AN INVESTIGATION ON THE DESIGN AND DEVELOPMENT OF HIGHLY COST-EFFECTIVE ELECTRONIC COMPONENTS FOR HUMAN WAVE SUPERVISING SYSTEMS

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ABSTRACT

This study primarily targets at energy-efficient electronic circuit creation for monitoring body sound, notably non-invasive real-time health diagnostics. With the proliferation of wearable health devices, low-power advancement circuits have become available for the continuous monitoring of physiological signals, such as heartbeats, lung sounds, and numerous other internal body sounds. These signals are crucial for the detection and management of diseases. This research focuses on ultra-low-power sensors, analog-to-digital converters, and efficient signal-processing approaches that minimize power consumption without affecting data accuracy. The issue with wearable health tech is that it has a hard time finding a happy medium between performance and energy efficiency. Most of these devices run on batteries, so they can only last so long before needing to be recharged. This system incorporates a sensor module to gather heart sound signals; data processing is handled by the controller module, an Arduino Mega 2560 R3. Using the TFT LCD screen, the user interacts with the interface, and the SD card stores the obtained information. The ESP8266 Wi-Fi module allows for wireless remote monitoring. Energy harvesting technologies and thermoelectric systems are the next sort of place where the author focuses his attention, boosting device autonomy via captured ambient energy sources. The results show that this is entirely feasible in the realm of wearable health monitoring systems and low-power, which can continuously monitor body sounds-a promising solution for health care management. This study, thus, helps toward the development of healthier, long-lasting, and efficient health monitoring devices with rising potential in handling real-time chronic condition management and early illness detection.

Keywords: *Wearable health gadgets, low-power sensors, energy-efficient electronic circuits, and apps for monitoring the body's sound.*

1. INTRODUCTION

It is possible to monitor health and identify diseases by deciphering a wealth of information contained in the sounds produced by the human body. As an example, hospitals have extensively used cardiopulmonary signals for many years to identify lung and heart conditions. It is crucial to know the foetal heart rate since it is a measure of the baby's vital signs and may be heard. It is possible to determine if the abdominal surgery was successful and whether there are any tissue adhesions by listening to the bowel sound (Cesen et al., 2020). Thanks to recent developments in high-performance circuits and digital signal processing, one-of-a-kind sound monitoring and diagnostic devices have been developed, which use the physiological noises created by various persons. Contrary to popular diagnostic methods that rely on dynamic power transfers, such as X-ray scanning and ultrasound detection, sound-based diagnosis and monitoring do not present or future human health risks. Sensors typically include a sound sensor for wirelessly monitoring the wearer's vitals, a portable base station (PBS) for tiny, portable devices, and a server for storing, organizing, and providing users with their recorded health data (Sahoo et al., 2019). Thanks to advancements in integrated circuits, wireless communication, mobile networks, and sensor technologies, low-power sound sensors that are perfect for daily usage have recently been created. Developing very energy-efficient electronic circuits, particularly for use in body sound monitoring, has been a major focus of research because to the increasing demand for such wearable health monitoring devices. So that these monitors can last for a long time on batteries while still providing the most accurate performance, low-power circuits are required for the devices that detect vital sounds like heartbeats and lung activity. Minimizing power usage without compromising data quality is the real difficulty. Here the researcher take a look back at some of the most recent developments in the fields of real-time body sound monitoring and energy efficiency in operation (Panda et al., 2023).

2. BACKGROUND OF THE STUDY

Increased interest in wearable health monitors has spurred significant progress toward more efficient electronic circuit design, especially for use in applications that measure bioacoustic emissions. Such devices monitor numerous physiological characteristics, such as heart rate, breathing rate, and internal body noises, which are crucial in real-time health diagnostics and chronic illness management. A fundamental basic problem in building such systems is the balance between strong performance and low power consumption as many wearables depend on battery operation and must operate for some length between recharges (Sughashini et al., 2021). Traditionally, body sound monitoring systems have combined stethoscopes and pulse oximeters, which are fairly power-intensive, hence reducing their mobility and practical usage for continuous monitoring. Recent breakthroughs in ultra-low-power electronics, notably ultra-low-power sensors, analog-to-digital converters, and signal-processing units, set the framework for improved body sound monitoring devices (Harun-Or-Rashid et al., 2021).

These boundaries strive to decrease power consumption for each component while still providing proper and reliable measurements. This is crucial for wearable health devices that have to be small while assuring long-term usage. Further, new ways to wireless communication protocols and energy harvesting have now established fresh opportunities for reduced dependency on old sources of electricity. Low-power wireless protocols like BLE and Zigbee offer high-data transmission and low power, letting body sound monitoring devices interface with mobile phones or any distant device with an extended duration of battery durability. The energy harvesting technologies include piezoelectric and thermoelectric systems employing ambient energy sources (such as movement or body heat) to power these devices for enhanced energy autonomy. The integration of this application for monitoring noises inside the body should be targeted at revolutionizing how one monitors health issues and their management via real-time and non-invasive user monitoring. This is where the desire for energy-efficient circuits forms the heart of smart health-monitoring gadgets, where extended lifetime performance with greater comfort on the user's side and in the manner of accuracy in collecting data are in high demand. This study is focused on research advancements that are now going on for body sound monitoring and finds possible options for constructing sustainable, energy-efficient electronic circuits (Adam et al., 2023).

3. PURPOSE OF THE RESEARCH

This study creates electrical circuits that are very efficient with energy for the purpose of body sound monitoring; this means that even more power may be saved without sacrificing performance or accuracy. This opens the door to the prospect of energy-efficient, continuous, real-time health monitoring via the investigation of advanced circuit designs, low-power sensors, and methods for data processing. The research also aims to improve the wearable gadget so that it can last longer between charges and doesn't need constant power source interruptions. Consequently, it would pave the way for more viable, trustworthy, and long-term approaches to creating solutions for non-invasive health monitoring systems.

4. LITERATURE REVIEW

Increasing demand for wearable health monitoring devices for continuous, non-invasive data collecting is driving the fast development of energy-efficient electronic circuits for body sound monitoring applications. Remote health monitoring, early illness diagnosis, and personal health care are all greatly enhanced by devices that can detect and analyze physiological sounds including heartbeats, lung noises, and blood flow. Decreased power consumption without compromising sound measuring accuracy or reliability remains the primary obstacle (Zhang et al., 2019). The high power consumption of most traditional stethoscopes and portable electrocardiogram (ECG) devices has long limited their usefulness in wearable form factors for monitoring physiological sounds. A lot of work has gone into developing low-power electronic circuits that can run continuously for extended periods of time without needing to be recharged often in the last several years. The development of more efficient amplifiers, signal-processing units, and low-power analog-to-digital converters (ADCs) has made it possible to record and analyze physiological sound signals with less power consumption. Power management is usually a major focus when designing these circuits, which lets the system enter low-power states plastically, such when measuring sound. The energy footprint of body sound monitoring systems has been kept low because to developments in low-power sensors. This has allowed them to be manufactured into tiny wearable devices. Research into energy-efficient signal processing methods is another important focus. In order to provide a high-quality, robust analysis, the DSP method was modified to reduce the computing burden. For effective processing of audio data, only important information is transferred or captured via the use of noise reduction and feature extraction techniques. Energy harvesting technology, specifically piezoelectric to thermoelectric systems, is an area that could use more investigation. One potential use is in wearable electronics, where the user can draw power from their own motion or body heat to keep their devices powered for longer. Other potential domains include low-power protocols for wireless communication, such as Bluetooth Low Energy (BLE). Using these, data transmission can be accomplished without draining the battery. These developments pave the way for the prospect of autonomously operating wearable health devices for extended periods of time, collecting and analyzing bodily sounds in real-time for the purposes of early diagnosis and individualized healthcare management. This research in low-power circuit design, energy harvesting, and wireless communication is crucial for overcoming current limitations and enabling the next generation of body sound monitoring systems. The demand for more sustainable and efficient wearable health technologies is on the rise, and researchers are working hard to meet this demand (Tung et al., 2022).

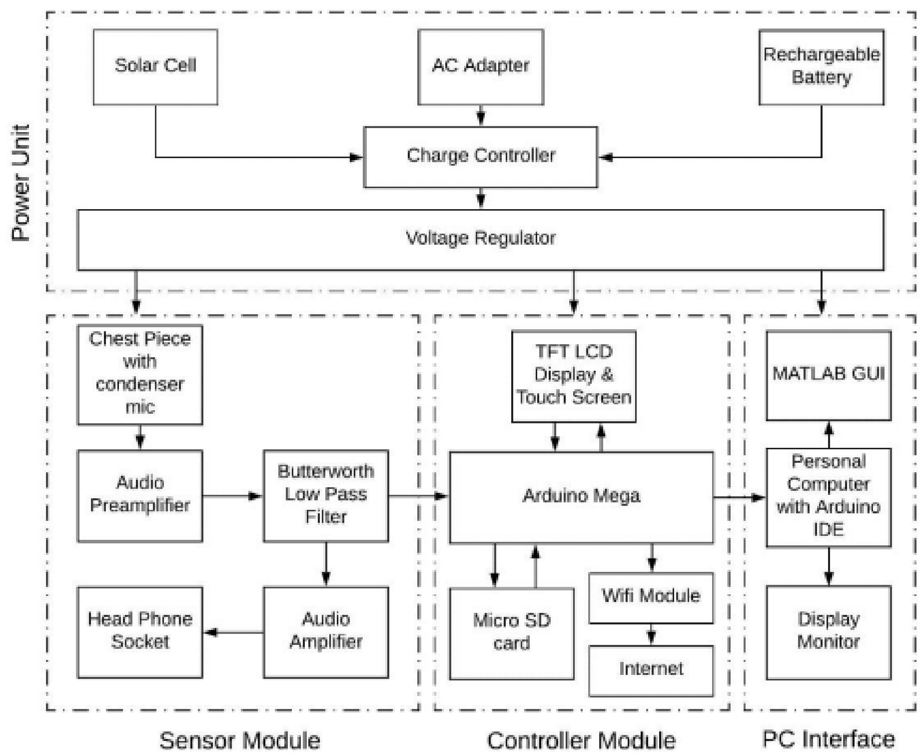
5. RESEARCH QUESTION

- In sound monitoring, what effect does wavelength have?

6. METHODOLOGY

The four main components of the proposed system are: Gathering and relaying the analogue signal of the heart rate to the controller is the responsibility of the Sensor Module. Central to the functioning is the controller module, which regulates the TFT LCD module's user interface (UI), establishes wireless connections with a personal computer, stores recorded signals on an SD card, and does basic analysis on cardiac sound data. The system's power comes from the power unit, which in turn pulls power from a variety of sources, some of which are renewable and others of which are not. Using PC Interfacing, the recorded cardiac signal is carefully analyzed. Following this, the researcher will take a close look at each module individually.

Figure 1: Block Diagram



Controller Module

The Controller Module is the central processing unit of this cardiac acquisition system. All of the essential tasks for the cardiac sound acquisition system are controlled and executed by it. Arduino Mega 2560 R3 boards serve as the controllers. Built inside the acquisition system is an onboard user interface that makes use of a 2.4-inch TFT touchscreen LCD. The TFT LCD module has an SD card port built right in. To that end, an 8GB memory card was also used for data storage. The Internet of Things (IoT) flavor and enhanced remote monitoring capabilities are brought to the system by the ESP8266 Wi-Fi module. In order to better visualize signals, PCG may be exhibited on an LCD screen via a USB connection and a personal computer that already has the Arduino IDE loaded. The outcomes of this module are based on following considerations:

- 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

Arduino Mega 2560 R3, an open-source hardware platform, is powered by the ATmega2560 CPU. If the student have little technical knowledge, the student can program and operate an Arduino board. The complete build of the Arduino Mega 2560 is shown in Fig. 2. When determining whether to include this device into this project, the student following criteria are taken into account: With its two voltage regulators, one for 5V and one for 3.3V, the student may freely set the voltage for any other hardware modules the student hook it up to.

- 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

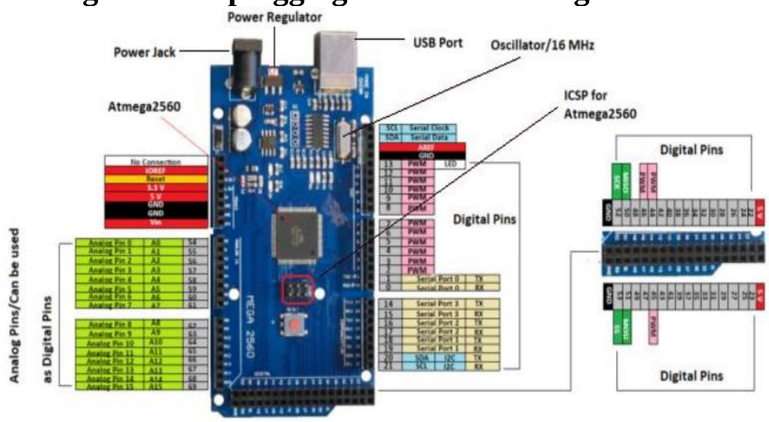


Table 1 provides a high-level overview of the Arduino Mega 2560 R3's technical specifications.

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

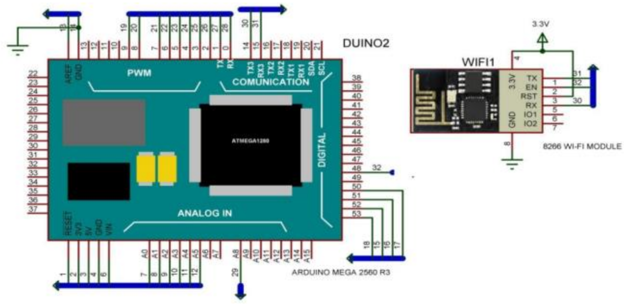
The Wi-Fi Module ESP8266

To transform the acquisition system into an IoT platform, this project uses an ESP8266 Wi-Fi module. The module is currently not performing any function, even though it is attached to the acquisition system. All plans for future projects involving the Internet of Things (IoT) deployment have this module installed. A brief description of the ESP8266 and how it is connected to the hardware is provided here. One possible use for the ESP8266 Wi-Fi module is end-point Internet of Things advances; it is a cheap, standalone wireless transmitter. An internet connection may be established between the heart sound acquisition system and the internet by use of the TCP/UDP connection protocol. To establish a connection with the ESP8266 Wi-Fi module, the Arduino Mega has to send a sequence of AT commands via UART at a certain Baud rate (115200 is the default). 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

Arduino boards do not have enough storage space to accommodate heart sound data files. Hence, an external storage device is required to keep the data. A non-volatile memory card format called an SD card was developed by the SD Card Association (SDA) for use in portable devices. An SD card is used to store the heart sound signal data in bulk here. Files ending in ".txt" contain the data. Because an SD card connector is already included into the TFT LCD module, no further module is required for this function. The pins of the TFT LCD that are associated with the SD cards are directly connected to the Arduino Mega. Each pin's matching connection is

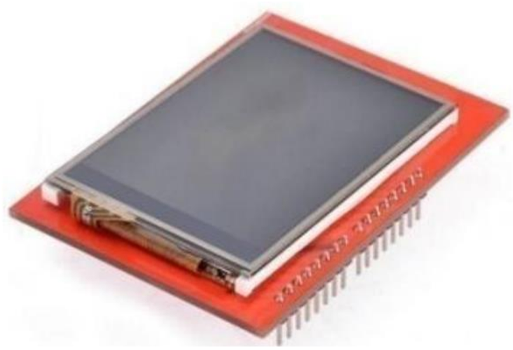
TFT LCD Pin	Arduino Pin	TFT LCD Pin	Arduino Pin
SD_CS	Pin 53	MOSI/SD_D0	Pin 51
SD_SCK	Pin 52	VCC	3.3 V
MISO/SD_DI	Pin 50	GND	GND

Researchers utilise an 8 GB memory card for the 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

A direct user interface is necessary to operate the full heart sound acquisition equipment. In this work, the user interface is designed using a 2.4-inch TFT touchscreen LCD. The developed user interface asks the user for the patient's name, age, and weight after showing the welcome message. The sensor choice page was then routed, and the functionality page appeared based on the user's input. Here, the user may touch the respective functionalities shown in the user interface to save, analyse, transmit, or observe the signal. The standard picture of a 2.4-inch TFT touch LCD module is shown in Fig. 4.

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

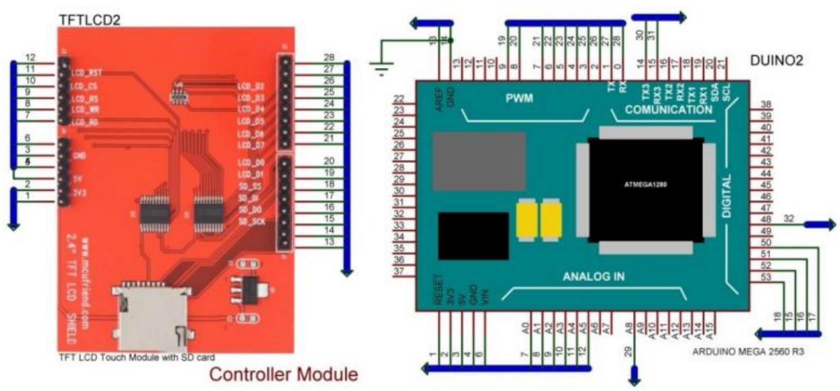


The used TFT module's short specifications are as follows:

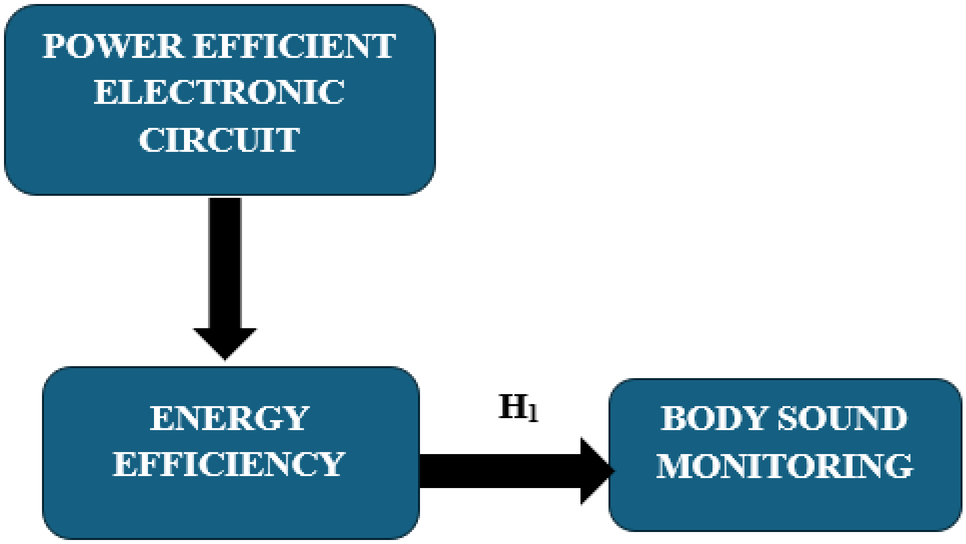
- 2.4" touchscreen TFT LCD
- 240 × 320 pixels
- 3.3V is the operating voltage.
- Modes of operation: 8-bit and SPI
- Interface IC: Interface ILI9341
- There is an SD card option for data storage.
- Interfaces with Arduino are simple (a free library is provided).

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

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

PC Interfacing

From the very start, PC connectivity is required since Arduino functions only according to certain instructions. The student may upload C code to Arduino boards using the Arduino IDE, a Windows tool that does the translation. The Arduino IDE software, which may be downloaded from the official website, is installed on a Windows PC. Arduino boards may now be directly connected to personal computers using a USB connection and an inbuilt USB port. By navigating to the "Tools" menu inside the Arduino IDE and selecting the relevant ports and boards, they may begin the interfacing process. Figure 6 shows the researcher's computer with the Arduino board and the Arduino IDE already installed.

Figure 6: Computer-Arduino Board Interfacing

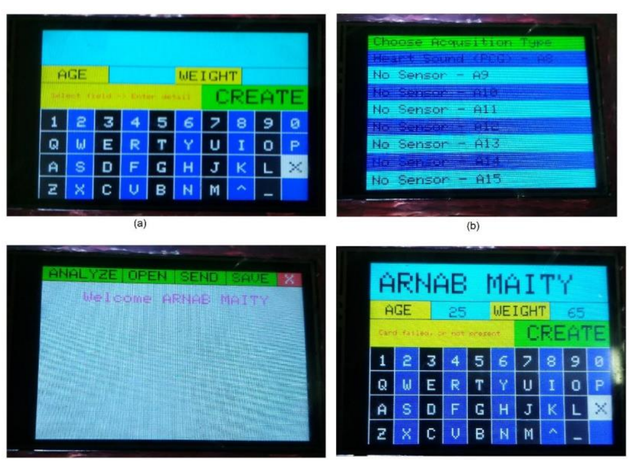
SD Card Interfacing

Connecting the SD card to the Arduino module is the first step in SD card interfacing. Just follow the procedure shown in Figure 5. The 'Read Write' SD card library sample was then uploaded to the boards once the PC and Arduino boards were connected via USB. As its name implies, this sample performs read/write operations directly on the memory card. The initial try at SD card recognition failed because the file format was incorrect. The student may use either the FAT16 or FAT 32 file system with the Arduino SD library. Before inserting the SD card into the slot, users must format it to utilize the FAT16 or FAT 32 file system. After then, reading and writing went off without a hitch.

Interface Testing for TFT LCD Touchscreen Screens and User Interfaces

An Arduino UNO is greatly enhanced with the LCD shield. Also, it's compatible with Arduino Mega, however the student will need an extra wired connection due to SD card connector variations. Connecting the shield to the Arduino Mega is the last remaining step after configuring it for the LCD and touch screen. However, the touch screen has to be calibrated due to variances in manufacture. The MCUFRIEND kvb library samples were used for calibration and visual testing by the researchers. After that, the researcher will have tested the desired user interface for every possible error message. Figure 7 displays views of the proposed user interface. The user is able to access patient data via window 7 (a) in the picture. There is no issue with the obligatory validation for any of the input fields either. Window 7 (b) asks the user to choose the sensor type before data collection can start. At the moment, this window can only receive data from the heart sound acquisition sensor. Other projects will make use of the remaining fields. Eventually, the acquisition system will include a plethora of sensors that can gather data all at once. Windows 7 (c) is the principal interface for handling the cardiac sound signal. Since the 'SEND' and 'analyse' operations are currently not functioning, they are being left as future scope. The patient's initial information and heart sound signal may be stored to the memory card instantly by clicking the "SAVE" button. A thorough validation mechanism has been developed and tested by researchers to identify and avoid system errors (such as a faulty or missing memory card) and unusual user input (such as entering a numerical value for an age or a name instead of a name). The memory card missing issue 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 integrated analog-to-digital converter (ADC) on most Arduino Mega boards allows them to handle analogue signals. The student can easily connect sensor modules with these 16 dedicated analogue pins. There are a lot of things that a four-analog-pin TFT LCD touchscreen module can do. The student may attach any sensor module to the remaining connections to collect or analyze data. The heart sound signal sensor may now perform its intended job thanks to the assignment of analog pin 8. The student may get signals of any kind using the extra analogue pins. As a result, the sensor choice window is now integrated into the user interface design and will be left for future enhancements. By converting the analogue signal to digital form, the built-in ADC of the Arduino Mega allows the signal to be saved to the memory card. The Arduino ADC has a 10-bit resolution and can sample at up to 77 kHz, according to the specs. The sampling rate of the derived heart sound signal is close to 5 kHz, even with SD card write and execution delays. Compared to the Nyquist Rate, this is much greater for a heart sound signal, which usually falls between the 10 to 500 Hz range.

Wi-Fi Module Interfacing

Although the Wi-Fi module is included in this project for the implementation of the Internet of Things, it is currently not delivering data wirelessly. This module was successfully linked to the acquisition system using the AT instructions. The researchers have confirmed that the Arduino and Wi-Fi module are properly connected and can communicate with each other. Data transmission and receiving over the Internet may be enabled with the addition of a single line of code to the main Arduino program, simplifying the process.

9. DISCUSSION

This paper details efforts to design and build electrical circuits for use in body sound monitoring systems that are more energy efficient without sacrificing the precision and dependability of the physiological data collected. Since these devices need to function for long periods of time without being recharged all the time, optimizing energy consumption while maintaining good performance is a major problem for wearable health devices. The use of low-power sensors, analog-to-digital converters, and signal processing algorithms is crucial in lowering the energy consumption. By including components like an Arduino Mega microcontroller, an ESP8266 Wi-Fi module, and an SD card for storing heart sound data, the system under development in this study enables the realization of real-time health monitoring. The use of Wi-Fi and other low-power wireless connection protocols for remote monitoring is an impressive feature of the design. Consequently, it improves the device's usability in everyday situations. However, in terms of the Wi-Fi module, the system has not yet achieved full deployment, and additional work is needed to enable efficient data transmission over wireless networks. Featuring a user-friendly interface on the screen of the TFT LCD and the ability to collect and store body sound signals with minimal power consumption, this continuous noninvasive health monitoring system offers a wonderful way to do real-time analysis and remote monitoring. Its competitive edge in wearable health technology makes it possible for anybody to monitor their health more conveniently and sustainably. Improved functionality and scalability in the long run can only be achieved by increased investment in energy harvesting, signal processing, and wireless transmission technology.

10.CONCLUSION

A major step forward in wearable health tech is the creation of energy-efficient circuits that can detect and record human body sound. Finding the sweet spot between low power consumption and great accuracy in detecting and analyzing physiological noises like heartbeats and lung activity is what this research stresses (Varshney et al., 2019). These devices are able to provide continuous, real-time health monitoring with little energy consumption because they use low-power sensors in conjunction with modern signal processing algorithms and wireless communication technologies like BLE and Wi-Fi. It improves the devices' autonomy via energy harvesting methods, which in turn reduces the need for regular charging and increases their utility over the long run. On top of that, healthcare providers and patients would benefit from a user-friendly interface—possibly in the shape of a TFT LCD touchscreen—and reliable data storage on SD cards. A emphasis on energy-efficient circuit design is necessary to build sustainable, dependable, and cost-effective devices in order to meet the ongoing need for non-invasive, wearable health monitoring solutions. Incorporating new, energy-efficient wearable gadgets into the current evolutionary path of smart health-monitoring systems is where this study's true worth lies; these advancements will aid in better illness management, earlier diagnosis, and more individualized care for society (Robinson et al., 2021).

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