A STUDY ON THE DEVELOPMENT AND RESEARCH OF VERY POWER EFFICIENT ELECTRONIC CIRCUITS FOR USE IN BODY SOUND MONITORING

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ABSTRACT

The need for an easy-to-use electronic system that can detect and monitor the routine of dosage administration during home treatment has risen, and with it, the significance of adherence monitoring in the healthcare industry, which has been steadily rising over the last several decades. Patients suffering from cystic fibrosis (CF), a debilitating chronic lung illness, must undergo constant therapy to alleviate their symptoms. Nevertheless, there is a lack of documented adherence to CF medical therapy. Low medicine use, greater hospitalisation, and gradual deterioration may result from non-compliance. To assess the effectiveness of dosed medication, anticipate aggravation, and ensure that patients comply with their treatment plans, a reliable monitoring system is required. Using a new low-power disposable electronic sensor module with limited memory, this thesis describes an electronic adherence monitoring system that has been built. The system systematically studies inhalation detection and exhibits benefit in computing needs and detection accuracy. There is little computational complexity and great accuracy with the chosen characteristics, proving their reliability. Powered by a tiny, foldable battery, the developed prototype can operate constantly for 28 days of therapy while using very little electricity. The portable gadget has a direct feedback system, audio processing, motion detection, data storage, and transmission capabilities; it can be coupled to the target dry powder inhaler and effectively monitors adherence. It has a quick decision-making system and real-time recognition capabilities, so it can record the length of inhalations, the date and time of occurrence, and the events of administration, even in loud environments.

KEYWORDS: Power Efficient, Electronic Circuits, Sound Monitoring, Health monitor

INTRODUCTION

There is a plethora of information that may be used for the diagnosis of diseases and the monitoring of health that can be obtained from the noises that are produced by the human body. As an example, cardiopulmonary signals have been used extensively in the clinical setting of hospitals for a big quantity of time to diagnose lung and heart problems. It is essential to be aware of the foetal heart rate, which can be determined by listening to the sound of the heartbeat. This is because the foetal heart rate is a key predictor of the health of the infant. The bowel sound may also be utilised to determine whether the abdominal surgery was effective and whether or not there were any adhesions of tissue. This is identical to the previous example. It is now feasible for people to construct one-of-a-kind sound monitoring and diagnostic systems that make use of the noises that are generated by the bodies of a variety of people. This is made possible by the development of digital signal processing and high-performance circuits, which have made it possible for individuals to develop such systems. The whole process of sound-based diagnosis and monitoring does not result in any immediate or prospective harm to the bodies of persons. This is because the technique does not include any physical contact. This stands in contrast to the diagnostic instruments that are often used, which are characterised by the utilisation of dynamic power transfers (Xiao, 2020).

Examples of such equipment are X-ray scanning and ultrasound technology for detection. The article presents a number of concepts, one of which is a wireless healthcare sensor that is capable of capturing the signals that are created by the human body and using them for the purposes of diagnostics and health monitoring. The sensors typically consist of three components: the sound sensor, which wirelessly preserves the body of the individuals, the small moveable equipment that functions as a portable base station (PBS), and finally the server, which is responsible for the commodities and methods of the recorded wellness data for the benefit of the end-users. The sound sensor is the most important component of the sensors. Because of the advancements that have been achieved in sensor technologies, integrated circuits, mobile networks, and wireless communication, it is now feasible to build sound sensors that use an extraordinarily low amount of power (Sim, 2019).

This advancement has made it possible to produce sound sensors. Because of this, they are particularly well-suited for applications that often take place. Within this article, it is structured in the following manner: Section II contains an explanation of the system's fundamental architecture, which may be found in the previous section. An in-depth discussion of the design and the components that make up the prototype of a wearable sound sensor stick for monitoring heart rate is included in section III of the report. This part also includes detailed information on the prototype (Dong, 2020).

BACKGROUND OF THE STUDY

In the transmission and distribution power system, electromechanical devices known as circuit breakers are used in order to connect or stop the flow of electricity at the generator, substation, or load point. Within the context of a conventional circuit, the circuit breakers have the ability to create, transmit, and interrupt currents. This is linked with the process of producing and sustaining currents for a certain amount of time, as well as with stopping currents under specified aberrant circuit circumstances, such as a short circuit, amongst other scenarios. The components that make up the breakers include a control circuit, a mechanism for opening and shutting, and contacts that break and create current. The lifespan of a breaker may extend over forty years if it is properly maintained. Circuit breakers are often left open in order to isolate a particular place within the network, and they are closed in order to join two sections of electrical cables together. On the other hand, they really do the protective and switching functions that were built specifically for them in many different scenarios (Khan, 2019).

In the event that there is a power loss, the protection relays of the system are able to recognise which circuit breakers need to be opened in order to isolate the issue and bring the system back to its regular functioning state. It is possible for the circuit breaker to trip many times throughout the course of a single occurrence. In the event that lighting is the source of brief difficulty on the queue, the only solution to the problem is to reclose the queue. When this is the case, reclosing relays are often used; they are responsible for triggering the breaker to instantly close the transmission line once it has been opened. If the issue continues to exist after the breaker has been closed again, the relay will immediately open the breaker. When the breaker has been opened and closed a few times, it will eventually get locked out. The telltale indicator of a problem in an electrical system is a current that is flowing across a short circuit. The operation of a device that interrupts current is often and frequently required. Then, it is not uncommon for a fleeting event to cause a disruption in the flow of current in a circuit. during times when very powerful currents are flowing. There is a possibility that the existing condition of the system will be enhanced by an additional transient stemming from the interruption itself (Liu, 2019).

When designing an RC relaxation oscillator, the noise performance of the oscillator is one of the most critical factors to consider. The reason for this is because the presence of any form of noise in this autonomous circuit raises the chance of adding phase noise or timing jitter, both of which have the potential to alter the output frequency. As part of this lesson that discusses oscillator noise, They get an understanding of the history of oscillator phase noise, how it is connected to jitter, and the two most common techniques to evaluate oscillator performance that are based on the Figure of Merit (FOM) method. Because of the presence of noise, the output of the oscillator may undergo alterations in both its amplitude and its phase. On the other hand, the rail-to-rail output of the RC relaxation oscillator will automatically reduce the amplitude disturbance that is caused by noise (Zhou, 2019).

PURPOSE OF THE STUDY

The main objective is to design electrical circuits that can detect human body noises with little power consumption. This is of the utmost importance in scenarios where devices must run continuously for long durations without being recharged or having their batteries replaced. Additionally, researchers want to enhance the overall dependability and performance of our body sound monitoring equipment. As part of this, researchers must provide precise and uninterrupted monitoring free from power outages.

LITERATURE REVIEW

Addressing the fundamentals of sound physics is an essential first step in any investigation of cardiac sounds. One way in which vibrations may be transmitted is by use of pressure waves, which are known as sound waves. A source of vibration may both put its own particle in motion and cause vibrations to propagate across its surrounding medium. Every time a particle moves, it causes a localised change in pressure, which in turn causes a domino effect that spreads throughout the medium at sound speed. Both the frequency and the magnitude of vibrations define the behaviour of sound. In this context, period refers to the length of a single cycle and frequency to the number of times a particle oscillates in each amount of time (Liu et al., 2019).

In addition to improper priming of the powder and sluggish inspiration, ineffective inhalation is one of the shortcomings of everyday medical therapy and the primary reasons of wrong medication administration. They tracked and assessed the use of seven inhaler devices among 100 trained users, including the most often prescribed pMDI. Although some users have had success with the inhalers, the majority have seen a decline in the rate of genuine medicine delivery due to a lack of adherence to professional instructions. The traditional pMDIs only worked 79% of the time. This evaluation ranked the methods as inadequate, suggesting that the medicine was only partially delivered and that consumers got very little, if any, powder at all (Samanta, 2019).

A botched inhalation might be the result of clumsy coordination, triggering at the wrong stage of inspiration, inhaling via the nose, coughing that is produced, priming that is improper or nonexistent, and other problematic behaviours. The distribution of powder is affected by inhaling quality in addition to inhaler operational errors. Furthermore, breathing rate, tidal capacity, and inspiratory flow vary across patients. The treatment quality is compromised by insufficient inhalation because the committed dosage is lowered. Due to a low inspiratory rate, just a little amount of the drug could reach the organ that needed it. Medical professionals may be hesitant to make adjustments to patients' prescriptions without concrete evidence of their actual use profiles, which makes it impossible to evaluate adherence. Because of the unavoidable rises in costs, the therapy may be impaired. The issue of improper inhalation has been addressed with the use of adherence monitoring to decrease medication misuse or waste by showing if users are getting the recommended dose of medicine. There is a lack of a valid and accurate adherence assessment, there is no clear boundary between adherence and non-adherence, and adherence varies from person to person because of their unique regimen, all of which contribute to assessing failure. Every patient's scenario is unique due to factors such as their age, gender, personality, level of illness knowledge, frequency of clinic visits, symptom intensity, family dynamics, and social milieu. Health care researchers currently lack agreement about the value of each treatment technique due to a lack of precise data regarding the prevalence of partial adherence caused by the lack of a reliable assessment of compliance (Mikulic, 2019).

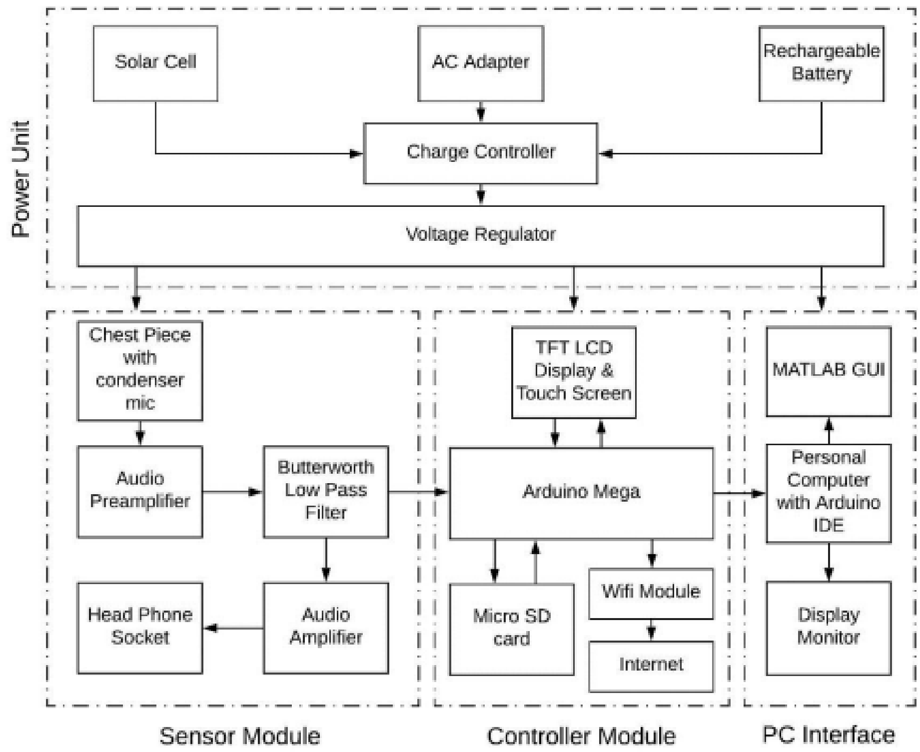
RESEARCH QUESTIONS

1. How to provide a design for implementing an automated system?
2. What is the state and functioning of medium and high voltage circuit breakers in real-time and reliably?

METHODOLOGY

There are four main components to the proposed system: The Sensor Module oversees taking an analogue reading of the heart rate and sending it on to the controller. The controller module is the central processing unit (CPU) of the system; it processes heart sound data for basic analysis, saves obtained signals on an SD card, communicates with the PC by Wi-Fi, and controls the user interface (UI) of the TFT LCD module. The power unit supplies electricity to the whole system from a variety of sources, including renewable and non-renewable energy sources. To do the in-depth analysis of the obtained heart sound signal, PC Interfacing is used. The following sections provide an in-depth analysis of each module.

Figure 1: Block Diagram



- **Sensor Module**

The term "sensor" refers to any instrument that can detect and transform a physical quantity into an electrical signal. A sensor module that can pick up on the human heartbeat is suggested in this study. First, a transducer microphone is connected to a chest piece that is put close to the heart. This allows the device to detect the heart's sound waves, which are then transformed into an electrical signal. After that, a low pass filter is used to remove components of high frequency noise from the amplified analogue electrical signal, which was originally generated by an opamp-based preamplifier. The processing of the filtered signal is now transferred to the controller module. A second audio amplifier has been installed, and now the filtered output may be directly listened to via the headphone socket, much like a cardiac monitor. They may use this module as an electronic stethoscope with ease; it has high-quality sound and a volume control.

- **Preamplifier Circuit**

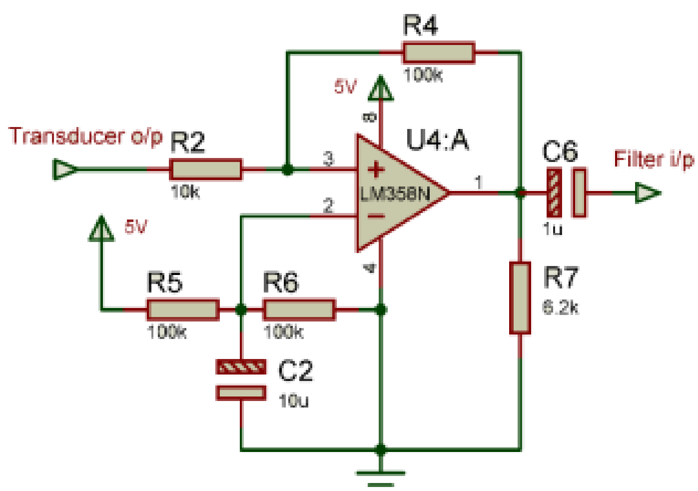
A preamplifier is a kind of electronic amplifier that boosts the strength of a weak electrical signal so that it may be processed further. In this case, a preamplifier circuit is used to prepare the signal for filtering via the following stage's low-pass filter. Here, researchers present the design of an LM358 IC passive pre-amplifier. LM358 is a dual operational amplifier that uses very little power.

Table 1. Specification of LM358

Specification	Value	Specification	Value
Supply Voltage	3-32V	O/P Current	2-20mA
Unity Gain BW	1 MHz	No. of opamp	2
DC gain	100 dB	Operating Temperature	-65 to 150 ^{0}C

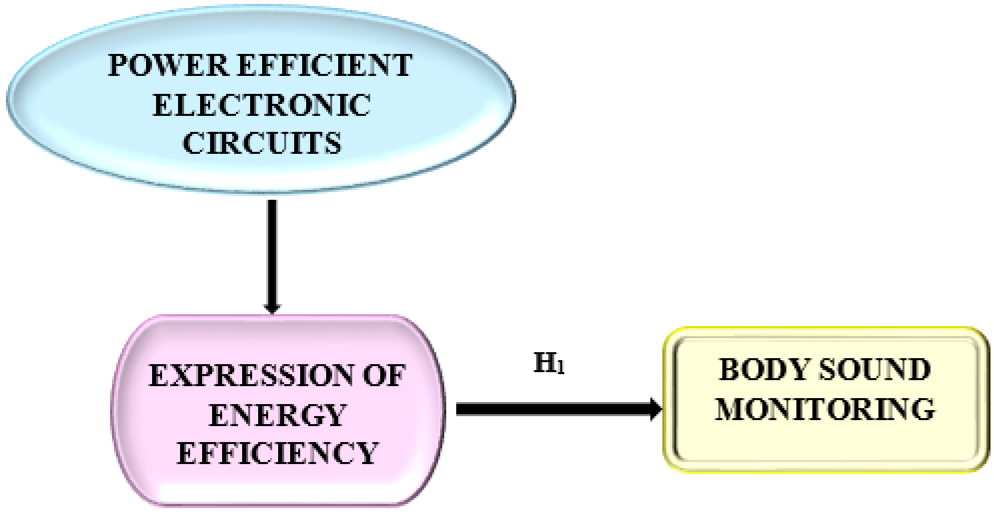
According to the datasheet, the following is a brief description of LM358. A maximum of 50 mV is possible for the analogue signal produced by the transducer, which often falls between the 1 mV to 10 mV range. Accordingly, a reading of 20 mV has been recorded. As a voltage level for input. Researchers need to carefully plan the design and choose the component values to raise the voltage level.

Figure 2. Preamplifier Circuit



It is feasible to achieve a maximum output voltage of 200 mV is the preamplifier. Therefore, to increase the power, a voltage boost of 20 dB is necessary. To construct this pre-amplifier, researchers followed the standard application circuit described in the LM358 datasheet, making only the most fundamental adjustments. Figure 2 shows the pin diagram of the LM358 and the preamplifier circuit in detail.

CONCEPTUAL FRAMEWORK



RESULT

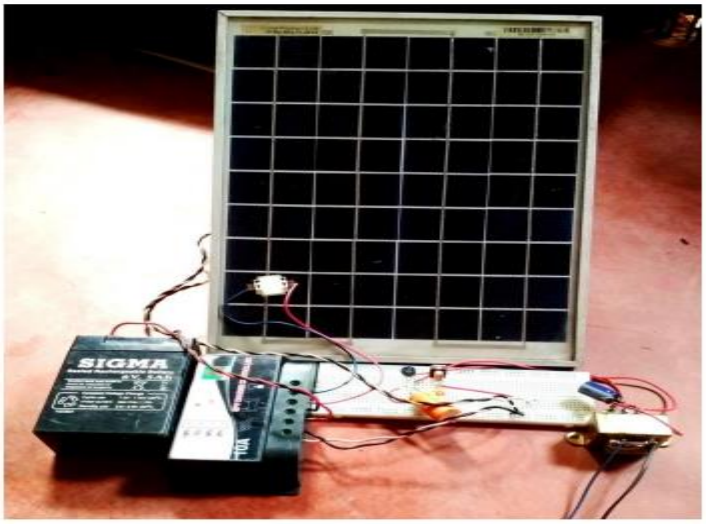
- **Module Testing**

Thorough testing of every component was necessary for the implementation of the hardware platform to ensure their successful performance when combined. In module testing, the findings and issues that arose from each module's testing are detailed.

- **Power-unit Testing**

Solar cells, transformers, charge controllers, and LM7812 voltage regulator ICs are all part of a power unit's testing scope. According to the specifications listed on the datasheets for the individual circuit components, each one worked as expected. The main circuit of the power unit that is implemented on the breadboard is shown in the figure. The completely recharged battery's backup duration is tested using a 5-watt LED bulb. The whole discharge process takes around five hours. Viewed in Fig. 3 are the power unit's used components.

Figure 3: Power-unit Components



- **Sensor Module Testing**

The preamplifier and low pass filter implementation were the primary areas of attention throughout the testing of the sensor module. To test noise immunity, it also considers the signal collection environment. The low pass filter of an oscilloscope was tested using a sinusoidal signal generated by a function generator. A sinusoidal signal generated by a function generator was used to test the low pass filter, and the results were satisfactory. In very loud environments, the sensor module does not get an accurate signal, even if the module functions flawlessly in less noisy environments.

- **Controller Module Testing**

The testing of the controller module includes the interfacing of the following modules: PC, Wi-Fi, TFT LCD, and SD card. Every test case makes use of the Arduino Mega and the Arduino IDE.

At the very beginning, they need to interface with a PC because Arduino requires special instructions in order to function. Instructions written in C and compiled into machine code may be uploaded to Arduino boards using the Arduino IDE, a PC-based tool. The official website for Arduino has been visited, and the software, known as Arduino IDE, has been installed on the Windows PC. Now, with an integrated USB connector and a USB cable, Arduino boards may be directly linked to personal computers. Researchers may begin the interfacing process in the Arduino IDE by going to the "Tools" menu and choosing the appropriate ports and boards. In Fig. 4, researchers can see the PC connected to the Arduino board and the Arduino IDE that came with the board.

Figure 4: Computer-Arduino Circuit Interfacing

After connecting the PC and Arduino boards via USB, the 'ReadWrite' SD card library sample was uploaded to the boards. This example does exactly what it says it will do: read and write directly to the memory card. The wrong file format of the memory card caused the SD card identification to fail on the very first attempt. The standard file systems that the Arduino SD library is compatible with are FAT16 and FAT 32. Researchers need to format the SD card to use the FAT16 or FAT 32 file system before they can put it into the SD card slot. Following that, the read/write operation worked without a hitch.

In most cases, the inbuilt analog-to-digital converter (ADC) processes analogue signals sent into the sixteen specialised analogue pins found on Arduino Mega boards. The four analogue pins on a TFT LCD touch screen module are used for several purposes. For data processing or collection, any sensor module may be interfaced with the remaining ports. The analogue pin 8 is where the heart sound signal sensor is supposed to go to carry out its designated function. Any other kind of signal acquisition may be accomplished using the other analogue pins. This is why the sensor choice window is part of the UI design and will be refined in subsequent iterations. To save the signal to the memory card, the built-in ADC of the Arduino Mega transforms the analogue signal into digital form. The specified specifications state that the Arduino ADC can reach a sampling rate of up to 77 kHz and has a 10-bit resolution. Although the obtained sample rate of the heart sound signal is about 5 kHz, this does not consider SD card write delay or execution delay. With a typical range of 10–500 Hz for heart sound signals, it's much higher than the Nyquist Rate.

The Wi-Fi module is a part of this project for the Internet of Things deployment; however, it is not yet transmitting data wirelessly. By use of AT instructions, this module has been effectively interfaced with the acquisition system. They have successfully verified all hardware connections and basic communication between the Arduino and Wi-Fi module. Adding a single line of code to the core Arduino programme enables data transmission and reception via the internet, making it easy to transmit data.

DISCUSSION

Researchers introduced the proposed technique for acquiring cardiac sounds. Every single item has been meticulously described, beginning with the block diagram and continuing down to the component level. Every part of the power unit, beginning with the power unit itself, has been described in detail. It is undeniably a green solution since it incorporates a non-renewable energy source. Connecting an innovative and inexpensive heart sound sensor module to any kind of controller or microprocessor allows for the reliable and effective gathering of data and heart sound listening. Though it may make desktop PCs less portable, PC interface aids in the effective interpretation of cardiac sound signals. A MATLAB GUI application for a heart disease diagnostic tool that is easy to use was a goal. Data storage, heart sound analysis, signal visualisation, and an intuitive, touchscreen-based user interface are just a few of the many features provided by the controller module. If the complete system can be executed with precision and experience, it will undoubtedly become a very valuable instrument for rural culture. They see the whole acquisition system put into action in real time in the following episode. The researchers have successfully developed the intended method for collecting cardiac sounds and have assessed its practicality in a real-life setting. Almost twenty-five different cardiac rhythms information has been gathered from the camp's patients. The results of the analysis show that the heart is functioning normally in some cases and abnormally in others. In order to conduct tests as the health camp, volunteers have requested to gather patient heart sound data. They may be able to gather the data effectively with some simple guidance. It demonstrated how user-friendly and straightforward the intended gadget is. It was the primary objective of their article. Practical testing has confirmed the accuracy of the acquisition system in every respect. The method may be enhanced and refined to identify diseases with more accuracy and reliability with further study. The acquisition system becomes an ideal Internet of Things (IoT) sensor node with the addition of a Wi-Fi module.

CONCLUSION

An easy-to-use, low-cost system for collecting cardiac sounds based on user instructions is the primary goal of this effort. This branch of research has been motivated by the present pandemic of cardiovascular disease. New researchers in this area may benefit greatly from the literature review chapter, which gives a more comprehensive overview of the existing systems and methodologies. To maintain a minimal design process, every module of the acquisition system is customised according to the required specification. Early prediction and real-time assessment on heart sound data are clearly provided by the real-time implementation and evaluation of the heart sound acquisition system. Anyone, including those without a basic understanding of medical technology, may easily and affordably get cardiac sound data from patients. The specialised doctor may then get the heart sound data after basic processing and visualisation. Due to its open-source software and hardware architecture and very inexpensive circuit components, the acquisition system is characterised as cost efficient. The system is lightweight and portable because to its user-friendly UI design and lightweight hardware components. It is an ideal Internet of Things (IoT) sensor node since the acquisition system includes a Wi-Fi module. Changing the uploaded code in the Arduino module is all it takes to make the system work for remote monitoring. In areas without access to traditional power grids, a power unit powered by renewable energy sources may make a significant difference. Taking everything into account, it's clear that a well-planned acquisition system, when implemented correctly, will have a significant influence on rural communities. Due to the high volume of patients during health camp hours, the need for less complex algorithms for de-noising and signal processing, and the successful implementation, the researchers are planning to devote a lot of time to this area in the future.

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