ANESTHESIA MONITORING DEVICE DEVELOPMENT

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DECLARATION

We hereby declare that this thesis is based on our explorations and investigations and the results found by ourselves. Materials of work found by other researcher are mentioned by reference. This thesis, neither in whole nor in part, has been previously submitted for any degree.

Signature of Supervisor

Signature of Authors

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Anesthesia Monitoring Device Development

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SECS, BRAC University, 2009

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This thesis explores the problems of anesthesia during any surgical operation for the patients. There are few aspects of this work: determine the specified problems for proper anesthesia and necessity to monitor the depth of anesthesia level. Study of the existing methods of monitoring the anesthesia level further provides the opportunity to design an efficient and compatible anesthesia monitoring device. Work with electroencephalogram (EEG) which is the most important method for anesthesia level detection. Aspects presented here widen future implementation and tests of the proposed models.

Table of Content

Declaration ………………………………………………………… i

Acknowledgement ………………………………………………………… ii

Abstract ………………………………………………………… iii

List of Figures ………………………………………………………… vi

List of Tables ……………………………………………………….. vii

List of Abbreviations……... ………………………………………………… viii

1. **Introduction** ………………………………………………………… 1

2. **Literature Review** ………………………………………………… 5

2.1 Anesthesia Stages ………………………………………………… 5

2.2 Qualitative Methods ………………………………………………… 6

2.2.1 Unspecified Dose of Drugs…... …………………………………… 7

2.2.2 Other Qualitative Methods ……………………………………………… 7

2.3 The Innovations to Determine The Depth of Anesthesia ……………… 8

3. **Proposed Anesthesia Level Monitoring Device** ……………………… 12

3.1 Need of an Efficient Device ………………………………………………. 12

3.2 Proposed Device ………………………………………………………… 13

4. **EEG Analysis** ……………………………………………………… …… 15

4.1 EEG Circuit ……………………………………………………….. 15

4.1.1 Front End ………………………………………………………… 16

4.1.2 Electrical Isolation ……………………………………………………. 17

4.1.3 Filter & Switch able Gain Amplifier & Level Shifter & Others ……... 17

4.2 Procedure to Take EEG Data ………………………………………….. 17

4.2.1 Electrode & Placement ………………………………………………. 18

4.3 EEG Data Analysis …………………………………………………… 20

4.3.1 Primary Data …………………………………………………………. 20

4.3.2. Work with Sigview …………………………………………………… 22

4.3.3 Problem with Primary Collected Data ……………………………… 24

4.3.4 Final EEG Data ………………………………………………………. 24

4.4 Result with t-Test ……………………………………………………… 29

5. **Conclusion** ………………………………………………………………. 34

References ……………………………………………………………… 35

List of Figures

Figure 2.1: EEG level during anesthesia ………………………………………… 10

Figure 3.1: Block diagram of the proposed device ……………………………… 14

Figure 4.1: EEG circuit ……………………………………………………………. 16

Figure 4.2: Instrumentation Amplifier …………………………………………… 16

Figure 4.3: Basic circuit connection of the front end AD524 ………………… 17

Figure 4.4: Electrode placement ………………………………………………… 20

Figure 4.5: $V_{cm\ Voltage}$ level ………………………………………………………. 21

Figure 4.6: Subject1 original EEG signal ………………………………………. 23

Figure 4.7: Filtered signal ....……………………… 24

Figure 4.8: FFT signal …………………………………………………………… 24

List of Tables

Table 2.1: Comparison of EEG bands ………………………………………………… 09

Table 4.1: Sleep data of subject1 ……………………………………………………. 22

Table 4.2: Awake data of subject1 ………………………………………………….. 22

Table 4.3: Sleep data for subject2 ………………………………………………….. 25

Table 4.4: LF & HF ratio for sleep ………………………………………………….. 26

Table 4.5: Awake data for subject2 ………………………………………………… 27

Table 4.6: LF & HF ratio for subject2 ……………………………………………… 29

Table 4.7: t-Test for sleep data for subject2 ……………………………………… 31

Table 4.8: t-Test for awake data for subject2 …………………………………… 32

Table 4.9: t-Test for ratio data ……………………………………………………… 33

Abbreviations

EEG – Electroencephalogram

BIS – BI-spectral Index

AEP – Auditory Evoked Potential

HRV – Heart Rate Variability

SP – Skin Potential

CMRR – Common Mode Rejection Ratio

Chapter one

Introduction

Anesthesia is an indispensable part of surgery. In the course of operation, either over or under-dosage of anesthetics will cause adverse effects on the patient. Conventionally, an anesthesiologist monitors depth of anesthesia in a patient based on observations on the underlying change of physiological symptoms such as breathing rates, blood pressure, heart beat, eye signs and the like as well as the patient's physical response to stimulation caused by the surgical procedure.

From the standpoint of the patient, the judgment whether the depth of anesthesia is sufficient or not is very important. When the depth of anesthesia is insufficient, the patient feels the full pain in the incision region, i.e., the patient is conscious. On the other hand because of simultaneous injection of drugs that paralyse the muscles of the whole body, the patient cannot talk or move to make signs to the doctor or the nurse that the anesthesia is insufficient and that he or she is feeling the pain. The intense pain brings severe trauma to the patient. Besides, the patient hears what the doctors and people around are talking about, and if it is a negative point on the patient's condition one can understand the metal trauma to the patient.

Although such occurrences are very few, almost one case in a thousand, but for the individual patients this is an experience no one would like to go through. In recent years survey shows that after such a undesirable situation in a surgical operation sometimes the patients forget the experience due to amnesia, but many patients suffer a mental disorder which is called post operative stress disorder. Throughout the rest of the life this experience haunts them over and over again as a horrifying nightmare.

This undesirable situation occurs due to two major factors:

1. All patients are anesthetized to the same degree.
2. No measuring devices are available to monitor whether the patients are anesthetized properly or not.

Therefore, a full proof monitoring system for the depth of anesthesia in a patient is a necessity, and it does not exist at present. Some efforts have been going on at different laboratories of the world but each is trying to address the situation using a single monitoring method or procedure. Anesthesia may be monitored with different methods like Electroencephalogram (EEG), Bi-spectral index (BIS) obtained from EEG; Auditory evoked potential (AEP), Heart rate variability (HRV) and Skin potential.

In the present work we proposed that a device giving a weighted combination of a few or all of the above procedures on a patient will possibly give a better and reliable monitoring of anesthesia. This will hopefully ensure the safety of the surgical operation as well as the risk to the patient.

This thesis is concerned with the development of an anesthesia monitoring device to detect the level of anesthesia reliably. In order to do this within the very limited timeframe available we performed the following:

1. We gathered relevant information from books, journals and internet.
2. We gathered information from anesthesia experts directly and observed real life surgical procedures. We observed the anesthesia procedures followed for different kinds of surgical operation at the BSMMU hospital, Dhaka.
3. We drew out a detailed plan for incorporating most of the above mentioned monitoring schemes in our proposed anesthesia level monitoring device. Each procedure will have an appropriate weight in the combination which will need to be ascertained through real life trial and errors, with the help of anesthesia experts.
4. Such a development procedure needs continuous work by a group over many years. Because of the very limited time available to us we tried to understand the development of a EEG hardware by studying a computerized Electrophysiology equipment developed by the project supervisor locally, with help from British scientists, earlier.
5. The project supervisor adapted the above equipment for EEG study through modifying the hardware and the software, which was used to obtain some real life data from volunteers for our present study.
6. From the information obtained we knew that when a person is asleep the EEG pattern has a dominance of frequencies around 8 to 12 Hz, which are also called α-waves. When a person is awake, β-waves between 12 and 15 Hz dominate. We expected that EEG from an anesthetized person would have a similarity to that from a person sleeping. Therefore for our preliminary work we wanted to see whether we can develop an index to

distinguish the sleep and awake conditions of a human subject. For this study we collected EEG data from a few volunteers repeatedly (20 for each condition) using the above equipment when they were awake and when they were asked to sleep.

7. The above EEG data was analyzed using a mathematical software package (Sigview) to obtain the Fast Fourier Transform (FFT) of the signals which gave their amplitudes in the frequency domain. Then components between 7 and 10 Hz and that between 12 and 15Hz were separated out and analyzed to get the mean, standard deviation, full range, etc. of their amplitudes within those two frequency windows. Simple ratios were obtained for all these parameters occurring within the two frequency windows. Finally statistical t-tests were performed between these parameters corresponding to the two situations (sleep and awake) to see if there was a significant difference between the findings.

This thesis is organized as follows: Chapter Two is a review on anesthesia and the existing methods are briefly described here. Chapter Three proposed anesthesia monitoring device. Chapter Four is concerned with EEG data analysis and Chapter Five concludes the thesis with future aspects.

Chapter Two

Literature Review

This chapter is written as a summery of the exploration done in the fields of determining the depth level of anesthesia and the existing methods with all the aspect.

Sections 2.1, 2.2, 2.3 below provide reviews on anesthesia and its procedure, the existing qualitative methods to observe the anesthesia process and the innovations to determine the depth of anesthesia level.

2.1 Anesthesia Stages

Anesthesia has traditionally meant the condition of having sensation (including the feeling of pain) blocked or temporarily taken away. This allows patients to undergo surgery and other procedures without the distress and pain they would otherwise experience. It is done with few steps –

1. Analgesia or Induction: Blocks the conscious sensation of pain.
2. Hypnosis or Sedative: producing unconsciousness.
3. Paralysis: preventing unwanted movement or muscle tone.
4. Muscle relaxation: Obstundation of reflexes, preventing exaggerated autonomic reflexes.

Recent medical case studies show that patients been prepared for surgery and other complicated operations by putting them into an anesthetized state sometimes can sense the pain due to surgery.

- Experiencing physical pain-1 of every1000 patients undergoing non-cardiac surgery, 3 of every 1000 cardiac patients.
- Australian researchers found that 56% of a group of 200 patients awaiting surgery had heard about awareness during operation.
- 42.5% of the group expressed anxiety about it.
- Post-traumatic stress disorder (PTSD) is a common result of awareness episodes.
- A 2001 study done at Boston University reported that 56.3% of a group of patients who had awakened during surgery met the diagnostic criteria for PTSD--as late as 17 years after their operation.

2.2 Qualitative Methods

Though anesthesia is a very important part during surgery but the way these patients are anesthetized is manually followed.

2.2.1 Unspecified Dose Of Drugs

More than 8-10 drugs are used for anesthesia. The drugs which are used for anesthesia are given to the patients by same degree with respect to their weight. Like – propofol is given 1-3 gm/kg. But it is not specified whether it is 1.5, 1.8 or 2.6 or 2.9. Rather than knowing the specified range doctors normally give the same dose for all the patients. But if a patient needs 1.5 gm/kg propofol and he is given 2.9 gm/kg then it turns into worse condition for the extra amount of drug for the patient during recovery stage from anesthesia. Sometimes patients fail to recover properly and go for coma. Normally doctors use their experience in search of specified range of drugs given for their patients. But it is definitely an important issue when patients need to be anesthetized using more than 8-10 drugs without knowing the specified drug range.

2.2.2 Other Qualitative Methods

To maintain the anesthetized condition doctors normally observe the patients whether they are sweating, tearing or not and also they check the heart rate very frequently using the patient monitoring device. If doctors get the patients started sweating or tearing then doctor comes to know that the patients need more anesthetics drugs and the patient is not yet anesthetized properly.

2.3 The Innovations to determine the depth of anesthesia

Very lately of this century but this proper anesthesia problems has grown its concern for all. And the necessity of determining the depth of anesthesia level has become prominent for this modern world. Few methods are innovated to determine the depth of anesthesia level but no methods are still properly used for various reasons. The explorations are as follows –

a) Electroencephalogram (EEG)

EEG is a complex recording of the electrical activity of the nerve cells in the brain. The EEG is typically described in terms of rhythmic activity and transients. The rhythmic activity is divided into bands by frequency.

Comparison table of EEG bands:

Comparison of EEG bands

Type	Frequency (Hz)	Location	Normally	Pathologically
Delta	up to 4	frontally in adults, posterior in children; high amplitude waves	• adults slow wave sleep • in babies	• sub cortical lesions • diffuse lesions • metabolic encephalopathy hydrocephalus • Deep midline lesions.
Theta	4 – 7 Hz		• young children • drowsiness or arousal in older children and adults • idling	• focal sub cortical lesions • metabolic encephalopathy • deep midline disorders • some instances of hydrocephalus
Alpha	8 – 12 Hz	Posterior regions of head, both sides, higher in amplitude on dominant side. Central sites (c3-c4) at rest.	• relaxed/reflecting • closing the eyes	• coma
Beta	12 – 30 Hz	both sides, symmetrical distribution, most evident frontally; low amplitude waves	• alert/working • active, busy or anxious thinking, active concentration	• benzodiazepines
Gamma	30 – 100 +		• certain cognitive or motor functions	

Table 2.1: Comparison of EEG bands

EEG level during anesthesia:

- Normal EEG level
- Deep anesthesia
- Light anesthesia

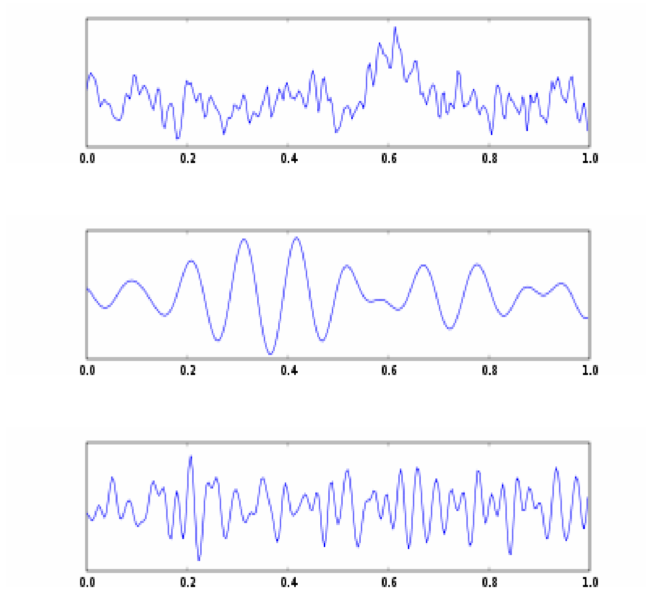

Fig 2.1: EEG level during anesthesia

EEG has several limitations. Most important is its poor spatial resolution. EEG is most sensitive to a particular set of post-synaptic potentials. But EEG has several strong sides as a tool of exploring brain activity.

b) Bi-spectral Index (BIS)

This method is very recent and very promising to overcome the improper anesthesia problem. It uses one channel EEG, analyses to get values at two specific frequencies. A proprietary (not disclosed) combination of these two values gives BIS. It is scaled from 100 to 0 so that the BIS value decreases linearly with increasing doses of anesthesia. But BIS values had little relationship to serum blood concentrations of anesthetic agents.

c) Auditory Evoked Potential

This method evoke potential from brain due to pulsed sound applied to an ear (extends to about 300ms). During anesthesia AEP is the very last to disappear and the first to reappear during recovery stage. It takes less than 30 seconds to get the signal from AEP (needs averaging over 100's of AEP's to eliminate noise) which is a very long time for instant control of drugs.

d) Heart Rate Variability (HRV)

Heart rate variability (HRV) is a measure of the beat-to-beat variations in heart rate. It is usually calculated by analyzing a time series of beat-to-beat intervals from the ECG with respect to anesthesia level.

e) Skin Potential

This method Measures potential difference between regions with higher perspiration to one with lower perspiration, typically in the hand. It differs in anesthesia and awareness.

Chapter Three

Proposed Anesthesia Level Monitoring Device

Though at present, to monitor and detect the depth of anesthesia, other than basing one's experience, an anesthesiologist also monitors and detects depth of anesthesia based on some of the most commonly used methods described in the previous chapters. But these methods are not sufficient itself to detect the anesthesia level. This chapter is concerned to propose a sufficient device to detect the depth of anesthesia level for any kind of surgical operation for a human body.

Sections 3.1, 3.2 below provide the idea for an efficient device to determine the depth of anesthesia level properly.

3.1 Need of a Efficient Device

Different methods are used to detect the anesthesia level. Where EEG is taken from brain electrical signal, AEP signal is taken from auditory signal or skin potential signals are taken from skin and ECG is taken from cardiac signals.

But the EEG signal based anesthesia monitoring device will not work properly if a patient has a neural surgery, again AEP will not work efficiently if a patient has an auditory surgery and this phenomena would also be same for ECG based anesthesia level monitoring device.

3.2 Proposed Device

We propose a device where five methods would be combined together. Five methods would be used to take signals from different part of the human body at a time. These five methods are EEG, BIS, AEP, HRV and SP. Where EEG and BIS signals would be available from brain electrical signals, AEP would be taken from auditory signals and other HRV and SP signals would be available from cardiac and skin signals respectively.

Measurement of:

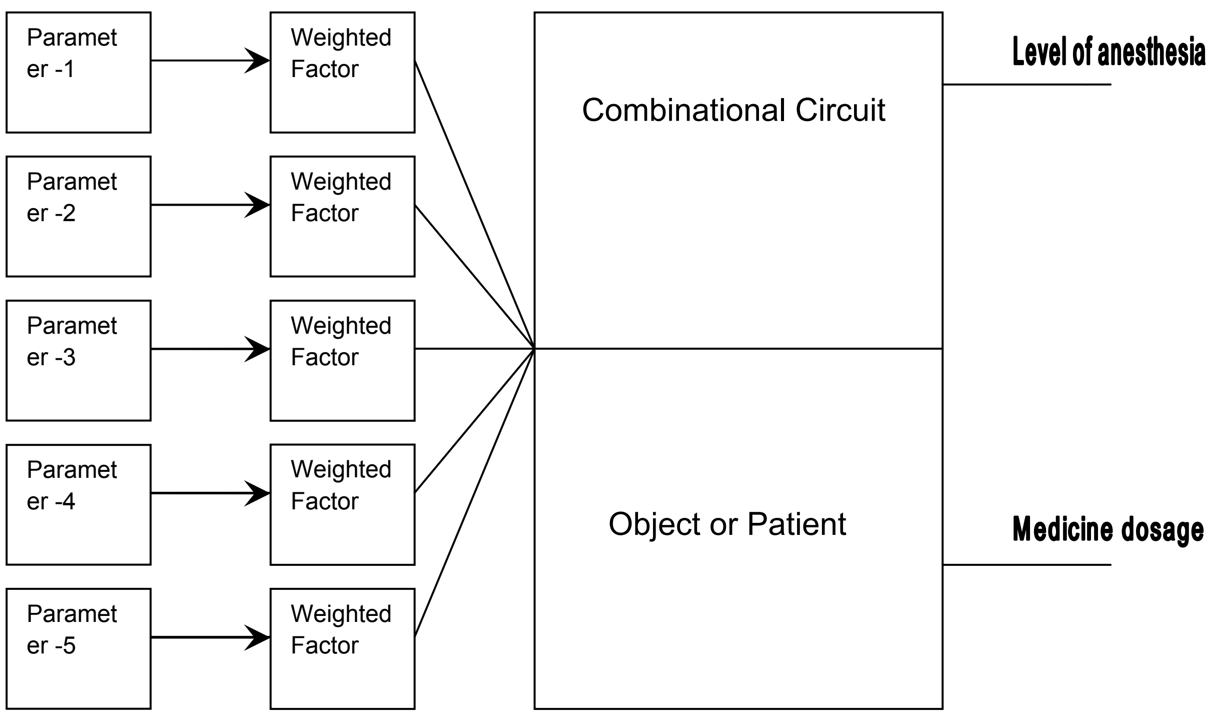

Fig 3.1: Block diagram of the proposed device

The signals taken from different part of the body are needed to multiply with some weighted factor. The combinational circuit would be designed such a way that the signals will be processed at a time and an average output will give the level of anesthesia.

The theory underlying BIS has not been publicly disclosed yet. As the BIS can determine the specific dosage of medicine for each patient particularly so a device combining with BIS technique must enhance and fulfill the commitment of anesthesia level monitoring perfectly.

Chapter Four

EEG Analysis

This chapter is concerned with our present work with EEG signals and understanding the EEG circuit design and fabrication, analyzing the data taken from EEG.

Section 4.1 below provides the information of EEG circuit, section 4.2 describes the EEG data analysis.

4.1 EEG Circuit

EEG circuit consists of the elements figured below-

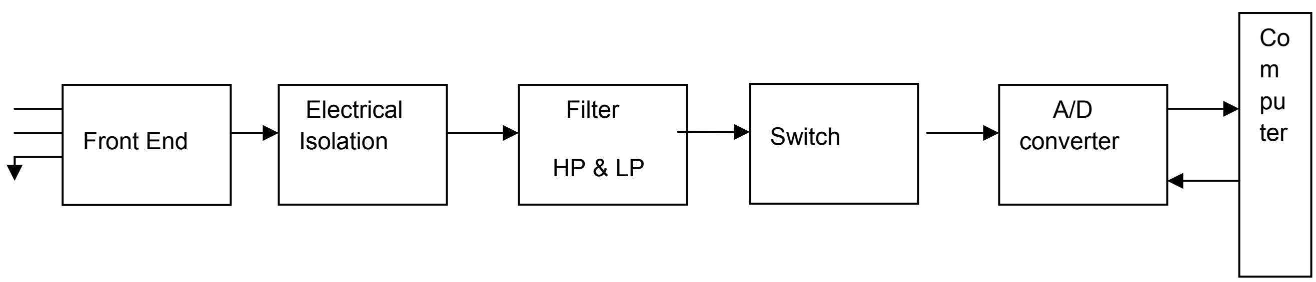

Fig 4.1: EEG circuit

4.1.1 Front End

Here front end consist of preamplifier which is a differential amplifier with high gain and high CMRR (common mode rejection ratio).

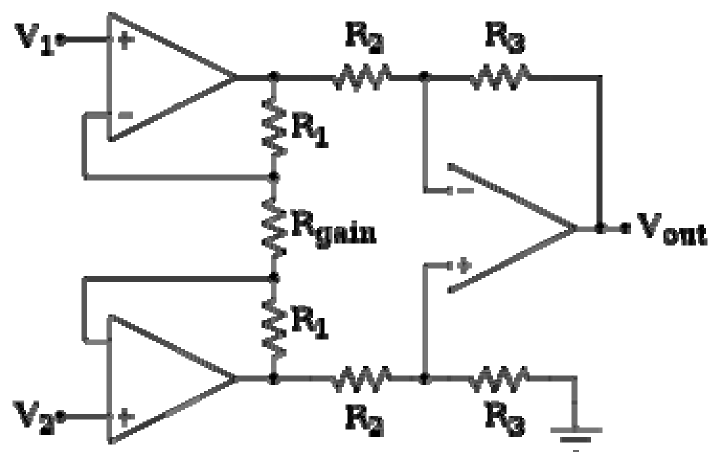

Fig 4.2: Instrumentation Amplifier

Basic circuit connection of the front end AD524 has high gain level. We have used the gain level up to 1000 and this circuit gain level value was up to 250,000. Here power supply was isolated patient safety and to get noise free signals. To get isolated power supply either battery or any special isolated power supply can be used here.

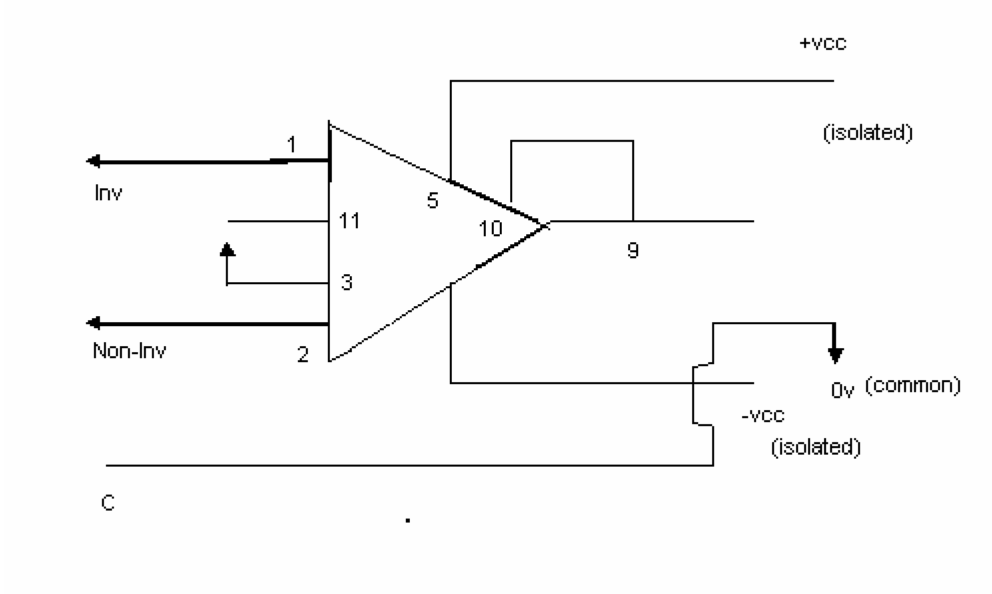

Fig 4.3: Basic circuit connection of the front end AD524

4.1.2 Electrical Isolation

Electrical isolation uses optocoupler to reduce noise from mains. And it is important for patient's safety as it isolates from mains. Optocoupler is a device that uses a short optical transmission path to transfer an electronic signal between elements of a circuit typically a transmitter and a receiver, while keeping them electrically isolated—since the electrical signal is converted to a light beam, transferred, then converted back to an electrical signal, there is no need for electrical connection between the source and destination circuits.

4.1.3 Filter & Switchable gain amplifier & level shifter & others

Here low pass filter and high pass filter has the frequency range of 0.2 Hz-100 Hz respectively. After getting the filtered signal switchable gain amplifier & level shifter is used to make the signal appropriate for the next stage of A/D converter. We have worked with 8 bit A/D converter and computer interface system was available there.

4.2 Procedure to take EEG data

We tried to develop this one channel EEG circuit described above. To get the EEG signals we have worked with this existing circuit in Trauma Center. To get the EEG signals certain steps have to follow properly to get a noise free, low resistive signal. The steps are as follows-

4.2.1 Electrode & Placement

An electrode is a conductor through which electric current is passed. Found in variable forms, electrodes may be wires, plates, or rods. An electrode may be constructed of metal, such as copper, silver, lead, or zinc. However, an electrode may also be made of a nonmetal substance, such as carbon.

In conventional scalp EEG, the recording is obtained by placing electrodes on the scalp area by light abrasion to reduce impedance due to dead skin cells. Here we have used the carbon rods.

Jelly is used for conductivity as used for ECG. As to maintain the contact resistance low, cleansing of skin is very important here which is maintained properly.

Here we have used three electrodes; each electrode is connected to one input of a differential amplifier; a common system reference electrode is connected to the other input of each differential amplifier. A common ground is put in the middle of the other two electrodes.

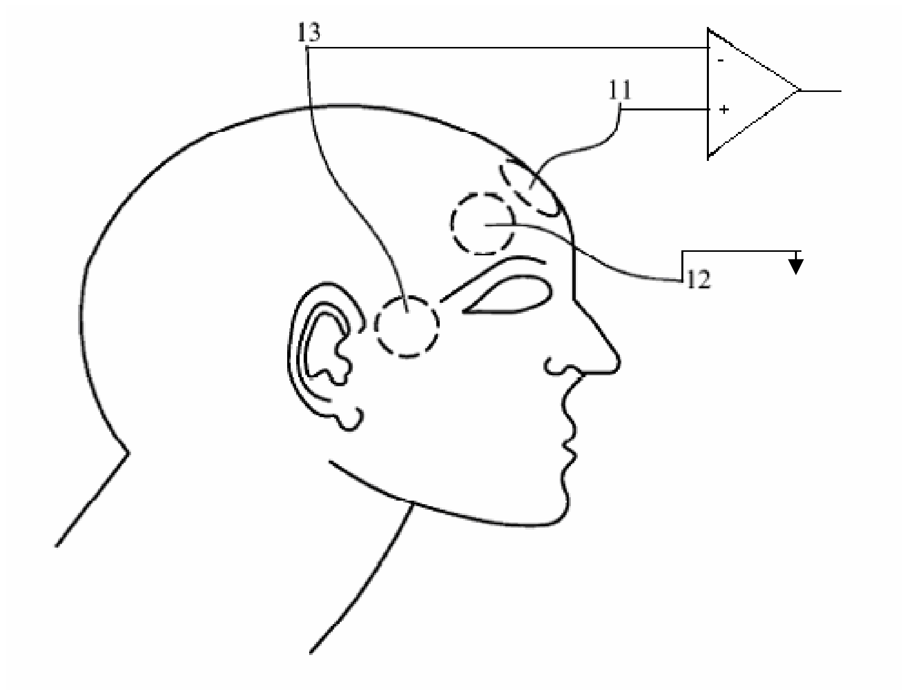

Fig 4.4: Electrode Placement

Ideally we should get the output level voltage,

$V_{out} = A_d (V_+ - V_-)$ Ideal

But practically we get an extra level of common mode gain and rejection voltage. This is as follows-

$V_{out} = A_d (V_+ - V_-) + A_{cm} V_{cm}$ Practical

A_{cm} is negligible and V_{cm} is chosen as common terminal.

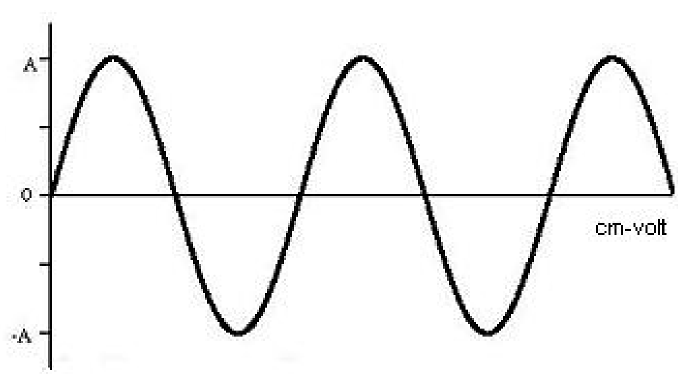

Fig 4.5: V_{cm} voltage level

V_+ and V_- remain symmetrically opposite, i.e. $V_{cm} = 0$.

So V_{cm} gives minimum $A_{cm}V_{cm}$ and cause for maximum CMRR.

4.3 EEG data Analysis

To get EEG data all the procedure described above is followed properly. We tried to first take the EEG signals from few subjects in different conditions like-in awake, in sleep etc. and tried to get a relationship using those data.

4.3.1 Primary Data

At the very beginning using this EEG circuit to take EEG signal in Trauma center our subject was Salam. And we observe various types of EEG signals in awake, in sleep and also when Salam moves his eyes and also during reading something.

Salam's data for two different conditions are as follows-

Sleep (Salam):

Data No.	LF Mean	HF Mean
1	0.135	0.093
2	0.122	0.143
3	0.15	0.114
4	0.185	0.185
5	0.091	0.093

Table 4.1: Sleep data of subject1

Awake (Salam):

Data No.	LF Mean	HF Mean
1	0.162	0.151
2	0.127	0.098
3	0.224	0.073
4	0.097	0.094
5	0.101	0.115

Table 4.2: awake data of subject1

Lately we tried to calculate the EEG signals in Sigview to get the alpha and beta value whether these values are distinguishable or not.

4.3.2 Work with Sigview

Sigview is a signal processing software and with the help of this we processed the EEG signals. Where 157 samples/sec was taken for every signal to analysis. FFT is done for the sampled signal, later on other calculations like mean, standard deviation, root mean square value and integral are calculated using this software of these EEG signals which helps to determine the desired results. The obtain graph from Sigview are as follows-

Subject1 Data:

The main EEG signal in Sigview taking 157 samples/sec:

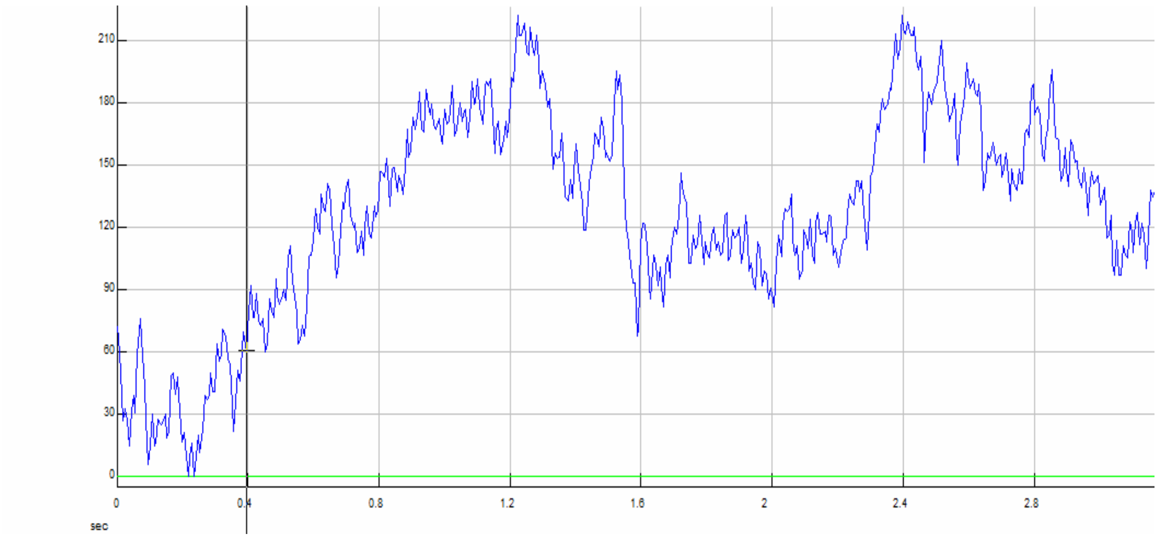

Figure 4.6: Subject1 original EEG signal

This signal is passed through a filter with frequency 7Hz-10Hz. And the required signal becomes-

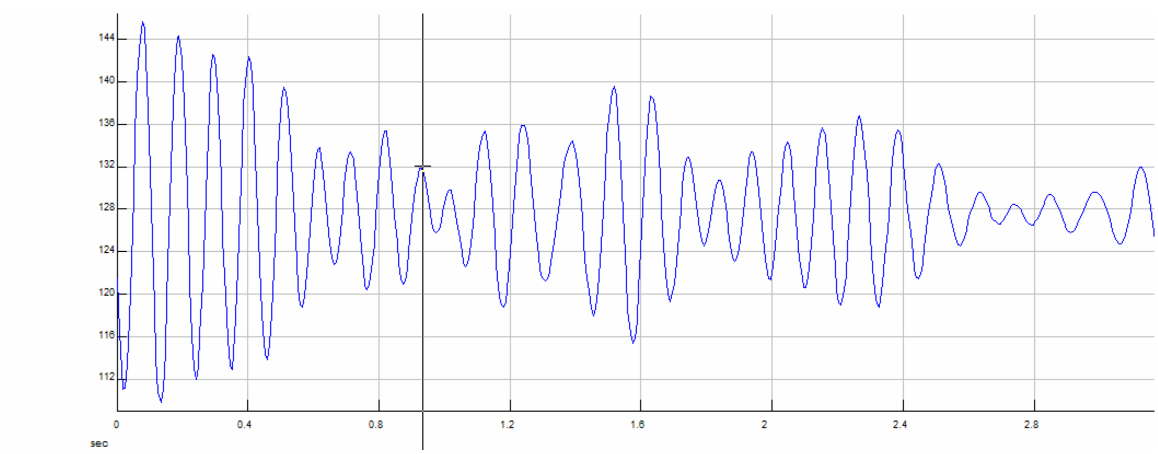

Figure 4.7: filtered signal

Next FFT is done with this sampled signal to get all other calculations.

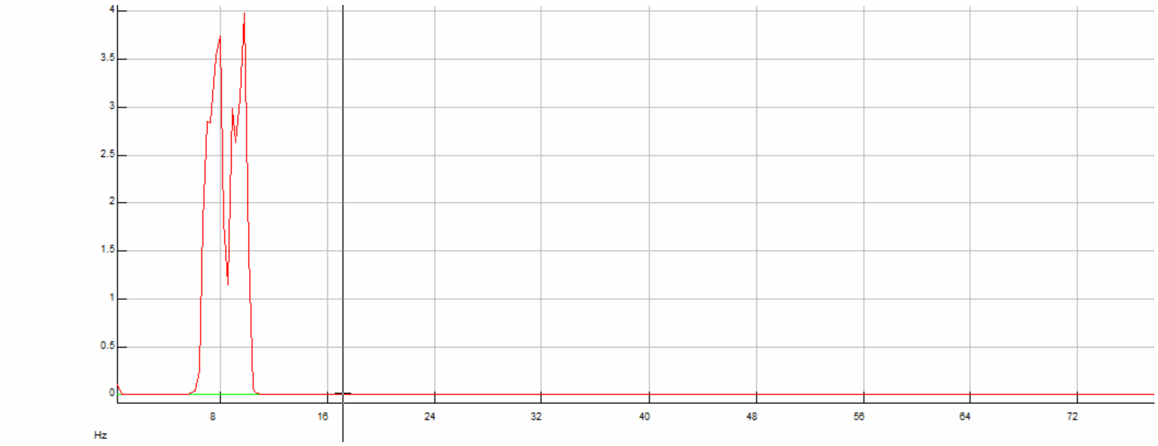

Figure 4.8: FFT signal

4.3.3 Problem with Primary collected data

With the EEG signals from the subject1 we couldn't get any significant difference between alpha and beta value. We couldn't get the desired value for sleep EEG data because that place was too much noisy and it seems that our subject1 couldn't sleep properly to make the significant change between the awake and sleep data. So we go for subject2 to collect another bunch of EEG data.

4.3.4 Final EEG data

The EEG data from subject2 is taken as the same procedure and analyzed and calculated the signals with Sigview.

The sleep data for subject2:

Data No.	LF Mean	LF Std.	LF RMS	LF Inte	HF Mean	HF Std.	HF RMS	HF Inte
1	0.174	0.978	0.994	13.645	0.066	0.332	0.339	5.178
2	0.306	1.578	1.607	24.004	0.212	1.063	1.084	16.612
3	0.122	0.614	0.627	9.585	0.091	0.456	0.465	7.169
4	0.303	1.492	1.522	23.76	0.198	0.964	0.984	15.5815
5	0.185	0.91	0.926	14.578	0.099	0.49	0.5	7.782
6	0.196	0.949	0.969	15.39	0.14	0.675	0.689	11.022
7	0.073	0.378	0.386	5.742	0.062	0.315	0.32	4.86
8	0.128	0.636	0.648	10.048	0.116	0.58	0.592	9.093
9	0.175	0.835	0.853	13.751	0.089	0.477	0.485	7.057
10	0.194	1.016	1.035	15.206	0.118	0.616	0.627	9.23
11	0.101	0.49	0.501	7.962	0.08	0.419	0.426	6.335
12	0.193	1.016	1.0351	15.206	0.117	0.616	0.627	9.23
13	0.131	0.651	0.664	10.293	0.108	0.557	0.568	8.515
14	0.116	0.616	0.627	9.162	0.06	0.316	0.322	4.776
15	0.199	0.966	0.987	15.668	0.086	0.438	0.447	6.761
16	0.131	0.668	0.681	10.327	0.685	0.333	0.34	5.381
17	0.169	0.81	0.828	13.312	0.074	0.403	0.41	5.886
18	0.037	0.18	0.184	2.93	0.037	0.18	0.184	2.93
19	0.114	0.56	0.572	8.963	0.053	0.311	0.316	4.22
20	0.127	0.685	0.696	9.97	0.068	0.359	0.366	5.4
Total	3.174	16.028	16.342	249.52	2.559	9.9	10.091	153.018
Result	0.158	0.8014	0.817	12.476	0.127	0.495	0.504	7.65

Table 4.3: Sleep data for Subject2

The ratio between Low Pass and High pass Filter: (sleep)

Data No.	Mean	Std	RMS	Inte.
1	2.64	2.95	2.93	2.64
2	1.44	1.48	1.48	1.44
3	1.34	1.35	1.35	1.34
4	1.53	1.55	1.55	1.52
5	1.88	1.86	1.85	1.87
6	1.4	1.41	1.41	1.4
7	1.177	1.2	1.206	1.0181
8	1.103	1.096	1.094	1.0105
9	1.948	1.75	1.758	1.948
10	1.644	1.649	1.65	1.647
11	1.262	1.169	1.176	1.256
12	1.649	1.649	1.644	1.647
13	1.21	1.168	1.169	1.2
14	1.933	1.949	1.947	1.918
15	2.313	2.205	2.208	2.317
16	0.191	2.006	2.002	1.919
17	2.283	2.009	2.019	2.261
18	1	1	1	1
19	2.15	1.8	1.81	2.12
20	1.867	1.908	1.901	1.846
Total	31.96	33.158	33.154	33.316
Result	1.598	1.657	1.657	1.665

Table 4.4: LF & HF ratio for sleep

The awake data for subject2:

Data No.	LF MEAN	LF STD	LF RMS	LF INTE	HF MEAN	HF STD	HF RMS	HF INTE
1	0.1158	0.577	0.589	9.089	0.108	0.629	0.639	8.475
2	0.085	0.423	0.431	6.666	0.133	0.667	0.68	10.448
3	0.093	0.464	0.474	7.373	0.063	0.311	0.318	4.997
4	0.107	0.561	0.571	8.44	0.114	0.114	0.587	8.979
5	0.097	0.473	0.483	7.665	0.12	0.608	0.62	9.44
6	0.151	0.765	0.78	11.902	0.143	0.685	0.7	11.238
7	0.095	0.468	0.478	7.505	0.0569	0.289	0.295	4.468
8	0.185	0.957	0.975	14.593	0.081	0.413	0.421	6.427
9	0.084	0.408	0.416	6.617	0.121	0.6	0.612	9.526
10	0.106	0.546	0.557	8.34	0.11	0.546	0.557	8.661
11	0.081	0.383	0.392	6.412	0.087	0.465	0.473	6.864
12	0.086	0.436	0.444	6.812	0.095	0.485	0.495	7.51
13	0.065	0.31	0.317	5.13	0.092	0.481	0.49	7.298
14	0.13	0.661	0.673	10.269	0.084	0.437	0.437	6.597
15	0.106	0.507	0.518	8.331	0.07	0.34	0.347	5.558
16	0.1	0.525	0.535	7.906	0.081	0.442	0.45	6.433
17	0.063	0.346	0.352	4.975	0.099	0.5	0.51	7.847
18	0.075	0.382	0.389	5.935	0.073	0.373	0.38	5.732
19	0.117	0.645	0.656	9.239	0.084	0.416	0.424	6.671
20	0.119	0.604	0.616	9.355	0.122	0.619	0.619	9.6
Total	2.0608	10.441	10.646	162.554	1.9369	9.42	10.054	152.769
Result	0.10304	0.52205	0.5323	8.1277	0.096845	0.471	0.502	7.638

Table 4.5: Awake data for subject2

The ratio between Low Pass and High pass Filter: (awake)

Data No.	Mean	Std.	RMS	INTE
1	1.072	0.917	0.921	1.072
2	0.639	0.634	0.633	0.638
3	1.476	1.491	1.49	1.475
4	0.938	4.921	0.972	0.939
5	0.808	0.777	0.779	0.811
6	1.055	1.116	1.114	1.059
7	1.669	1.619	1.62	1.679
8	2.283	2.317	2.315	2.27
9	0.694	0.68	0.679	0.694
10	0.963	1	1	0.962
11	0.931	0.823	0.828	0.934
12	0.905	0.898	0.896	0.907
13	0.706	0.644	0.646	0.702
14	1.547	1.512	1.54	1.556
15	1.514	1.491	1.492	1.498
16	1.234	1.187	1.188	1.228
17	0.636	0.692	0.69	0.634
18	1.027	1.024	1.023	1.023
19	1.392	1.55	1.547	1.384
20	0.975	0.975	0.995	0.974
Total	22.646	26.268	22.368	22.439
Result	1.132	1.313	1.118	1.121

Table 4.6: LF & HF ratio for subject2

4.4 Result with t-Test

A t- test that uses a statistic which under the null hypothesis has the t distribution, to test whether two means differ significantly.

This test is only used when both:

- the two sample sizes (that is, the number, *n*, of participants of each group) are equal;
- it can be assumed that the two distributions have the same variance.

Violations of these assumptions are discussed below.
The *t* statistic to test whether the means are different can be calculated as follows:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{S_{X_1X_2} \cdot \sqrt{\frac{2}{n}}}$$

where

$$S_{X_1X_2} = \sqrt{\frac{S_{X_1}^2 + S_{X_2}^2}{2}}.$$

Here is the grand standard deviation (or pooled standard deviation), 1 = group one, 2 = group two. The denominator of *t* is the standard error of the difference between two means.
For significance testing, the degrees of freedom for this test is 2*n* − 2 where *n* is the number of participants in each group.

So,df =2n-2

For Subject2:
Two sample:
1)Alpha wave((7-10)Hz):
2)Beta wave((12-15)Hz):

t-test :

Group	Group One	Group Two
Mean	0.10304000	0.09684500
SD	0.52205000	0.47100000
SEM	0.11673393	0.10531880
N	20	20

Table 4.7: t-Test for sleep data for subject2

Intermediate values used in calculations:
t = 0.0394
df = 38
standard error of difference = 0.157

Confidence interval:

The mean of Group One minus Group Two equals 0.0061950000 95% confidence interval of this difference: From -0.3120849699 to 0.3244749699

P value and statistical significance:

The two-tailed P value equals 0.9688 by conventional criteria; this difference is considered to be not statistically significant.

Sleep

Two sample:

1)Alpha wave((7-10)Hz):
2)Beta wave((12-15)Hz):

t-test:

Group	Group One	Group Two
Mean	0.158000	0.127000
SD	0.801400	0.495000
SEM	0.179198	0.110685
N	20	20

Table 4.8: t-Test for awake data for subject2

Intermediate values used in calculations:
t = 0.1472
df = 38
standard error of difference = 0.211

Confidence interval:

The mean of Group One minus Group Two equals 0.031000 95% confidence interval of this difference: From -0.395390 to 0.457390

P value and statistical significance:

The two-tailed P value equals 0.8838 by conventional criteria, this difference is considered to be not statistically significant.

The ratio between Beta wave and Alpha wave individually both awake and sleep situation. Then, t-test

Two sample

1) Ratio of awake

2) Ratio of sleep

T-test

Group	**Group One**	**Group Two**
Mean	1.1323000	1.5980000
SD	1.3134000	1.6570000
SEM	0.2936852	0.3705165
N	20	20

Table 4.9: t-Test for ratio data

Intermediate values used in calculations:

t = 0.9850

df = 38

standard error of difference = 0.473

Confidence interval:

The mean of Group One minus Group Two equals -0.4657000 95% confidence interval of this difference: From -1.4228199 to 0.4914199

P value and statistical significance:

The two-tailed P value equals 0.3309 by conventional criteria; this difference is considered to be not statistically significant.

Result For t-test:

- We don’t get any difference between beta and alpha both awake and sleep condition.
- Don’t get any difference between awake and sleep (L/F).

So, all the results show above that we couldn’t get the desired significant value for any signal. The working environment of Trauma center was not good for any subject to sleep properly and due to short period of time we couldn’t manage enough time to go there several times to collect the data.

Chapter Five

Conclusion

Within the timelines we have tried to cover a widely expended topic. In this thesis we have covered all the theoretical evaluation of anesthesia. The methods of determining anesthesia level are hugely considered to search a better method. Revising all the existing methods we have proposed a device by which the need of proper anesthesia will fulfill the demand very accurately. According to the proposed device, as a one step ahead we started to work with EEG signals and we experience such prospects and also practical difficulties working in this field.

Now a days this topic has become a greater concern world wide and developed countries like Bangladesh is also not staying calmly rather than doing research in this topic. In this circumstance our small effort will enhance and help our country’s biomedical engineering world. And the proposed device has a widen space with promising prospects for the biomedical instrumentation world.

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