Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

A simpler measurement method for galvanic skin response using LM317 IC and its validation

Rajarshi Das

rajarshidas687@gmail.com

Netaji Subhash Engineering College

Mainakh Chakroborty

Netaji Subhash Engineering College

Tarak Das

Netaji Subhash Engineering College

Method Article

Keywords: Constant Current Source, Electrodermal Activity, Galvanic Skin Response (GSR), LM317 IC, Skin Impedance, Tetrapolar Measurement

Posted Date: May 15th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-9710082/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

A simpler measurement method for galvanic skin response using LM317 IC and its validation

Rajarshi Das[1*], Mainakh Chakroborty[2†], Tarak Das[3*]

[1*, 2] Student, Department of Biomedical Engineering, Netaji Subhash Engineering College, Kolkata, 700152, West Bengal, India.

[3*] Assistant Professor, Department of Biomedical Engineering, Netaji Subhash Engineering College, Kolkata, 700152, West Bengal, India.

*Corresponding authors. E-mail(s): rajarshidas687@gmail.com; tarakdas111@gmail.com;
Contributing author: mainakhnsec@gmail.com; †This author contributed equally to this work.

Abstract

Galvanic Skin Response (GSR) is also known as Electrodermal Activity (EDA) which is basically a physiological signal which tells us about the variations in skin conductance which is caused by sympathetic nervous system activity. We need a constant current source which will be used as excitation source that helps to measure the GSR accurately, as the skin impedance is too much sensitive to sweat secretion, electrode contacts and other environmental factors. This research paper accentuates the design, application and experimental documentation of a low-cost constant current source made with LM317 IC for the measurement of skin impedance. To deliver a stable current over a wide range of load resistances, the circuit is designed to ensure reliable voltage variations which are proportional to the changes in skin impedance. While performing several tests with the circuit, the results have shown stable constant-current behaviour for different resistive loads which validates the relevance of the design for GSR applications. In addition to this, a future extension using a tetrapolar electrode configuration is proposed to minimize the effects of electrode-skin interface and improve the measurement accuracy. This advanced system provides a simple, robust and an economical solution for biomedical instrumentation and physiological monitoring.

Keywords: Constant Current Source, Electrodermal Activity, Galvanic Skin Response (GSR), LM317 IC, Skin Impedance, Tetrapolar Measurement.

1. Introduction

The phenomena caused by the changes in the electrical properties of the skin due to the various activities of the sweat glands are known as Galvanic Skin Response. As sympathetic nervous system controls the eccrine sweat gland, for emotional arousal, stress and autonomic function, GSR is used as a sensitive and non-invasive indicator. It is used for psychological research, biofeedback systems, polygraph testing and clinical assessment of autonomic disorders.

The impedance of the skin varies due to the dynamic changes in sweat secretion, temperature, pressure, and electrode contact conditions. The traditional GSR measurement systems generally use constant-voltage source for excitation, where the current variation takes place due to changes in skin conductance but this approach was found to be unstable and non-linear due to the variation in skin resistances[1].

To overcome these limitations, we have developed a constant-current excitation system that became the preferred method for the measurement of GSR. We maintained a fixed current through the skin, the variation in voltage directly helped us understand the changes in skin impedance, which lead to improved linearity, repeatability, and measurement accuracy. This paper focuses on the development of a constant current source using the LM317 regulator and its application in measurement of skin impedance.

2. Physiological basis of skin impedance

The skin impedance is influenced by the activity of eccrine sweat glands, which secrete electrolyte-rich sweat containing sodium and chloride ions. Even minimal sweat secretion significantly increases skin conductance and

decreases resistance. The GSR response occur within 2–10 seconds following an emotionally or cognitively relevant stimulus[2].

From existing literatures, it is found that GSR is associated with theory of muscular, vascular and secretory activities, among these theories secretory activity theory is widely accepted. This theory explains the connection of GSR with pre-secretory and secretory processes of sweat glands. Therefore, an accurate, low noise and stable constant current source is required to measure these physiological changes accurately.

3. Constant current excitation for galvanic skin response (GSR) measurement

Using a constant-current GSR system, a small amount of current is applied to the skin and the voltage drop is measured. The advantage of using this method over constant –voltage method is that it shows linear relation between skin resistance and measured voltage. It stabilises electrode movement and contact pressure which enhances system stability, repeatability and reduces the measurement artifacts.

Silver-Silver Chloride (Ag-AgCl) electrodes are mostly used for their low polarization and stable electrochemical properties. Low current level ranging from microampere to milliampere is delivered, which ensures subject's safety and also reduces electrode polarization[3].

4. Design, development and methods

4.1. Circuit components

The components we have used to design the constant current source consists of LM317 IC, 1 kΩ potentiometer to adjust output current, Direct Current (DC) regulated power supply (5 – 20 V), Resistors of different values and a Digital Multimeter.

4.2. LM317-Based constant current source

LM317 is a three-pin IC which can be used as an adjustable voltage regulator. By connecting a resistor between its output (OUT) and adjustment (ADJ) pins it can also be used as a constant current source[4].
LM317 maintains a fixed reference voltage of approximately 1.25 V between these pin[5]. As a result, the output current is determined by:

$$I = \frac{1.25}{R_p}$$

where R_p is the sense resistor connected between the OUT and ADJ pins.

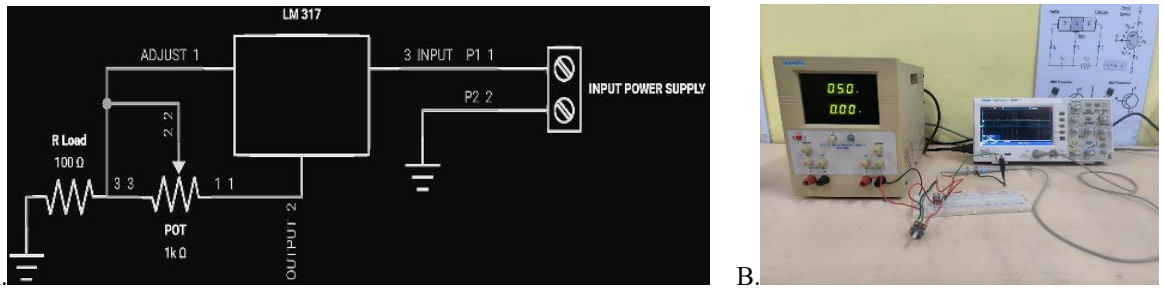


Figure 1. (A) Circuit Diagram of Constant Current Source and (B) Experimental Setup for Constant Current Source

4.3. Method to run the circuit at low load resistance

The circuit was operated with load resistances of 100 Ω, 220 Ω, 330 Ω, 430 Ω, 470 Ω and 510 Ω using a 5 V DC supply. We got the output current stable at 3.5 mA on every variable load resistance. The output voltage increased proportionally with resistance, as expected.
The output current of the circuit is determined using the standard LM317 current-setting relation given by:

$$I_{out} = \frac{1.25}{R_p}$$

where R_p is the value of the potentiometer selected to obtain the desired constant current.

Given:

$$R_p = 348\ \Omega$$

Substituting the value into the above equation:

$$I_{out} = \frac{1.25}{348}$$
$$I_{out} \approx 3.5\ \text{mA}$$

4.4. Method to run the circuit at high load resistance

For higher load values of 1.0 kΩ, 1.1 kΩ, 2.2 kΩ, 3.3 kΩ, 4.4 kΩ the input voltage was increased to 15 V DC to ensure sufficient compliance voltage.

At higher load resistance values, the constant current of 3.5 mA was not maintained due to limitations imposed by the compliance voltage of the current source. To analyse this behaviour, load resistances of 1.0 kΩ, 1.1 kΩ, 2.2 kΩ, 3.3 kΩ, 4.3 kΩ, and 5.1 kΩ were considered. The average load resistance was calculated to represent the high-resistance operating region of the system.

The average load resistance is given by:

$$R_{avg} = \frac{1.0 + 1.1 + 2.2 + 3.3 + 4.3 + 5.1}{6} = 2.83\ \Omega$$

For a desired constant current of 3.5 mA, the voltage required across the load is:

$$V_L = I \times R_{avg} = 0.0035 \times 2833 \approx 9.92\ \text{V}$$

In an LM317-based constant current configuration, an internal reference voltage of approximately 1.25 V must be maintained across the sense resistor (potentiometer), in addition to a minimum dropout voltage of approximately 3 V for proper regulator operation. Thus, the minimum input voltage required to maintain constant current regulation is:

$$V_{in(min)} = V_L + 1.25 + V_{drop}$$
$$V_{in(min)} = 9.92 + 1.25 + 3 \approx 14.17\ \text{V}$$

By the calculations and its results, we can say that an input supply voltage of 14.2 V is at least required to get a constant current of 3.5 mA across the high load resistance range mentioned above. For safety and stability of the circuit an input voltage of 15 V DC is applied as input voltage. Hence, by this we can assume that the deviation of constant current was due to insufficient input voltage.

5. Result, discussion and analysis

The developed circuit was tested in two parts with variable load resistances (R_L), lower resistances of 100 Ω, 220 Ω, 330 Ω, 430 Ω, 470 Ω and 510 Ω using a 5 V DC input supply and with higher resistances of 1.0 kΩ, 1.1 kΩ, 2.2 kΩ, 3.3 kΩ, 4.4 kΩ using the 15 V DC input supply. This variation in the voltage was done to achieve constant current of 3.5 mA through all the ranges of lower to higher resistances. Below (Table 1) shows the voltage (V) across load resistance (R_L) and the current (A) through load (R_L), also we can observe from the table that the value of voltage across load resistances increase with the increasing value of the load resistance, maintaining a stable constant current.

Table 1. Measured values from the developed constant current circuit using variable load resistances

Load (R_L) in (Ω)	Voltage (V) across load (R_L)	Current (A) through load (R_L)
100	0.35	0.0035
220	0.78	0.0035
330	1.17	0.0035

430	1.53	0.0035
470	1.68	0.0035
510	1.84	0.0036
1.0k	3.57	0.0035
1.1k	3.91	0.0035
2.2k	7.83	0.0035
3.3k	11.61	0.0035
4.3k	15.17	0.0035
5.1k	17.95	0.0035

From (Table 1) after analysing the measured values, we have formed a linear graph shown in (Figure 2) the value of load resistances (R_L) over X axis and value of voltage (V) across load resistance (R_L) over Y axis. The straight line with positive slope shows positive linear relationship and directly proportional relationship (as the line passes through origin) between load resistances (R_L) and voltage (V) across load resistance (R_L), therefore it proves the stable constant current (A) through load resistances (R_L).

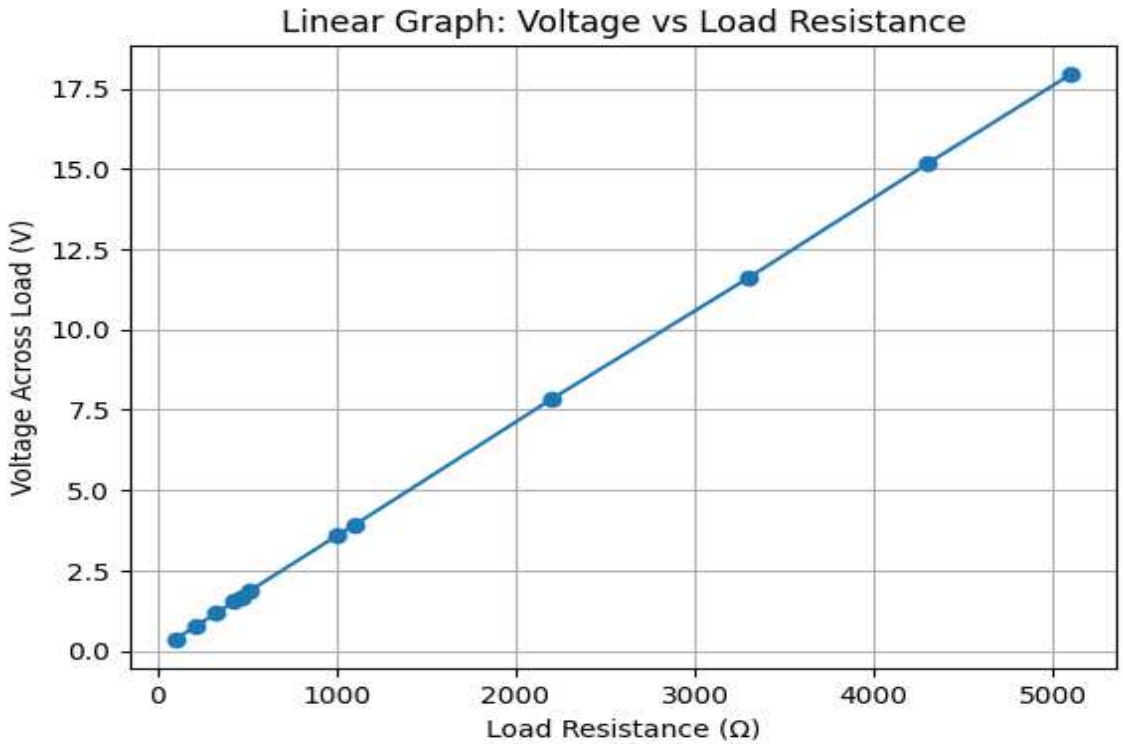


Figure 2. Voltage vs Load Resistance Graph

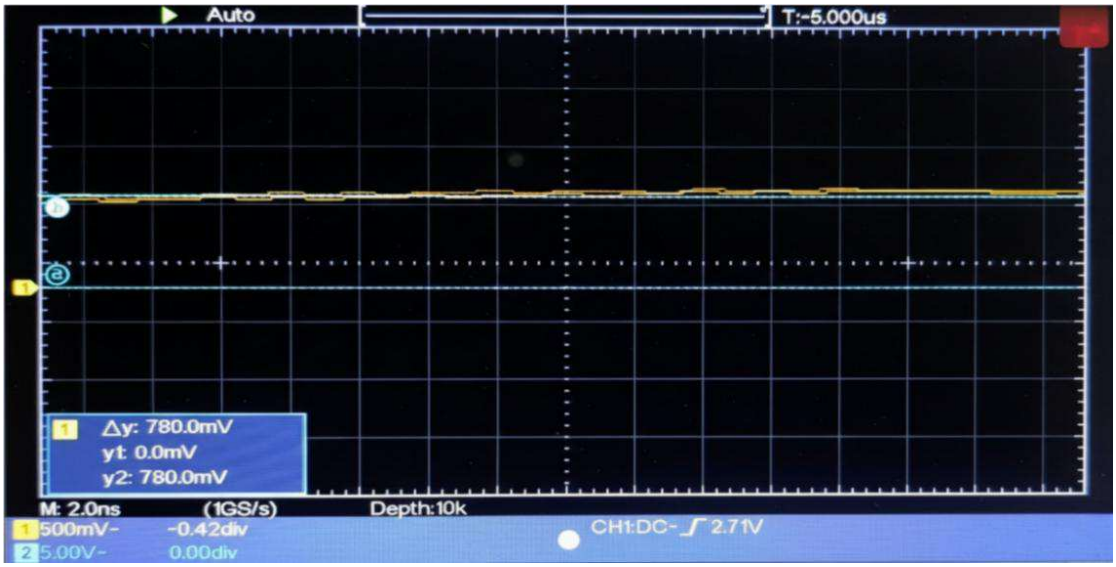


Figure 3. Oscilloscope Reading of Voltage (V) across Load Resistance (R_L) 220Ω

5.1. Measurement on test subjects

To measure the GSR value from the test subjects, the experimental setup is being modified by replacing the load resistances R_L by two conductive electrodes which were placed on the wrist of the subjects to measure their GSR values.

A DC regulated power supply is used to supply 15 V (± 0.20 V) to ensure that the circuit and output current stays constant and stable for accurate data acquisition. From the existing literature, we came to know that the electrical resistance of human skin typically ranges between 200 Ω and 2000 Ω for a small contact area[6]. That's why, the potentiometer was calibrated and fixed at 348 Ω to get constant current.

After completion of system modification, GSR data were collected from 25 participants from age between 19 to 23 years under same environmental and physiological conditions to minimize deviations in data.

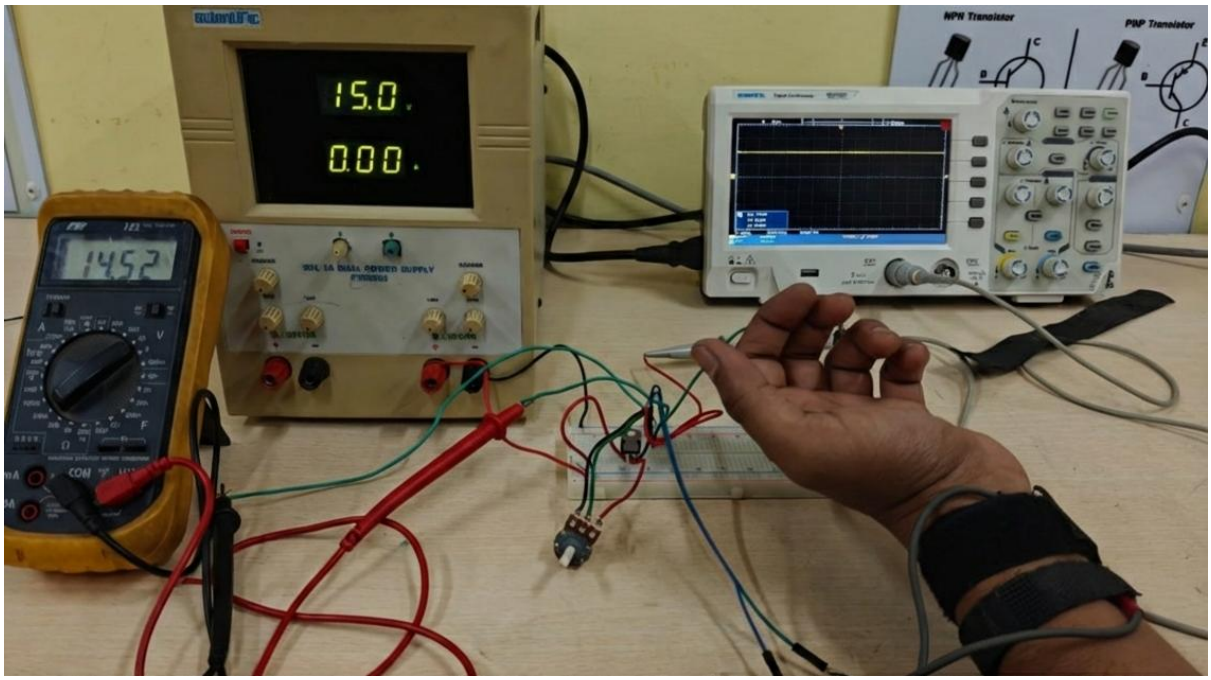


Figure 4. Experimental Setup to Measure GSR from Test Subjects

Table 2: Measured values from the subject using developed GSR module

Serial No.	Subject's Age (In Years)	Voltage (Without Electrode Placement) -A(V)	Potential Drop (After Electrode Placement) - B(V)	Voltage Difference (A-B) (V)	Resistance /GSR Value (Ω)
1	23	14.81	13.68	1.13	322.85
2	21	14.81	13.75	1.06	302.85
3	21	14.81	13.66	1.15	328.57
4	19	14.81	13.65	1.16	331.43
5	23	14.81	13.71	1.1	314.29
6	20	14.81	13.86	0.95	271.43
7	22	14.81	13.58	1.23	351.43
8	19	14.81	13.58	1.23	351.43
9	22	14.81	13.76	1.05	300
10	23	14.81	13.9	0.91	260
11	20	14.81	13.83	0.98	280
12	19	14.81	13.81	1	285.71
13	22	14.81	13.63	1.18	337.14
14	20	14.81	13.73	1.08	308.57
15	23	14.81	13.85	0.96	274.29
16	19	14.81	13.88	0.93	265.71
17	21	14.81	13.65	1.16	331.43
18	20	14.81	13.88	0.93	265.71
19	19	14.81	13.59	1.22	348.57
20	21	14.81	13.76	1.05	300
21	20	14.81	13.85	0.96	274.29
22	19	14.81	13.64	1.17	334.29
23	22	14.81	13.72	1.09	311.43
24	20	14.81	13.74	1.07	305.71
25	22	14.81	13.79	1.02	291.43

5.2. Validation of developed GSR circuit with reference GSR module

We have validated our developed GSR Circuit (Constant current Source circuit made with LM317 IC) by comparing it with a reference GSR Module (Groove GSR Sensor V 1.2) to evaluate its accuracy and reliability[7]. We have measured the GSR value of 25 subjects simultaneously on our developed GSR circuit and on reference GSR module. We have recorded the GSR data and the raw voltage input from GSR module to Arduino UNO microcontroller's analog pin through Arduino IDE and Tera term software to compare more specifically with our developed circuit.

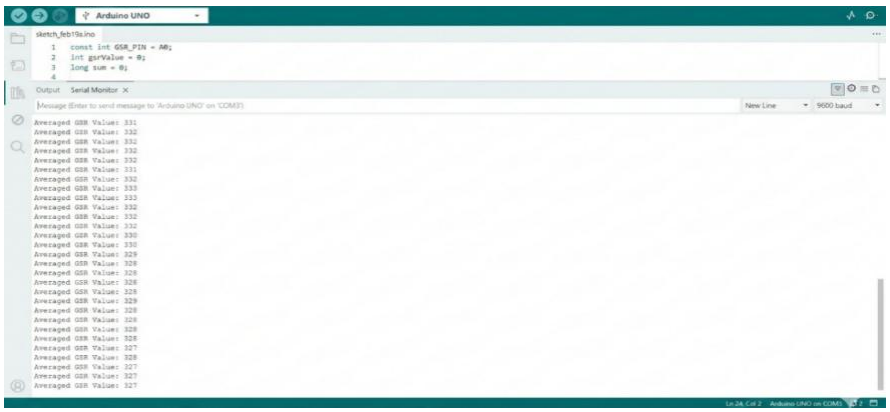


Figure 5. GSR Data from GSR Module on Arduino IDE Software

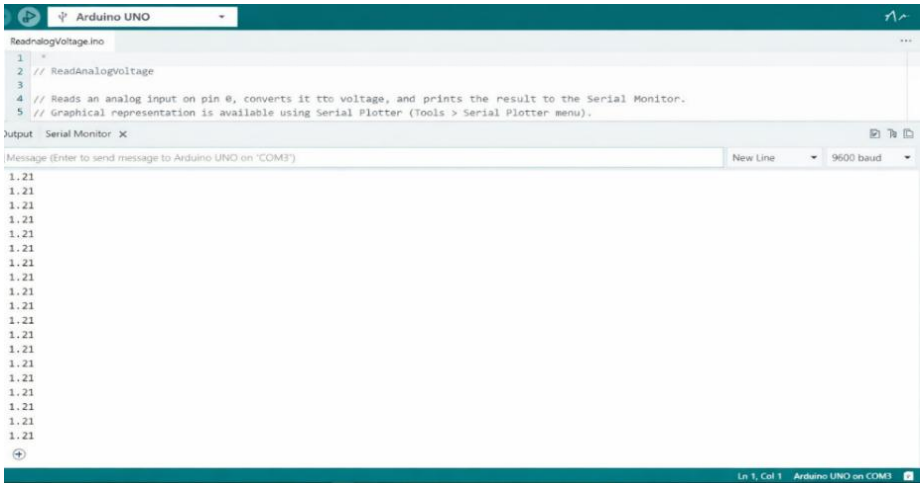


Figure 6. Raw input voltage from GSR module to Arduino UNO microcontroller's analog pin

We have taken the mean of raw input voltage and GSR data of 25 subjects from GSR module, the result came as 1.22 V for raw input voltage at Arduino UNO microcontroller's analog pin and GSR as 327 Ω. Hence the current delivered to the subject from the GSR module is –

$$I = \frac{V}{R}$$

$$I = \frac{1.22}{327}$$

$$I = 0.00372\ A$$

Here we can see that the current delivered from the GSR module is approximately to 3.7 mA which is much close to the stable constant current delivered from the developed GSR circuit, made using LM317 IC which is 3.5 mA.

6. Comparative analysis of developed circuit and reference module GSR data

After successfully recording the data from GSR module and developed circuit, a combined dataset is formed to run some validation models using python codes.

Table 3: Combined dataset consisting of both data from developed GSR circuit and GSR module

Subject ID	GSR_IC (Developed circuit)	GSR_Module
1	322.85	327
2	302.85	302
3	328.57	324
4	331.43	314
5	314.29	309
6	271.43	268
7	351.43	345
8	351.43	334
9	300.00	310
10	260.00	260
11	280.00	320

12	285.71	286
13	337.14	338
14	308.57	305
15	274.29	273
16	265.71	268
17	331.43	333
18	265.71	270
19	348.57	283
20	300.00	296
21	274.29	270
22	334.29	329
23	311.43	305
24	305.71	308
25	291.43	286

*Mean GSR value of each subject is taken from GSR module

We ran Direct Statistical Comparison, Linear Regression Equivalence, Leave-One-Subject-Out, Linear Support Vector Regression, Bland-Altman analysis on this data set (Table 3) to analyse and compare the data recorded from our developed GSR circuit with a marketized GSR module (Groove GSR Sensor V 1.2).

Python code to run these models and other instructions can be found at - https://github.com/rajarshidas687-blip/LRV-and-SVR-Validation-Model.git

The result generated from the different kinds of comparison and validation models, we ran on combined dataset were analysed and we got a satisfactory output.

6.1. Direct statistical comparison model

In Direct Statistical Comparison the values were compared using Mean Absolute Error (MAE), Root Mean Square Error (RMSE) and Coefficient of Determination (R^2). The output came as:

MAE: 8.69
RMSE: 16.62
R^2: 0.652

The R^2 value 0.652 indicates a moderate to strong correlation between the developed GSR circuit and GSR module measurements. The MAE and RSME values also define the acceptable and satisfactory average prediction error.

6.2. Linear regression equivalence model

From LRE validation model, we got the regression slope, intercept point and LRE graphical plot. Also, from the formula given below we found out the Coefficient of Determination R^2[8].

$$GSR_{MODULE} = 0.7235\, GSR_{IC} + 81.2387$$

$R^2 = 0.671$

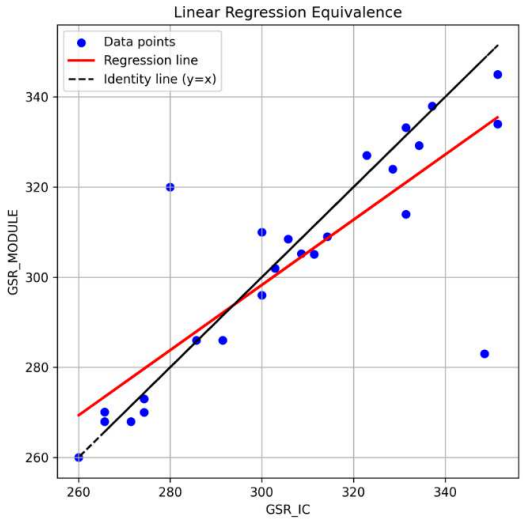


Figure 7. Graphical representation of the output of LRE model

The mathematical and graphical output from this model explains that the regression slope (0.7235) suggests the proportional agreement and the intercept (81.2387) indicates a systematic offset between the system. Hence, the R^2 value confirms substantial linear association[8].

6.3. Leave-One-Subject-Out (LOSO) – Support vector regression (SVR) model

LOSO is highly acceptable and reliable validation model, specially used for biomedical signals[9]. Hence, we also used this model and compared its output with direct statistical comparison (DSC) model. The output of LOSO model came as:

MAE: 8.35
RMSE: 16.60
R^2: 0.6529238921539822

While comparing LOSO and DSC model, the output of both the model indicates moderate predictive capability and constant generalization among the subjects, it defines the stable inter device relationship under subject independent validation.

6.4. Bland - Altman analysis model

To assess the agreement between Support Vector Regression (SVR) predicted developed GSR values with reference of developed GSR circuit values Bland-Altman analysis was performed[10].

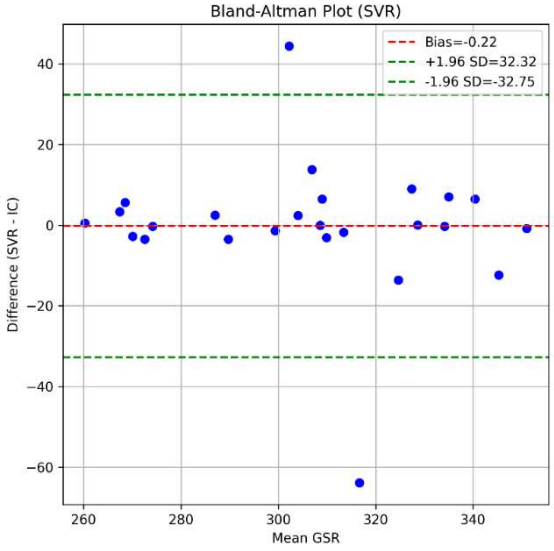


Figure 8. Graphical representation of the output of Bland-Altman analysis model

The mathematical output is:

Bland - Altman Bias: -0.22
Limits of Agreement: [-32.75, 32.32]

The negligible systematic error of the mean bias was -0.22. The 95% limits of agreement ranged from -32.75 to +32.32, it suggests that most predictions errors fall within ±32 units. This analysis indicates acceptable agreement for physiological GSR measurements.

We have also compared the measured GSR values from the developed GSR circuit with a reference article[11]. The comparison proves that our developed GSR circuit works efficiently and gives output within desired range. GSR ranges[11] are:

- No stress: $GSR_{normal} \leq 200$
- Minor stress: $200 < GSR_{normal} \leq 300$
- High stress: $300 < GSR_{normal} \leq 400$
- Very high stress: $400 < GSR_{normal} \leq 500$

7. Future scope

We propose to create a low cost GSR module with tetrapolar (four – electrode) measurement system. In this system, two electrodes will be used to carry forward the constant current, while the other two electrodes will be used for measurement of the resulting voltage. This system decreases the influence of electrode – skin contact impedance and polarization effects.

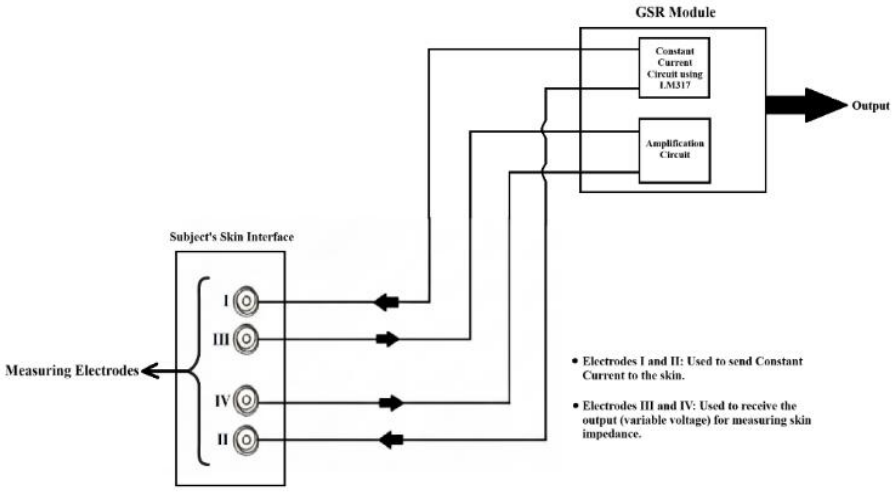


Figure 9. Block Diagram of Tetrapolar GSR Module

8. Conclusion

In conclusion, this study presents about the development of a simple, low-cost constant current source using LM317 IC to measure the GSR value. From the experimental observation and result analysis here we can conclude that this circuit can deliver stable constant current across a wide range of load resistances, also from the experimental observation on the test subjects we can ensure that the circuit stayed stable and delivered constant current during GSR measurement and is capable for future modifications and provides a foundation for development of tetrapolar GSR module for further accuracy and signal quality, which will help in psychophysiological researches and clinical monitoring applications.

Acknowledgement

We are grateful for the guidance and support of our guide for valuable suggestions throughout this work. We extend our appreciation to the Department of Biomedical Engineering of Netaji Subhash Engineering College, Kolkata for providing the necessary facilities to carry out the research. The encouragement and assistance received from peers and participants are also duly acknowledged.

References

1. Das T, Mitra C, Paul H, Banerjee S (2022) International Journal of Research Publication and Reviews Study the Changes of Bioelectrical Skin Impedance of Human body Associated with Different Physiological Parameters. International Journal of Research Publication and Reviews 3:2617–2621. https://doi.org/10.55248/gengpi.2022.31288

2. Sharma M, Kacker S, Sharma M (2016) A Brief Introduction and Review on Galvanic Skin Response. International Journal of Medical Research Professionals 2:. https://doi.org/10.21276/IJMRP.2016.2.6.003

3. Boucsein W, Fowles DC, Grimnes S, et al (2012) Publication recommendations for electrodermal measurements. Psychophysiology 49:1017–1034. https://doi.org/10.1111/j.1469-8986.2012.01384.x

4. Design LM317 Constant Current Source Circuits. https://www.bristolwatch.com/ccs/LM317.htm. Accessed 1 Mar 2026

5. LM317 pdf, LM317 Download, LM317 Description, LM317 Datasheet, LM317 view ::: ALLDATASHEET ::: https://www.alldatasheet.com/datasheet-pdf/download/22749/STMICROELECTRONICS/LM317.html. Accessed 12 Dec 2025

6. McCleary RA (1964) Independence of Galvanic Skin Response Amplitude and Sweat Production. Journal of Investigative Dermatology 42:443–448. https://doi.org/10.1037/h0059810

7. Pagar V, Bhadane P, Shaligram A (2022) Stress Detection Using Galvanic Skin Response With Affective Impact Of Different Climate Conditions. J Pharm Negat Results 13:3961–3969. https://doi.org/10.47750/pnr.2022.13.S10.482

8. Campbell H (2023) Equivalence Testing for Linear Regression. Psychol Methods 29:88–98. https://doi.org/10.1037/met0000596

9. Borup K, Kidmose P, Phan H, Mikkelsen K (2023) Automatic sleep scoring using patient-specific ensemble models and knowledge distillation for ear-EEG data. Biomed Signal Process Control 81:. https://doi.org/10.1016/j.bspc.2022.104496

10. Scott LE, Galpin JS, Glencross DK (2003) Multiple Method Comparison: Statistical Model Using Percentage Similarity. Cytometry B Clin Cytom 54:46–53. https://doi.org/10.1002/cyto.b.10016

11. Swetha K, Kiran K V.D. (2025) Kalman-Normalized GSR Analysis for Real-Time Stress Quantification in Wearable Systems. Int J Telemed Appl 2025:8828363. https://doi.org/10.1155/ijta/8828363