



PRIFYSGOL CYMRU

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UNIVERSITY OF WALES

**Trinity Saint David**

# **Implementation of a stress detection device using galvanic skin response technology**

**By**

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Project submitted as part of the requirements for the award of the  
B.Eng, (Hons) Electrical & Electronic Engineering.

April 2018

## **Student Declaration**

I, Jordan Mark Randel declare that I am the sole author of this Project; that all references cited have been consulted; that I have conducted all work of which this is a record, and that the finished work lies within the prescribed word limits.

This work has not previously been accepted as part of any other degree submission.

**Signed:** .....

**Date:** .....

### **Form of Consent**

I, Jordan Mark Randel hereby consent that my Project, submitted in candidature for the

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**Date:** .....

## **Abstract**

This report details the process of providing a solution to creating a stress detection device that can be used in order to aid in managing stress levels to increase a person's general health. The report set out to carry out research into galvanic skin response technology which had some interesting findings and was surprising to see how the technology is used in many different products on the market today. An initial schematic was designed with making use of a microcontroller and modified until it functioned correctly in simulations. However, when the design was transferred into build it did not function the same way as the simulations so the product was re-designed with new schematics and software. However, it was found once testing that to be able to use the product meaningfully the connection for the skin resistance would need to be better. Electrodes were manufactured and used but did not prove to be the solution. A connection test written into the software could be a good addition to the product. Skin conductance is dependent of many factors which also proved difficult to control without extra hardware such as temperature sensors or an accelerometer. The project as a whole was successful as the majority of the work carried out met the aims and objectives set at the start of the project. It has been recommended to have an extra set of electrodes for the other hand, also a better display of stress could have been included and an app integrated.

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## **1. Report Introduction**

This report details a project that aims to provide a microcontroller based design to help detect and manage stress levels through the use of galvanic skin response technology. Stress level thresholds will be established after the schematics have been designed and simulated so that a series of lights can illuminate as stress levels rise and fall.

This report will contain:-

- Background research on stress and how it affects us.
- Background research on galvanic skin response technology.
- Market research on existing systems using galvanic skin response technology.
- Microcontroller selection
- Circuit design
- PCB design
- Microcontroller code design
- Build of prototype
- Testing/simulations
- Project costs
- Project evaluation
- Project recommendations
- Project conclusion
- Reflection

Software to be used within this project:-

- Microsoft Word
- Microsoft Excel
- Proteus
- CCS Compiler
- Easy PC

## 1.1. Introduction

As times are changing, people are beginning to focus more on what they can do to keep themselves fit and healthy. However, as modern life is fast-paced, stress is becoming a bigger problem in our lives. Bearing this in mind, what if there was a way that people could detect and ameliorate stressful conditions throughout their day? An electronic stress detection device could enable that by helping users see when they are becoming stressed so that they can put measures in place to relax themselves.

Everyone deals with stress in different ways, some like to do calming activities such as yoga, meditation or listening to music. Others deal with stress throughout their day by doing activities such as boxing, working out or playing football. Breathing exercises can be an effective way of reducing stress as when you breathe deeply your subconscious sends a message to your brain to calm down and relax. This can help reduce your heart rate and blood pressure [1].

Electrodermal activity (EDA) measures the electrical conductivity of a person's skin through sweat glands, it happens subconsciously when reacting to all kinds of stimuli, positive and negative. It is one of the most sensitive measures for arousal or stress. In a bid to reduce a person's stress levels, a stress detection device can be made to monitor the stress levels of a person through electrodes on their fingers. When high stress levels are detected the device can make that person aware of their stress levels and then they can try to reduce their stress levels in the best way they can. If people were able to actively recognise when they are getting stressed, then they could learn what methods are best to control their stress levels. Overtime, they may then be able to not only to reduce their stress levels when they are becoming stressed but also stop themselves from becoming stressed in the first place.

Improvements in technology have meant that EDA has become an important variable in monitoring one's health; it can help detect stress levels. Stress is now being directly linked to physical and mental health issues. The NHS has advised people that suffer with stress can be prone to headaches, heart and sleep problems [2], as well as feel anxious, worried or even fearful.

## 2. Planning

### 2.1. Overall Aim

The overall aim of the project is to provide a microcontroller based solution to creating a stress detection device that can be used in order to aid in managing stress levels to increase a person's general health.

### 2.2. Aims & Objectives

| <b>Aims</b>                   | <b>Objectives</b>                                                                                                                                                                                                                                                     |
|-------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Planning</b>               | The planning section is important as it includes the aims, objectives, Gantt chart and a project breakdown.                                                                                                                                                           |
| <b>Research</b>               | The research onion is analysed to help determine the type of method that will be used for the project. Background research is completed along with market research.                                                                                                   |
| <b>Design</b>                 | Once enough research has been looked at the design will begin. The schematic drawings and code will be completed on Proteus. The PCB will be designed on EasyPC. The software for the microcontroller will be completed and simulated using Proteus and CCS Compiler. |
| <b>Testing &amp; Analysis</b> | Testing will be carried out throughout the project and the results will be analysed. The design will be modified if required.                                                                                                                                         |
| <b>Evaluation</b>             | A conclusion will evaluate the project as a whole to see if the aims and objectives have been clearly met. A list of improvements will be suggested.                                                                                                                  |

Table 1- Aims & Objectives

In order to achieve the overall aim of the project, the following aims will need to be met:

- Research galvanic skin response technology.
- Research existing products on the market that make use of galvanic skin response technology.
- Manufacture a Galvanic Skin Response Sensor.
- Design a schematic for the circuit.
- The system must incorporate a microcontroller.
- Carry out tests on users under different conditions and analyse the data received to get a threshold that indicates a stressful condition has taken place.

The objective of the project is to design a product that utilises galvanic skin response technology to detect a stressful condition and be able to output a visual representation to the user of their stress levels through a LED bar graph. Data can be recorded with the use of TX and RX communication to gather data through a computer.

### 2.3. Expected outcome

At the end of the project, it is expected that a stress detection product will have been designed and built to allow users' to effectively manage their stress levels.

Knowledge and skills would have been gained in galvanic skin response technology, designing an electronic circuit, writing C code for a microcontroller, modelling and building a Printed Circuit Board (PCB). Also, report writing, time management and project management skills will be gained.

## 2.4. Project Breakdown

| Major Milestone            | Breakdown of Tasks          | Task Description                                                                                                                                 | End Date         |
|----------------------------|-----------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|------------------|
| Project Proposal           | Project Proposal            | Have an idea for a project; create a proposal that includes the reasoning of why the project is necessary and feasible.                          | 27 April 2017    |
| Project Plan               | Block Diagram               | A technical specification to show the design as a block diagram.                                                                                 | 20 April 2017    |
|                            | Research Methodology        | Identify the research methodology to be used.                                                                                                    | 25 April 2017    |
|                            | Produce Gantt Chart         | Produce a detailed Gantt chart that includes milestone dates.                                                                                    | 27 April 2017    |
| Research and Investigation | Benefit Analysis            | Describe how the project can benefit the public and the investigator.                                                                            | 08 June 2017     |
|                            | Market Research             | Research the existing products already on the market.                                                                                            | 10 August 2017   |
|                            | Component Investigation     | Research what components are best suited and will be used in the final design.                                                                   | 24 August 2017   |
|                            | Cost Analysis               | Create a cost analysis sheet with the final costs of the project.                                                                                | 07 November 2017 |
| Implementation             | Design a Prototype          | Produce a first design prototype circuit using simulation software.                                                                              | 30 November 2017 |
|                            | Procurement                 | Purchase components ready for build.                                                                                                             | 23 January 2018  |
|                            | Build the GSR Sensor        | Put the GSR sensor together.                                                                                                                     | 14 February 2018 |
|                            | Build the Prototype         | Put the design together on a bread board by following schematic design created.                                                                  | 14 February 2018 |
|                            | Design & Upload Code to PIC | Design a system flow diagram to describe how the code will work.<br>Upload the code to the microcontroller.                                      | 08 April 2018    |
|                            | Testing                     | Test all works.                                                                                                                                  | 15 April 2018    |
| Analysis                   | Analyse the Data            | Analyse the data collected from the test. See if the device is working correctly.                                                                | 22 April 2018    |
|                            | Update the Design           | If something is not working correctly or any changes need to be made to the threshold, either create new prototype or edit existing and re-test. | 24 April 2018    |
|                            | Build Final Design PCB      | Build a final design PCB layout.                                                                                                                 | 25 April 2018    |

|                     |                           |                                                                                            |               |
|---------------------|---------------------------|--------------------------------------------------------------------------------------------|---------------|
| <b>Evaluation</b>   | <b>Conclude Project</b>   | Explain the final outcome of the project and if it was a success.                          | 20 April 2018 |
|                     | <b>Review Gantt Chart</b> | Check to see that the timescales set out in the beginning were met and where they changed. | 27 April 2018 |
|                     | <b>Skills Learnt</b>      | What new skills were acquired from completing the project.                                 | 23 April 2018 |
|                     | <b>Self-Evaluation</b>    | Write a self-evaluation.                                                                   | 23 April 2018 |
| <b>Final Report</b> | <b>Final Report</b>       | Final Report                                                                               | 26 April 2018 |
| <b>Final Viva</b>   | <b>Final Viva</b>         | Final Viva                                                                                 | 05 May 2018   |

Table 2 - Project Breakdown

## 2.5. Gantt Charts

### 2.5.1. Original Gantt Chart

| Major Milestone            | Breakdown                          | Start             | Finish            |
|----------------------------|------------------------------------|-------------------|-------------------|
| Project Proposal           | Project Proposal                   | 01 January 2017   | 27 April 2017     |
| Project Plan               | Block Diagram                      | 20 March 2017     | 20 April 2017     |
|                            | Research Methodology               | 20 April 2017     | 25 April 2017     |
|                            | Produce Gantt Chart                | 25 April 2017     | 27 April 2017     |
| Research and Investigation | Benefit Analysis                   | 27 April 2017     | 08 June 2017      |
|                            | Market Research                    | 01 June 2017      | 10 August 2017    |
|                            | Component Investigation            | 10 July 2017      | 24 August 2017    |
|                            | Cost Analysis                      | 24 August 2017    | 07 September 2017 |
| Implementation             | Design a Prototype                 | 24 August 2017    | 26 October 2017   |
|                            | Design Code                        | 10 September 2017 | 16 November 2017  |
|                            | Procurement                        | 16 November 2017  | 23 November 2017  |
|                            | Upload Code onto PIC               | 23 November 2017  | 30 November 2017  |
|                            | Build the GSR Sensor               | 23 November 2017  | 14 December 2017  |
|                            | Build the Prototype                | 23 November 2017  | 14 December 2017  |
|                            | Testing for Threshold              | 14 December 2017  | 21 December 2017  |
| Analysis                   | Analyse the Data                   | 21 December 2017  | 18 January 2018   |
|                            | Update the Design and final design | 11 January 2018   | 25 January 2018   |
|                            | Conclude Project                   | 25 January 2018   | 08 February 2018  |
| Evaluation                 | Review Gantt Chart                 | 08 February 2017  | 15 February 2018  |
|                            | Skills Learnt                      | 12 February 2018  | 22 February 2018  |
|                            | Self-Evaluation                    | 19 February 2018  | 01 March 2018     |
|                            | Final Report                       | 19 February 2018  | 15 March 2018     |
| Final Report               | Final Report                       | 15 March 2018     | 29 April 2018     |
| Final Viva                 | Final Viva                         | 15 March 2018     | 05 May 2018       |

**Project:** Stress Dection and Relieving Product using GSR Technology

**Start Date:** 01/17

**Projected Finish Date:** 05/18

A Gantt chart has many benefits as it allows you to think through each task, what is involved in the task and the timescales of them. If tasks are not completed on schedule it will have knock on effects to the project later on. This original Gantt chart has tasks spread out with a fair amount of time to complete each task but this does not account for unforeseeable problems.

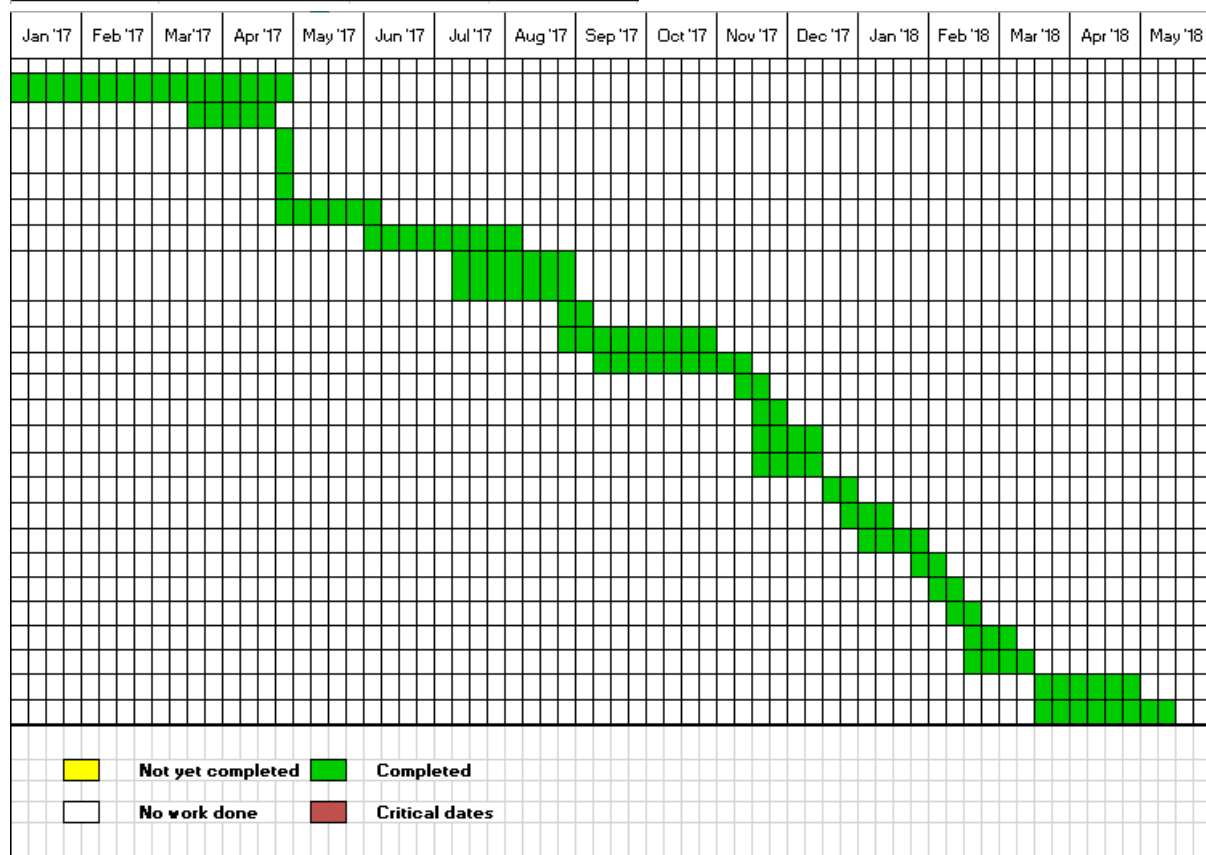


Figure 1 – Original Gantt Chart

## 2.5.2. Interim Viva 1 Gantt Chart

| Major Milestone            | Breakdown               | Start            | Finish           |
|----------------------------|-------------------------|------------------|------------------|
| Project Proposal           | Project Proposal        | 01 January 2017  | 27 April 2017    |
| Project Plan               | Block Diagram           | 20 March 2017    | 20 April 2017    |
|                            | Research Methodology    | 20 April 2017    | 25 April 2017    |
|                            | Produce Gantt Chart     | 25 April 2017    | 27 April 2017    |
| Research and Investigation | Benefit Analysis        | 27 April 2017    | 08 June 2017     |
|                            | Market Research         | 01 June 2017     | 10 August 2017   |
|                            | Component Investigation | 10 July 2017     | 24 August 2017   |
| Implementation             | Cost Analysis           | 24 August 2017   | 07 November 2017 |
|                            | Design a Prototype      | 24 October 2017  | 30 November 2017 |
|                            | Design Code             | 10 November 2017 | 21 December 2017 |
|                            | Procurement             | 03 January 2018  | 23 January 2018  |
|                            | Upload Code onto PIC    | 23 January 2018  | 30 January 2018  |
|                            | Build the GSR Sensor    | 23 January 2018  | 14 February 2018 |
|                            | Build the Prototype     | 23 January 2018  | 14 February 2018 |
|                            | Testing                 | 14 February 2018 | 21 February 2018 |
| Analysis                   | Analyse the Data        | 21 February 2018 | 28 February 2018 |
|                            | Update the Design       | 28 February 2018 | 01 March 2018    |
|                            | Build Final Design PCB  | 01 March 2018    | 15 March 2018    |
| Evaluation                 | Conclude Project        | 15 March 2018    | 15 March 2018    |
|                            | Review Gantt Chart      | 15 March 2018    | 15 March 2018    |
|                            | Skills Learnt           | 22 March 2018    | 22 March 2018    |
|                            | Self-Evaluation         | 29 March 2018    | 29 March 2018    |
| Final Report               | Final Report            | 15 March 2018    | 29 April 2018    |
| Final Viva                 | Final Viva              | 15 March 2018    | 05 May 2018      |

Project: Stress Dection and Releiving Product using GSR Technology  
Start Date: 01/17  
Projected Finish Date: 05/18

This Gantt chart was updated when the interim viva 1 was put together. It is clear to see here that tasks have not been completed on time to the original Gantt chart and this has resulted in less time being allowed for tasks later on. Also, one critical date was not met and the date has been pushed forward.



Figure 2 - Interim Viva 1 Gantt Chart

## 2.5.2. Interim Viva 2 Gantt Chart

| Major Milestone            | Breakdown                   | Start            | Finish           |
|----------------------------|-----------------------------|------------------|------------------|
| Project Proposal           | Project Proposal            | 01 January 2017  | 27 April 2017    |
| Project Plan               | Block Diagram               | 20 March 2017    | 20 April 2017    |
|                            | Research Methodology        | 20 April 2017    | 25 April 2017    |
|                            | Produce Gantt Chart         | 25 April 2017    | 27 April 2017    |
| Research and Investigation | Benefit Analysis            | 27 April 2017    | 08 June 2017     |
|                            | Market Research             | 01 June 2017     | 10 August 2017   |
|                            | Component Investigation     | 10 July 2017     | 24 August 2017   |
|                            | Cost Analysis               | 24 August 2017   | 07 November 2017 |
| Implementation             | Design a Prototype          | 24 October 2017  | 30 November 2017 |
|                            | Procurement                 | 03 January 2018  | 23 January 2018  |
|                            | Build the GSR Sensor        | 23 January 2018  | 14 February 2018 |
|                            | Build the Prototype         | 23 January 2018  | 14 February 2018 |
|                            | Design & Upload Code to PIC | 14 February 2018 | 08 March 2018    |
|                            | Testing                     | 01 March 2018    | 15 March 2018    |
| Analysis                   | Analyse the Data            | 15 March 2018    | 22 March 2018    |
|                            | Update the Design           | 22 March 2018    | 29 March 2018    |
|                            | Build Final Design PCB      | 29 March 2018    | 05 April 2018    |
| Evaluation                 | Conclude Project            | 22 March 2018    | 20 March 2018    |
|                            | Review Gantt Chart          | 22 March 2018    | 21 March 2018    |
|                            | Skills Learnt               | 22 March 2018    | 22 March 2018    |
|                            | Self-Evaluation             | 29 March 2018    | 29 March 2018    |
| Final Report               | Final Report                | 22 March 2018    | 29 April 2018    |
| Final Viva                 | Final Viva                  | 22 March 2018    | 05 May 2018      |

Project: Stress Dection and Releiving Product using GSR Technology  
Start Date: 01/17  
Projected Finish Date: 05/18



This Gantt chart was updated after interim viva 2. Similar to the last update to the Gantt chart at interim viva 1, tasks were not completed to the projected dates so again tasks have been shifted across giving even less time to complete tasks.

### 2.5.3. Final Gantt Chart

| Major Milestone                                                                                           | Breakdown                   | Start            | Finish           |
|-----------------------------------------------------------------------------------------------------------|-----------------------------|------------------|------------------|
| Project Proposal                                                                                          | Project Proposal            | 01 January 2017  | 27 April 2017    |
| Project Plan                                                                                              | Block Diagram               | 20 March 2017    | 20 April 2017    |
|                                                                                                           | Research Methodology        | 20 April 2017    | 25 April 2017    |
|                                                                                                           | Produce Gantt Chart         | 25 April 2017    | 27 April 2017    |
| Research and Investigation                                                                                | Benefit Analysis            | 27 April 2017    | 08 June 2017     |
|                                                                                                           | Market Research             | 01 June 2017     | 10 August 2017   |
|                                                                                                           | Component Investigation     | 10 July 2017     | 24 August 2017   |
|                                                                                                           | Cost Analysis               | 24 August 2017   | 07 November 2017 |
| Implementation                                                                                            | Design a Prototype          | 24 October 2017  | 30 November 2017 |
|                                                                                                           | Procurement                 | 03 January 2018  | 23 January 2018  |
|                                                                                                           | Build the GSR Sensor        | 23 January 2018  | 14 February 2018 |
|                                                                                                           | Build the Prototype         | 23 January 2018  | 14 February 2018 |
|                                                                                                           | Design & Upload Code to PIC | 14 February 2018 | 08 April 2018    |
|                                                                                                           | Testing                     | 01 March 2018    | 15 April 2018    |
| Analysis                                                                                                  | Analyse the Data            | 15 March 2018    | 22 April 2018    |
|                                                                                                           | Update the Design           | 22 March 2018    | 24 April 2018    |
|                                                                                                           | Build Final Design PCB      | 29 March 2018    | 25 April 2018    |
| Evaluation                                                                                                | Conclude Project            | 20 April 2018    | 20 April 2018    |
|                                                                                                           | Review Gantt Chart          | 14 April 2018    | 27 April 2018    |
|                                                                                                           | Skills Learnt               | 22 April 2018    | 23 April 2018    |
|                                                                                                           | Self-Evaluation             | 22 April 2018    | 23 April 2018    |
| Final Report                                                                                              | Final Report                | 22 March 2018    | 29 April 2018    |
| Final Viva                                                                                                | Final Viva                  | 22 April 2018    | 05 May 2018      |
| Project: Stress Dection Product using GSR Technology<br>Start Date: 01/17<br>Projected Finish Date: 05/18 |                             |                  |                  |

As shown in this final Gantt chart everything managed to get finished but what the Gantt chart doesn't show is the extend of what. For example, testing was completed but maybe not all the tests that were planned to be done were completed. The only part that hasn't been completed yet is the Viva which will take place a week after the report is submitted.



### 3. Research & Development Methodology

When beginning research it is essential to implement research methodology to ensure that the most is gained from the research. It establishes the research types that need to be undertaken as a guide, it gives direction to the project. The method that has been chosen for the project at hand is the 'research onion' that was developed by Saunders et al. (2012). The 'onion' is a metaphor for the layers of research which build up the key parts of the research strategy [3].

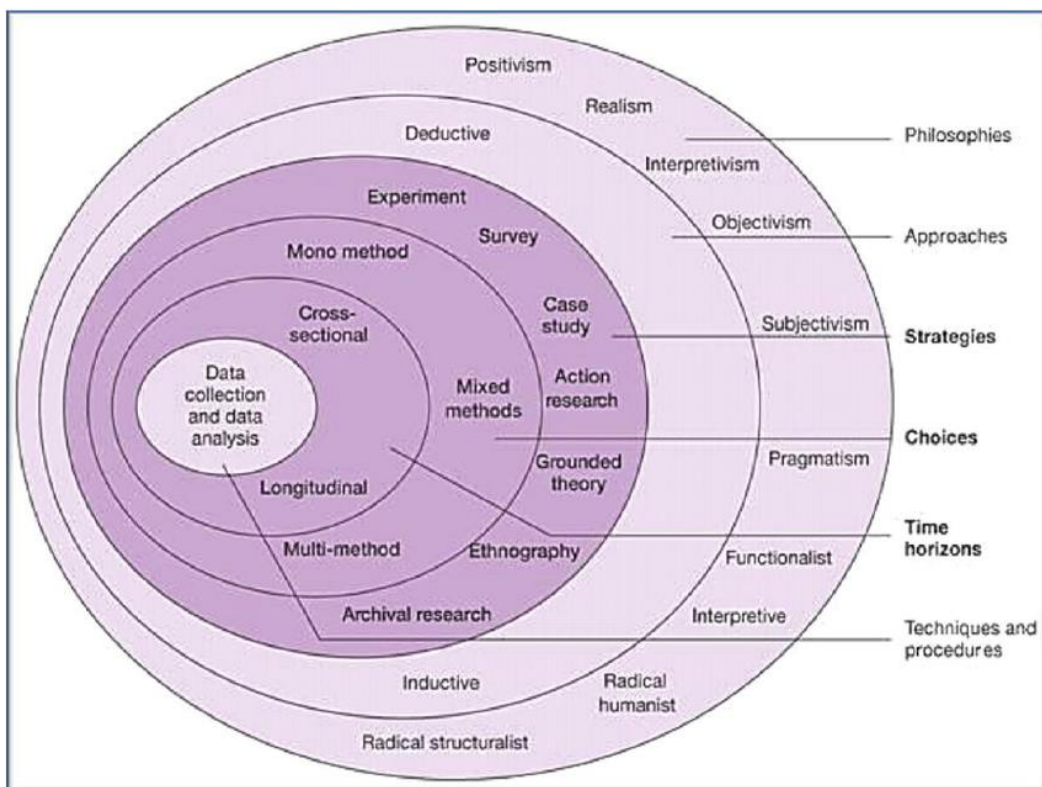


Figure 3 - Research Onion [18]

### 3.1. Research Philosophy

The research philosophy part of the onion is the first layer, at this early stage the choice of investigation will set the direction and create the structure. There are many parts that form this layer. However, it is proposed that the project should take a positivistic approach. The positivistic approach takes sources as truth; it usually involves research that has been proven. The project is a unique product but will be designed from research of existing circuits and research but will only use this as a starting point. When the device is built, the data produced will be quantitative as it will produce specific data.

### 3.2. Research Approach

The second layer of the onion is the approach; this is where the author plans the research. There are two main directions taken in this layer. The deductive approach is explained by proving answers through testing and theory. Data will need to be gathered for this approach by completing testing for evidence. This approach will be used; it means the problem at hand will have a definitive answer and result that will be confirmed by testing. The use of GSR technology will benefit as it is very sensitive information which can detect very small changes in conductivity. The theory of it has been considered and will have quality checks as well as an evaluation after it has been built.

### 3.3. Research Strategy

This layer of the onion covers the research strategy, it focuses on the method that will be used to locate the information needed and also how the research will be achieved. Again, in this layer of the onion there are many different strategies that can be taken. However, the plan for the project is to do some experimental research through testing out different schematicd and electrodes. Also, action research will help alongside archival research when finding out information about the system for the device. It will be used through the whole process. Experimental research is very self-explanatory, this method is done by carrying out tests for investigation and to gather data to analyse. Action and archival research is research that follows a certain process and research that involves primary sources.

### 3.4. Choices

This layer of the onion focuses on the type of choices that will be taken for research whether the methods used will be quantitative or qualitative. A multi method choice means that both quantitative and qualitative methods will be used in the study process. Therefore, a multi method approach will be taken forward as it reduces the threat to construct validity.

### 3.5. Time Horizon

In this deep layer of the onion there is two main types, longitudinal and cross-sectional. Time horizons look at the amount of time the studies will take, cross-sectional being a short time study and longitudinal is over a long-term study. This project will adopt a cross sectional horizon as the data collected will be the from the GSR sensor which is to observe the mood of a person. Results may not be the most reliable due to different variables, such as the emotional state of a person; it will not be able to distinguish between stress, excitement and possibly another emotion. However, the study is intended to examine a changeover instantly at specific points rather than over a long period so this is the appropriate method.

### 3.6. Data Collection

Data collection is the centre of the onion which is comprised of two methods, primary and secondary, for data collection. Primary data is gathered by the use of questionnaires, testing, interviews etc. Secondary data is collected from other people findings from tests and research. Secondary data can be unreliable is it is not coming from a reputable source. Both primary and secondary data will be used in the data collection in this report. Secondary will be used mostly at the beginning of the investigation stages, to gain knowledge and understanding of the theory and principles behind the technology. Some primary research will be used when testing the device along with other tests.

### 3.7. Research and Development Conclusion

The methods that will be used from each layer of the research onion are as follows:

Research Methodology – Positivistic

Research Approaches – Deductive

Research Strategies – Experimental, Archival & Action Research

Choices – Multi Method

Time Horizons – Cross-Sectional

Data Collection – Primary & Secondary Data

## **4. Research & Review of Literature**

### **4.1. Background Research**

#### **4.1.1. Stress**

Stress is a feeling of being under too much pressure, some stress is normal and can help you overcome situations. However, this pressure can eventually become too much to be able to cope and that is where stress can really take its toll on a person and people closest to them.

Each individual overcomes stress in their own way such as taking part in activities such as football, boxing or working out in the gym. Breathing exercises can be an effective way of reducing stress as when you breathe deeply your subconscious sends a message to your brain to calm down and relax. This can help reduce your heart rate and blood pressure [1].

Stress is now being directly linked to physical and mental health issues. The NHS has advised people that stress more can be prone to headaches, heart and sleep problems [2], as well as feel anxious, worried or even fearful.

Although stress can arise from many different areas of a person's life, one of the biggest stress factors in a person's life is work-related stress. In fact, Mind completed a survey of over 2000 people in 2013 which indicates that work-related stress is the biggest stress factor with 34% of people agreeing with this statement. Financial problems were a close second at 30%. Some of the key findings from the survey are below:

- “One in five (19 per cent) take a day off sick because of stress, but 90 per cent of those people cited a different reason for their absence.
- One in ten (9 per cent) have resigned from a job due to stress and one in four (25 per cent) have considered resigning due to work pressure.
- Of the 22 per cent who have a diagnosed mental health problem, less than half (10 per cent) had actually told their boss about their diagnosis.” [4]

The HSE website shows you the amount of workers suffering from stress at work and the toll it takes on the work force and the company. Many of the factors listed in the chart below can or could have been controlled.

526,000 workers suffering from work-related stress, depression or anxiety (new or long-standing) in 2016/17

12.5 million working days lost due to work-related stress, depression or anxiety in 2016/17

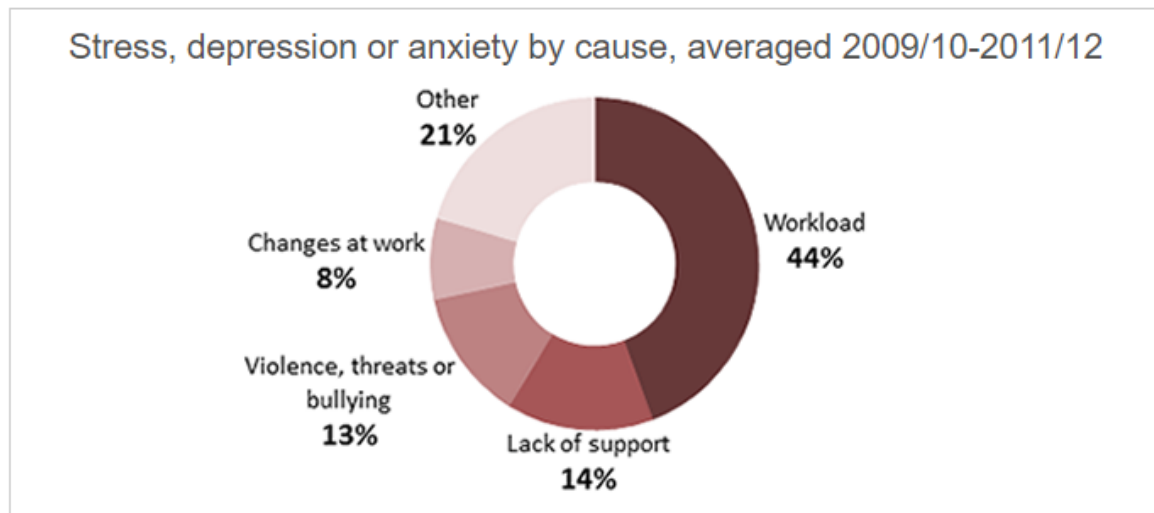


Figure 4 - Work-Related Stress, Depression or Anxiety [25]

It is in everyone's best interest to try to reduce stress levels. Stress doesn't only cost a company money but it costs a person their health and happiness.

#### 4.1.2. Electrodermal Activity

EDA is a common term used to describe the continuous change in the electrical phenomena occurring in the skin. It is also commonly referred to as Galvanic skin response (GSR). The property that will be focused on is the skin conductance, a measured EDA value is caused by measuring the electrical phenomena between two parts of the skin.

Skin conductance can be measured due to the sweat secreted from sweat glands all over the body. The iMotions definitive pocket guide to GSR informs us that “Our body has about three million sweat glands”. The areas of the body which secrete sweat the most due to the amount of sweat glands are the forehead, cheeks, palms, fingers and the bottom of the feet [5].

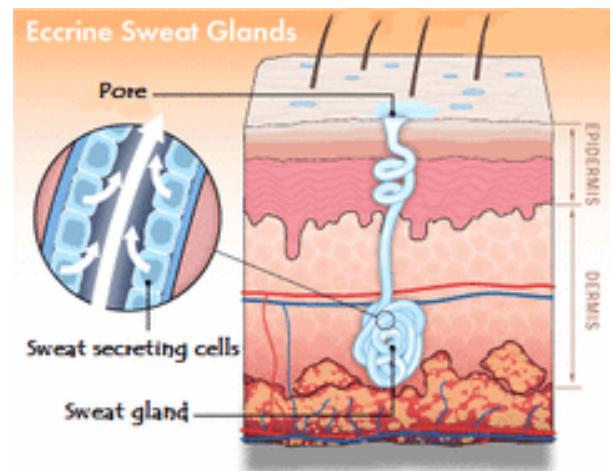


Figure 5 - Anatomy of sweat glands [19]

There are three main functions of sweat glands that are affected by emotional arousal. The first function being to cool the skin when a person is getting warm to decrease body temperature. Another function is excretion; the sweat glands will secrete sweat to expel waste matter or products. The third function is to protect, sweat gland secretion protects from hazards in the environment by diluting harmful chemicals [6].

Skin conductance measurement can be derived into two types, tonic and phasic.

Background tonic or skin conductance level (SCL) is a slow changing level of skin conductance which varies over time depending on a person's psychological state. It is the skin conductance without any discrete environmental stimuli. These tonic changes in the SCL take place between tens of seconds to minutes. To measure SCL you must measure the entire level of skin conductance, it is associated to a person's total arousal. Rapid phasic responses or skin conductance responses (SCR) are hasty increases or peaks in skin conductance which is associated with short term events. They occur in the presence of discrete environmental stimuli, such as sight, sound, smell or cognitive processes [7].

SCRs can be illustrated by four factors, SCR latency, SCR rise time, SCR amplitude and SCR half recovery time, the interval between SCR peak and point of 50% recovery of SCR amplitude.

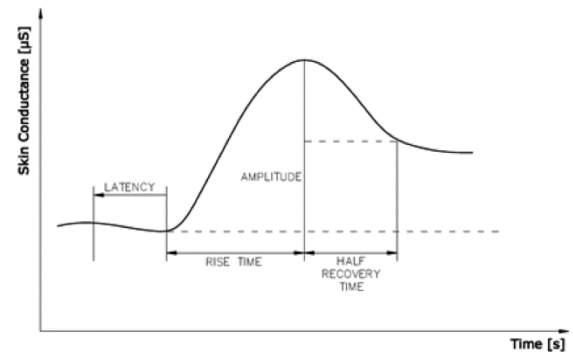


Figure 6 - Skin conductance response [10]

The range of resistance of a person's skin between two fingers is typically between 50k Ohms and 10M Ohms [8]. Skin conductance is measured in Siemens, but the units for skin conductance are so small they are measured in microsiemens ( $\mu\text{S}$ ) or (mho), where;

Equation 1 - Siemens Equation

$$1\text{S} = \frac{1\text{W}}{1\text{W}}$$

In a DC circuit, mathematically, conductance and resistance are equal to one another. R, the resistance of a component in ohms and then G is the conductance in Siemens, then;

Equation 2 - Resistance Equation

$$R = \frac{1}{G}$$

So,

Equation 3 - Conductance Equation

$$G = \frac{1}{R}$$

Skin resistance tends to be higher when in a person is in a relaxed state compared to a stressful state. This is because when a person is stressed they tend to secrete more sweat which means there is an increase in skin conductance which equals a decrease in skin resistance [6].

When measuring a person's EDA, the signals that are recorded are usually corrupted by electrocardiogram artefacts (ECG) which occurs from the person's body movements or poor

electrode contact [9]. The signals can also be corrupted by high environmental temperature. This could make it a lot harder to interpret the results correctly, an accelerometer and thermometer could be used to allow us to see if the results have been corrupted by environmental temperature or physical activity as small as just moving your wrist. The conductance reading will feed back to a microcontroller. There is no universal reading that indicates a stressful condition. When trying to work out a threshold to indicate a stressful condition has taken place it will be essential to play around with the readings that are being recorded from different people under different conditions.

The SCLmin of a person can be obtained by carrying out measurements over time to find the smallest and flattest interval of skin conductance. It should be noted that there should be no physical activity at this point and the person should be in room temperature. Similarly, to find the SCLmax the largest smooth interval of skin conductance will need to be recorded. The person's current SCL can be expressed as a proportion if we assume that a person's SCRmin is 0 and SCRmax is the largest response to a discrete event then the following equation can be derived [10]:

Equation 4 - Skin conductance response equation [10]

$$\text{SCRrel} = \frac{\text{SCR}}{\text{SCRmax}}$$

Microcontrollers are a great solution to creating circuits that require complex instruction. The great thing about using a PIC microcontroller is that you can make changes to the PIC program and you won't have to re-design a circuit. PICs are programmed from using numbers, such as binary or hexadecimal [11]. PICs tend to operate on ELV (extra-low voltage), which is below 50V [12].

#### 4.2. Measuring Electrodermal Activity

EDA can be measured by applying a direct current (DC) via electrodes on the skin or by applying an alternating current (AC) instead. The electrodes are placed on the first and second finger of one or maybe both hands. One electrode emits the electrical signal and the other is the receiver allowing the circuit to be established with the skin acting as a resistor. One hand can be more responsive than the other so if there is not much response on the first hand then it is a good idea to try the other.

### 4.3. Electrode Materials

The electrode material must be considered when measuring skin conductance, the material will need to be offer high electrical conductivity and low resistance.

| Material     | Electrical Conductivity<br>10.E6 Siemens/m | Electrical Resistivity<br>10.E-8 Ohm.m | Cost Scoring<br>1-High, 5-Low |
|--------------|--------------------------------------------|----------------------------------------|-------------------------------|
| Silver       | 62.1                                       | 1.6                                    | 1                             |
| Copper       | 58.5                                       | 1.7                                    | 2                             |
| Brass        | 15.9                                       | 6.3                                    | 3                             |
| Aluminium    | 36.9                                       | 2.7                                    | 4                             |
| Carbon Steel | 5.9                                        | 16.9                                   | 5                             |

Table 3 - Electrode Materials [13]

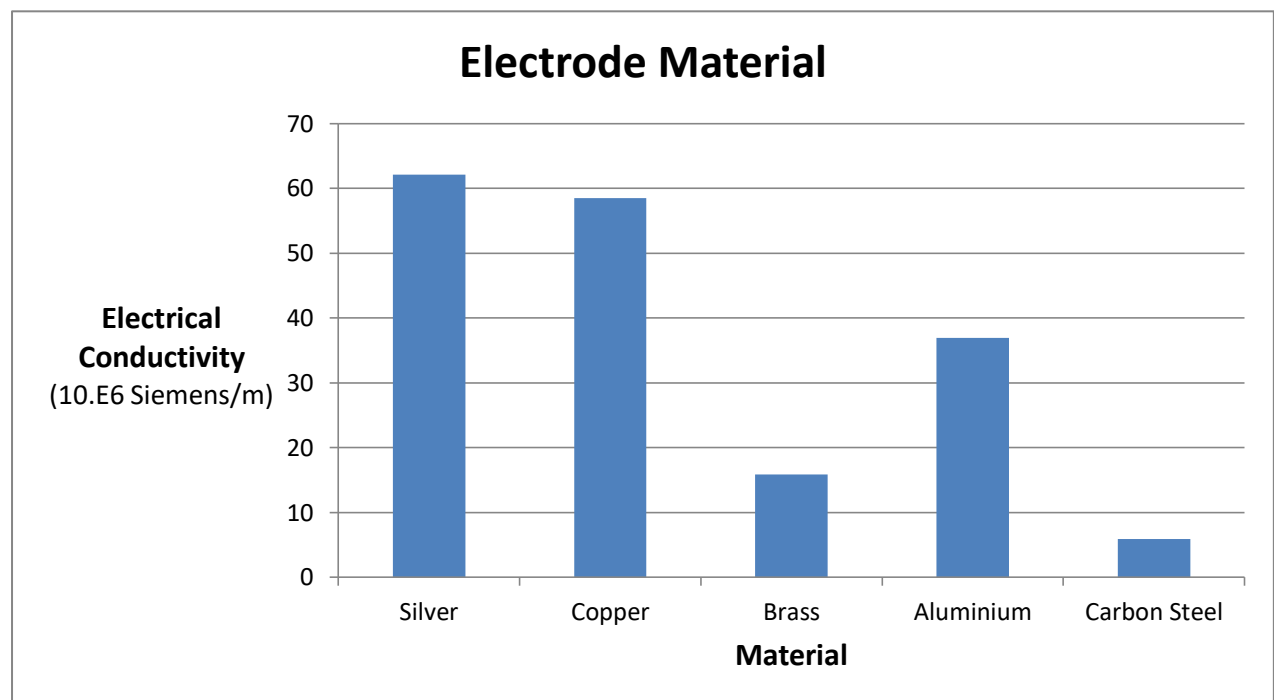


Figure 7 - Electrode Material Graph

Performance wise the best material to use for the electrodes would be silver, it has the highest electrical conductivity therefore the lowest resistivity. However, it does tend to cost a lot more than the other metals listed. Copper is a close second in terms of performance and can be purchased at a much lower price. Thin copper foil is also readily available which is another reason why copper is likely to be the best option in this case, this can be stuck onto some Velcro to use as finger electrodes.

## 4.4. Market Research

### 4.4.1. Affectiva Bluetooth-enabled emotional arousal sensor

Physiological and psychological activities are now becoming more easily measured when using electrodermal response (EDR) as it is one of the most important bio-electric signals. For this reason, Affectiva Incorporated introduced a wearable EDR-based device [14]. The device measures emotional arousal via skin conductance, whilst also tracking movement and temperature [15].



Figure 8 - Affectiva Arousal Sensor [15]

### 4.4.2. Moodmetric Ring



Figure 9 - Moodmetric Ring [16]

Another product that is currently on the market that makes use of EDA is the Moodmetric ring which connects to an app to take real-time measurements to measure long term stress. The image to the right shows

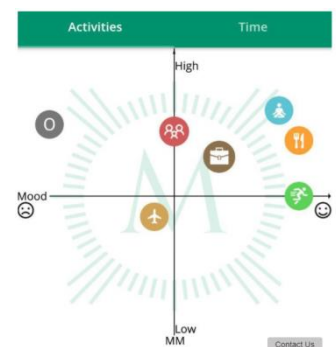


Figure 10 - Moodmetric App [16]

the app in use which contains different stress level scorings for the relative life category. The ring measures on a scale of 1 to 100 for stress, users such as Esmeralda Tuomi have said that the ring has helped prove that they can reduce their stress levels through horse riding [16].

#### 4.5. Uses of GSR

GSR has many uses, it is best known for being used in truth meters. However, GSR is not the most accurate for truth meters, it is also used in Biofeedback.

One use of GSR is Biofeedback, using a GSR sensor you can measure your body's responses to arousal. Using this information you can try to relax yourself. GSR can help you guide yourself into relaxation and manage your own stress levels. As stress can be harmful to your heart as well as increasing the chance of strokes, this is why relaxation is important.

Relaxation therapy has been proven in some research to manage and prevent relapse into major depression. The research was carried out by the University of Oxford. The therapy given to participants helped equip them with the skills to understand and prevent the thoughts and feelings linked with depression, to stop future relapse. Information was gathered from several randomised trials, all 1,258 participants received mindfulness-based therapy. The trials "found that 38% of those who received the therapy experienced a depressive relapse in comparison to 49% of patients who didn't receive treatment" [17].

GSR can be used in media when testing for new adverts. A media company could play viewers who are being monitored through GSR sensors their new advert and analyse the results to see how they react emotionally to the advert. This could be very affective for certain types of adverts that are trying to play on your emotions. The downfall when measuring EDA is that it is not clear whether the participant is actually becoming stressed or if they are experiencing any other emotion as many emotions increase EDA.

## 4.6. Hardware

### 4.6.1. Operational Amplifiers

#### 4.6.1.1. *Characteristics of an ideal Operational Amplifier*

**Infinite Voltage Gain** – this means the gain of the amplifier without any feedback should be infinite.

**Infinite Bandwidth** – all signals from DC upwards should have equal amplification.

**Infinite Input Resistance** – ideally the input resistance should be infinite to prevent any loading on the input signal.

**Zero Output Impedance** – so any changes in the load impedance doesn't affect the output voltage.

**Zero Offset** - the output should be zero when the input is zero, this can be achieved by applying a small voltage to the offset null pin.

#### 4.6.1.2. Operational Amplifier Circuits

One of the basic building blocks for electronic circuits is the operational amplifier. There are many different operation amplifier configurations.

##### 4.6.1.2.1. Inverting Operational Amplifier

In this circuit the output ( $V_s$ ) is fed back into the inverting pin (-) through a feedback resistor ( $R_2$ ). The input signal is fed into the inverting pin (-) through a resistor ( $R_1$ ). The positive pin (+) is connected to ground.

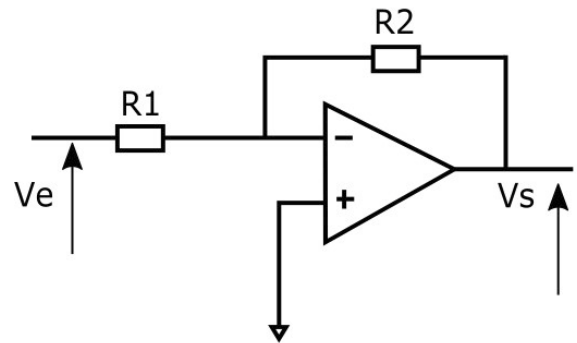


Figure 11 - Inverting Op Amp Circuit [23]

In this configuration, if  $R_1$  and  $R_2$  are equal then the signal that is outputted will be exactly the opposite of the input signal. This is shown in the equation below due to the negative sign. If both input and output signal need to be the same then a non-inverting operational amplifier circuit is required.

$$V_s = -V_e \frac{R_2}{R_1}$$

Equation 5 - Op Amp Gain Equation (Inverting)

#### 4.6.1.2.2. Non-Inverting Operational Amplifier

The non-inverting operational amplifier configuration is very similar to the inverting. However, the input voltage is directly applied to the inverting pin and the feedback loop end is connected to ground. This allows for an output

signal that is in phase with the input.

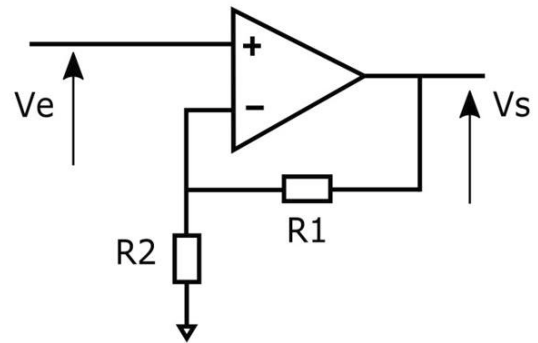


Figure 12 - Non-Inverting Op Amp Circuit [23]

$$V_s = V_e \left(1 + \frac{R_2}{R_1}\right)$$

#### Equation 6 - Op Amp Gain Equation (Non-Inverting)

#### 4.6.1.2.3. Voltage Follower

In a voltage buffer circuit the voltage output is equal to the voltage input. This circuit is not used for amplification it is used to create a circuit of a high impedance input and low impedance output. These circuits are used when the power supply is based on a voltage divider as the voltage outputted from the voltage divider can change dramatically.

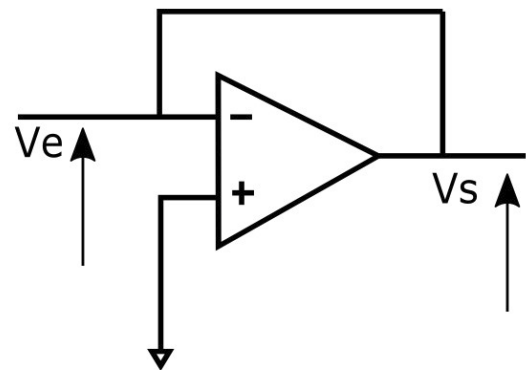


Figure 13 - Voltage Follower Circuit [23]

#### 4.6.1.3. 741 Op-Amp

One of the most commonly used operational amplifiers (op-amps) is the 741 op-amp. It has an inverting (-) input and a non-inverting input (+), it has a large voltage gain with very high input impedance and a low output impedance.

In the inverting amp the signal is connected in series with  $R_{in}$ , the output of the 741 is fed back through the feedback resistor ( $R_f$ ), and the

non-inverting input is connected to ground. As the input of the 741 goes positive, the output will go negative and vice versa. The gain of the 741 is adjusted by the two resistors  $R_f / R_{in}$ . Because the output goes negative as the input goes positive, and the output is fed back through  $R_f$ , the point where they connect at the inverting input will always be at 0V, and is known as the virtual earth.

The circuit can be adjusted to create a non-inverting amplifier; the input signal is merely fed into the non-inverting terminal. The two resistors are connected from the output to ground with feedback being taken from the middle of the potential divider and connected to the inverting input. In this configuration the output will be in phase with the input, the gain can be worked out:

$$Gain = 1 + \frac{R_f}{R_{in}}$$

Equation 7 - Op Amp Gain Equation (Non-Inverting)

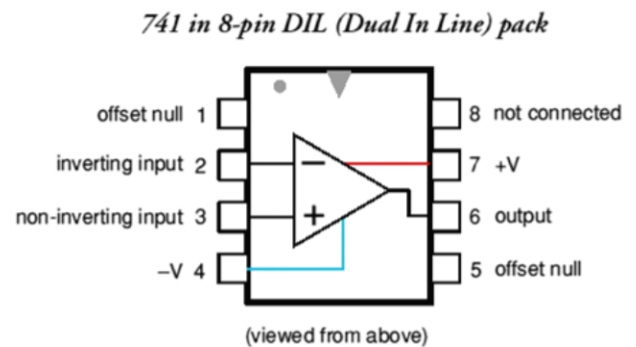


Figure 14 - 741 Op Amp [20]

#### 4.6.2. Microcontrollers

A microcontroller is a programmable system much like a PLC (Programmable Logic Controller) although there are notable differences. A PLC can be fairly large in size, however microcontrollers are small in size as shown in the image to the right.

A microcontroller contains memory, and a processor that is utilised as an embedded system. Microcontrollers are widely used today embedded in products or machinery such as mobile phones, vehicles and many other appliances and can vary in complexity. Input and output devices can be configured for sensor for data such as temperature, LCD displays, switches, as well as many others.

A microcontroller can be programmed by writing code such as C and then uploading it to the microcontroller. Microcontrollers can come in different bit sizes for example, 8, 16 and 32 bit which refers to the size of the databus. The design will most likely make use of a 9V battery. However, the voltage will need to be stepped down to through a 5V voltage regulator in order to be compatible with the microcontroller.

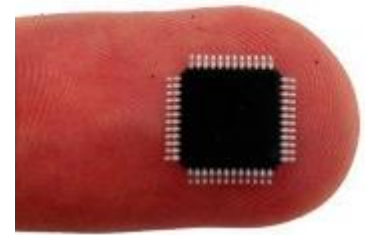


Figure 15 - Surface Mount Microcontroller [21]

## **5. Project Requirements**

### **5.1. Hardware**

- Batteries (9VDC)
- Battery connector
- Toggle Switch
- Electrodes (copper strip on Velcro) as copper is one of the best conductors.
- Cable
- Microcontroller
- Breadboard
- LEDs
- Operational amplifier
- 5V Regulator
- Resistors
- Capacitors
- Diodes
- 9 Pin D-Type Connector (RS232)

### **5.2. Software**

The software that will be used throughout the process of designing, manufacturing and the device will be:

- CCS Compiler for programming the PIC.
- MATLAB
- Proteus for the schematic design.
- EasyPC for the PCB design.
- Microsoft Word
- Microsoft Excel

## 6. Component Selection

Most of the components in the design are just general components such as resistors, capacitors and LEDs which are readily available.

### 6.1. Microcontroller

When selecting a microcontroller there are a lot of different specifications that will need to be considered. However, this system will not need a very complex microcontroller.

#### 6.1.1. Pin Count

One specification needed for selecting a microcontroller is the amount of pins needed.

There is 1 analog signal, provision for RS232, 8 LED outputs, this makes 11 pins. Other pins required will be 2/4 for the supply. A minimum of 20 pins required, PICs pin count standards near this amount are 14, 20, 28. So, a pin count of 20 would be sufficient to allow for some expansion.

#### 6.1.2. Internal Oscillator

To figure out the size of the internal oscillator needed a 4MHz internal oscillator can be considered firstly. A 4MHz internal oscillator would have 1 million instructions in a microsecond as PICs need 4 clock cycles per instruction because they are designed with quadrature architecture.

- 3 instructions to select a channel
- 30 microseconds delay to settle
- 5 instructions to start the conversion
- 6 microseconds delay for the conversion
- 4 instructions to read the analog to digital conversion
- 30 instructions to store the data

The above equals 78 microseconds per channel for the 1 analog reading and storage. Delays equal 36 microseconds, this can't be helped. However, if we were to subtract 36 by 78 this equals 42 microseconds. Also, the loop time will need to be considered, so in reality the amount of time per reading can be doubled. Therefore, 42 microseconds divided by around 150 calculates to less than 1. So, 4MHz would be great enough.



## 6.2. Battery Selection

The battery for this project will be a standard 9V battery alkaline battery. The PIC needs 5V to operate so a 5V voltage regulator was added which feeds the GSR circuit and the 8 LED outputs, each LED draws 20mA when used. A power on LED is also fed via the battery but only draws 20mA. As the voltage regulator will need a higher voltage inputted to work correctly the standard AAs and AAAs which are the most common alkaline batteries won't be feasible unless they are combined as they are 1.2V. There is not a great deal of current being drawn by the system. Therefore, the logical battery to use would be a standard 9V battery.



Figure 18 - 9V Battery [24]

## 7. First Design

### 7.1. Block Diagram

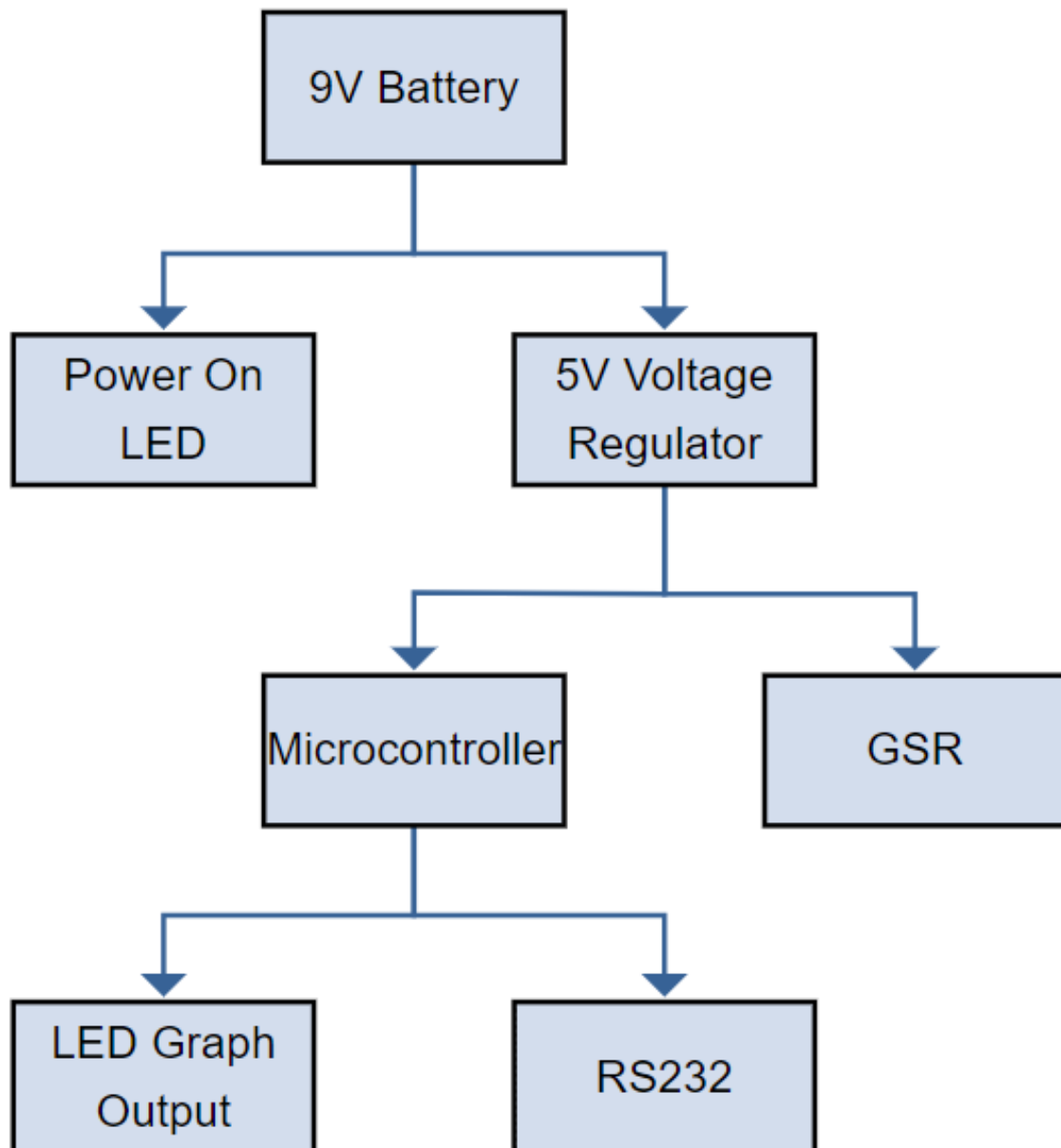


Figure 19 – System Block Diagram

## 7.2. Flowchart

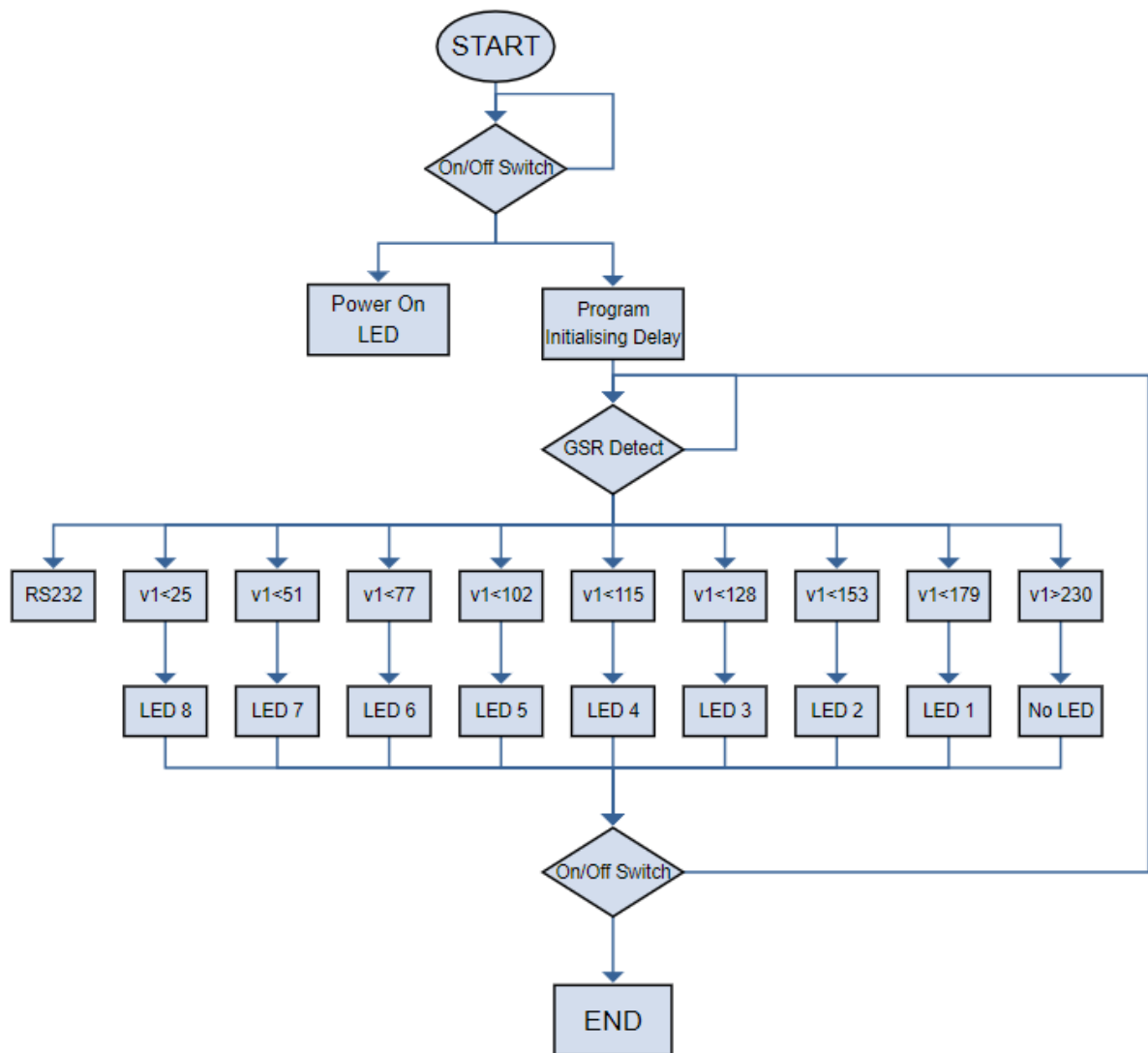


Figure 20 - System Flowchart

### 7.3. Schematic Design

#### 7.3.1. Initial Circuit Design

Skin resistance fluctuates between 50KΩ and 10MΩ so a 10MΩ is added to linearise the relationship between Z1 and Vout. The signal will need to be buffered after the voltage divider with an op amp. To accommodate non-linearities of op amps near the voltage rails its relevant to set the positive input to the op amp to the middle of the power supply input which is generated by R8, R9 and C3 using equation 8.

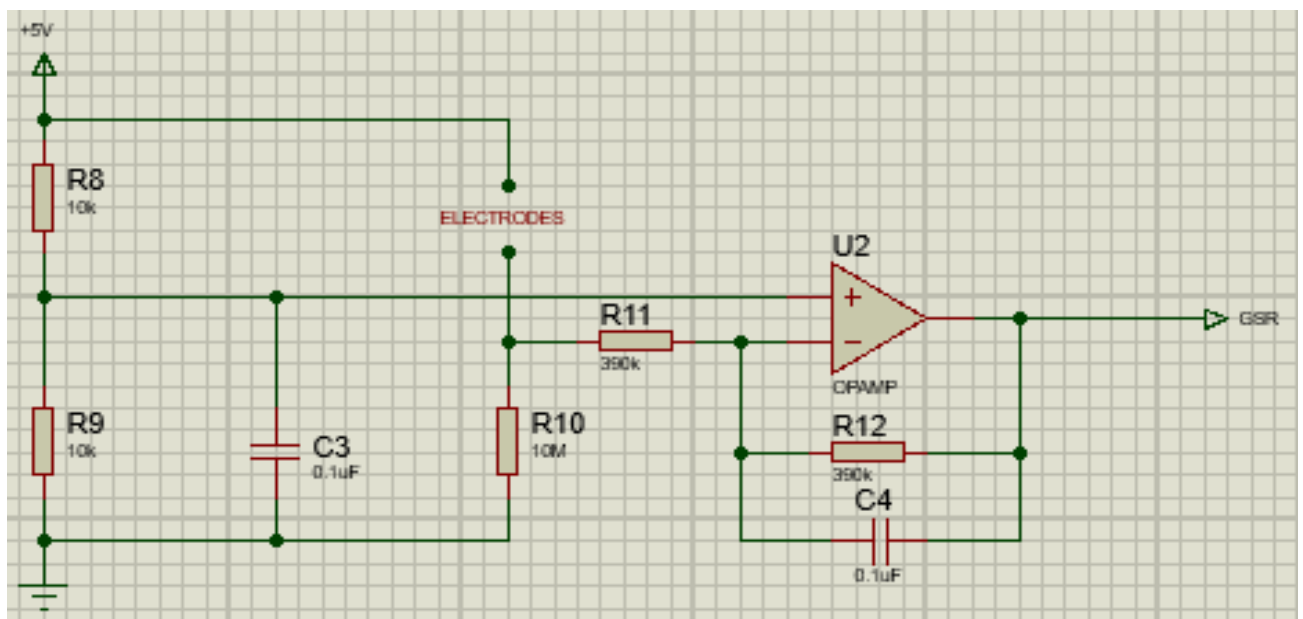


Figure 21 - GSR Circuit

$$\text{Voltage Divider} = V \times \frac{R1}{R1 + R2}$$

Equation 8 - Voltage Divider Equation

$$5 \times \frac{10000}{10000+10000} = 2.5V$$

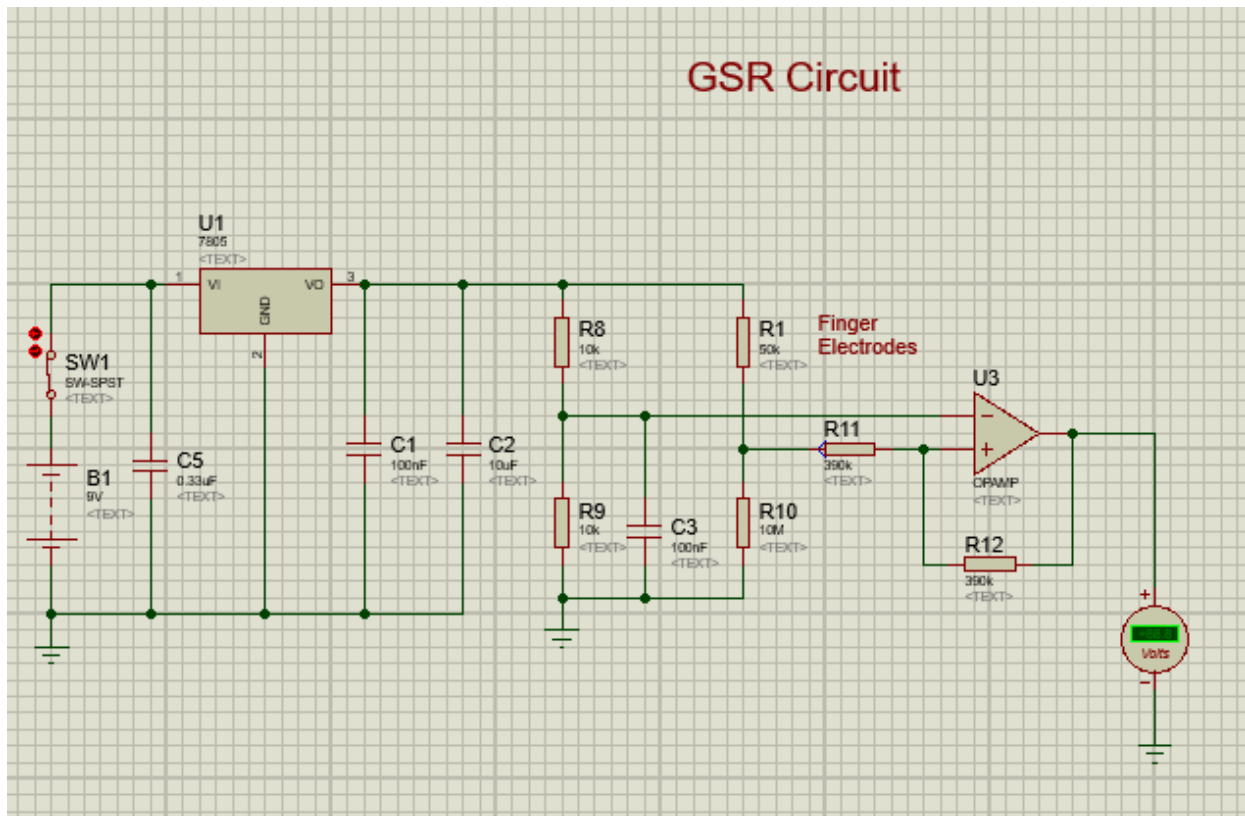


Figure 22 - Initial GSR Circuit Design

Skin resistance oscillates between 50K $\Omega$  and 10M $\Omega$ . The circuit has been tested to see what voltages were outputted from the circuit when using resistor values instead of actual skin resistances. This way it can be seen what gain will be needed for the amplifier circuit and if any other changes need to be made.

| Resistance ( $\Omega$ ) | Voltage (V) |
|-------------------------|-------------|
| 50K                     | 0.31        |
| 100K                    | 0.56        |
| 250K                    | 1.05        |
| 500K                    | 1.49        |
| 750K                    | 1.74        |
| 1M                      | 1.90        |
| 3.3M                    | 2.34        |
| 5M                      | 2.42        |
| 7M                      | 2.47        |
| 10M                     | 2.51        |

Table 4 - Initial GSR Circuit Voltages

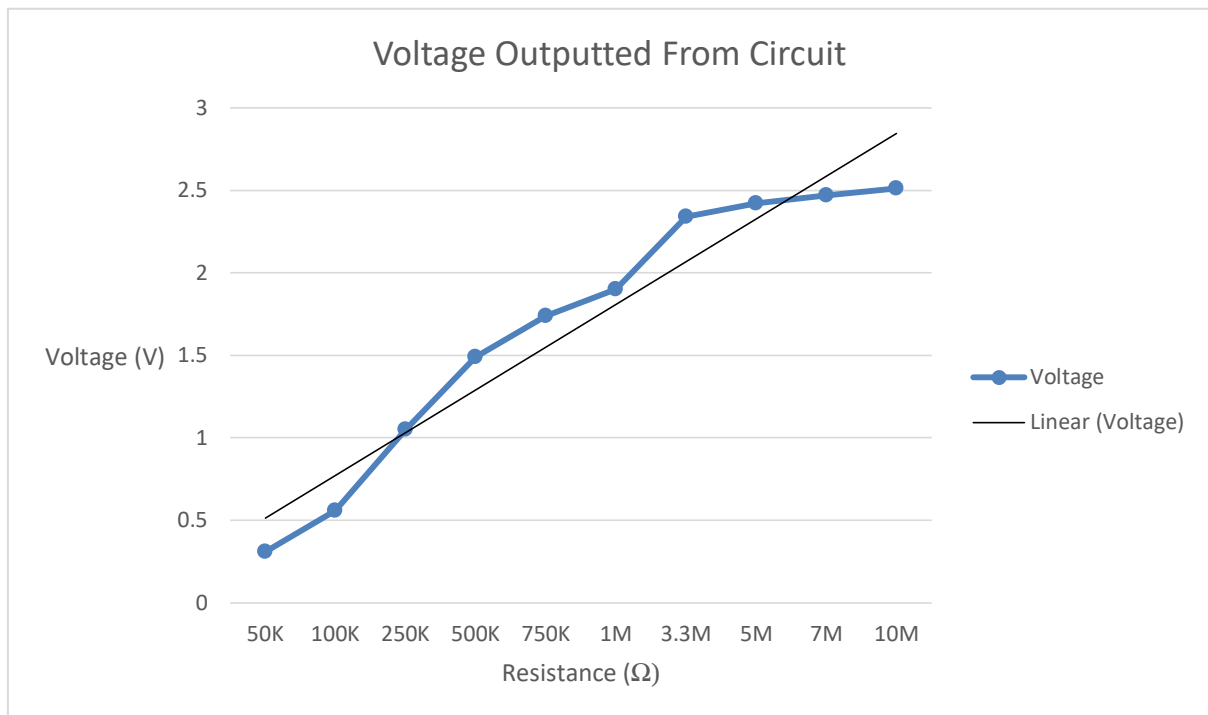


**Figure 23 - Initial GSR Circuit Voltages**

With the current design, there is only a possible range of around 2.5V. However, it would be ideal if this ranged up to 5V as a microcontroller can take up to 5V. Towards the higher values of resistance the voltage doesn't increase much. An extra operational amplifier can be added in a non-inverting configuration with the gain of 2 using equation 7. This will increase the voltage range of the circuit; this can be added in a later design. However, the next design should try to linearise the voltage range that is outputted.

### 7.3.2. Second Circuit Design

As you can see in the image below the circuit is the same but the resistors R11 and R12 have been increased to 1M $\Omega$  from 390k $\Omega$ .

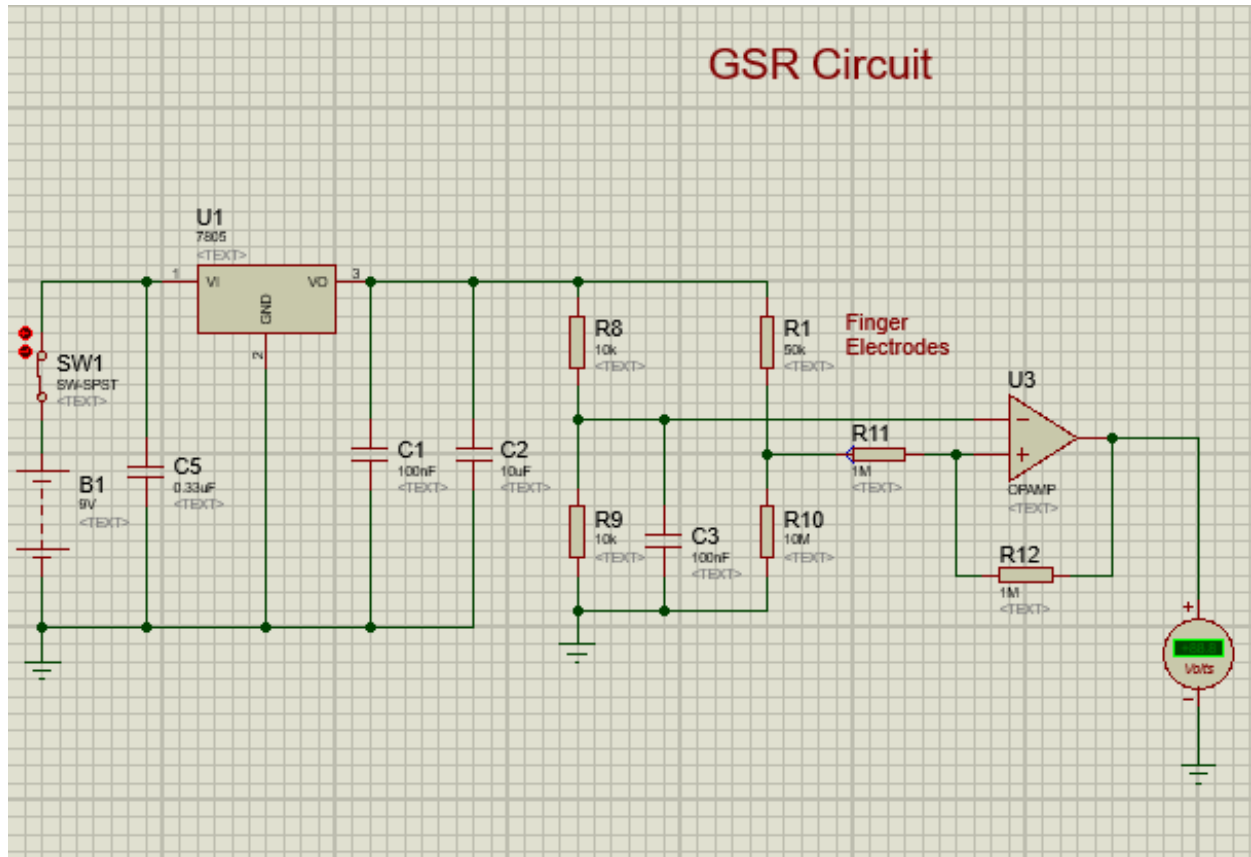


Figure 24 - Second GSR Circuit Design

Once again the circuit has been tested to see what voltages were outputted from the circuit when using resistor values instead of actual skin resistances and using 1M $\Omega$  for R11 and R12.

| Resistance ( $\Omega$ ) | Voltage (V) |
|-------------------------|-------------|
| 50K                     | 0.17        |
| 100K                    | 0.30        |
| 250K                    | 0.61        |
| 500K                    | 0.99        |
| 750K                    | 1.26        |
| 1M                      | 1.45        |
| 3.3M                    | 2.16        |
| 5M                      | 2.33        |
| 7M                      | 2.44        |
| 10M                     | 2.53        |

Table 5 - Second GSR Circuit Voltages

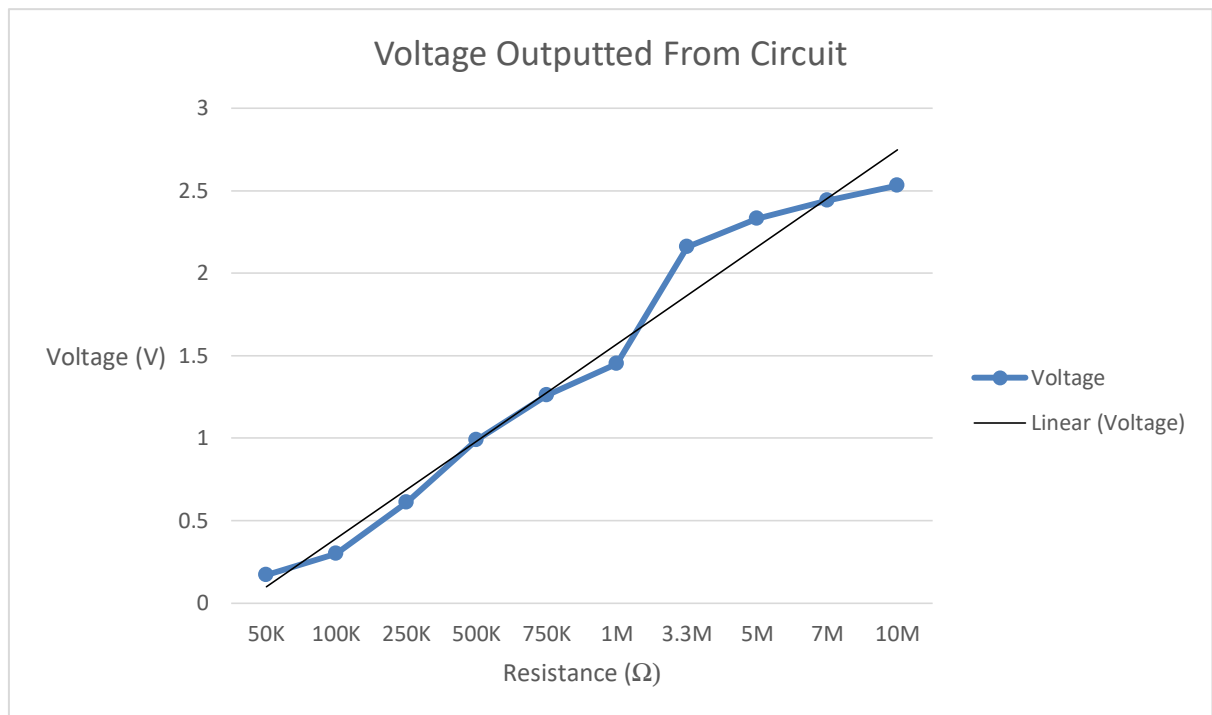


Figure 25 - Second GSR Circuit Voltages

This design definitely is more linear than the initial design. This will help later on when writing the program for the LED graph outputs. The next step now is to add the extra operational amplifier in a non-inverting configuration.

### 7.3.3 Third Circuit Design

As you can see in the image below the circuit now has an extra operational amplifier in a non-inverting configuration. The gain needed is two, so using equation 7 the gain is calculated:

$$Gain = 1 + \frac{1M\Omega}{1M\Omega} = 2$$

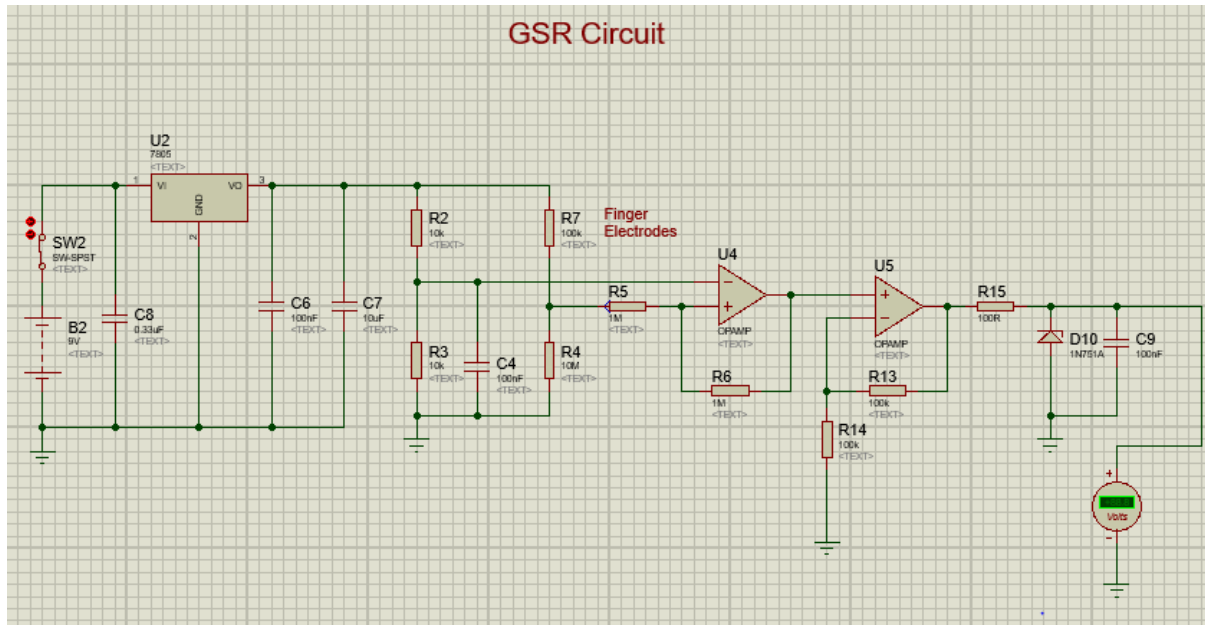


Figure 26 - Third GSR Circuit Design

The updated circuit has been tested to see what voltages were outputted from the circuit when adding the extra non-inverting amplifier to the circuit.

| Resistance (Ω) | Voltage (V) |
|----------------|-------------|
| 50K            | 0.33        |
| 100K           | 0.59        |
| 250K           | 1.23        |
| 500K           | 1.99        |
| 750K           | 2.52        |
| 1M             | 2.91        |
| 3.3M           | 4.33        |
| 5M             | 4.67        |
| 7M             | 4.88        |
| 10M            | 5.04        |

Table 6 - Third GSR Circuit Voltages

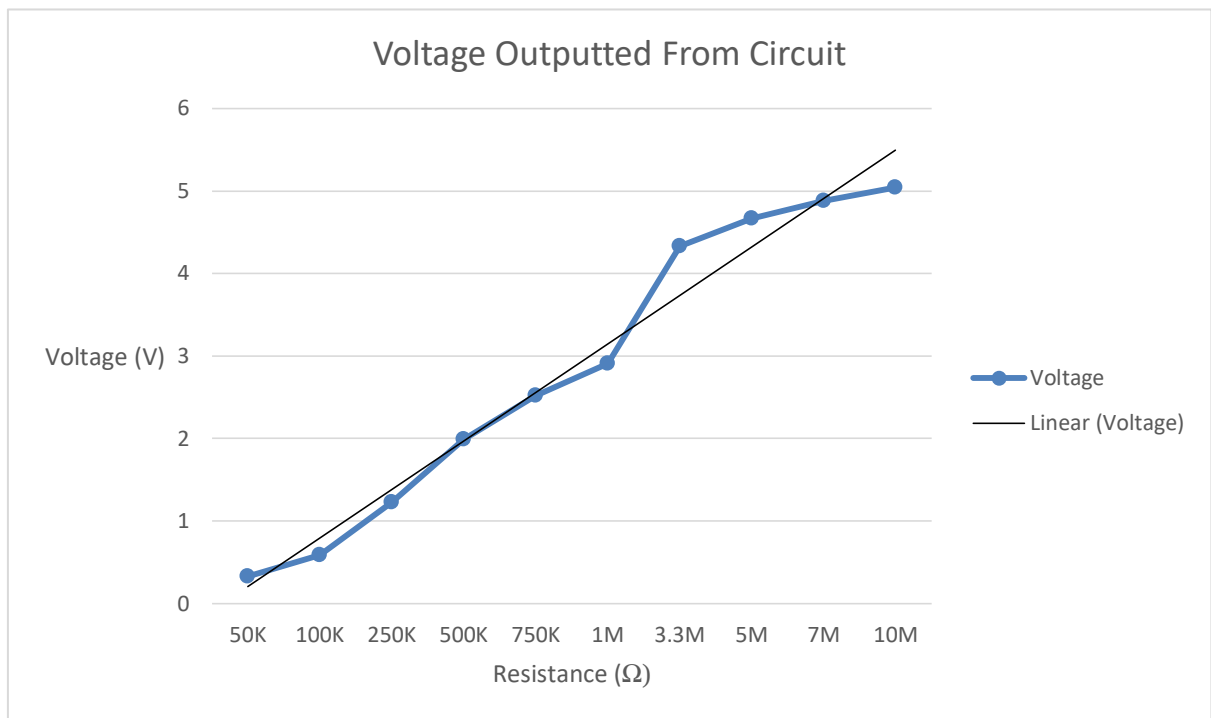


Figure 27 - Third GSR Circuit Voltages

This design now reaches the full 5V which was required with a fairly linear voltage response.

This circuit is the power for the system. A 9V battery supplies a power on LED and a voltage regulator that outputs 5V. A toggle On/Off switch is placed just after the battery. There is a 0.33uF capacitor added to the input of the voltage regulator, this capacitor cleans up the signal by shorting noise to ground. Another capacitor, 100nF, is added to the output of the

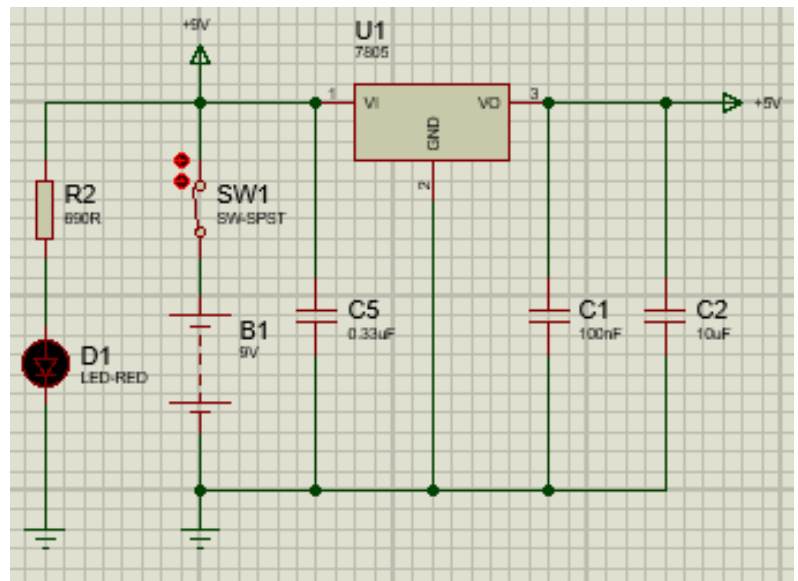


Figure 28 - System Power Distribution

voltage regulator as a filter to clean up high frequency noise. A final 10uF tank capacitor is added on the output of the voltage regulator that stores some voltage if power's lost.

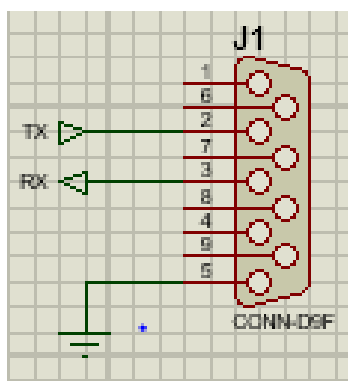


Figure 29 - RS232 Port

The RS232 is needed to be able connect to a computer. RS232 is a standard protocol for connecting to a computer which allows for serial data exchange. One pin needs to be used for transmitting data whilst another needs to be used for receiving data.

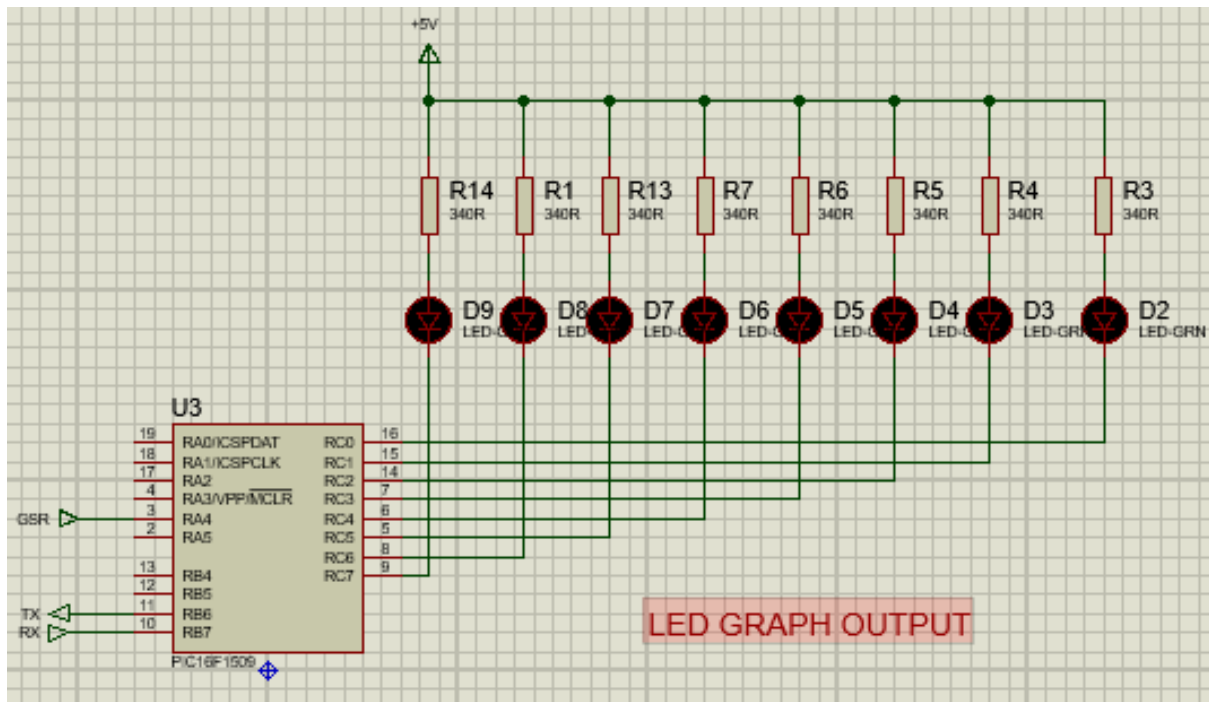


Figure 30 - Microcontroller

The PIC being used is a PIC16F1509. The PIC has an analogue signal coming in from the GSR circuit. The PIC also accommodates a RS232 port to connect to a computer to see signals as they happen for tests. The PIC also has LED outputs that makes up a LED graph, as stress rises then more LEDs will illuminate to give a visual representation of the stress. A capacitor of 0.1uF is added between VDD and VSS.

Using table 7 the voltage set points for when each LED should illuminate can be selected. There are 8 LEDs so there will need to be at least 8 set points for turning on each LED. To work this out for coding purposes 5V will need to be divided by 256 which equals 19.53mV. To work out the voltage set points for coding the following calculations are completed for each selected voltage set point.

| Resistance ( $\Omega$ ) | Voltage (V) |
|-------------------------|-------------|
| 50K                     | 0.33        |
| 100K                    | 0.59        |
| 250K                    | 1.23        |
| 500K                    | 1.99        |
| 750K                    | 2.52        |
| 1M                      | 2.91        |
| 3.3M                    | 4.33        |
| 5M                      | 4.67        |
| 7M                      | 4.88        |
| 10M                     | 5.04        |

Table 7 - Third GSR Circuit Voltages

For example, for a set point at 1V:

$$\frac{1}{19.53 \times 10^{-3}} = 51.2$$

- No LED on Set Point – 4.5V = 230
- Voltage Set Point 1 – 3.5V = 179
- Voltage Set Point 2 – 3V = 153
- Voltage Set Point 3 – 2.5V = 128
- Voltage Set Point 4 – 2.25V = 115
- Voltage Set Point 5 – 2V = 102
- Voltage Set Point 6 – 1.5V = 77
- Voltage Set Point 7 – 1V = 51
- Voltage Set Point 8 – 0.5V = 25

As the above shows, as skin resistance is increasing, skin conductance is decreasing which means a person is becoming more relaxed. So, as a person is becoming stressed the table above shows that voltage should decrease. After measuring a number of peoples skin resistances they seem to be more around the 100k $\Omega$  to 1M $\Omega$  mark so after this point there are bigger spacing between the LED set points.

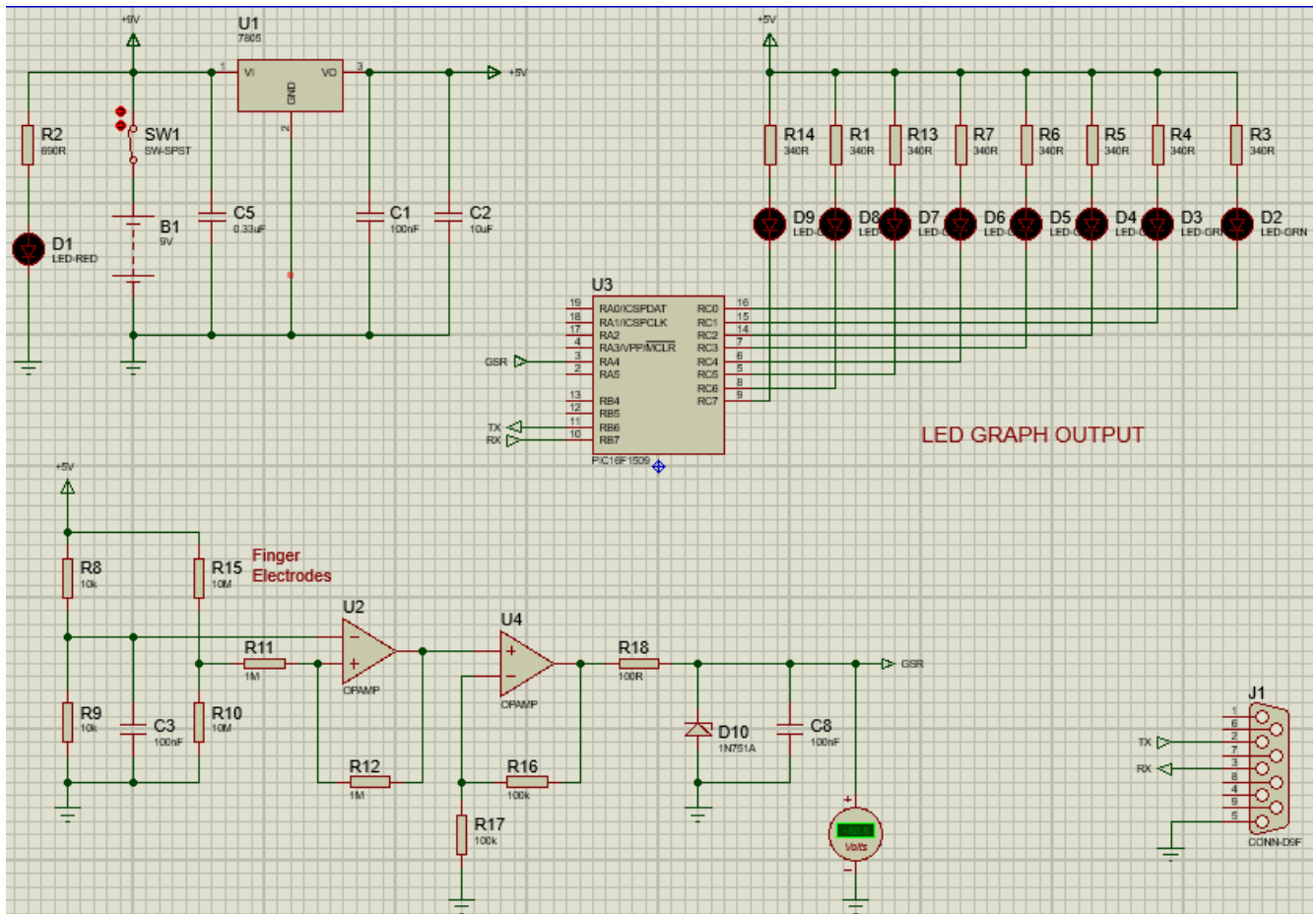


Figure 31 - Full Schematic

## 7.4. PCB Design

Below is the first design that will be built and tested. The schematic design was completed and simulated in Proteus, that design has now been transferred onto EasyPC so that the PCB can be designed.

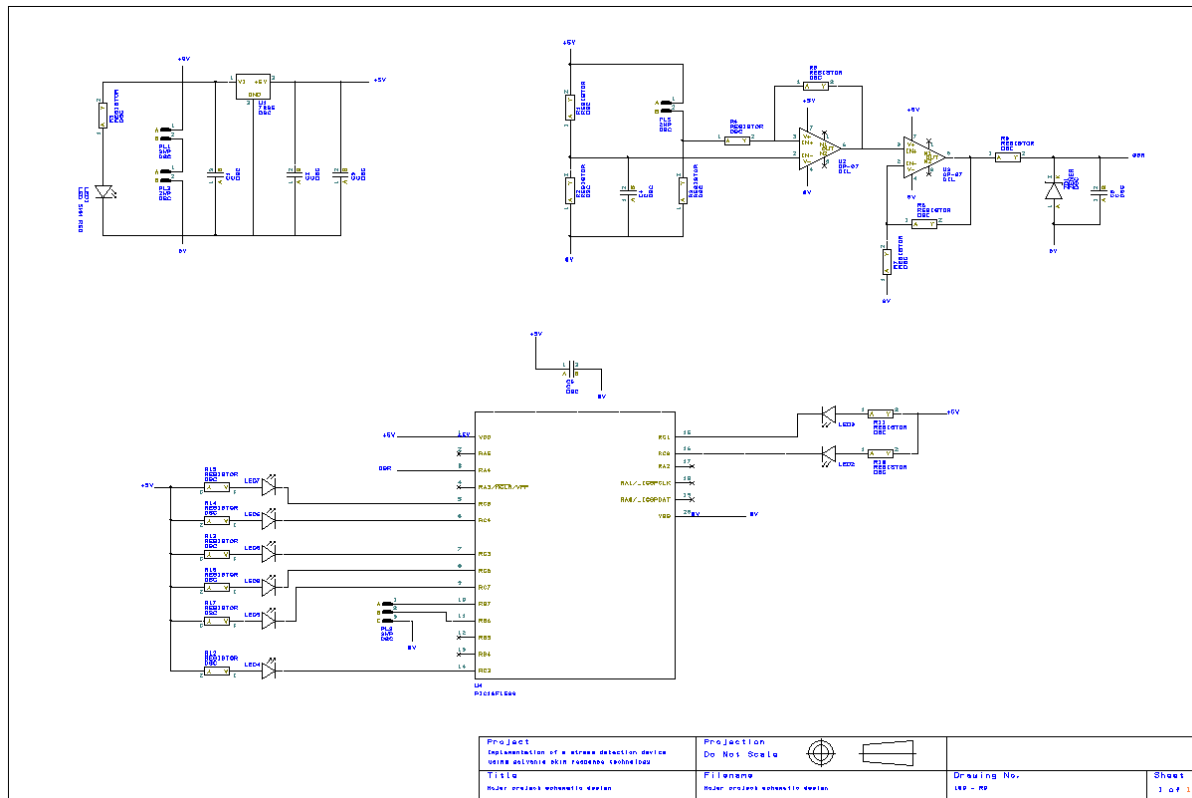


Figure 32 - EasyPC Schematic Design

Below shows the completed PCB design to the schematics drawn above. This image shows that the PCB design has no errors in the design so would therefore be suitable for manufacture.

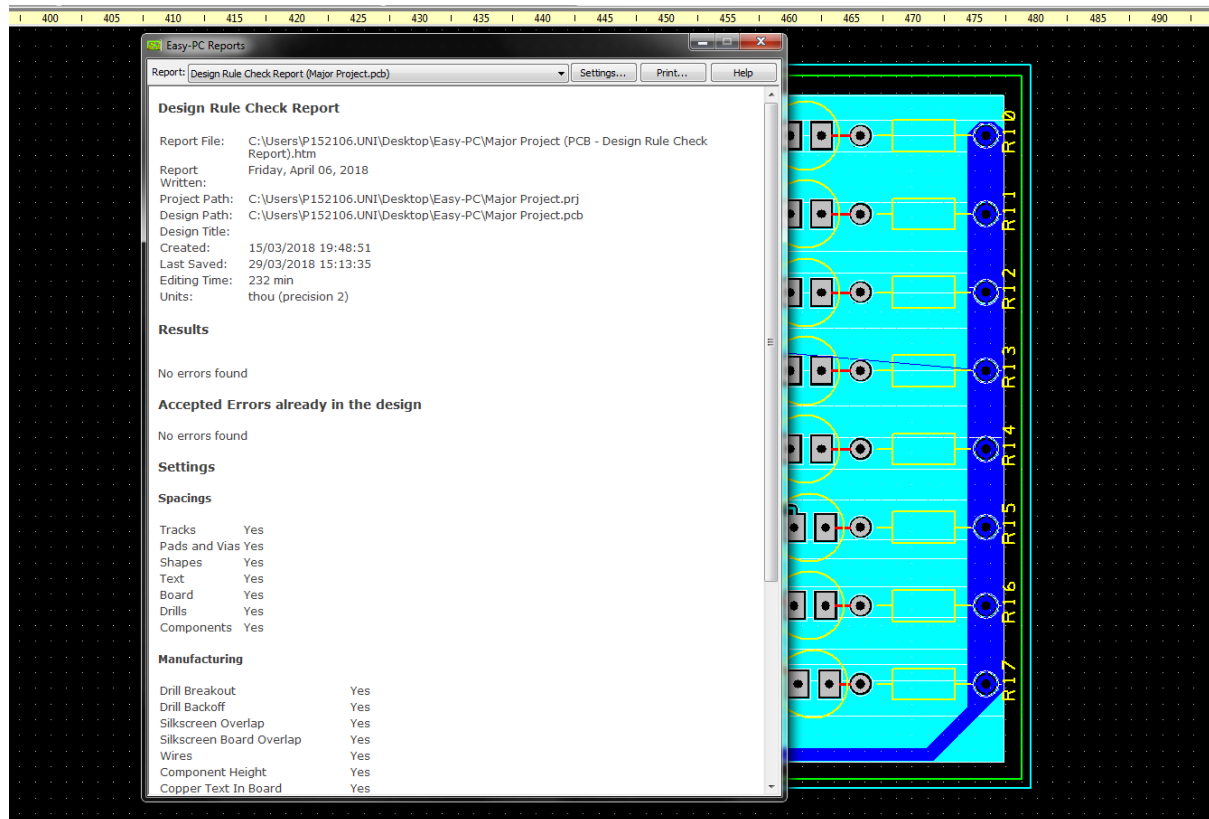


Figure 33 - No errors in PCB Design

In the image below only the top layer is showing, this layer also has the +5V copper pour on which is shown in blue.

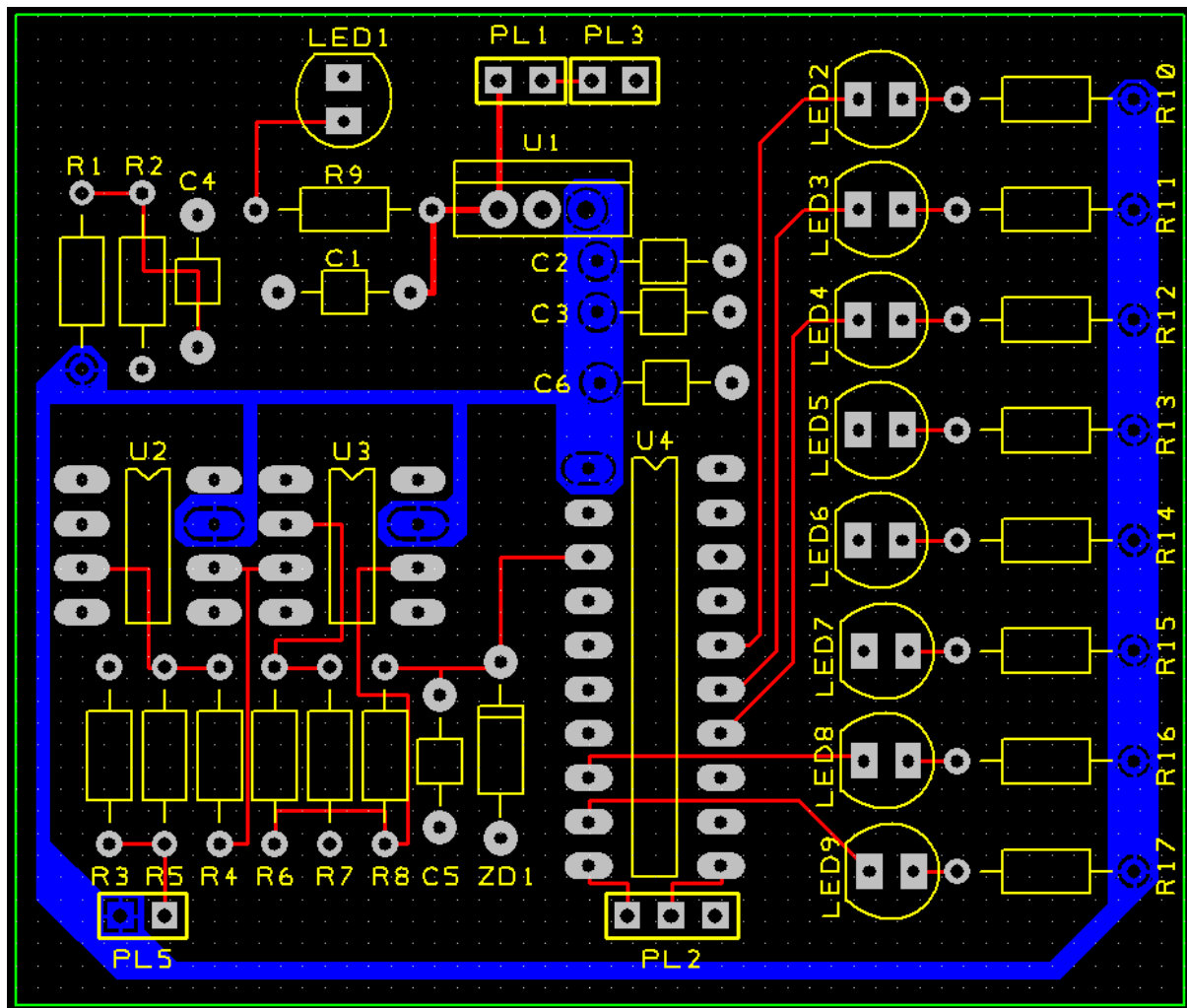


Figure 34 - PCB Top Layer View

In the image below only the bottom layer is showing, this layer also has few tracks. The only tracks on this layer are ones that would end up overlapping other tracks if they were on the top layer. This layer has the 0V copper pour on which covers the board, shown here in light blue.

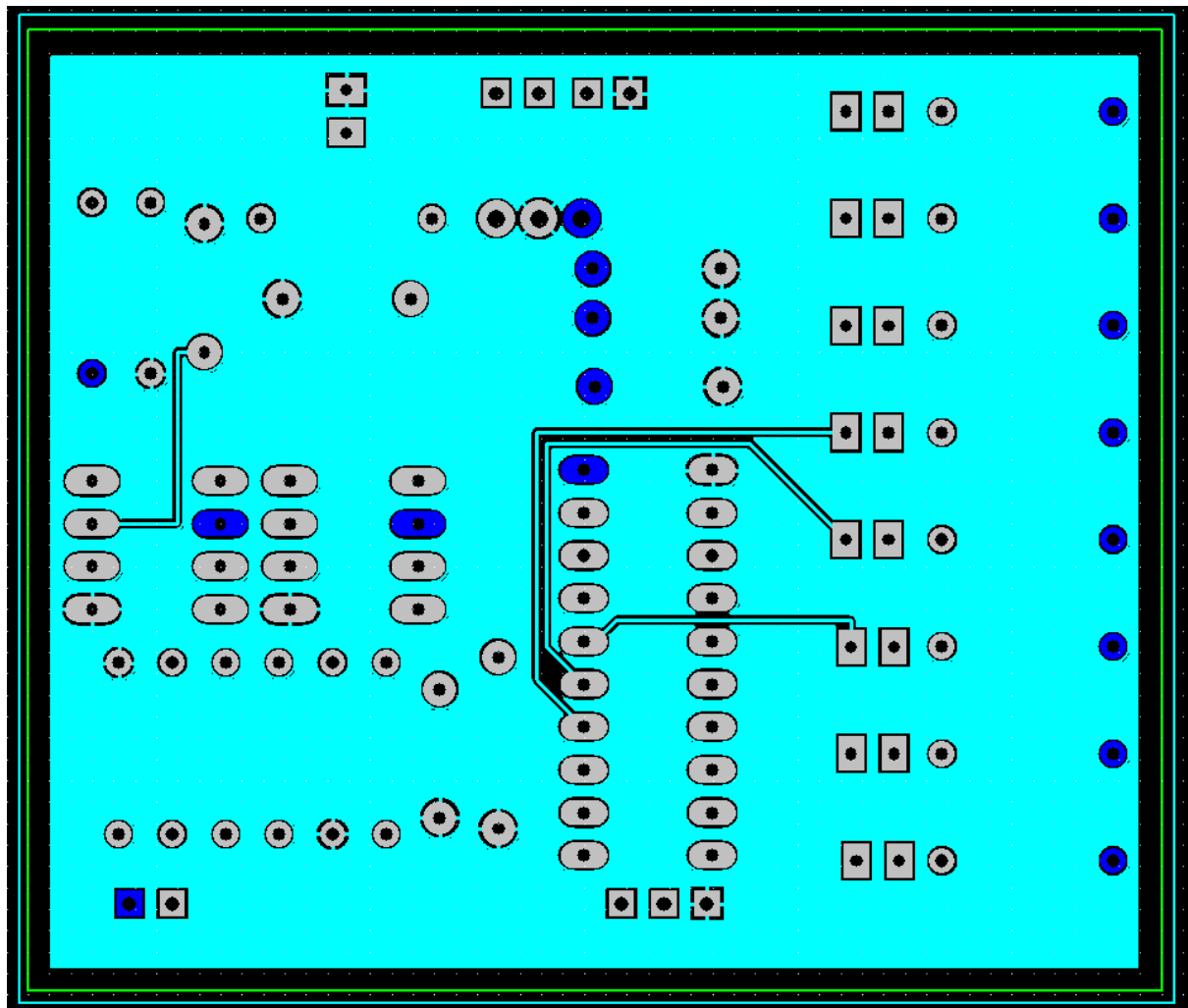


Figure 35 - PCB Bottom Layer View

In the image below both the bottom and the top layer are shown.

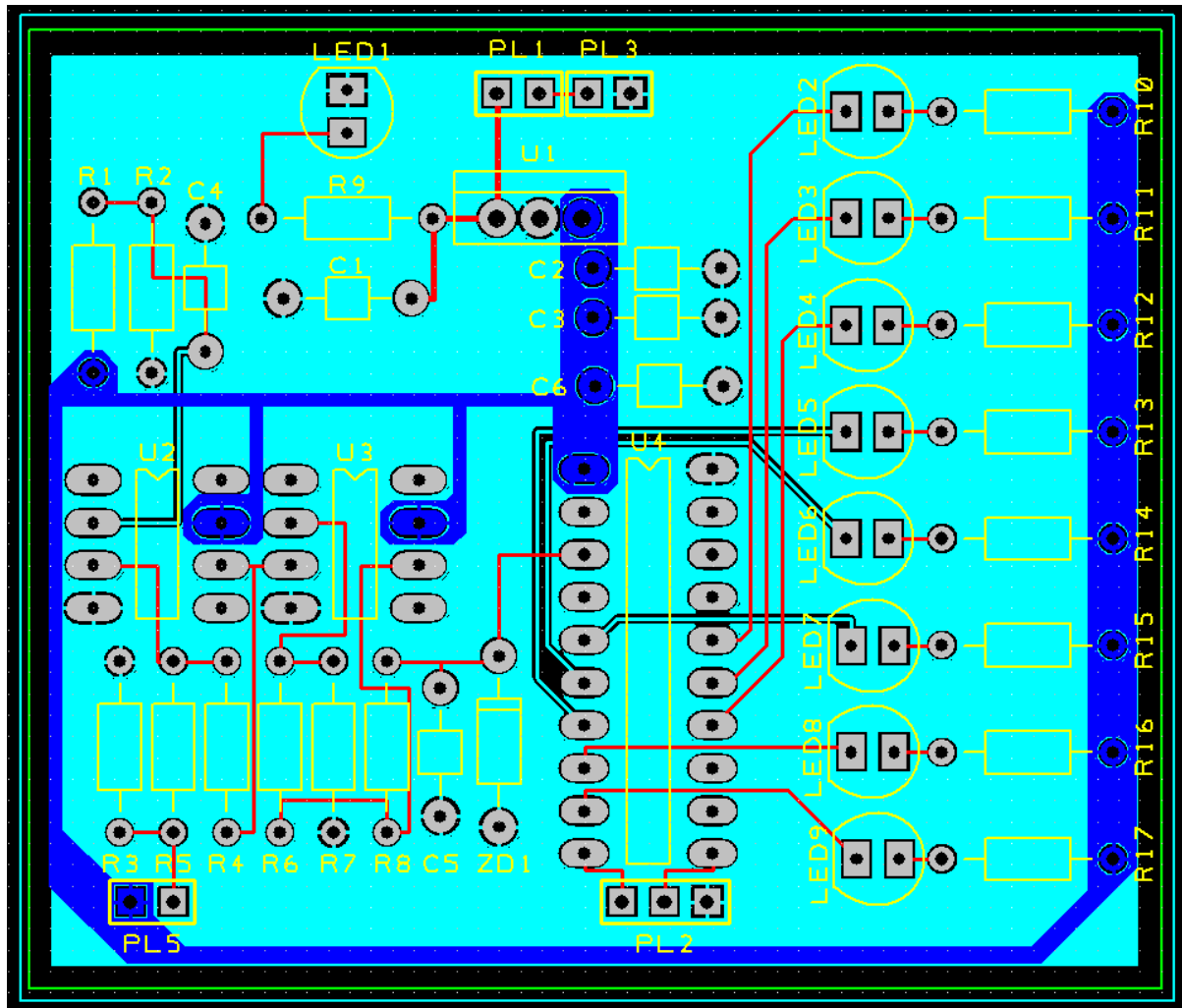


Figure 36 - PCB Composite View

The image below is a top layer view 3D representation of the PCB. Note that the PCB does not have any drill holes, this is because the PCB was intended to be mounted using sticky pads. All the connectors were kept to the outside of the PCB to avoid disrupting any of the components on the PCB. All components used are through hole mounted not surface mount.

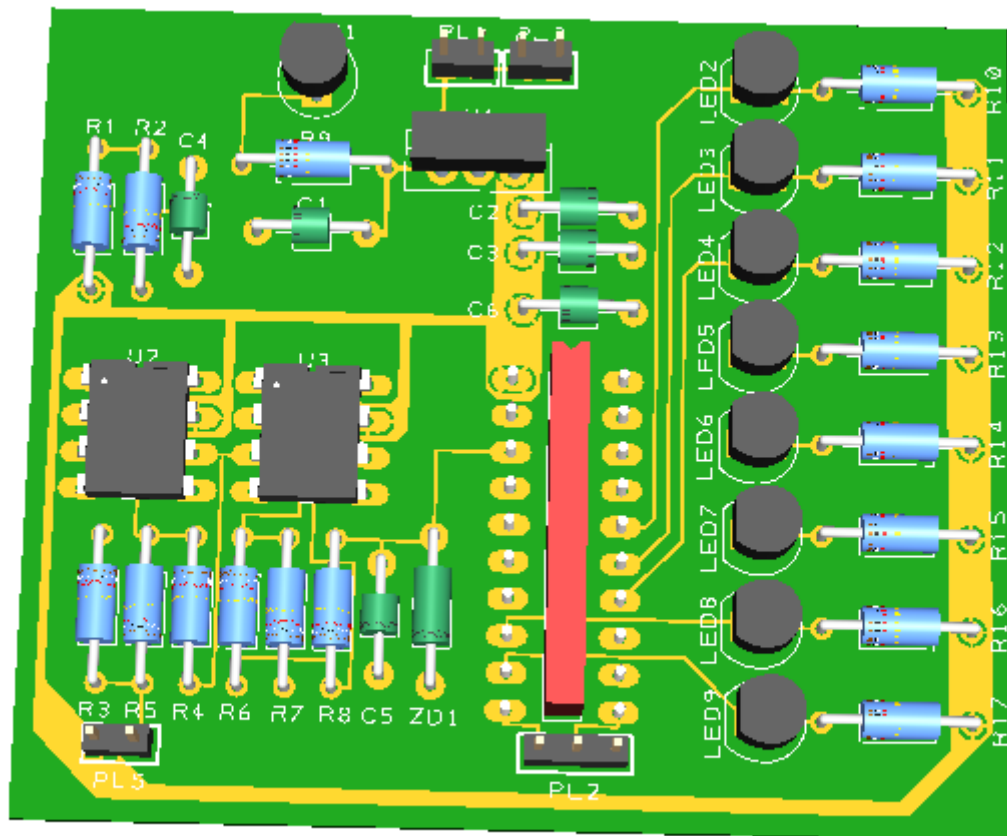


Figure 37 - PCB 3D Top Layer View

The image below is a bottom layer view 3D representation of the PCB.

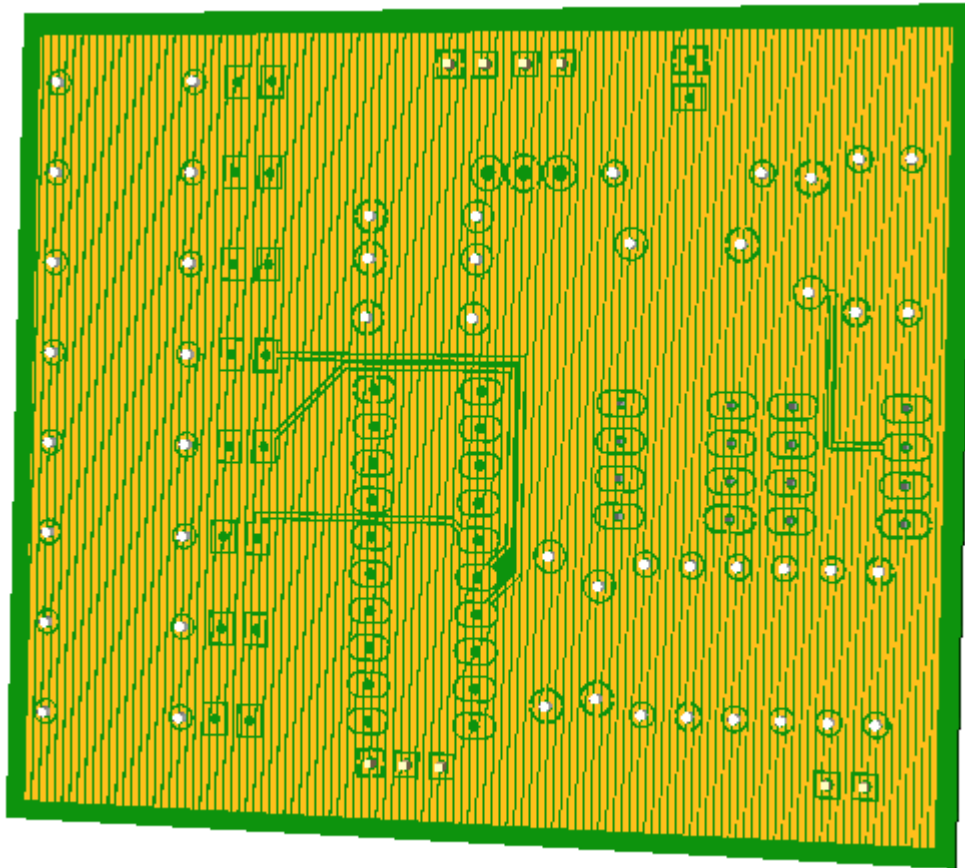


Figure 38 - PCB 3D Bottom Layer View

The PCB board size was 67.3 x 57 (mm). Euro circuits charge €48 for this size which equates to roughly £41.95.

| Price summary                         |                     |         |
|---------------------------------------|---------------------|---------|
| Service                               | PCB proto           |         |
| Delivery term                         | 7 working days      |         |
| Estimated shipment date               | 17-04-2018          |         |
| Quantity                              | 1 PCBs              |         |
| Board surface / Order surface         | 0.38 dm² / 0.38 dm² |         |
| Prices                                | Net                 | Gross*  |
| Single PCB                            | € 39.67             | € 48.00 |
| Total boards                          | € 39.67             | € 48.00 |
| Express transport                     | € 0.00              | € 0.00  |
| Total                                 | € 39.67             | € 48.00 |
| * The gross prices include 21.0% VAT. |                     |         |
| Proceed                               |                     |         |

Figure 39 - PCB Board Price [26]

## 7.5. Coding

```
#include <16F1509.h>
```

```
#device ADC=8
```

```
#FUSES PUT           //Power Up Timer
```

```
#FUSES NOMCLR        //Master Clear pin used for I/O
```

```
#FUSES NOPROTECT     //Code not protected from reading
```

```
#FUSES BROWNOUT      //Reset when brownout detected
```

```
#FUSES NOCLKOUT       //I/O function on OSC2
```

```
#FUSES IESO           //Internal External Switch Over mode enabled
```

```
#FUSES FCMEN          //Fail-safe clock monitor enabled
```

```
#FUSES NOWRT          //Program memory not write protected
```

```
#FUSES STVREN         //Stack full/underflow will cause reset
```

```
#FUSES BORV25         //Brownout reset at 2.5V
```

```
#FUSES NOLPBOR        //Low-Power Brownout reset is disabled
```

```
#FUSES NOLVP          //No low voltage prgming, B3(PIC16) or B5(PIC18) used for I/O
```

```
#use delay(internal=8MHz)
```

```
#define led1  PIN_C0
```

```
#define led2  PIN_C1
```

```
#define led3  PIN_C2
```

```
#define led4  PIN_C3
```

```
#define led5  PIN_C4
```

```
#define led6  PIN_C5
```

```
#use rs232(baud=9600,parity=N,xmit=PIN_B6,rcv=PIN_B7,bits=8,stream=PORT1)
```

```

#define LED_PIN_C5

#define DELAY 500

#include <main.h>

void main()
{
    unsigned int value=0,v1=0,skin_response=0;

    setup_adc_ports(sAN3);
    setup_adc(ADC_CLOCK_INTERNAL);

    while(TRUE)
    {

/*          //Example blinking LED program

        output_c(2);
        delay_ms(DELAY);
        output_c(63);
        delay_ms(DELAY);

        //TODO: User Code

*/

        set_adc_channel(3);

        delay_us(30);

        value = read_adc();

```

```

    v1=value;
skin_response=value;

    // v1++;

    if (v1>230)    {value=0;}

    if (v1<179)    {value=1;}

    if (v1<153)    {value=2;}

    if (v1<128)    {value=3;}

    if (v1<115)    {value=4;}

    if (v1<102)    {value=5;}

    if (v1<77)     {value=6;}

    if (v1<51)     {value=7;}

    if (v1<25)     {value=8;}


    switch(value)
    {
        case 0:    output_c(255);

                    break;

        case 1:    output_c(254);

                    break;

        case 2:    output_c(252);

                    break;

        case 3:    output_c(248);

                    break;

        case 4:    output_c(240);

                    break;
    }

```

```
        case 5:  output_c(224);
                break;

        case 6:  output_c(192);
                break;

        case 7:  output_c(128);
                break;

        case 8:  output_c(0);
                break;

    }

    printf("GSR Level %U\n\r",skin_response);

    delay_ms(10);

}

}
```

## 8. First Design Cost Analysis

The project as a whole is fairly inexpensive as all the components are readily available. This cost should be an accurate guide in the overall costs involved in the project.

| Component                                          | Quantity | Cost   | Total Cost | Supplier | Part Number        |
|----------------------------------------------------|----------|--------|------------|----------|--------------------|
| Breadboard                                         | 1        | £2.34  | £2.34      | Farnell  | PSG-BB-400         |
| Jump Wire Kit                                      | 1        | £6.84  | £6.84      | RS       | SKS-140            |
| Green LED (Power On)                               | 1        | £0.70  | £0.70      | RS       | L-53GD             |
| Red LED (LED Graph)                                | 8        | £0.46  | £3.68      | RS       | L-53HD             |
| On/Off Switch                                      | 1        | £1.19  | £1.19      | Farnell  | MCTA3-4R2-V        |
| Battery (9V)                                       | 1        | £3.49  | £3.49      | Maplin   | L46AL              |
| Op Amp, 8 Pin, 5V                                  | 2        | £0.34  | £0.68      | RS       | MCP6241-E/P        |
| 10MΩ Resistor                                      | 1        | £0.19  | £0.19      | Vishay   | VR37000001005JR500 |
| 1MΩ Resistor                                       | 2        | £0.02  | £0.04      | TE       | CFR100J1M0         |
| 10KΩ Resistor                                      | 3        | £0.06  | £0.06      | RS       | 707-7745           |
| 100KΩ Resistor                                     | 2        | £0.02  | £0.04      | TE       | CFR16J100K         |
| 340Ω Resistors                                     | 8        | £0.14  | £1.12      | TE       | YR1B340RCC         |
| 681Ω Resistor                                      | 1        | £0.47  | £0.47      | TE       | YR1B681RCC         |
| 1000Ω Resistor                                     | 1        | £0.035 | £0.035     | RS       | 707-8827           |
| 100nF Capacitor                                    | 3        | £0.93  | £0.93      | Nichicon | USR1H0R1MDD        |
| 10uF Capacitor                                     | 1        | £0.07  | £0.07      | Vishay   | 515D106M016JA6AE3  |
| Voltage Regulator                                  | 1        | £0.39  | £0.39      | Maplin   | L78S05CV           |
| Microcontroller                                    | 1        | £1.23  | £1.23      | RS       | PIC16F1509         |
| Electrodes<br>(Copper Strip, Cables<br>and Velcro) | 1        | £5     | £5         | -        | -                  |
| 9 Pin D Type<br>Connector                          | 1        | £12.58 | £12.58     | FCT      | FC09P0G1           |
| 2 Way PCB Mount<br>Terminal Block                  | 4        | £0.43  | £1.72      | RS       | 790-1098           |
| 3 Way PCB Mount<br>Terminal Block                  | 1        | £1.90  | £1.90      | TE       | 282834-3           |

Table 7 - Cost Analysis

The total for this bill of materials is £44.24.

## 9. First Design Simulations & Analysis

### 9.1. Voltage Regulator Output Measurement

Here a steady 9V power supply was applied to the input of a 5V voltage regulator. In increments, the voltage was dropped to see when the power supply would drop below outputting 5V and also when it would completely drop out. The output voltage dropped below 5V when the input voltage was below 6.5V. The voltage dropped out completely when the input voltage hit around 1V.

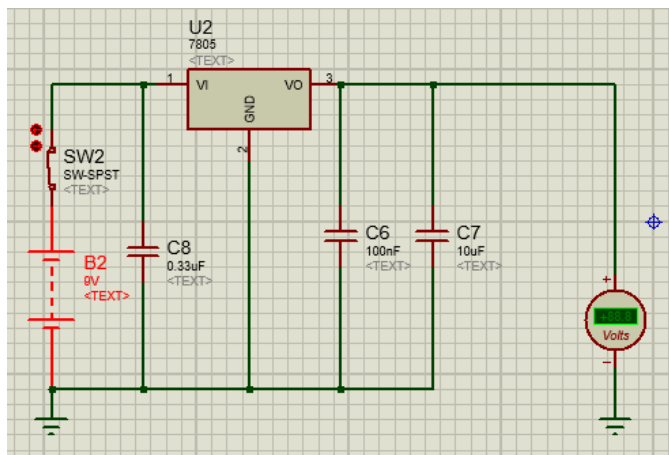


Figure 40 - Voltage Regulator Circuit

| Power Supply (V) | 5V Voltage Regulator (V) |
|------------------|--------------------------|
| 9.0              | 5.00                     |
| 8.5              | 5.00                     |
| 8.0              | 5.00                     |
| 7.5              | 5.00                     |
| 7.0              | 5.00                     |
| 6.5              | 5.00                     |
| 6.0              | 4.81                     |
| 5.5              | 4.32                     |
| 5.0              | 3.82                     |
| 4.5              | 3.32                     |
| 4.0              | 2.83                     |
| 3.5              | 2.33                     |
| 3.0              | 1.84                     |
| 2.5              | 1.35                     |
| 2.0              | 0.86                     |
| 1.5              | 0.37                     |
| 1.25             | 0.14                     |
| 1.0              | 0                        |
| 0                | 0                        |

Table 8 - Voltage Regulator Output

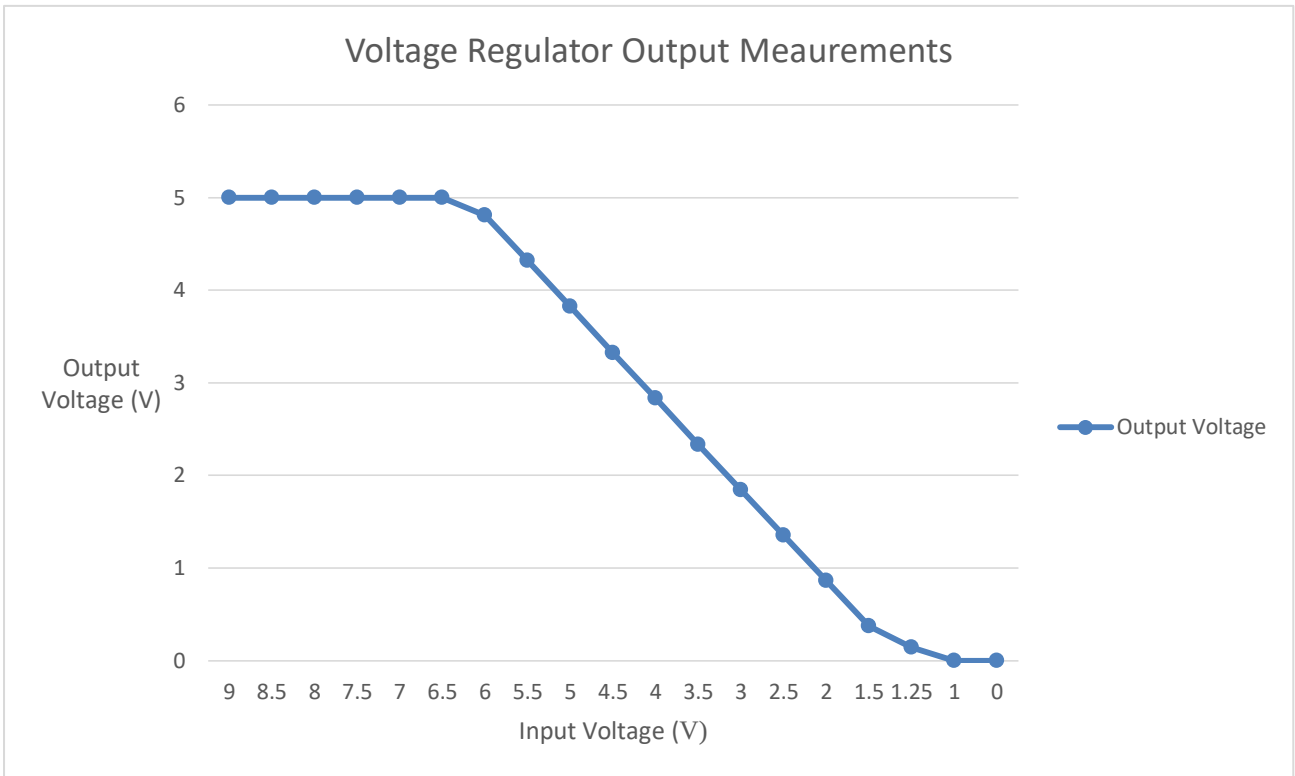


Figure 41 - Voltage Regulator Output Measurement Graph

## 9.2. Full Schematic Simulation

The system is simulated on Proteus to check that the system LED graph outputs are working correctly.

In this image the voltage being outputted by the circuit is 4.52V. As this is above the voltage 3.5V value for the first LED voltage set point, no LED should be illuminated as shown.

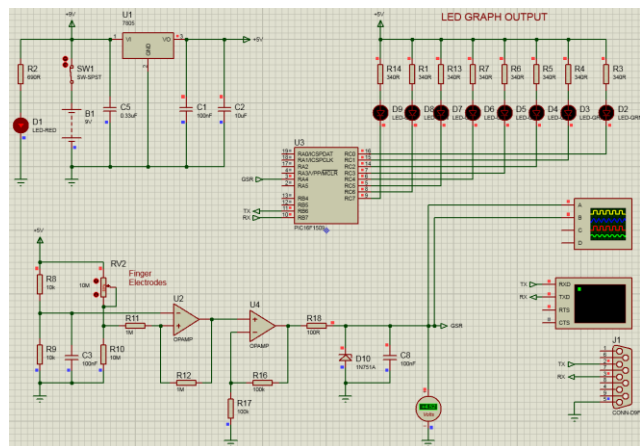


Figure 42 - LED Graph Simulation (No LEDs)

In this image the voltage being outputted by the circuit is 3.45V. As this is below the voltage value for the first LED voltage set point but above the 3V value set point for the second LED, only the first LED should be illuminated as shown.

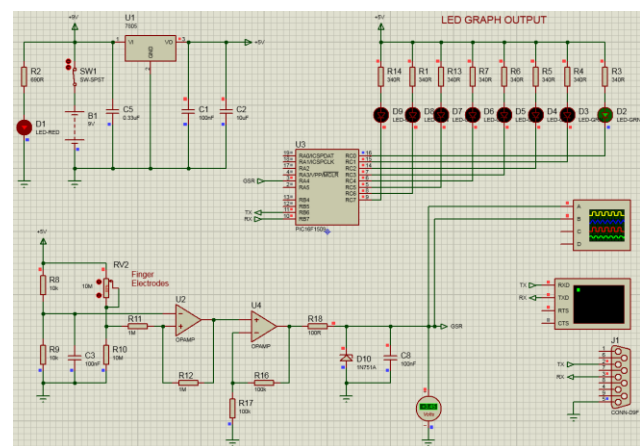


Figure 43 - LED Graph Simulation (1 LED)

In this image the voltage being outputted by the circuit is 2.91V. As this is below the voltage value for the second LED voltage set point but above the 2.5V value set point for the third LED, the first two LEDs should be illuminated as shown.

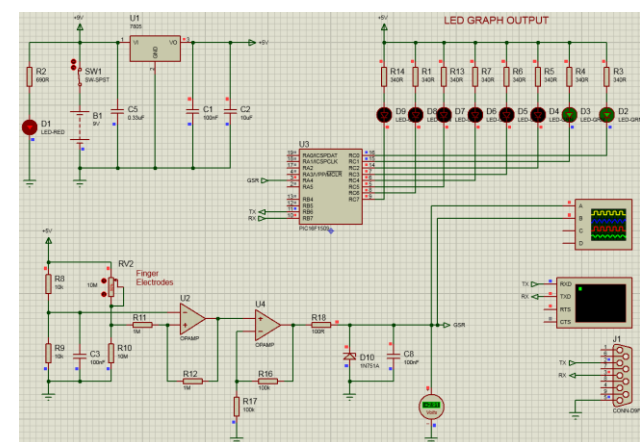


Figure 44 - LED Graph Simulation (2 LEDs)

In this image the voltage being outputted by the circuit is 2.42V. As this is below the voltage value for the third LED voltage set point but above the 2.25V value set point for the fourth LED, the first three LEDs should be illuminated as shown.

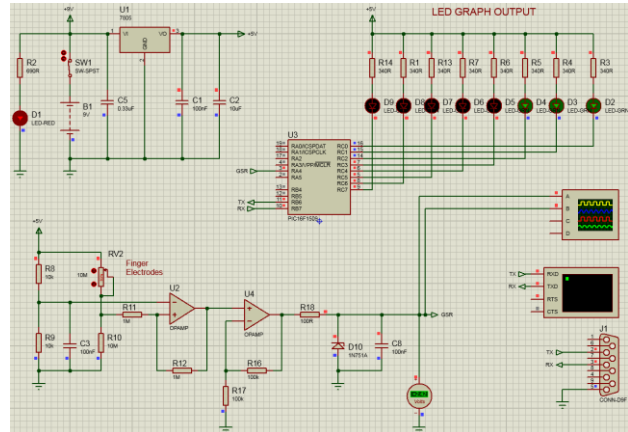


Figure 45 - LED Graph Simulation (3 LEDs)

In this image the voltage being outputted by the circuit is 2.22V. As this is below the voltage value for the fourth LED voltage set point but above the 2V value set point for the fifth LED, the first four LEDs should be illuminated as shown.

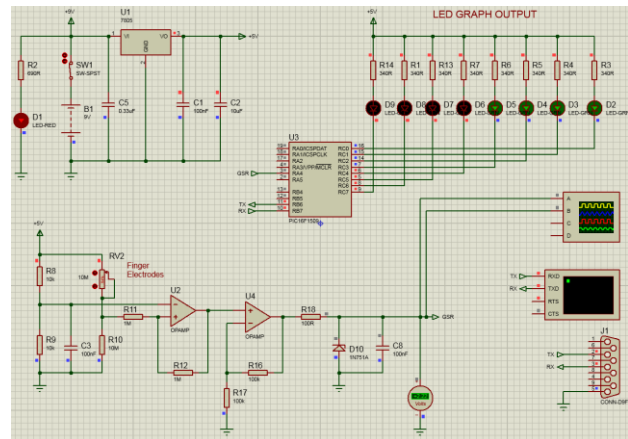


Figure 46 - LED Graph Simulation (4 LEDs)

In this image the voltage being outputted by the circuit is 1.99V. As this is below the voltage value for the fifth LED voltage set point but above the 1.5V value set point for the sixth LED, the first five LEDs should be illuminated as shown.

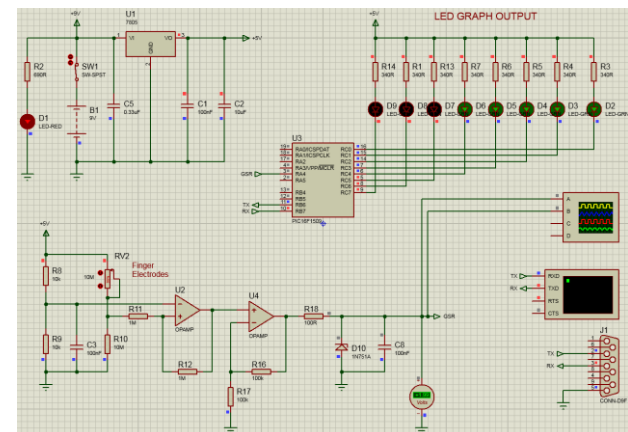


Figure 47 - LED Graph Simulation (5 LEDs)

In this image the voltage being outputted by the circuit is 1.4V. As this is below the voltage value for the sixth LED voltage set point but above the 1.0V value set point for the seventh LED, the first six LEDs should be illuminated as shown.

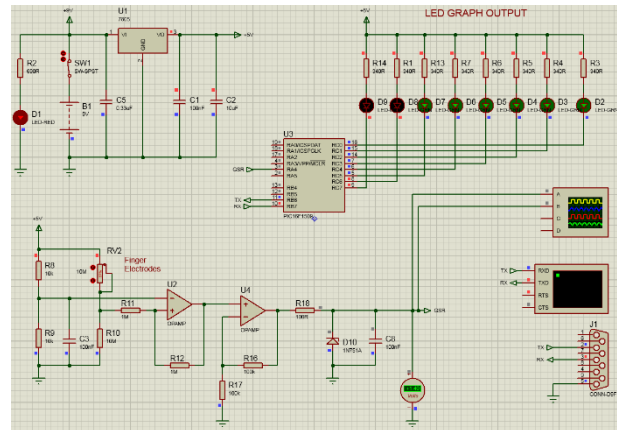


Figure 48 - LED Graph Simulation (6 LEDs)

In this image the voltage being outputted by the circuit is 0.59V. As this is below the voltage value for the seventh LED voltage set point but above the 0.5V value set point for the eighth LED, the first seven LEDs should be illuminated as shown.

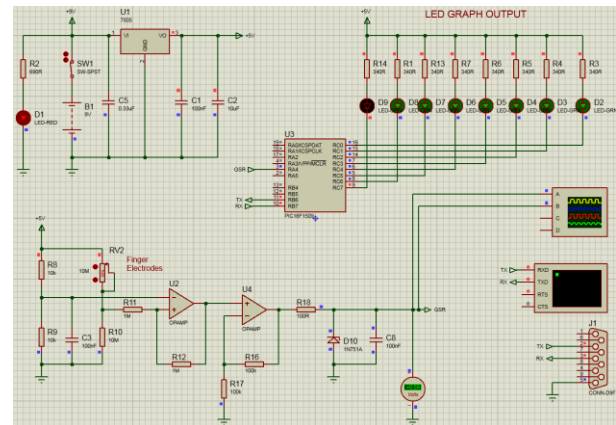


Figure 49 - LED Graph Simulation (7 LEDs)

In this image the voltage being outputted by the circuit is 0.05V. As this is below the voltage value set point for all eight LEDs then all eight LEDs should be illuminated as shown.

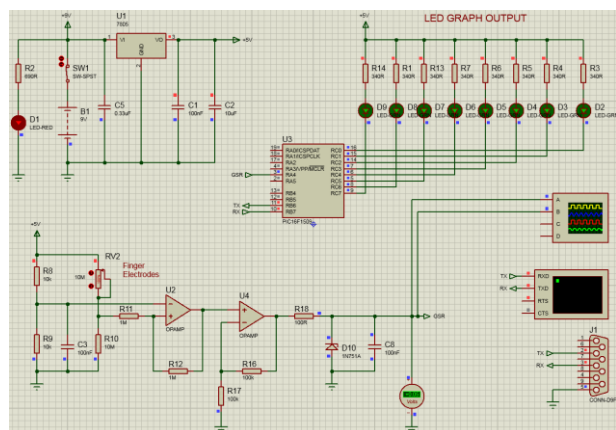


Figure 50 - LED Graph Simulation (All 8 LEDs)

## 10. First Design Build

### 10.1. Finger Electrodes

It was found in the research that the best material to use as finger electrodes for this project would be copper. Firstly, a small tri-rated cable was stuck onto a sticky back copper strip. The cores of the cables were spread out to improve the connection. The copper strip is then stuck to some Velcro so it can be strapped around a person's fingers.



Figure 51 - Build of Finger Electrodes

## 10.2. Circuits

The circuits were built to the schematics designed.

A breadboard was used to build these circuits.

Firstly, the power circuit for the project was built. A multimeter was used to check the correct voltages were being outputted from the circuit.



Figure 52 - Build of Power Circuit

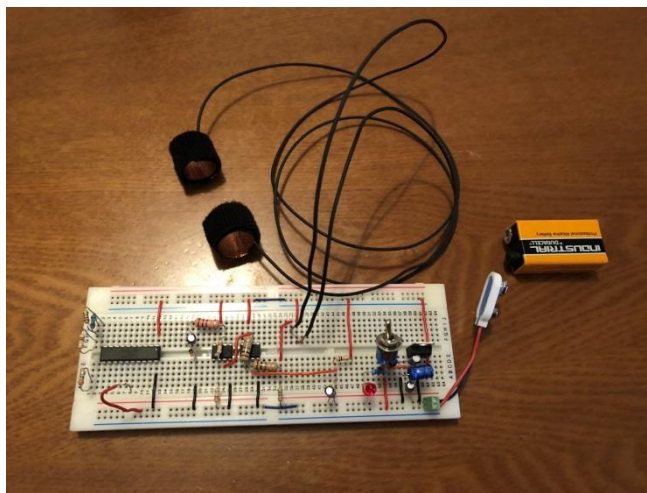


Figure 53 - Build of GSR Circuit to Design 3

Next, the GSR circuit that was built to design 3 was added onto the breadboard. The finger electrodes were incorporated into the circuit here. Testing of the circuits was the next step.

## 11. Testing & Analysis of First Design

### 11.1. Testing of GSR Circuit

The image below shows the power and GSR circuit built to the schematic design. However, when doing physical testing the circuit did not act as expected in the simulations. The table here shows the voltages that the GSR circuit was outputting after using discrete resistor values for skin resistance. The changes in the voltage over a large span of resistance is very small in some areas. The design will need to be modified to fix this problem.

| Resistance ( $\Omega$ ) | Voltage (V) |
|-------------------------|-------------|
| 100K                    | 2.26        |
| 270K                    | 2.29        |
| 470K                    | 2.34        |
| 560K                    | 2.36        |
| 750K                    | 2.42        |
| 870K                    | 2.45        |
| 1M                      | 2.53        |
| 2.2M                    | 3.62        |
| 3.3M                    | 4.1         |
| 4.7M                    | 4.21        |
| 10M                     | 4.26        |

Table 9 - Physically Testing GSR Circuit

As shown on the graph below the actual voltage output from the circuit is completely different to what is happening when simulating on Proteus.

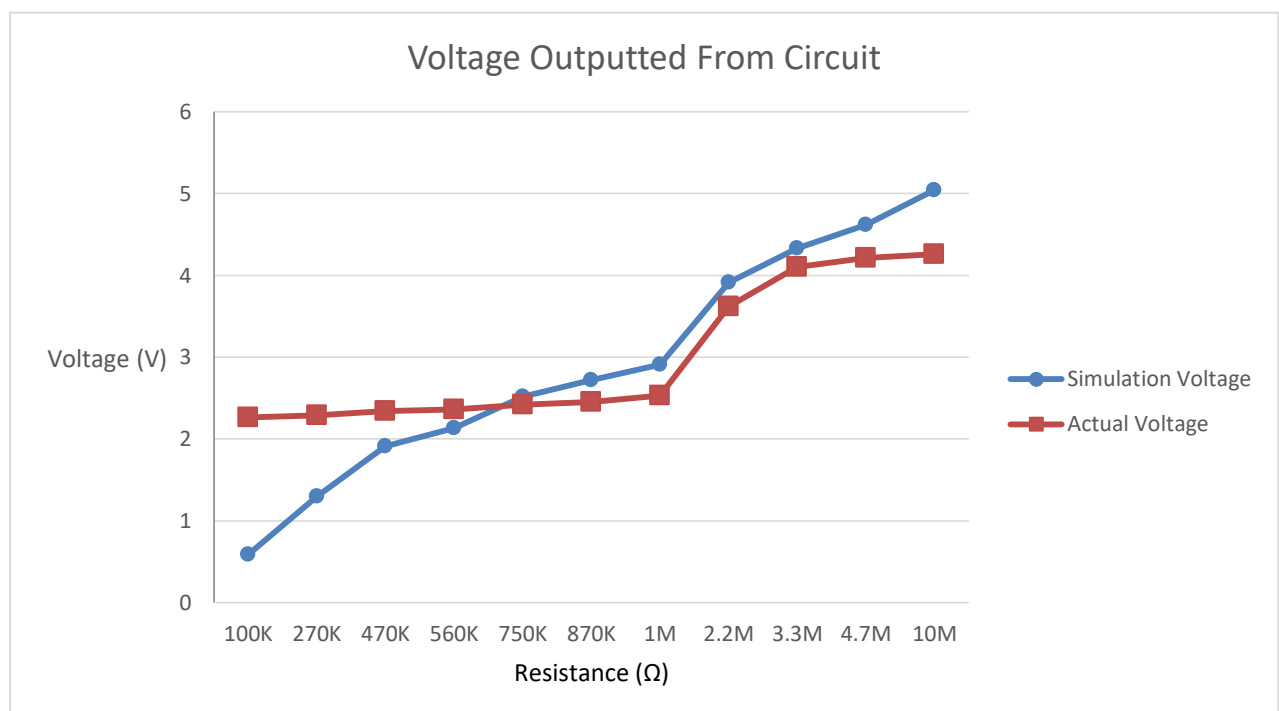


Figure 54 - Physically Testing GSR Circuit

## 12. Testing & Analysis of Second Design

### 12.1. Block Diagram

The system block diagram will be the same on this design as on the first design.

### 12.2. Flowchart

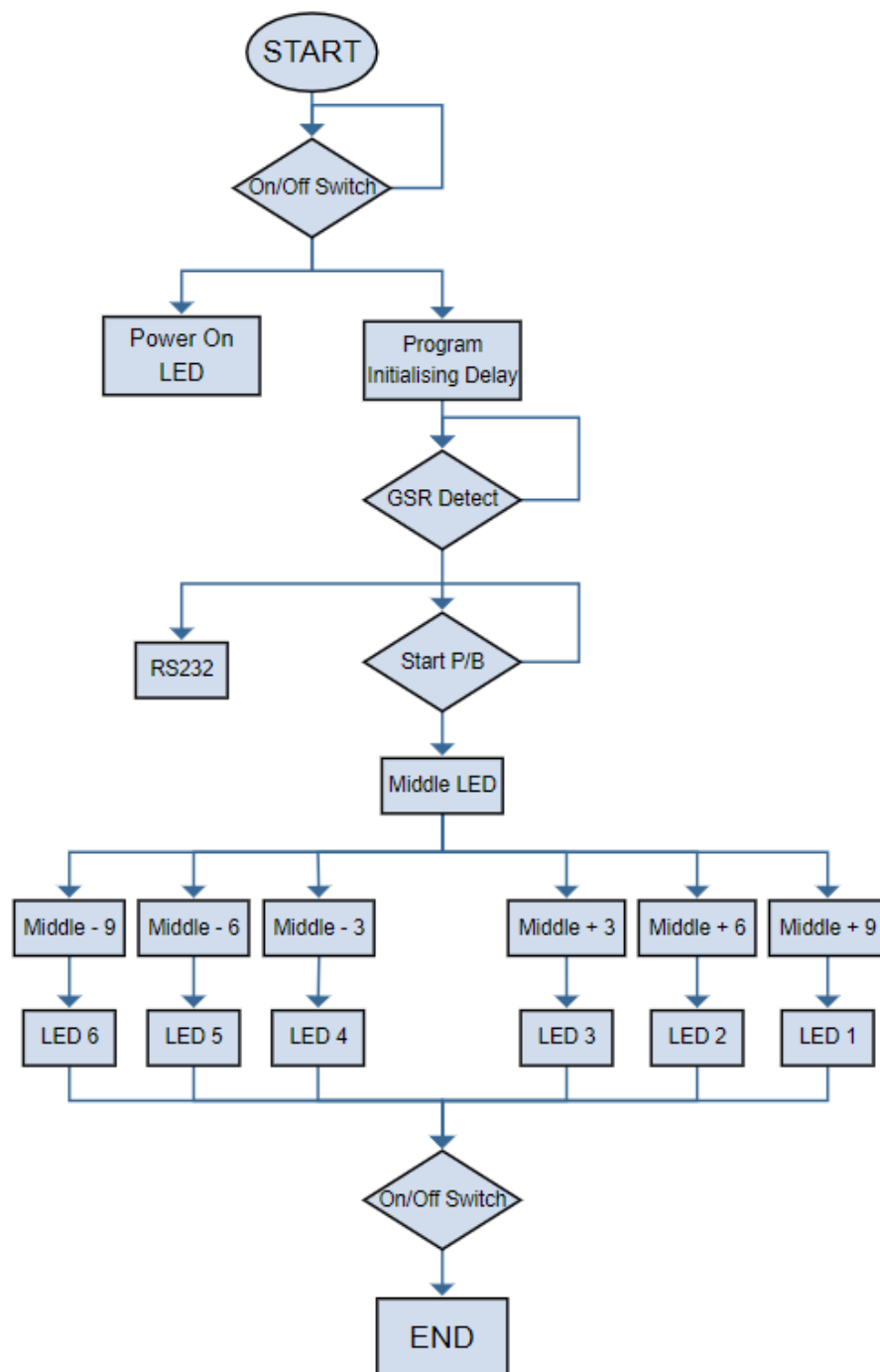


Figure 55 - System Flowchart

## 12.3. Schematic Design

### 12.3.1. Power Circuit Design

The new power circuit design is exactly the same as the previous although it now has a second 9V battery for the supply to the operational amplifier. It is now able to give a +9V and -9V supply to the operational amplifier.

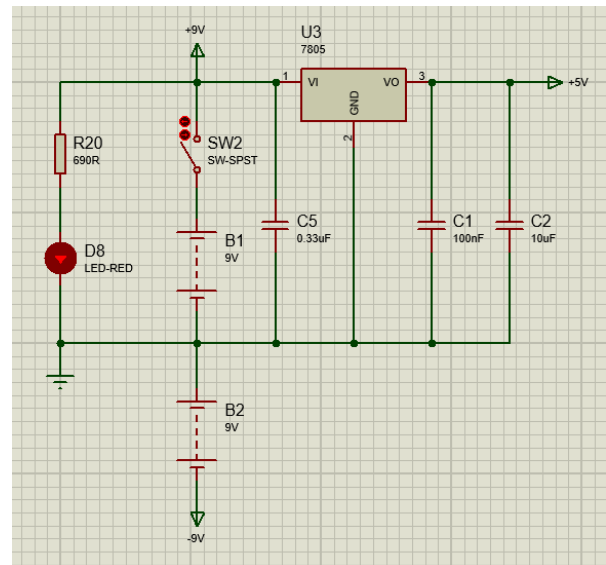


Figure 56 - Power Circuit Design

### 12.3.2. GSR Circuit Design

The GSR circuit now has a small potentiometer at the start to tune the fixed voltage when building the project as the op amp that will be used won't be exactly like the one on this schematic as it is an ideal op amp. The other leg of the op amp is tied to ground. The skin resistance acts as the feedback resistor to alter the gain of the circuit. Here the skin

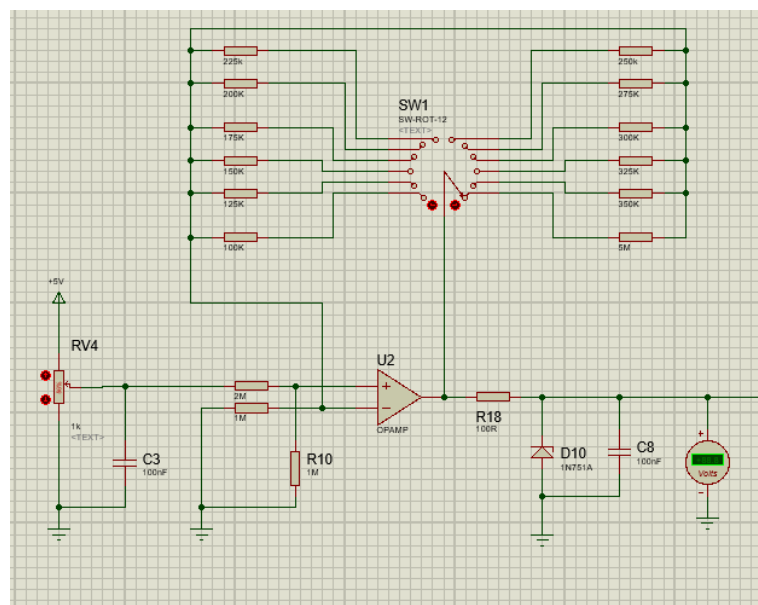


Figure 57 - GSR Circuit Design

resistance is a switch that is

switching between different resistors

to make it easy for simulation for testing purposes. The output has a 5V clamp to protect the microcontroller.

### 12.3.3. Microcontroller Circuit Design

The microcontroller has been changed now to 28 pin controller because when searching for a suitable microcontroller that now needed to have a 12 bit A/D resolution there were no suitable controllers that were 20 pin. By using a 12 bit A/D resolution microcontroller it will have a range from 0 – 4095. Over

5V, this means the microcontroller can detected changes as low as 1.22mV.

The microcontroller will be set up to capture and correct errors, have fuses, a power up timer, and detect brownout at 2.5V and to print once a second.

The GSR signal is inputted into pin A0. There is a start pushbutton that is connected to B0, this start signal will be pulled to ground when it is not pressed to avoid it floating. There are now only 7 LEDs being outputted from the microcontroller this is because the middle LED will illuminate first once the start pushbutton is pressed. This will give the baseline for the user. If the user becomes more stressed then LEDs in one direction will illuminate. If the user becomes less stressed then LEDs in the other direction will illuminate. The reason for having LEDs both sides of the baseline is so the user can see what is helping them relax as well as what is making them more stressed. The GSR level is also being outputted to RS232.

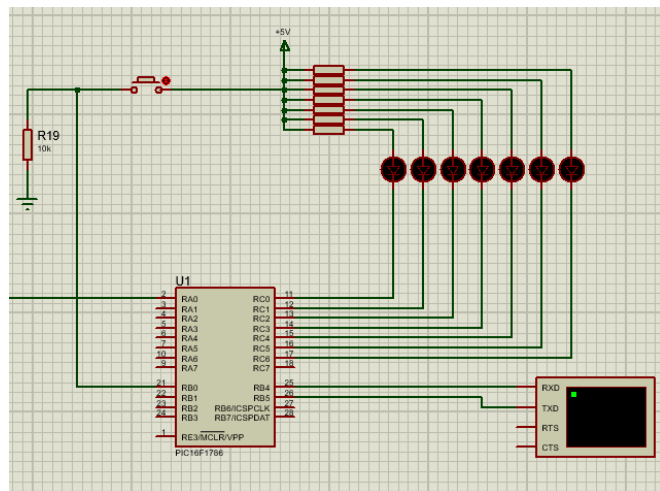
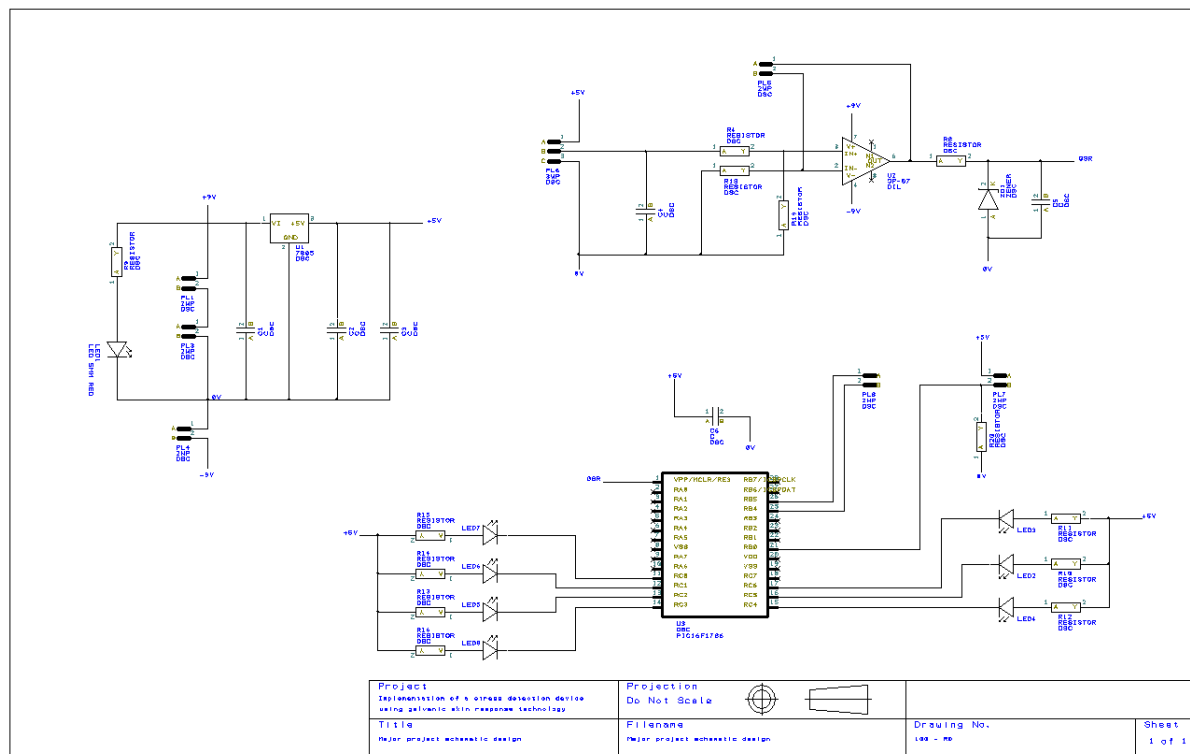


Figure 58 - Microcontroller Circuit Design

## 12.4. PCB Design



### Figure 59 - Easy PC Schematic View

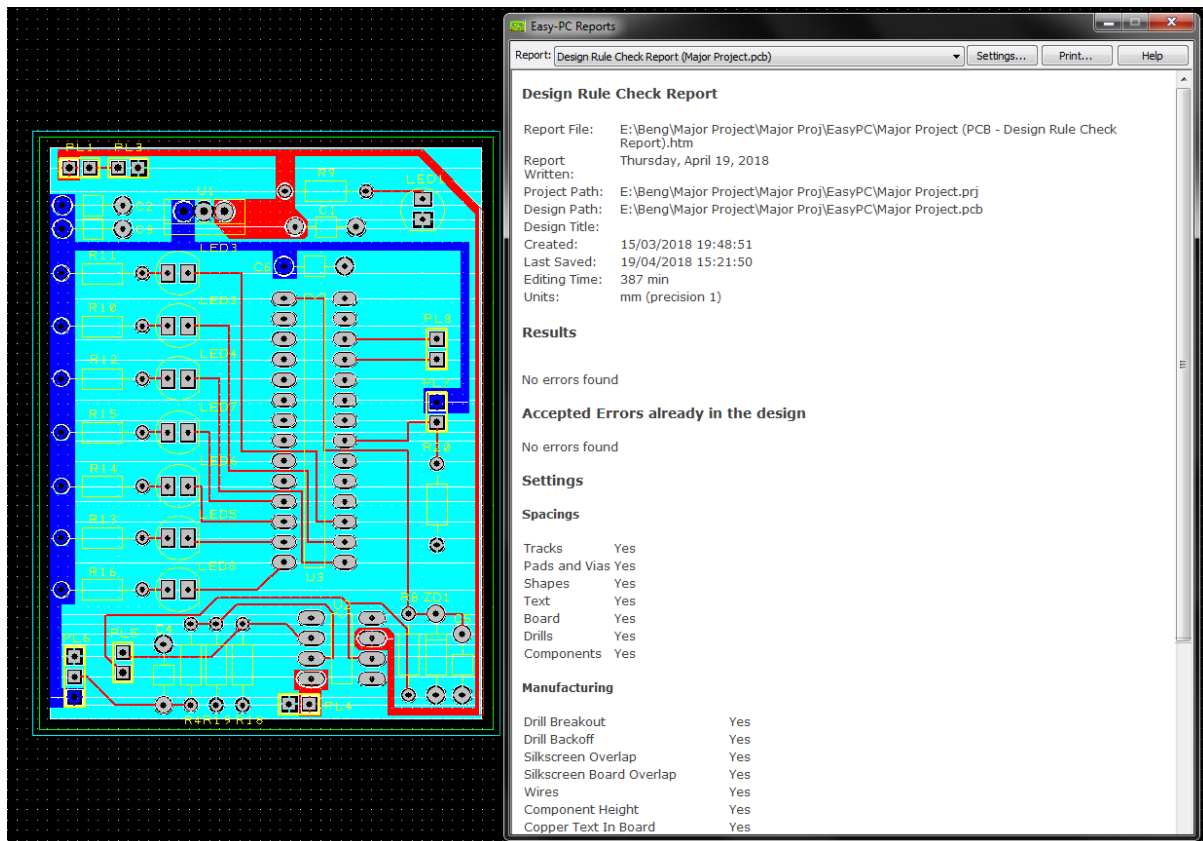


Figure 60 - No Errors in PCB Design

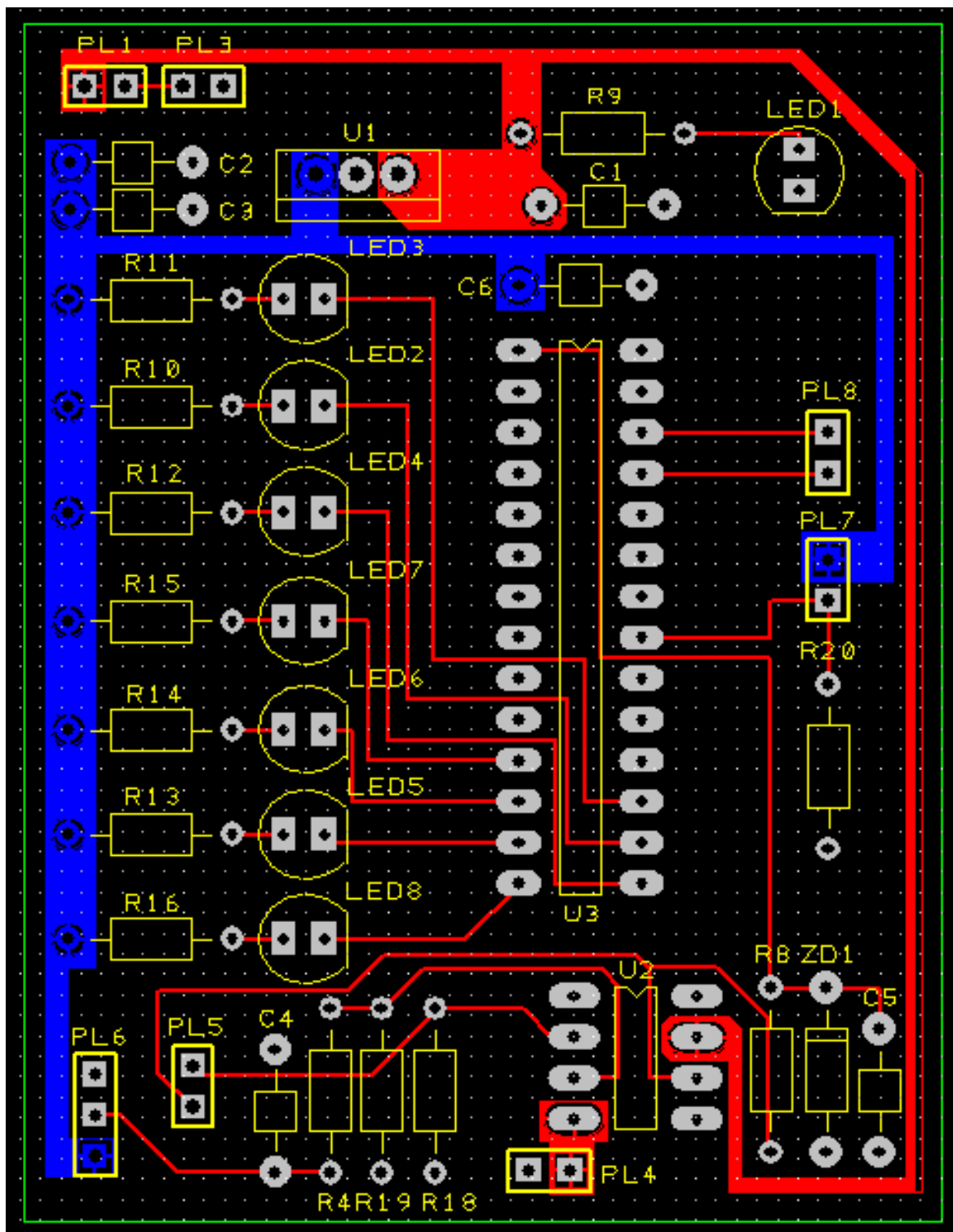


Figure 61 - PCB Top Layer View

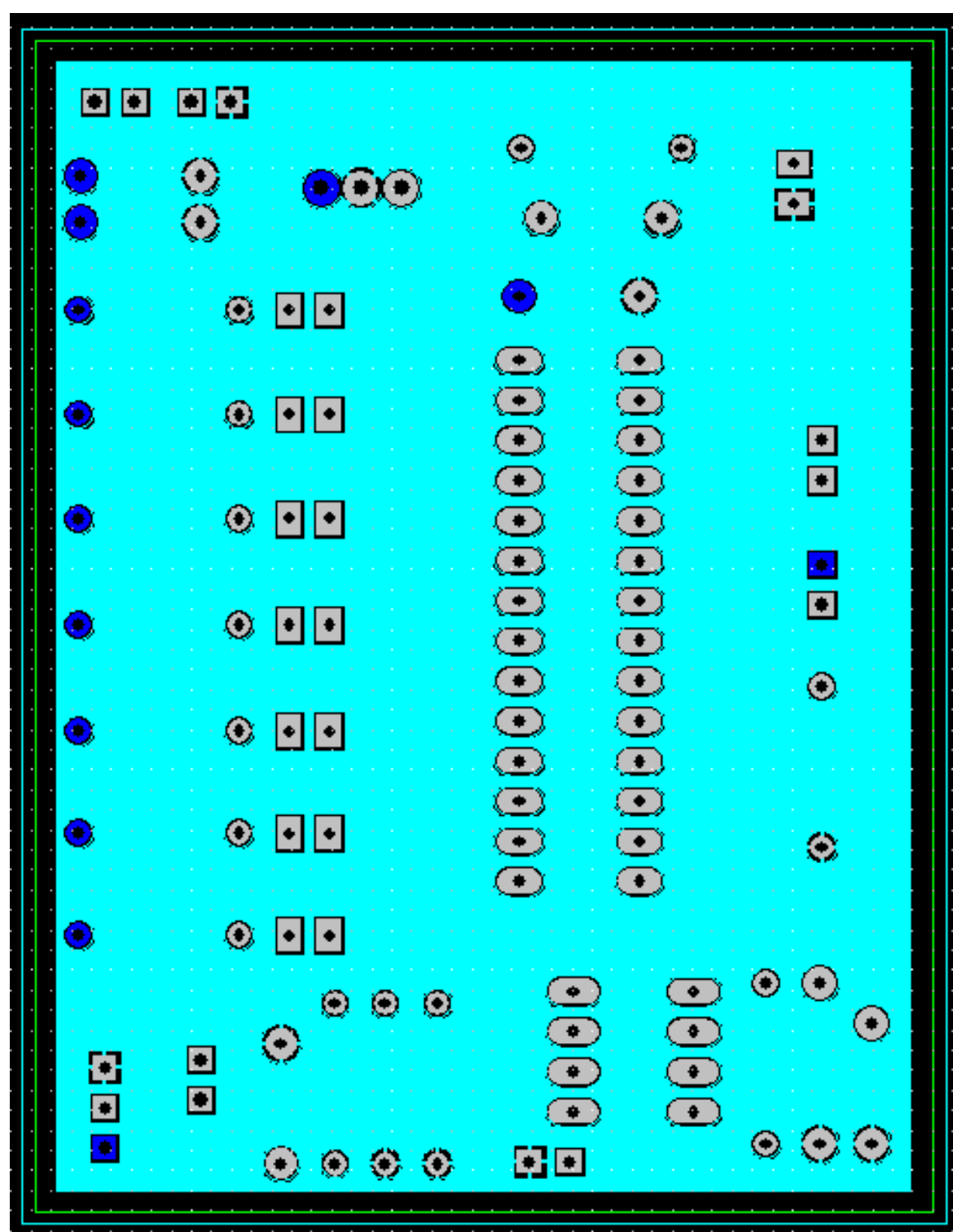


Figure 62 - PCB Bottom Top Layer View

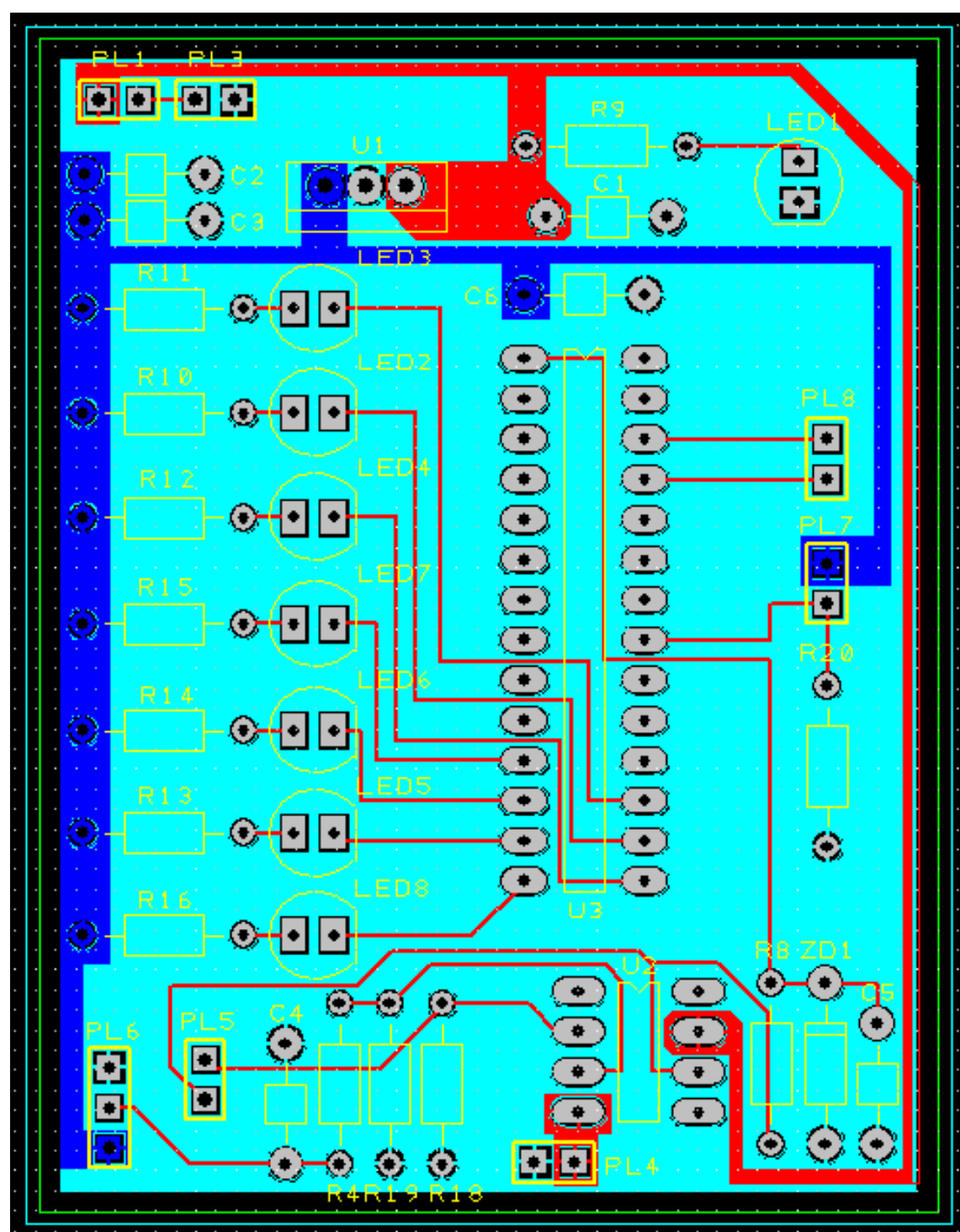


Figure 63 - PCB Composite View

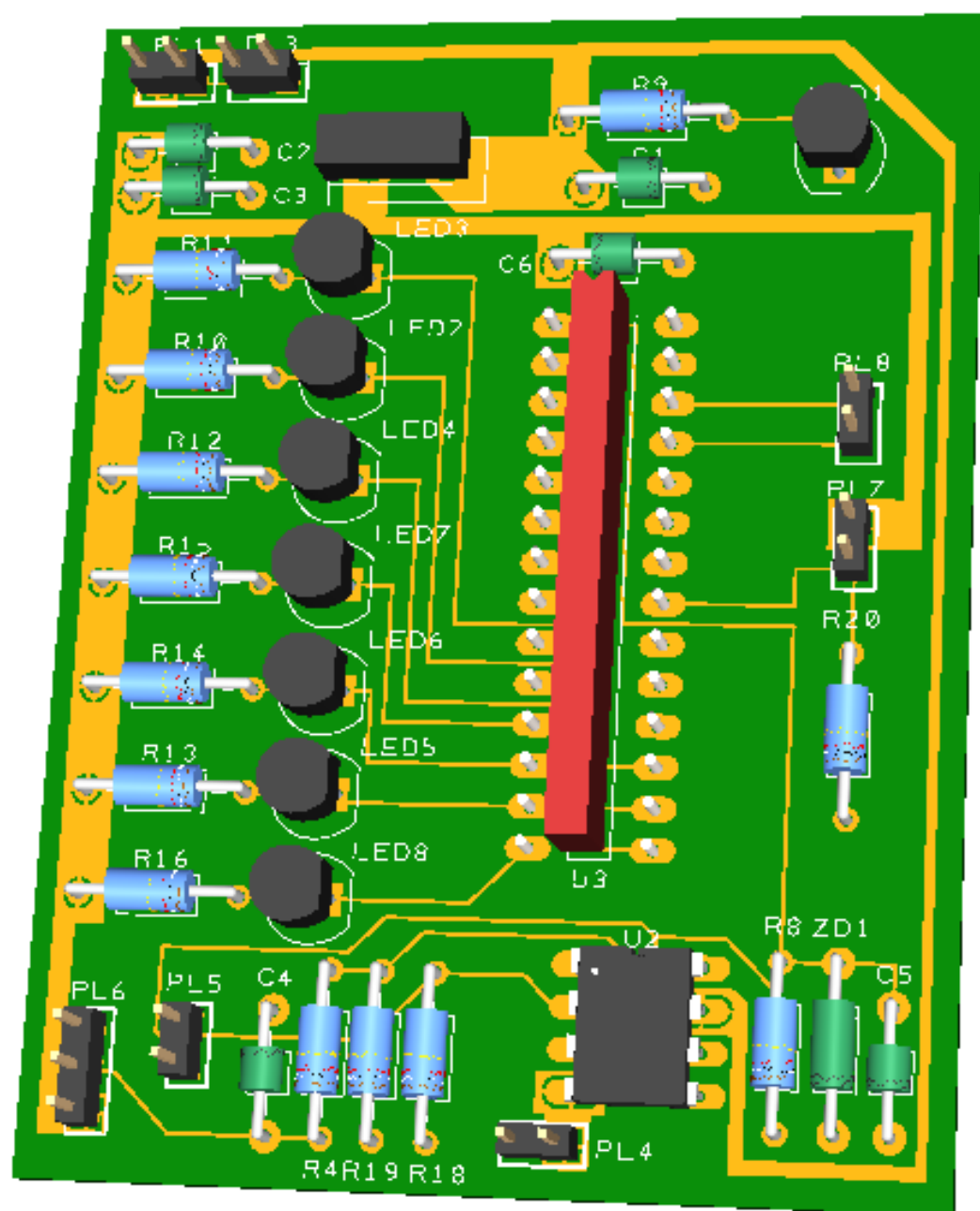


Figure 64 - 3D PCB Top Layer View

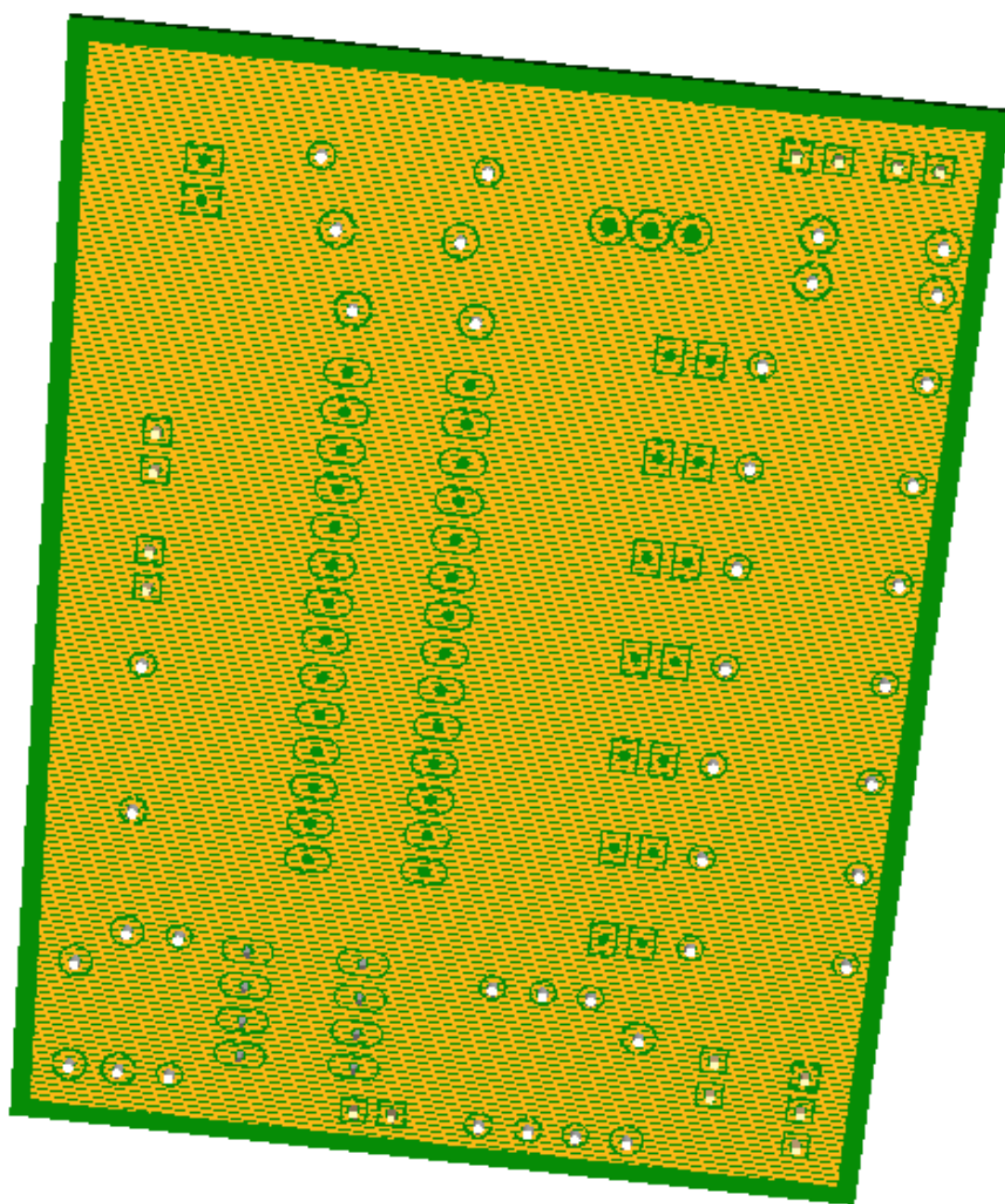


Figure 65 - 3D PCB Bottom Layer View

## 12.5. Coding

```
1 #include <16F1786.h>
2 #device ADC=12
3
4 #FUSES PUT //Power Up Timer
5 #FUSES NOMCLR //Master Clear pin used for I/O
6 #FUSES NOPROTECT //Code not protected from reading
7 #FUSES NOCPD //No EE protection
8 #FUSES BROWNOUT //Reset when brownout detected
9 #FUSES NOCLKOUT //I/O function on OSC2
10 #FUSES IESO //Internal External Switch Over mode enabled
11 #FUSES FCEN //Fail-safe clock monitor enabled
12 #FUSES NOWRT //Program memory not write protected
13 #FUSES NOVCAP //VCAP pin disabled
14 #FUSES STVREN //Stack full/underflow will cause reset
15 #FUSES BORV25 //Brownout reset at 2.5V
16 #FUSES NOLPBOR //Low-Power Brownout reset is disabled
17 #FUSES NOLVP //No low voltage prgming, B3(PIC16) or B5(PIC18) used for I/O
18
19 #use delay(internal=16MHz)
20 #use rs232(baud=9600,parity=N,xmit=PIN_B4,rcv=PIN_B5,bits=8,stream=PORT1,errors)
21
22 #define LED PIN_C0
23 #define DELAY 50
24
```

Figure 66 - Code Main H File

```
*main.c x main.h x
1 #include <main.h>
2
3 unsigned int counter=0;
4 char flag=0;
5
6 #INT_TIMER2
7 void TIMER2_isr(void)
8 {
9     counter++;
10    if(counter==40)
11    {
12        flag=1;
13        counter=0;
14    }
15 }
16
17 void main()
18 {
19     unsigned long middle=0;
20     unsigned long value;
21     char flag2=0;
22     setup_adc_ports(sAN0);
23     setup_adc(ADC_CLOCK_INTERNAL);
24     setup_timer_2(T2_DIV_BY_16,245,16); //787 us overflow, 12.5 ms interrupt
25
26
27     enable_interrupts(INT_TIMER2);
28     enable_interrupts(GLOBAL);
29
30     output_c(0x00); // set all leds for test
31     delay_ms(1000); // wait 1 sec
32     output_c(0xff); // set all leds off
33
34     while(TRUE)
35     {
36
37         if(input(PIN_B0))
38         {
39             set_adc_channel(0);
40             delay_us(30);
41             middle = read_adc();
42             printf("default GSR Level %Lu\n\r",middle);
43             flag2=1;
44         }
45
46         set_adc_channel(0);
47         delay_us(30);
48         value = read_adc();
49         if(flag)
```

Figure 67 - Code Main C Part 1

```

main.c x main.h x
43         flag2=1;
44     }
45
46     set_adc_channel(0);
47     delay_us(30);
48     value = read_adc();
49     if(flag)
50
51     {
52         printf("GSR Level %Lu  Middle = %Lu\n\r",value,middle);
53         flag=0;
54     }
55     if(flag2)
56     {
57         if(value==middle)
58         {
59             // turn on centre led
60             output_low(PIN_C3);
61         }
62
63         if(value<((middle - 3))) // ((middle - ((middle/100)*1)))
64         {
65             // turn on led
66             output_low(PIN_C2);
67         }
68         else
69         {
70             // turn on led
71             output_high(PIN_C2);
72         }
73
74         if(value<((middle - 6))) // ((middle/100)*2)))
75         {
76             // turn on led
77             output_low(PIN_C1);
78         }
79         else
80         {
81             // turn on led
82             output_high(PIN_C1);

```

Figure 68 - Code Main C Part 2

```
*main.c x main.h x
82         output_high(PIN_C1);
83     }
84     if(value<=(middle - 9))                // ((middle/100)*5)))
85     {
86         // turn on led
87         output_low(PIN_C0);
88     }
89     else
90     {
91         // turn on led
92         output_high(PIN_C0);
93     }
94     if(value>=(middle + 3))                //middle/100)*1)))
95     {
96         // turn on led
97         output_low(PIN_C4);
98     }
99     else
100    {
101        // turn on led
102        output_high(PIN_C4);
103    }
104    }
105    if(value>=(middle + 6))                // ((middle/100)*3)))
106    {
107        // turn on led
108        output_low(PIN_C5);
109    }
110    else
111    {
112        // turn on led
113        output_high(PIN_C5);
114    }
115    }
116    if(value>=(middle + 9))                // ((middle/100)*6)))
117    {
118        // turn on led
119        output_low(PIN_C6);
120    }
121    else
122    {
123        // turn on led
124        output_high(PIN_C6);
125    }
126    }
```

Figure 69 - Code Main C Part 3

### 13. Second Design Cost Analysis

The project as a whole is fairly inexpensive as all the components are readily available. This cost should be an accurate guide in the overall costs involved in the project.

| Component                      | Quantity | Cost   | Total Cost | Supplier  | Part Number        |
|--------------------------------|----------|--------|------------|-----------|--------------------|
| Breadboard                     | 1        | £2.34  | £2.34      | Farnell   | PSG-BB-400         |
| Jump Wire Kit                  | 1        | £6.84  | £6.84      | RS        | SKS-140            |
| Green LED (Power On)           | 1        | £0.70  | £0.70      | RS        | L-53GD             |
| Green LED (LED Graph)          | 1        | £0.70  | £0.70      | RS        | L-53GD             |
| Yellow LED (LED Graph)         | 4        | £0.21  | £0.84      | RS        | L-53YD             |
| Red LED (LED Graph)            | 2        | £0.21  | £0.42      | RS        | L-53HD             |
| On/Off Switch                  | 1        | £1.19  | £1.19      | Farnell   | MCTA3-4R2-V        |
| Battery (9V)                   | 2        | £3.49  | £6.98      | Maplin    | L46AL              |
| Op Amp, 8 Pin, 5V              | 1        | £0.34  | £0.34      | RS        | MCP6241-E/P        |
| 2MΩ Resistor                   | 1        | £0.62  | £0.62      | Vishay    | RN55D2004FB14      |
| 1MΩ Resistor                   | 2        | £0.02  | £0.04      | TE        | CFR100J1M0         |
| 10KΩ Resistor                  | 1        | £0.06  | £0.06      | RS        | 707-7745           |
| 340Ω Resistors                 | 7        | £0.14  | £0.98      | TE        | YR1B340RCC         |
| 681Ω Resistor                  | 1        | £0.47  | £0.47      | TE        | YR1B681RCC         |
| 100Ω Resistor                  | 1        | £0.035 | £0.035     | RS        | 707-8827           |
| 0.33uF Capacitor               | 1        | £0.22  | £0.22      | Nichicon  | UVY1HR33MDD        |
| 100nF Capacitor                | 3        | £0.93  | £0.93      | Nichicon  | USR1H0R1MDD        |
| 10uF Capacitor                 | 1        | £0.07  | £0.07      | Vishay    | 515D106M016JA6AE3  |
| Voltage Regulator              | 1        | £0.39  | £0.39      | Maplin    | L78S05CV           |
| Microcontroller                | 1        | £1.66  | £1.66      | Microchip | PIC16F1786-I/SP    |
| Potentiometer                  | 1        | £6.06  | £6.06      | Vishay    | PRV6SAABJYB25102KL |
| Electrodes                     | 1        | £5     | £5         | -         | -                  |
| 9 Pin D Type Connector         | 1        | £12.58 | £12.58     | FCT       | FC09P0G1           |
| 2 Way PCB Mount Terminal Block | 4        | £0.43  | £1.72      | RS        | 790-1098           |
| 3 Way PCB Mount Terminal Block | 2        | £1.90  | £2.80      | TE        | 282834-3           |

Figure 70 - Cost Analysis of Second Design

The total for this bill of materials has increased slightly to £54.99, mainly due to the pot.

## 14. Second Design Simulations & Analysis

### 14.1. Proving the A/D Resolution of the PIC is Sufficient

It was stated earlier in the report that the microcontroller could detect changes as low as 1.22mV. The system will need to be able to detect changes in resistance of 5K $\Omega$ . This image first shows the voltage at 105K $\Omega$ , which is 1.02509V.

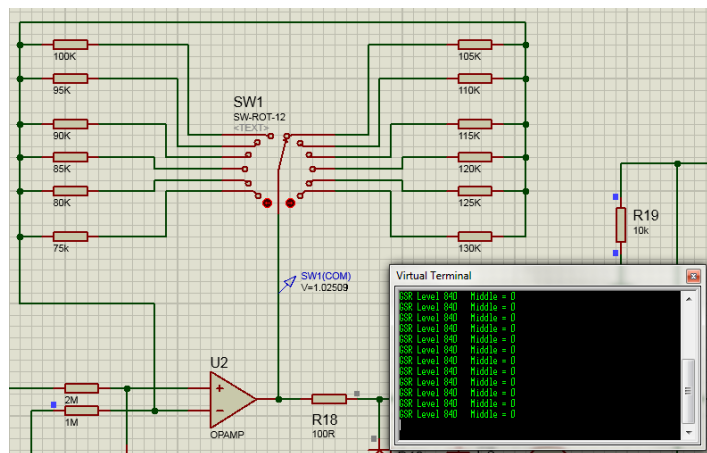


Figure 71 - Voltage at 105K $\Omega$

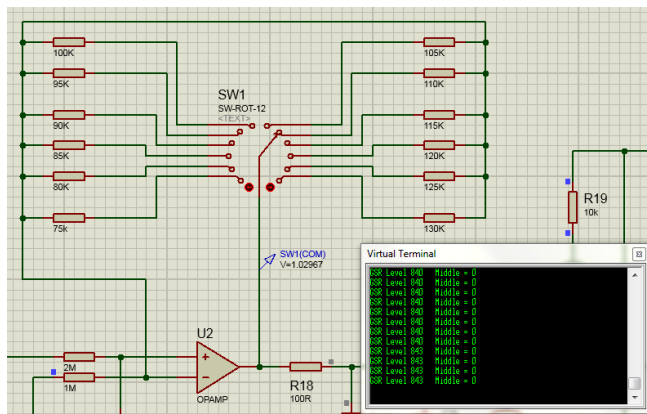


Figure 72 - Voltage at 110K $\Omega$

In this image the 'skin resistance' is now 110K $\Omega$  and the voltage is now 1.02967V. So, in a change of 5K $\Omega$  the voltage has changed by 0.00458V. There is a change of around 4.5mV so this proves that the A/D resolution of the microcontroller is sufficient.

## 14.2. Full Schematic Simulation of Second Design

The range for GSR was dropped from reduced 50K $\Omega$  - 10M $\Omega$  down to 5M $\Omega$  because the range was so vast it has proved difficult to get a full linear voltage swing. The design will now have a 3V swing.

| Resistance ( $\Omega$ ) | Voltage (V) |
|-------------------------|-------------|
| 50K                     | 0.97        |
| 100K                    | 1.02        |
| 250K                    | 1.16        |
| 500K                    | 1.37        |
| 750K                    | 1.58        |
| 1M                      | 1.77        |
| 1.5M                    | 2.14        |
| 2M                      | 2.47        |
| 2.5M                    | 2.77        |
| 3.3M                    | 3.21        |
| 4M                      | 3.54        |
| 5M                      | 3.97        |

Table 10 - Voltage Outputted from GSR Circuit

The new design definitely is more linear than the last design. This may be due to the smaller resistance range, but this will definitely help when writing the program for the LED graph outputs.

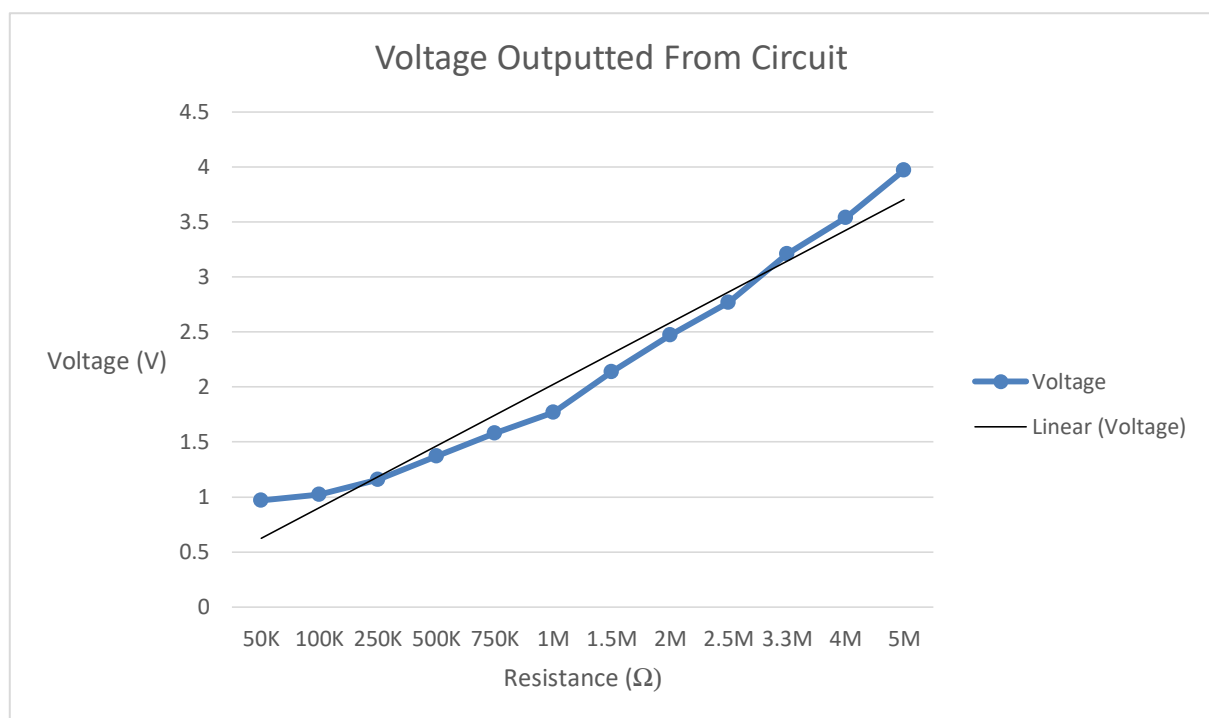


Figure 73 – Voltage Outputted from GSR Circuit

[illegible]

The screenshot shows a Proteus simulation of a 555 timer circuit. The circuit includes a 555 timer (U1) configured as an astable multivibrator, driving a 7-segment display (U2) and a 4x4 LED matrix (U3). A 'Signal Generator' window shows a square wave output. The 7-segment display shows the hexadecimal digit '0'.

For full completion of the simulation purposes, all the LEDs will be tested and documented that each LED does illuminate in resistance drops by  $5K\Omega$  or by 3 in GSR level as shown in the code.

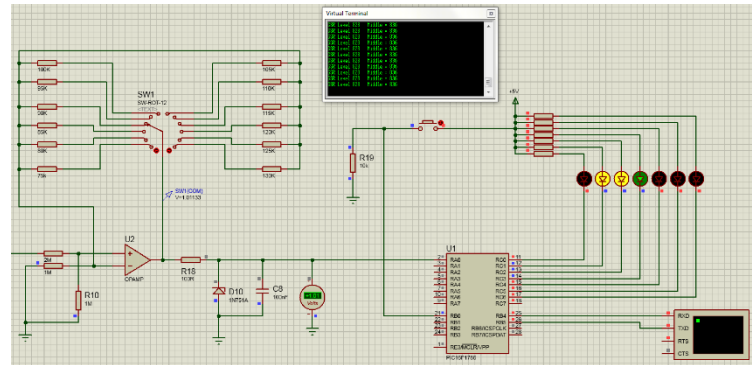


Figure 78 - Second Drop in Skin Resistance

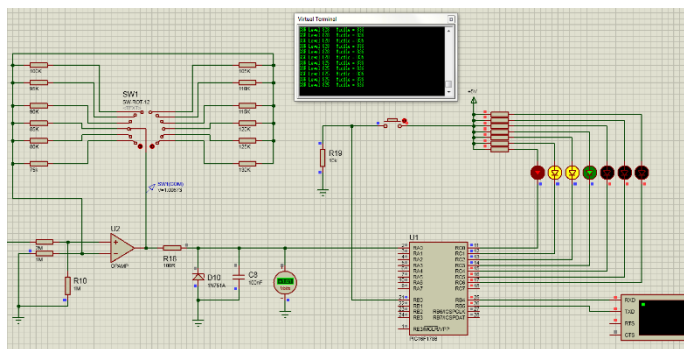


Figure 79 - Final Drop in Skin Resistance

The last LED has illuminated, it is a red LED to show that the person is at the furthest level that is being detected for stress.

This image shows the LEDs now illuminating in the opposite direction again to show a person becoming more relaxed so their skin resistance is increasing therefore their skin conductance is decreasing.

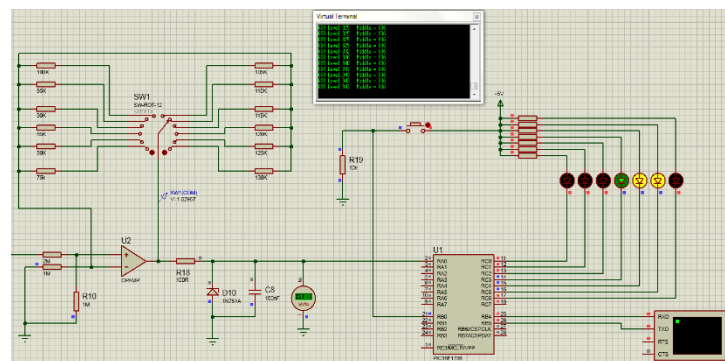


Figure 80 - Further Increase in Skin Resistance

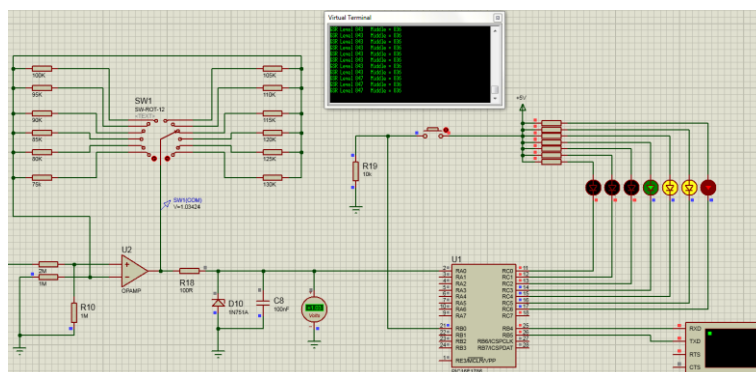


Figure 81 - Final Increase in Skin Resistance

Finally, here the person is now very relaxed so it is at the opposite end of the stress meter. Again, a red LED is used to show the end of the graph.

Here is a zoomed in image to show the RS232 is working correctly. The virtual terminal shows that a GSR reading is being taken and transmitted but the 'middle' reading has not yet been taken as the start button has not been pressed.

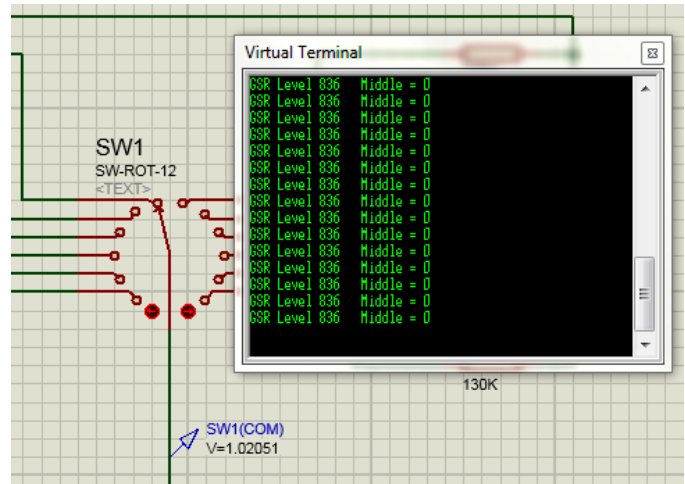


Figure 82 - RS232 Transmitting GSR Level

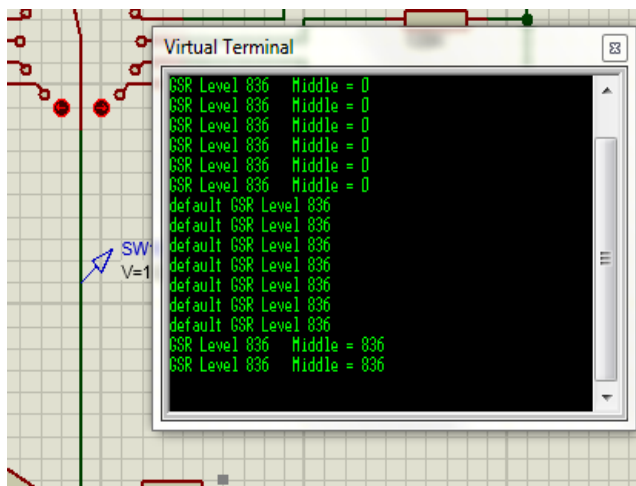


Figure 83 - RS232 Transmitting GSR Level & Middle

This image shows that the RS232 is transmitting the GSR level but the middle reading hasn't been taken yet, like in the previous image. However, the start pushbutton is then pressed and so the middle reading has then been taken, the RS232 has begun to transmit the reading.

In this next image it is shown that the GSR level has dropped by 8. The RS232 has transmitted this data. The middle reading has stayed the same as it should.

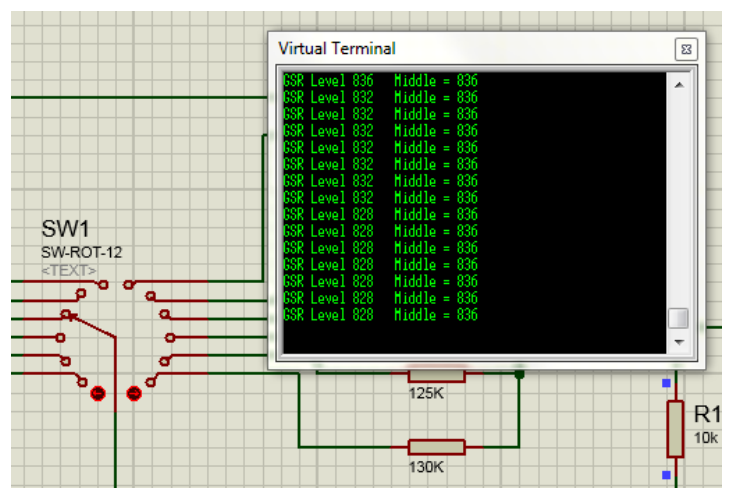


Figure 84 - RS232 Transmitting changes in GSR Level

## 15. Second Design Build

### 15.1. Finger Electrodes

It was found when using the finger electrodes that the connection wasn't great. So, a new set of finger electrodes were made. This time the cable was stripped back far enough so that it could reach the end of the electrodes.

Hopefully, with a larger surface area covered by the copper cable it would maintain a better connection.

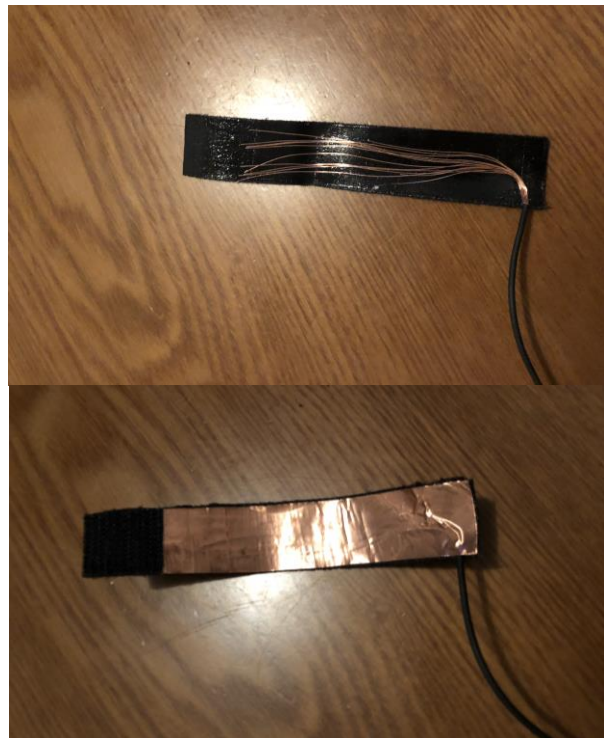


Figure 85 - Finger Electrode

## 15.2. GSR Circuit

The power circuit that was previously built is still the same. The only change to the power now is that another battery to produce the -9V has been added to supply the operational amplifier. The GSR circuit has changed completely. It now incorporates a potentiometer which is used to tune the input voltage to the op amp as on Proteus

it uses an ideal op amp but no real op amp will be ideal. In the image

the electrodes have not been added yet. They will be wired into the 2 pin connector that currently has a resistor is ready for testing.

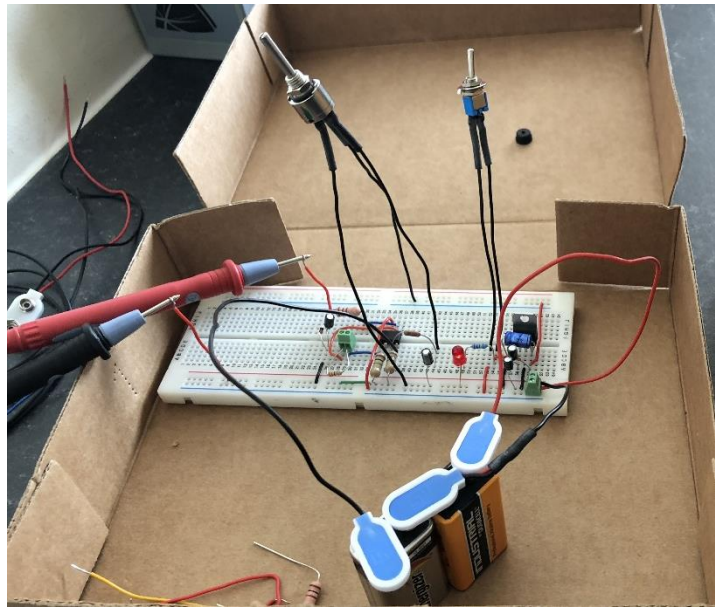


Figure 86 - GSR Circuit Build

15.3. Microcontroller Circuit

Before the microcontroller was added to the breadboard the GSR circuit was tested to make sure it was working correctly, this is shown in the next section. Firstly, the microcontroller also needed to have the code uploaded to it which is shown being completed in this image. The power and ground pins had to be connected to the correct pins before downloading as well as the data and clock pins. These pins are shown in the image below.

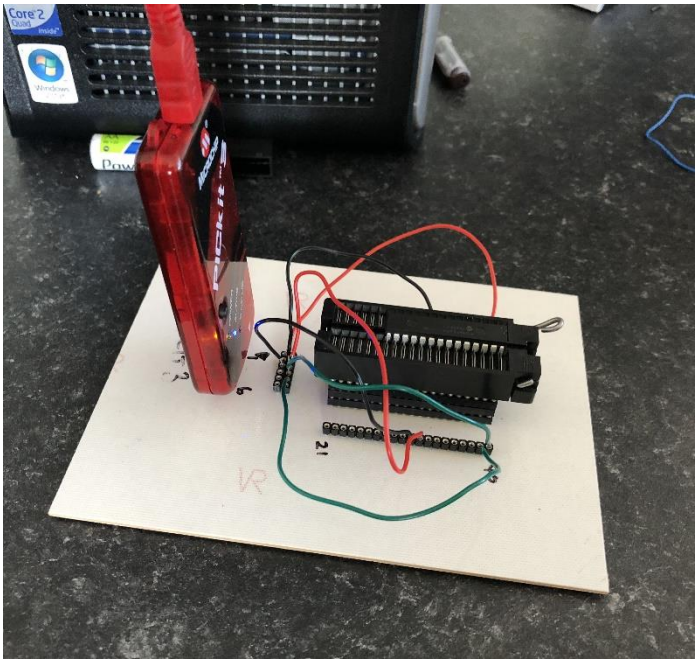


Figure 87 - Uploading Code onto Microcontroller

Pin Diagram – 28-Pin SPDIP, SOIC, SSOP

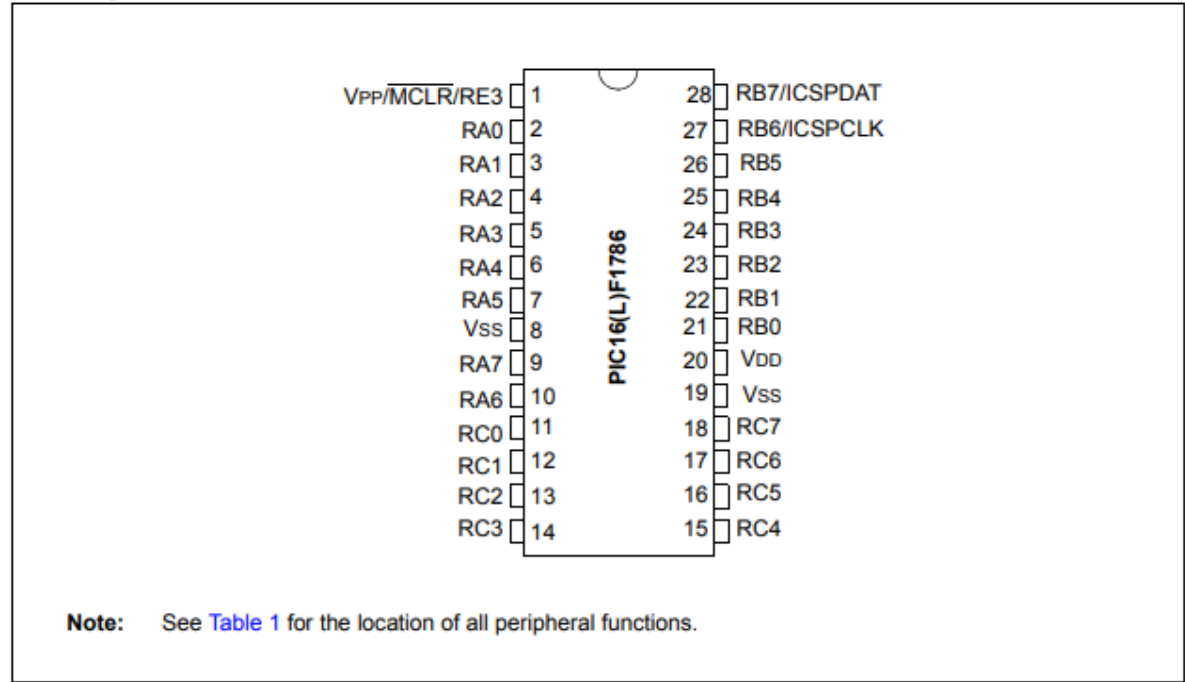


Figure 88 - PIC16F1786 Pin out [22]

## 15.4. Build of Housing

Firstly, the GSR level LEDs were fitted along with the potentiometer and the start pushbutton. A guard could be fitted later on over the potentiometer so that it is not accidentally changed after the initial tuning.



Figure 89 - Components Mounted on Enclosure



Figure 90 - Toggle Switch on Enclosure

Next, the toggle on/off switch was mounted at the top of the enclosure.

The breadboard was fixed into place and the wiring between the components mounted on the enclosure was completed. Heat shrink was fitted around the LEDs to ensure nothing would be in contact with each other.

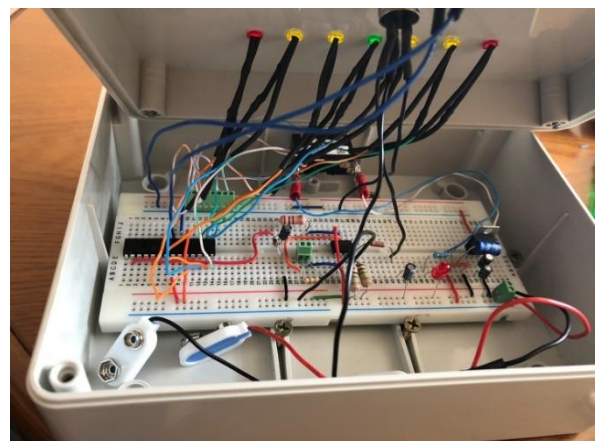


Figure 91 - Breadboard Mounted into Enclosure

Before fitting the electrodes into place the circuit was tuned using the 100K $\Omega$  resistor. Once this was finished the stuffing gland was fitted along with the batteries.

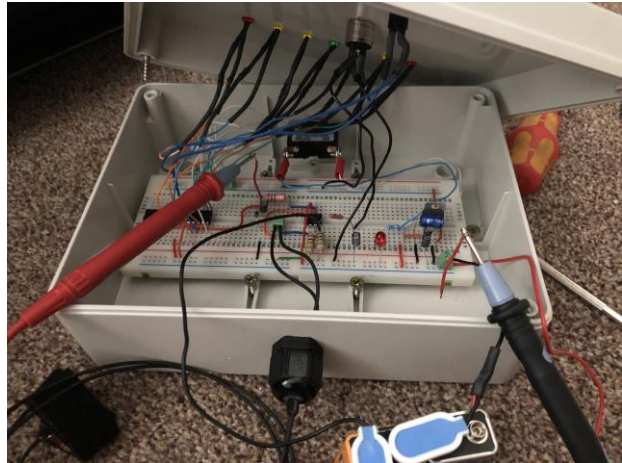


Figure 92 - Fitted Finger Electrodes



Figure 93 - Finished Prototype Build

The labels were then added to the front of the enclosure for completion.

## 16. Testing & Analysis of Second Design

### 16.1. Testing of GSR Circuit

Some of the following tests were carried out before the build of the enclosure was completed. When testing the GSR circuit different resistor sizes were used so there is a known resistance acting as the skin resistance so that it can be seen if the circuit is having similar voltages to the Proteus simulations. At the beginning the potentiometer is tuned using a 100K $\Omega$  resistor as skin resistance. The voltage that is being outputted from the circuit after tuning is 1.01V. In the simulations the circuit was outputting around 1.02V.

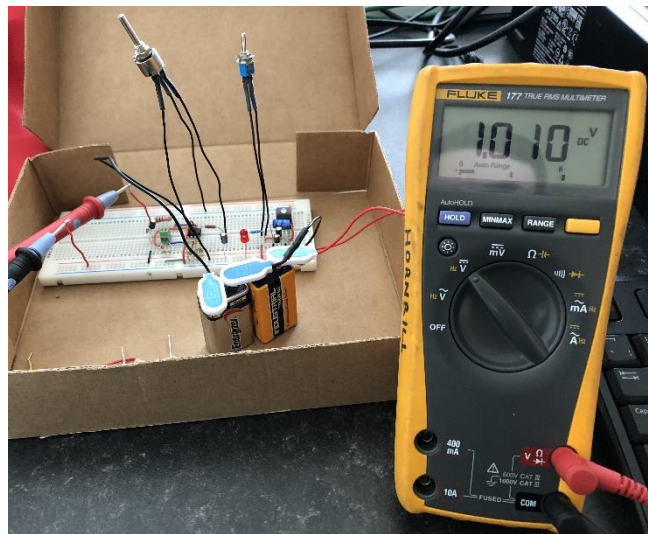


Figure 94 - GSR Output Voltage at 100K $\Omega$

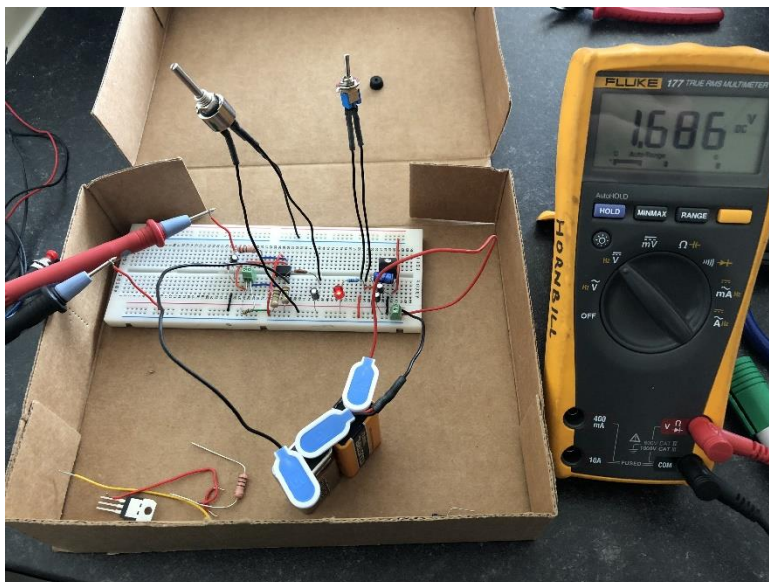


Figure 95 - GSR Output Voltage at 1M $\Omega$

A number of different resistors were tested which is shown in the following table and graph to see if the voltages were similar to the simulations completed through the full range of resistances. This image has a 1M $\Omega$  resistor used for skin resistance.

In this image a  $3.3\text{M}\Omega$  resistor is used for skin resistance giving a 3.5V output.

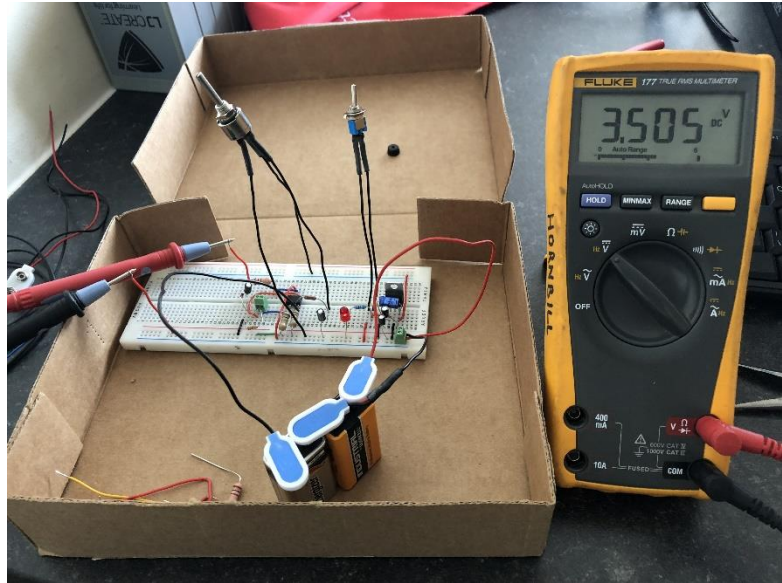


Figure 96 - GSR Output Voltage at  $3.3\text{M}\Omega$

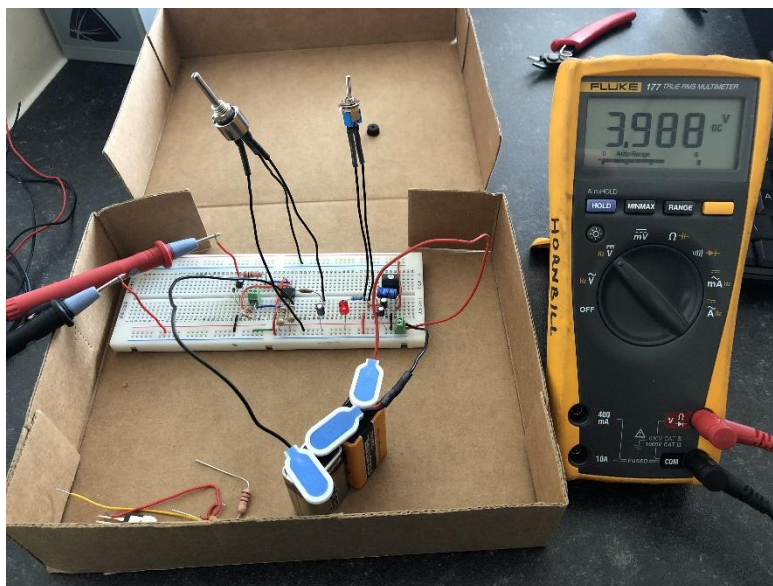


Figure 97 - GSR Output Voltage at  $4.7\text{M}\Omega$

The resistor used here is a  $4.7\text{M}\Omega$  resistor is used for skin resistance giving a 3.98V output. This is at the higher end of the resistance range that will be considered for skin resistance.

This table and graph contain the results of the tests above. A sharp increase in voltage can be seen after the resistance has grown to over 1M $\Omega$ . The graph doesn't seem to be as linear as they were with the resistances values used in the simulation stage.

| Resistance ( $\Omega$ ) | Voltage (V) |
|-------------------------|-------------|
| 100K                    | 1.01        |
| 270K                    | 1.14        |
| 470K                    | 1.30        |
| 560K                    | 1.37        |
| 750K                    | 1.48        |
| 870K                    | 1.53        |
| 1M                      | 1.68        |
| 2.2M                    | 2.59        |
| 3.3M                    | 3.50        |
| 4.7M                    | 3.98        |

Table 11 - Voltage Outputted from Actual GSR Circuit

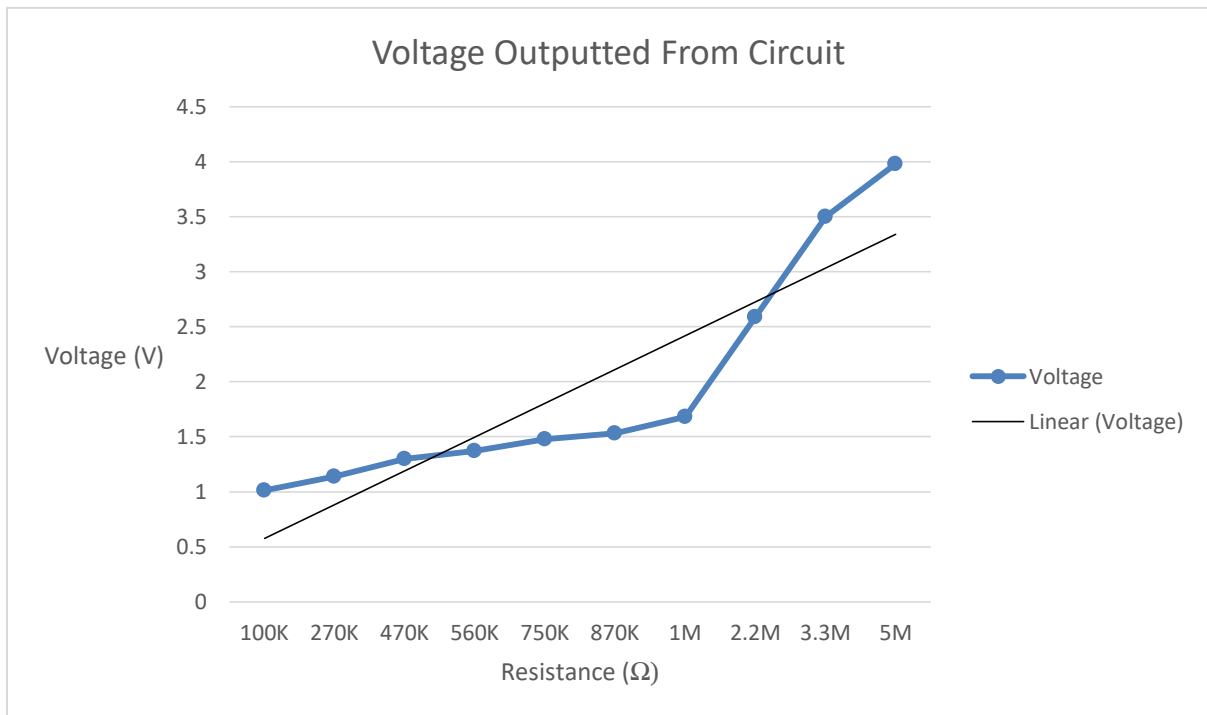


Figure 98 - Voltage Outputted from Actual GSR Circuit

This table and graph are the result of the simulations completed using the same resistor values as the physical testing.

| Resistance ( $\Omega$ ) | Voltage (V) |
|-------------------------|-------------|
| 100K                    | 1.02        |
| 270K                    | 1.17        |
| 470K                    | 1.35        |
| 560K                    | 1.42        |
| 750K                    | 1.58        |
| 870K                    | 1.67        |
| 1M                      | 1.77        |
| 2.2M                    | 2.59        |
| 3.3M                    | 3.20        |
| 4.7M                    | 3.84        |

Table 12 - Voltage Outputted from Simulated GSR Circuit

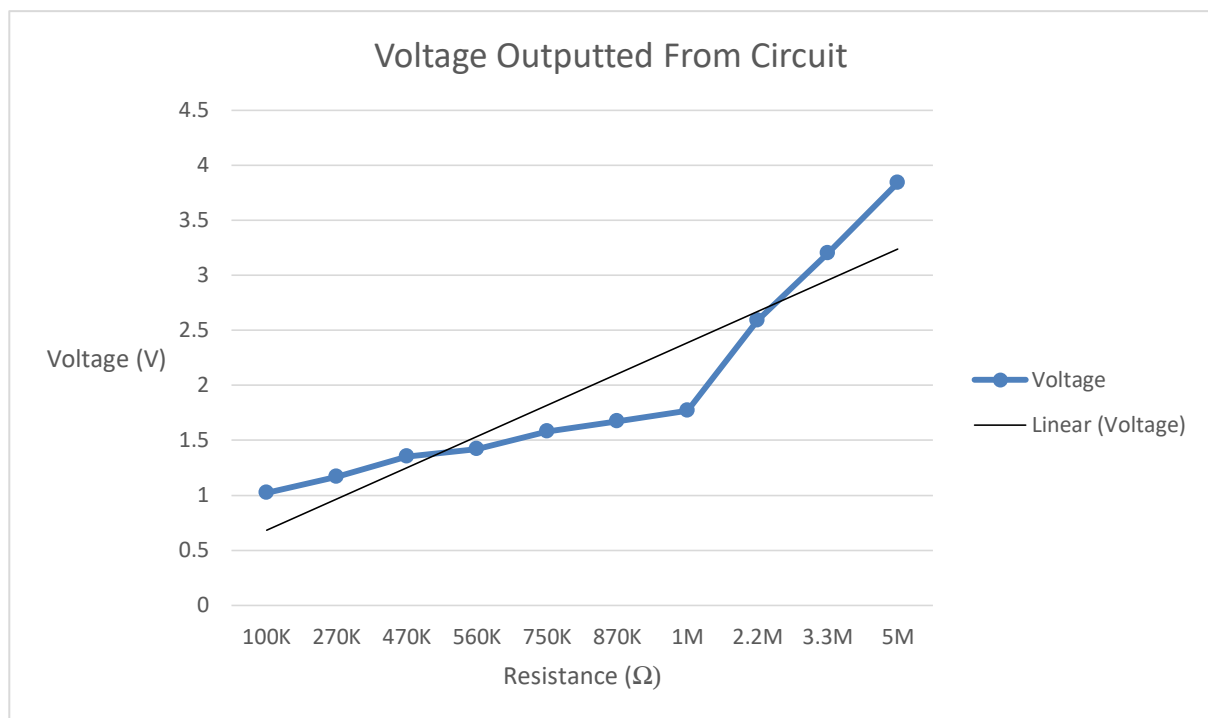


Figure 99 - Voltage Outputted from Simulated GSR Circuit

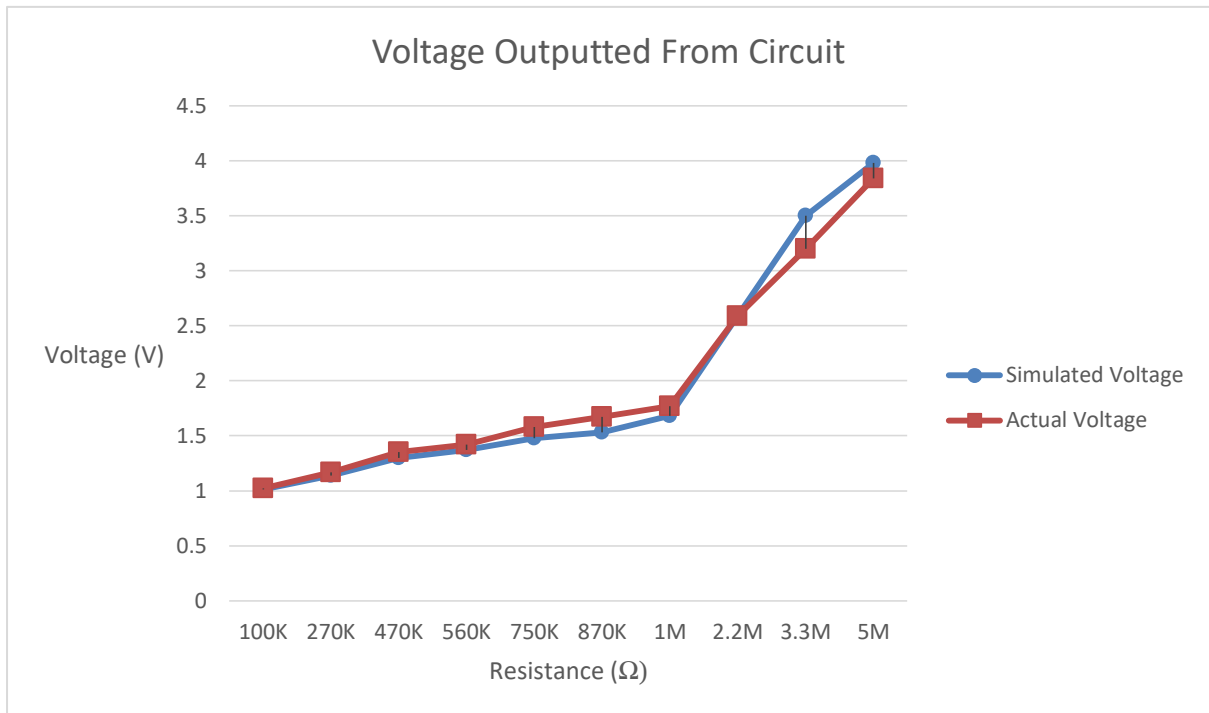


Figure 100 - Compared Voltages

Although the voltages are not exactly the same, they are very similar. The biggest difference was at the 3.3MΩ with a difference of 0.3V. This proves that the design and software has been successful. It would now have to be used to do some meaningful tests.

## 17. More Testing

### 17.1. Skin Resistance

A number of subjects' skin resistance was measured to find out the typical resistances that can be expected. In the research it was found that skin resistance can be anywhere between 50K $\Omega$  to 10M $\Omega$ , this is a huge range to consider. The skin resistances detailed in the table to the right were measured in a warm room.

| Subject | Resistance ( $\Omega$ ) |
|---------|-------------------------|
| 1       | 98K                     |
| 2       | 83K                     |
| 3       | 58K                     |
| 4       | 86K                     |
| 5       | 83K                     |
| 6       | 153K                    |

Table 13 - Skin Resistance

All the skin resistances were at the lower end of the range for skin resistance. This could be due to the temperature of the room and other factors. The next step is to measure the same subjects skin resistances in a cooler room once they have relaxed for 15 minutes before the measurements are taken.

## 17.2. Trails

To check that the product is working in the correct way certain tests/trials should be carried out on different users. Some examples of the tests that would have been completed are as follows:

- Sit back in your chair and relax.
- Try and think about something that makes the subject anxious.
- Read a paragraph displayed to them out loud as fast as possible.

Unfortunately, there were some issues when testing due to the contact for when skin resistance is taken this meant. Although the product worked to the design and code that was finished it is not clear whether the product would work practically because of these issues.

## 18. Evaluation

After undertaking the build, tests and analysis for the project it can be evaluated against the aims and objectives to see if these have been met. The main objective was to provide a microcontroller based solution to creating a stress detection device that can be used in order to aid in managing stress levels to increase a person's general health. Overall, it can be evaluated that the main objective has been somewhat met as the design clearly shows in simulation that the device will aid users in managing their stress levels as their stress levels increase more lights will illuminate.

The aims set for the project are listed below along with whether or not these aims have been met or not:

- Research galvanic skin response technology – This has been completed in section 4. The research into galvanic skin response technology included finding out about stress and what causes people stress as well as the potential outcomes of too much stress. Statistics from reputable website were included to back up the claims. Then GSR or EDA was researched directly to find out what skin conductance is and the types of skin conductance. Also, how skin conductance changes and why it changes. The most suitable material to use for electrode for measuring GSR was looked at by comparing the materials conductivity, resistivity and cost.
- Research existing products on the market that make use of galvanic skin response technology – This has also been completed in section 4. The uses of GSR and what products they have been used in were looked at.
- Manufacture a Galvanic Skin Response Sensor – The GSR sensor has been manufactured in the build section. It was simply a finger electrode made from a copper foil, cable and Velcro.
- Design a schematic for the circuit – This aim has also been met as the schematic design was originally designed then went through a number of revisions to get to the

first design that was taken into build. Once the testing of this design was completed the design then changed further.

- The system must incorporate a microcontroller – The system does include a microcontroller which reads the GSR signal and outputs to LEDs for a visual representation of stress. The microcontroller also sends the GSR signal through RS232 to a computer which can be used for testing and analysis.
- Carry out tests on users under different conditions and analyse the data received to get a threshold that indicates a stressful condition has taken place – This aim has not been met due partly to time management and partly by issues encountered on the way. One of the major issues was found late when testing the product, because the electrodes were not gaining great enough contact with the skin it meant that skin resistance was fluctuating when the subject was moving even slightly because of the pressure on the electrodes.

Ideally the product would have been built on a PCB, soldered in place and mounted in an enclosure for full completion. However, this was not produced but the demonstration of the prototype proved the circuit, coding and build. Although the product worked to the design and code that was finished it is not clear whether the product would work practically because issues such as electrocardiogram artefacts.

## **19. Conclusion & Recommendations**

### **19.1. Conclusion**

This report was created to document the creation of a microcontroller based stress detection device that can be used to aid in managing stress to increase a person's general health. The report contains the details of the research, design and implementation. Overall, the device was a success as it was design and simulated to a working condition. Once the research was had finished the design was completed. Through simulation, build and test the design gradually changed as it was recognised that the device could be improved further by making amendments to the design. The major problem was when the simulation of the first design saw that the design was working fine in simulations but once it was built and tested the design did not function the same. This was overcome by a new design and new software.

The introduction provides an outline or rational for the project. As life is becoming more stressful due to matters such as longer working hours and extra workloads. Also, a brief overview of what EDA or GSR is and its effect on a person. It also gives some details on how the project at hand will work.

The planning for the project is the key building block for the project as it gives guidance on what tasks need to be undertaken and the deadlines that will need to be met. The planning worked somewhat but overcoming problems were not taken into consideration which ended up setting the project back slightly. This mixed with some time management problems meant towards the end of the project some things were not completed. An example of when the timescales had to be adjust was when the first viva came around one critical date was not met. Gantt charts were used throughout the project and did help in giving a clear visualisation of the timescales for the project.

The research onion helped when utilising the correct methodology and so information was gathered using methodology detailed. The research gave an understanding of stress and how it affects us, statistics were found to back up claims. Research was completed on EDA, what it is and how it should be measured, this was a good starting point for the project. Also, the materials to use as electrodes were considered which proved worthwhile as this

research was utilised in the build of the finger electrodes. Skin conductance was looked in and the types of responses and its relationship with skin resistance and sweat. Background information on microcontrollers, op amp configuration proved useful when in the design process. Also, market research proved that the technology is currently used in products that are on sale now. This also sparked some ideas for the project and also some recommendations for the project if it was to be completed again. Overall, the research was successful as it all aided a final working device.

The design, implementation and testing went well as the design was created and was re-addressed a number of times which shows that problems were found at different stages as documented in the design and in the testing stages, this shows the process was working. One of the problems that was found during tests were that the electrodes did not gain enough contact so they also had to be re-made as shown in the report. One of the issues with this type of electrode is that the copper strip completely covers the subjects' fingers which will mean that naturally the skin will secrete more sweat as it begins to get warmer under the electrodes. The subjects' skin resistance also fluctuated if any pressure was put on to the electrodes making it difficult to test the product properly. Also, for better testing the product would need to be soldered instead of using a breadboard as some of the connections are temperamental when opening and closing the enclosure to measure voltages. A microcontroller was chosen and proven in the simulation to be suitable for the application. Using the software provided an understanding of the system and aided hugely in the build and test stages.

To conclude the project, all aspects of the project were successful, the research, design, simulations and testing were all successfully achieved. However, more testing could have been done using the device once it was fully functioning.

## 19.2. Recommendations

Skin conductance is dependent of many factors such as the participant's age, gender, the room temperature, humidity and also medication. Certain aspects can be combated such as temperature and humidity. Using temperature and humidity sensors to know if a person is secreting sweat through heat or stress is useful. A lot of the time the sweat builds up when the skin is in contact with the electrodes, that sweat would usually evaporate.

Participants need to stay quite still when their skin conductance is being measured. However, to be able to tell if a person's skin conductance is changing due to that person moving an accelerometer can be incorporated in the design to know when a subject is moving.

A second GSR measurement could be taken on the opposite hand as some studies suggest that EDA can be meaningfully different on the left and right hand. Studies also suggest that measuring on the dominant and non-dominant hand can miss some important information.

If all LEDs are illuminated in the stressful direction this would mean the person is at a maximum for stress. A buzzer could be implemented to sound when a person hits this level of stress to alert them.

More LEDs or a different type of display could be added to circuit so that a bigger range can be considered. This would not be difficult to add next time around because the software to add more lights will be almost duplicates of current code. If a display was to be used more code would need to be produced but this would likely be the better option as it could have a larger range with a numerical display.

An app could be made that records the data for a person to view later on. It could connect up to an electrical device through Bluetooth. This would result in higher costs to the project in hardware and software.

It can be quite difficult to keep a good connection at times with the electrodes so often they have to be fiddled with until a good connection is kept. A connection test could be incorporated next time. There could be a time period where at the start of the system that the connection must good. So the if the PIC receives the voltage for the whole of this time

period then a LED can illuminate to tell you to begin test by pressing the start pushbutton. However, if the voltage drops out because the connection is lost then this timer will reset and the system cannot begin.

With the current design if the user wanted to reset the 'middle' then they would need to power down then power up again. Therefore, it would be wise to add a reset pushbutton so that the system can start again without powering down.

If the project was to be designed ready for manufacture then the LEDs would be made smaller as well as a smaller housing and a PCB like the one designed so the product could be wearable.

A GSR level is outputted through RS232, it would need to be transposed into a graph so it can be seen to increase and decrease. It can then be used for analysis and pinpointed when, why and how there was that change in the users stress level.

## **20. Reflection**

My degree begun at Neath Port Talbot College, I undertook a Foundation Degree in Electrical and Electronic Engineering. I then furthered my education on the Beng (Hons) Electrical and Electronic Engineering degree which has been both enjoyable and a demanding experience. I must admit when I first started the major project I could not see the light at the end of the tunnel until I begun working through the supporting modules which gave me the background knowledge on how I would need to proceed to make the major project more manageable.

Seeing this project out from beginning to end has given me the confidence in my own skills that I will be able to apply to my career ahead. The skills I have gained through this process are not only theoretical but also practical skills after creating a prototype which I have design and implemented. Although at times I could not see the solution to particular problems in my product, with the guidance of my lecturers I overcame them.

However, I now understand that I will need to improve upon my time management skills as I feel that this was my biggest downfall. There are aspects of my project that I would have liked to do but simply in the end did not have the time to do so.

To conclude I think the major project was successful because even if I did not complete everything I set out to complete.

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