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Sleep Health Monitoring through Arduino UNO & EXG

Shashank Kumar, Nickey Ray, Dr. Manoj Kumar Pandey, Dr. Sakshi Kathuria
Amity Institute of Information and Technology Amity University Gurugram, Haryana, India

Abstract- This article outlines the minimum requirements for record- ing standard and sleep EXG. The Epilepsy Guidelines Work- ing Group, in collaboration with the International League Against Epilepsy and the International Federation of Clini- cal Neurophysiology, has developed guidelines for clinical practice guidelines related to epilepsy. All studies were eval- uated using PRISMA and GRADE evidence rating, with QUADAS-2 assessing the risk of bias in technical and meth- odological review studies related to sleep induction meth- ods. We will use a modified version of Delphi for the is-sue, where we couldn't find enough credible public evidence to establish consensus on expertise. The process was aided by the GRADE system to generate recommendations. We em- ployed evidence that was either of low or moderate value. Our team developed 16 scenarios based on consensus to es- tablish minimum standards for recording routine and sleep EXG. Technical specifications, recording duration, induce- ment to sleep time and provocative methods are part of the recommendation.

Keywords- EXG, Arduino, Electrocardiography, Neurophysi- ology, Epilepsy, Microcontrollers, Spectrogram Analysis, EMG (Electromyography), ECG (Electrocardiography), EEG (Electroencephalogram)

I.INTRODUCTION

By integrating Arduino technology with EXG sleep health monitoring, the process of managing individual well-being has made significant strides. Sleep has been shown to be es- sential for one's overall health. These disruptions to sleep are linked to a wide range of health conditions, including chronic depression and anxiety. The baseline for researchers and developers who use Arduino based systems is increasingly derived from modern sleep monitoring solutions.

The innovative uses of Arduino microcontrollers, such as the recently released Arduino Nano 33. By utilizing EXG data, BLE Sense has helped identify sleep stages. The systems use lightweight machine learning models that have been trained using Arduino technology to train on large datasets such as the Sleep-EDF Ex-Banded Database, and can discriminate between awake, light sleep, deep sleep and REM sleep with accuracy. The use of an Arduino was demonstrated in a re- cent project that accurately classified single-channel EXG data with 77% accuracy, highlighting the potential of this technology to revolutionize traditional sleep studies for home study.

Also, users can use a range of sensors powered by Arduino to track brain activity and physiological parameters such as heart rate and movements. This analysis provides a compre- hensive view of how well he or she sleeps. Tests have shown that when the electrodes are placed on the subjects' heads

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and the appropriate signal processing techniques are used, the data is as precise as that provided by commercial de- vices.

Users can monitor their sleep pattern changes over time us- ing real-time analysis and visualization capabilities provided by Arduino-based systems. The use of spectrogram analyses by developers facilitates the understanding of patterns and making informed decisions during sleep.

Despite the technological advancements, there are limitless possibilities for EXG sleep health monitoring with Arduino. Advanced algorithms and sensor technologies are being de- veloped to improve system functionality through improved accuracy. The use of sleep monitoring tools is made more accessible to individuals and allows them to make informed lifestyle choices that impact their health.

Sleep quality monitoring using embedded ML on the Ar- duino Nano 33 BLE Sense

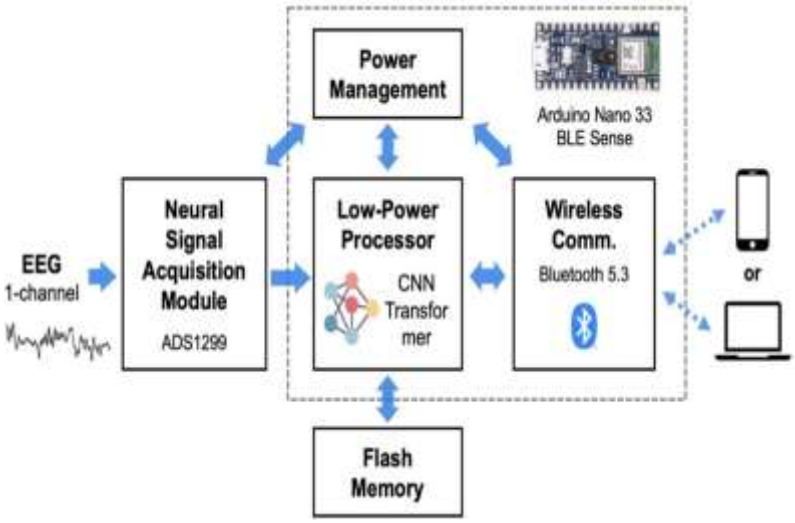

Fig 1 Tracking Sleep quality

II. METHODOLOGY FOR THE ARDUINO EXG-BASED SLEEP

Health Monitoring Project

The methodologies of an Arduino-based EXG sleep health monitor-ing project frequently in-corporate sever-al key com-ponents, in-clud-ing the hardware selection, data ac- quisi-tion, signal pro cessing, and analysis. The following sec-tions provide their respective de tails about the aspects considered re-lative to dif-ferent real implementations.

1. Hardware Elements

- **Microcontroller:** One of the popular choices would be the Arduino Nano 33 BLE Sense. The microcontroller is able to process and has enough in-built sensors, meaning it can ac- commodate light models of machine learning that may be used to classify sleep stages using data collected from EXG.
- **EXG Sensor:** There are several kinds of EXG sensors, and most can be used in devices such as the NeuroSky TGAM. This kind of sensor can, for example, record an EEG of the brain waves needed to analyze the various stages of sleep.
- **More sensors:** according to the scope, these can be addi- tional also which may include heart rate sensors, motion sensors or light sensors providing an all-embracing view of sleep health.

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2. Data Collection

- **Amplification of Signal:** EXG signals are weak, of about 20 μV. These signals must be amplified, and it may be achieved through the use of operational amplifiers and filters in such a manner that the Arduino may be able to read those signals.
- **Sampling Rate:** when record EXG signal, the low rate of sample must be between 200Hz to 250Hz, which would oth- erwise show a sampling rate capable of attaining detailed signal to analyze during various stages.
- **Data Storage:** The compressed Raw EXG data is dumped into the SD card which holds a minimum number of spac-es; for example, collected data of a whole night would hardly consume more than 10 MB. For such sizes, one can monitor a long term without frequent over-writing of the data.

3. Signal Processing

- **Filtering:** Signals coming from EXG pass through a series of filters. It includes the entire background noise removal through some band-pass filter before its proper interpreta- tion concerning sleep stages, thereby improving it.
- **Machine Learning Models:** Train a customized machine learning model, such as a 1D convolutional neural network, on existing datasets, like the Sleep-EDF Expanded Data- base, using processed EXG data to classify sleep stages as awake, REM, and deep sleep. Preliminary implementations yield an accuracy of about 77%. Subject-specific training re- sulting in even higher accuracies

4. Data Analysis

- **Real-time Monitoring:** The system can be designed to pro- vide real-time feedback on the quality of sleep by sending data wirelessly to a computer or mobile device3. This allows users to trace sleep patterns over time.
- **Statistical Analysis:** Batch processing of the data collected allows for detailed statistical analysis for trends in quality of sleep over time. Techniques like random forest models could be used for this.
- **User Interface:** A dashboard can be created that encom- passes all the sleep data, and parameters can include stages of sleep and overall quality so the user can better understand his or her sleep health

5. Future Developments

Future developments of such projects can be:

More Advanced Sensors for Full Monitoring can Be Integrated, like Snoring Detection.
Mobile Applications can be Designed for Easy Access to Sleep Data

Techniques can also be used on machine learning algorithms so that they classify better sleep stages. These can be made feasible to offer new ways for the devel- opers so as to make effective Arduino-based sleep health monitoring system using EXG signals that present new in- sights into individual sleep patterns as well as general health.

III. MODULES AND MATERIALS

The system consists of all the different kinds of components doing their thing within the system. Some are meant for in- put, some for output, and a few are employed in the system to create some kind of link be-tween the inputs and the out- puts.

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1. Arduino UNO

The Arduino Uno is an open-source microcontroller board, widely utilized by Arduino.cc based on the Microchip AT- mega328P microcontroller. This board was designed in 2010 and is utilized as a primary platform for newcomers and ex- perienced programmers in electronics. The board has 14 dig- ital I/O pins and six of the pins support PWM output, 6 ana- log input pins, and is programmable using the Arduino Inte- grated Development Environment (IDE) via a USB connec- tion.

Key Specifications

- Microcontroller: ATmega328P
- Clock Speed: 16 MHz
- Flash Memory: 32 KB (with 0.5 KB used by the bootloader)
- SRAM: 2 KB
- EEPROM: 1 KB
- Operating Voltage: 5V
- Input Voltage Range: 7V to 20V
- Size: 68.6 mm x 53.4 mm

Arduino Uno is user friendly and ideal for educational pur- poses. It has multiples protocols on which it communicates through: Seri-al, I2C, and SPI. The project is Open source, as such, upgraded and modified then placed freely in the public domain where users easily modify and share designs- thus building a collaborative community of people develop- ing and using it.

Fig.2 Arduino Uno Cable

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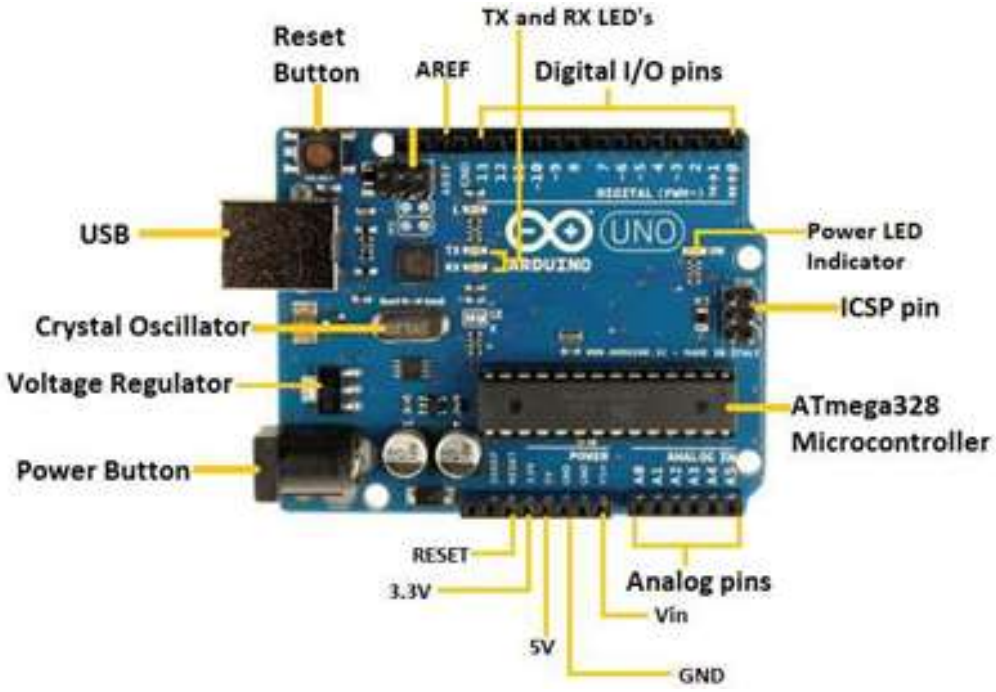

Fig.3 Arduino Uno

2. EEG

EEG is an electroencephalogram, which is a painless medi- cal test that measures the electrical activity of the brain. This technique produces an electrocardiogram, which is a graph- ical representation of the heart's electrical im-pulses. The EEG is generated by placing electrodes on the skin, which detects electrical changes.

Key Features of EXG

- Non-invasive: The procedure involves attaching electrodes to the skin, making it safe and pain-less.
- Real-time monitoring: EXG offers real-time feedback about the rhythm and rate of the heart, thus helping to diag- nose a majority of diseases in the heart.
- Diagnostic tool: It is essential for diagnosing arrhythmias, myocardial infarction or heart attacks, and other anomalies of the heart.

Parts of an EXG

- P Wave: It describes atrial depolarization. It means the atria are contracting.
- QRS Complex: It describes ventricular depolarization that indicates the contraction of the ventricles.
- T Wave: It describes ventricular repolarization that is the re-polarization of the ventricles, and hence the process of re- covering of the ventricles.

Applications

EXGs are widely used in hospitals to conduct examination of patients and keep an eye on patients suffering from heart diseases. It also helps to monitor the response of medicines or even pacemakers. In emergencies, it can analyze the acu- ate cardiac conditions. Electrocardiog-raphy is a primary procedure in cardiology that can help fetch valuable infor- mation regarding the heart's health and function.

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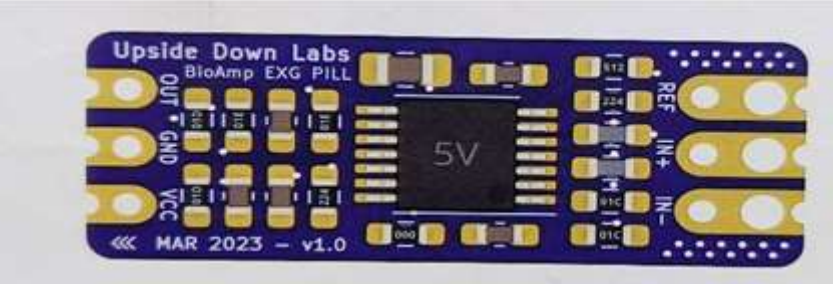

Fig.4 EXG

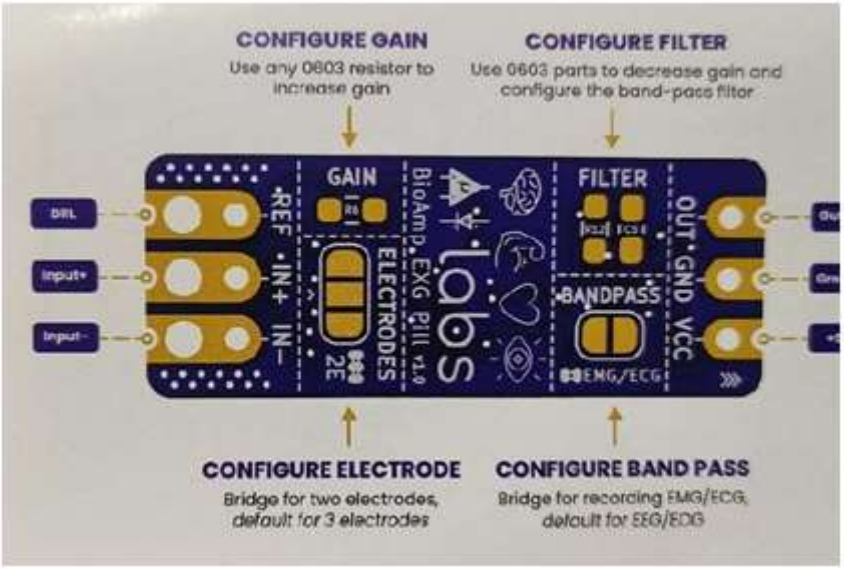

Fig.5 EXG Components

Bio Amp Band is a gadget that is devised solely for acquir- ing biopotential signals, mainly the EMG data from a human body. The Upside Down Labs promote this series of prod- ucts to inspire more DIY neuroscience endeavours and greater awareness of bio-signals.

3. Bio Amp Band: Features

- Design: Bio Amp Band is a stretchable band which has dry electrodes. It can be worn for various activities easily and comfortably. This design can help in achieving an accu- rate EMG signal, without the usage of traditional gel elec- trodes. Therefore, it is more usable and convenient.
- Compatibility: It can be combined with Bio Amp EXG Pill, a type of analogue front-end in the acquisition of biopo- tential signals. With this, one would be able to have quality EMG signal recording and data analysis through the soft- ware.
- Applications: Bio Amp Band can be applied for a range of applications from muscle activity monitoring to rehabilita- tion, as well as education in the neuroscience field. This is one fantastic tool to have real-time access to explore the electrical activity within muscles.
- Ease of use: The device is as simple to set up as attaching the band to the Bio Amp hardware using a cable; attach the electrodes to the skin and begin recording signals. The no- code approach makes it accessible even to those with mini- mal technical know-how.

Conclusion

Generally, the Bio Amp Band is an innovative solution in bi- opotential monitoring, which allows for hands-on learning and experimentation in neuroscience and biomedical engi- neering.

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Fig. 6 Channel Bio Amp Band

4. Bio Amp Cable

Bio amp cables are the types of connectors that are used with bioamplifiers to record and transfer biopotential signals generated within the human body. They play a significant part in several biomedical applications, especially in fields of electrophysiology, where the acquisition of an accurate signal is greatly needed.

Critical Characteristics of Bio Amp Cables

- Signal Transmission. Bio amp cables connect the elec- trodes that are pasted on skin to a bio-amplifier so that it sends electrical signals without much interference. The elec- trical signal generated by functioning of physiological con- dition, like beating of heart and activity of the brain, shall be transmitted effectively with high quality.
- Compatibility: Most of these cables are compatible with a range of bio amplifier systems, such as electrocardiography (ECG), electromyography (EMG), and electroencephalog- raphy (EXG). For example, the Bio Amp EXG Pill can be connected using a Bio Amp cable for recording different bi-opotential signals.
- Configurational Combinations: Some Bio Amp cables contain electrodes that can be connected with different com- binations of differential inputs IN+ and IN- combined with reference connections REF, that way, it makes a system very flexible depending on what is being measured.
- Signal Quality: The Bio Amp cable design has been tar- geted to minimize noise and to maximize the integrity of signals that are critical in most clinical and research settings. This is especially so when measuring weak bio-potential sig- nals, that are highly susceptible to interference resulting from external electrical noise.

Applications

Bio Amp cables are highly applied in the research laborato- ries, clinical diagnostics, and educational areas for monitor- ing a wide range of physiological parameters. They play an important role in studies concerning sleep health monitoring, neurological assessment, and muscle activity monitoring.

Overall, Bio Amp cables are critical elements in the kit of researchers and healthcare providers engaged with bio-po- tential measurements for precise data capture from living be- ings.

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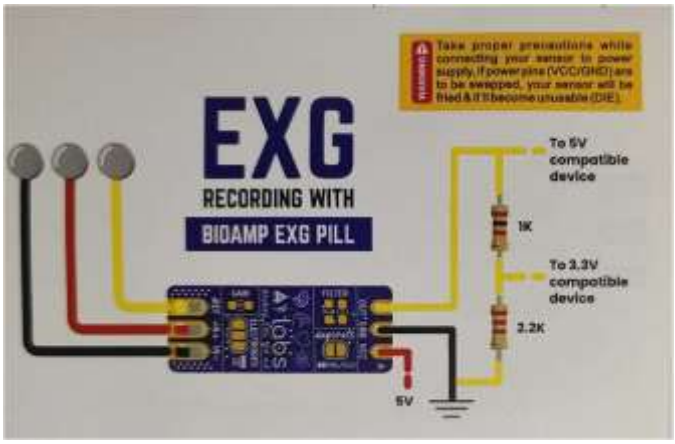
Fig 7 Bio Amp Cable



5. Gel Electrode

Gel electrodes are perhaps the most used electrode in many biomedical applications, such as electroencephalography or EXG, electrocardiography or ECG, and electromyography or EMG. They have a conductive gel that makes conducting easier between the electrode and the skin which allows for an improvement in quality of the electrical signal recorded.

Key Properties of Gel Electrodes

- This mainly consists of water, thickeners like polyvinyl al- cohol or carboxymethyl cellulose, and electro-lytes that can allow electricity conduction in gel electrodes. Such a com- position to the gel leads to moisture retention and decreased skin irritation in constant use.
- Functionality: The main function of gel electrodes is to minimize the impedance that is created by the interface of the skin and the electrodes. These help record better bio-po- tentials by facilitating proper signal transfer from the skin to the electrodes. This is particularly necessary when the pre- cise measurement is needed, like clinical diagnostics or la- boratories.
- Types There are two types namely, solid gel and wet type electro des. Solid gel electrodes are mostly non-irritative to the skin and can be used for a longer period of time. Wet gels provide an immediate conductive environment but cause irritation over time periods.

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Benefits

High Signal Quality: The contact of the skin with the elec- trodes is stable with low impedance in gel electrodes. Thus, these are best suitable for high density EXG recordings and sensitive measurements.

Less Artifacts: They show fewer movement artifacts com- pared to the dry or water-based electrodes which ensures better collection of data during dynamic activity

Applications

Gel electrodes are part of clinical practice for monitoring heart activity, or ECG; brain activity, or EXG; and muscle activity, or EMG. They have many other significant uses in research for the measurement of all other physiological phe- nomena, such as skin conductance and biofeedback applications.

In simple words, the gel electrodes are of great significance in the reliability and accuracy of recording biopotential across applications in medicine as well as in research. De- sign: the main objective of electrode design will be to max- imize the conductivity along with the minimization of dis- comfort that is caused by the patient or subject during the monitoring sessions.

Fig. 8 Gel Electrode

6. Jumper Cable

Jumper cables are also known as booster cables or jumper leads. They are electrical cables used primarily for connect- ing two vehicles to jump start a car with a dead battery. They usually consist of two insulated wires with alligator clips at- tached at each end, thus making it possible to attach them to the vehicle's battery terminals

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Major Features of Jumper Cables

- **Building:** Jumper cables have thick, elastic copper wires, covered to avoid electric shocks and short circuit. The diam- eter of the cable is very important; usually, a preferred cable diameter varies between 4 to 6 gauge. This depends upon the requirement of the conductor.
- **Size:** Jumper cables are normally between 10 and 25 feet, that is, ideal length to allow connection of battery when the automobiles cannot be straightened parallel one to another.
- **Colour Coding:** The jumper cable is colored too; red con- nects to positive, (+) and black to negative, connection so as avoid wrong connection can lead to dangers of electrical ones

Applications

- **Jump-Starting Cars:** The basic function of jumper cables is to connect a dead battery to a good one so that the dead bat- tery can be recharged and the vehicle can be started.
- **Emergency Situations:** They are the lifeline of the roadside as they help the drivers to revive their vehicles on their own and without any professional assistance.

Precautions for Safety

There are precautions while jumper cables are used.

- First, automobiles need to be switched off before placing the cables
- Now, the red clip is to be attached to the positive terminal of the dead battery and then on the positive terminal of the good battery.
- Connect the black clip to the negative terminal of the dead car, holding it in such a way that it is not in contact with the terminal so it won't short out, then connect the other end of the black clip to another unpainted metal of the dead car.

Hence, jumper cables are very essential in the maintenance of cars and emergency situations because it will easily solve dead batteries while safety and proper handling while using are of utmost importance.

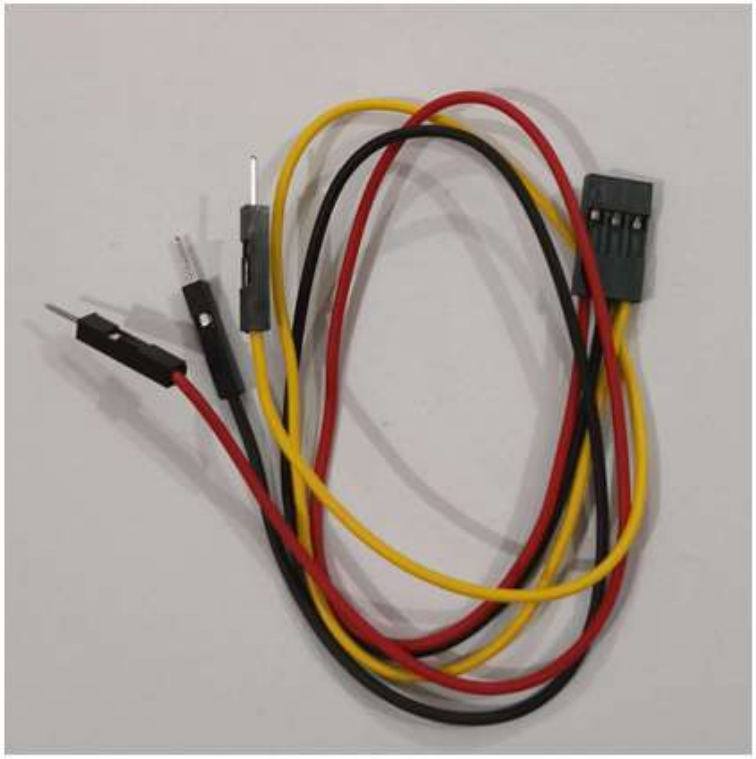

Fig.9 Jumper Cable

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IV. INSTALLATION

This is the design of a sleep monitoring device by using electrocardiogram signals. EXG records the electrical activ- ity of your heart, and by analyzing these recordings, it may give an insight into the different stages of sleep, the variabil- ity of your heart rate, and other sleep-related aspects.

Assembling & Implementation Components Needed

- Arduino Uno board
- EXG sensor
- Breadboard
- Jumper wires
- Power Source
- USB cable

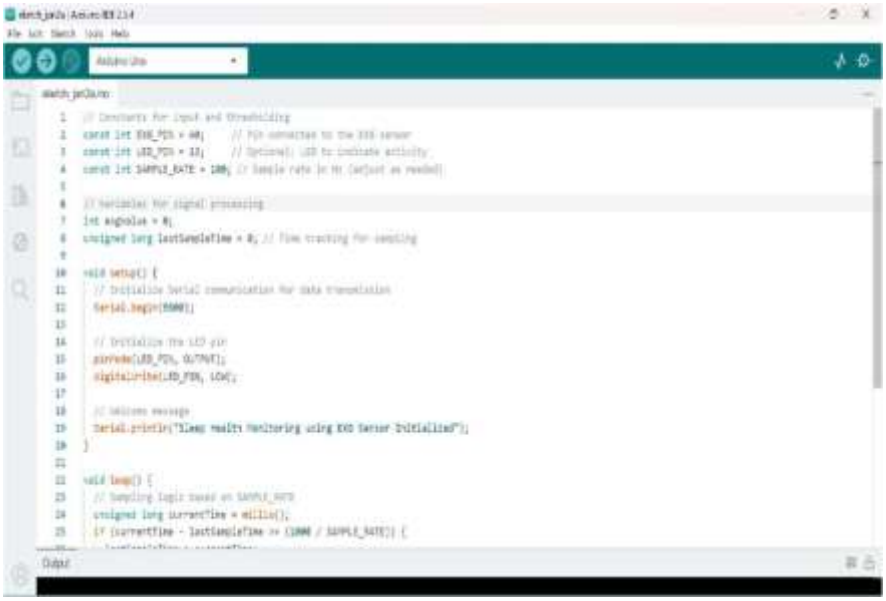
Circuit Configuration

Attach the ECG Sensor

- Connect the VDD and VSS pins of the ECG sensor to the 5V and GND pins of the Arduino, respectively.
- Connect the LO+ and LO- pins to the analog input pins of the Arduino (e.g., A0 and A1).
- Connect the output pin (OUT) to an analog input pin (e.g., A2).
- Power Supply

Connect power source to the power input pins of the Arduino.

Implementation



Features of the Code:

Data Collection

Reads data streaming in from an EXG sensor connected to an analog pin.
Samples the data at SAMPLE_RATE defined elsewhere

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LED Indicator
An LED lights up when the signal gets past a certain thresh- old. Useful to know that the analog pin is actually picking up data, or for general debugging.

Serial Transmitter
Transmits raw EXG data over Serial for offloading to Py- thon or another environment
Next Steps:

Hardware Setup
Connect the EXG sensor to Arduino. Make sure the data output pin is connected to the defined EXG_PIN in this case being A0.

Power the EXG sensor, and ensure signal quality is of good quality

Data Analysis
Raw data, which has been processed in a host program ei- ther Python or MATLAB may be used for analyzing sleep patterns. This may be Noise filtration from a signal Identification of sleep stages based on EEG and ECG pat- terns.

Anomaly detection, such as sleep apnea or abnormal heart rate.

Add Memory/Storage

Use an SD card module to store data locally if real-time transmission is not needed.

Data Processing and Analysis
You can apply several signal processing techniques to ana- lyze the EXG data:

- Heart Rate Computation: Apply peak detection or Fourier Transform to compute the heart rate.

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- Sleep Stage Detection: A frequency domain analysis of the ECG signal is done to detect the stages of sleep. Those are mainly two, such as REM and NREM.
- HRV: Variation with time in the heartbeats will be calcu- lated to quantify stress and activity of the autonomic nerv- ous system.

Other things that should be kept in mind

- Calibration: The calibration of the ECG sensor would be done for the measurement purpose.
- Noise Reduction: Add noise reduction methods such as fil- tering on the ECG signal to yield a better quality signal.
- Power Efficiency: Utilize low power components and in- corporate power saving mechanisms to enable long term monitoring.
- User Comfort: Design a comfortable and secure mecha- nism of attaching the ECG sensors to the body.

With the aid of hardware and software components, you can design an ECG-based sleep health monitor. Do not forget to consult medical professionals so that you would have proper understanding of the results in terms of the related health implications.

V. CONCLUSION

It has been shown to be promising for understanding and im- proving sleep health by integrating EXG monitoring into Ar- duino platforms. Studies have classified sleep stages with an accuracy of 77%. Alternative systems that are certainly much more expensive than traditional polysomnography methods. Real-time processing and analysis of EXG data not only enhance the user experience but also enable users to take proactive steps toward better sleep hygiene. Further- more, future advancements in machine learning techniques and sensor technology will make this system even more ef- fective and potentially reliable. Such future developments will include multi-channel EXG monitoring which, in turn, will give much more profound insights into the sleeper's pat- terns, say, sleep apnea. Another significant advantage of the use of Arduino-based solutions might open the use up to people interested in monitoring the health of their sleep themselves, and not exploited with really complex medical equipment. As these technologies advance, they are bound to change the face of personal health management. It would then enable the user to understand quality sleep and the po- tential to correct the issues that can affect one's overall well- being. In the wider sense, Arduino EXG sleep health moni- toring contributes to individual health and opens up a door for more research into the science of sleep.

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