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An Overview of Medical Electronics

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ABSTRACT: In today's scenario, technology is improving and enhancing important features in order to meet the needs of commercial and industrial applications. Quantum electronics is also a component of the technology used to develop and create medical devices. Electronic engineering is offering different methods to alter medical care in the age of engineering. Sensors are often employed in the area of medical application to detect and analyse human body illness, and these medical application sensors are developed utilizing electronics engineering. Using medical electronics, surgeons can provide more effective medical therapy and illness assessment. As the population ages, the need for high-quality, low-cost healthcare and medical diagnoses/treatment has risen significantly. Intelligent instrument/clinical devices that cure intractable neurological illnesses or chronic diseases, sophisticated biomimetic devices/systems, artificial organs, and other medical electronics are being created with heterogeneous integration of technology. Medical electronics is a field that straddles engineering, biology, and medicine, and it offers tremendous possibilities for business and new scientific discoveries. There will be two implanted medical electronic systems on display. The sub-retinal implantation system for visual prosthesis and the close-loop deep brain stimulation (DBS) system for epilepsy are two of the options which have been discussed here.

KEYWORDS: Biosensors, Medical Electronics, Organs, Stethoscope, Technology.

1. INTRODUCTION

Medical electronics tools may be used to develop medical equipment and measurement devices, resulting in low-cost medical care. Biometric equipment and artificial organs are being created with the integration of technology to identify and cure chronic illnesses. Medical electronics is a rapidly evolving area of science and technology. The need to offer low-cost medical diagnosis and treatment for a fast growing population is a critical element in medical electronics research and development. Medical electronics are critical to the future development of the electronics sector. Biosensors, microsystems, integration, and wireless sensor interface are all part of the fundamental framework of a medical technology system. Medical devices, which are developed by medical electronics experts, are used to address health-related problems in medical electronics. Medical electronics engineers are sometimes known as equipment doctors. Multispecialty hospital surgeons or physicians may utilize such instruments and gadgets for analysis [1], [2]. The technology that is developed by medical electronics experts is responsible for the functioning operation and upkeep. Elements of biology and medical science engineering are used to address a variety of health-related issues and measures. Health management, artificial organs, body part replacement systems, instrumentation electronics, delivery care systems, and medical information systems are among the most researched topics[3].

The aging population, high demand for low-cost medical diagnostic and treatment devices/systems, and a rise in unmet clinical requirements are all driving forces in medical electronics research and development [4]. New biomimetic gadgets, systems, instruments, and appliances will be created at the cutting edge of medical electronics to cure intractable neurological illnesses or chronic diseases, restore health, and prolong life. It's an area that will help the electronics industry expand in the future. The exciting possibilities and difficulties of medical electronics have sparked a lot of research in both academia and industry[5]. Microsystems, biomaterials, packaging/integration, and the biotic-abiotic interface are all part of the overall architecture of a medical electronic system. Sensors/actuators, bio-signal processing units, power harvesting and management devices, and RF communication components make up a microsystem. Biomaterials include biocompatibility, biophysics, bio adhesives, and organics. High-density connections, flexible substrates, inert coating, hermetic containers, and thin-film polymers are all needed for packaging and integration. Tissue response, neurology, electrophysiology, cell development, and biomarkers are all linked to the biotic-abiotic interface[6].

1.1 Applications of Medical electronics:

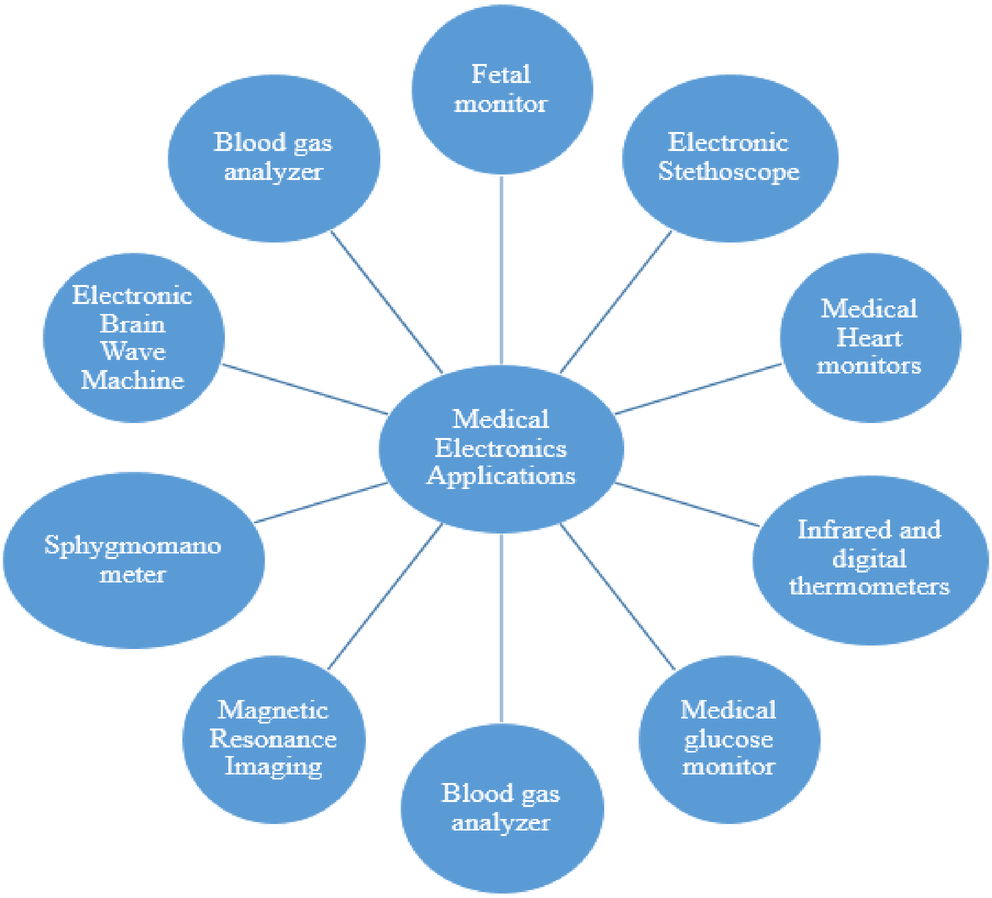

Figure 1: Representation of several applications of medical electronics.

Figure 1 represents several applications of medical electronics few of which have been discussed below.

1.1.1 Electronic Stethoscope and Sphygmomanometer:

The sound of the inside body may be heard by the physician, who can then analyze the working and malfunctioning of the human body's organs. Engineers have created a gadget for real concept analysis that visually generates a more effective and quantitative value with display settings. The provided voice print of the body is useful in diagnosing the illness and providing the necessary therapy after monitoring. The electronic stethoscope is more practical and is often utilized in medical diagnostics to improve treatment outcomes. Blood pressure, which is measured by a sphygmomanometer, is another physiological parameter. Blood pressure must be monitored on a regular basis in individuals who have a pacemaker implanted in their bodies, and all necessary treatments must be provided[7].

1.1.2 Magnetic Resonance Imaging electronically;

Imaging methods are extensively employed in the area of medical electronics to identify the interior object of the body for diagnosis determination. Magnetic Resonance Imaging [MRI] has a wide range of diagnostic applications. Magnetic resonance is generated in atoms known as hydrogen atoms, which are distinguished in pulse, resulting in a picture. These pulses are produced by electromagnetic erection, collision with an axis, and the results[8].

1.1.3 Electronic Brain Wave Machine:

Electronic brain wave machines, which record the electrical movements of the scalp using electroencephalography by collecting the neurons from the brain, are used to detect brain diseases such as brain death, sleeping disorders, and unhealthiness. Electronic equipment and devices of this kind are often employed in the medical sector to treat mental illnesses.

1.1.4 Electronic Blood Glucose Monitor and Infrared digital Thermometers:

Medication, different diets, and environmental diseases can influence the human body's blood sugar levels. Electronic blood glucose monitors are devices that use electronics to measure blood sugar levels in people with diabetes. People's needs are addressed by portable gadgets that allow sugar levels to be tested using single strip type machines known as glucometers. Heart disease, neurological damage, and renal disease are some of the illnesses caused by low and high blood sugar levels. The temperature of the body is a common component, and it is also needed by the measuring instrument. Bluetooth and a mix of hardware and software are used to measure temperature utilizing the infrared thermometry concept, which can send and receive data from recorded temperature. The temperature data that is received may be magnified for additional examination[2]. The data from the infrared temperature sensor is amplified and transmitted to the treatment location through mobile technology. This method allows for long-term monitoring of the patient's temperature and successful therapy.

1.1.5 Defibrillator for medical electronics:

A variety of instruments are utilized in the area of medical engineering to diagnose and treat the human body. Defibration is a procedure used to treat heart conditions that are very sensitive, such as cardiac arrhythmia and pulseless ventricular tachycardia. Defibration is the technique of using a healing shock to the heart. To reverse fibrillation, an electric charge is needed[9].

1.1.6 Fetal Monitor and Medical heart monitors:

Fetal monitoring is used to monitor the baby's heart rate throughout the pregnancy. An electronic fetal monitor includes a Doppler instrument, often known as a fetoscope, that functions similarly to a stethoscope. For monitoring the heartbeat of the baby, an electrical instrument known as a transducer is attached to broad and elastic bands around the belly. Another band across the abdomen was used to measure contractions during the monitoring. During wired and wireless monitoring, the transducer is linked to an electrical machine.

1.2 Subretinal Implantation System For Visual Prostheses:

In the retina, photoreceptors convert incoming light into electrical and chemical signals, which are then processed by other neurons and transmitted to ganglion cells. To create the sensation of vision, ganglion cells transmit spike signals from the retina to the brain. Retinitis Pigmentosa (RP) and age-related macular degeneration (AMD) are two disorders in which photoreceptors deteriorate and lose their ability to transmit visual information to other retinal cells in the retinal network. As a consequence, the sufferers' eyesight is impaired. Implanting retinal prosthetic devices to give effective electrical stimulation to the remaining retinal cells is a potential approach to restore vision for these individuals (FES).

Retinal prosthesis are divided into two categories based on the stimulation site: subretinal and epiretinal implants . Subretinal stimulation electrodes are placed under photoreceptors, whereas epiretinal stimulation electrodes are placed above ganglion cells. Photodiode-array chips have been suggested for subretinal implantation. Incident light transmits image and power, which is subsequently converted to stimulation current via photodiodes. There is no need for an external battery, direct cable, or radio-frequency connection since power and data are delivered through light. However, because of the low conversion efficiency of on-chip photodiodes, the stimulation current of subretinal prosthesis using photodiode arrays is inadequate.

A new Divisional Power Supply Scheme (DPSS) is suggested to address the aforementioned issue. Photodiode arrays are utilized to convert light into stimulation current in the implant chip using the novel method, and on-chip solar cells are employed to power the device and increase the stimulation current. The photodiode array is further split into N sections, each of which is powered alternately by all solar cells through a control circuit. Only one area is powered by all on-chip solar cells at a time in order to produce enough stimulation current. When compared to the technique of powering N locations at once, the stimulation current may be approximately N times higher. In the human visual system, an afterimage may last for around 40 milliseconds. The condition is known as vision persistence. The previous stimulus is retained and integrated with the next if the following stimulating interval is less than the duration of visual persistence. A full picture may be perceived if the N areas are stimulated individually throughout the period of visual persistence.

To minimize substrate leakage current, the 0.18-m twin-well CMOS technology with deep Nwell (DNW) structure is used to combine MOSFET devices and solar cells together. An experimental chip is being developed to test the suggested structure's idea and function.

A control-signal generator, a 4x4 photodiode array with four divisions, and solar cells make up the experimental chip. The manufactured device has an output stimulation current of 8.55 A under visible light intensity of 1.3 mW/cm2 with a signal frequency of 40 Hz, according to the measurement findings. Using an infrared light source may increase the output stimulation current. The output current of an IR source under 10 mW/cm2 may approach 60 A. For a 2000-pixel implant chip, the estimated number of solar cells is 5000 units, occupying approximately 0.5 mm2 of chip space.

1.3 Closed-Loop Deep Brain Stimulation (DBS) System For Epilepsy:

In addition to pharmacological and surgical therapies, other treatments and technologies have been suggested in recent years to study and treat epilepsy. Several prosthetic devices that use deep brain stimulation (DBS) or vagus nerve stimulation (VNS) are gaining popularity in clinical settings. These devices utilize open-loop continuous brain stimulations in conjunction with a restricted efficacy rate of approximately 45 percent to treat medically resistant epilepsies. Furthermore, the device lifespan is typically restricted by the use of continuous stimulations and an implanted battery, necessitating recurrent surgeries for customers to replace the battery/devices.

A close-loop epilepsy prosthetic device with temporospatial seizure detection and responsive therapeutic stimulation is suggested to address the aforementioned constraints:three-dimensional micro-machining electrodes and a system chip with analog front-end, bio-signal processing unit, RF telemetry, and RF power transmission/regulation circuitries. The suggested 3D microelectrode arrays are utilized for recording and targeted stimulation of cortical nerves at various levels. The use of RF power transfer eliminates the need for a high-capacity battery, extending the lifespan of the proposed implanted devices even more. Low-power analog front-end and bio-signal processing circuitries are used to detect the seizure signal before it spreads across the brain and trigger targeted cortical stimulation on the electrodes to suppress epilepsy.

The suggested System-on-Chip (SoC) for the closed-loop DBS system is made up of four components: a neural-signal acquisition unit, a bio-signal processor, a radiofrequency transceiver, and a wireless power transmission unit. The electrocorticogram (ECoG) signals of the patient are detected and digitized in the acquisition unit. Multichannel low-noise analog frontend (AFE) and analog-to-digital converters are included in the device (ADC). AFE includes amplifiers with adjustable strength from 100 to 5000 V/V, as well as band-pass filters with 1 Hz and 10 kHz cut-off frequencies, respectively. In the ADC design, a successive approximation (SAR) architecture is used. The SAR ADC has a 10-bit resolution and a sampling rate of 500 kS/s.

The bio-signal processor receives the ECoG data and uses a real-time algorithm to identify seizures. It regulates the firing of the seizure-inhibiting on-chip stimulator. The RF transmitter transmits the collected neural signals for monitoring and receives the instruction for parameter setting from the external remote controller. The telemetric spectrum for the transceiver is chosen from the Medical Device Radiocommunication Service (MedRadio) band, which ranges from 401 MHz to 406 MHz and has been authorized by the FCC. The transceiver uses on-off-keying (OOK) modulation and has a maximum data rate of 4 MHz. The 13.56 MHz (ISM band) wireless power transmission device is intended to extend the battery life. The integrated rectifier converts AC power to DC, which is then controlled by the LDO regulator to keep the supply voltage stable for the remainder of the chip's circuitry.

2. LITERATURE REVIEW

M. Köstinger *et al.* discussed Advancements of Medical Electronics in which the discriminating Haar features (DHFs) and a novel efficient support vector machine are used in the article to provide an accurate and efficient eye recognition technique (eSVM). The DHFs are retrieved from the 2D Haar wavelet transform using a differentiating feature extraction (DFE) technique. Based on two unique measure vectors and a new criteria in the whitened principal component analysis (PCA) space, the DFE technique may extract numerous discriminating features for two-class issues. The eSVM outperforms the traditional SVM for eye detection in terms of computing economy without compromising generalization performance. Experiments on the Face Recognition Grand Challenge (FRGC) database and the BioID face database show that DHFs have promising classification capability for the eye detection problem; the eSVM runs much better than the normal SVM; and the suggested eye detection approach obtained near real-time eye detection greater improvement eye detection efficiency than some state-of-the-art eSVM methods[10].

Elsevier discussed Medical Electronics Applications in which he explained how Medical electronics, or more particularly, physiological measuring equipment, has evolved considerably in recent years. Electronics advancements have opened up new and improved applications, particularly in the fields of data capture and analysis, as well as image technology.

These improvements have been followed by stricter safety and liability laws. This book is designed to address the requirements of students on an increasing number of undergraduate and master's level courses. It is a short and easy-to-understand introduction that provides a comprehensive overview of the different relevant disciplines.

Khanna V discussed Implantable Medical Electronics in which the paper is divided into two sections on Basic Concepts and Principles and Applications, offers an all-encompassing view of the electronics background required for this task. The heart, brain, spinal cord, and the network of nerves that connect the brain and spinal cord to the main organs, including ear and eye prosthesis, are all addressed in the second part.

3. DISCUSSION

Medical gadgets and medical electronics were somewhat undeveloped 100 years ago. However, there were three key existing technologies that paved the way for many more advancements over the next 100 years. The stethoscope, electrocardiography, and X-ray medical imaging are examples of these tools. Although these technologies had been described and were accessible to some degree when the IEEE Proceedings pages first appeared, they had not yet reached the level of broad use that they have today. The stethoscope is the earliest of them, and it assisted doctors in hearing bodily noises and relating them to healthy and unhealthy organs. Physicians' use of the stethoscope was more of an art than a science in the beginning, but as the Proceedings progressed, so did this technology. Engineers were able to make this a more quantitative process by presenting the sounds visually and eventually utilizing methods like voiceprint analysis to aid the physician in diagnosis and therapy monitoring.

The electrocardiograph had been developed a few years before the publication of the Proceedings, but it was difficult to use, particularly for ill patients, and was seen as more of an oddity than a practical medical device at the time. It is now an essential component of our healthcare system, as are gadgets developed from it, such as cardiac patient monitors. X-rays were also a new technique 100 years ago, but unlike electrocardiography, doctors recognized the usefulness of this technology right away and rapidly embraced it. Over the past 100 years, many advancements in fundamental technology have culminated in computer tomography and sophisticated image processing. Other technologies for creating high-quality and 3-D medical pictures have been developed over the years, making medical imaging a critical component of clinical treatment today. Looking into the future is often challenging, but it is obvious that the ehr system will play a significant role in consolidating data from different medical devices and making patient data easily accessible wherever it is required. Future medical devices will need to be capable of solving not just diagnostic and therapeutic medicine problems, but also social issues such as global inequalities in medical care availability, continuously increasing healthcare prices, and healthcare for space travel.

4. CONCLUSION

As a result of the current demand for medical electronics, a significant shift in technology is taking place. By using electronics engineering in the area of medical electronics, advancements in medical electronics are offering hand-to-hand medical services. Sensor technologies are coming to medical engineering. Wireless brain sensors, 3-D printing, health wearables, artificial organs, precision medicine, telehealth, robotic surgery, and other innovations resulting from the progress of electronics devices are all beneficial to medical advancement. Medical electronics will offer virtual technologies for diagnosis and therapy in the future years.

Two implanted medical electronic systems are presented in this article. A Divisional Power Supply Scheme (DPSS) is suggested for the implanted subretinal chip in the subretinal implantation system for visual prosthesis. The proper function was successfully confirmed by the experimental chip. The suggested architecture and system have been proven to be promising for future high resolution subretinal prosthesis in both experimental and calculation findings. More study will be done to determine the best design for both the stimulation chip and the subretinal implant system in terms of animal testing and clinical trials.

A successful in vivo trial on animals utilizing a prototype multi-chip module system has been shown in the close-loop DBS system for epilepsy. The prototype system will be implemented utilizing the proposed SoC chip. The prototype equipment will be used to perform animal experiments in the future. The suggested SoC-based close-loop epilepsy prosthetic system is smaller, uses less power, and has a longer battery life. It will be a highly promising therapeutic option and platform for epilepsy seizures and other neurological diseases.

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