

Signal Conditioning Circuit for respiration rate monitoring using GOP based sensor

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Abstract: Various researchers have developed more efficient, eco-friendly sensors for the wearable electronics. The major work was focused on exploring the temperature and pressure sensitivity of the graphite. Graphite based sensor have proven to be the best replacement for the harmful and non-biodegradable sensors due to the excellent sensitivity of the GOP(Graphite-on-paper) sensors. Thermal conductivity of the graphite can be used to monitor the respiration rate non-invasively. A novel approach is used to design the respiration rate monitoring system. As shown in the Figure [18], design consists of three components a) GOP based sensor, b) Signal Conditioning Circuit, c) Alerting system using ESP8266 NodeMCU. The dimensions of the GOP sensor were finalized after a series of experiments. The final dimensions of the sensor are chosen such that they have least variation in resistance at room temperature (i.e., 300k). The sensor was placed on a double tape to avoid change in resistance due to piezoelectric effect. As mentioned in the above sections, the GOP sensor is low-cost, flexible, eco-friendly, home-made, highly sensitivity and doesn't require any clean rooms for manufacture. It is observed that the GOP sensor signals lie in the range 1Hz-0.5kHz, concluded from the FFT analysis of the signal. A Signal Conditioning circuit is designed for the GOP sensor to make the signal compactible for ESP8266 MCU, for further processing. The Circuit designed is flexible in nature and dimensions are 20mm×29mm. The Signal Conditioning Circuit consists a) Second Order Bandpass filter b) Stage-I Amplifier c) Voltage shifter Circuit d) Stage-II Amplifier which condition the signal to the range 0-(3.3V). The results obtained from the simulation and hardware implementation were satisfactory. The circuit could detect normal respiration. After observing the conditioned signal, we can observe peaks and nadirs, which have occurred due to respiration. Using this signal, we can measure the respiration rate. The Alerting system consisting the ESP8266 NodeMCU which has WIFI module. An alert message can be sent to the mobile through the ESP8266 NodeMCU in case of abnormal respiration rate. The whole system including the Sensor, Signal Conditioning Circuit, alerting system can be embedded on the mask. This system does not require any contact of the patient's philtrum. This enhances the comfort of the elderly people and children.

Index Terms—

I. INTRODUCTION

THE wearable devices embedded with biosensors are able to monitor real-time health care parameters. These wearable devices are designed to recognize various health care parameters such as glucose, lactate, pH, cholesterol, etc., and body indicators, i.e., heart rate, temperature, respiratory rate, respiration, alcohol, monitoring work, etc., have applications that can be available for both medical diagnosis and quality monitoring. The rapid development of nanomaterials based on the solution has provided a promising perspective on the wearable sensory sector by enabling their inexpensive production by printing a wide variety of flexible polymeric substrates. Sensors are classified as biological and fluidic, embedded in the human body, or natural, attached to substrates/gadgets that are separately worn to monitor human-related analytes, as

well as external motives. The various types of wearable sensors are shown in Figure [1].

Respiration is the level of human breathing for a period of time. The average range of respiration rate for a healthy person in normal conditions is 15-20 breaths per minute, while values above 25 and under 12 are considered alarming [3,13]. Respiratory rate changes due to various disorders such as asthma, chronic obstructive pulmonary disease (COPD), chronic obstructive pulmonary disease, pneumonia, nasal congestion, cough, mildew, etc. Therefore, monitoring the level of continuous breathing which is very important in early detection and diagnosis of any abnormalities that occur. A variety of sensors are designed to analyze respiration rate. For example, more precise and ultrasensitive heat sensors were used to detect nasal function during respiration [14]. A slight change in temperature due to inhalation and exhalation is considered a respiratory reference. Polymer-based sensors (PVDF) were also used as cantilevers to exploit piezoelectric structures when bending [15]. Such values are bulky, disturbing, and unfriendly, especially among the elderly. Therefore, wearable technology is highly desirable, as it can be applied to other parts of the body without interfering with the function of the nose.

The chest expansion and contraction as you inhale and exhale, respectively, can be easily detected using strain sensors. Large-area printed electronics enabled such development with much ease, allowing the effective integration onto non-planar substrates. Screen-printed pressure sensors based on MWCNT pastes have been reported in the textile substrate for respiratory rate measurements [16]. The sensor was integrated into the fabric, which allowed for easy wear. Changes in electrical resistance as a result of chest expansion and contraction were recorded with each breath inside and out. MWCNT / PDMS nanocomposites were also tested to monitor respiration rate using a stress sensor based on the capacitive properties of integrated electrodes (IDEs) [17]. In another development, a new method of measuring respiration based on paper-based moisture sensors was proposed [18]. Black carbon printed on both sides of the paper was used to produce sensors in the form of IDEs. Changes in ionic conductivity of the sensor are caused by fluctuating levels of humidity that occur as a result of respiration. Lightweight sensors are embedded in a wearable mask and data is sent wirelessly to a smartphone. The PVDF-based sensor was proposed to detect respiratory rate in changing mobility conditions [19].

The PVDF layer is embedded between two printed layers of Ag, which produce an electrical signal due to changes in the human chest. Graphene has recently been investigated to have various sensing applications. A fully painted respiratory sensor has recently been produced using silica nanoparticles film coated with a thin layer of graphite [20]. Sensors are made in a flexible substrate so that they can form a systematic integration into the random area of the human body. Graphene-oxide-based sensors were developed in another exciting development, where the sensor was embedded in a wearable mask equipped with radio-frequency identification (RFID) for continuous breathing monitoring [21]. Active graphene can extend the sensory features, and the sensors can be used for selective analyzes for improved performance. A similar process was adopted to develop wearable sensors that work in a variety of ways. Simultaneous monitoring of live signals and live organic compounds (VOCs) was achieved through the action of graphene films [22]. Here the sensor was mounted on the wrist to monitor the heart rate and breathing rate. Monitoring respiration during sleep is also important, as apnea is one of the most common sleep disorders [23]. A printed sensor, embedded on the human body, can detect the movement of the breath by measuring changes in the magnetic vectors. MWCNT / PDMS nanocomposites were also tested to monitor respiration rate using a stress sensor based on capacitive structures of inter digitated electrodes (IDEs) [17]. In another development, a new method of measuring respiration based on paper-based moisture sensors was proposed [18]. Black carbon print on both sides of the bottom paper was used to produce sensors in the form of IDEs. Changes in ionic conductivity of the sensor are caused

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Finally, I want to conclude that respiration rate monitoring can be done using low-cost, flexible, and environment-friendly sensors. The manufacturing of the sensor doesn't require highly equipped clean rooms and can be made using graphite pencils available in local stores. These above literatures also gave me the inspiration to design a respiration rate monitoring system.

II. SIMILAR WORK IN THIS SUBJECT MATTER

Note: Each paragraph summarizes one similar act or research paper. The end of the paragraph contains the reference number.

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Briefly, the paper reports the construction of a low-cost, low-power, flexible, eco-friendly, and non-solution carbon field-effect transistor with cellulose paper such as both substrate and dielectric and pencil graphite as gate, source, water extraction. and channel without the use of detailed processes, complex tools and / or toxic chemicals. FET was used to demonstrate the detection of human movement using a stress sensor and shows the highest sensitivity to finger movements when combined with hand gloves. It was noted that sensory function is productive and stable over time. The successful development of this durable, paper-based FET and its use in identifying human movement shows the potential for eco-friendly, functional, flexible and wearable electronic devices that derive multiple uses for health care, robots and humans-machine interface (HMI) [2].

In this paper, a flexible screen-printed sensor based on polyaniline-graphite nanocomposite is introduced as well as a novel method of controlling sensor boundaries by changing the distance between the electrode and the number of electrodes. The positive synergistic effects of graphite acting as a support for polymer chains were discussed. In contrast to pure polyaniline, all polyaniline-graphite nanocomposites showed excellent thermal stability and only a slight decrease in reaction at even 55 °C. Using these flexible humidity sensors, the unaffected fingerprint sensor was shown with a change of 14.32% at a distance of 0.2 cm from the sensor surface. Finally, an artificial device was inserted inside the N95 mask to show the respiratory monitoring system showing significant differences in high intensity with different respiratory levels, thus, allowing us to create a map of normal, deep and disturbed respiratory levels [1].

In conclusion, the results here show the less expensive and biodegradable flow sensors using ubiquitous pencil graphite as a hot film sensor layer, simply made from inexpensive, reusable and decaying printing paper using the drawing method and subsequent laser cutting method. They have demonstrated a GOP-based patch type sensitive thermal flow sensor that can monitor the human respiratory system in real time. Highly sensitive and decomposing flow sensors built in a clean, simple and easy-to-use housing indicate that GOP-based devices are environmentally friendly, lightweight and wearable that can be used to monitor human breathing [3].

Briefly, they report a simple and easy-to-use method to prepare a flexible, robust, practical, environmentally friendly and economical (0.32%) sensor with range of strain from -0.62% to 0.62% under stressful and strong, comparable flexible conditions. Different GF sensors of difficulty calculated from the smoothness of graphite pieces and the separation or rearrangement between graphite pieces of trace pencil on paper. By studying the behaviour of the sensory service by multi-bending frequency test (> 10,000 cycles), stress sensors allow a simple sensory field of recurring output signals to $\pm 0.32\%$ type within a relative resistance variation of 10.33%. Interestingly, sensors are able to monitor micro strain [4].

Composition, characterization, and temperature sensor reaction are shown in this paper. Graphite on wearable paper with low cost, home-made, environmentally-friendly heat sensor is introduced with an active response. Here is introduced the conductive ink and graphite as an electrode. The continuous attachment resistance is 1.175 Ω -m. They test the temperature sensor response by changing the temperature. Due to the negative thermal coefficient of graphite by increasing resistance the temperature is reduced. After the preparation of conductive paste a very simple process is used to make the sensor. After the sensor design was performed the temperature sensor was monitored for room temperature and body temperature. Analysis of the temperature change function from 20 ° C to 60 ° C was performed with an iron plate and the iron plate was fired with an electric heat gun. [5]

This paper reports on the thermal properties of graphite in paper (GOP). A negative temperature coefficient of resistance (TCR) from -2,900 to -4,400 ppm / K has been identified in the GOP. This negative and large TCR is caused by an increase in thermionic emissions above the potential low pressure with increasing temperature. The potential barrier was found to be 33 meV between the graphite letters. This paper also demonstrates the use of GOP in the highly sensitive (0.83 mV / (m / s) 0.8 / mW) GOP-based anemometer, which demonstrates the potential for using this material in low-cost and sensitive heat sensors [6].

This paper has fabricated and tested graphite and silver nanoparticles-based sensors on low cost and light-weight paper substrates for respiration monitoring activities. The GOP sensor involves simple fabrication processes and enables high throughput with low investment and price. The silver nanoparticle on paper sensor required no special sintering techniques as the nanoparticles chemically sintered at room conditions. The as-fabricated sensors were characterized inside a humidity chamber and GOP sensor showed the best sensitivity of 0.0564% in the linear regime. The information on breathing index, an important metric to assess the fitness status of a person was obtained by performing light and vigorous exercises. The use of facile fabrication methods, high moisture sensitivity over a wide dynamic range, low overall cost, environmentally friendly materials and the application towards long term human respiration monitoring constitute the novelty of this work. However, the related signal processing and instrumentation are needed to develop the whole system for a viable commercialization product, which includes developing low power consuming data acquisition electronics [7].

In conclusion, the results presented herein demonstrate the simple and solution-free fabrication of the economical, multifunctional and environment-friendly wearable therapy systems with thermally stable properties, low power consumption and fast thermal response. The heaters also functioned as a highly sensitive human-motion sensing device. The successful demonstration of the high-resolution droplet mass sensor indicated the obvious advantage of using a polymeric substrate for motion sensing in wet conditions. Other functions such as drag-force air flow

sensors were also developed with low energy consumption. We believe that the devices constructed by this solvent-free, user-friendly and rapid prototyping approach are evidence for wearable electronic devices which find various practical applications in thermal therapy, healthcare and real-time monitoring systems with high performance and low cost [8].

In summary, graphite on paper was used as a functional material to implement electronic components such as resistors, capacitors, their combinational first order passive circuits and physical and chemical sensors such as temperature sensor, pH sensor and humidity sensor. This was achieved via direct writing or mechanical abrasion of graphite pencil on cellulose paper which involves the deposition of few layers to multi layers of conductive graphene flakes intercalated by clay and wax. The performance of the as fabricated devices was similar to those fabricated by using capital intensive equipment and eco-unfriendly materials. This approach offers a simple, solvent-free, eco-friendly, inexpensive green fabrication method of passive electronic devices and physiochemical sensors on paper, in use-and-recycle or use and-throw electronics applications.[9]

Wearable devices for health monitoring have recently been shown to provide significant benefits for early disease detection. In this article, they designed and manufactured a paper-based stretch breathing sensor using graphite (cellulose fiber) on paper as the sensor material. For graphite on paper sensors, a paper-cutting structural design using a simple laser cutting approach has been proposed. With such a cut paper structure with up to 20% expandability, you can eliminate the problem of cracking when the paper-based sensor is stretched and mounted on a curved surface such as a philtrum. We have succeeded in monitoring human breathing in real time. The proposed sensor has the advantages of being elastic, flexible, inexpensive, non-invasive, and highly sensitive, and has great potential for wearable health technology. [10]

In this paper, they introduced a new class of wireless wearable RFID sensors that can monitor different breathing patterns using GO's which have advantageous detection and hygroscopicity features. The ability to correlate the effects of changes in GO resistance with respiratory rate has been demonstrated. In addition, such portable RFID systems enable simultaneous detection of several parameters, especially humidity and temperature [11].

They have demonstrated a microwave-assisted synthetic approach to separate several graphene layers from coconut shell biomass. The gas detection characteristics of the manufactured paper-based BRG sensor show better detection efficiency at very low concentrations of acetone gas at room temperature. In addition, a paper-based BRG sensor monitors and distinguishes exhaled breath between diabetics and healthy people [12].

A. Novel aspect

As mentioned in the above section various researchers have developed more efficient, eco-friendly sensors for the wearable electronics. The major work was focused on exploring the temperature and pressure sensitivity of the

graphite. Graphite based sensor have proven to be the best replacement for the harmful and non-biodegradable sensors due to the excellent sensitivity of the GOP(Graphite-on-paper) sensors. Thermal conductivity of the graphite can be used to monitor the respiration rate non-invasively.

A novel approach is used to design the respiration rate monitoring system. As shown in the Figure [18], design consists of three components

- GOP based sensor,
- Signal Conditioning Circuit,
- Alerting system using ESP8266 NodeMCU.

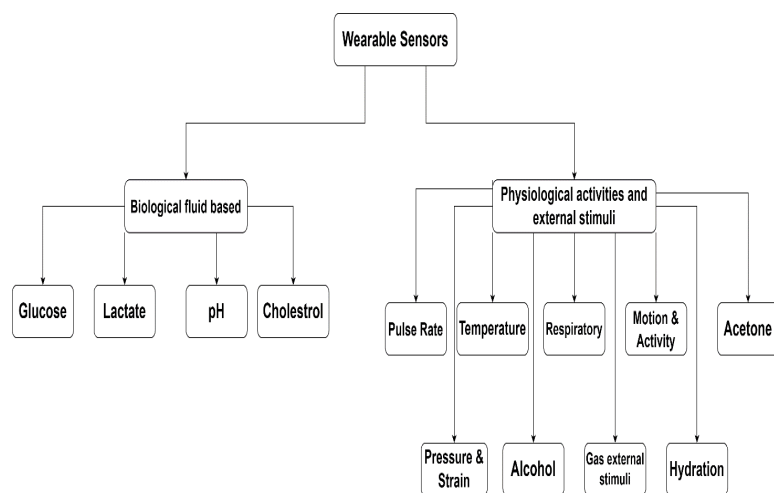


Figure (1) Wearable sensors flowchart

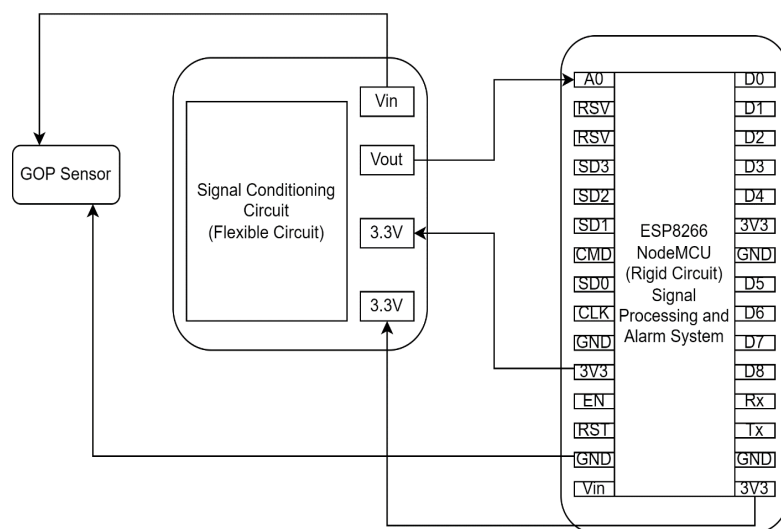


Figure (18)-Circuit diagram of the respiration rate monitoring system

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Figure (2)-Graphite on paper sensors placed on the double tape

S.No	Dimensions	Variation in R(HB)	Variation in R(C)
1	1cm×3cm	6000	15250
2	1cm×2.5cm	10000	40000
3	1cm×2cm	4500	5000
4	1cm×1.5cm	1000	1300
5	1cm×1cm	1150	600
6	1cm×0.5cm	270	900
7	0.5cm×3cm	109000	3500
8	0.5cm×2.5cm	17500	1350
9	0.5cm×2cm	128000	1250
10	0.5cm×1.5cm	8500	650
11	0.5cm×1cm	4000	600
12	0.5cm×0.5cm	3000	850
13	0.3cm×3cm	800000	175000
14	0.3cm×2.5cm	385000	100000
15	0.3cm×2cm	550000	245000
16	0.3cm×1.5cm	150000	80000
17	0.3cm×1cm	2975	13000

Table [1]: Variation in resistance across variation in dimensions of the sensor at constant temperature 300k.

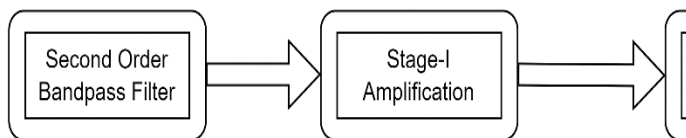


Figure (16)-Block Diagram of the Signal Conditioning Circuit

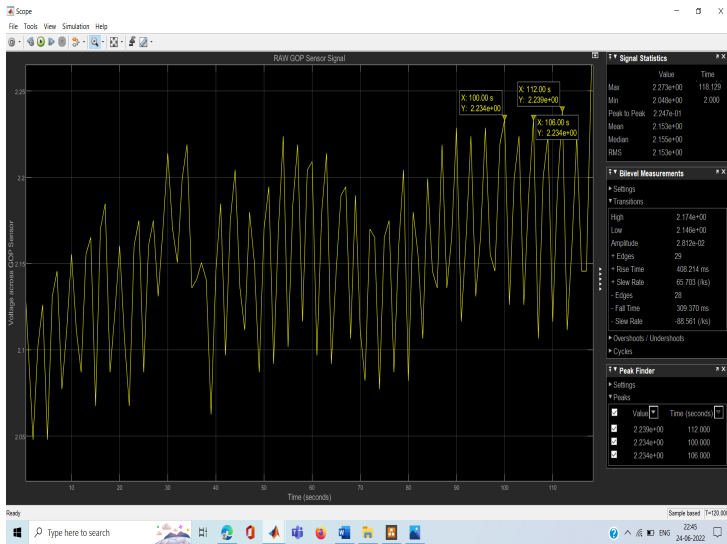


Figure (5)-Raw GOP sensor signal

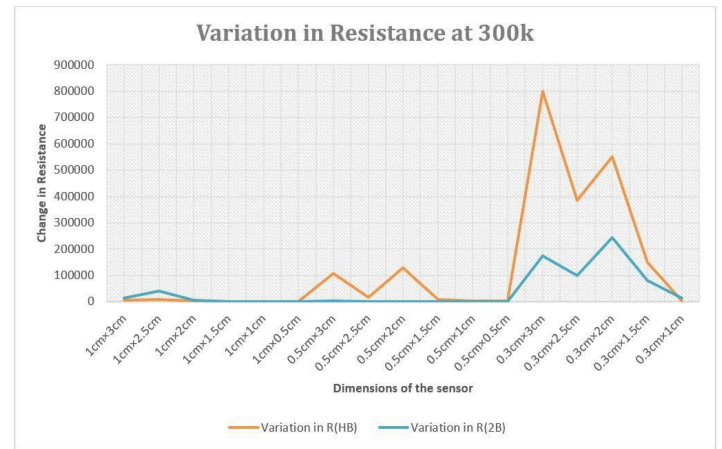


Figure (4)-Graph showing the variation in resistance across variation in dimensions of the sensor[3B,4B] at constant temperature 300k.

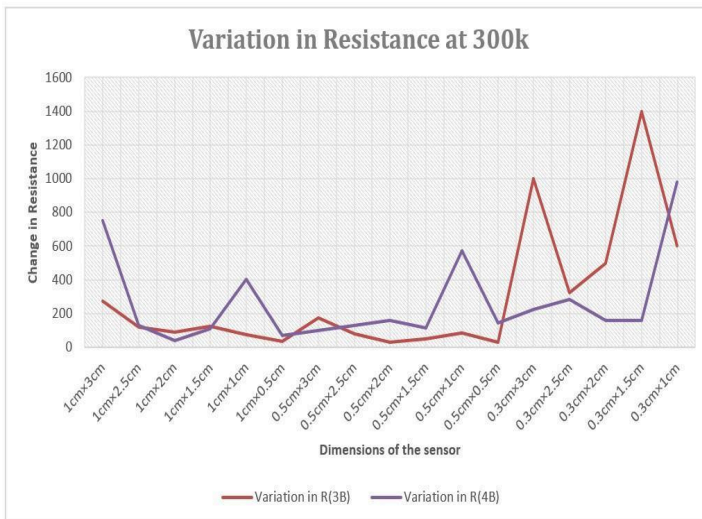


Figure (3)-Graph showing the variation in resistance across variation in dimensions of the sensor [HB,2B] at constant temperature 300k.

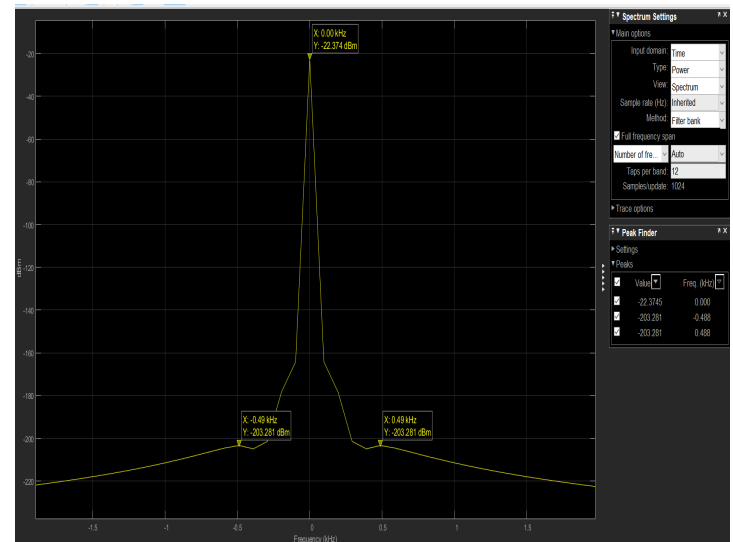


Figure (6)-Power Spectrum Analysis of the Raw GOP sensor signal

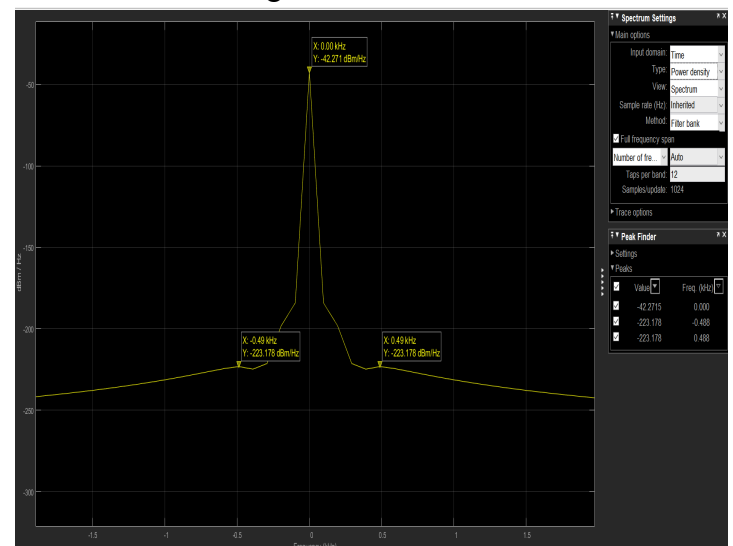


Figure (7)-Power Density Spectrum Analysis of

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t he Raw GOP sensor Signal

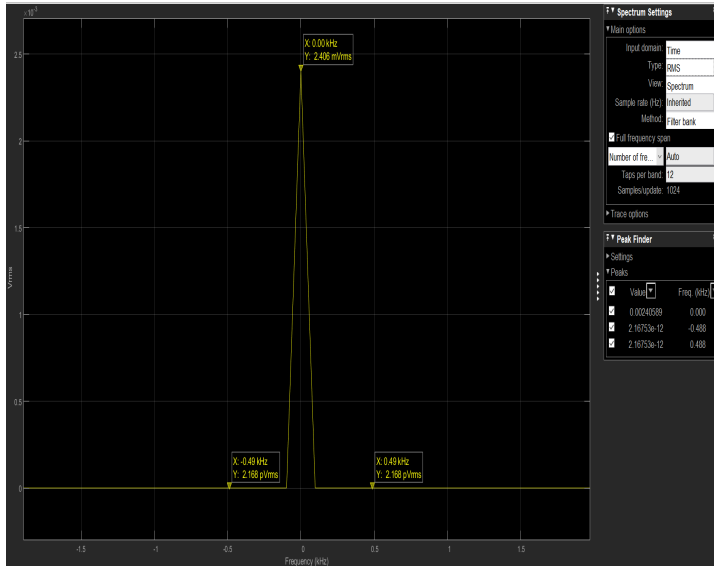


Figure (8)-RMS Spectrum Analysis of the GOP sensor signal

S.No	Parameter	Assumed Parameter	Calculated Parameter
1	F_l	1Hz	-
2	F_u	0.49KHz	-
3	R1	10K	-
4	C1	-	15 μ F
5	R2	-	3.2K
6	C2	0.1 μ F	-

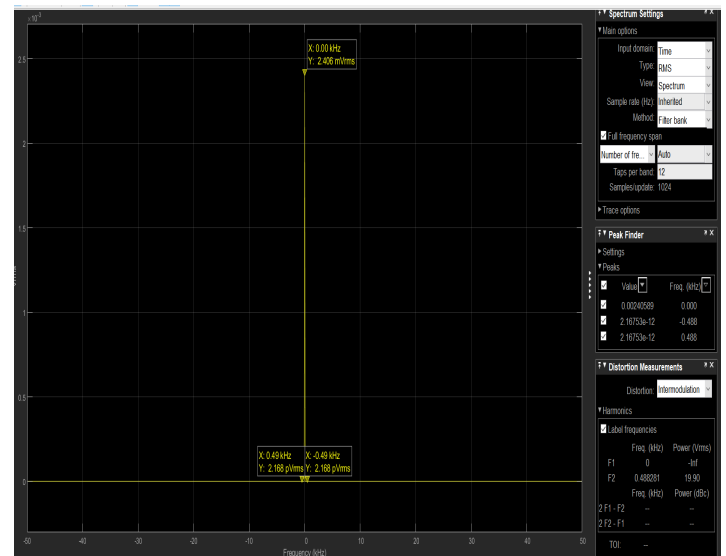


Figure (9)-Distortion Measurements

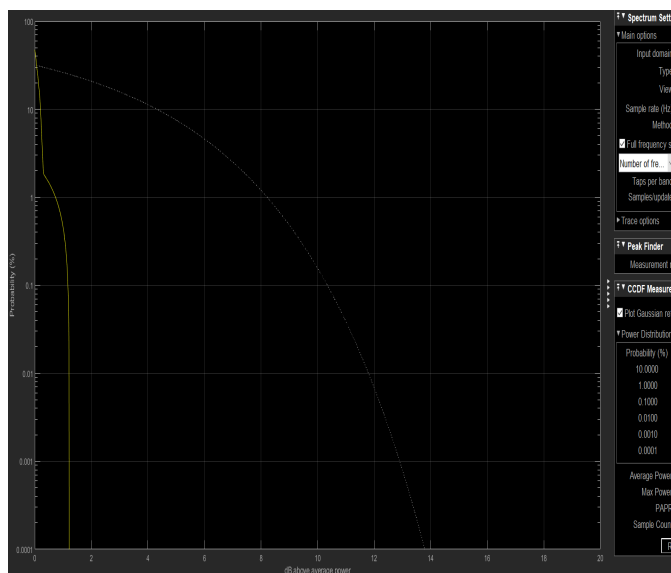


Figure (10)-CCDF Measurements

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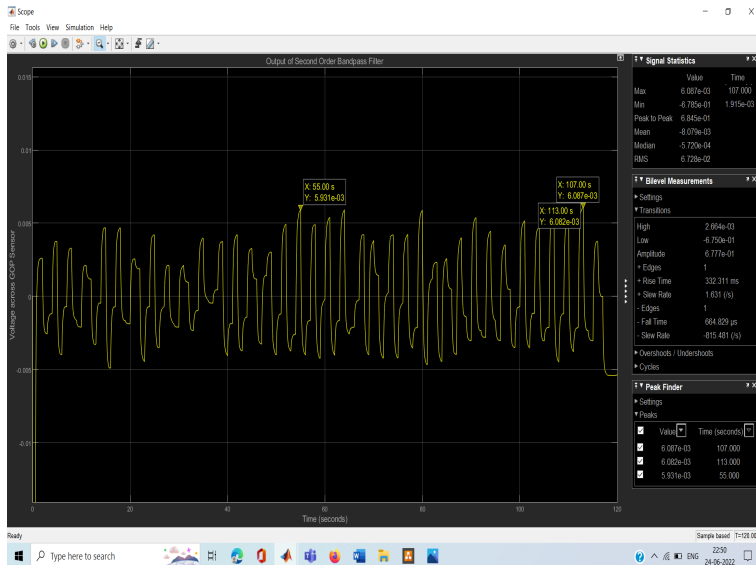


Figure (11)-Output of Second order bandpass filter

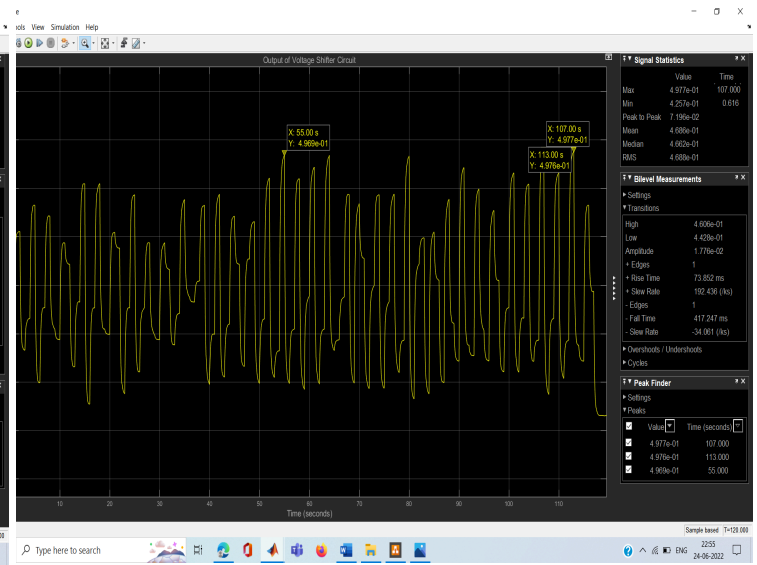


Figure (13)-Output of Voltage Shifter Circuit

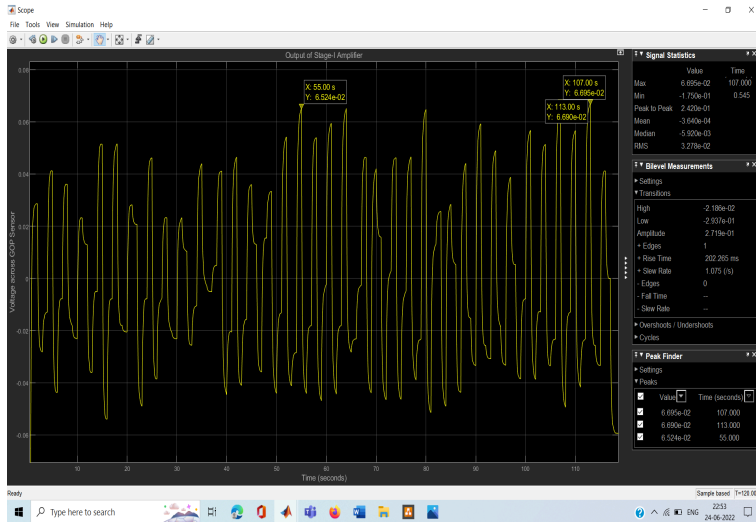


Figure (12)-Output of Stage-I Amplifier

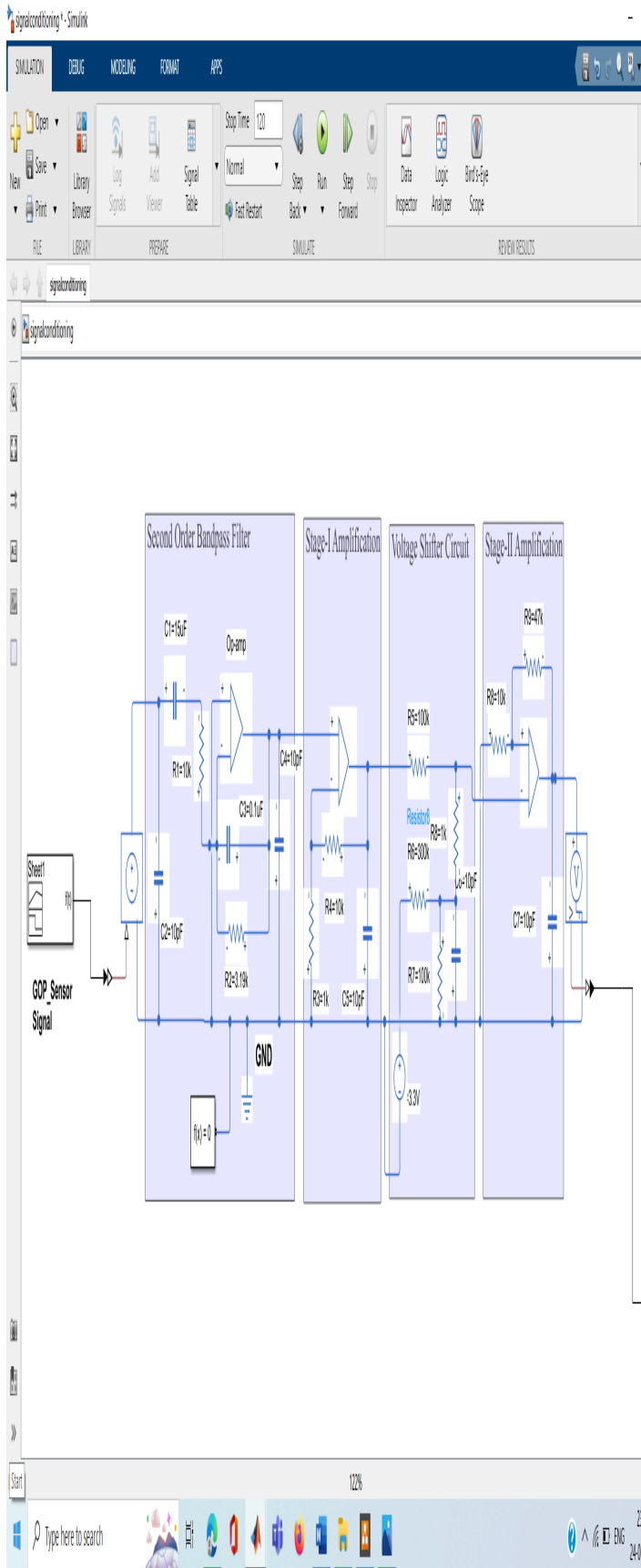
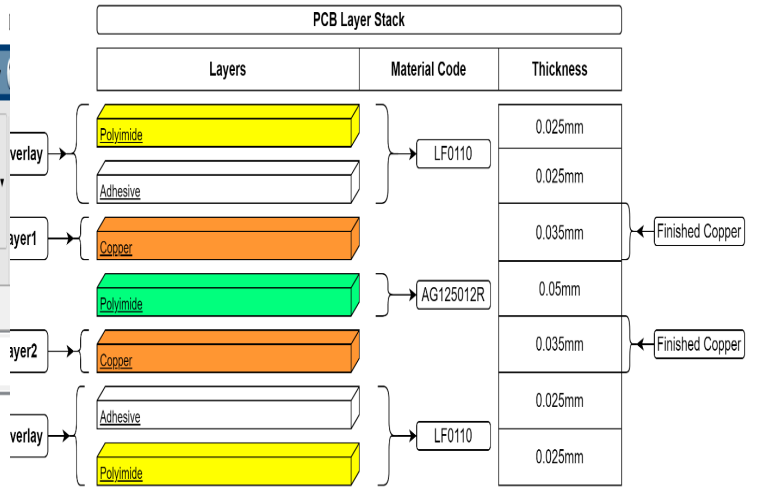


Figure (19)-PCB Layer Stack

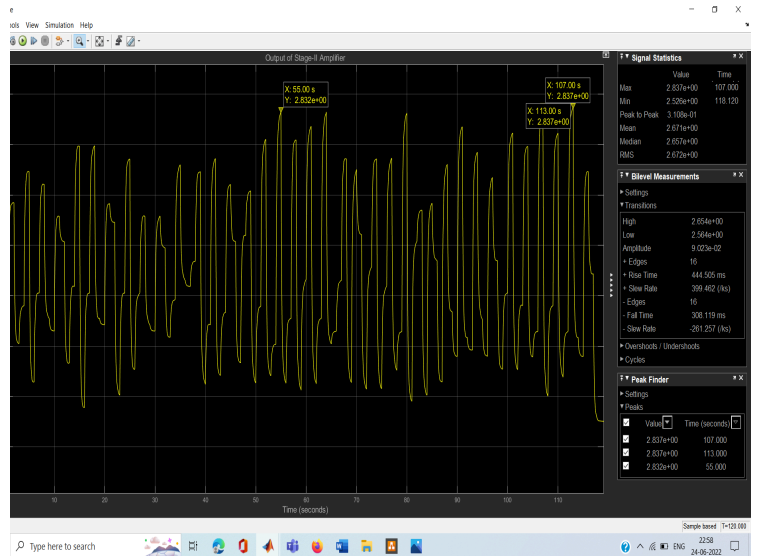


Figure (14)-Output of Stage-II Amplifier

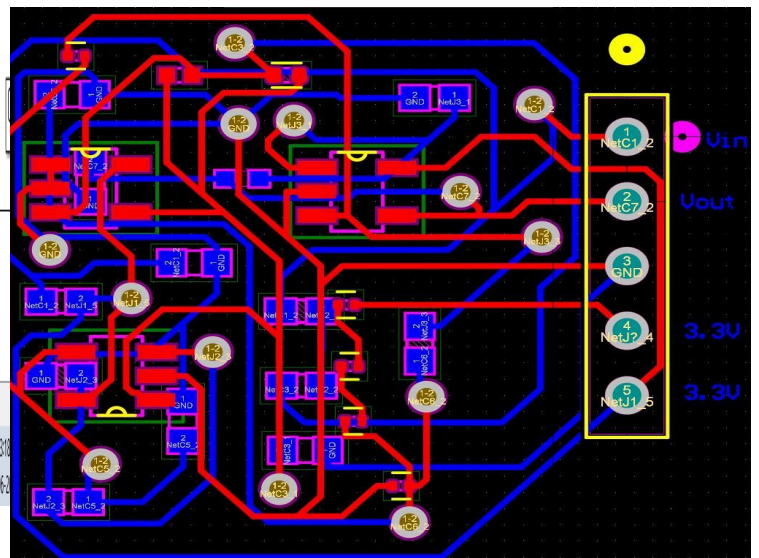


Figure (24)-Circuit Layout

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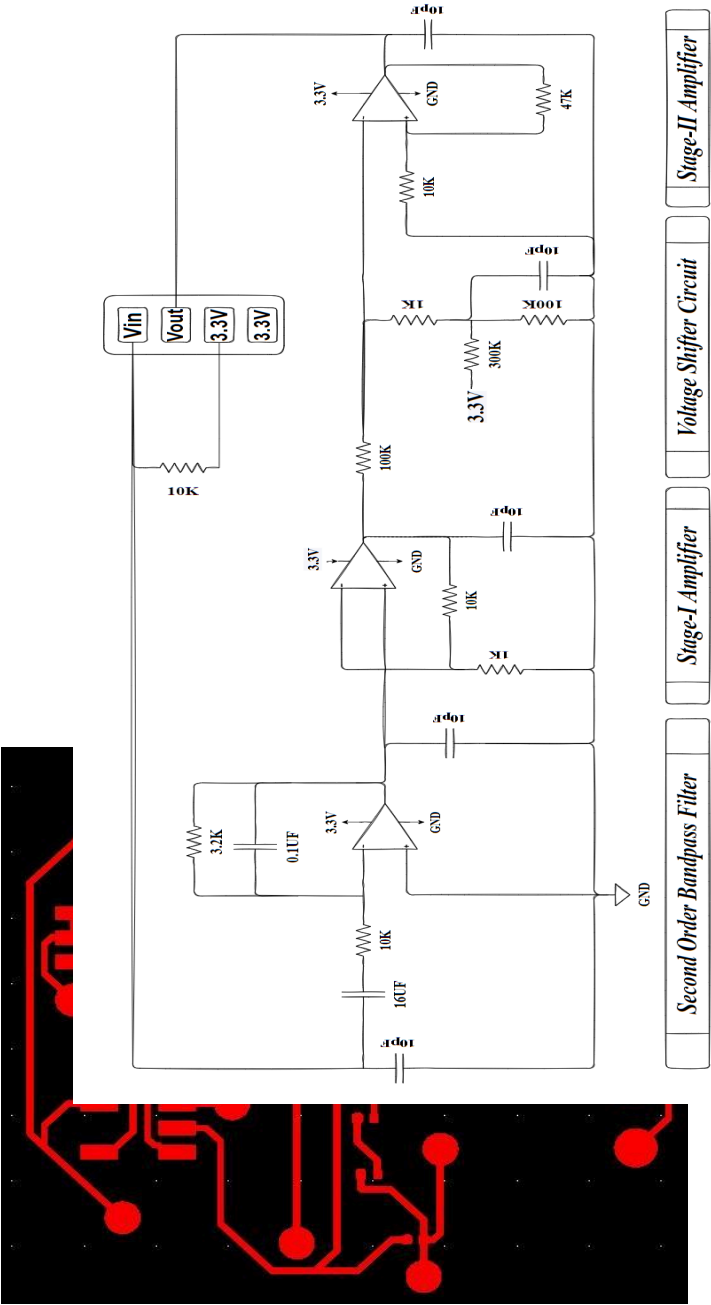


Figure (23)-Top Layer Layout

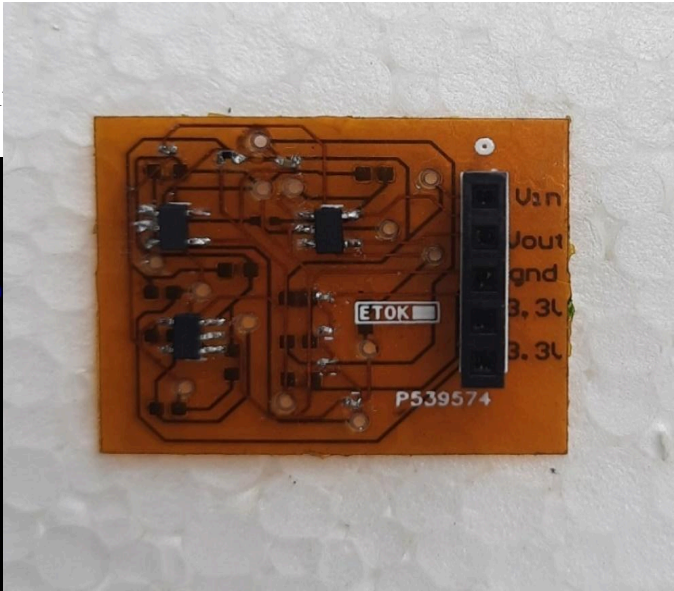


Figure (20)-PCB Top View

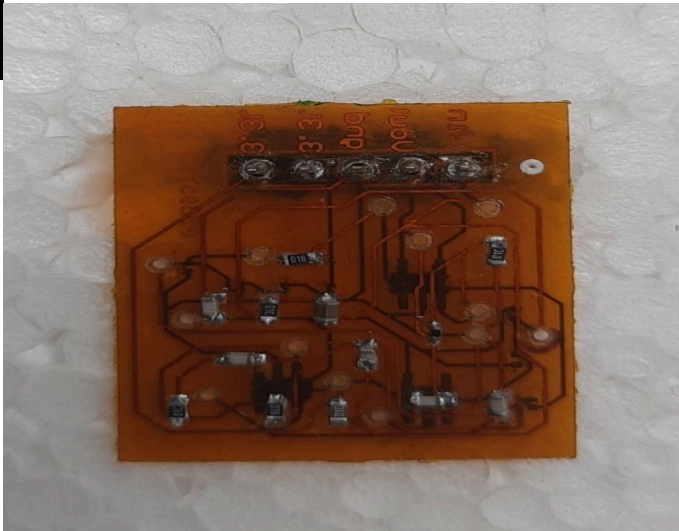


Figure (21)-PCB Bottom view

Materials/Components used:

S. No	Description	Unit price	No. of Units	Amount
1	PART: S7038-ND DESC: CONN HDR 5POS 0.1 GOLD PCB	37.99	1	37.99
2	PART: 478-1163-1-ND DESC: CAP CER 10PF 50V C0G/NP0 0603	3.567	10	35.67
3	PART: 311-47.0KLRCT-ND DESC: RES 47K OHM 1% 1/16W 0402	7.75	1	7.75

4	PART: 311-2283-1-ND DESC: RES SMD 3.2K OHM 0.5% 1/16W 0402	13.96	1	13.96
5	PART: 445-9117-1-ND DESC: CAP CER 15UF 10V X5R 0603	39.55	1	39.55
6	PART: 1276-1043-1-ND DESC: CAP CER 0.1UF 25V X5R 0402	7.75	1	7.75
7	PART: RNCP0603FTD10K0CT-ND DESC: RES 10K OHM 1% 1/8W 0603	4.73	10	47.3
8	PART: MCP6231UT-E/OTCT-ND DESC: IC OPAMP GP 1 CIRCUIT SOT23-5	30.24	4	120.9
9	PART: RNCP0603FTD1K00CT-ND DESC: RES 1K OHM 1% 1/8W 0603	7.75	2	15.5
10	PART: 311-100KMCT-ND DESC: RES 100K OHM 1% 1/20W 0201	3.257	10	32.57

Table [3]-Components in the PCB

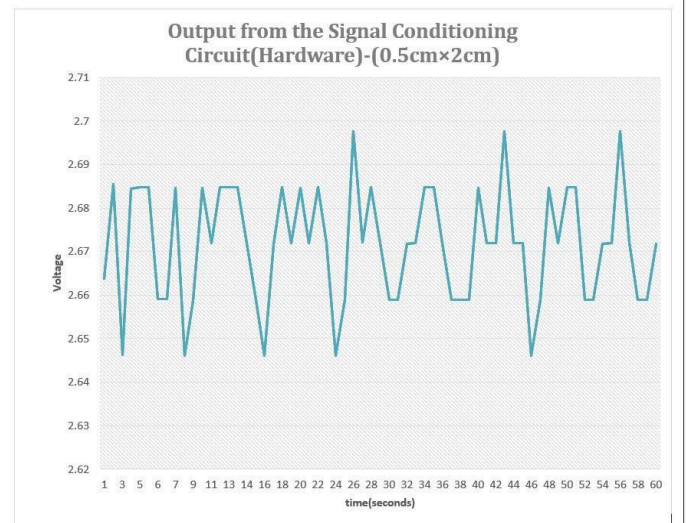


Figure (26)- Output from the Signal Conditioning Circuit (Hardware)-(0.5cm×2cm)

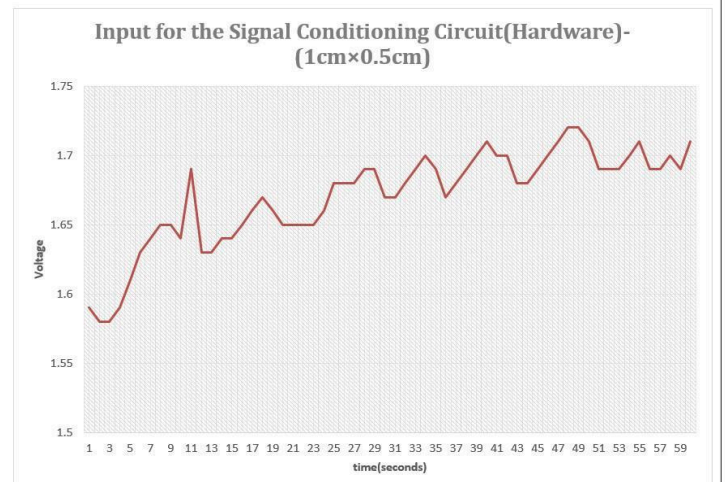


Figure (27)- Input for the Signal Conditioning Circuit (Hardware)-(1cm×0.5cm)

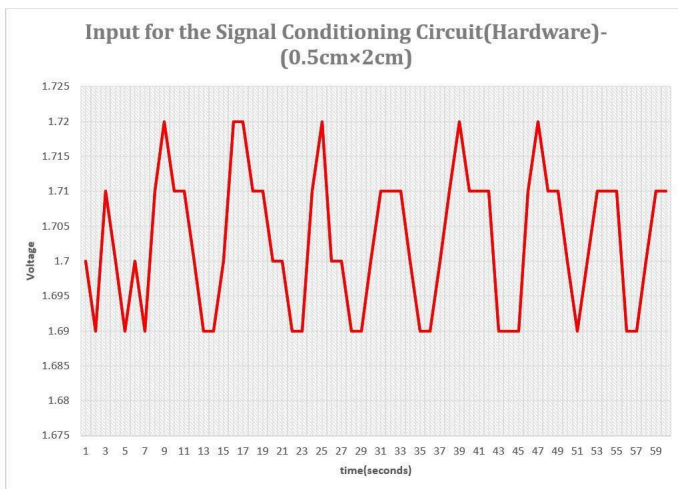


Figure (25)- Input for the Signal Conditioning Circuit (Hardware)-(0.5cm×2cm)

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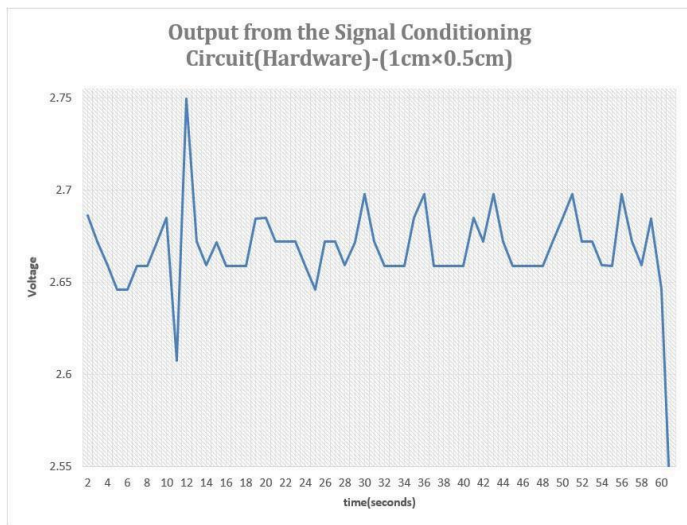


Figure (28)- Output from the Signal Conditioning Circuit (Hardware)-(1cm×0.5cm)

21	1.7	2.684756	1.65	2.671871
22	1.69	2.672007	1.65	2.671869
23	1.69	2.684673	1.65	2.671874
24	1.71	2.671964	1.66	2.659
25	1.72	2.684739	1.68	2.646066
26	1.7	2.671975	1.68	2.671828
27	1.7	2.64617	1.68	2.671875
28	1.69	2.65885	1.69	2.659072
29	1.69	2.697689	1.69	2.671726
30	1.7	2.672042	1.67	2.69758
31	1.71	2.684733	1.67	2.672189
32	1.71	2.672026	1.68	2.65895
33	1.71	2.658958	1.69	2.658915
34	1.7	2.658913	1.7	2.658918
35	1.69	2.671817	1.69	2.68466
36	1.69	2.671876	1.67	2.697689
37	1.7	2.684799	1.68	2.658973
38	1.71	2.684833	1.69	2.658908
39	1.72	2.671952	1.7	2.658916
40	1.71	2.658997	1.71	2.658918
41	1.71	2.658911	1.7	2.684715
42	1.71	2.658917	1.7	2.671937
43	1.69	2.684636	1.68	2.697579
44	1.69	2.671997	1.68	2.671979
45	1.69	2.67187	1.69	2.658939
46	1.71	2.697662	1.7	2.658909
47	1.72	2.67191	1.71	2.658919
48	1.71	2.671867	1.72	2.65892
49	1.71	2.646088	1.72	2.671786
50	1.7	2.658848	1.71	2.684732
51	1.69	2.684526	1.69	2.697626
52	1.7	2.671977	1.69	2.672202
53	1.71	2.684826	1.69	2.671862
54	1.71	2.68484	1.7	2.658995
55	1.71	2.658942	1.71	2.658919
56	1.69	2.658911	1.69	2.697672
57	1.69	2.671843	1.69	2.67202
58	1.7	2.671878	1.7	2.658987
59	1.71	2.697662	1.69	2.684643
60	1.71	2.672078	1.71	2.64615

Time(sec)	Input Voltage to the PCB-(0.5cm×2 cm)	Output Voltage from the PCB-(0.5cm×2 cm)	Input Voltage to the PCB-(1cm×0.5cm)	Output Vo the PCB-(1cm
1	1.7	2.663706	1.59	2.6736430
2	1.69	2.685491	1.58	2.686158
3	1.71	2.646232	1.58	2.671957
4	1.7	2.684505	1.59	2.658992
5	1.69	2.684842	1.61	2.646113
6	1.7	2.684842	1.63	2.645966
7	1.69	2.659052	1.64	2.658823
8	1.71	2.659052	1.65	2.658919
9	1.72	2.684572	1.65	2.671714
10	1.71	2.646074	1.64	2.684768
11	1.71	2.658827	1.69	2.60721
12	1.7	2.684696	1.63	2.749714
13	1.69	2.671947	1.63	2.672019
14	1.69	2.684818	1.64	2.659001
15	1.7	2.684835	1.64	2.671803
16	1.72	2.684835	1.65	2.658911
17	1.72	2.671964	1.66	2.658911
18	1.71	2.658993	1.67	2.658917
19	1.71	2.646057	1.66	2.684445
20	1.7	2.671572	1.65	2.684844

Table [5]: Hardware for GOP sensor of dimensions 1cm×0.5cm
Table [4]: Hardware for GOP sensor of dimensions 0.5cm×0.5cm

The dimensions of the GOP sensor were finalized after a series of experiments. The final dimensions of the sensor are chosen such that they have least variation in resistance at room temperature (i.e., 300k). The sensor was placed on a double tape to avoid change in resistance due to piezoelectric effect. As mentioned in the above sections, the GOP sensor is low-cost, flexible, eco-friendly, home-made, highly sensitivity and doesn't require any clean rooms for manufacture. It is observed that the GOP sensor signals lie in the range 1Hz-0.5kHz, concluded from the FFT analysis of the signal. A Signal Conditioning circuit is designed for the GOP sensor to make the signal compactible for ESP8266 MCU, for further processing. The Circuit designed is flexible in nature and dimensions are 20mm×29mm. The Signal Conditioning Circuit consists

- a) Second Order Bandpass filter
- b) Stage-I Amplifier
- c) Voltage shifter Circuit
- d) Stage-II Amplifier

which condition the signal to the range 0-(3.3V). The results obtained from the simulation and hardware implementation were satisfactory. The circuit could detect normal respiration. After observing the conditioned signal, we can observe peaks and nadirs, which have occurred due to respiration. Using this signal, we can measure the respiration rate. The Alerting system consisting the ESP8266 NodeMCU which has WIFI module. An alert message can be sent to the mobile through the ESP8266 NodeMCU in case of abnormal respiration rate. The whole system including the Sensor, Signal Conditioning Circuit, alerting system can be embedded on the mask. This system does not require any contact of the patient's philtrum. This enhances the comfort of the elderly people and children.

B. Design and Methodology

The respiration rate monitoring system includes three components:

- GOP Sensor
- Signal Conditioning Circuit
- Signal Processing Circuit

The Sensor fabrication:

Materials Required: 4B graphite pencil, A4 sheet paper, double tape

Methodology: Sensor was fabricated by mechanical abrasion of pencil graphite trace on paper for 10-12 times. The Dimension of the sensor was finalized after a series of experiments. The sensor is shown in Figure [2]. Different graded pencils with various dimensions are experimented for variation in resistance at constant room temperature. The results are tabulated in the Table [1]. The graphs for the data in the Table [1] are attached in the Supplementary material.

From the table and the graphs, we can conclude that the 4B graphite pencil's resistance is stable at given room temperature (300k).

We can also conclude that the dimensions 1cm×0.5cm, 0.5cm×2cm are suitable for the sensor because the variation is minimal.

Graphite on paper based sensor is placed on a double tape to avoid resistance change due to the piezoresistive effect under bending or twisting in the wearing process.

To Design the Signal Conditioning Circuit, GOP sensor signal was observed. The Signal obtained from the contains the noise. To filter the noisy signal the FFT was performed on the signal. To design the circuit the following analysis were done:

- a) Power Spectrum Analysis of the Raw GOP sensor signal
- b) Power Density Spectrum Analysis of the Raw GOP sensor Signal
- c) RMS Spectrum Analysis of the GOP sensor signal
- d) Distortion Measurements
- e) CCDF Measurements

The analysis results are shown in Figure [5],[6],[7],[8],[9],[10].

III. CALCULATIONS

The above graphs shows that the FFT analysis conclude that the signal frequencies lie between 1Hz to 0.49kHz.

So, to extract the signal and reduce the noise a bandpass filter must be used.

To design a bandpass filter, we need the lower cut-off frequency as 1Hz and upper cut-off frequency as 0.49kHz.

So, to find the values of the capacitor and resistor of the filter, we can the below formulas:

$$F_l = \frac{1}{2\pi R_1 C_1} \quad -(1)$$

$$F_u = \frac{1}{2\pi R_2 C_2} \quad -(2)$$

We can substitute the F_l as 1Hz and assume either R1 or C1 as some value and find the remaining parameter. This methodology can be followed using F_u .

The values obtained are tabulated:

The Figures [11],[12],[13],[14] shows the outputs of each stage of the Signal Conditioning Circuit. The Figure [17] shows the entire circuit schematics.

IV. RESULTS AND OBSERVATIONS

Hardware implementation:

Flexible Circuit with polyimide substrate was manufactured. The Figure [19] shows the PCB Layout Stack of the Signal Conditioning Circuit. The PCB was designed using Altium PCB Designer Software. The Figures [22],[23],[24] shows the PCB layouts of bottom layer, top layer and entire layout of the circuit. The Figures

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[20],[21] shows the fabricated PCB.

The results are shown in the Figures [25],[26],[27],[28]. The outputs will be provided to the ESP8266 NodeMCU. The NodeMCU ESP8266 development board comes with an ESP-12E module. This module contains an ESP8266 chip with a Tensilica Xtensa 32-bit LX106 RISC microprocessor. This microprocessor supports RTOS and operates at adjustable clock frequencies from 80 MHz to 160 MHz. The NodeMCU has 128KB of RAM and 4MB of flash memory for storing data and programs. The high processing power and deep sleep operation function with built-in Wi-Fi / Bluetooth make it ideal for IoT projects. The NodeMCU can be powered via a micro-USB socket and a VIN pin (external power pin). It supports UART, SPI and I2C interfaces. It has a 10-bit ADC and a 2.4GHz antenna. For the programming the nodemcu, we follow this methodology. The signal from the PCB is processed and the median voltage is determined and this value will be considered as threshold voltage. A count variable will declare. When the input voltage crosses the threshold value in a time interval of 1sec, then the count value increases by 1 unit. The count value obtained per minute is considered as respiration rate. An alert message will be sent to the mobile in case of abnormal respiration rate. Normal respiration rate of an adult is 12-16 breaths/sec.

A. References

V. LITERATURE SURVEY

Reflections on the reference [2]:

This particular work was focused on the manufacture on the FET's using graphite on paper. This work utilizes the strain sensitivity of the graphite. But my work focuses on using the negative temperature co-efficient nature of graphite. The change in resistance of graphite on paper sensor due to change in temperature during respiration. My work focuses on designing a respiration rate monitoring system.

Reflection on the reference [1]:

A flexible screen-printed sensor based on polyaniline-graphite nanocomposite is introduced as well as a novel method of controlling sensor boundaries by changing the distance between the electrode and the number of electrodes. Using these flexible humidity sensors, the unaffected fingerprint sensor was shown with a change of 14.32% at a distance of 0.2 cm from the sensor surface. Finally, an artificial device was inserted inside the N95 mask to show the respiratory monitoring system showing significant differences in high intensity with different respiratory levels, thus, allowing us to create a map of normal, deep and disturbed respiratory level. But my work uses the thermal properties of the graphite. It focuses on building a signal conditioning circuit that is compatible for

ESP8266 nodemcu.

Reflections on the reference [3]:

Less expensive and biodegradable flow sensors using ubiquitous pencil graphite as a hot film sensor layer, simply made from inexpensive, reusable and decaying printing paper using the drawing method and subsequent laser cutting method. They have demonstrated a GOP-based patch type sensitive thermal flow sensor that can monitor the human respiratory system in real time. But my work focuses on using the signal conditioning circuit to extract the signal from the sensor and make it compactable for ESP8266 nodemcu.

Reflections on the reference [4]:

They report a simple and easy-to-use method to prepare a flexible, robust, practical, environmentally friendly and economical (0.32%) sensor with range of strain from -0.62% to 0.62% under stressful and strong, comparable flexible conditions. By studying the behaviour of the sensory service by multi-bending frequency test (> 10,000 cycles), stress sensors allow a simple sensory field of recurring output signals to $\pm 0.32\%$ type within a relative resistance variation of 10.33%. But my work exploits the thermal properties of the graphite sensor. The work focuses on designing a respiration rate monitoring system.

Reflections on the reference [7]:

This paper has fabricated and tested graphite and silver nanoparticles-based sensors on low cost and light-weight paper substrates for respiration monitoring activities. The GOP sensor involves simple fabrication processes and enables high throughput with low investment and price. The silver nanoparticle on paper sensor required no special sintering techniques as the nanoparticles chemically sintered at room conditions. The as-fabricated sensors were characterized inside a humidity chamber and GOP sensor showed the best sensitivity of 0.0564% in the linear regime. Furthermore, the sensors tested on three healthy subjects under different respiratory conditions provided useful information about the breathing rate and pattern. My work focuses on using only graphite on paper sensor. It uses thermal properties of the graphite. It focuses on designing the respiration rate monitoring.

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