Development of Galvanic Skin Response Sensor System to Measure Mental Stress

By

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13887

Dissertation submitted in partial fulfilment of
the requirements for the
Bachelor of Engineering (Hons)
(Electrical & Electronic)

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CERTIFICATION OF APPROVAL

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Approved by,

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UNIVERSITI TEKNOLOGI PETRONAS
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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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YEO LIP WEE

ABSTRACT

Stress is a very normal reaction when a person is feel threaten or upset in some way. Generally, stress happen when a person ability is not able to meet with the situational demands. It can be either positive or negative. Stress can give a person to have high concentration to face certain circumstances as well as better reaction to handle difficult situation. On the other side, it can also cause sickness to a person if one is suffer from overstress. A person will have health issues like the risk of depression and neurological disorders like stroke if mental stress level is too high. Thus, a device is necessary to measure the stress level so that the stress level can be regulate before it is out of control. Although there are several of methods in the market that are able to measure the stress level, but there are all expensive and complicated. Thus, this project will be focusing on developing a Galvanic Skin Response Sensor that are able to measure stress level based on the skin conductivity. GSR sensor is an economical tool to measure stress level with simpler analysis. Complete methodology and findings are shown as we go through the report.

Acknowledgement

Final Year Project from Final Year 1st Semester to Final Year 2nd Semester is going to end, therefore I would like to sincerely thank Universiti Teknologi Petronas for giving me the chance and opportunity to carry out the final year project to improve my technical skills as well as management skills before I step into working life.

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INTRODUCTION

1.1 Background of the project

In modern life, stress is getting common which it has become a way of life that everyone will face in every stages of life. Nowadays, people are getting easier to feel stress due to a lots of frustrations and demands in life especially those who live in city. For example, inflation has led to those who live in city face many difficulty in their life and eventually lead to increase in stress level. For student with tons of homework given by teacher will also make them stress if cannot finish it on time. Nevertheless, even with the increase of car in road also will make drivers and passengers stress due to traffic jam. Thus, stress can be shows in many ways in different kind of circumstance.

The stress response can let us stay alert and focused if working properly as this is the way that body protecting us. Stress can also protect our life during emergency action because it gives us extra strength and better reaction to defend ourselves or handle difficult situations. However, stress can cause a lots of problem if it is over its limit such as affecting our mood, health, productivity as well as our quality of life. We may get used of stress and did not notice that how much it affects us in a negative way.

Every people experiences stress in different way because everyone behave and think differently. It can affect our mindset and behavior in certain way. With the changing of attitude of a person, it can affected our relationship in workplace and also home. Moreover, it can cause serious mental and physical health sickness if one person is suffer too much stress. Studies showed mental stress could increase the risk of depression and neurological disorders such as stroke. Early symptoms include poor memory, difficult to concentrate and have depressive feeling. Thus, it is important to be able to measure stress level and handle it if it is out of control.

Basically, stress is a reaction inside human body. Our nervous system will produced a kind of stress hormones such as adrenaline as well as cortisol in the sweat when we are facing stress. These hormones enable our body to face any emergency situation and also lower down the skin's resistance. For this, detection for stress level can be done by measuring skin conductance because body tissues such as skin is able to conduct electricity. This is how our nervous system be able to sending the information from one part of body to another. Besides that, the constant and slight variation of electrical activity found in skin can be measured and charted. Galvanic skin response is the fluctuation found in the skin's electrical conductivity based on certain conditions of our body.

It is an important element to measure the galvanic skin response for some of the psychotherapy and behavioral therapy. On the other hand, research on stress and anxiety level are also being carried out with this response. We also need to ensure that we can monitor our own stress level so that we can control ourselves. Thus, this compels the need for simple and economical tools to monitor one's mental stress level at office or home.

1.2 Problem statement

Stress always affects people in many ways. Everyone definitely facing stress in their life but experiences it differently. Serious stress issue can lead to severe mental and physical problems which have chain effect on our relationships at home, work, and school. Studies showed mental stress could increase the risk of depression and neurological disorders such as stroke. Early symptoms include poor memory, difficult to concentrate and have depressive feeling. Thus, it's important to have a device that we can use to measure mental stress and take prevention earlier before it affected the mind, body and behavior.

The state-of-art instrument to diagnose stress is cortisol sensor. It detects the hormone cortisol which is produced by the adrenal gland during stressed. Sample of cortisol can be found in the saliva. However, the issue of this instrument is that it required expensive microfluidic fabrication technologies and complex analysis techniques. Thus, developing an economical and portable tool to measure and monitor one's mental stress level is important.

1.3 Objective

- To review different diagnostic tools for mental stress.
- To design and implement a galvanic skin response sensor system to measure mental stress.
- To integrate the GRS with a data acquisition system.
- To refine the sensitivity of the Galvanic Skin Response Sensor for better classification of stress level.

1.4 Scope of study

First of all, understanding how stress can occur in people is important before the sensor can be design and implement. It is crucial because this symptom can become dangerous in certain situations.

Besides, the resistance of human body is also being investigated when the hormones is produced inside the sweat gland such as adrenaline and cortisol when stress occurred. The relationship of the hormone produce during stress and skin conductance is being studied. The sensor can detect the different conductance of the skin by using two electrodes if a person is under stress.

Afterward, the design and implementation of the galvanic skin response sensor is being study. It is because there are various kind of devices that can use the measure stress level in the market. However, most of it is expensive and the method used is complicated. Thus, a design of cheaper and simple galvanic skin response sensor is important. How the data is being collected is also an important factor to be learn as the data collected is used to analyses the accuracy of the device so that further improvement can be done.

1.5 Relevancy and Feasibility

The project is relevant to the Electrical and Electronics Engineering because it required those knowledge to build the device. The understanding of the relationship between skin conductance and resistance with the stress level required electrical knowledge's. Besides, Basic circuit understanding is needed in order to understand the components properties, how they connect to each other's and also the voltage and current flow.

On the other hand, the microcontroller such as Arduino Board is used to integrate the circuit with the laptop for data collection and analysis. Programming skills is needed in build up a code to integrate the board and process it to show the output in the laptop. Nevertheless, engineering analysis skills is necessary to analyses the output and do discussion for further improvement on the device.

Galvanic Skin Response Sensor is a feasible project because stress is getting common nowadays in this fast develop world. People are easier to feel stress from many aspect such as work, relationship, unable to achieve something and so on. Thus, this device helps people to detect the stress level with simple analysis. It is a very economical device as compared to other same function devices such as EEG and HRV which is expensive and required sophisticated understanding skills. GSR sensor is more user-friendly because it only measure the change in skin resistance to get the stress level in voltage form.

Chapter 2

LITERATURE REVIEW

2.1 Critical Analysis

There are a few kinds of method that are used to study human's emotional state such as detecting the stress level of someone. In [1], electrodermal activity (EDA), heart rate (HR), heart rate variability (HRV), Electrocardiography (ECG), electroencephalogram (EEG), and galvanic skin response (GSR) have also been widely used to determine the emotional state of people by researchers. Those methods also act as an indicator of human response towards to stress. From all of the methods above, the most common and widely use method is by using heart rate measurement, EEG and skin conductance level which also known as SCL. Most of the stress detection method is carry out in lab because of the portability limitation. That is the reason why [1] state that people still unable to measure their stress level which will bring an impact to their health. Thus, a study to build a portable device to measure stress level is highly recommended.

One of the most common way of measuring stress level is the EEG which also known as electroencephalography. It is widely use in biomedical research to study about the human brain. The studies of measuring human stress level using EEG can be found in [2] and [3]. Generally, they use different signal frequency features and classify different data acquired by brain activity because EEG is the reflection of brain activity. In order to improve the efficiency and performance of the system, a suitable segments of EEG signals must be selected. In [2], the subject is being stressed under pictures induction environment. The best segment of signal is being selected and the EEG parameters is being extracted using linear and nonlinear method. The classification can obtained the accuracy of 82.7 % by using the Elma classifier which is a great improvement. Besides that, [3] also use another method of classification to process the EEG signal which called as Brain-Computer Interface (BCI). The performance of the classifying the EEG signal which is correlated to

the chronic mental stress can reach up to 90% of the accuracy by extracting the EEG using Magnitude Square Coherence Estimation (MSCE).

On other hand, Heart Rate Variability is being discussed in [4] with its capability for being another parameters to measure mental stress. It is used to measure the autonomic nervous system status by measuring the changes in length of time of consecutive heartbeats. The interval between two heartbeats is known as RR interval and it is measured in milliseconds from the peak of an R wave to another. The paper in [4] used the HRV and Galvanic Skin Response (GSR) together to measure the stress level because GSR alone is unable to identify the condition of the most vital organ of human body which is the heart. It is important to understand the cardiac responses in condition of anxiety, stress or even anger so that any diseases can be identify and the physician can guide his patients which would help them to regulate their health condition.

A device can be found in [5] which also used heart rate (HR) and also galvanic skin response (GSR) to detect stress. However, the system in [5] is different with the system in [4] because it contained stressor which is based on the fuzzy logic. Basically the device used fuzzy logic to analyze different data from both HR and also GSR. The purpose of using the fuzzy logic is to induce the stress properly to the subject to obtain a set of data for study and validate. This stress-detection system required a fast decision from the subject which is suitable to stress them. It is very simple and noninvasive thus very suitable for real applications. The accuracy of the system can reached up to 99.5% when the period for the measurement is last for 10s.

On the other hand, research in [6] shows that an ambulatory device is being developed to measure the autonomic nervous system (ANS) in blind people in order to help them measure stress level. The device measures heart rate, electrodermal activity and also skin temperature by using a noninvasive sensors. The blind subject is required to walk in urban space by following a charted course which involve a set of conditions. The heart rate and the electrodermal activity is being is being analyzed. The results shows that the subject is getting stress when there are some obstacles appear suddenly. These results are very useful

in the process of developing an ambulatory device to measure stress under real life conditions.

Besides that, stress can be also detected by using speech in [7]. The studies shows that respiration is related with certain emotional situation because a person respiration will increase when he/she experience a stressful experiment. In the experiment, GSR and speech signal are being collected and trained using the classifiers. The results for the speech signal actually have more predictive power than the GSR signal but it is also more person dependent. Based on the result using Support Vector Machine (SVM) classifiers, the accuracy for stress detection reach 92%. Moreover, Voice Stress Analysis (VSA) found in [8] can also use to detect stress which almost similar with the method in [7] but it is more complicated. It can measure fluctuations in the physiological micro tremors present in the body muscle which includes the vocal cords. Generally, the frequency range for the micro tremor is between 8 to 12 Hz when not stressed. In this paper, the Adaptive Empirical Mode Decomposition (AEMD) which is the time-frequency analysis method is used for the voice stress detection.

As for the Galvanic Skin Response (GSR) sensor, there are various studies of propose different functions of GSR in biomedical with the concept of measuring skin conductance [9]. For example, the studies in [10] shows that sweat level can use to diagnose the diabetes by diagnose Sudomotor Dysfunction first. The concept is that when the different low voltage amplitude pulses are applied on the electrodes, the response of the electrical current of the skin is measured. The skin conductance is then calculated from the applied voltage as well as the measured current. Thus, it can be used to predict disease such as diabetes accurately. Besides that, the other types of medical application is that sweaty hand can also be used to detect epileptic attack as in [11]. Besides that, GSR can also be used to detect stress level which lead to a stress sensor is being developed based on GSR in [12]. In this paper, the GSR sensor is used to measure the skin conductance by wrapping the sensor around the subject fingers. The data are collected by using the Analog to Digital Converter which is the ZigBee boards and the output is collected in the form of voltage

and displayed in the laptop. From this experiment, the GSR sensor is able to detect the stress state with an accuracy of 76.56%.

GSR is actually a simple and useful device to measure the stress level by using the hormone produce in sweat gland when nervous. Theoretically, GSR is a change in the electrical properties of the skin in response to different kinds of stimuli. In the paper of [13], a new way to analyze the GSR signal patterns is by using the principle component analysis (PCA). This paper shows that PCA is used to evaluate the measurements and differentiate the GSR signal with the healthy and psychotic patients. Generally, the output of the GSR sensor can be measured using the changes in the voltage from the surface of the skin during measurements.

In [14], a wearable sensing devices is developed to study the human emotions with the GSR signal. The features of GSR signal is being extracted and categorize using the classifiers for identifying the emotion. The high accuracy of classifier will contributed to improving the human mental health for the future by applying this system. However, the paper stated that there are a few challenges for this system because disturbance always happen by subjective or objective factor when monitoring the subject such as the subject is not focus or subject is too sleepy. On the other hand, GSR signal is affected by environment easily such as temperature, humidity or even the body movement and this causes inaccurate for the results obtained.

The resistance of human body is inversely proportional to the stress based on galvanic skin response theory in [1]. When a person is extreme stress, his/her resistance of skin can be reduced to 500kilo-ohms or less. On the other hand, the resistance can reach to 2 mega ohms or more when is in relax state. The changes of resistance is caused by the secretion of hormones such as adrenaline into the bloodstream and intensify the concentration. Thus, electricity conductance can be measured. However, it is not only the body resistance that will change when the hormone is secreted, the body heart rate will also increase and the body reflexed become quicker. In the paper of [15], principal component analysis is used to analyses the evoked GSR which is almost similar with the paper in [13]. PCA reduce

the dimension of the GSR data and saving as much information as possible. The overall rating for the method can reached up to 82% of accuracy.

2.2 Summary of GSR Literature Review

Although Galvanic Skin Response Sensor is a very useful device to measure the stress level, it also had its limitation. The accuracy will be affected when a subject is in different position such as sit, stand, walk or jump. Usually the subject is being tested in the lab for the stress level measurement which generally rested in a fix position. In paper [16], it state that it is impractical to exclude the physical activity that will affected the results when developing a pervasive stress monitoring system. Thus, this paper studied the change of physiological responses caused by the mental stress with different body position. In this paper, ECG is used together with GSR to get a better accuracy of detecting the stress level while the body position is controlled by the accelerometer. The results gathered is being studied and classified. It shows that it can achieved a 92.4% of accuracy for stress classification for 10-fold cross validation as well as an 80.9% of accuracy for between-subjects classification.

Chapter 3

METHODOLOGY AND PROJECT WORK

3.1 Research Methodology

Several methods have been used in conducting a research on the project topic:

1. Literature survey on mental stress and its measurement tools

2. Literature survey on hardware implementation of galvanic skin response sensor

3. Discussion with project supervisor

3.1.1 Literature survey on mental stress and its measurement tools

In order to carry out the project, an analysis and better understanding of the galvanic skin response is done in the early stages of the project development. Basic understanding on how the stress occurred as well as how to measure the stress level using the galvanic skin response and others measuring tools must be learned. In order to get all these knowledge, study through the research papers from other researchers is important.

3.1.2 Literature survey on hardware implementation of galvanic skin response sensor

The way to build the sensor has been review and each of the components needed to build the device is studied. This is to prevent any waste of components and to ensure that the device is construct without any incompatible issues. Therefore, some manual and datasheets have been utilized fully to search for the information.

3.1.3 Discussion with Project Supervisor

The title for this project is given by the project supervisor. In order to better understand on how the project is going to be carry out, a frequent meeting with supervisor is necessary.

3.2 Project Methodology

1. Various journals and researches papers are being studies to understand more about on how stress can occurred and how to measure it.

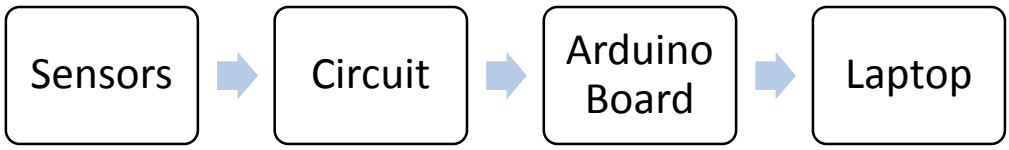
2. The relationship between the stress level and the skin conductance is being studies and various methods which have the similar function as galvanic skin response sensor are also being investigated.

3. Suitable types of components will be identified and have to be purchased in order to build the galvanic skin response sensor to measure mental stress. The steps to construct the device is being studied.

4. Once the device is complete, it will be integrated with the analog to digital components for data analysis.

5. Data will be gathered and being analysis for the accuracy of the device. Discussion is being done for the improvement for further research after analyzing the data.

3.3 Galvanic Skin Response Sensor Block Diagram



1. Sensors - The sensors are used to measure the skin conductance to detect the stress level. It is because when human is stress, the resistance in the body will reduce. Thus, skin conductance can be measured.

2. Circuit - The circuit is used to produce output voltage with the skin resistance. On the other hand, it is use to filter out noises and also amplifying the GSR signal.

3. Arduino - Board The Arduino Board is use to connect the sensor circuit with the laptop for data analysis. It also contain the A/D converter to convert the analog signal to digital signal in order to read the data in laptop.

4. Laptop - The laptop is used to study the data gathered and do analysis by using certain software such as Simulink.

3.4 Tools and Components

1.	Resistors 10MΩ	**x3**	**7.**	Battery holder, 2xAA	**x1**
2.	Resistors 10kΩ	**x2**	**8.**	Batteries, AA	**x2**
3.	Capacitors: 10nF	**x1**	**9.**	Breadboard	**x1**
4.	Capacitors: 0.1µF	**x1**	**10.**	Galvanic Skin Response Sensor	**x1**
5.	Op-Amp IC, MCP6241	**x1**	**11.**	Arduino Board	**x1**
6.	Laptop	**x1**			

3.5 Gantt chart

3.5.1 FYP 1

No	Details	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Selection of Project Topic														
2	Study and Research on Stress and Galvanic Skin Response Sensor														
3	Purchasing of Components needed														
4	Submission of Extended Proposal														
5	Project Work and Prototype Testing														
6	First Prototype Completion														
7	Proposal Defense and Progress Evaluation														
8	First Prototype Testing Completion														
9	Submission of Interim Draft Report														
10	Submission of Interim Report														

Processes Milestones

3.5.2 FYP 2

No	Details	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Continue of Project Work															
2	Data Collection and Analysis															
3	Reconstruct Prototype into PCB															
4	Submission of Progress Report															
5	Continue Project Work and Prototype Testing															
6	Submission of Draft Final Report															
7	Submission of Dissertation (soft bound)															
8	Submission of Technical Paper															
9	Final Viva															
10	Submission of Project Dissertation (Hard bound)															

Processes Milestones

3.6 Project Works

1. The project started with the researched on the relationship between the stress level as well as the skin conductivity. The GSR methods as well as other methods of measuring stress such as EEG and HRC is studied and compared.

2. After gathered the information for the Galvanic Skin Response theories, the circuit of the GSR Sensor is draw using the Multisim software. The circuit is drew as showed below:

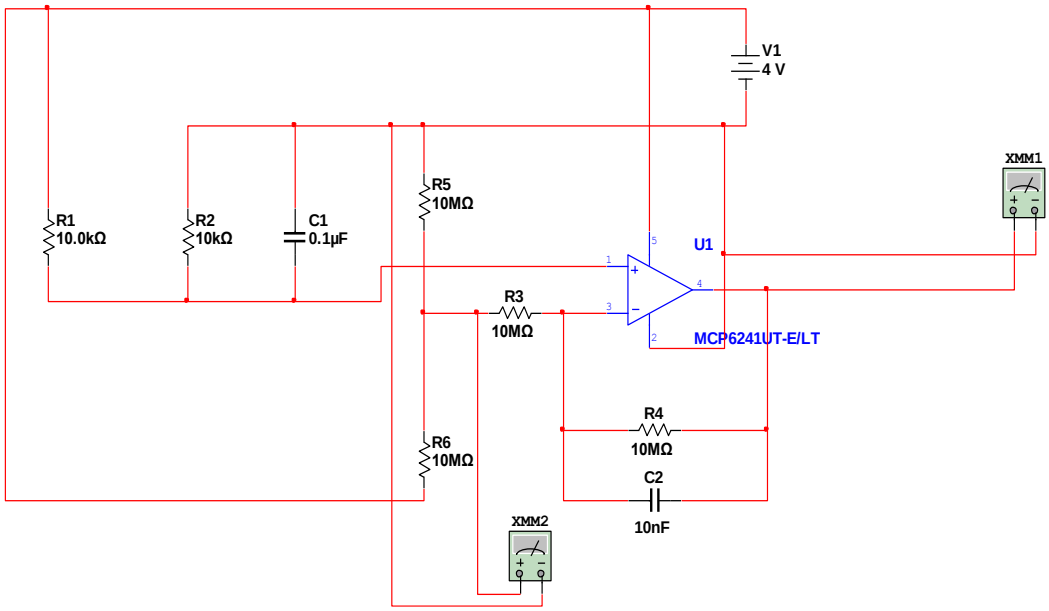


Figure 1: The Galvanic Skin Response Circuit

3. After the circuit is sketched, it is run to ensure that the circuit is working by Multimeter before the omp-amp as well as the output to check the voltage results. The result is shown in Chapter 4.

4. After ensure the circuit is working, the components are purchased and the prototype is built. The prototype is shown in Chapter 4.

5. The circuit is connected to the microcontroller which is the Arduino Board as shows below. The board named Arduino Uno and this board enable to collect the analog output from the circuit and display in the laptop which helps in data collection for the device.

Figure 2: Arduino Board

6. In order to integrate the board with laptop. Arduino and Processing software is used. Arduino software is used to read the board that connect to the laptop while the Processing software is used to generate the output. The processing code enable to display an Arduinoscope which shows the output signal graph.

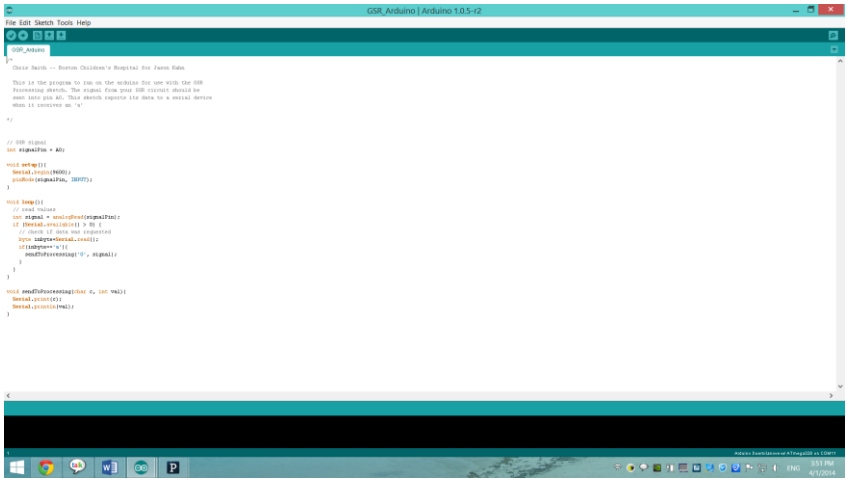


Figure 3: Arduino code

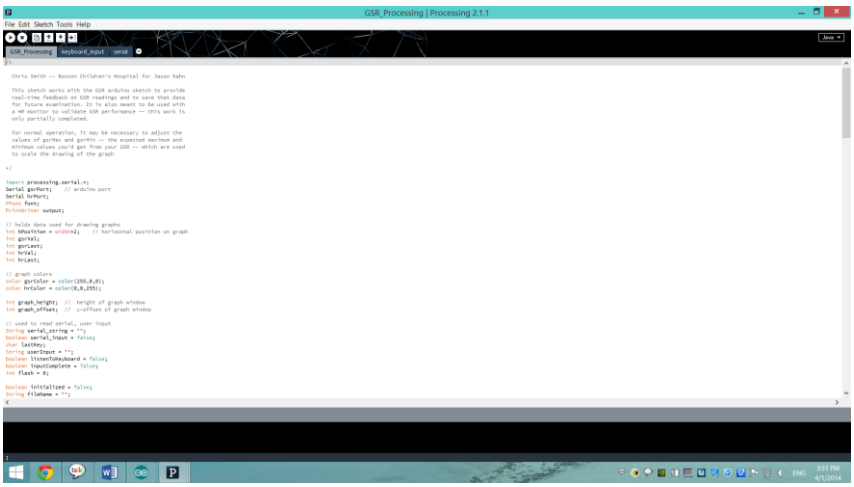


Figure 4: Arduinoscope Processing Code

7. The Galvanic Skin Response Sensor output signal is being collected in term of sensor value for analysis.
8. The collected data is being compiled in Microsoft Excel and band-pass filtering using MATLAB by setting the frequency from 0.48Hz to 4.8Hz.
9. The filtered graph is being analyzed to determine the threshold for the number of stress detected.

3.7 Circuit Explanation

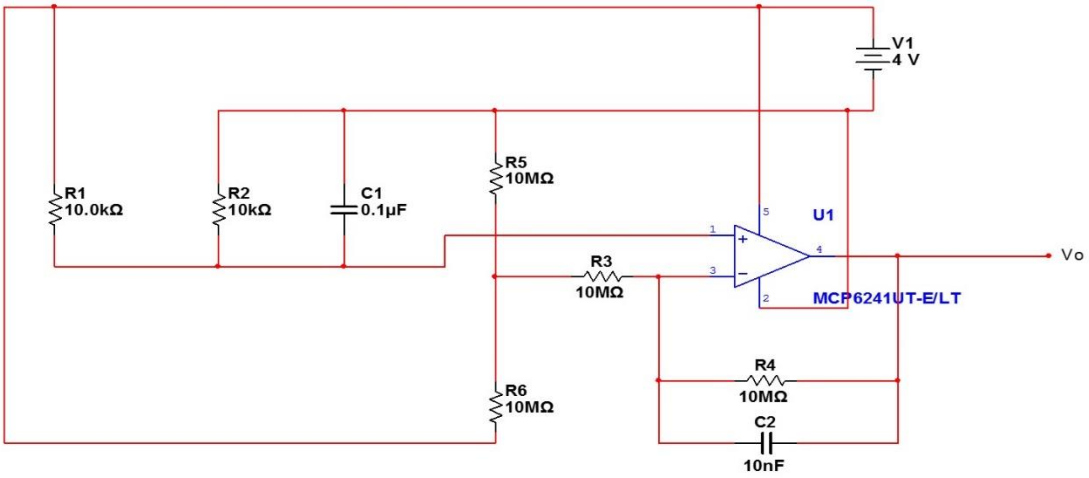


Figure 5 : GSR Circuit

Based on the circuit above, R6 is the resistance across human body which used for the measurement of skin conductance. The resistance of human body usually fluctuates between 50k to 100M ohms. So 10 M ohms is used for R5 in order to linearize the relationship between R6 and also Vo. However, it will create a very high impedance which is susceptible to noise.

Therefore, the signal is buffer with an op amp in order to convert the high impedance to low impedance so that the high impedance will not interfere with the desired operation. On the other hand , the circuit is also connect with low pass filter to remove any high frequency noise (60Hz) because GSR is a slow signal (1~2Hz). Value of R3 and R4 is the same, so the circuit has no amplification.

In order to accommodate the non-linearities of the op amps, the input of the op amp is set to be at the middle of the power supply which generated from R1, R2 and C2.

The voltage across the body resistance is: $Va = \frac{10M\Omega}{10M\Omega+R6}V1$ and the output voltage is $Vo \approx \frac{R_4}{R_3}(Vref - Va) + Vref.$

3.8 Stress Test Methodology

1. Five students are being selected as the test subjects for the GSR Sensor.
2. They are required to test for the relax state and stress state.
3. Three different position (sit, stand and walk) are required for each state to collect the data for different position because position will affected the accuracy of the device.
4. In the relax state, the subjects are sitting, standing and walking quietly without any interruption.
5. In the stress state, the subjects are required to do a set of mathematic questions in one minute in MATLAB as shown below :

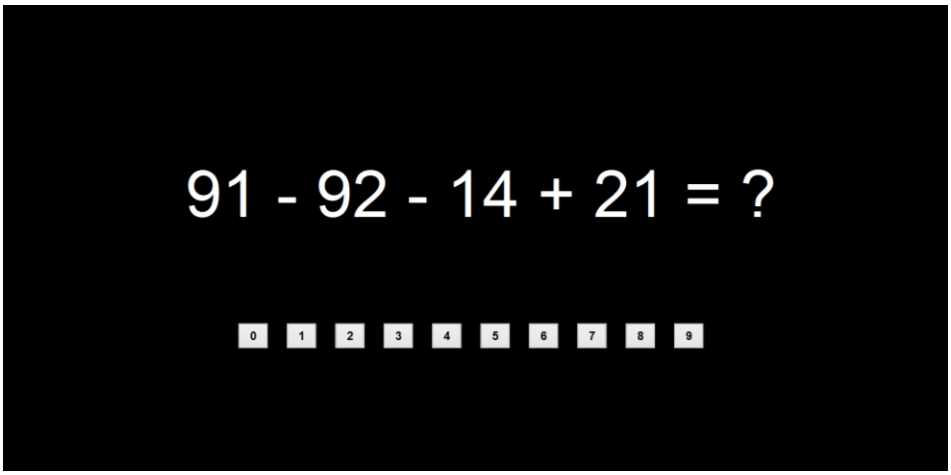


Figure 6: MATLAB mathematic question

6. The data are collected when the subjects are being relaxed and stressed. Each position last for a minute.
7. The data are in term of sensor value which is the GSR value. The maximum value for GSR is 1024 which equals to 5V. Thus 1GSR=0.004882812V.
8. The data collected is being analyze and band-pass filtered from 0.48Hz to 4.8Hz.
9. The graphs are plotted in Chapter 4.
10. The number of stress detected is being determined by setting up the threshold using the average of absolute maximum of the value of relax and stress state.
11. The data collected is showed in the table in Chapter 4.

Chapter 4

RESULTS AND DISCUSSIONS

4.1 Simulation of circuit

The results of simulation of Multisim is shown below:

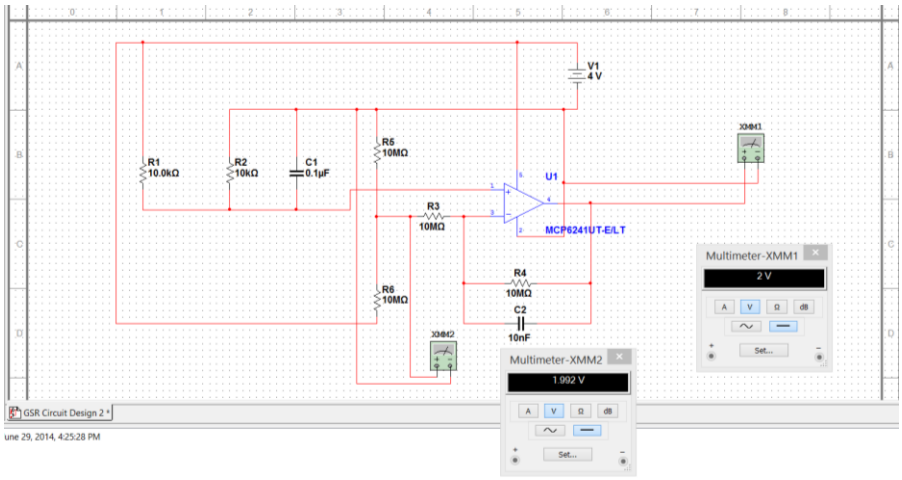


Figure 7: The schematic for GSR circuit

From the diagram, we can see that there are 2 multimeters. First multimeter is put before the omp-amp while another one is put at the output voltage. GSR theory state that when there is a drop in resistance, the voltage will increases as body skin conductance increases. R6 is the body resistance where multimeter 2 measured the voltage at that point (Va).

4.2 Prototype

4.2.1 First prototype built based on the circuit designed

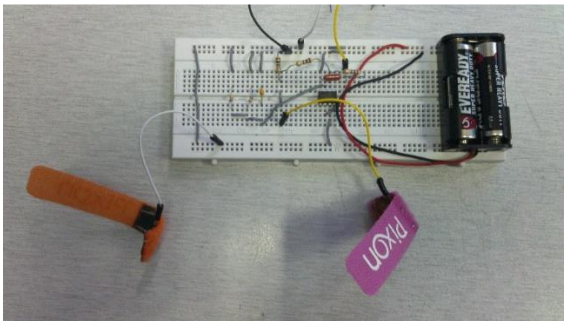


Figure 8: First GSR Sensor Prototype

4.2.2 Prototype connect with Arduino board to display result in laptop

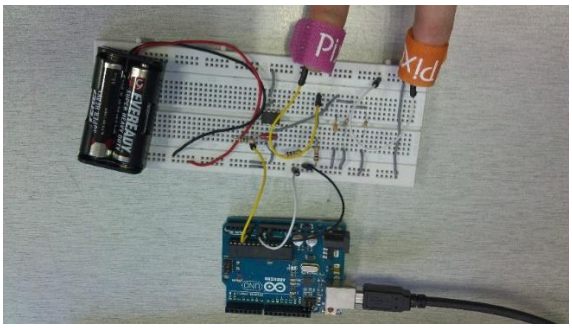


Figure 9: Connection of Prototype with Arduino Board

4.2.3 Final Prototype connect with Arduino board to display result in laptop

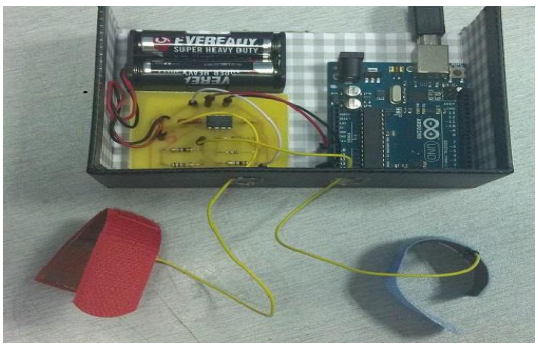


Figure 10: Final Prototype

4.3 Analyze the change in resistance to the output voltage

The results from the changed in resistances to be voltage output is recorded as below. From the table, the Theoretical values are based on formula calculation where experimental values are based on the testing using the prototype.

Table 1 : Change in Va and Vo to the resistance value

RL (ohms)	Va (Theoretical)	Va(Experimental)	Vo (Theoretical)	Vo(Experimental)
1.00E+04	3.996	4.033	0.004	0.161
3.30E+05	3.872	3.882	0.128	0.312
6.60E+05	3.752	3.642	0.248	0.464
1.00E+06	3.636	3.467	0.364	0.581
2.00E+06	3.333	3.167	0.667	0.913
5.00E+06	2.667	2.643	1.333	1.567
1.00E+07	2	2.023	2	2.041
2.00E+07	1.333	1.587	2.667	2.441

Figure 11: Resistance Value

The resistance range is from 10kΩ to 20MΩ.

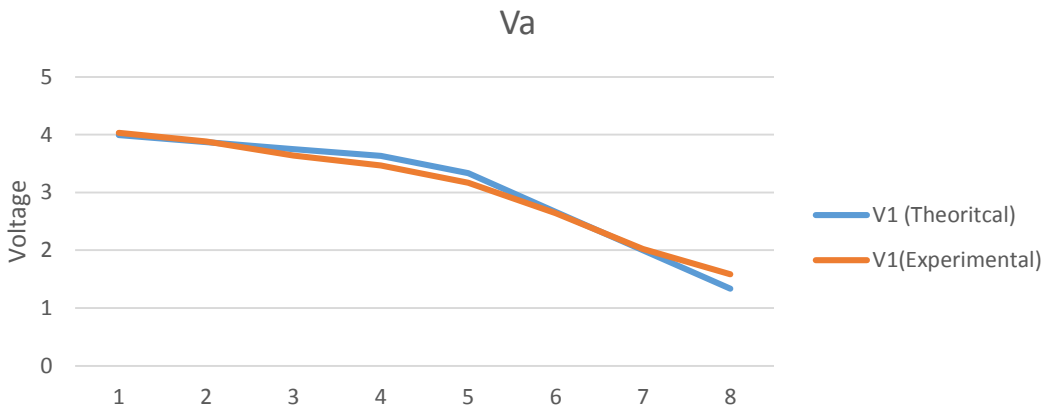


Figure 12: Change in Va based on change in resistance

The Va is measured at the point where the resistance changes. The theoretical circuit calculation is $Va = \frac{10M\Omega}{10M\Omega+R6}V1$, where V1 is the input voltage which is 4V. Based on the equation, when R6 increase, Va will be decrease. In the graph, the blue line is the theoretical value based on calculation where orange line is the experimental value based on prototype. The results is very near.

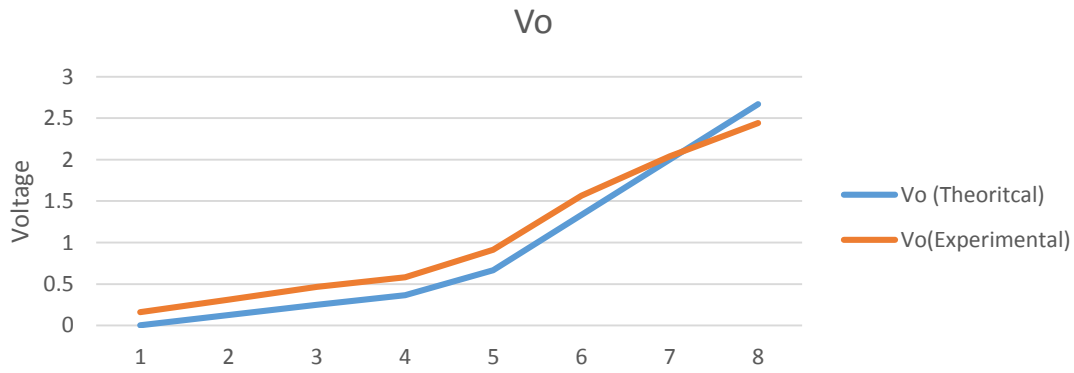


Figure 13: Change in Vo based on change in resistance

Vo is measured from the output of the circuit. The theoretical circuit calculation is $Vo \approx \frac{R_4}{R_3}(Vref - Va) + Vref$. From the equation, we can see that when Va is increasing, Vo will decreasing. This means that when R6 increase, the Vo will also increase as shown from the graph above. The blue line is the theoretical value based on calculation whereas the orange line is the experimental value based on prototype. The results are very close.

4.4 Analyze the output signal of prototype with a subject

By using the Arduino as well as the Processing software. The output graph can be show in the laptop. The results are shown as below:

4.4.1 Subject sitting quietly

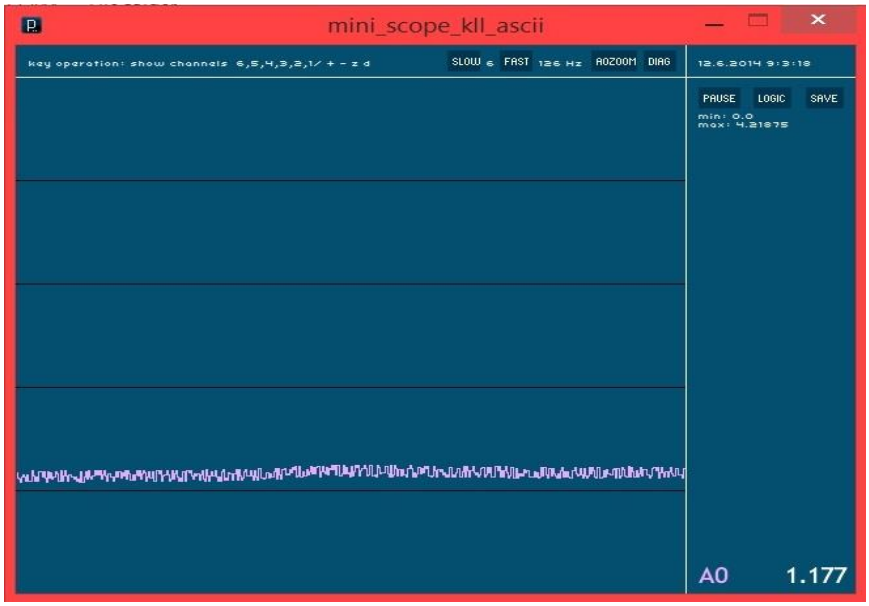


Figure 14: GSR output signal 1

Based on the figure above, the graph shows the output of the Galvanic Skin Response Sensor. The test subject is sitting quietly and it shows a smooth line for the output signal.

4.4.2 Subject take a big breath

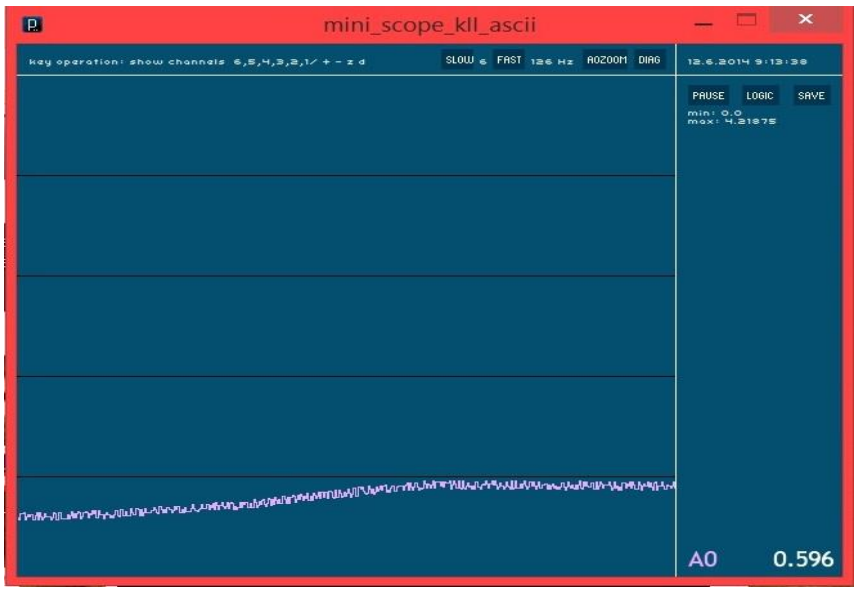


Figure 15: GSR output signal 2

From the graph above shows the subject is taking a big breath. We can see that the signal is slowly going down which make a change in the output voltage value. This means that there is a change in resistance in body when the subject is taking a big breath.

4.5 Analyze the output signal for relax and stress state

4.5.1.1 Student 1 in Microsoft Excel

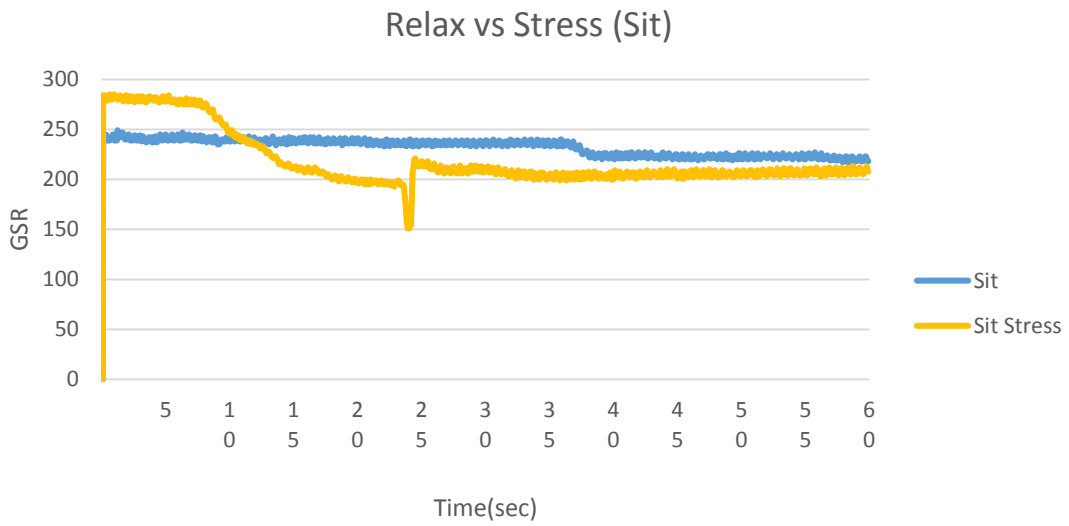


Figure 16 : Student 1 Relax vs Stress (Sit)

Based on the graph, we can see that the blue line is when subject 1 sitting in relax state, the graph is more straight. There is a little spike at the beginning is mostly likely due to the finger touching the circuit. On the other hand, the the subject 1 is being stres by doing calculation, the GSR value is slowly reducing and we can see the spike at around 25sec which means the subject got stress a little bit.

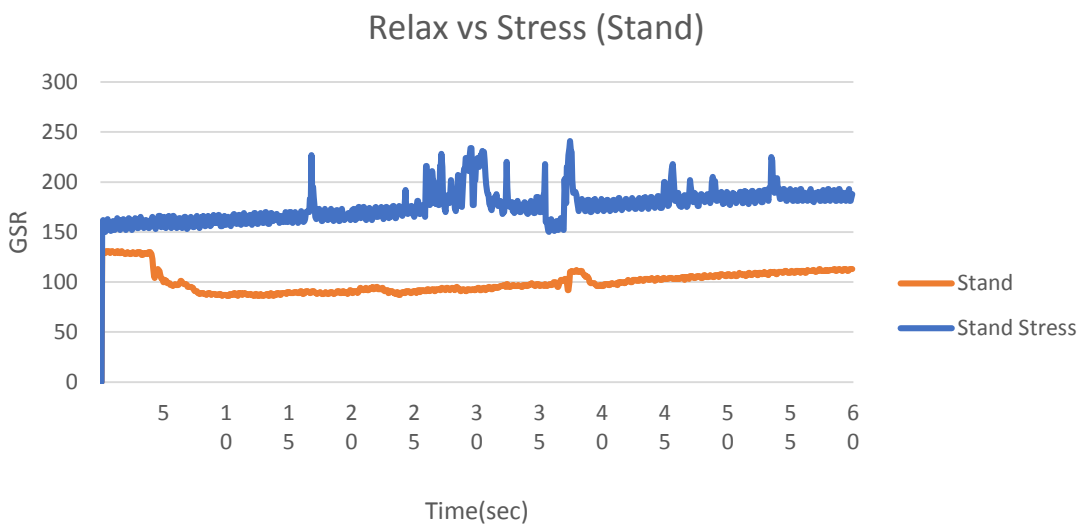


Figure 17 : Student 1 Relax vs Stress (Stand)

When the subject 1 is standing, the relax state is still very constant which is a almost a straight line for orange line. However, the subject 1 got a few times of big spike from around 10 to 25 sec when the subject is being stress with mathematic questions.

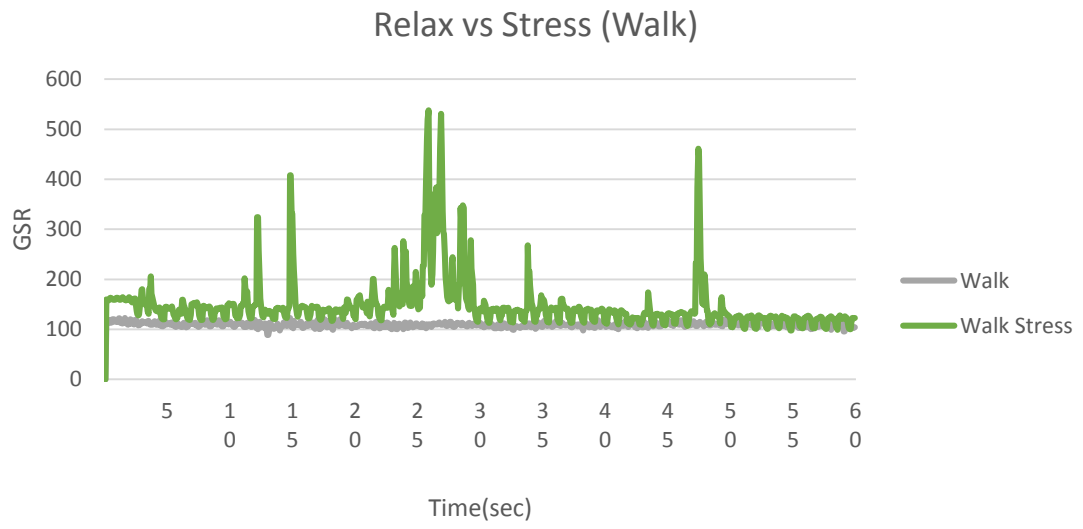


Figure 18 : Student 1 Relax vs Stress (Walk)

As for walking position, the subject 1 got a very constant result with walking position in relax state which can be seen in grey line. On the other hand, when the subject is walking while being stress up with the calculation, we can see a few large spike in the GSR value.

4.5.1.2 Filtering Student 1 graph in Matlab

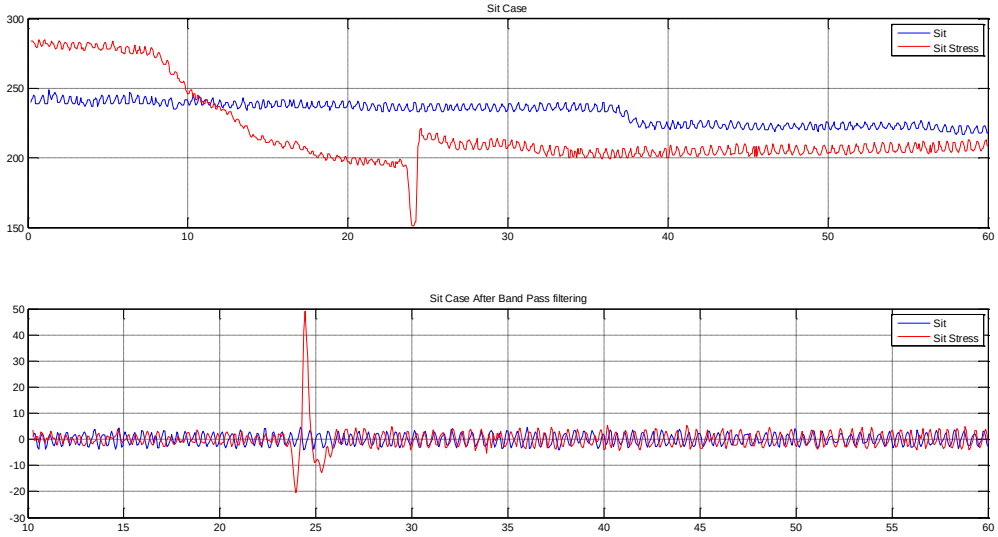


Figure 19: Sitting Case after band pass filtering

- Stress detection threshold for sitting = 4.9492
- Number of sit stress detected during stress state = 33
- Number of sit stress detected during relax state = 0

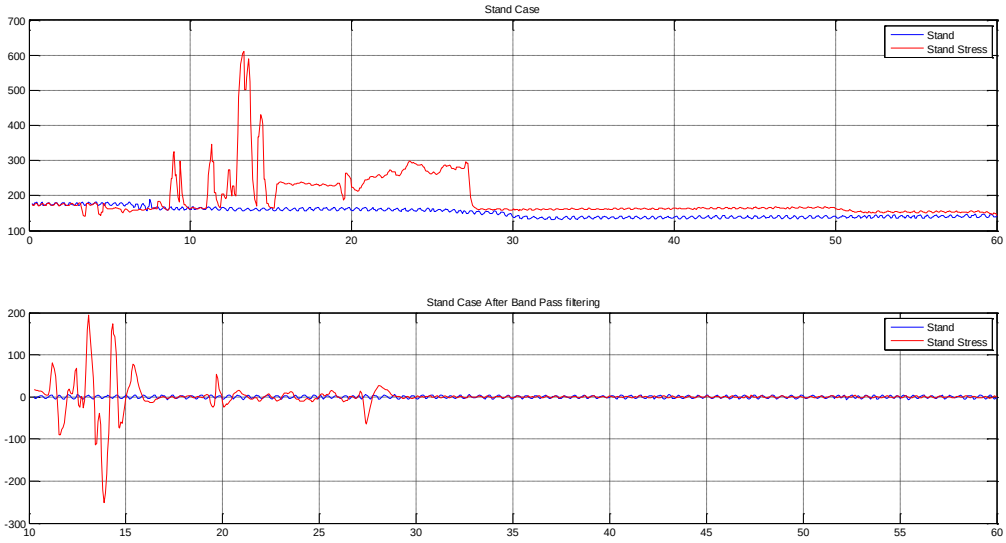


Figure 20: Standing Case after band pass filtering

- Stress detection threshold for standing = 48.2464
- Number of stand stress detected during stress state = 47
- Number of stand stress detected during relax state = 0

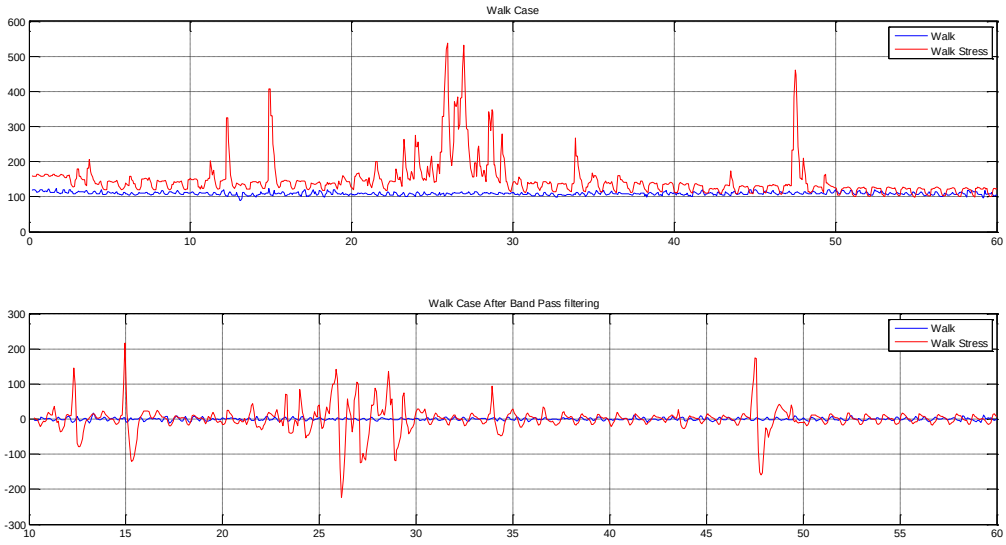


Figure 21 : Walking Case after band pass filtering

- Stress detection threshold for walking = 21.6197
- Number of walk stress detected during stress state = 172
- Number of walk stress detected during relax state = 0

4.5.2.1 Student 2 in Microsoft Excel

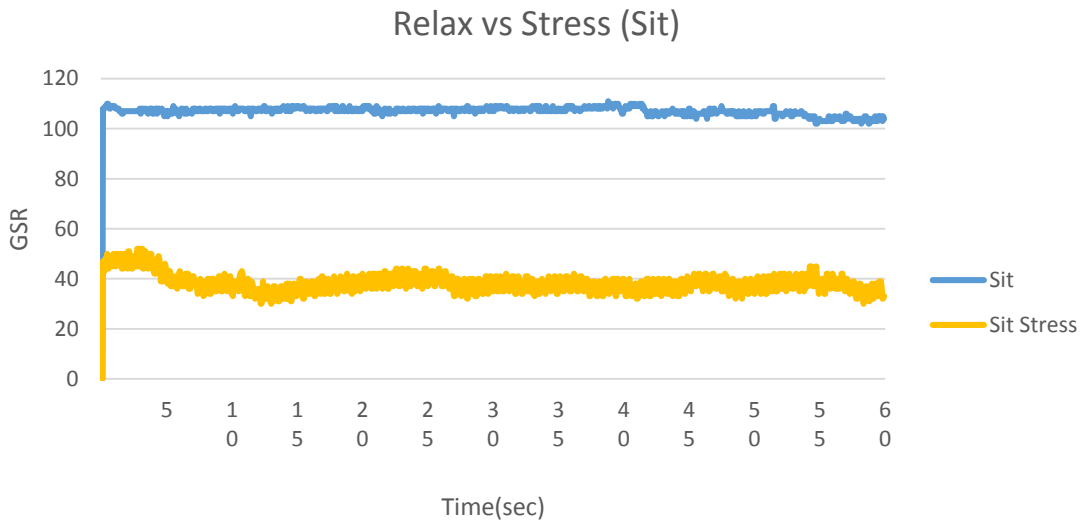


Figure 22 : Student 2 Relax vs Stress (Sit)

For the blue line, the subject 2 initially is having a small spike for the relax state which likely due to disturbance from outside source during testing. Afterward, it got a very constant straight line. When the subject is being stress up, we can see that the yellow line is unstable.

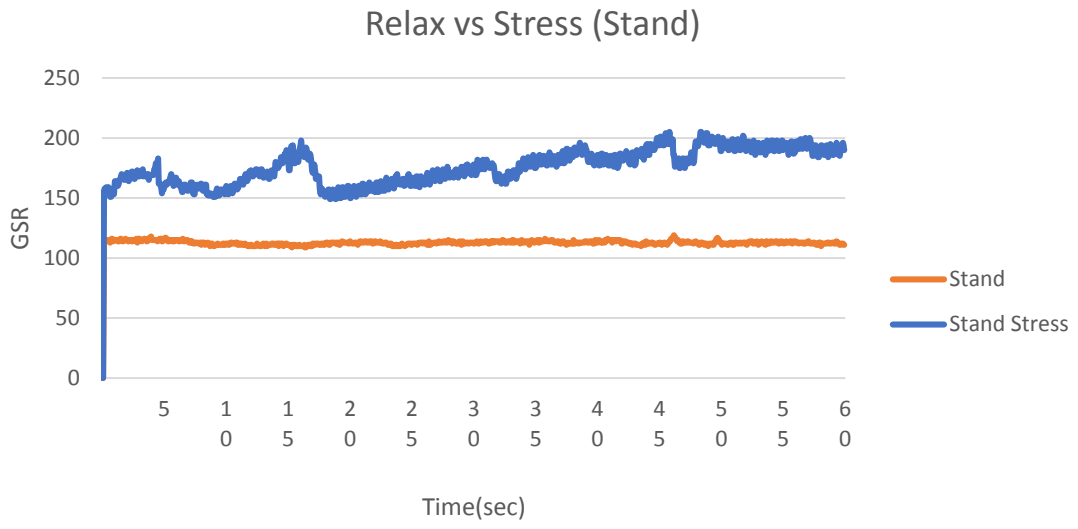


Figure 23 : Student 2 Relax vs Stress (Stand)

Based on the graph above, the subject 2 is having a constant GSR value for relax state which is the orange color. However, when he is being stressed up with the

calculation, we can see that there is fluctuation in the GSR value which is show in blue line.

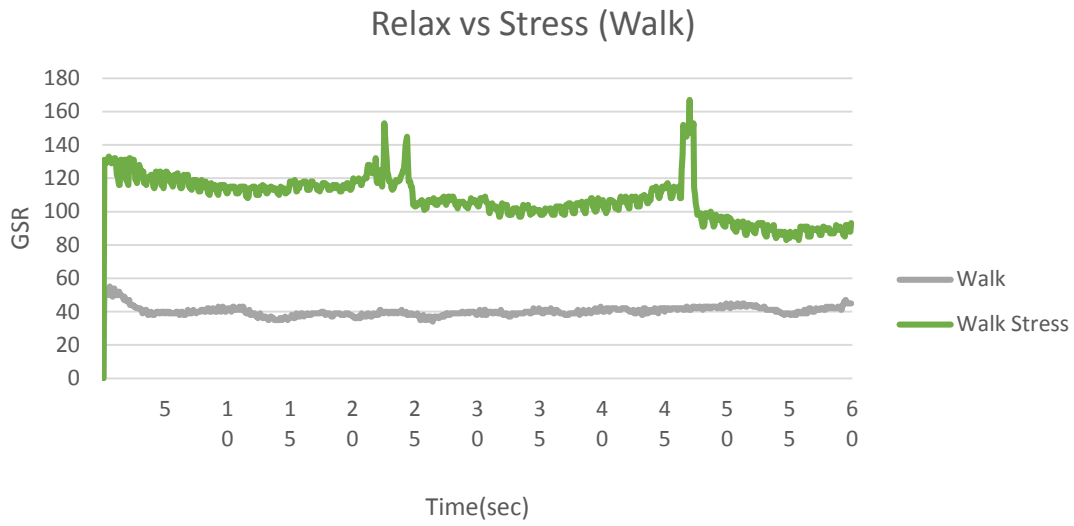


Figure 24 : Student 2 Relax vs Stress (Walk)

The subject 2 relax walking state is quite constant which can be seen in grey line but there is a few small spike which likely due to the disturbance such as noise from outside. While the green line shows that the subject 2 is being stress with mathematics and there is a drop in GSR value as well as a few obvious spike.

4.5.2.2 Filtering Student 2 graph in Matlab

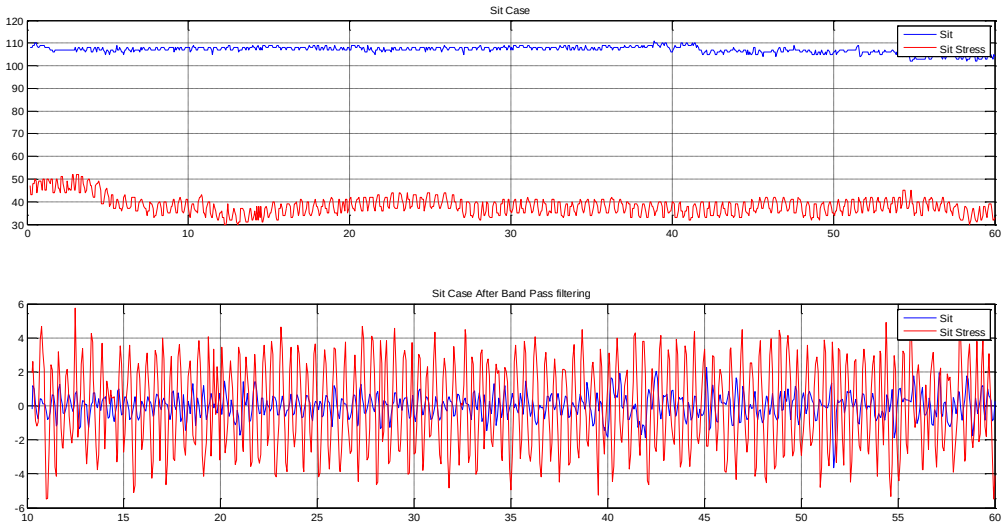


Figure 25 : Sitting Case after band pass filtering

- Stress detection threshold for sitting = 3.9798
- Number of sit stress detected during stress state = 63
- Number of sit stress detected during relax state = 0

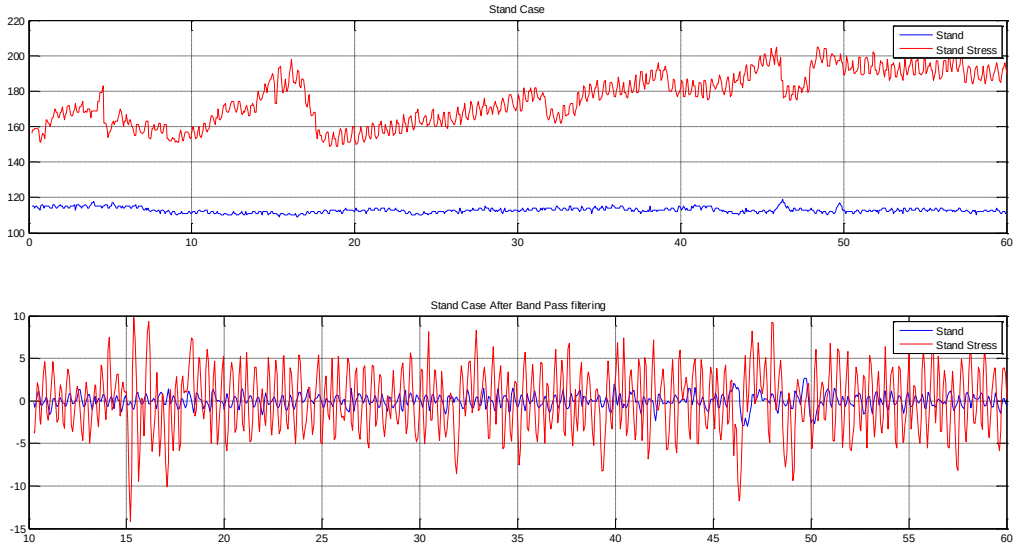


Figure 26 : Standing Case after band pass filtering

- Stress detection threshold for standing = 7.9667
- Number of stand stress detected during stress state = 22
- Number of stand stress detected during relax state = 0

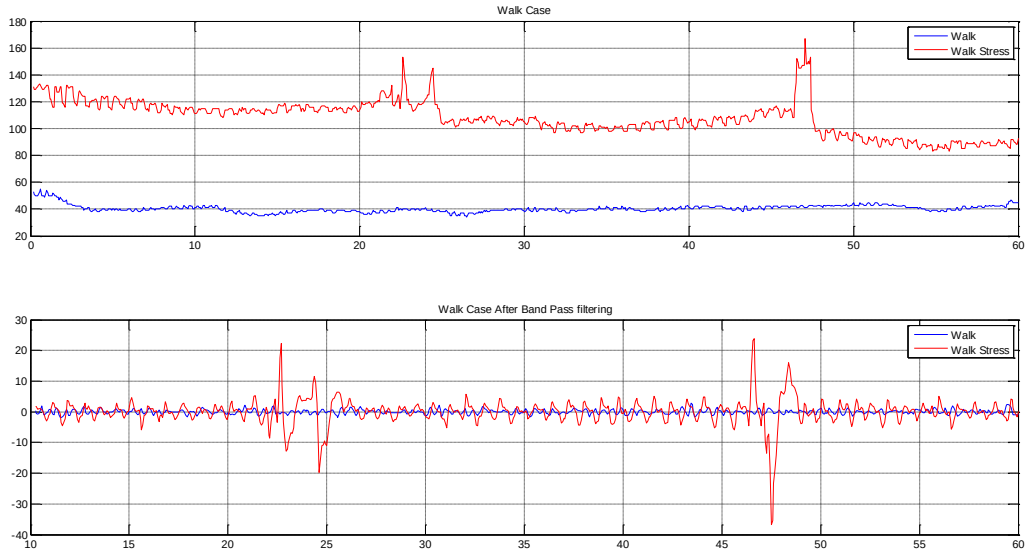


Figure 27: Walking Case after band pass filtering

- Stress detection threshold for walking = 4.3329
- Number of walk stress detected during stress state = 97
- Number of walk stress detected during relax state = 0

4.5.3.1 Student 3 in Microsoft Excel

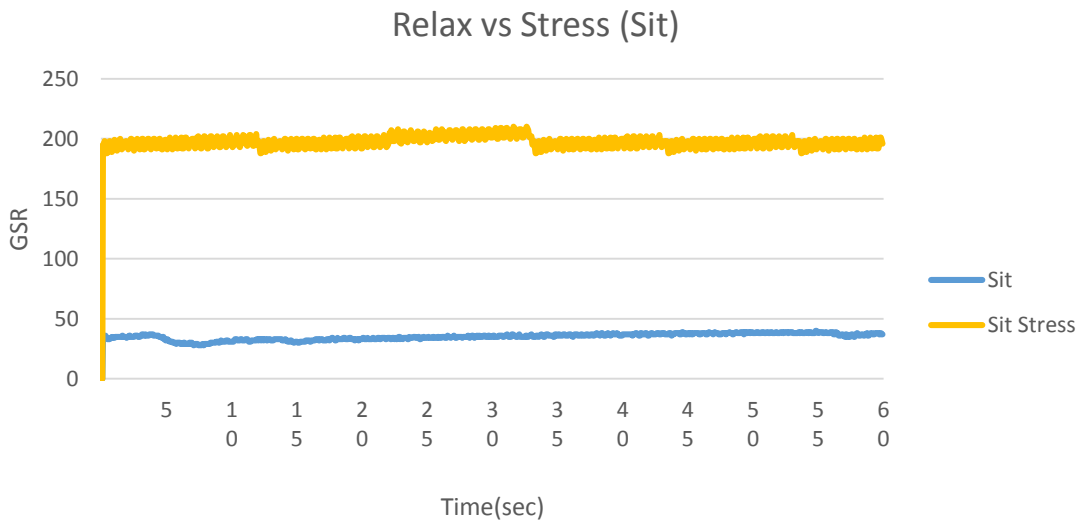


Figure 28 : Student 3 Relax vs Stress (Sit)

The subject 3 relax sitting state which shows in blue line is also very constant without and interruption. On the other hand, the yellow line is unstable. Although

there is no obvious spike in the yellow line, but the unstable condition of yellow line also shows that the subject 3 is being stressed up by the mental calculation.

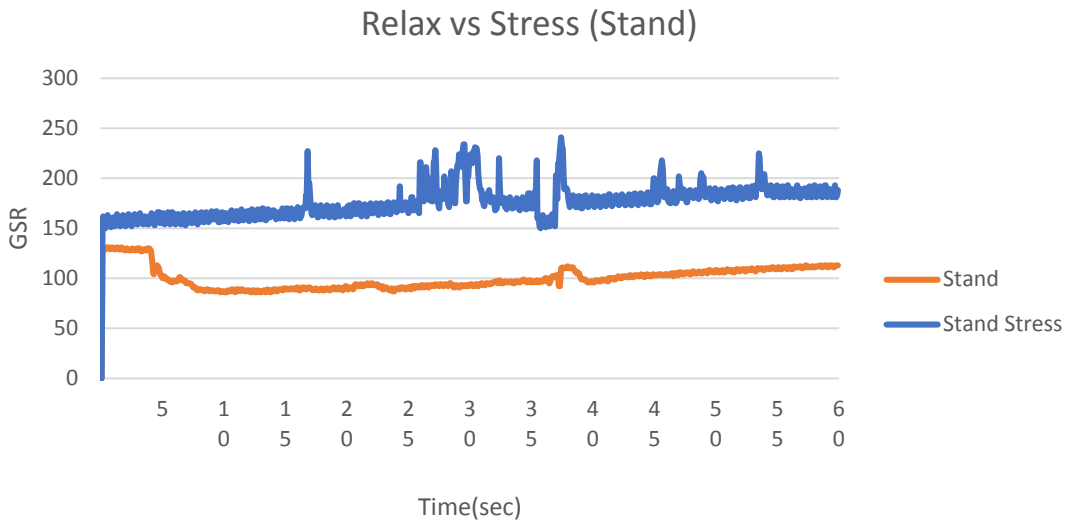


Figure 29 : Student 3 Relax vs Stress (Stand)

The subject 3 got a quite constant orange line graph when he is standing in relax state but sometime a small disturbance is unavoidable. As for the standing in stress state, we can see there are a few spike when the subject is doing mental calculation. This shows that the subject is being stress up.

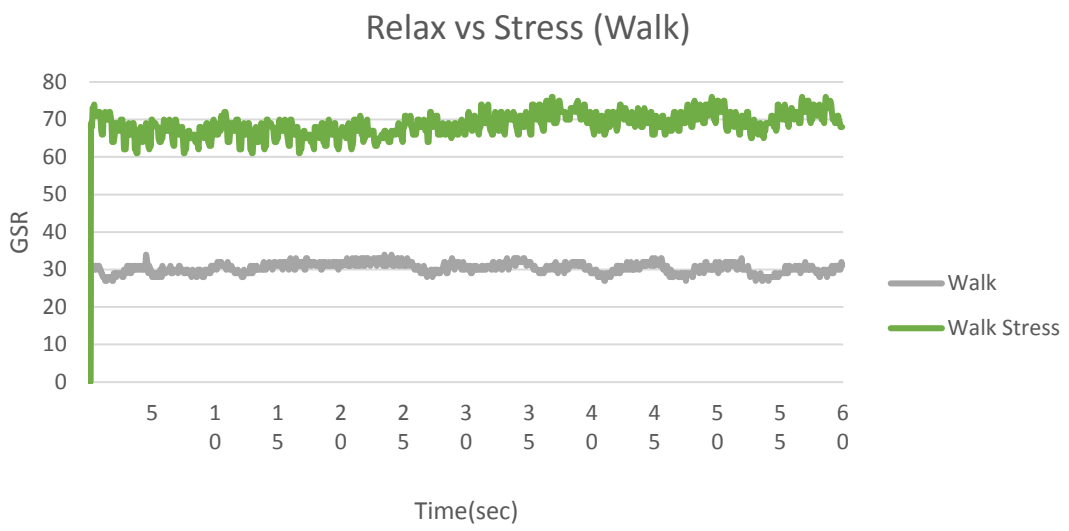


Figure 30 : Student 3 Relax vs Stress (Walk)

In walking position, subject 3 got constant but minor unstable at 30sec which likely due to the interruption from the outside noise. On the other hand, subject 3 already understand the trick to do the calculation, this is where the subject is able to get a very constant reading for walk stress without any spike in green line.

4.5.3.2 Filtering Student 3 graph in Matlab

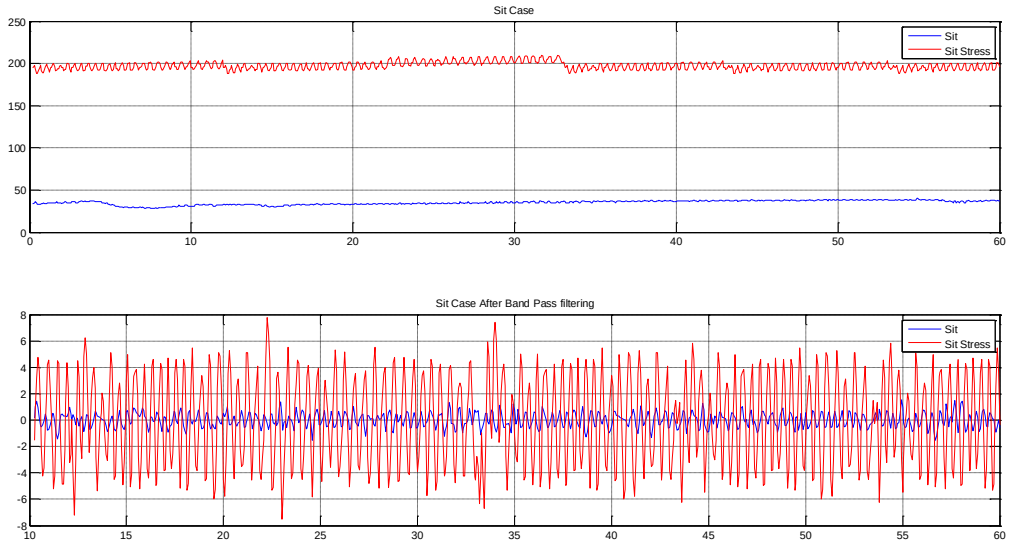


Figure 31 : Sitting Case after band pass filtering

- Stress detection threshold for sitting = 3.6305
- Number of sit stress detected during stress state = 294

- Number of sit stress detected during relax state = 0

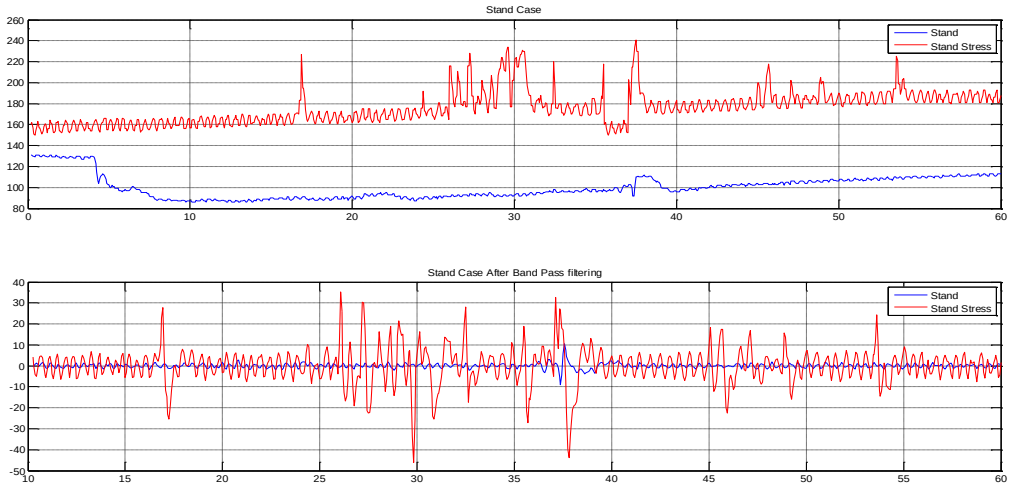


Figure 32 : Standing Case after band pass filtering

- Stress detection threshold for standing = 11.5464
- Number of stand stress detected during stress state = 93
- Number of stand stress detected during relax state = 0

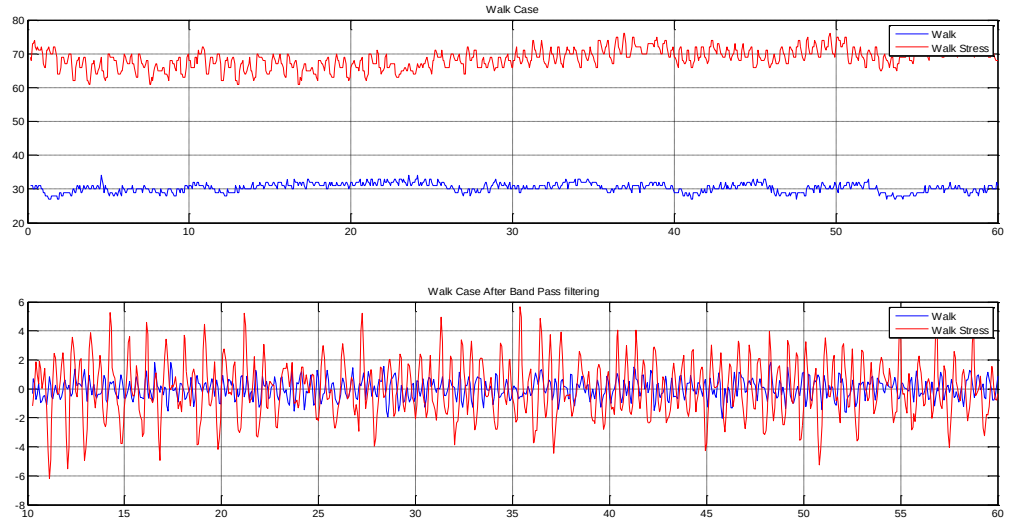


Figure 33 : Walking Case after band pass filtering

- Stress detection threshold for walking = 3.972
- Number of walk stress detected during stress state = 32
- Number of walk stress detected during relax state = 0

4.5.4.1 Student 4 in Microsoft Excel

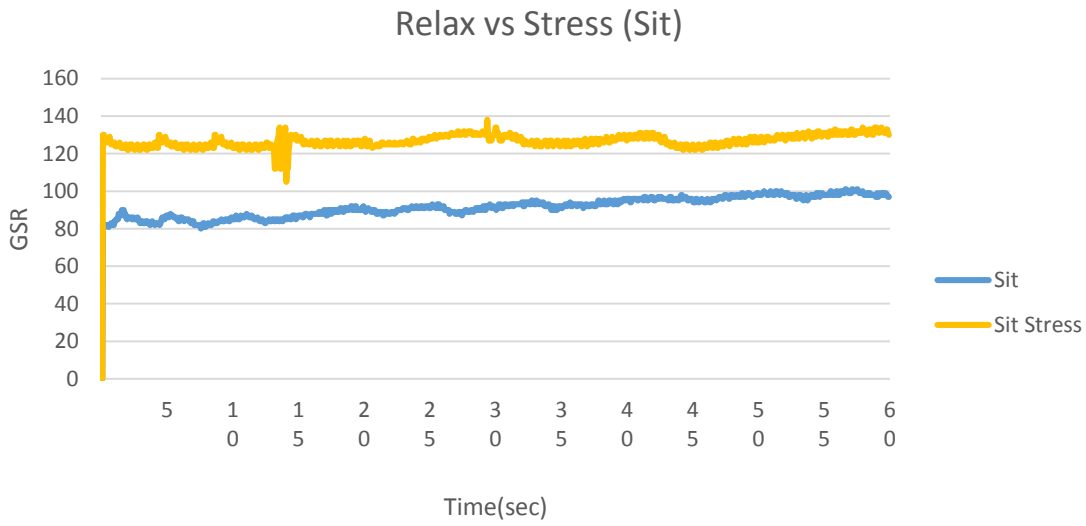


Figure 34 : Student 4 Relax vs Stress (Sit)

As for student 4, the blue line graph which indicate the sitting relax state is quiet constant overall. The yellow line which indicate the sitting stress state does shows a spike at 15sec and 30 sec which means at that time the student might feel nervous or a little bit stress.

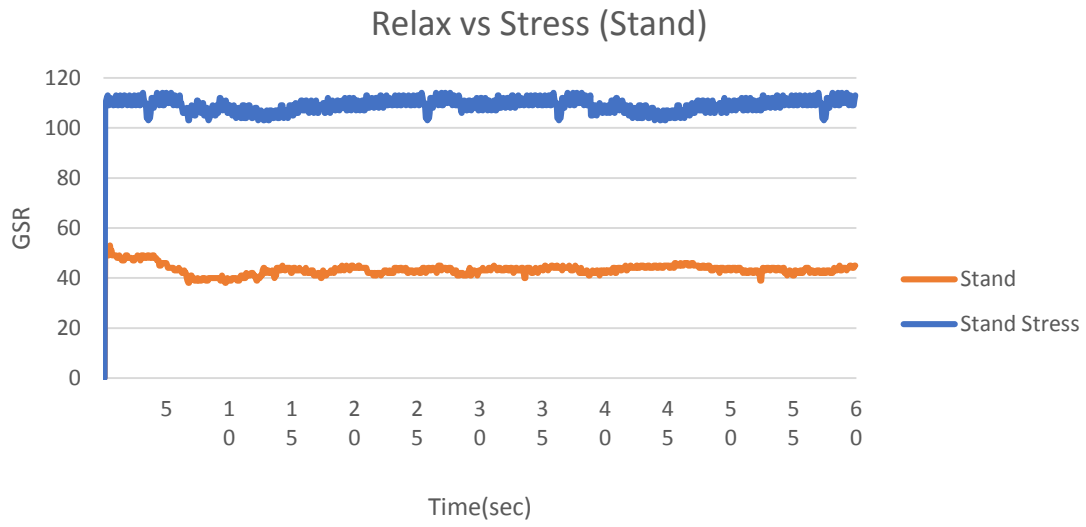


Figure 35 : Student 4 Relax vs Stress (Stand)

When student 4 is in standing position, the relax state (orange line) and stress state (blue line) GSR value is very close. However, we can see that when he is in relax

state, the graph does shows a more constant results as compared to the stress state which fluctuate more.

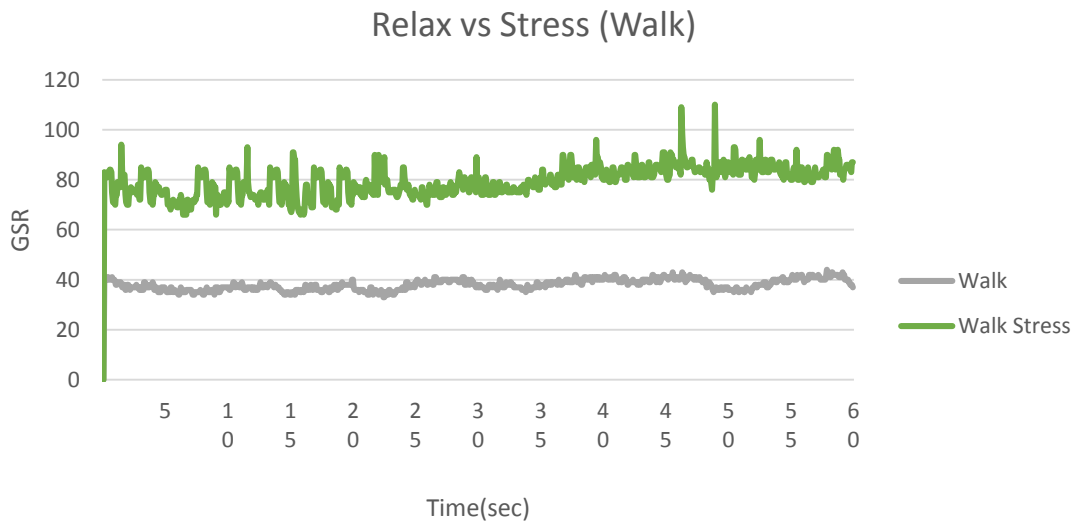


Figure 36 : Student 4 Relax vs Stress (Walk)

When the student 4 is in walking position, the relax walking state shows a very constant graph which show in grey color. It does shows a constant change in amplitude for relax state but this mostly likely cause by heavy steps. As for the stress state show in green line, the results are more unstable and fluctuate a lot which most probably cause by the stress test.

4.5.4.2 Filtering Student 4 graph in Matlab

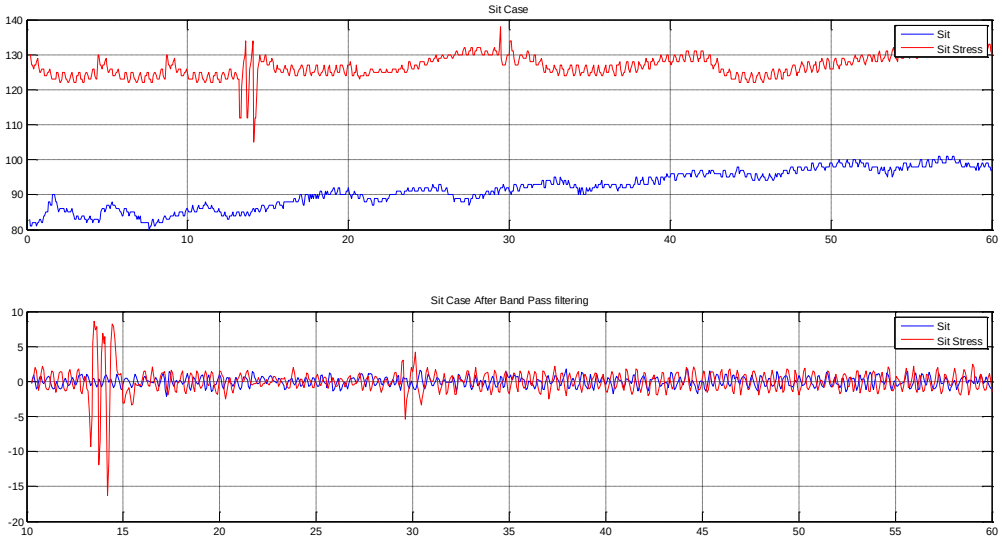


Figure 37: Sitting Case after band pass filtering

- Stress detection threshold for sitting = 3.589
- Number of sit stress detected during stress state = 21
- Number of sit stress detected during relax state = 0

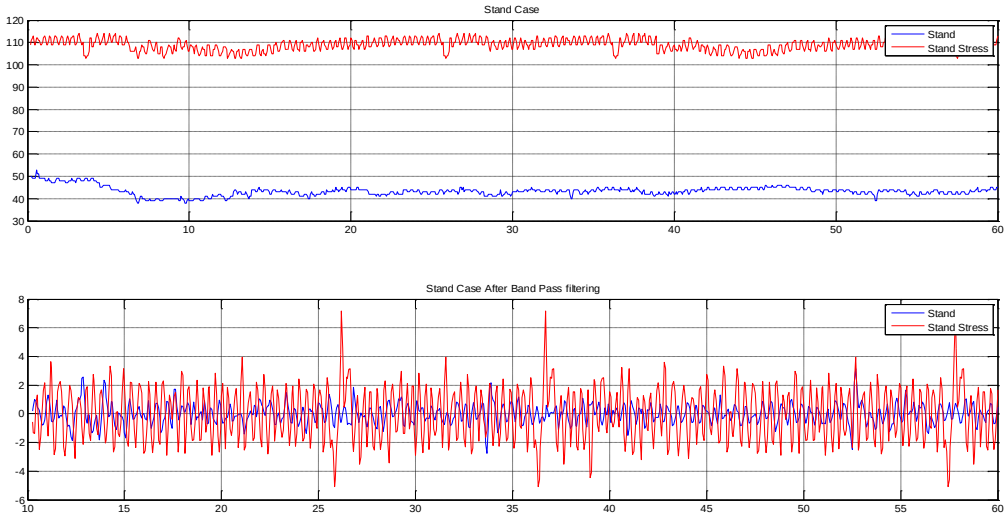


Figure 38 : Standing Case after band pass filtering

- Stress detection threshold for standing = 4.6975
- Number of stand stress detected during stress state = 6
- Number of stand stress detected during relax state = 0

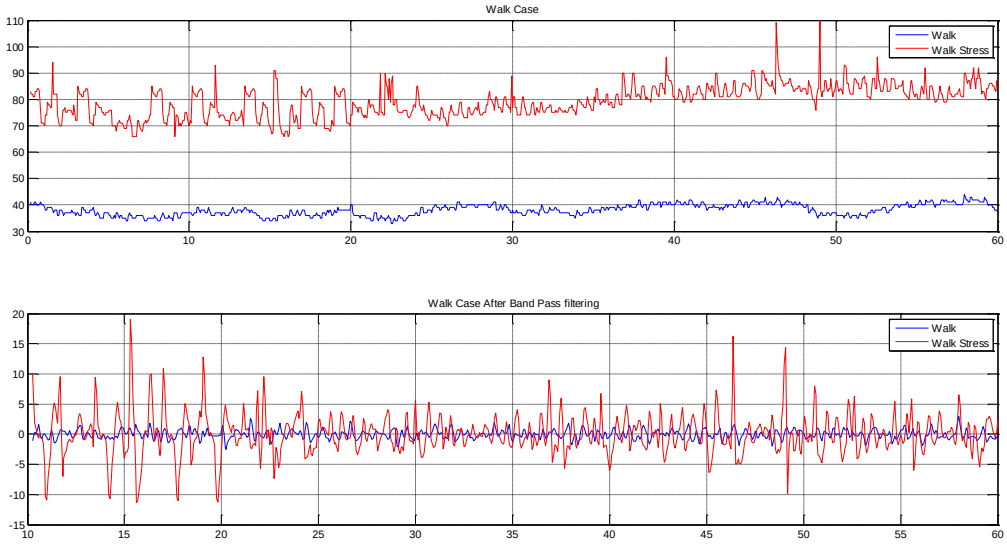


Figure 39 : Walking Case after band pass filtering

- Stress detection threshold for walking = 6.6441
- Number of walk stress detected during stress state = 45
- Number of walk stress detected during relax state = 0

4.5.5.1 Student 5 in Microsoft Excel

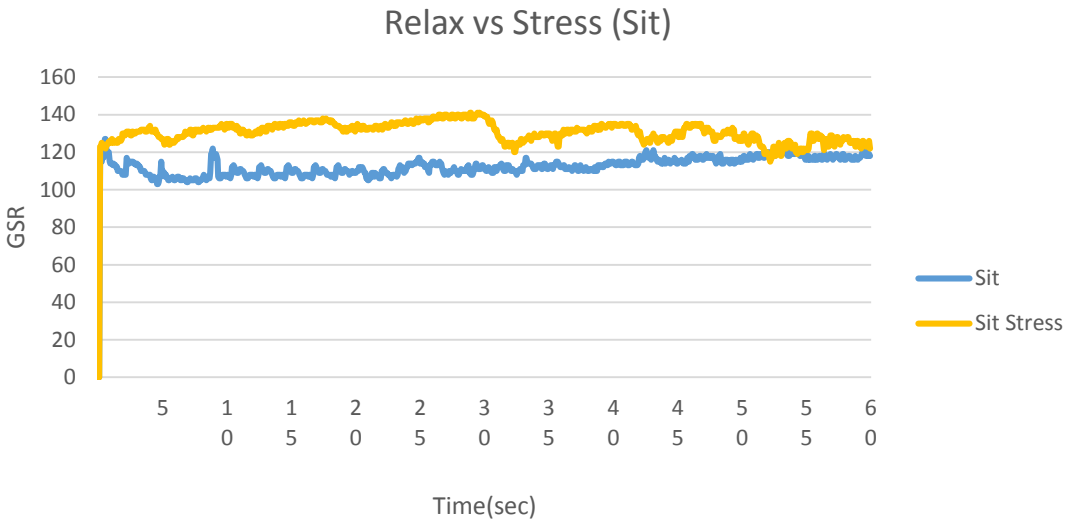


Figure 40 : Student 5 Relax vs Stress (Sit)

Student 5 gave a straight but unstable blue line graph which indicate relax state. The instability is mostly likely cause by the interference when doing the test where somebody is walking around. However, the sitting stress state which shows in yellow line does shows a more fluctuate graph when subject 5 is being stress by the calculation.

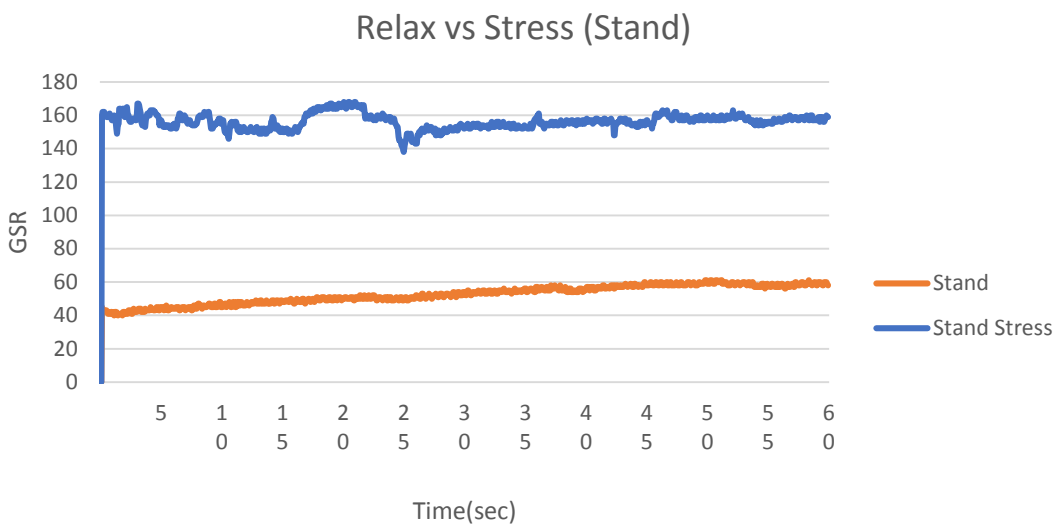


Figure 41 : Student 5 Relax vs Stress (Stand)

When the student 5 is in standing position, the results are almost same with the previous students. When he is relax which shows in orange color, the graph is stable and straight. On the other hand, when the subjects is being tested with the mental calculation, the blue line graph become unstable where it fluctuate with some spikes.

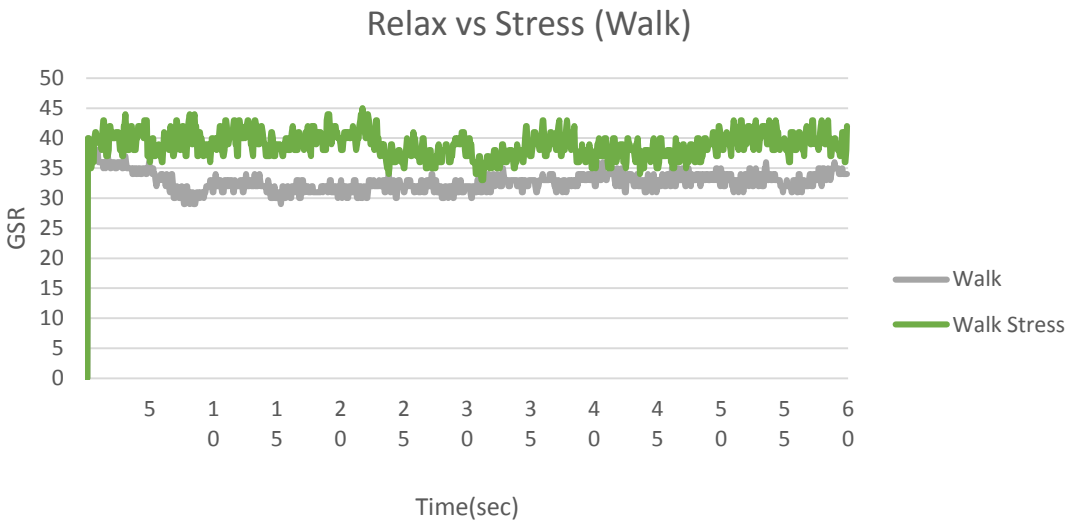


Figure 42 : Student 5 Relax vs Stress (Walk)

Lastly is the student 5 walking position for relax and stress state which shows in grey line and green line respectively. The walk in relax state is not very stable is

because the subject 5 walking steps is not constant. As for the stress state, the spike can only be found at around 40 sec which means the mental calculation does not stress subject 5 enough.

4.5.5.2 Filtering Student 5 graph in Matlab

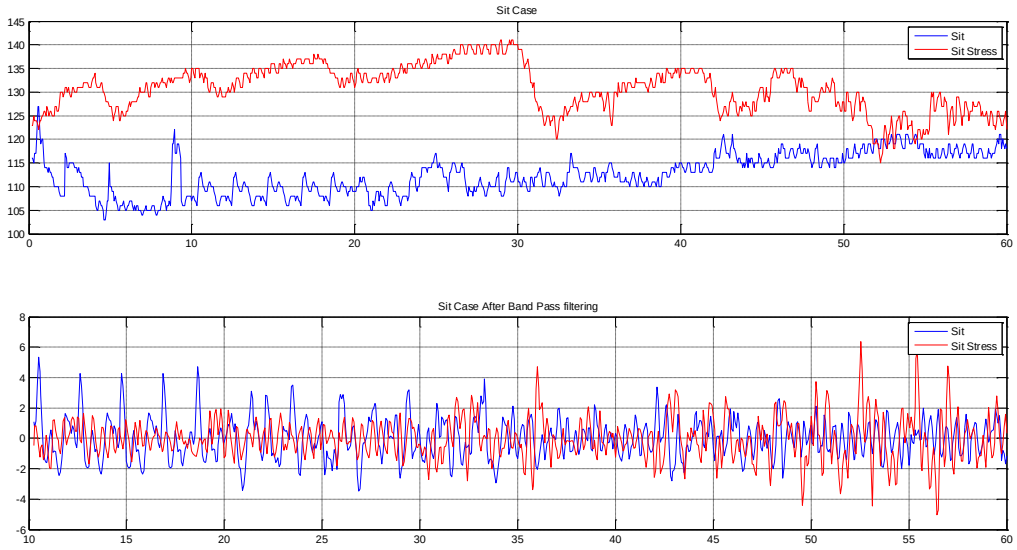


Figure 43: Sitting Case after band pass filtering

- Stress detection threshold for sitting = 7.095
- Number of sit stress detected during stress state = 0
- Number of sit stress detected during relax state = 0

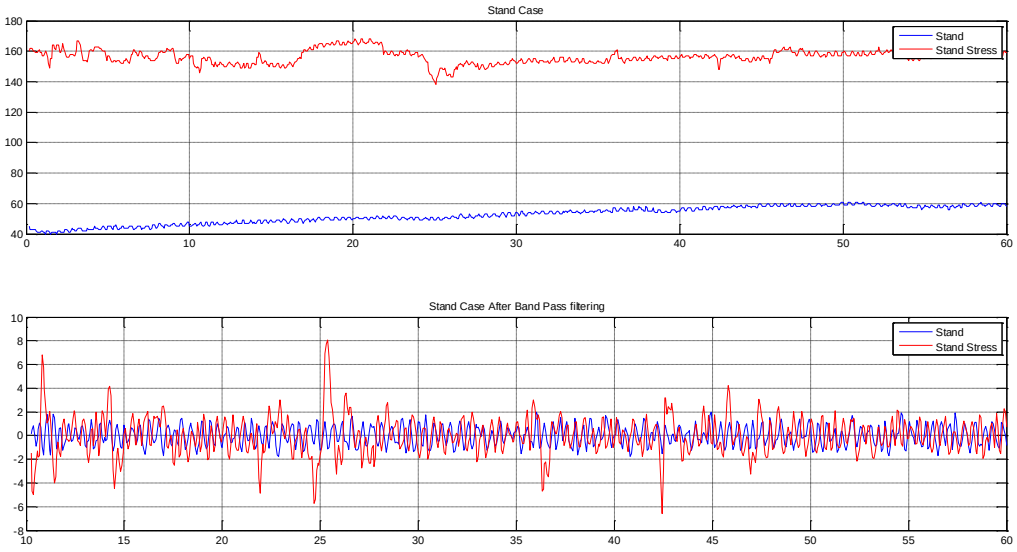


Figure 44 : Standing Case after band pass filtering

- Stress detection threshold for standing = 4.6628
- Number of stand stress detected during stress state = 13
- Number of stand stress detected during relax state = 0

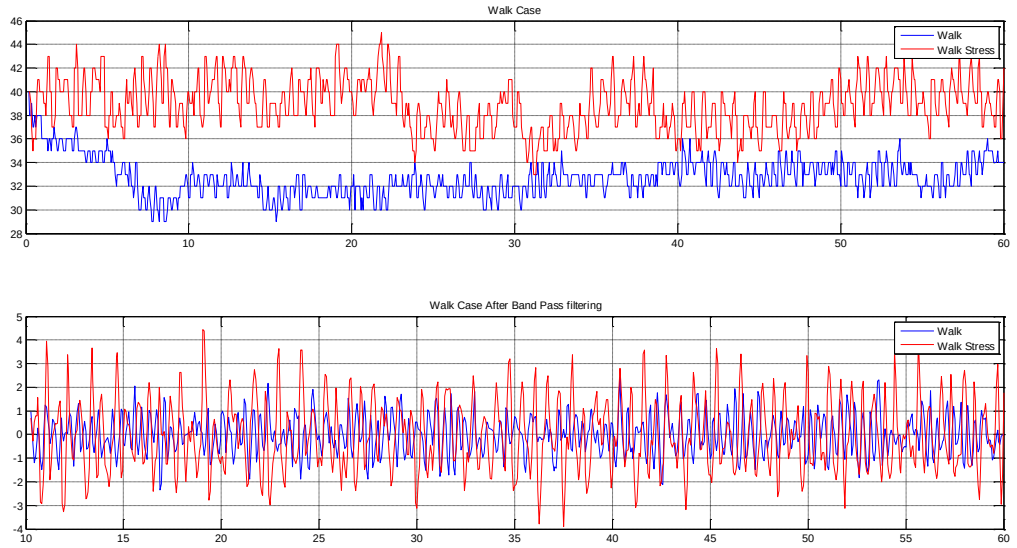


Figure 45 : Walking Case after band pass filtering

- Stress detection threshold for walking = 3.5578
- Number of walk stress detected during stress state = 12
- Number of walk stress detected during relax state = 0

4.6 Number of stressed detected

The number of stressed detected is obtained from the filtered Matlab graph but setting up the threshold using the average of absolute maximum of both relax and stress state.

Table 2 : Number of stress detected during relax state

	Relax State				
Subject/ Position	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5
Sitting	0	0	0	0	0
Standing	0	0	0	0	0
Walking	0	0	0	0	0

From the table above, we can clearly see that there are no stress detected when subjects are in relax state because the value is not over the threshold limit.

Table 3 : Number of stress detected during stress state

	Stress State				
Subject/ Position	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5
Sitting	33	63	294	21	0
Standing	47	22	93	6	13
Walking	172	97	32	45	12

On the other hand, we can see that each subject is stress up when they required to answer the mathematical questions within the time limit. The more number of stress detected, the more stress are the subject. Subject 1 is most stress when answering the question in walking position. Subject 3 get most stress when answering the question in sitting position and Subject 5 not feel much stress because the questions are too easy for him.

Chapter 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Generally, Galvanic Skin Response use the skin conductivity to measure the stress level. It is mainly because human body will have a drop in resistance when the person is under stress. Thus, the output signal measure in voltage will have a short spike at the period when the resistance have sudden drop. The measuring is done between two fingers by pressing one probes at each finger. Based on the circuit design for the GSR sensor, there is a low pass filter which remove high frequency. Based on the project, the circuit will be connected with an Arduino board which is an interface between the circuit and also the laptop. The circuit is connect to the analog input via the jumper wire and the board will connect to the laptop using the USB. Arduino software is used to read the board and the Processing software is used to produce the output graph. Initially, the prototype is being test with the change in resistance to the output voltage value. Afterwards, it is being tested with five students with three different position which are sitting, standing and walking. Each position is tested with relax state as well as stress state by providing mental calculation design in Matlab with time limit. The collected data is filtered in Matlab to convert the low pass filter to band pass filter and also normalize the relax state and stress state graphs. The number of stress detected is being determined by setting up the threshold using the absolute maximum of both relax and stress state. If the value is more than threshold, stress is detected and vice versa. Based on the project so far, the objectives are achieved. The different diagnostic tools are analyzed in Chapter 2. The GSR sensor system is designed and implemented by getting 5 subjects for mental stress measurement. The GSR is integrated with data acquisition system which is the Arduino board for data collection. Lastly, the sensitivity of the system is refined by filtering the output in MATLAB for better classification of stress level.

5.2 Recommendation

The recommendation for this project is to combine this sensor with other type of sensor such as Heart Rate Sensor or Voice Stress Detection Sensor to increase the accuracy of the results. Moreover, the position will affect the reading of the system, thus combining the GSR sensor with accelerometer can improve the accuracy of the device by classifying the stress position and level. On the other hand, GSR sensor can include the LCD display so that the reading can directly obtained the results without going through the laptop for portability.

REFERENCES

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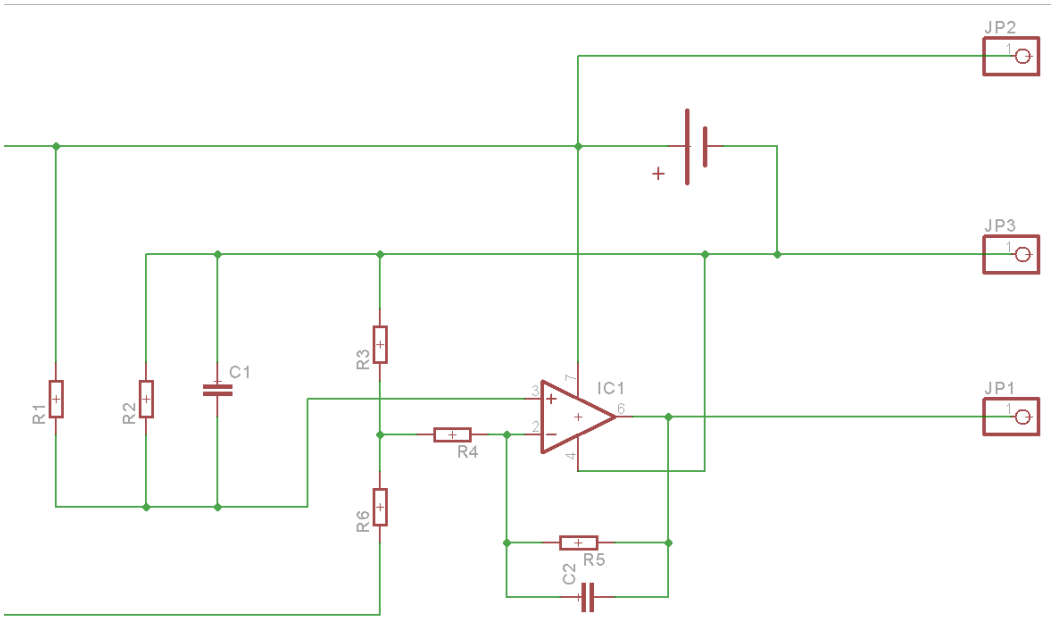
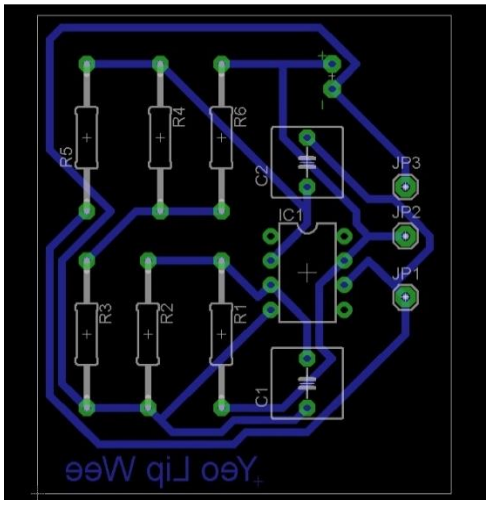
APPENDICES



Appendix 1: Schematic Diagram for GSR Circuit in EAGLE software



Appendix 2: Board Diagram for GSR Circuit in EAGLE software

D=000.0

MICROCHIP MCP6241/1R/1U/2/4

50 µA, 550 kHz Rail-to-Rail Op Amp

Features

- Gain Bandwidth Product: 550 kHz (typical)
- Supply Current: I_Q = 50 µA (typical)
- Supply Voltage: 1.8V to 5.5V
- Rail-to-Rail Input/Output
- Extended Temperature Range: -40°C to +125°C
- Available in 5-pin SC-70 and SOT-23 packages

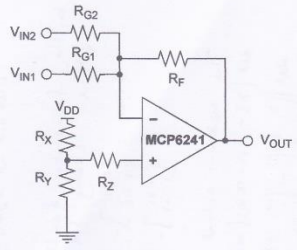
Applications

- Automotive
- Portable Equipment
- Photodiode (Transimpedance) Amplifier
- Analog Filters
- Notebooks and PDAs
- Battery-Powered Systems

Design Aids

- SPICE Macro Models
- Mindi™ Circuit Designer & Simulator
- Microchip Advanced Part Selector (MAPS)
- Analog Demonstration and Evaluation Boards
- Application Notes

Typical Application

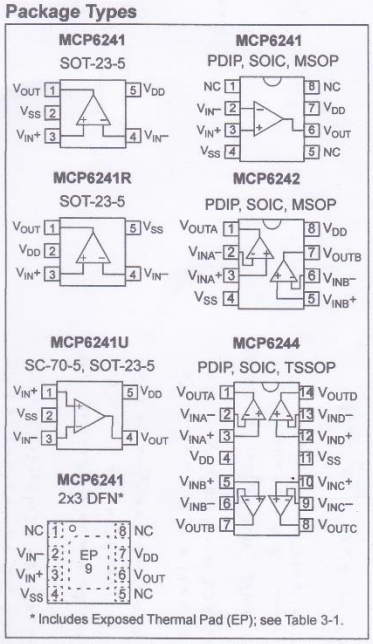


Summing Amplifier Circuit

Description

The Microchip Technology Inc. MCP6241/1R/1U/2/4 operational amplifiers (op amps) provide wide bandwidth for the quiescent current. The MCP6241/1R/1U/2/4 has a 550 kHz gain bandwidth product and 68° (typical) phase margin. This family operates from a single supply voltage as low as 1.8V, while drawing 50 µA (typical) quiescent current. In addition, the MCP6241/1R/1U/2/4 family supports rail-to-rail input and output swing, with a common mode input voltage range of V_{DD} + 300 mV to V_{SS} – 300 mV. These op amps are designed in one of Microchip's advanced CMOS processes.

Package Types



* Includes Exposed Thermal Pad (EP); see Table 3-1.

Appendix 3: Datasheet for IC MCP6241 pin check

1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings †

$V_{DD} - V_{SS}$ 7.0V
Current at Analog Input Pins ($V_{IN}+$, $V_{IN}-$).....±2 mA
Analog Inputs ($V_{IN}+$, $V_{IN}-$) †† ..... $V_{SS} - 1.0V$ to $V_{DD} + 1.0V$
All Other Inputs and Outputs ..... $V_{SS} - 0.3V$ to $V_{DD} + 0.3V$
Difference Input Voltage ..... $|V_{DD} - V_{SS}|$
Output Short Circuit Current .....Continuous
Current at Output and Supply Pins .....±30 mA
Storage Temperature .....–65° C to +150°C
Maximum Junction Temperature (T_J).....+150°C
ESD Protection On All Pins (HBM; MM) ..... ≥ 4 kV; 300V

† Notice: Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operational listings of this specification is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

†† See **Section 4.1.2 "Input Voltage and Current Limits"**.

DC ELECTRICAL CHARACTERISTICS

Electrical Characteristics: Unless otherwise indicated, T_A = +25°C, V_{DD} = +1.8V to +5.5V, V_{SS} = GND, $V_{CM} = V_{DD}/2$, R_L = 100 kΩ to $V_{DD}/2$ and $V_{OUT} \approx V_{DD}/2$.

Parameters	Sym	Min	Typ	Max	Units	Conditions
Input Offset						
Input Offset Voltage	V_{OS}	-5.0	—	+5.0	mV	$V_{CM} = V_{SS}$
Extended Temperature	V_{OS}	-7.0	—	+7.0	mV	T_A= -40°C to +125°C, $V_{CM} = V_{SS}$ **(Note 1)**
Input Offset Drift with Temperature	$\Delta V_{OS}/\Delta T_A$	—	±3.0	—	µV/°C	T_A= -40°C to +125°C, $V_{CM} = V_{SS}$
Power Supply Rejection	PSRR	—	83	—	dB	$V_{CM} = V_{SS}$
Input Bias Current and Impedance						
Input Bias Current:	I_B	—	±1.0	—	pA	
At Temperature	I_B	—	20	—	pA	T_A = +85°C
At Temperature	I_B	—	1100	—	pA	T_A = +125°C
Input Offset Current	I_{OS}	—	±1.0	—	pA	
Common Mode Input Impedance	Z_{CM}	—	10^{13}||6	—	Ω||pF	
Differential Input Impedance	Z_{DIFF}	—	10^{13}||3	—	Ω||pF	
Common Mode						
Common Mode Input Range	V_{CMR}	V_{SS} – 0.3	—	V_{DD} + 0.3	V	
Common Mode Rejection Ratio	CMRR	60	75	—	dB	V_{CM} = -0.3V to 5.3V, V_{DD} = 5V
Open-Loop Gain						
DC Open-Loop Gain (large signal)	A_{OL}	90	110	—	dB	V_{OUT} = 0.3V to V_{DD} – 0.3V, $V_{CM} = V_{SS}$
Output						
Maximum Output Voltage Swing	V_{OL}, V_{OH}	V_{SS} + 35	—	V_{DD} – 35	mV	R_L = 10 kΩ, 0.5V Input Overdrive
Output Short-Circuit Current	I_{SC}	—	±6	—	mA	V_{DD} = 1.8V
	I_{SC}	—	±23	—	mA	V_{DD} = 5.5V
Power Supply						
Supply Voltage	V_{DD}	1.8	—	5.5	V	
Quiescent Current per Amplifier	I_Q	30	50	70	µA	I_O = 0, $V_{CM} = V_{DD} - 0.5V$

Note 1: The SC-70 package is only tested at +25°C.

Appendix 4: Datasheet for IC MCP6241 for Electrical Characteristics