PREMIER UNIVERSITY CHATTOGRAM

DEPARTMENT OF **COMPUTER SCIENCE AND ENGINEERING**

ASSIGNMENT

COURSE NAME	Biology for Engineers
COURSE CODE	BIO 2101
ASSIGNMENT TOPIC	**1. Positron Emission Tomography and Cochlear Implants: Key Concepts and Applications.** **2· Instrumentation Amplifier Design for EMG Monitoring.**
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SUBMITTED TO	
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	SECTION	A

Ans to the question No 1(a)

Positron Emission Tomography (PET)

Positron Emission Tomography (PET) is a non-invasive imaging technique that provides detailed images of processes within the body. It is widely used in medical diagnostics to observe metabolic processes and identify abnormalities at a cellular level.

Working Principle:

PET involves the injection of a radio-tracer, which is a small amount of a radioactive substance that emits positrons. When these positrons encounter electrons in the body, they annihilate each other, producing gamma rays. These gamma rays are detected by the PET scanner, which then constructs detailed images based on the radiation detected. The tracer's distribution and concentration reveal metabolic activity and function.

Schematic Diagram:

In Positron Emission Tomography (PET) imaging, the process involves several key components and steps that are represented in the schematic diagram. Here's a clear description of the PET imaging process as illustrated in the diagram:

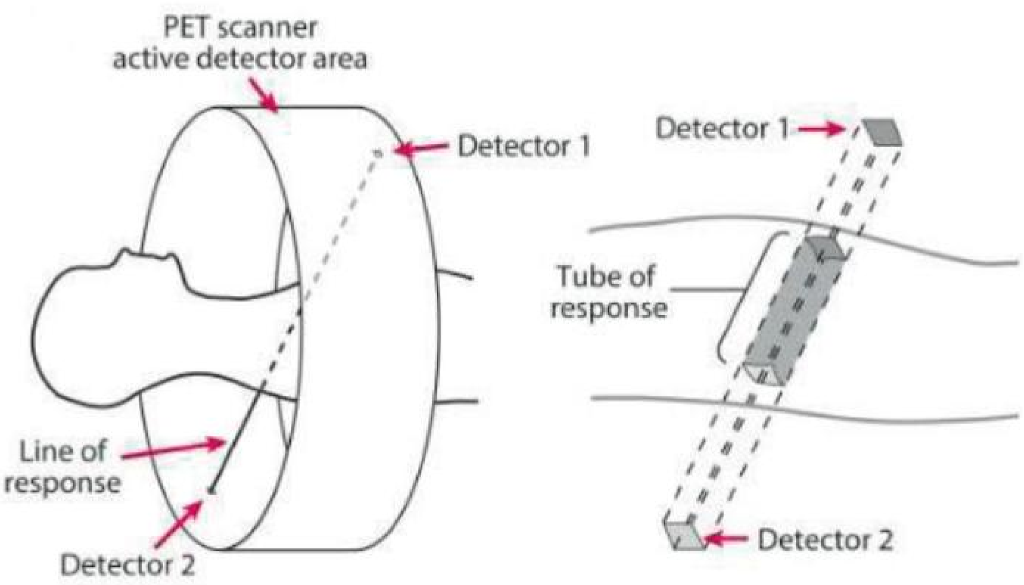


Diagram Reference:(https://www.researchgate.net/publication/331962868_Mathematical_Modelling_Numerical_and_Data_Analysis_BIOCHEMISTRY_AND_TECHNOLOGY_OF_18_FFLUTEMETAMOL_FOR_THE_AMYLOID_PET_IMAGING_IN_ALZHEIMER'S_DISEASE)

Patient and Gantry: The patient is placed inside the PET scanner's gantry, which is surrounded by a ring of detectors.

Detection of Annihilation Photons: When positrons from the radio-tracer annihilate with electrons, they produce two gamma photons traveling in opposite directions.

Coincidence Detection: The detectors pick up these photons within a few nanoseconds of each other, defining a line of response (LOR) where the annihilation occurred.

Tube of Response: Due to the finite size of the detectors, the LOR is represented as a tube encompassing possible annihilation locations.

Advantages:

High Sensitivity: PET imaging is highly sensitive, meaning it can detect even small changes in metabolic processes within the body. This sensitivity is crucial for identifying subtle physiological changes that may not be visible with other imaging techniques. By detecting low levels of radio-tracer uptake, PET can identify abnormalities at a very early stage.

Functional Imaging: Unlike traditional imaging methods that primarily provide anatomical information, PET allows for the visualization of metabolic processes and physiological functions. This means PET can show how tissues and organs are functioning in real time, providing a deeper understanding of the body's biochemical processes. For example, it can reveal how different parts of the brain are active during specific tasks or how tumors are metabolically active.

Early Detection: PET is particularly valuable for the early detection of diseases. It can identify abnormalities before they become clinically apparent, which is essential for conditions like cancer, neurological disorders, and cardiac diseases. Early detection enables timely intervention and treatment, which can significantly improve patient outcomes. For instance, PET scans can detect cancerous tumors at an earlier stage than other imaging methods, allowing for more effective treatment options.

Limitations:

Radiation Exposure: PET imaging involves the use of radioactive tracers, which results in exposure to radiation. Although the radiation levels are generally low and considered safe, repeated or high-dose scans can pose risks. Careful consideration and adherence to safety guidelines are necessary to minimize potential health impacts from radiation exposure.

Cost: PET scans are more expensive compared to other imaging techniques such as X-rays or ultrasound. The high cost is attributed to the specialized equipment required, the production of radio-tracers, and the complexity of the scanning process. This can limit accessibility for some patients and healthcare settings.

Resolution: PET imaging has limited spatial resolution compared to other imaging modalities like MRI (Magnetic Resonance Imaging) or CT (Computed Tomography). While PET provides excellent functional and metabolic information, its ability to precisely localize small structures or fine anatomical details is not as high as that offered by MRI or CT. This limitation can sometimes make it challenging to pinpoint exact locations of abnormalities or small lesions.

Ans to the question No 1(b)

Cochlear Implants

A cochlear implant is a medical device designed to provide a sense of sound to individuals with severe to profound sensorineural hearing loss. It works by bypassing damaged parts of the ear and directly stimulating the auditory nerve.

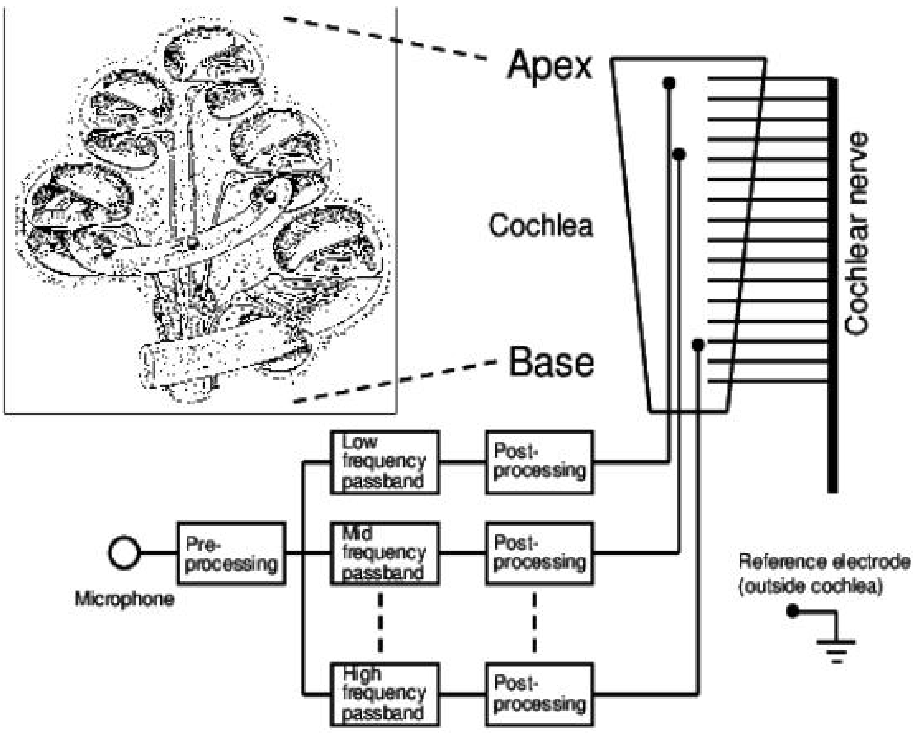
Working Principle:

The cochlear implant consists of an external component (microphone and processor) and an internal component (receiver and electrode array). The microphone picks up sound, which is then processed and converted into electrical signals. These signals are transmitted to the internal components, which stimulate the auditory nerve directly via the electrode array, enabling the recipient to perceive sound.

Schematic Diagram:

The schematic of a cochlear implant, which includes approximately twenty electrodes that stimulate groups of nerve fibers. Instead of using a single signal for all electrodes, the signal is processed through multiple pass band filters, each with a different frequency. The filtered outputs are then connected to individual electrodes to mimic the natural 'place-coding' of hair cells in the ear.

Diagram Reference:(https://www.researchgate.net/publication/241454469_Use_of_suprathreshold_stochastic_resonance_in_cochlear_implant_coding)



Electrodes: The implant typically includes around twenty electrodes. Each electrode stimulates a group of nerve fibers to produce auditory sensations.

Signal Processing: The incoming sound signal is first processed by a series of pass band filters, each tuned to different frequency ranges. This filtering separates the sound into various frequency components.

Channel Assignment: The output from each filter is then directed to a specific electrode. This process is intended to mimic the natural frequency tuning of hair cells in the cochlea, thereby simulating the ear's place-coding mechanism.

Information Transmission: The electrodes can either stimulate different populations of nerve fibers with distinct signals or multiple electrodes can be linked to the same filter channel, stimulating a larger nerve fiber population with a common signal.

Noise and Speech Comprehension: Internal noise within the implant can increase the diversity of responses from the electrodes, potentially enhancing speech comprehension by improving the trans-information. However, excessive noise can reduce the overall information transmitted.

Advantages:

Restores Hearing: Cochlear implants can effectively restore hearing for individuals with severe to profound hearing loss. By bypassing damaged or non-functional hair cells in the cochlea, these devices directly stimulate the auditory nerve, allowing users to perceive sound. This restoration significantly enhances the quality of life by enabling users to hear environmental sounds, music, and conversations, thus improving their overall auditory experience and interaction with the world.

Speech Understanding: Cochlear implants enhance the ability to understand speech, which is crucial for effective communication. The device processes and converts sound signals into electrical impulses that the brain can interpret, allowing users to recognize and distinguish speech sounds more clearly. This improvement in speech comprehension facilitates better social interactions, educational performance, and occupational opportunities, helping users to engage more fully in daily activities.

Adjustable: Cochlear implants are programmable and can be customized to meet the specific hearing needs of each individual. Audiologists can adjust the device settings, such as the frequency and intensity of sound stimulation, to optimize auditory performance based on the user's hearing abilities and preferences. This adaptability ensures that the cochlear implant can be fine-tuned to provide the best possible hearing experience and accommodate changes in hearing over time.

Limitations:

Surgical Procedure: Implanting a cochlear device requires a surgical procedure, which carries inherent risks and potential complications. The surgery involves placing the internal components of the implant into the cochlea and can be associated with risks such as infection, bleeding, or damage to surrounding structures. Additionally, there may be a recovery period during which the patient needs to follow post-operative care instructions and adjust to the device.

Learning Curve: Users of cochlear implants often experience a learning curve as they adapt to interpreting the sounds produced by the device. The auditory signals generated by the implant may sound different from natural hearing, and users may need time to relearn how to process and understand these new auditory inputs. This adjustment period can vary in length and may require auditory training and support from hearing specialists.

Cost: Cochlear implants and their associated procedures are expensive. The high cost includes not only the device itself but also the surgical implantation, post-operative care, and ongoing programming and maintenance. This significant financial investment can be a barrier for some individuals, especially in regions with limited healthcare coverage or resources.

Ans to the question No 2

Introduction to Electromyography (EMG)

Electromyography (EMG) is a technique used to measure the electrical activity produced by muscles during contraction and at rest. It is commonly used in clinical and research settings to assess muscle function, diagnose neuromuscular disorders, and study motor control. EMG signals provide valuable insights into muscle activity and are often utilized in applications such as rehabilitation, prosthetics control, and biofeedback systems.

Here, we focus on the design of an instrumentation amplifier circuit for measuring EMG signals, ensuring the accuracy and amplification required for effective signal processing.

Journal Reference for the circuit :

A Topical Review on Enabling Technologies for Internet of

Medical Things: Sensors, Devices, Platforms and Applications.

August 2023

DOI:10.20944/preprints202309.0189.v1

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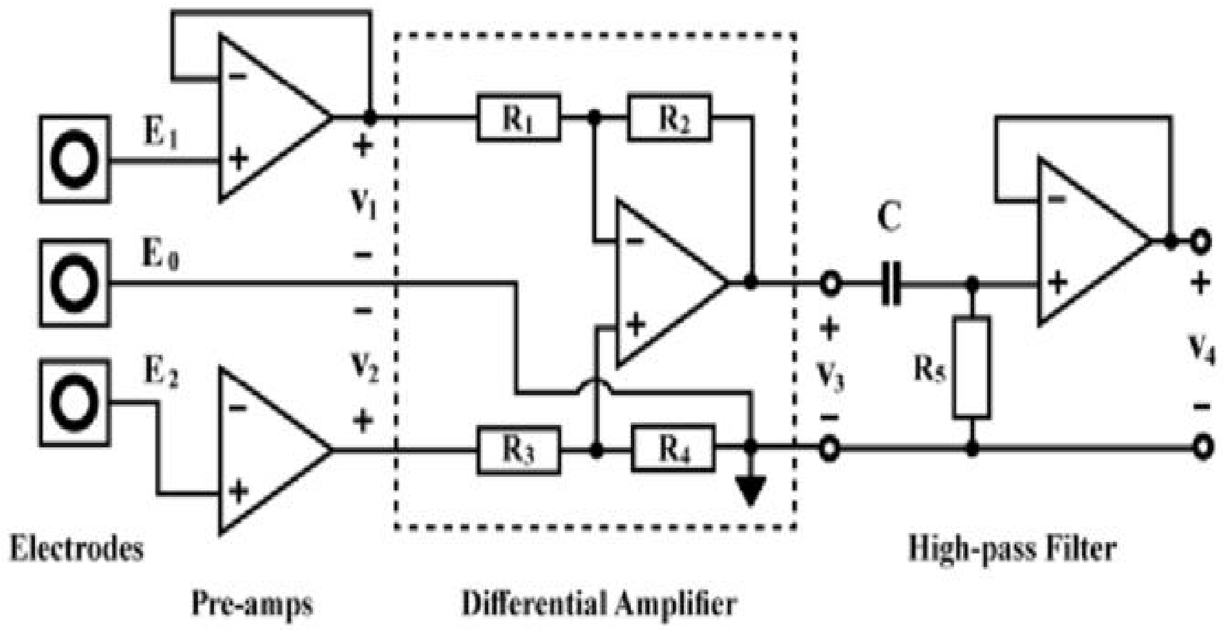
(https://www.researchgate.net/publication/373691501_A_Topical_Review_on_Enabling_Technologies_for_Internet_of_Medical_Things_Sensors_Devices_Platforms_and_Applications)

Circuit Diagram:

The electrical activity detected by the electrodes is first amplified by the preamps. The amplified signals are then processed by the differential amplifier to highlight the difference between the electrode measurements. The high-pass filter removes any unwanted DC components from the signal, leaving only the relevant muscle activity data. Finally, the filtered signal is displayed on an oscilloscope for further analysis.



Circuit Components:

Power Supplies:

Two 9V batteries are connected to the circuit to power the sensor. These dual power supplies provide both positive and negative voltages, essential for amplifying small EMG signals, ensuring that the operational amplifiers (op-amps) can handle both the positive and negative signal swings from muscle activity. The dual supply allows for more precise signal amplification.

Electrodes:

Three electrodes are used in this circuit for signal collection:

+ Two measurement electrodes (typically made of silver-silver chloride) are placed on the muscle, about three inches apart, one at the top of the biceps and the other near the lower end. These electrodes detect the electrical potential difference generated by muscle contraction.

+ One reference electrode is placed near the elbow, providing a stable baseline signal to help filter out external noise and interference.

+ These electrodes measure the voltage differences between the muscle tissue (E1 and E2), which will then be processed by the circuit.

Preamplifiers:

+ The signals picked up by the electrodes are generally very weak, often in the micro volt range. A preamplifier is used to boost these weak signals to a level where they can be further processed.

+ The preamp is typically designed with a high input impedance to prevent loading effects on the electrodes and to ensure accurate signal capture. It amplifies the signals E1 and E2 for further processing.

Differential Amplifier:

+ The heart of the EMG circuit is the differential amplifier. This amplifier takes the two input signals from the electrodes (E1 and E2) and amplifies the difference between them while canceling out any common-mode noise (such as electrical interference from power lines or body movement artifacts).

+ This common-mode rejection ensures that the circuit focuses on the electrical signals directly related to muscle contractions, improving the signal quality for EMG analysis.

Capacitor (High-Pass Filter):

+ A capacitor is placed between the differential amplifier and the oscilloscope. This capacitor acts as a high-pass filter, allowing only the high-frequency components of the EMG signal (related to muscle contraction) to pass through while blocking any low-frequency DC components.

+ The DC voltage is often caused by static charge buildup or electrode-skin interaction, and it can distort the actual muscle activity signals. The high-pass filter ensures that the circuit only measures the dynamic, AC component of the muscle activity.

Fourth Operational Amplifier (Op-Amp):

+ The fourth op-amp in the circuit further processes the signal by improving signal gain and applying final filtering. This stage ensures that the output signal is clean and ready for visual observation.

Oscilloscope:

+ The processed EMG signal is fed to an oscilloscope, where it is displayed for real-time monitoring and analysis. The oscilloscope allows clinicians or researchers to observe the muscle activity in the form of electrical waveform, which can be analyzed for diagnostic or research purposes.

Working Principle:

Here's how the entire circuit works in sequence:

When the muscle contracts, small electrical signals (in the micro volt range) are generated and picked up by the two measurement electrodes (E1 and E2) attached to the muscle surface.

These signals are fed into the preamplifiers, where they are amplified for easier processing.

The differential amplifier then amplifies the difference between E1 and E2 while canceling out noise and interference common to both electrodes (e.g., environmental electrical noise).

The capacitor, acting as a high-pass filter, removes any DC offset and allows only the AC signals representing muscle activity to pass through.

The filtered signal is then processed further by the final op-amp stage to ensure clarity.

The processed signal is displayed on the oscilloscope as a waveform, which can be analyzed to study muscle behavior and diagnose neuromuscular issues.

Conclusion:

To conclude, this EMG sensor circuit provides a powerful tool for monitoring muscle activity by amplifying and filtering small electrical signals from the muscles. The differential amplifier, combined with the high-pass filter and other components, ensures that the circuit captures accurate muscle signals while minimizing noise and interference. This system is widely used in medical diagnostics, prosthetics control, and anesthesiology research.