the connector until an audible click is heard.

Step 5. Power on the *Device* and ensure that the Injury Detection Sensor is functioning as intended.

9.3.2. Replacing a Damaged Attachment Band

Step 1. Ensure that the *Ztriker* is in the powered down state.

Step 2. Remove the Injury Detection Sensor from the Attachment Band Pocket.

Step 3. Undo the 4 Phillips head screws and remove the *Ztriker* Attachment Plate.

Step 4. Remove the damaged Attachment band and prepare the replacement Attachment Band for installation.

Step 5. Align the alignment holes on the Attachment Band with the guideposts on the *Ztriker*.

Step 6. Replace the Attachment plate and tighten the 4 Phillips head screws that were removed in Step 3.

NOTICE

Note: Do not overtighten the Phillips head screws as this may lead to damage to the *Ztriker* device.

Step 7. Insert the Injury Detection Sensor into the replacement Attachment Band pocket.

10. Frequently Asked Questions

Q: Is the *Ztriker* waterproof?

A: No, the *Ztriker* is not waterproof. The *Ztriker* is sweat and splash resistant but is not intended to be submerged or sprayed with water for any period of time. Doing so can cause damage to the *Ztriker* device.

Q: How do I turn off my *Ztriker*?

A: Push the power switch to the 'OFF' position.

Q: Why are my sensors are not powering on after charging?

A: Contact the manufacturer for further assistance.

Q: Why are my strikes are not being recognized?

A: Check to make sure that Bluetooth connection has indeed been established, then make sure no background apps are running on your phone which might interfere with the connected device.

11. Customer Support

E-mail

Cha110@sfu.ca

Phone

1-236.996.4848

Mailing Address

Sibulus Inc.

13450 102 Ave #250

Surrey, BC

Canada V3T 0A3

Part II: Technical Support Manual

1. Preface

This manual is intended for use by a trained service technician to assist in the servicing procedure. Servicing performed by untrained technicians can result in damage to the *Ztriker* device which can result in personal injury and void the warranty.

2. Glossary

SpO2	A measure of the concentration of oxygen in the blood

3. Health and Safety

3.1. Conventions Used in This Manual

These warnings mean that it is certain or highly probable that death or severe injuries **will** occur, if no precautions are taken.

These warnings mean that death or severe injuries **may** occur if no precautions are taken.

These warnings mean that minor injuries **may** occur if no precautions are taken.

These warnings mean that damage to property **may** occur if no precautions are taken.

WARNING: choking hazard. Small parts. Keep away from children and pets.

CAUTION: Electrical shock risk.

CAUTION: Failure to use the device in ways other than intended may cause injuries.

CAUTION: Device contains small parts, keep away from children and pets.

FIRE HAZARD: device includes lithium ion battery which may present a serious fire hazard if damaged, defective, or improperly used.

4. Legal and Regulatory

4.1. Disclaimers

Sibulus makes no representations or warranties with respect to this manual and reserves the right to make changes to the specifications of the *Ztriker* product without notice and without obligation to notify of such revisions.

4.2. IC Notice to Users in accordance with current issue of RSS GEN

This device complies with Industry Canada license exempt RSS standard(s).

Operation is subject to the following two conditions:

1. This device may not cause harmful interference and
2. This device must accept any interference, including interference that may cause undesired operation of the device.

4.3. FCC Warning

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

5. Device Description

Displayed below in fig. 1 is a visual description of the *Ztriker* Measurement Unit case and interior components. Components shown in Fig.1 are then identified in Table I.

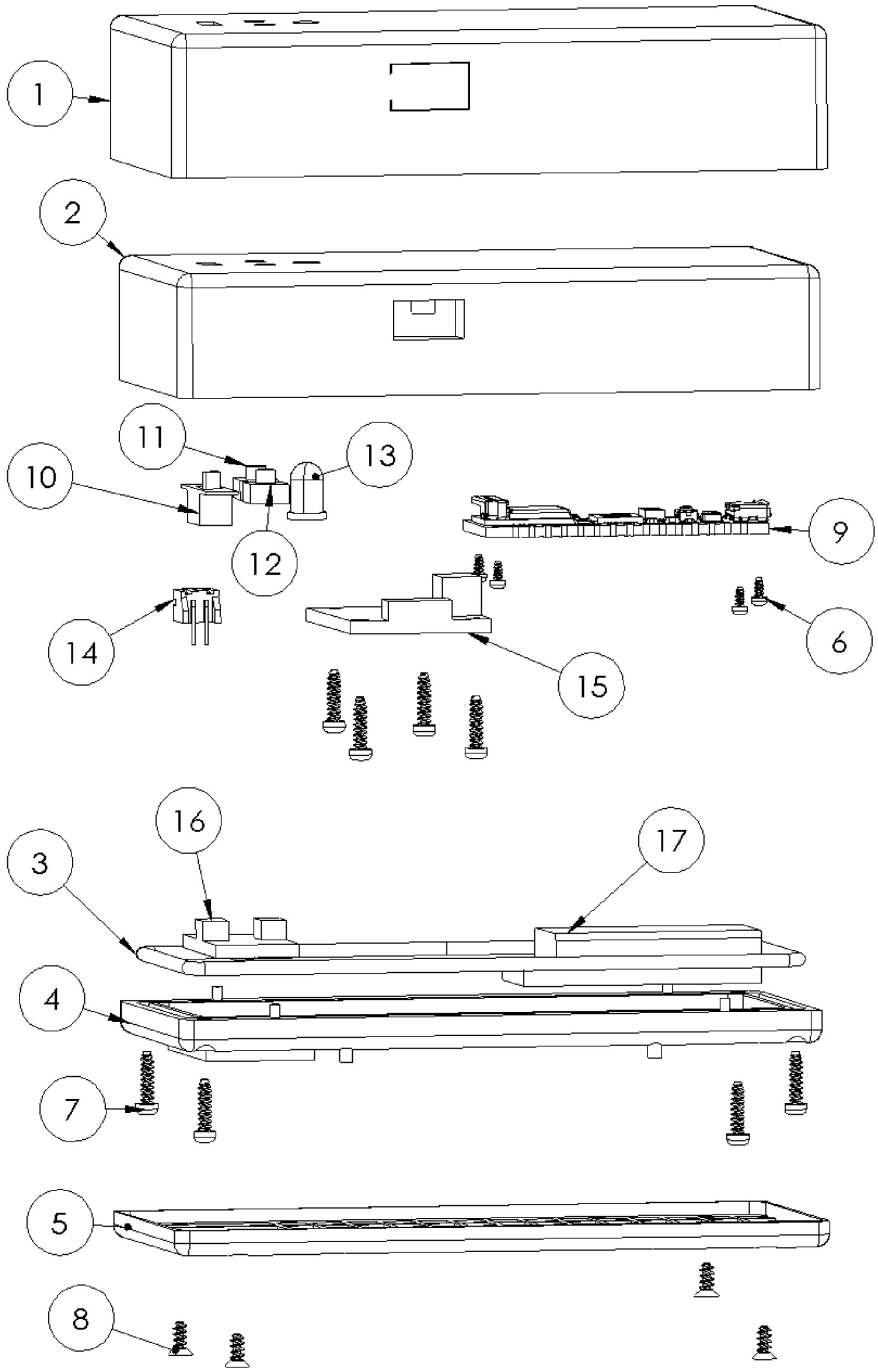


Figure 1. Measurement Unit assembly

Table I. Measurement Unit components

#	Item	#	Item
1	Dust Cover	10	Power Switch
2	Measurement Unit Upper Case	11	Sync Button
3	O-Ring	12	Record Button
4	Measurement Unit Lower Case	13	Status LED
5	Attachment Plate	14	Injury Detection Sensor Connector
6	3mm M1.4 Torx Head Thread Forming Screw	15	Battery Charging and Monitoring Module
7	8mm M2 Torx Head Thread Forming Screw	16	Heartrate and SpO2 Sensor
8	5mm M2 Phillips Head Thread Forming Screw	17	Battery
9	Primary Processing and Radio Module		

5.1. Mechanical Components

The *Ztriker* has 9 unique mechanical components with a total of 22 mechanical parts as seen in Fig.2 and identified in Table II.

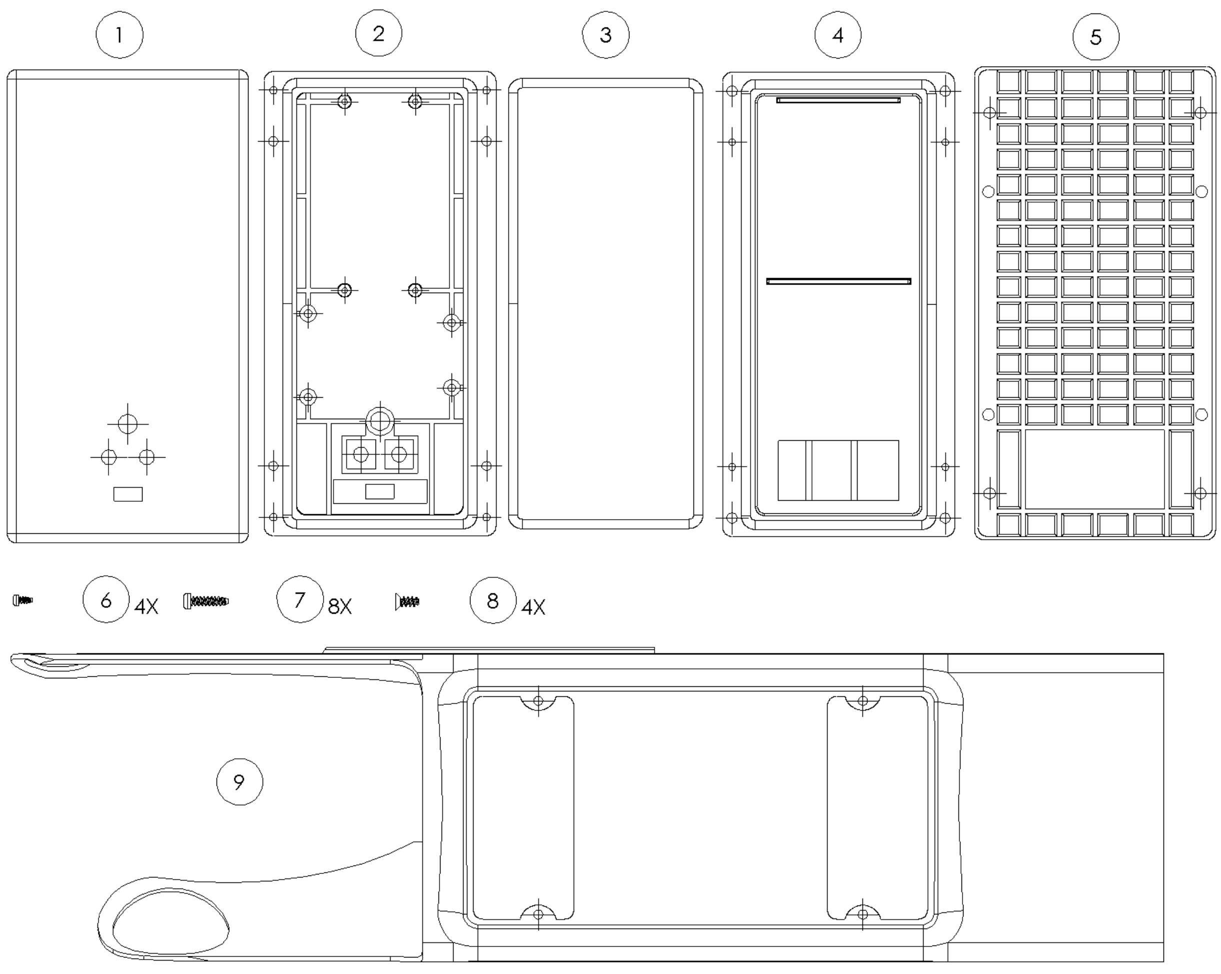


Figure 2. Ztriker mechanical components

Table II. Ztriker mechanical component identification chart

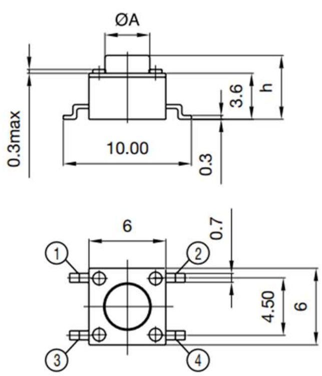
1	Dust Cover top view	6	3mm M1.4 Torx Head Thread Forming Screw X4
2	Measurement Unit Upper Case interior view	7	8mm M2 Torx Head Thread Forming Screw X8
3	O-ring	8	5mm M2 Phillips Head Thread Forming Screw X4
4	Measurement Unit Lower Case interior view	9	Attachment Band
5	Attachment Plate interior view		

5.2. Electrical Components

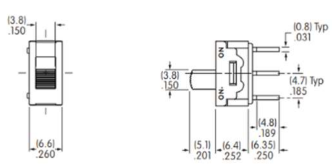
Peripheral Hardware:

- Flex Sensor

- RGB LED
- Pushbutton

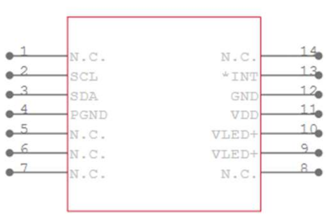


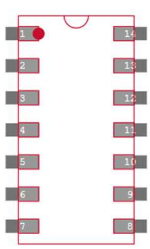
- Single Pull Double Throw Slide Switch



Pulse Oximeter and Heart rate monitor

- MAX30101





- MAX 32664

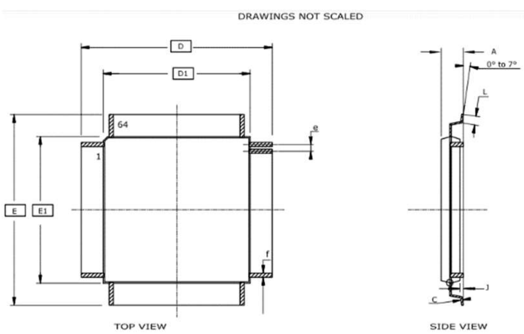
Arduino Nano 33 IOT

Arduino Nano 33 IOT Components:

- SAMD21 Cortex®-M0+ 32bit low power ARM MCU

Datasheet:

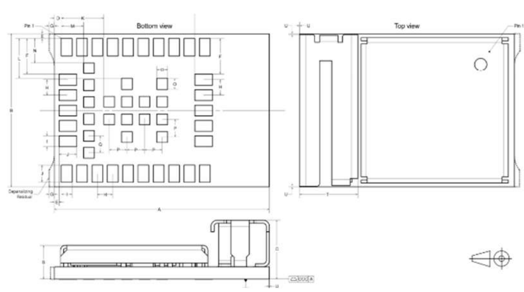
https://content.arduino.cc/assets/mkr-microchip_samd21_family_full_datasheet-ds40001882d.pdf



- u-blox NINA-W102

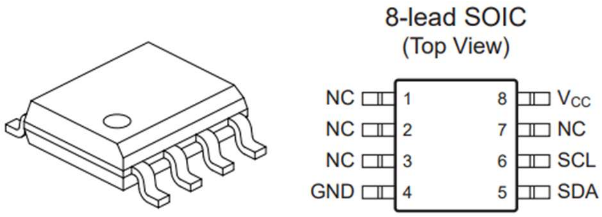
Datasheet:

https://content.arduino.cc/assets/Arduino_NINA-W10_DataSheet_%28UBX-17065507%29.pdf

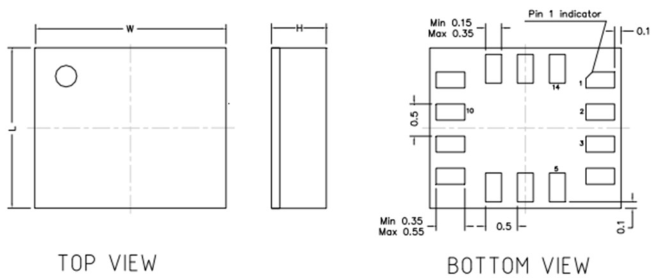


- ATECC608A

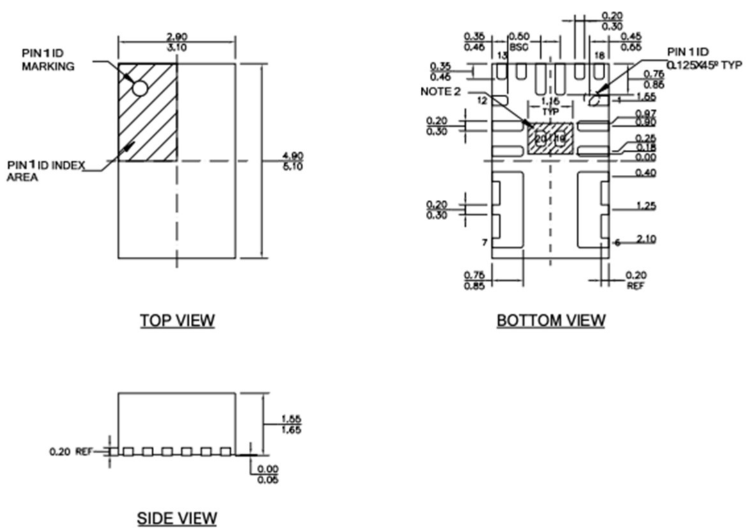
Datasheet:
https://content.arduino.cc/assets/microchip_atecc608a_cryptoauthentication_device_summary_datasheet-DS40001977B.pdf



- LSM6DS3



- MPM3610



6. Maintenance

Before performing maintenance on the *Ztriker* always make sure that the device is in the powered down state to reduce the risk of personal injury and damage to the device. Before performing service ensure that you have all required tools readily available. These include, but are not limited to, a soldering iron, a heat gun, a size 000 Phillips head screwdriver or bit, and a size 3 and a size 6 torx screwdriver or bit. Preliminary steps before servicing include the removal of the attachment plate, as well as the attachment band, and the disconnecting of the Injury Detection Sensor. The preliminary steps are as follows:

Step 1. Ensure that the *Ztriker* is in the powered down state.

Step 2. Remove the Dust Cover from the Measurement Unit.
Step 3. Remove the Injury Detection Sensor from the Attachment Band Pocket and unplug the connection from the Measurement Unit. Set aside the Injury Detection Sensor for reassembly.
Step 4. Undo the 4 Phillips head screws and remove the *Ztriker* Attachment Plate.
Step 5. Remove the Attachment band.

After servicing has been performed make sure to completely reassemble the *Ztriker* and that no components are missing. Component locations are presented in Fig. 3.

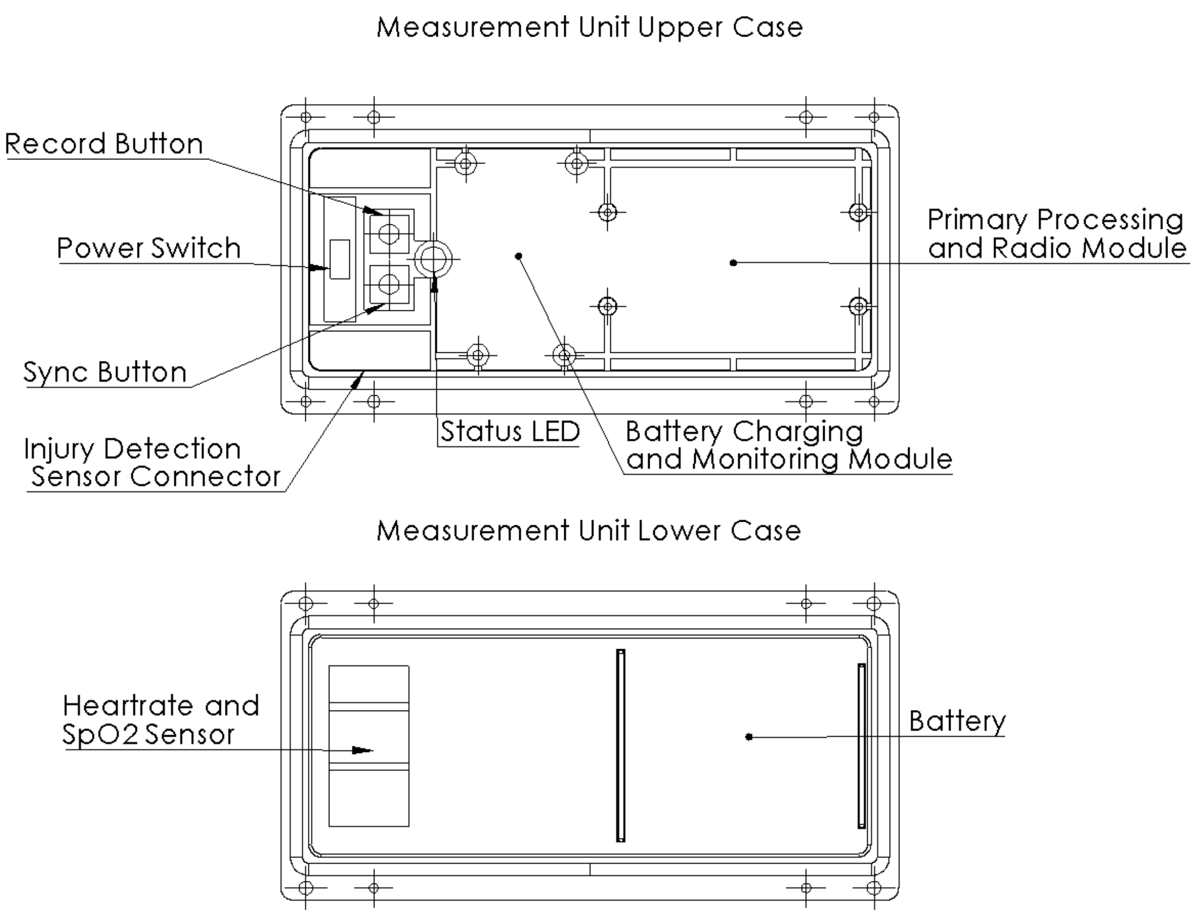


Figure 3. Measurement Unit internal layout

⚠CAUTION	**CAUTION**! Electrical shock risk. Only perform service on the device if you are trained to do so.

6.1. Battery Replacement

Required Tools: Size 6 torx screwdriver or bit, heat gun, soldering iron, small flathead screwdriver, razorblade, double-sided tape.

	**DANGER!** The device contains lithium-ion batteries. Exposure to lithium can cause severe damage to humans. If the lithium-ion batteries have been punctured, please dispose of safely and according to your local regulations.

Step 1. Using the size 6 torx screwdriver undo the four 8mm long M2 torx head screws.

Step 2. Separate the top and bottom halves of the measurement unit.

Step 3. Using the heat gun, gently heat the area around the battery. Doing so will soften the adhesive and allow for easier removal of the battery using the flathead screwdriver.

Step 4. After the battery has been separated from the lower half of the Measurement Unit Case, carefully remove the solder on the tabs using the soldering iron.

Step 5. Carefully solder the tabs on the new battery to the connections.

Step 6. Ensure that the *Ztriker* powers on.

Step 7. Using the heat gun, heat up the adhesive to get a good adhesion with the new battery. If required, completely remove the old adhesive using a razorblade and apply a new piece of double-sided tape.

Step 8. Replace the new battery in the old battery's location and reassemble the Measurement Unit.

6.2. Replacement of Switches, Buttons, the Injury Detection Sensor Connector, and the Heartrate and SpO2 Sensor

Required Tools: Size 6 torx screwdriver or bit, heat gun, soldering iron, razorblade, hot glue gun

Step 1. Using the size 6 torx screwdriver undo the four 8mm long M2 torx head screws.

Step 2. Separate the top and bottom halves of the measurement unit.

Step 3. Using the heat gun, gently heat the area around the component to be removed. Doing so will soften the glue and allow for removal of the component.

Step 4. Using the soldering iron, de-solder the connections and solder the connections on the new component.

Step 5. Ensure that the component works as intended.

Step 6. Use the heat gun to heat up the remaining glue until soft enough to insert the new component. It may be required to remove excess glue with the razor blade first. If so, add a new layer of hot glue afterwards.

Step 7. Reassemble the Measurement Unit.

6.3. Replacement of Primary Processing and Radio Module

Required Tools: Size 3 torx screwdriver or bit, soldering iron

Step 1. Using the size 6 torx screwdriver undo the four 8mm long M2 torx head screws.

Step 2. Separate the top and bottom halves of the measurement unit.

Step 3. Use the size 3 torx screwdriver to undo the four 3mm long M1.4 torx head screws.

Step 4. Carefully de-solder all connections on the old module and solder the connections to the new module.

Step 5. Ensure that the *Ztriker* functions as normal.

Step 6. Reassemble the Measurement Unit.

6.4. Replacement of Battery Charging and Monitoring Module

Required Tools: Size 6 torx screwdriver or bit, soldering iron

Step 1. Using the size 6 torx screwdriver undo the four 8mm long M2 torx head screws.

Step 2. Separate the top and bottom halves of the measurement unit.

Step 3. Use the size 6 torx screwdriver to undo the four 8mm long M2 torx head screws that secure the Battery Charging and Monitoring Module in place.

Step 4. Carefully de-solder all connections on the old module and solder the connections to the new module.

Step 5. Ensure that the *Ztriker* functions as normal

Step 6. Reassemble the Measurement Unit.

7. Parts List

Table III. Ztriker parts list

Item	Part Name	Part Number	Quantity	Description
1	Attachment Band	SIB-ZSTR-000	1	A compressive band made of stretchable fabric. Used to secure the

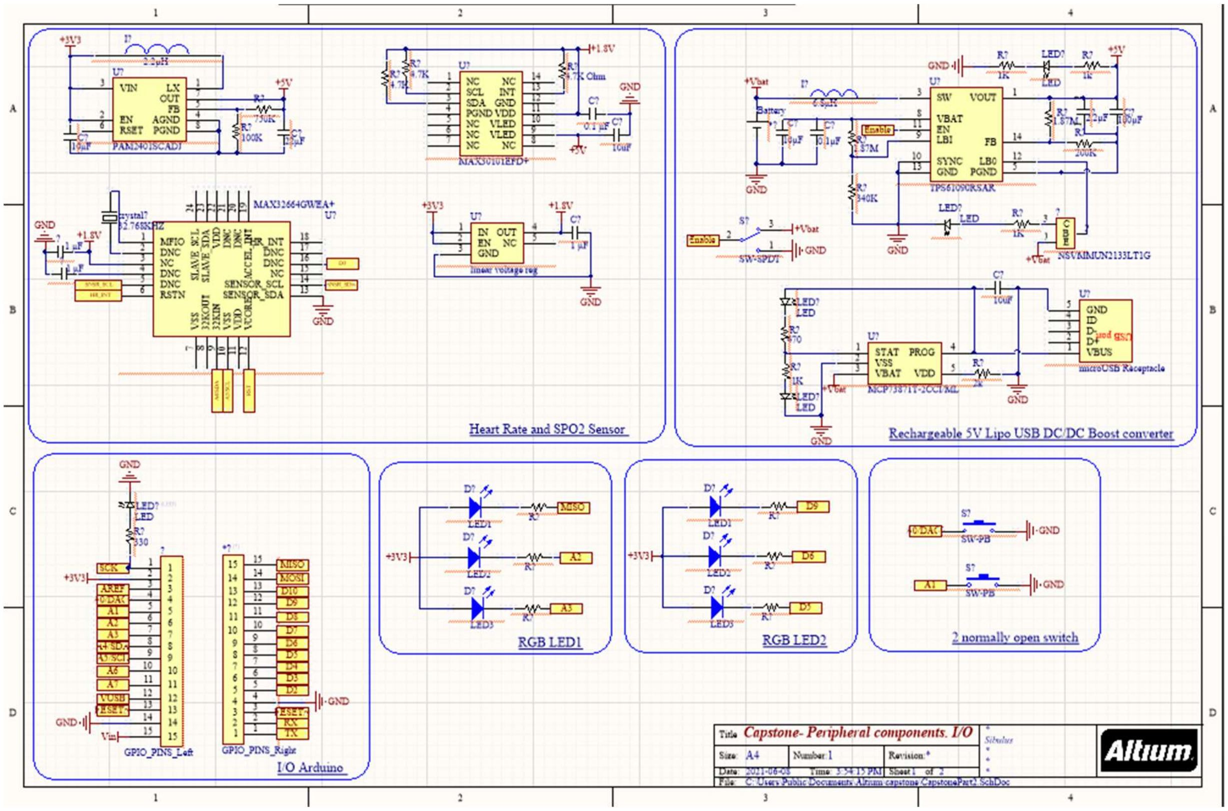
				Ztriker to the user's arm.
2	Measurement Unit Upper Case	SIB-ZSTR-001	1	The upper component of the housing for the *Ztriker*'s electrical components.
3	Measurement Unit Lower Case	SIB-ZSTR-002	1	The lower component of the housing for the *Ztriker*'s electrical components.
4	Attachment Plate	SIB-ZSTR-003	1	Secures the Measurement Unit to the Attachment Band.
5	Dust Cover	SIB-ZSTR-004	1	Silicone rubber cover for the Measurement Unit. Helps prevent the intrusion of dust and moisture.
6	O-Ring	SIB-ZSTR-005	1	A Silicone rubber O-ring that rests between the upper and lower Measurement Unit Cases. Works in tandem with the Dust Cover to help prevent the intrusion of moisture.
7	Primary Processing and Radio Module	SIB-ZSTR-006	1	Data processing module for the *Ztriker*. Primary components include a SAMD21 Cortex®-M0+ 32bit low power ARM MCU, a u-blox NINA-W102 radio module, and a LSM6DS3 IMU.

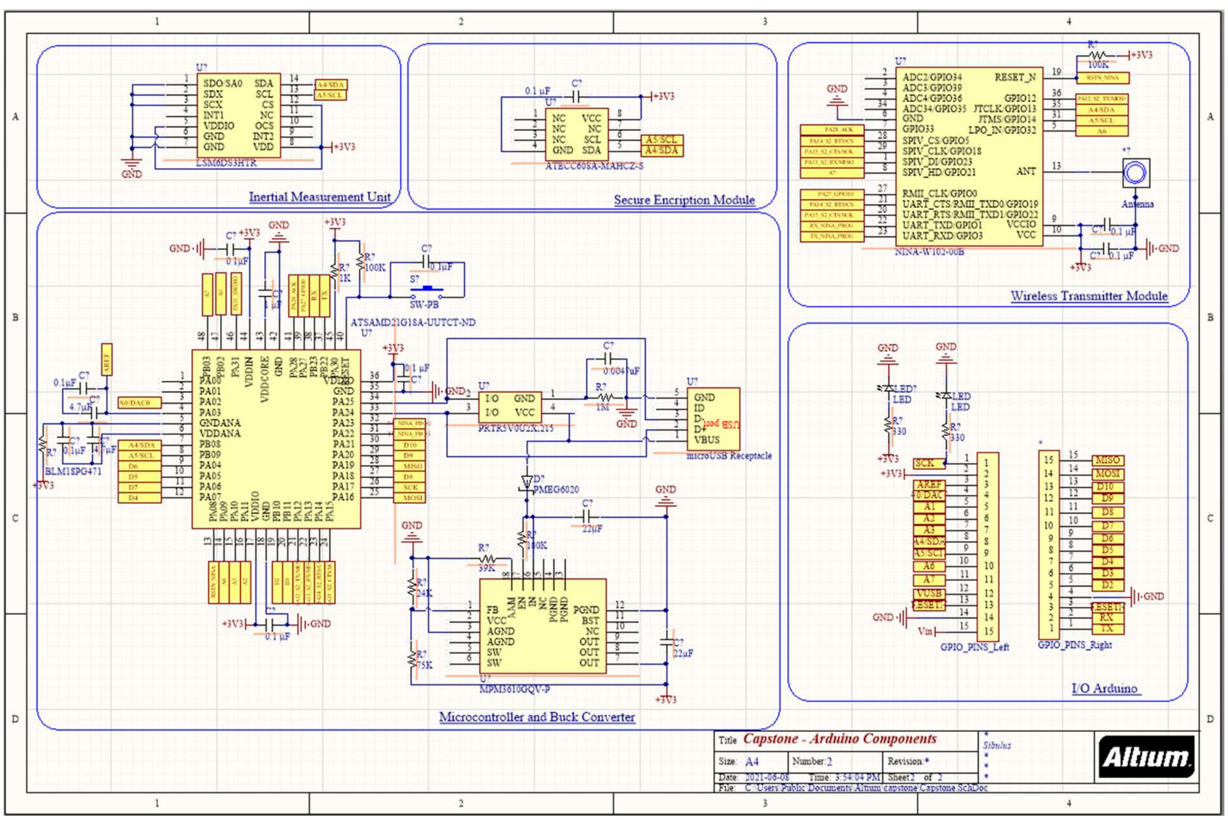
8	Battery Charging and Monitoring Module	SIB-ZSTR-007	1	Monitors the state of charge and controls the charging algorithm for the Battery.
9	Heartrate and SpO2 Sensor	SIB-ZSTR-008	1	Detects user heartrate and blood-oxygen saturation using reflected light. Comprised of the MAX32664 Biometric Sensor Hub and the MAX30101 Pulse Oximetry and Heart Rate Module.
10	Injury Detection Sensor	SIB-ZSTR-010	1	A flexible, variable resistor with a 25kΩ nominal resistance.
11	Injury Detection Sensor Connector	SIB-ZSTR-011		A through hole 2-pin right angle JST connector.
12	Battery	SIB-ZSTR-012	1	A 500 mAh, 3.7 nominal voltage lithium-ion battery good for 300 charge cycles.
13	Power Switch	SIB-ZSTR-013	1	A toggle switch to turn on the *Ztriker*.
14	Sync Button	SIB-ZSTR-014	1	A push button to initiate a wireless connection.
15	Record Button	SIB-ZSTR-015	1	A push button to initiate data collection.
16	Resistor 1	SIB-ZSTR-016	1	1 1MΩ resistor intended to reduce the current draw and error of the Injury Detection Sensor.
17	Resistor 2	SIB-ZSTR-017	3	220Ω resistor used between the control ports and

				common anode of RGB LED’s
18	Resistor 3	SIB-ZSTR-018	2	10K Ω resistor used between the pushbutton switch pulled high to 3V3.
19	Status LED	SIB-ZSTR-019	1	An RGB LED that visually communicates the status of the *Ztriker*.
20	M1.4 Torx Head Thread Forming Screw	SIB-ZSTR-020	4	3mm long Torx head screw that secures the Primary Processing and Radio Module in the Measurement Unit.
21	M2 Torx Head Thread Forming Screw	SIB-ZSTR-021	8	8mm long Torx head screw that secures the Battery Charging and Monitoring Module in the Measurement Unit and secures the two halves of the case together.
22	M2 Phillips Head Thread Forming Screw	SIB-ZSTR-022	4	5mm long Phillips head screw that secures the Attachment Plate to the Measurement Unit.

8. Circuit Schematic

The circuit schematic is intended for service technicians in electrical repair of the device. All components and connections are included where the first schematic sheet titled *Capstone-Peripheral components*. *I/O* display all components connected to the I/O terminals of the Arduino Nano 33 IOT and the schematic sheet titled *Capstone – Arduino Components* are those components included on the Arduino.


Heart Rate and SPO2 Sensor
Rechargeable 5V Lipo USB DC/DC Boost converter
RGB LED1
RGB LED2
2 normally open switch
I/O Arduino
Title Capstone- Peripheral components, I/O
Size: A4
Number: 1
Revision: *
Date: 2021-06-08
Time: 3:54:15 PM
Sheet 1 of 2
Altium


Inertial Measurement Unit
Secure Encription Module
Wireless Transmitter Module
Microcontroller and Buck Converter
I/O Arduino
Title Capstone - Arduino Components
Size: A4
Number: 2
Revision: *
Date: 2021-06-08
Time: 3:54:04 PM
Sheet 2 of 2
Altium

The circuit schematic Diagram can be summarized by the following wired connections made between the electronic parts consisting of the Arduino Nano 33 IOT. Powerboost 500 Battery charging and Monitoring Module, Sparkfun Pulse Oximeter-Heart Rate Sensor, RGB LED, Pushbutton, Toggle Switch, Flex Sensor, resistors, and battery.

1. Battery Charging and Monitoring Module to Battery connection positive and ground terminals.
2. Heart Rate Sensor SDA and SCL to Arduino port A4 and A5 respectively.
3. Heart Rate Sensor Reset and MFIO pins to Arduino port D2 and D3 respectively.
4. Heart Rate Sensor positive and ground wires to Arduino Vin and GND pins respectively.
5. Pushbutton first terminal pulled high to 3V3 using 10K resistor.
6. Pushbutton first terminal to Arduino port D12.
7. Pushbutton second terminal to Arduino GND.
8. RGB red pin to 220 Ohm resistor to Arduino port 9.
9. RGB green pin to 220 Ohm resistor to Arduino port 6
10. RGB blue pin to 220 Ohm resistor to Arduino port 5.
11. RGB power pin to Arduino 3V3.
12. Flex Sensor terminals to Arduino port A0 and through 10K Ohm resistor to GND.
13. Battery Charging module Enable terminal to middle port on toggle switch.
14. Battery Charging module Batt terminal to ON side port on toggle switch.
15. Battery Charging module GND terminal to OFF side port on toggle switch.

9. Software downloads

For the firmware of the device, an Arduino program is uploaded onto the Arduino Nano 33 IOT using a micro-USB cable to computer connection. Wireless transfer software updates can also be done using the Arduino IOT cloud platform. The link contains the firmware program which can be reuploaded onto the Arduino Nano. The program comes preinstalled on the device however for the purposes of reinstallation, viewing and debugging of the existing software, this link can be used.

The GitHub link below includes the libraries with C++ and .h files used

https://github.com/SibulusCapstone/Ztriker

Instructions for firmware upload:

1. Download the Libraries onto your computer.
2. Log into the Arduino IOT Cloud platform at https://login.arduino.cc/
3. Install the firmware program using the Arduino web editor.
4. Install the libraries using the Arduino IDE dropdown menu by clicking the *Sketch > Include Library > Add .ZIP libraries.*
5. Connect the Arduino Nano 33 IOT to the computer via micro-USB cable select the correct port and board type in the *tools* dropdown menu.
6. Download and install the .ino file onto the Arduino Nano 33 IOT.

10. Technical Support

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Phone

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