AN INQUIRY INTO THE DESIGN AND DEVELOPMENT OF VERY COST-EFFECTIVE ELECTRONIC COMPONENTS FOR HUMAN WAVE MONITORING SYSTEMS

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ABSTRACT

The development of energy-efficient electronic circuits for the monitoring of bodily sound, particularly for non-invasive real-time health diagnostics, is the primary focus of this research. There are now low-power advanced circuits that can continuously monitor physiological signals like heartbeats, lung noises, and a plethora of other interior body sounds, all because to the rise of wearable health gadgets. In order to diagnose and control illnesses, these signals are fundamental. In order to reduce power consumption without compromising data accuracy, this study focuses on ultra-low-power sensors, efficient signal-processing methods, and analog-to-digital converters. The problem with wearable health gear is that it struggles to balance power efficiency with performance. There is a limited amount of time between charges for most of these gadgets since they use batteries. An Arduino Mega 2560 R3 serves as the system's controller and reads heart sound signals from a sensor module. The user interacts with the interface via the TFT LCD screen, and the information acquired is stored on the SD card. Using the ESP8266 Wi-Fi module, remote monitoring may be done wirelessly. To further increase device autonomy by capturing ambient energy sources, the author then moves on to discuss energy harvesting technologies and thermoelectric systems. Wearable health monitoring systems that continuously monitor body sounds using low-power are a promising solution for health care management, and the results prove that this is completely feasible in this realm. Consequently, this research contributes to the creation of better health monitoring devices that last longer, are more efficient, and have the ability to manage chronic conditions in real-time and detect illnesses early on.

Keywords: *Power, Circuit, Wireless Monitoring, Device Autonomy.*

1. INTRODUCTION

The human body makes a great deal of noise, and by decoding this noise, it is feasible to track health and detect illnesses. For a long time now, for instance, cardiopulmonary signals have been widely employed in hospitals to detect heart and lung diseases. Because it is audible and serves as a gauge of the baby's vital indicators, the fetal heart rate is critical to be aware of. By monitoring the bowel sound, one may ascertain the efficacy of the abdominal surgery and the presence or absence of tissue adhesions (Chen et al., 2019). Modern advances in digital signal processing and high-performance circuits have allowed for the creation of one-of-a-kind sound monitoring and diagnostic devices that make use of physiological sounds produced by different people. There are no current or prospective dangers to human health from sound-based diagnosis and monitoring, in contrast to well-known diagnostic technologies that depend on dynamic power transfers, such X-ray scanning and ultrasound detection (Georgopoulou et al., 2021). In most cases, a sound sensor will be used to wirelessly track the wearer's vitals, a PBS will be used for small, portable devices, and a server will be used to store, organize, and provide users with their recorded health data. New low-power sound sensors, ideal for everyday use, have recently been developed as a result of developments in integrated circuits, wireless communication, mobile networks, and sensor technologies. The growing need for wearable health monitoring devices has prompted intense research into the development of very energy-efficient electronic circuits, with an emphasis on those used in body sound monitoring. Monitors that pick up on critical noises like heartbeats and lung activity need to include low-power circuitry so that their batteries can last a long period without sacrificing accuracy. The true challenge is in reducing power consumption without sacrificing data quality. A review of current advances in operational energy efficiency and real-time body sound monitoring is presented here (Khairudin et al., 2021).

2. BACKGROUND OF THE STUDY

There has been a lot of advancement in more efficient electronic circuit design, particularly for applications that detect bioacoustic emissions, due to the increased interest in wearable health monitors. Important for both acute diagnosis and the treatment of long-term health conditions, these devices track a wide range of physiological parameters, including heart rate, respiration rate, and internal body sounds. Since many wearables rely on battery operation and need to run for a while between recharges, striking a balance between robust performance and low power consumption is a foundational basic difficulty when developing such devices (Khalid et al., 2022). The mobility and practicality of body sound monitoring devices have been limited by the power-intensive combination of stethoscopes and pulse oximeters, which has historically limited their use for continuous monitoring. The groundwork for better body sound monitoring devices was laid by recent innovations in ultra-low-power electronics, particularly in ultra-low-power sensors, analog-to-digital converters, and signal-processing units. These limits are an effort to reduce power consumption for all components without sacrificing accuracy or reliability in measurements. For tiny, long-lasting wearable health equipment, this is of the utmost importance. Additionally, novel approaches to energy harvesting and wireless communication protocols have opened up new possibilities for reducing reliance on outdated power sources (Rashid et al., 2021). Devices that monitor the human body's ambient noise may connect to distant devices, such as smartphones, thanks to low-power wireless protocols such as Bluetooth Low Energy (BLE) and Zigbee, which allow for high-data transfer while using very little power. Utilizing ambient energy sources (such movement or body heat) to power these gadgets for greater energy autonomy, energy harvesting technologies like piezoelectric and thermoelectric systems are used. Revolutionizing health problem monitoring and management via real-time, non-invasive user monitoring should be the goal of integrating this software for tracking internal body sounds. Here is where the need for energy-efficient circuits lies at the core of smart health-monitoring devices, where there is a strong need for longer lifespan performance, user comfort, and accurate data collection methods. Current research on body sound monitoring is the primary emphasis of this paper, which also identifies potential avenues for the development of environmentally friendly and economically viable electronic circuits (Palmieri et al., 2022).

3. PURPOSE OF THE RESEARCH

This research develops energy-efficient electrical circuits for use in body sound monitoring, which opens the possibility of even greater power savings without compromising performance or accuracy. By delving into cutting-edge circuit designs, low-power sensors, and data processing technologies, the possibility of energy-efficient, continuous, real-time health monitoring becomes a reality. Improving the wearable device's autonomy and reducing its need on a continuous power source are further goals of the project. As a result, it would open the door to more practical, reliable, and sustainable methods of developing non-invasive health monitoring systems.

4. LITERATURE REVIEW

Research and development of energy-efficient electronic circuits for use in body sound monitoring applications is accelerating in response to the growing need for wearable health monitoring devices that can collect data continuously and non-invasively. Health care, early disease detection, and remote monitoring are all substantially improved by technologies that can detect and analyze physiological sounds, such as heartbeats, lung noises, and blood flow. Reducing power consumption without sacrificing the precision or reliability of sound measurements is still the key challenge (Liu et al., 2020).

Wearable versions of conventional stethoscopes and portable electrocardiogram (ECG) instruments have long been considered impractical due to their excessive battery consumption. Research and development efforts in recent years have focused on creating low-power electronic circuits that can operate continuously for long durations without frequent recharging. Modern low-power analog-to-digital converters (ADCs), signal processors, and amplifiers have greatly reduced the amount of power needed to capture and interpret physiological sound data. When creating these circuits, power management is often front and center. This allows the system to enter low-power states plastically, which is useful for tasks like sound measurement (Marumo et al., 2022). With the advancement of low-power sensors, body sound monitoring systems have been able to keep their energy footprint low. Because of this, they may now be turned into small, wearable gadgets. Another key area of research is the development of signal processing systems that are energy efficient. A modification was made to the DSP approach to alleviate the computational effort, allowing for the provision of a high-quality, robust analysis. Noise reduction and feature extraction methods allow for efficient audio data processing by transferring or capturing just the most significant information. There needs to be more research into energy harvesting technologies, particularly piezoelectric to thermoelectric systems. One possible use is in wearable electronics, which might allow users to extend the battery life of their gadgets by harnessing the power of their own movements or body heat (Chowdhry, 2022). Wireless communication protocols with minimal power consumption, such Bluetooth minimal Energy (BLE), are another possible area of study. These allow data transfer to be carried out without using the battery. The potential for autonomously functioning wearable health devices for long periods of time, collecting and analyzing body sounds in real-time for early diagnosis and personalized healthcare management is opened up by these advancements. If we want to build better body sound monitoring systems in the future, we need to do more research into energy harvesting, wireless communication, and low-power circuit design. Researchers are putting in a lot of time and effort to find wearable health technologies that are more efficient and environmentally friendly (Li et al., 2023).

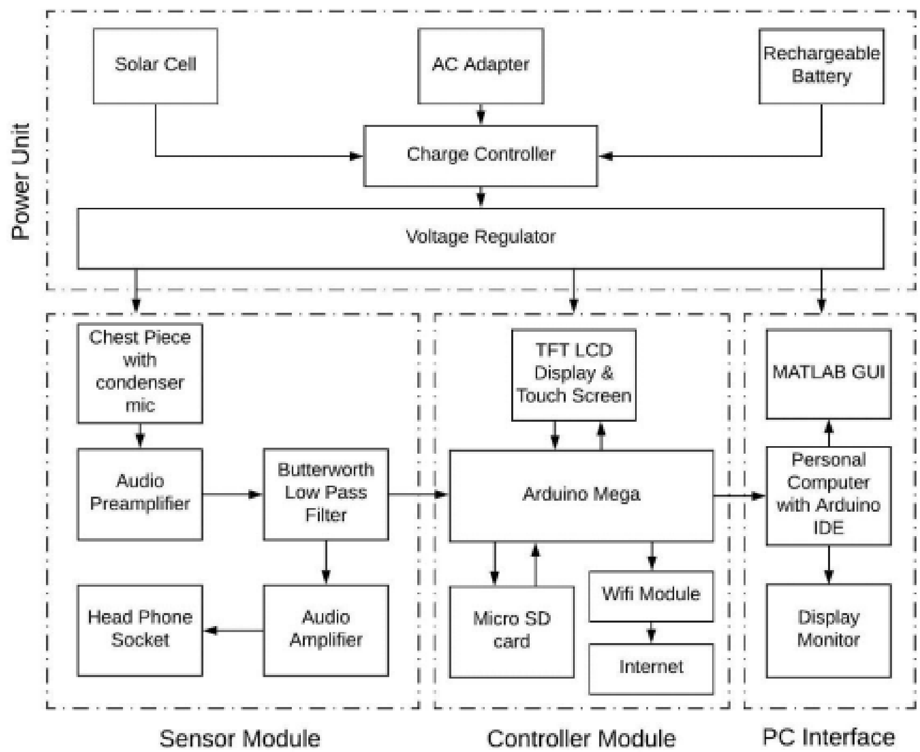
5. RESEARCH QUESTION

- How wavelength effects in body sound monitoring?

6. METHODOLOGY

The proposed system consists of four main modules: the sensor module is responsible for collecting and transmitting the analogue signal of the heart rate to the controller; the controller module regulates the user interface (UI) of the TFT LCD module; it establishes wireless connections with a personal computer; it stores recorded signals on an SD card; and it performs basic analysis on cardiac sound data. The system is powered by a power unit, which draws power from various sources, some of which are renewable and some of which are not. After that, we will examine each module separately.

Figure 1: Block Diagram



Controller Module

This cardiac acquisition system's brain is the Controller Module. It regulates and performs all of the necessary operations for the cardiac sound acquisition system. The boards that control it are Arduino Mega 2560 R3. An onboard user interface using a 2.4-inch TFT touchscreen LCD is included into the acquisition system. An SD card connection is included inside the TFT LCD module. Consequently, data was also stored on an 8GB memory card. Thanks to the ESP8266 Wi-Fi module, the system now has an IoT twist and better remote monitoring capabilities. A computer with the Arduino IDE installed may display PCG on an LCD screen using a USB connection, allowing for improved signal visualization. The following factors were taken into account to determine the results of these module:

- Data on heart sounds is stored on SD cards.
- Using Wi-Fi to transmit the heart sound data
- The procedures are carried out using a touchscreen-based user interface.
- Analysis of heart sound at a basic level
- Connecting to a Personal Computer
- Show the signal on the computer screen.

Arduino Mega

The open-source hardware platform known as Arduino Mega 2560 R3 runs on the ATmega2560 central processing unit. The programming and operation of an Arduino board does not need a high level of technical expertise. The assembled Arduino Mega 2560 is seen in Fig. 2. The following factors are considered while deciding whether to include this item into this project: the researcher have complete control over the voltage of any other hardware modules the researcher connect it to thanks to its two voltage regulators, one for 5V and one for 3.3V.

- The Arduino Mega has more I/O pins, a larger size, and more memory.
- The open-source Arduino IDE programming software is compatible with all Arduino boards.
- The Arduino Mega is specifically designed for complicated projects that need extra memory or intricate processes like 3D printing or signal processing.
- There are three methods to power the board: using a USB cable, transferring a code to the board, or using the board's Vin, power port, or battery.

- This board has a resettable poly-fuse that keeps the computer's USB port from overheating when there is a lot of electricity passing through it.

Figure 2: Unplugging the Arduino Mega 2560 R3

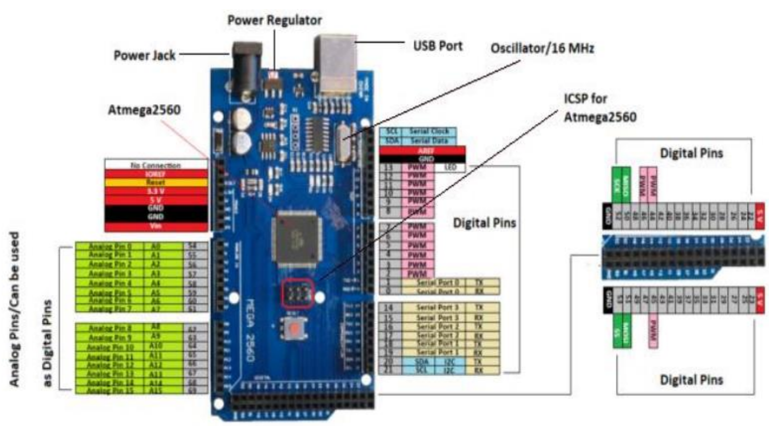


Table 1 provides a high-level overview of the Arduino Mega 2560 R3's technical specifications.

Table 1: Arduino Mega Technical Specifications

Specification	Value	Specification	Value
Microcontroller	ATmega2560	Flash Memory	256 KB of which 8 KB used by boot loader
Operating Voltage	5V	SRAM	8 KB
Input Voltage (recommended)	7-12V	EEPROM	4KB
Input Voltage (limits)	6-20V	Clock Speed	16 MHz
Digital I/O Pins	54 (of which 14 provide PWM output)	DC Current per I/O Pin	40 mA
Analog Input Pins	16	DC Current for 3.3V Pin	50 mA

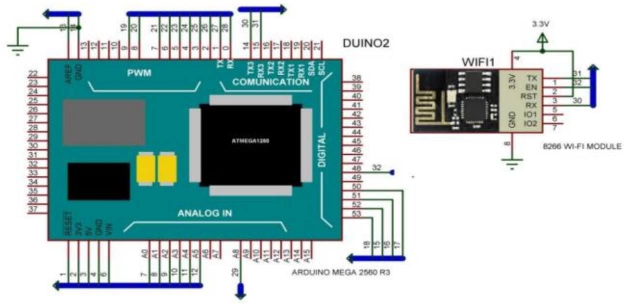
The Wi-Fi Module ESP8266

Through the use of an ESP8266 Wi-Fi module, this project converts the acquisition system into an IoT platform. Despite being connected to the acquisition system, the module is not functioning at the moment. With this module installed, all future project plans that include the implementation of the Internet of Things (IoT) are guaranteed to succeed. Here the researcher can find a concise explanation of the ESP8266 and its connections to the hardware. As an inexpensive, independent wireless transmitter, the ESP8266 Wi-Fi module might find utility in end-point Internet of Things advancements. The TCP/UDP connection protocol allows the heart sound acquisition device to connect to the internet. The default Baud rate for the Arduino Mega's UART transmissions is 115200, however it may be adjusted to connect to the ESP8266 Wi-Fi module. The ESP8266 can

- 802.11 b/g/n 2.4 GHz Wi-Fi that supports WPA and WPA2,
- GPIO stands for general-purpose input/output.,
- The serial communication protocol of the Inter-Integrated Circuit (I^2C),
- Conversion from analogue to digital (10-bit ADC)
- The serial communication protocol known as the Serial Peripheral Interface (SPI),
- DMA (Direct Memory Access) and I^2S (Inter-IC Sound) share pins with GPIO.
- UART (on certain pins, as well as the option to activate a transmit-only UART on GPIO2)
- PWM, or pulse-width modulation.

Hardware Connection: Fig. 3 displays the hardware connection that is already in place for the acquisition system.

Figure 3: Interface Between the Arduino Mega Board and the ESP8266 Wi-Fi Module



Module for SD cards

The storage capacity on Arduino boards is insufficient to hold files including heart sound data. So, to preserve the data, an external storage device is necessary. For use in portable devices, the SD Card Association (SDA) established a non-volatile memory card format known as an SD card. For this purpose, an SD card is used to store the cardiac sound signal data in bulk. The data is contained in files that end in ".txt". The TFT LCD module already has an SD card socket, so the researcher won't need any more modules to make it work. The Arduino Mega is directly linked to the TFT LCD pins that are related with the SD cards. Connecting each pin in the correct way is

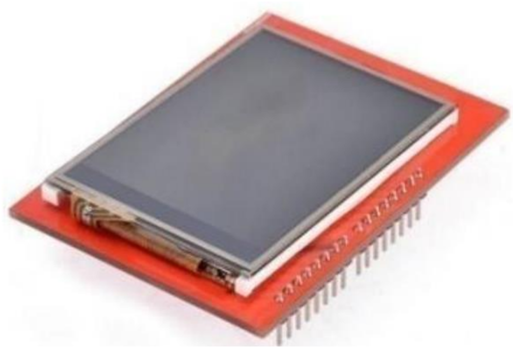
TFT LCD Pin	Arduino Pin	TFT LCD Pin	Arduino Pin
SD_CS	Pin 53	MOSI/SD_D0	Pin 51
SD_SCK	Pin 52	VCC	3.3 V
MISO/SD_DI	Pin 50	GND	GND

Researchers utilise an 8 GB memory card for othe work. The maximum RAM needed for each 4-second heart sound data set is 200 KB. It is possible to store around 35,000 data samples on the memory card. Figure 21 depicts the interface circuit between the Arduino Mega and the memory card.

UI & TFT LCD Module

The whole cardiac sound acquisition apparatus cannot be operated without a direct user interface. A 2.4-inch TFT touchscreen LCD is used in the design of the user interface in this work. Following the display of the welcome message, the user is prompted by the designed user interface to enter the patient's name, age, and weight. Based on the user's input, the functionality page was shown after the sensor choice page was routed. To record, examine, send, or see the signal, the user may just tap on the corresponding buttons on the interface. Figure 4 shows the 2.4-inch TFT touch LCD module in its conventional form.

Figure 4: The Display is a 2.4-inch TFT Touch LCD

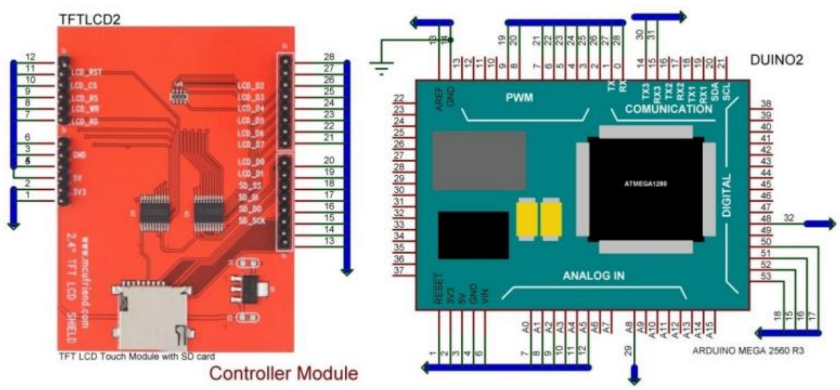


The used TFT module's short specifications are as follows:

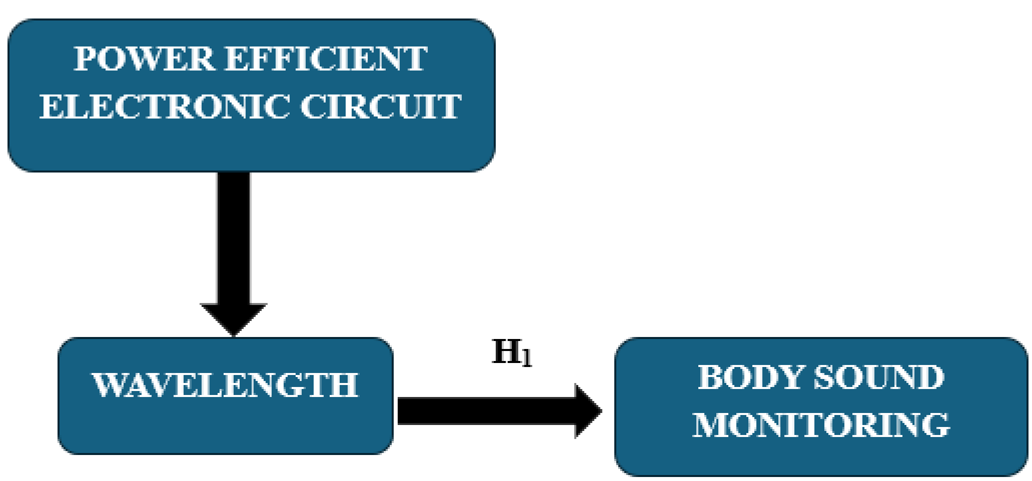
- 2.4" touchscreen TFT LCD
- 240 × 320 pixels
- 3.3V is the operating voltage.
- Modes of operation: 8-bit and SPI
- Interface IC: Interface ILI9341
- There is an SD card option for data storage.
- Interfaces with Arduino are simple (a free library is provided).

The LCD module is a plug-and-play shield that allows the Arduino UNO boards to have an LCD screen placed right on top of them. However, the Arduino Mega boards (i.e., 50, 51, 52, and 53) have different SD card ports, thus an additional wire has been added to enable the module. Fig. 5 illustrates the link in detail.

Figure 5: Arduino Mega Board Compatibility with LCD and SD Card Interface



7. CONCEPTUAL FRAMEWORK



8. RESULTS

Interfacing with a personal computer, wireless network, TFT LCD, and SD card is all part of testing controller modules. A Mega and the Arduino IDE are used in each and every test scenario.

PC Interfacing

Since Arduino only follows certain instructions, a PC connection is necessary from the get-go. If the researcher have a Windows computer, the researcher may use the Arduino IDE to translate C code and upload it to Arduino boards. A Windows PC is used to install the Arduino IDE software, which may be obtained from the official website. Nowadays, most computers include a USB connector on the inside, so it's possible to connect an Arduino board straight to a computer. Accessing the "Tools" option inside the Arduino IDE allows users to choose the appropriate ports and boards, allowing them to begin the connectivity process. This researcher's PC already has the Arduino board and the Arduino IDE loaded, as shown in Figure 6.

Figure 6: Computer-Arduino Board Interfacing

SD Card Interfacing

The first stage in SD card interfacing is to connect the card to the Arduino module. Simply adhere to the steps outlined in Figure 5. After connecting the PC and Arduino boards via USB, the 'Read

Write' SD card library example was then uploaded to the boards. This example reads and writes data straight to the memory card, as the name suggests. The wrong file format caused the first attempt at SD card identification to fail. When using the Arduino SD library, the researcher have the option to utilize either the FAT16 or FAT 32 file system. To use the FAT16 or FAT 32 file system, users must format the SD card before putting it into the slot. Everything went smoothly from then on out in terms of reading and writing.

Interface Testing for TFT LCD Touchscreen Screens and User Interfaces

The LCD shield is a fantastic addition to an Arduino UNO. Furthermore, it is compatible with Arduino Mega; however, an additional wired connection will be required owing to changes in SD card connectors. After setting up the LCD and touch screen, the final step is to connect the shield to the Arduino Mega. But because of manufacturing variations, the touch screen has to be calibrated. For both the visual and calibration tests, the researchers turned to the MCUFRIEND kvb library samples. We will have validated the intended user interface for all potential error messages after that. A representation of the suggested UI is shown in Figure 7. In the image, window 7 (a) provides access to patient data for the user. Additionally, none of the input fields fail the mandatory validation. Prior to beginning data collection, Window 7 (b) prompts the user to choose the kind of sensor. Only the heart sound acquisition sensor can currently provide data to this window. We will use the remaining fields for other initiatives. In the long run, the acquisition system will include a multitude of sensors that can simultaneously collect data. The primary user interface for managing the cardiac sound signal is Windows 7 (c). They are being left as future scope as the 'SEND' and 'analyse' processes are not operating at the moment. Pressing the "SAVE" button immediately saves the patient's first data and heart sound signal to the memory card. To detect and prevent system problems (like a corrupted or missing memory card) and odd user input (like substituting a numerical value for an age or a name for a name), researchers have built and tested a comprehensive validation protocol. The problem with the memory card not being there is seen in Figure 7 (d).

Figure 7: Different Windows of the Designed User Interface (a) Window for Patient Information (b) Window for Sensor Selection (c) Window for Functionality (d) Error Related to Memory Card Validation

Sensor Module Interfacing

The majority of Arduino Mega boards include an analog-to-digital converter (ADC) built in, thus they can process analog signals. These 16 dedicated analogue pins make it easy to connect sensor modules. A TFT LCD touchscreen module with four analog pins can accomplish a lot of things. To gather or process data, the researcher may connect any sensor module to the remaining ports. Assigning analog pin 8 allows the heart sound signal sensor to function as planned. The additional analogue pins may receive signals of any kind. Now that it is part of the user interface design, the sensor choice window may be left for future upgrades. In order to store the signal to the memory card, the built-in ADC of the Arduino Mega converts the analogue signal to digital form. The specifications state that the Arduino ADC can sample at a maximum of 77 kHz and has a resolution of 10 bits. Despite SD card write and execution delays, the derived heart sound signal maintains a sampling rate close to 5 kHz. For a heart sound signal, which typically ranges from 10 to 500 Hz, this is much higher than the Nyquist Rate.

Wi-Fi Module Interfacing

The Wi-Fi module is a part of this endeavor to build the IoT, although it isn't transmitting data wirelessly just yet. The AT instructions were followed to successfully attach this module to the acquisition system. The researchers have verified that the Wi-Fi module and Arduino are correctly linked and can exchange data. A single line of code added to the main Arduino program enables data transmission and reception via the Internet, simplifying the procedure.

9. DISCUSSION

Our goal in this work is to present the results of the effort to develop more efficient electrical circuits for use in bio-sound monitoring systems without compromising the accuracy or reliability of the physiological data that are gathered. An important challenge for wearable health devices is managing energy usage without sacrificing functionality, as these devices need to work for extended periods of time without constant recharging. Reduced power consumption can only be achieved by the use of signal processing algorithms, low-power sensors, and analog-to-digital converters. An SD card for recording heart sound data, an ESP8266 Wi-Fi module, and an Arduino Mega microcontroller are all part of the system that is being developed in this research to allow real-time health monitoring. What really sets this design apart is its use of Wi-Fi and other power-efficient wireless connection protocols for remote monitoring. Thus, it enhances the device's practicality in regular use. There is still more work to be done to ensure effective data transfer across wireless networks, and the system has not yet reached complete deployment with regard to the Wi-Fi module. This continuous noninvasive health monitoring system provides a great method for real-time analysis and remote monitoring, thanks to its user-friendly interface on the TFT LCD screen and its capacity to gather and store body sound signals with little power consumption. Thanks to its innovative wearable health technology, everyone can keep tabs on their health in a more practical and eco-friendly way. Greater investment in energy harvesting, signal processing, and wireless transmission technologies is the only way to achieve improved functionality and scalability in the long term.

10.CONCLUSION

Development of power-efficient circuits capable of detecting and recording human bodily sound is a significant advancement in wearable health technology. The focus of this study is on determining the optimal power usage for detecting and analyzing physiological sounds, such as heartbeats and lung activity, with high levels of accuracy. Utilizing state-of-the-art signal processing algorithms and wireless communication technologies such as BLE and Wi-Fi, these devices are capable of offering continuous, real-time health monitoring while consuming little energy. By using energy harvesting technologies, it enhances the devices' autonomy, which ultimately decreases the frequency of charging and maximizes their long-term value. In addition, a trustworthy SD card storage system and an intuitive user interface (maybe in the form of a TFT LCD touchscreen) would be of great service to healthcare practitioners and patients. To address the continuous need for non-invasive, wearable health monitoring solutions, it is crucial to prioritize energy-efficient circuit design while developing durable, reliable, and reasonably priced devices. Better disease management, earlier diagnosis, and more personalized care for society will result from incorporating new, energy-efficient wearable devices into the present evolutionary path of smart health-monitoring systems, which is where the real value of this work resides (Mahdi et al., 2022).

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