Research Article

Wearable Embedded System Design and Development for Hydration Monitoring via Bio impedance Analysis

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Abstract : In terms of human physiology, water is the single most important factor in ensuring optimal health. As a universal medium, it is essential to every function in the body. Dehydration is a common ailment that may occur when there is an abnormal loss of bodily fluids. Physical and cognitive abilities are both hampered by dehydration. In this study, we discuss the ideation, design, and implementation of a wearable embedded device that can detect a person's fluid status. Wearable medical devices (WMDs) are on the rise in the biomedical industry because they provide a patient management system, guarantee patients' physical and mental health via constant monitoring, and lower the financial and logistical barriers to providing medical care anywhere. This work use bioelectrical impedance analysis (BIA), one of various methods for tracking fluid intake.

Keywords: Wearable Medical Devices (WMDs), bioelectrical Impedance Analysis (BIA). Dehydration.

Introduction

Over the last two decades, the Personal Healthcare System (PHS) has emerged as a popular concept in the realm of medical technology, providing patients with convenient electronic health services through wearable, implantable, and other mobile devices. This technology enhances their capacities by enabling remote, noninvasive monitoring through varied degrees of intelligence, pervasive monitoring, feedback evaluation solution, and wireless data transfer. The mathematical measurement of water level in the body through bio-impedance analysis has the potential to be implanted with the help of this research and development based on wearable portable technology. The portability of the system requires careful consideration when deciding on the development platform, microcontroller, instrumentation, and calibration devices[1[2]. These components must be as energy-efficient as possible, take up as little space as possible, and be affordable. Ultra low power MSP430 value line series microcontrollers were used to integrate the system created and reported on in this study because to its superior speed, low power consumption, and memory configurability. Since the idea of hydration measurement is based on the water content in the body and related bodily factors, which vary subjectively, it is helpful to examine the relevant background knowledge, such as the many forms of dehydration and their consequences, as well as the various measurement techniques available. It is crucial to examine the vitality of water in the human body, as described, prior to moving on to the instrumentation parts. Water, according to doctors and the published literature, is the single most important nutrient for human health. Interestingly[3-7], we are around 75% to 80% water as neonates, and that number gradually decreases as we mature, until it is roughly 60% for males and 50% for women (Anonymous, 2011). It's also common knowledge that water is an essential component of every one of the body's biochemical reactions. This includes a wide range of processes, such as chemical reactions, lubrication, nutrition supply, waste disposal, heat dispersion, and temperature control.

In addition to its roles in biophysical and biochemical processes, it also plays a significant part in circulation, digestion, cellular nutrition and oxygen uptake, and waste removal. Human hydration status evaluation and dehydration detection are now the primary focuses of the effort. Dehydration is a state in which the amount of water in a living organism is dangerously low, and it is a common problem in everyday life, particularly for athletes, those in physically demanding jobs, and people with conditions that cause them to lose large amounts of fluids[8-11]. The significance of being hydrated cannot be overstated; dehydration has negative effects on cognitive and physical functioning and should be avoided at all costs. However, it becomes particularly difficult to precisely pinpoint the juncture at which dehydration begins in the case of sportspeople, athletes, and active labourers. However, it is impossible for a person to sense dehydration or, for that matter, hydration, without the assistance of a medical professional. Considering the significance of this issue, we present the ideation, design, and development of a wearable embedded device to monitor a person's hydration levels[12][13]. The system created is an example of a smart, embedded gadget meant to be worn by patients while they undergo therapy and receive immediate feedback. The working class in a developing nation has particular financial challenges. We've zeroed down on this detail in an effort to create a cheap, mass-produced device for determining hydration levels. The method of bioelectrical Impedance Analysis (BIA), which is relatively new to the field of biomedical research, provides the basis for this equipment. By analysing the passive electrical characteristics of biological tissues, BIA is one of the well-established diagnostic procedures. The resistance of the bodily fluids to the passage of an electric current is measured. In our system, body temperature is also measured to increase precision. The FPGA is at the heart of this instrument because of its need for mobility, low power consumption, granular customisation, and dynamic reconfiguration. First, however, it's important to have a look at what other people have discovered in this area[14].

Need of Dehydration Measurement

In reality, self-regulatory mechanisms are built into the body's very structure. The thirst signals the body's demand for water. Thirst, the body's natural response to being dehydrated, is for the organism to seek out and consume fluids. It happens when the human body's water volume drops below a certain point. triggers thirst by increasing osmolite concentration and associated signalling. process in the physiology of maintaining a constant water level. Water homeostasis, seen here in a diagram drawn from the Europeon Hydration Institute, requires maintaining an adequate blood flow to all bodily tissues while minimising water loss. Dehydration Needed The body's own self-measuring mechanisms reveal its dehydrated status. The thirst signals the body's demand for water. Dehydration manifests itself in the form of thirst, a need for fluids that drives living things to replenish their fluid stores. Water balance control involves dy via this process. It happens when the human body's water volume drops below a certain point. Osmoreceptors are brain cells that sense osmolite concentration and relay that information to the neurological system, where it causes you to feel thirsty. What follows The thirst process in water homeostasis physiology is shown in Figure 1. Homeostasis of water is shown in Figure 1 [14], which was modified from the Europeon Hydration Institute. Vasopressin is secreted at the same time to curb water loss by diluting the urine. By monitoring blood flow, the body may identify water retention and adjust vasopressin production accordingly. signal the dehydrated state and the body's attempts to self-regulate. The thirst signals the body's demand for water. The need to replenish lost fluids, or thirst, is a telltale indicator of dehydration. Water balance control involves dy via this process. It occurs when the human body's water volume drops below Osmoreceptors are specialised cells in the brain that relay sensory information to the neurological system.

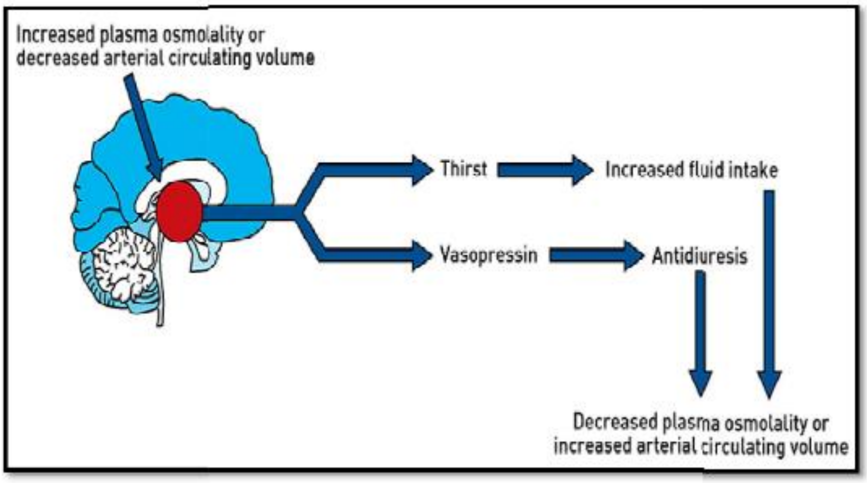

Figure 1. Physiology of water homeostasis

Literature Review

Gyutae Oh et.al (2016) This article describes the wearable device's GUI (graphic user interface) software architecture. We create the whole system architecture, including the real-time operating system, to ensure the wearable gadget functions properly. For GUI presentation, we also provide GUI routines and an objective-oriented library format. We validated the suggested architecture's usability in a wearable device setting by deploying the software we'd developed there.

Kok Yee Roger Lu et.al(2016) The purpose of this study is to discuss the design of a wearable device for the treatment of prosopagnosia. An autonomous embedded platform constructed within eyeglasses operates a real-time facial recognition application. An HDMI output, power supply input, Raspberry Pi Camera Module input, microUSB, and composite video output are implemented on a custom designed I/O board for the prototype. The system-on-module consists of a Raspberry Pi Compute Module and a Raspberry Pi Camera. The face recognition programme runs as well as the original PC-based solution, which was also based on OpenCV.

Gregoire Surrel et.al(2015) Recent developments in microelectronics have made it possible to create a new class of inexpensive, power-efficient, miniaturised, and intelligent sensor nodes. This next-generation of embedded sensor nodes has the potential to automate the analysis of complicated biosignals. In this article, we introduce INYU, a personal sensor system for tracking mental and physical wellness. Electrocardiogram (ECG), respiration rate, and skin conductance are some of the important vital indicators that are continually gathered by the device. INYU may use this data to provide a unique real-time approach for online heart-beat classification and correction, one that employs a probabilistic model to ascertain whether or not a heartbeat is likely to occur given a set of given temporal parameters. For this reason, INYU may use this technique to swiftly determine whether a beat is occuring normally or if there is an issue in the series (such as a skipped, excess, or misplaced beat). Both time-domain (RMSSD, SDNN) and frequency-domain (LF/HF) techniques for automated Heart-Rate Variability (HRV) analysis now make use of this novel methodology.

Damian Anzaldo et.al (2015) : Wearable sports and fitness technology: a study of the current market and technological developments in the domain of System-on-Chip (SoC). Smart clothes and equipment with built-in sensors are only two examples of the wearable options discussed. Trends in low-power secure computing are one of the technical issues covered.

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Selection of appropriate platform for portable impedance analyzing system

When it comes to DDS-based ICs with a standard communication interface, Analogue Devices is a market leader. We looked at the AD5933 IC, a state-of-the-art system-on-a-chip (SoC) that combines an impedance converter with a network analyzer, before settling on it to perform the DDS function. This IC integrates a number of functionalities into a single chip. It can produce frequencies up to 100 kHz with a precision of less than 0.1 Hz, making it ideal for measuring complicated impedance at a specific frequency. In addition to an A/D converter, it has an on-board analogue solution with programmable gain amplifier, low-pass filter, and current-to-voltage controller. This approach makes use of an on-board DSP engine to sample the response signal and use the DFT method for processing. AD5933 IC's internal structure is shown in the figure. A single two-wire interface protocol, I 2 C, controls the whole device via its programmable setting register. This block relays the parameters generated by other blocks of functionality to the microcontroller through the SDA and SCL wires. Another feature that increases this IC's versatility is an inbuilt temperature sensor that is accurate to within 20 degrees Celsius. Impedance may be measured from 1K to 10M. The device's application note states that it can use external analogue operational amplifier circuitry to measure impedances from 100 to 1K to within 0.5%. Therefore, up to 100 kilohertz of frequency may be generated with good accuracy, and 100 ohms to 10 megaohms of complex impedance can be measured. With an impedance range that typically falls between 300 and 800 ohms, it falls squarely within the usable range for bio-impedance measurements on humans under the current system. The advantages of the suggested on-board technology solution include a versatile platform, low costs, low energy consumption during computing, and simple personalization and communication. The fact that the IC AD5933 can provide such high-quality results while taking up so little space (it comes in a 16-lead SSOP package) is very important to our study. The AD5933-based portable impedance analyzer may be broken down into two primary sections in terms of design flexibility and simplicity: (1) designing a DDS-based portable frequency generator, and (2) implementing a portable single-frequency and multi-frequency bio-impedance analyzer. In addition to its usage in electrochemical analysis, blood coagulation detection, electro impedance spectroscopy, proximity sensing, and portable precise function synthesis, the aforementioned configuration has many additional practical uses.

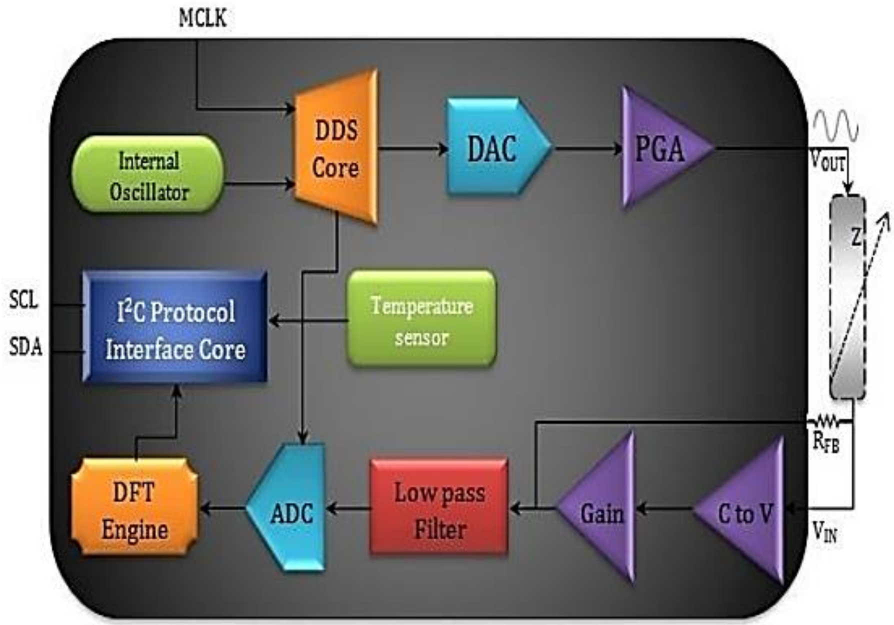

Figure 1: Internal structure of functional block diagram of Impedance Network Analyzer IC AD5933

Experimental Setup

The system is then tested on the known impedance value and the acquired value is compared to validate the correctness of the result. Statistical analysis was performed on the output data by drawing a graph of the frequency against the bioimpedance value. learnt a lot about a lot of different things. Three men and two women make up the sample for this in-depth examination.

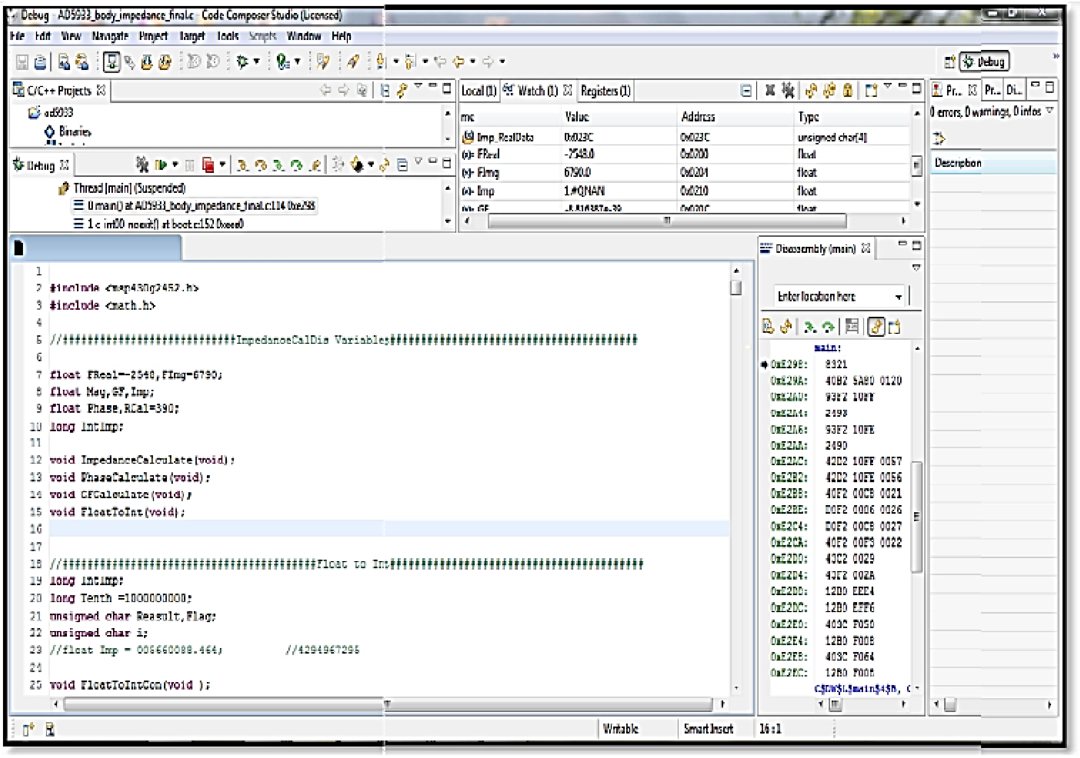

Figure 2: The programming workbench at debugging Mode

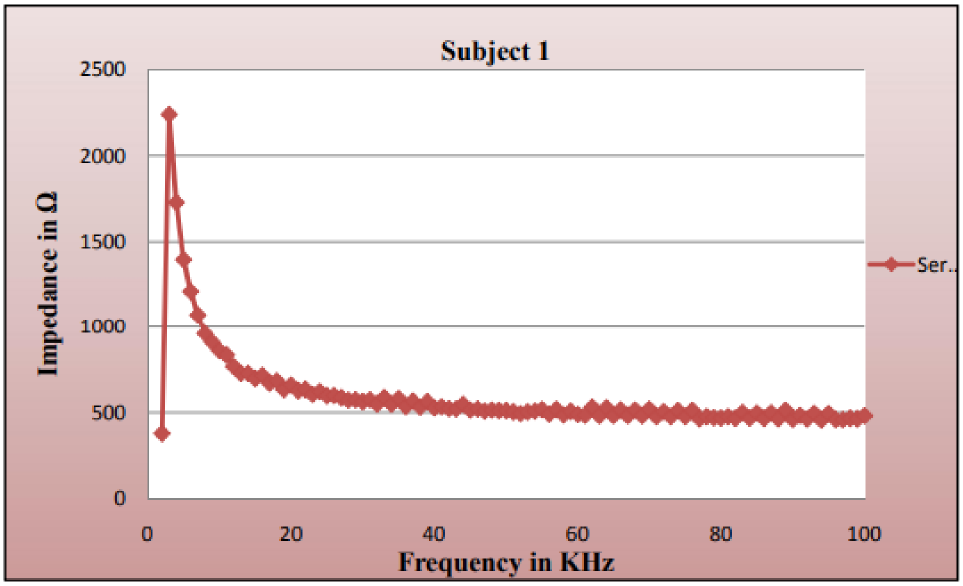

Figure 2: Bio-impedance analysis on subject 1 – male at various frequencies

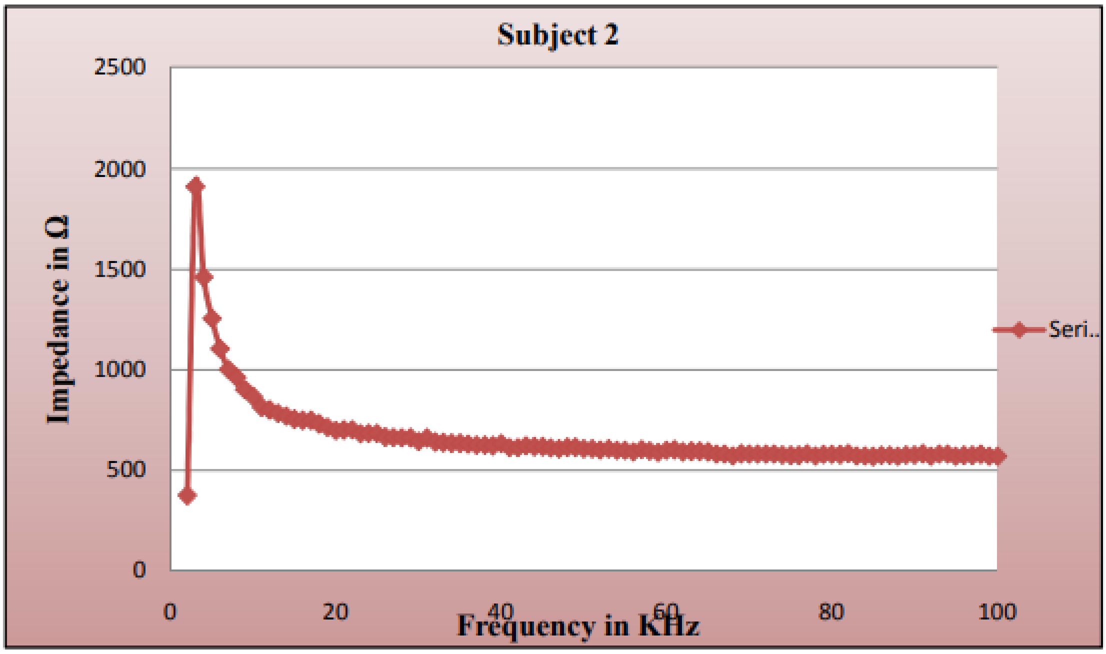

Figure 3.: Bio-impedance analysis on subject 2 – female at various frequencies

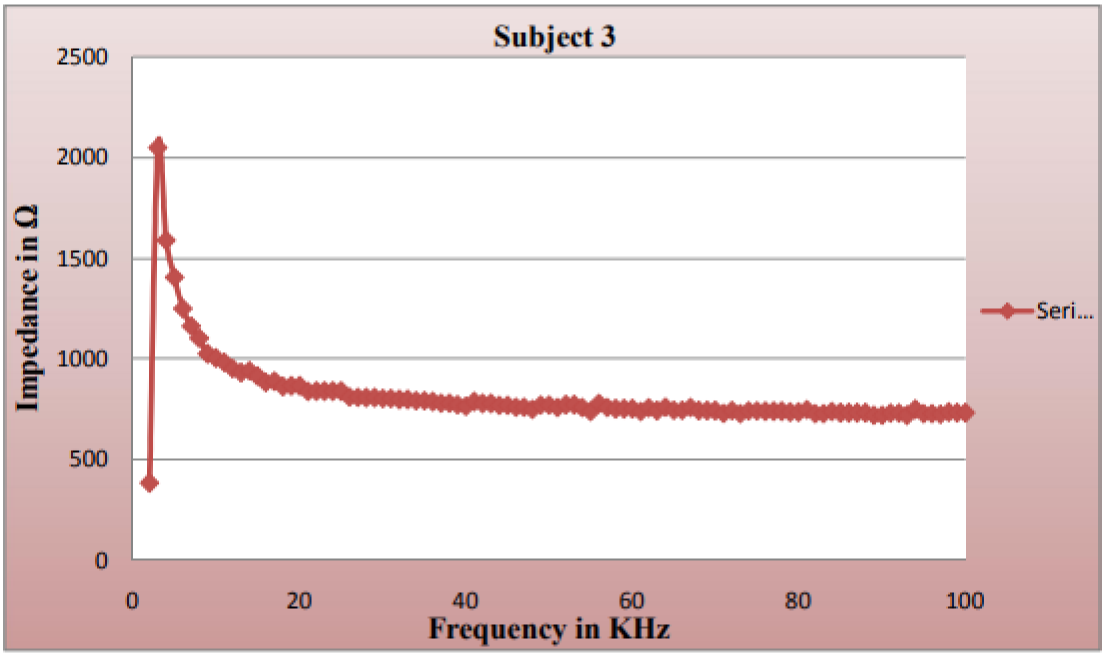

Figure 4: Bio-impedance analysis on subject 3 – female at various frequencies

A medical expert reviews the complete frequency versus bio-impedance graph and verifies the findings. Passed current with low frequencies cannot enter the cell and instead travels via the exterior area, or extracellular fluid. The characteristics of the cell membrane are altered as the frequency of the current running through it rises, resulting in a larger zone of penetration. Increasingly frequent changes in bio-impedance value are shown in detail on the accompanying graph. The impedance value is seen to stabilise at frequencies over 40 KHz. As can be seen in Figures 2, 3, and 4, the graph also guaranteed that the bio impedance value of female subjects was greater than that of male subjects.

Conclusion

This study's focus is on creating a wearable and transportable embedded medical system for monitoring the body's hydration levels while on the go. The system is built and developed with low power, low cost, tiny, and light weight metrics in mind, in order to meet the needs of this technology. A microcontroller-based system designed to meet the requirements of mobile medical applications. Because to advancements in miniaturisation, hydration monitoring may now be provided outside of a clinical setting, in the comfort of one's own home, on the pitch, or while travelling. Because it only sends a little current through the body (less than 800A) and uses a low-voltage power source, the system is designed to prevent microshocks. The low-power RF devices and smart Bluetooth technology solution provided by the TI MSP430 microcontroller make it simple to upgrade to new wireless technologies while continuing to use the same platform.

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