Engineering Capstone Project (OENG1168) Completion Plan

Investigation of Materials to Develop a Wearable Stress Monitoring Device

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1 Executive Summary

The aim of this project is to investigate the materials and methods available for the development of a wearable device able to assess levels of stress through the monitoring of pulse, galvanic skin response, and skin temperature. Within this report a detailed plan for the completion of the project will be outlined. A general overview of completed tasks will be provided as well as a brief explanation of the current state. The report will then provide a list of tasks that are yet to be completed, to achieve what the team set out in the project proposal. Overall, it will become clear the limitations the current device possesses, and the methods by which we hope to proceed towards a viable prototype. To visualise the expected trajectory of the project, a Gantt chart will be provided with both a high-level overview and a more detailed breakdown of sub-tasks. By the conclusion of the project the device should be physically unobtrusive and able to distinguish between stressed and relaxed states.

Contents

2 Introduction

With the growing popularity of IoT technologies and the continual development of computational power relative to size, wearable technologies are expected to become an indispensable and integral part of our daily life. A valued adoption of wearable technology includes the use of wearables to enhance health monitoring more specifically stress monitoring. Stress is any physical, chemical or emotional factor that causes the human body to release hormones which consequently elicits other bodily responses such as increased muscle tension, higher pulse rate and heightened alertness. The current prototype of our device is capable of reading sensor data from our microcontroller and displaying the data on a mobile device, however further developments are still required to make our prototype fully functional.

The main aim of this completion report is to provide an outline of the tasks required to complete the development of a wearable device that can capture data related to stress. The tasks required include research, design and engineering, and an extensive timeline has been established to ensure that milestones are met, and the development is on track to finish within the time allocated. Furthermore, for the required tasks that need to be completed, a risk matrix has been created to evaluate any obstacles or pitfalls that the team may encounter for the duration of the project, and contingency plans have been put in place to prepare for the possibility of certain scenarios.

3 Completed Tasks

To date, the completed tasks in aggregate have successfully achieved the construction and testing of a prototype which demonstrated the ability to collect measurements of the three main physiological signals: galvanic skin response, skin temperature and pulse. The prototype was then able to display the data on a web server hosted on the microcontroller and accessed via web browser. Figure 1 demonstrates the physical aspects of the device and Figure 2 illustrates the web browser access portal.

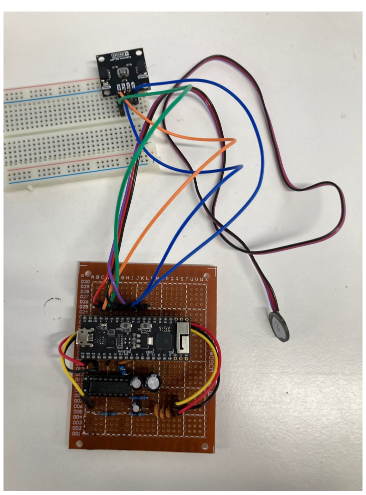


Figure 1: Physical Aspects of the Device

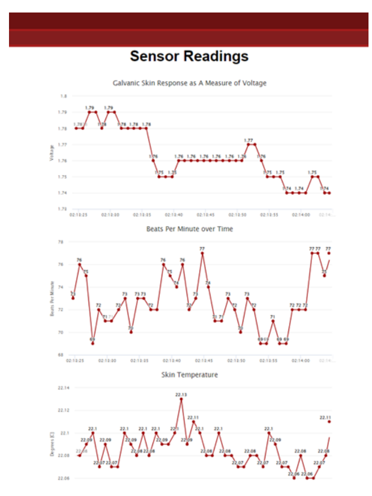


Figure 2: Web Portal

3.1 Tasks Completed

An itemised list of completed tasks categorised into engineering and research follows.

3.1.1 Engineering

1. Design of a circuit which can record skin conductivity measurements.
2. Design of electrodes for use with the skin conductance sensor.
3. Testing the design and implementation of electrodes.
4. Testing of circuitry to collect and filter skin conductivity measurements.

3.1.2 Research and Literature Review

1. Investigation of options for sensors to collect physiological signals
2. Preliminary research into PPG, GSR, ECG, EEG, and Skin temperature.
3. Preliminary research into testing procedures.
4. Preliminary research into physiological signals with a relationship to stress.

3.2 Current Limitations

The current state of the device, being a prototype, is restricted in functionality. The device currently has no method of securely mounting to the body without completely restricting movement while testing. The web server is currently hosted directly on the microcontroller. While this increases the speed of development, it restricts both the amount data able to be stored as well as the accessibility of the data.

4 Tasks to be Completed

The following itemised list of tasks to be completed aims to resolve some of the limitations listed above and develop the device into a fully functional system. The intention of each task is briefly outlined below.

4.1 Research

1. Review of mounting options
   Research into the different potential locations for sensor placement given the literature on body mobility, sensor efficacy, sensitivity to locomotion, and other factors which could influence the placement of sensors on the body.
   1. Pulse Sensor: Ensure the signal for the heartbeat is significantly above the level of noise and variability during locomotion.
   2. GSR Sensor: Ensure the signal for the GSR is consistent with the commercial sensor when mounted during testing.
   3. Temperature Sensor: Ensure the reading from the temperature sensor is only influenced by skin temperature and external factors are negligible
2. Sensor placement locations
   - Research into the different methods of mounting PCBs (Flexible, Rigid-Flex and Rigid) will be conducted by looking through existing wearable devices, DIY projects, and commercially available attachment systems for suitable methods to mount the PCBs and other components to the human body in a way that does not interfere with data collection for the device and provides a high level of comfort.
3. Research of testing procedures
   - Research different testing procedures used throughout literature to measure stress levels in order to determine the best testing procedure for our system.
4. Methods to derive stress from collected data
   - Research through the existing literature to determine relationships between the physiological signals being measured and stress, as well as collecting the potential methods for categorising stressed and relaxed states used in literature to better inform testing procedures.
5. Research Battery and Charging Options
   - Investigate options which can both sufficiently power the device and simultaneously possess a small form factor to limit the impairment of mobility of the user.
6. Investigate power saving methods
   - Identify methods by which power consumption can be kept to an absolute minimum. This may include sleep modes of the microcontroller and or special functions of sensors.
7. Investigate options for PCB material
   - Identify the possibilities for materials and construction of the PCB which contains the GSR sensor and the Temperature Sensor.

4.2 Engineering

1. Design and build mobile application
    1. Front-end Tasks
        1. Create a Figma design for the user interface.
            - Create a prototype of the user interface which will be used as a baseline when the front-end programming begins.
        2. Develop UI in HTML and JS.
            - Program the front-end layout the interface and display the data obtained from the relevant sensors.
        3. Adding display and user responsiveness.
            - Create a responsive interface to improve the user-journey.
    2. Back-end Tasks
        1. Setting up MySQL database.
            - Set up the database schema and creating the models to store the data. Relationships between different tables will also be established.
        2. Developing PHP script.
            - Create the PHP script that is responsible for receiving incoming requests from the ESP32 microcontroller board and inserting the data into the database.
        3. Setup domain name and web hosting service.
            - Sign up for a hosting service and picking a certain domain name.
2. Finalise Schematic for Galvanic Skin Response Sensor and Temperature Sensor
    - Compile the schematic for the GSR Sensor and Temperature Sensor and combining the two into a unified schematic.
3. Design and build PCB for temperature and GSR sensors
    - Design a custom PCB which possesses the ability to measure both GSR and skin temperature with a small form factor.
4. Test PCBs
    - Ensure the fabricated PCBs perform the required functions and eliminating any faults.
5. Testing of sensors for placement on body
    - Test multiple locations around the body for the physiological responses received by all the sensors to better understand the mounting systems available for the device.

4.3 Testing

1. Determine what is being measured in terms of stress
    - Create a robust definition for stress which can be used to label a user as stressed in a way which can relate to physiological responses.
2. Determine a relationship between stress and physiological signals
    - Determine a method to categorise a user as stressed based on the physiological data collected by the device, as well as creating a calibration process for the method should this be user specific.
3. Design testing procedure for the system
    - Design a procedure to test the reliability, accuracy, comfort, and consistency of the system.

5 Risks and Obstacles

This section contains the potential events which could constrain the timely completion of the project.

5.1 Research

1. Pre-existing literature not being available that facilitates the development of the device.
2. Significant literature being found which alters the course of the project.
3. Appropriate options for powering the device cannot be identified by the allotted time.
4. An appropriate relationship cannot be determined or identified that links the various physiological signals collected to the level of stress.
5. The various options for PCB material are inappropriate to the application of the device.

5.2 Engineering

1. The manufacture of PCBs by the manufacturer is delayed to the point where it is impossible to utilise a custom PCB in the final delivery of the project.
2. The purchase of components is delayed and extends beyond a reasonable timeline.
3. Faults exist in the custom PCB because of poor design or manufacture which make the manufactured PCBs unusable.
4. Database schema relationship is incompatible with the applications need.
5. Database models are not optimized for frequent queries.
6. Failure to configure the PHP script to communicate with microcontroller.

5.3 Design

1. An appropriate design of the GSR sensor custom PCB cannot be achieved in the pre-determined timeline.
2. An appropriate design of the Skin Temperature sensor custom PCB cannot be achieved in the pre-determined timeline.
3. Appropriate locations cannot be determined for the various sensors.
4. Appropriate locations cannot be determined for the various components (MCU, Battery).
5. An appropriate physical proportioning of the custom PCB cannot be achieved to not restrict the movement of the user.
6. User interface and layout do not meet UX expectations.

5.4 Testing

1. Stress cannot be defined in a manner that is able to be qualified.
2. A relationship between stress and the measured physiological signals cannot be reliably established.
3. Testing of the device proves that the desired outcome has not been achieved.

5.5 Other

1. Communication within the project team breaks down.
2. Communication with the project supervisor or other important stakeholders breaks down.

5.6 Risk Matrix

	Rare	Unlikely	Possible	Likely	Near Certain	Legend
Negligible						Low Risk
Minor						Medium Risk
Moderate						High Risk
Major						Very High Risk
Extreme						Extreme Risk

Risk Assessment for Completion Report				
Section Name	Risk Index	Risk Rating		
		Likelihood	Consequence	Rating
RESEARCH	(1)	Unlikely	Moderate	Medium Risk
	(2)	Rare	Major	Medium Risk
	(3)	Unlikely	Minor	Low Risk
	(4)	Rare	Moderate	Low Risk
	(5)	Rare	Minor	Low Risk
ENGINEERING	(1)	Likely	Major	Very High Risk
	(2)	Likely	Major	Very High Risk
	(3)	Possible	Moderate	High Risk
	(4)	Possible	Moderate	High Risk
	(5)	Possible	Minor	Medium Risk
	(6)	Unlikely	Moderate	Medium Risk
DESIGN	(1)	Unlikely	Moderate	Medium Risk
	(2)	Unlikely	Moderate	Medium Risk
	(3)	Unlikely	Moderate	Medium Risk
	(4)	Possible	Negligible	Low Risk
	(5)	Unlikely	Minor	Low Risk
	(6)	Unlikely	Moderate	Medium Risk
TESTING	(1)	Unlikely	Moderate	Medium Risk
	(2)	Unlikely	Major	High Risk
	(3)	Unlikely	Extreme	Extreme Risk
OTHER	(1)	Unlikely	Major	Medium Risk
	(2)	Unlikely	Major	Medium Risk

6 Mitigation Strategies

This section intends to preemptively identify possible solutions to the complications and obstacles identified above The number of each mitigation strategy refers to the corresponding risk.

6.1 Research

1. In the case that preexisting literature does not exist to support our claims or advise our future decisions, relevant testing will be conducted.
2. In the case that existing literature is found that alters the course of our project, the project team will conduct an evaluation of the current state of the project and significant components that could be reused in the continuation of the project down a new path.
3. In the case that an appropriate option cannot be found to appropriately power the device, an auxiliary power device can be used to demonstrate the feasibility of work that has been completed to date.
4. If an appropriate relationship cannot be determined between the physiological signals and stress, the project will be modified into a health monitoring system which will not require any additional components.
5. In the case that flexible PCBs are not found to be appropriate for the application, or to obstruct regular movements of the user, an appropriate solution will have to be found.

6.2 Engineering

1. In the case that manufacture of the PCBs is delayed, the PCB design will be included as an item for future development and the Veroboard will be used for the final demonstration.
2. In the case that the purchase of the componentry is delayed , alternative components will be utilised where the originals cannot be reasonably acquired.
3. If faults exist within the manufacture of the PCB, and a reasonably expected amount of testing cannot determine the root cause the Veroboard will be used to construct a method of demonstration.
4. To address the database relationship risk, a database schema will be created and thoroughly mapped.
5. If models are not optimized for frequent queries, an alternative mitigation plan is to sacrifice some user experience for performance.
6. If the PHP script can't communicate with the microcontroller, the prototype network architecture will be used as a backup.

6.3 Design

1. In the case that an appropriate design of the custom GSR sensor cannot be achieved, an off-the-shelf GSR sensor will be used.
2. In the case that an appropriate design for the skin temperature sensor PCB cannot be achieved, the AHT20 development board used within the prototype will be used.
3. If appropriate locations cannot be determined for the sensors, the best-fit locations determined during prior testing will be used for each sensor
4. If appropriate locations cannot be determined for the components, the additional components will be put into a small bag and carried with the user
5. If an appropriate sizing of the custom PCB cannot be identified, the system will be demonstrated within a limited range of motion.
6. If the user interface and layout do not meet the UX expectations, a possible strategy is to begin rapid prototyping starting from early stages of development.

6.4 Testing

1. Stress will be first defined as a physical, mental, or emotional factor that causes bodily or mental tension and refined from there.
2. Processes found in literature will first be used to categorise the physiological signals into stressed and relaxed and refined from there if required.
3. See all above strategies.

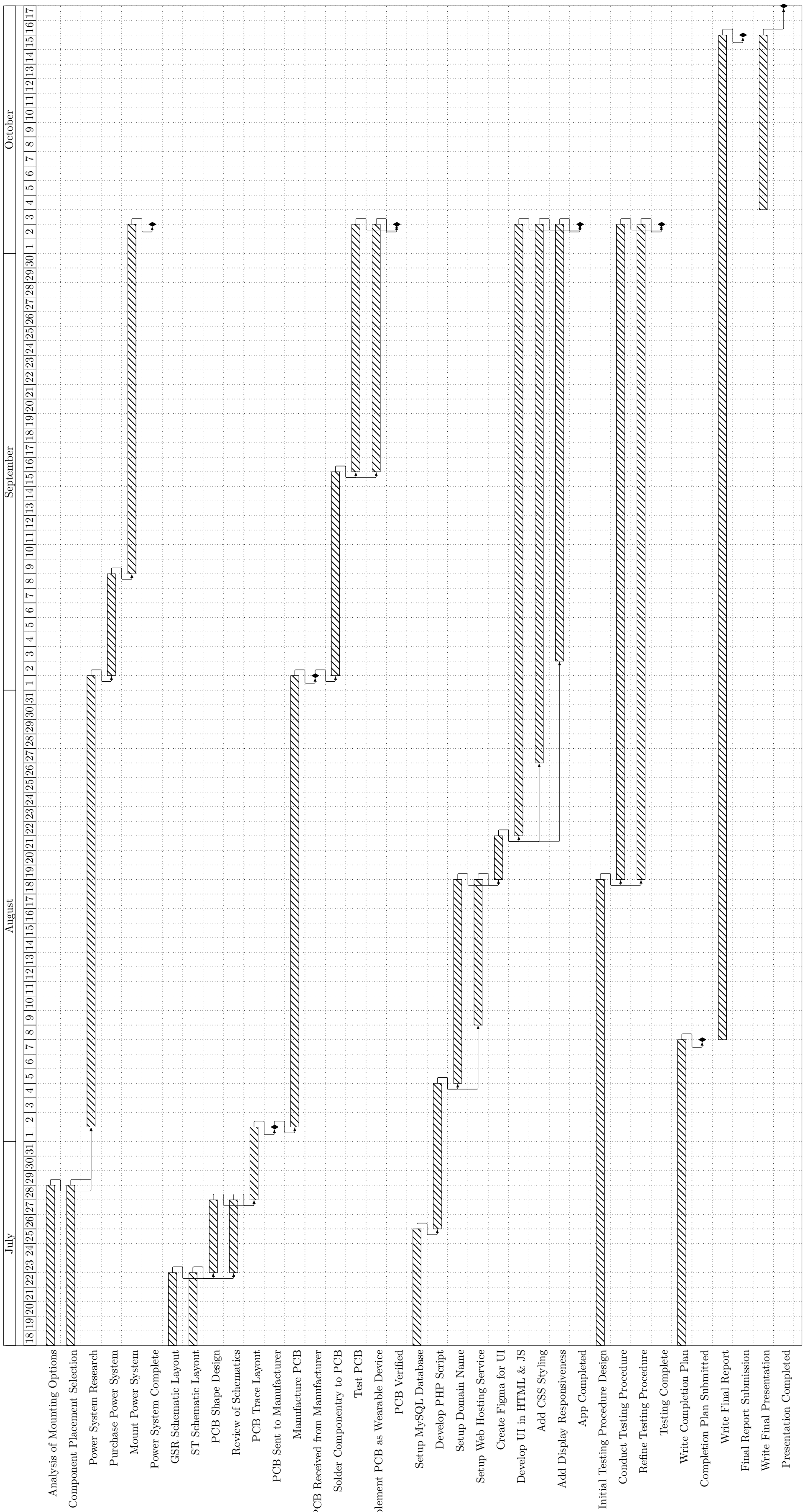
6.5 Other

1. Ensuring that regular scheduled meetings with both the project and supervisors are undertaken.

7 Expected Project Finances

Item	Projected Cost (AUD)
PCB Manufacturing	$100
PCB Components	$90
Textile Components	$50
E-Textile Components	$25

8 Timeline


July
August
September
October
Analysis of Mounting Options
Component Placement Selection
Power System Research
Purchase Power System
Mount Power System
Power System Complete
GSR Schematic Layout
ST Schematic Layout
PCB Shape Design
Review of Schematics
PCB Trace Layout
PCB Sent to Manufacturer
Manufacture PCB
PCB Received from Manufacturer
Solder Componentry to PCB
Test PCB
Implement PCB as Wearable Device
PCB Verified
Setup MySQL Database
Develop PHP Script
Setup Domain Name
Setup Web Hosting Service
Create Figma for UI
Develop UI in HTML & JS
Add CSS Styling
Add Display Responsiveness
App Completed
Initial Testing Procedure Design
Conduct Testing Procedure
Refine Testing Procedure
Testing Complete
Write Completion Plan
Completion Plan Submitted
Write Final Report
Final Report Submission
Write Final Presentation
Presentation Completed

9 Appendix

9.1 Contribution Table

Section	Contributor(s)	Percentage Responsibility
Executive Summary	Ahad	100%
Introduction	Ahad	100%
Completed Tasks	Alec	100%
Tasks to be Completed	Ahad, Alec, Oliver	33%, 33%, 33%
Risks and Obstacles	Ahad, Alec, Oliver	33%, 33%, 33%
Mitigation Strategies	Ahad, Alec, Oliver	33%, 33%, 33%
Risk Table	Ahad	100%
Timeline	Ahad, Alec, Oliver	30%, 30%, 40%
Editing	Ahad, Alec, Oliver	30%, 30%, 40%
Formatting	Oliver	100%
Expected Project Finances	Alec	100%

9.2 PCB Quote

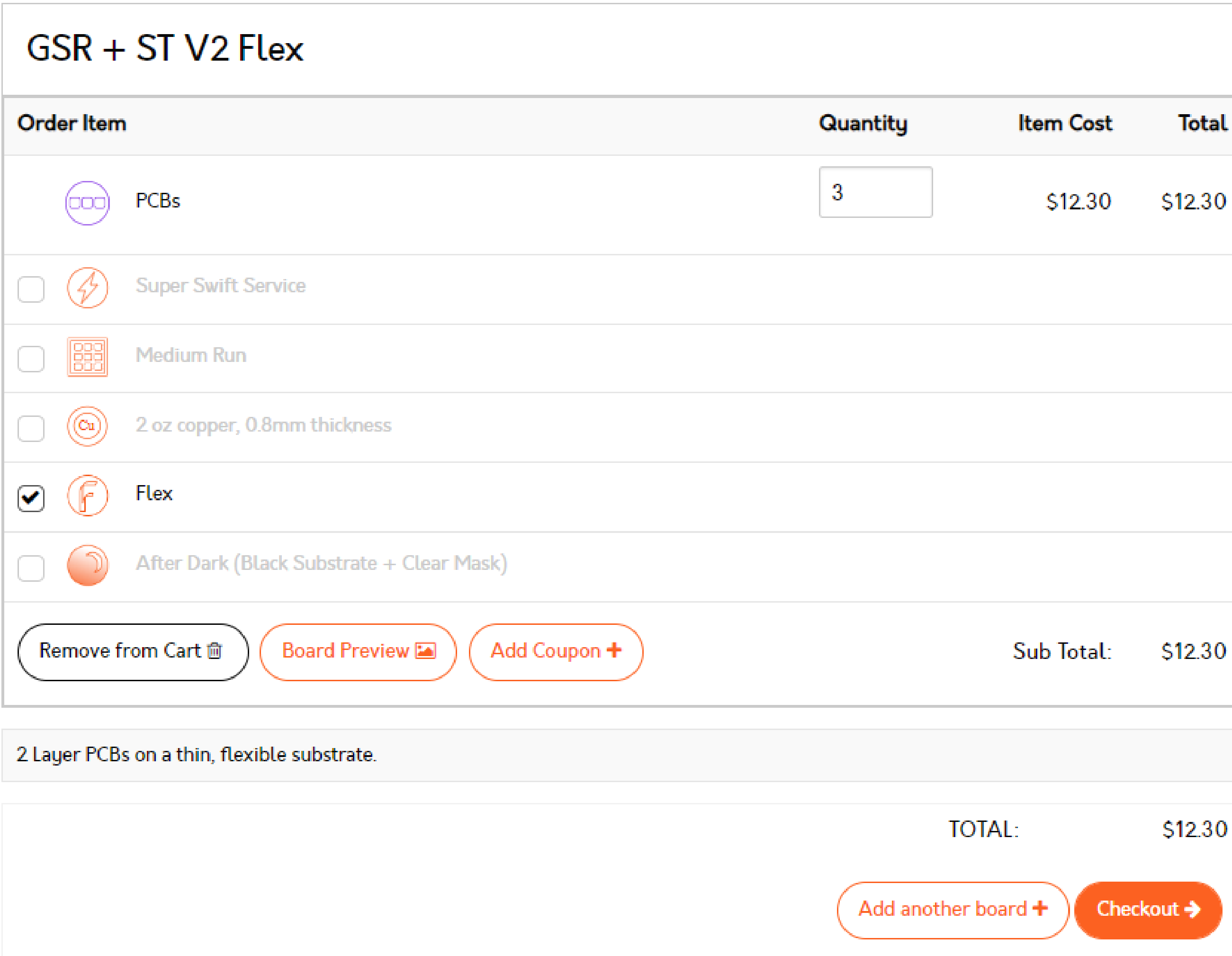


Figure 3: PCB Manufacturing Quote

9.3 PCB Component List

	Part	Qty Needed Per Board	Price per 50
Capacitors	0.1u	5	$3.46
	1000p	1	$8.66
	1u	2	$4.76
	100u	1	$20.04
	47u	1	$11.13
	10u	1	$6.01
Resistors	1M	2	$18.59
	1K	2	$4.88
	2.4K	1	$1.72
	10K	2	$4.88
	0.22K	1	$4.36
			$88.49
			$88.49

Figure 4: PCB Components Pricing Table