somi

June 13th, 2021

Dr. Craig Scratchley
School of Engineering Science
Simon Fraser University
Burnaby BC, V5A 1S6

Re: ENSC 405W Requirement Specifications for Somi's Chesto Alarm™

Dear Dr. Scratchley,

Please find the requirements specification for Somi's Chesto Alarm™ attached to this letter. The Chesto Alarm™ is a smart alarm system programmed to wake its users up at the most optimal time through the analysis of sleep stages. Our mission is to help our users start their day right using the Chesto Alarm™, which tackles the problem of sleep inertia at its core.

The document contains an overview of the Chesto Alarm™, and outlines the features and constraints that should be met for each phase of the project. These requirements will provide a high-level overview of our system, details regarding the hardware and software design, as well as the engineering, sustainability, and safety standards that the Chesto Alarm™ will follow.

Somi is a team of six Computer Engineering students: Maple Tan, Minji Ju, Sachin Momuli, Bing Qiu (Grace) Zhang, Haopeng (Kevin) Cao, and Linhan Pei.

Thank you for your time in reviewing our requirements specification for the Chesto Alarm™. If you have any questions or concerns, please contact our designated Chief Communications Officer, Kevin Cao at hca119@sfu.ca.

Sincerely,

Maple Tan
Chief Executive Officer
Somi

Somi's Chesto Alarm™ Requirements Specification

Version 1.0

Company 4

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Abstract

Studies of sleep inertia have shown impaired cognitive and sensory-motor performance. This document specifies the requirements specifications for Chesto Alarm™, a product designed with the motivation of delivering a solution to sleep inertia by method of a smart alarm system. Current market solutions do not accurately predict the best time to wake up, as these solutions tend to use actigraphy or rely on movement detection. Chesto Alarm™ will use an algorithm that will determine the most optimal wake-up time, ideally in a light sleep stage, by tracking the users' sleep stages and patterns. By waking users up in a light sleep stage, the amount of sleep inertia is reduced. The requirements specification has been documented with reducing the effects of sleep inertia with Chesto Alarm™. The following documentation contains specifications for high-level design and constraints of the product. The product will follow as closely with existing relevant standards listed in the document, with considerations to environment and user safety.

Table of Contents

Abstract **2**

Table of Contents **3**

Revision History **5**

i. List of Figures **6**

ii. List of Tables **6**

1. Introduction **7**

1.1 Background 7

1.1.1 Introduction to Sleep Stages 7

1.1.2 Introduction to Sleep Inertia 7

1.1.3 Intended Use 8

2. System Overview **9**

2.1 High level Overview 9

3. Requirements **11**

3.1 System Requirements 11

3.2 Hardware Requirements 12

3.2.1 Durability 12

3.2.2 Components 12

3.3 Software Requirements 13

3.3.1 Connectivity 13

3.3.2 Performance 14

3.3.2 User Interface 14

3.3.3 Privacy and Security 15

3.3.4 Application Backend 15

4. Engineering Standards **17**

4.1 Safety Standards 17

4.2 Implementation and Management Standards 17

5. Sustainability **19**

5.1 Material Reutilization 19

5.2 Toxic Material Avoidance 19

5.3 Battery Recycling 20

6. Safety Requirements **21**

6.1 General Safety 21

6.2 Safe Hearing 21

6.3 Electrical Safety 21

7. Conclusion **23**

Appendix **24**

Appendix A: Acceptance Test Plan 24

Appendix B: Glossary 26

References **27**

Revision History

Date	Version	Description
June 13, 2021	1.0	Creation of Document

i. List of Figures

Figure 1. System overview diagram 9
Figure 2. Sensors 10

ii. List of Tables

Table 1. High-Level Acceptance Test Plan 24

1. Introduction

Chesto Alarm™ is a smart alarm clock system designed to reduce sleep inertia by analyzing the sleep patterns and sleep cycles to find the most optimal wake-up time.

1.1 Background

In this section, some background knowledge for sleep stages and sleep inertia will be provided, followed by a description of Chesto Alarm™'s intended uses.

1.1.1 Introduction to Sleep Stages

The American Academy of Sleep Medication defines five stages of sleep during the sleep cycle: Wake (Sleep Stage 0), Sleep Stage 1 (N1), Sleep Stage 2 (N2), Sleep Stage 3 (N3), and Sleep Stage REM (R) [1].

Sleep stages are typically measured in laboratory settings [2] using polysomnography (PSG) that include monitoring brain activity with electroencephalography (EEG), eye movement with electrooculography (EOG), muscle activity with electromyography (EMG), and heart rhythm with electrocardiography (ECG/EKG) [3].

1.1.2 Introduction to Sleep Inertia

Sleep inertia is that grogginess you feel upon awakening, and is associated with significant deterioration of cognitive performance [4]. Sleep inertia can last anywhere between a minute up to 4 hours [5]. Reduced reaction time and alertness, decrease in performance in decision-making tasks, and a decline in motor dexterity [5] are some of the impairments that accompany high levels of sleep inertia. This impairment can be equivalent, or greater than, the impairment after up to 40 hours of sleep deprivation [4].

Sleep inertia is strongly affected by the sleep stage upon awakening, especially from waking up from deeper stages of sleep [6]. It is found that the awakening in slow wave sleep (SWS), also known as stage 3, is associated with greater sleep inertia compared to awakening in stage 1 or 2 [5][7].

Some real world impacts that sleep inertia has, includes safety concerns over fine motor skill tasks that happen soon after waking and driving accidents in the mornings. Sleep inertia was shown to be a factor in several commercial incidents including a near crash of a large military aircraft [8]. In a more relatable scenario, drowsy driving was reported to be involved in 2.3 to 2.5% of all fatal car crashes in the U.S., between 2011 and 2015 [9]. A significant portion of these accidents may be caused by high amounts of sleep inertia, due to sleep inertia impacting cognitive and reactive performance, which is one of the problems we hope to address with Chesto Alarm™.

1.1.3 Intended Use

Chesto Alarm™ is intended for users that want to wake up well rested and start the day with a better mentality. Current alarms where you choose a fixed time to wake up at, have no way of knowing what sleep cycle a person is in, and in most cases, will disrupt deep sleep, and have an 89% chance of experiencing some sleep inertia in the morning [10].

2. System Overview

This section provides a high-level overview of Chesto Alarm™. The diagram depicted in *Figure 1* shows the overview of the entire system, divided into hardware and software components.

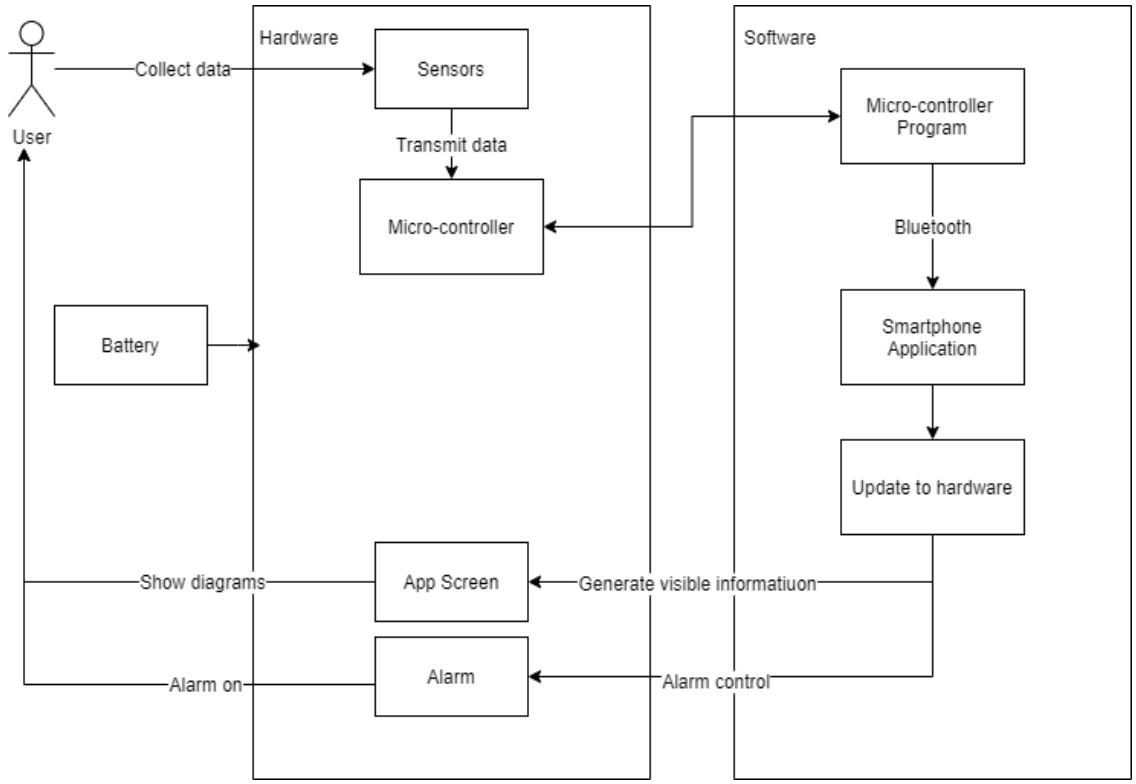

Figure 1. System overview diagram

2.1 High level Overview

Chesto Alarm™ is a smart alarm system based on sleep stage analysis. The device, in accordance with the smartphone application, will determine the optimal wake-up time within the user-defined alarm time range by analyzing the user's sleep stages and patterns.

As sleep stage monitoring is found to be done with EEGs, EOGs, EMGs, and ECGs, Chesto Alarm™ will be using at least two of the four sensors shown in *Figure 2*. These sensors will be used to obtain the optimal wake time. When the device is turned on, the sensors will collect and transmit the data to the microcontroller.

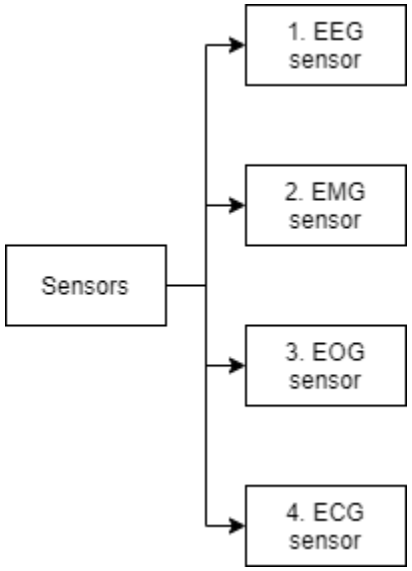

Figure 2. Sensors

A microcontroller will be programmed as the central processing unit (CPU) and will be in charge of signal processing and analysis, to find the optimal wake time for the user. After signal processing, the microcontroller will send the processed data over bluetooth to a connected smartphone.

A companion smartphone application will plot the processed data into graphs, to visually display a user's sleep stages throughout the night. This application will also allow users to set a range of time, a wake period, at which a user would like to be woken up. Chesto Alarm™ will determine the ideal wake time by analysing the past sleep stages, combined with the assistance of AI to help predict the next sleep stages of a user. The precise time of awakening would be calculated to ensure that the user would be in their lightest sleep stage, ideally in Stage 1, within the wake period.

3. Requirements

This section will list the requirements that will be met during design and development of Chesto Alarm™.

The labelling schema that will be used to define each requirement specification is as follows:

[Req X.Y.Z-Phase]

X - Section
Y - Subsection
Z - Requirement Number
Phase - ‘a’ = alpha (proof-of-concept), ‘b’ = beta (prototype), ‘p’ = production

3.1 System Requirements

This section will specify the major user-facing requirements of Chesto Alarm™. As a smart portable alarm system, a user needs to be able to use Chesto Alarm™ throughout the intended timeframe of approximately 8-10 hours. As we want the device to improve the sleep quality of the user, we need to take measures for this to be achieved. The following requirements address these high-level constraints.

[Req 3.1.1-a]: System must be able to differentiate between the wake (Sleep Stage 0) and non-wake stages (Sleep Stage 1, Sleep Stage 2, Sleep Stage 3, Sleep Stage REM).

[Req 3.1.2-b]: System must be able to detect the stage of sleep a user is in.

[Req 3.1.3-b]: System must be able to differentiate between different sleep stages, namely between the non-wake stages (Sleep Stage 1, Sleep Stage 2, Sleep Stage 3, Sleep Stage REM).

[Req 3.1.4-a]: Device must be compatible with a smartphone application.

[Req 3.1.5-b]: System must be able to transmit signals to a smartphone application.

[Req 3.1.6-b]: Device must be able to determine the optimal time of awakening.

[Req 3.1.7-a]: Device must be able to sound an alarm to wake a user up.

[Req 3.1.8-a]: Device must work during day or night time.

[Req 3.1.9-p]: Device must not impair the user's ability to fall asleep.

[Req 3.1.10-p]: Device must not impair the user's ability to wake up.

3.2 Hardware Requirements

This section will specify the hardware components necessary for Chesto Alarm™ to effectively monitor and function as an optimal alarm system. As a device that is required to be attached to a user while sleeping, the following requirements will take into account the user's ergonomics.

3.2.1 Durability

This section will specify the durability requirements of Chesto Alarm™. The requirements are based on the existing wearable products in the market, *Bose® Sleepbuds* [11] and *Kokoon: Sleep Headphones* [12], which are of similar form factor/use case.

[Req 3.2.1.1-p]: System must be able to withstand minor water splashes and be IP64 resistant as to protect from perspiration.
[Req 3.2.1.2-p]: System must be able to withstand a contact pressure of 6N.
[Req 3.2.1.3-p]: System must be resistant to surface scratches.
[Req 3.2.1.4-b]: Internal components must not be damaged or affected over 12 hours of consecutive use.
[Req 3.2.1.5-b]: System must be able to withstand low height drops from at least 1 meter without any damage to internal components.
[Req 3.2.1.6-p]: Device must be operational at a minimum temperature of 0°C.
[Req 3.2.1.7-p]: Device must be operational at a maximum temperature of 45°C.

3.2.2 Components

This section will specify the requirements of the hardware components necessary to ensure proper functionality of Chesto Alarm™. These constraints will also take into account the user experience. Such features that will be considered is to clearly show what the current state of the system is, which include the power state and the bluetooth connectivity state.

[Req 3.2.2.1-b]: Device must have a left/right side indicator.
[Req 3.2.2.2-a]: Device must have a physical power button.
[Req 3.2.2.3-a]: Device must have a physical bluetooth pairing button.
[Req 3.2.2.4-a]: Device must have at least 1 LED for signaling transmission of data,
[Req 3.2.2.5-p]: Device must be under 100 grams in weight.
[Req 3.2.2.6-a]: Device must indicate the power status (ON/OFF) with at least 1 LED.

[Req 3.2.2.7-a]: Device must include an EEG sensor for data transmission.
[Req 3.2.2.8-a]: Device must include a micro controller for signal processing.
[Req 3.2.2.9-b]: Device must be enclosed in a solid structure.
[Req 3.2.2.10-a]: Device must include a battery.
[Req 3.2.2.11-p]: Device must have a battery life of at least 9 hours.
[Req 3.2.2.12-p]: Device must be able to fully charge within 3 hours.
[Req 3.2.2.13-p]: Device must have a USB-C port for charging.
[Req 3.2.2.14-a]: Device must have at least 1 LED for displaying charging status.

3.3 Software Requirements

This section will specify the software requirements necessary for Chesto Alarm™ to correctly perform as a sleep cycle based alarm system.

3.3.1 Connectivity

This section will specify the details of connectivity between Chesto Alarm™ and a smartphone device.

[Req 3.3.1.1-a]: Device must support at least bluetooth 4.1.
[Req 3.3.1.2-a]: The device must connect via bluetooth to a bluetooth-compatible smartphone.
[Req 3.3.1.3-b]: Device must support a bluetooth range of up to 10m.
[Req 3.3.1.4-a]: Device must be able to be disconnected from bluetooth.
[Req 3.3.1.5-b]: Device must enter bluetooth pairing mode on start up when no pairing information exists on the device.
[Req 3.3.1.6-a]: Device must save bluetooth pairing information upon successful connection with a smartphone.
[Req 3.3.1.7-b]: Device must indicate whether it is in pairing mode, paired mode, or in a disconnected mode with at least 1 LED.
[Req 3.3.1.8-b]: Device must indicate whether a bluetooth connection was successful, pending, or failed with at least 1 LED.
[Req 3.3.1.9-b]: Device must establish bluetooth connectivity upon successful pairing within 20 seconds.
[Req 3.3.1.10-p]: Device must turn off if bluetooth pairing is not established within 5 minutes.

[Req 3.3.1.11-p]: Device must be able to erase its saved bluetooth information from the device or from the smartphone app.

[Req 3.3.1.12-a]: Device must only connect to one smartphone at a time.

[Req 3.3.1.13-b]: Device must abort bluetooth pairing mode before the device is powered off.

[Req 3.3.1.14-b]: Device must transmit signal data to the application without packet loss.

3.3.2 Performance

This section will specify the performance of the smartphone application in regards to size, start up time and compatible operating system.

[Req 3.3.2.1-p]: Application must be compatible with Android 7+ and iOS 13+.

[Req 3.3.2.2-b]: Application must load within 3 seconds.

[Req 3.3.2.3-b]: Application must not be larger than 100MB in size.

[Req 3.3.2.4-b]: Application must not exceed 500MB of RAM during execution.

[Req 3.3.2.5-p]: Application must not crash when in use.

[Req 3.3.2.6-b]: Application must request access from the user to use microphone/ location.

[Req 3.3.2.7-b]: Reports generated by the application must not exceed 10MB per file.

[Req 3.3.2.8-b]: Application must have an option to share your sleep tracking data by email.

[Req 3.3.2.9-b]: Application must be able to create a report (pdf) of your previous sleep schedule over a period of time.

3.3.2 User Interface

This section will specify the interfaces that will be included in the smartphone application. The logic of the 30-minute wake window has been adapted from similar existing applications, *Urbandroid's Sleep as Android* [30].

[Req 3.3.2.1-b]: Application must have less than five navigational interfaces.

[Req 3.3.2.2-b]: Application must have large, simple icons for navigating through interfaces.

[Req 3.3.2.3-b]: Application must show estimated battery life for the device.

[Req 3.3.2.4-b]: Application must notify the user through the application if the battery of the device is critical, defined as less than 20%.

[Req 3.3.2.5-a]: Application must have an interface to schedule an alarm.

[Req 3.3.2.6-a]: Application must allow the user to define a minimum of a 30-minute window for when a user would want to be woken up.

[Req 3.3.2.7-b]: Application must allow the user to view past sleep statistics.

[Req 3.3.2.8-b]: User must have the option to delete selected past sleep statistics.

[Req 3.3.2.9-b]: User must have the option to delete all past sleep statistics.

[Req 3.3.2.10-b]: Application must be able to generate a graph based on past sleep statistics.

[Req 3.3.2.11-b]: User must be notified of any overheating caused by the device via push notifications pertaining to similar message: “Overheating detected. Device turning off.”

3.3.3 Privacy and Security

This section will specify the privacy and security requirements that will be considered for users.

[Req 3.3.3.1-b]: Application must not ask for more permission than needed, i.e. no location, camera, or microphone access.

[Req 3.3.3.2-b]: Correct login information must be confirmed before prior data is accessible.

[Req 3.3.3.2-b]: Application must allow the user to redact any private information while generating a report.

3.3.4 Application Backend

This section will specify the backend requirements for our smartphone application. Users will be able to log in to their accounts to view their sleep statistics.

[Req 3.3.4.1-b]: Application must store the total hours of sleep a user slept for.

[Req 3.3.4.2-b]: Application must store the sleep stage from which the user has woken up from.

[Req 3.3.4.3-b]: Application must store the time spent in each sleep stage.

[Req 3.3.4.4-a]: Application must allow the user to set an alarm for future dates.

[Req 3.3.4.5-a]: Application must have a default alarm set at the latest time of the user-defined wake window for occurrences in which sensors no longer detect sleep patterns.

[Req 3.3.4.6-a]: Application must update the alarm time with respect to detected signals.

[Req 3.3.4.7-b]: Application must be able to store and validate user credentials.

[Req 3.3.4.8-a]: User shall have the option to save login information on device.

[Req 3.3.4.9-p]: Application must store past sleep statistics in a secure database.

[Req 3.3.4.10-p]: Database must be accessible through SQL query.

4. Engineering Standards

This section will specify the engineering standards that Chesto Alarm™ should adhere to. Since Chesto Alarm™ consists of a close-to-ear device that will contain a battery and may potentially contain a sound sink, the following engineering standards will be considered.

4.1 Safety Standards

IEC 60065:2014 - Audio, video and similar electronic apparatus — Safety requirements [13]

CSA C22.2 No. 62368-1:19 - Audio/video, information and communication technology equipment — Part 1: Safety requirements [14]

ISO 11904-1:2002 - Acoustics — Determination of sound emission from sound sources placed close to the ear [15]

CAN/CSA-C22.2 No. 61508-1:17 - Functional safety of electrical/electronic/programmable electronic safety related systems — Part 1: General requirements [27]

CSA C22.2 No. 0.23-15 (R2020) - General requirements for battery-powered appliances [28]

CAN/CSA-C22.2 NO.107.2-01 (R2016) – Battery chargers for use on nominal system voltages not exceeding 600 V intended for household, commercial, or industrial use in accordance with the rules of the Canadian Electrical Code [16]

4.2 Implementation and Management Standards

IEEE 802.15.2 - Bluetooth and Wi-Fi coexistence mechanism [17]

IEEE/ISO/IEC 8802- Information technology — Telecommunications and information exchange between systems [18]

IEEE 2700-2017 - Standard for Sensor Performance Parameter Definitions [19]

ISO/IEC/IEEE 24748-1:2018 - Systems and software engineering — Life cycle management — Part 1: Guidelines for life cycle management [20]

IEEE 1012-2016 - IEEE Standard for System, Software, and Hardware Verification and Validation [21]

IEEE/ISO/IEC 41062-2019 - ISO/IEC/IEEE International Standard - Software engineering — Recommended practice for software acquisition [22]

ISO 01.110 - Technical Product Documentation — Including Rules for Preparation of User Guides, Manuals, Product Specifications, etc. [23]

5. Sustainability

With increasing innovation in technology, environmental concerns have also been increasing. Consumers are paying more attention to whether products they purchase are environmentally friendly. Technological development has heightened the degree of convenience in our daily lives; however, the benefits have also consumed a great amount of Earth's finite resources. As a response to environmental concerns, Chesto Alarm™ will try to follow closely to the *Cradle-to-Cradle* design for a sustainability-friendly solution by method of *material reutilization*, toxic material avoidance, and battery recycling[24][25].

5.1 Material Reutilization

Chesto Alarm™ device is not reusable; thus, it will use recyclable materials like steel, aluminum, plastic, copper and gold [29]. Method of reutilizing these materials is to dispose of it through a recycling program as the device is made of natural materials. Also, it is helpful to reduce the use of plastic in packaging the device. Overall, the recycling methods should be able to meet the requirement of industry standards.

[Req 5.1.1-p]: At least 50% of the device components must be composed of recyclable natural materials.

[Req 5.1.2-p]: Packaging of the device must use recyclable products.

[Req 5.1.3-p]: Internal packing inserts must be comprised of molded pulp packaging.

[Req 5.1.4-p]: Device must use electronic components that can follow standard electronics recycling processes.

[Req 5.1.5-p]: Device must be constructed in a way to easily separate the recyclable and non-recyclable portions.

5.2 Toxic Material Avoidance

Toxic materials like brominated flame retardants (BFRs) and polyvinyl chloride (PVC) are heavily used in making electronics devices [26]. These halogenated compounds contain hazardous chemicals such as chlorine, fluorine and bromine, which are harmful for human health. Thus, Chesto Alarm™ will avoid using any such toxic materials.

[Req 5.2.1-p]: Device must not contain any toxic materials for humans.

[Req 5.2.2-p]: Device must not contain any toxic materials for the environment.

5.3 Battery Recycling

Chesto Alarm™ will utilize the industry-standard lithium-ion batteries [31]. Lithium-ion batteries are rechargeable so production of e-waste can be reduced. There are also many battery disposal depots for recycling of lithium-ion batteries. Once the battery has reached the end of its life, it can be disposed of at those locations.

[Req 5.3.1-a]: Device must use a lithium-ion battery that can be recycled.
[Req 5.3.2-p]: Device must have a removable battery that can be replaced by users.

6. Safety Requirements

Chesto Alarm™ will comply with relevant Canadian, USA and European safety standards (FCC, UL, TUV, CE) as specified in *Section 4*. This section provides safety requirements to avoid any possible damage or harm that may occur as a result from usage of Chesto Alarm™.

6.1 General Safety

General Safety requirements are formed with respect to potential hazards resulting from human errors. Physical design constraints of Chesto Alarm™ follows the design of similar consumer products, namely *Bose® Sleepbuds* [11] and *Kokoon: Sleep Headphones* [12], to ensure safe usage.

[Req 6.1.1-p]: Device must not have any sharp edges.
[Req 6.1.2-p]: Point-of-contact part of the device must be cushioned with soft silicone.
[Req 6.1.3-p]: Device must be able to be fixated on human body with no damage.
[Req 6.1.4-p]: Internal temperature of device must not exceed 45°C.
[Req 6.1.5-p]: Device must turn off upon internal temperature exceeding 45°C.
[Req 6.1.6-p]: Device must not turn on while charging.

6.2 Safe Hearing

Safe Hearing requirements will be followed if a noise component is to be included in Chesto Alarm™. The requirements are included to ensure user safety regarding safe hearing. The Safe Hearing requirement specifications follow the standards guidelines under [13] and [14].

[Req 6.2.1-p]: Standard acoustic output level LAeqT must be less than 85dBA
[Req 6.2.2-p]: Maximum output from device must be less than 100dBA.

6.3 Electrical Safety

Damage detection and enclosement of electrical circuitry requirements have been included for user safety.

[Req 6.3.1-p]: System must not create interference with nearby electrical devices.

[Req 6.3.2-a]: Operating voltage of microcontroller must not be over 5V.

[Req 6.3.3-p]: All electrical components must be enclosed in an insulated hardware casing.

[Req 6.3.4-p]: Device must have a failsafe for battery overcharging.

[Req 6.3.5-p]: Device must stop charging when the internal device temperature is above 45°C.

[Req 6.3.6-p]: Device must not shock the user during typical usage.

[Req 6.3.7-p]: Device must be protected from electrostatic discharge (ESD).

7. Conclusion

This document describes the functional requirement specifications of Chesto Alarm™ to be met with a proof-of-concept product by August 2021.

These requirements include the system as a whole, hardware and software aspects of Chesto Alarm™. Engineering standards, along with sustainability and safety requirements, are also considered to ensure that Chesto Alarm™ will be user friendly and safe for the environment.

The Chesto Alarm™ is an innovative solution to reducing sleep inertia at its core. With accurate analysis of the user's sleep patterns, Chesto Alarm™ is able to wake a user up at an optimal time that helps mitigate the effects of sleep inertia.

Appendix

Appendix A: Acceptance Test Plan

The test plan outlined in Table 1 will evaluate the fundamental functionalities for a proof-of-concept prototype of Chesto Alarm™.

Table 1. High-Level Acceptance Test Plan

#	**Purpose**	**Test Description**	**Acceptance Criteria**
1	Verify data is retrievable from sensors.	Ensure that each sensor connected to the microcontroller is able to produce the expected data.	The data read out from the sensors match the expected output.
2	Validate accuracy of differentiating between sleep and wake state.	Use other sleep tracking apps and hardware to determine the expected sleep stage.	Chesto Alarm™ must detect when a user is in a sleep stage or a wake stage within 20% of the expected sleep stage.
3	Validate connectivity with a smartphone via the companion smartphone application.	Use different smartphones, including Apple iPhones and Android phones to connect and disconnect Chesto Alarm™ from bluetooth.	Majority of compatible smartphones should be able to successfully pair and unpair with Chesto Alarm™.
4	Validate battery duration can sustain overnight.	Test consecutive usage of device overnight.	Chesto Alarm™ device must be operational throughout the duration of sleep.
5	Validate graphs can be plotted by processed data.	Use different ranges of data and plot them by using a drawing program.	The smartphone application must show the correct graphs on screen.
6	Validate correct LED colours are displayed during different system states.	Run the system through various system states.	LED colours are correctly displayed during different system states.

7	Validate alarm is able to be set from the smartphone application.	Set the alarm at a desired time.	Alarm should ring at set time.

Appendix B: Glossary

ECG/EKG	Electrocardiogram
EEG	Electroencephalogram
PSG	Polysomnography
SWS	Slow Wave Sleep
EOG	Electrooculography
EMG	Electromyography
BFRs	Brominated flame retardants
PVC	Polyvinyl chloride
LAeqT	Equivalent continuous A-weighted sound pressure level
dBA	Decibels of sound pressure level measured using the A-weighting network
ESD	Electrostatic discharge

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