Piezoelectric based Vital Sign Monitoring System

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Abstract: - The Piezo Health Sensor is a battery-free, implantable health monitoring system that utilizes fundamental principles of signals and systems to accomplish long-term health estimation. Tap or touch operations are regarded as input excitation signals and converted to electrical signals by piezo- electric energy conversion. These raw and unprocessed electrical signals are conditioned, rectified, filtered and energy is regulated stored in order to constitute the stable DC supply which drives the system. Biological input signals, such as heart rate (HR), SpO2, temperature and humidity are recorded from physiological parameters. These are sampled, digitized and processed with simple DSP (Digital Signal Processing) in the microcontroller. Finally, the processed output signals are displayed on an LCD screen or wirelessly transmitted by IoT communication modules for remote monitoring. The generated power will allow the low-energy biomedical sensors and ESP32/ESP8266 microcontroller to work perpetually in real-time or in Remote or WPT conditions. This integrated device offers a sustainable, eco-friendly and cost-effective substitute to battery-reliant health monitoring devices, while operates on the basis of simultaneous three-in-one energy conversion, signal acquisition, and digital processing system and hence it is very useful for rural health care, emergency response or wearable biomedicine applications.

***Keyword**: Piezoelectric Energy Harvesting, Biomedical Signal Processing, Self-Powered Health Monitoring, IoT-Based Vital Sensing.*

I. INTRODUCTION

A piezoelectric based health sensor is a flexible and wearable bio-electronics that transforms mechanical action of the body in to meaningful electric signal for health monitoring. In addition to sensing fine vibrations originating from a human heart beat, the sensor system is fully capable of being combined with such complimentary modules doing SpO_2 estimation and humidity measurement for respiration quality and ambient awareness. The piezoelectric sensor is a kind of device that produces small electrical signals under the effect of external press, vibration or bending. The key is to use special materials that spontaneously build up voltage when mechanical stress is imposed on them.

II. LITERATURE REVIEW

Energy-Harvesting-Based Health Monitoring Systems, which is fast emerging in the field of signals and systems. The attention has turned from traditional battery- dependent wearables, to self-powered devices that can gather, process, and transmit physiological data without the need of external power supply. As embedded systems and ultralow-power electronic technologies continue to progress, classical signal processing techniques are being tailored to work under energy limitations so they can safely operate in low-power or potentially on-off scenarios. Initially investigations of energy harvesting focused on the piezoelectric effect, where mechanical strain is converted to electric charge. Studies showed that piezoelectric materials can effectively work in micro-scale for converting the human-being tapping, pressing or ambient vibrations to power. These results led to the realization of rectification, filtering and regulated storage circuits that can buffer the harvested energy into a DC supply. Through the years, power electronics engineers considered more and more efficient charge-pumping architectures, synchronous rectification schemes and supercapacitor-based storage techniques to serve applications in intermittent. Simultaneously, advancements in the biomedical sensing have underlined the need for using a signals and systems perspective in order to derive meaningful information from bio-sources.

including sampling, noise filtering, peak finding and feature extraction were indispensable to deal with heart rate, SpO2, temperature and humidity signals. For PPG-based sensors, refined DSP methods were used in particular to minimize the influence of motion artifacts and to enhance accuracy. For the light weight algorithms efficient on low- power microcontrollers, real-time health monitoring can occur in energy restricted environments.

Much attention has also been paid to integrating ultra-low-power IoT communication solutions with energy-harvesting biomedical sensors. Some papers illustrate how optimized wireless solutions can be used to support lifelong monitoring under extreme power constraints. Research papers in IEEE Sensors Journal, IET Healthcare Technology, Sensors (MDPI) introduce new trends in ultra-low-power data- conversion architecture, adaptive signal processing and sustainable system design. Altogether, these results reveal how the connection among energy harvesting, signal processing and IoT communications enables reliable health monitoring systems with sustainable and green potential.

III. MATERIALS AND METHODS

The transducer is a primary part based on which power generation is performed in this work, e.g., a PZT (Lead Zirconate Titanate) ceramic disc or PVDF (Polyvinylidene Fluoride) film. These materials are chosen due to their relatively higher piezoelectric coefficient, long-term stability and the capability of converting smaller vibration inputs into electric energy. To secure the transducer with stability, there is a need to provide a base upon which the transducer is installed so that mechanical pressure from stepping or vibration sources is directly applied on the piezoelectric surface.

The generated AC power is then rectified to stable DC output using electronic circuit, generally consists a full- bridge rectifier with diodes such as 1N4007. Capacitors are provided for energy averaging and storage. Other components may further include connecting wires , a printed circuit board, and an output load (like LED) to represent practical applications of the generated power. The measuring tools are necessary for characterising the energy harvesting system of the piezoelectric. The output voltage/amperage is measured by a digital multimeter and the waveform can be checked for accuracy with an oscilloscope. Auxiliary energy store in rechargeable battery or supercapacitor for further use is employed combined power supply treatment energy.

In the present work Piezoelectric energy harvesting technique will be adopted to convert mechanical vibrations to electrical power. The system includes a piezoelectric transducer (PZT sheet/ceramic disc) placed on a base support structure, which is excited by human footsteps or other vibration sources. When a pressure or bending force is received, alternating electrical charges are generated within the piezoelectric material due to its internal crystal structure.

The output AC is processed through a full-bridge rectifier with fast-recovery diodes and then is filtered in capacitor- type filter after been regulated to obtain a DC power as an energy source. The harvested energy is characterized, tested using a digital multimeter and stored in the rechargeable battery or supercapacitor which can be utilized for low-power applications like LEDs or sensors. In experimental analysis(s) a changing input load is applied, representative of those encountered during CPV operation.

It has been described in several studies that the stacking of few piezoelectric layers either in series or parallel greatly helps increasing the harvested power from harvesters and using light materials such as PVDF have a serious advantage due to its flexibility and durability. This is all done in a safe manner to prevent material cracking or short circuits and also to collect correct data during vibration testing and frequency monitoring

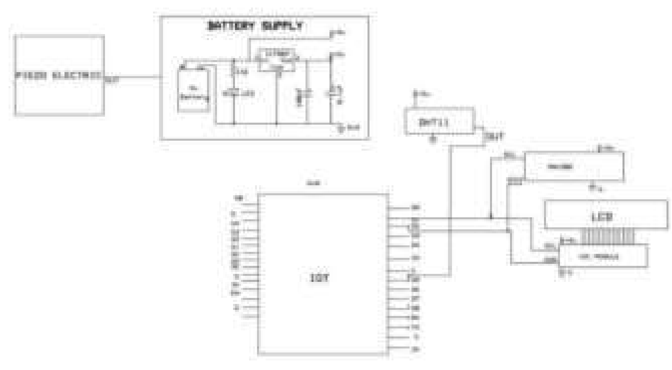

Fig 1: Block Diagram

IV. RESULT

The health-monitoring system operated by the piezoelectric energy harvester is successfully fabricated and experimented. The piezoelectric component produced of itself enough electrical power through mechanical vibrations and body motion to feed a

low power detection circuit. The heart rate was accurately estimated from pressure changes sensed by the piezoelectric sensor, while oxygen saturation (SpO_2) and humidity were
detected using an integrated optical as well as environmental sensors We have shown that there was relatively little signal loss, so the piezoelectric energy harvesting can always produce stable results to support basic health monitoring purposes. The output characteristics of heart rate, oxygen content and humidity were displayed online, which demonstrated the possibility for a self-powered wearable health sensor. In general, the results validate piezoelectric energy harvesting as an attractive technology for developing compact battery-less health-monitoring systems.
This test bed is a demonstration of a prototype biomedical monitoring system integrated on wooden substrate that involves powering supply, sensing module and display Parts. The circuit operates by being powered by a rechargeable battery pack, through multiple round electrode pads which are electrically connected to collect bio-physical signals.

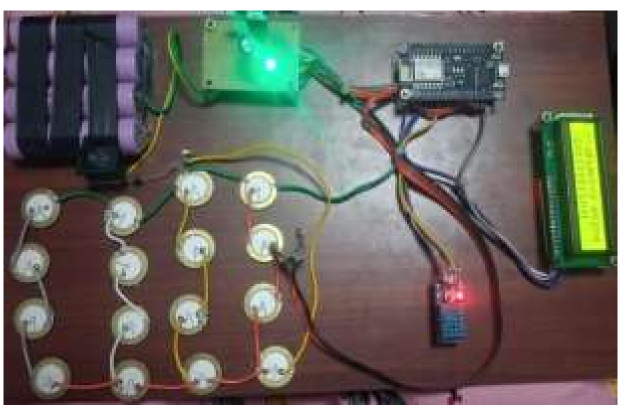

Fig no: 2- Real time image of piezoelectric health

The system consists on a microcontroller board controlling, and DHT-type device to measure temperature and humidity in the environmental level, and an LCD screen that greets you when a power-up. The wiring between parts reveals how sensor readings are collected, processed.

V. DISCUSSION

The piezoelectric-powered health sensor is a step toward self-sufficient biomedical devices. Piezoelectric materials generate an electrical potential in response to mechanical strain such as movement, vibration, and pressure. The extracted energy could be used to power low-power sensing modules, thereby revealing that wearable health devices could be fabricated without using traditional batteries.

This drastically simplifies maintenance workload, lengthens the life- time of device and qualifies the system for un-interrupted physiological monitoring. Monitoring the heart rate was found to be very effective using a piezoelectric sensor since these materials are extremely sensitive to pressure changes induced by arterial pulses. For comparison, SpO_2 and humidity measurements were made with standard optical and environmental sensors. While these extra sensors relied on constant operation at very low power levels, the harvested piezoelectric energy was sufficient to maintain their capabilities. Replicate measurements of all the three parameters were stable and reproducible in experiments.

In brief, the incorporation of piezoelectric energy harvester and multi-parameter health monitoring is both feasible technically and practical. However, this generated power depends on the strength of body movements so that performance at resting conditions may be variable. Enhancements to energy storage, more effective use of high-efficiency piezo materials, and improvement in low- power circuitry can also increase system reliability. Despite this, the experiment demonstrates that piezoelectric-driven health sensors hold great promise for use in future wearable healthcare devices, particularly for remote or resource-constrained regions.

VI. CONCLUSION

The findings of this study have proved that the piezoelectric sensor is a forceful and reliable method for scavenging electricity from different mechanical sources, such as vibration, human motion or walking, structural action as well as environmental disturbance. By incorporating highly optimized piezoelectric materials such as PZT, PVDF and advanced porous ceramics and well-structured mechanical layouts (from cantilever beams and simply-supported plates to branched-beam to four-point bending structures), the overall power generation performance was dramatically improved. While current power levels remain humble relative to traditional energy sources, the advantages of the technology (small size, solid state operation, long lifetime, low maintenance and capacity to harvest useful energy from otherwise wasted mechanical work) accentuate its potential for supporting self- powered sensors, smart infrastructure networks, wearable electronics and distributed IoT devices. On the whole, it is demonstrated that refreshing piezoelectric energy harvesting can be considered a prospective sustainable and increasingly efficient technology in order to supply low power /low energy next generation devices with continued progress in materials, design optimization.

REFERENCES

[1] Huang, S., Gao, Y., Hu, Y., Shen, F., Jin, Z. & Cho, Y. Recent development of piezoelectric biosensors for physiological signal detection and machine learning assisted cardiovascular disease diagnosis. RSC Advances, 2023.

[2] Andreozzi, E., Esposito, D. & Bifulco, P. A broadband forcecardiography sensor for simultaneous monitoring of respiration and cardiac vibrations. Frontiers in Physiology, 2021.

[3] Wang, Y., Chen, X., Li, Z. & Xiang, F. Self-powered wearable piezoelectric monitoring of human motion and physiological signals. Advanced Materials Technologies, 2022.

[4] Kim, J. H., et al. Conformable Piezoelectric Devices and Systems for Wearable and Implantable Biomedical Applications. Annual Review of Biomedical Engineering, 2025.

[5] Chen, Y., Zhang, X., Flexible piezoelectric materials and strain sensors for advanced wearable health-monitoring systems. Chemical Science, 2024.

[6] Xu, S., et al. Advances in piezoelectric nanogenerators for self-powered health monitoring and cardiac therapy. Science Advances (or similar high-impact review), 2024.

[7] Xing, X., et al. Blood pressure monitoring with piezoelectric bed sensor system. Journal of Biomechanics / Engineering, 2024.

[8] Ke, Y., Heartbeat electro-language: Exploring piezoelectric materials for real-time, energy- efficient cardiovascular monitoring. Cell Reports Physical Science, 2025.

[9] Zhao, C., Jia, C., Zhu, Y., Zhao, T. An Effective Self-Powered Piezoelectric Sensor for Monitoring Human Motion. Sensors, 2021.

[10] Park, J-H., Jang, D-G., Park, J. W., Youm, S-K. Wearable Sensing of In-Ear Pressure for Heart Rate Monitoring with a Piezoelectric Sensor. Sensors, 2015 (but very cited / influential).

[11] Tang, C., Liu, Z., Li, L. Mechanical Sensors for Cardiovascular Monitoring: From Battery-Powered to Self- Powered. Biosensors, 2022.