Introductory Neuroscience and Neuro Instrumentation
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Lecture 41
Basics of BCI Experimentation: Experimental Setup and Biopotential Acquisition

Hi, welcome to the lecture series of brain-computer interface experimentation. Before we start the module I want to clarify one thing that whatever BCI interface or BCI experimentation we have discussed so far that term is used for a generic a brain-computer interface which means whenever the brain waves are recorded and processed in any computational unit I referred in this lecture series as BCI, this is just not to get confused with BCI 2000 software suit.

So, BCI 2000 is another nice tool to process this brain wave but here in this lecture series of 4 part series I am discussing most of the stuff not only processing but how to generate stimuli, how to insert stimuli, how to acquire biopotential, what are the necessary requirements for experimental protocol and what are the signal processing, so do not confuse get confused with the term. And now let us begin our today's module that is on experimental setup and bio potential acquisition. So, two of the very very essential and critical sub-process of the new instrumentation, so we will have a look at each of them one by one.

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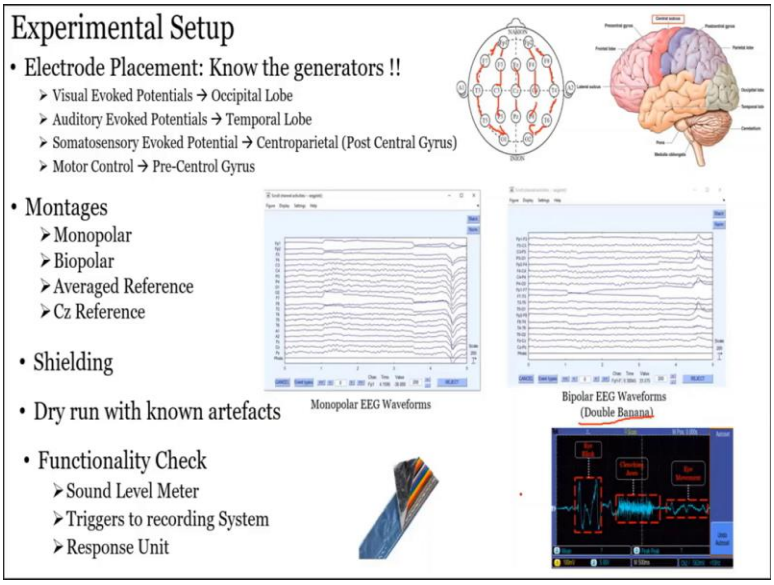

So, let us begin first with experimental setup. So, first question you should have before performing any easy recording is exactly how many electrodes are used and where you are going

to put that, so and who will decide where to put electrodes. So, you should be aware that targeted potential is getting generated from which part of brain, so there are some responses or some potentials which is constant across the scalp, so they are known as a far field potential, like if I talk about auditory brainstem response which is known as AVR, so that is far field response. So, you can put your electrode anywhere here and you will get required you no response, whereas there are some tips, there are some generators are known considering the area of brain.

Now, if you see that, this is the top view, this is the top view of your 10 20 system of your head and electrodes can be placed here using 10 20 system FP1 F3 C3 V3, I think professor Hardik would have already covered about 10 20 system and doctor Mahesh has told you about various region of brain. So, there are few tips or few like rules a not rules but like a thumb rule that if you want to record a visual evoked potential occipital lobe is the one of the good way a good landmark where you can put your electrodes.

Whereas in case of auditory evoked potential you can put your electrode in temporal or even frontal side. Now, reason behind that is visual cortex lies near to the occipital lobe so you get a prominent response if you put your electrode at occipital lobe in case of a recording VEP. Similarly, sort of sensory evoked potential you can record in the area called postcentral gyrus. So, in pre-central gyrus mostly motor controls and all are monitored, so these are the kind of a basic areas of scalp where you put electrode if you want to specifically record evoked potential listed here.

So, always a good practiced that before starting an experiment you should have a clear cut idea where you are going to put the electrode and for that as I said whether the targeted response is near field of far field and are the generator knows, though that is the thing that even if I say I will get auditory of potential I will get it prominently in temporal lobe in other places in other electrode also I will get the response.

But near to the site of generation it will be more so easy to capture easy to analyse, so it is a kind of a tip, so this is first thing that you must know where you are going to put your electrodes and more importantly how many number of electors are required. Now, based on your problem you can have different number of electrodes if you want to check for any kind of epilepsy then you should consider all the channels.

Whereas if you just want to see whether a person can hear it properly or whether a person can see the things properly or not, in that case are two to three electrodes are enough if that have been kept at a proper place. So, moving ahead first once you know how many electrodes are required and where you are going to put them next we will take care about the montages.

Now, very important term, what is montage. So, once you acquire the bio potential values montage is just a way to represent them. Now, sometimes we take our reference value, now what is the point or why people take reference value? The reason behind if you take a reference from nearby electrodes it will help you to nullify the common mode noise.

So, you can see two images right now, here if you see this is a mono polar images absolute value of FP1 FP2 and all, all the channels have been taken so you can map this this FP1 here FP2 I think you all of you should know by this time what is FP1 FP2 and all this thing could, so this is a mono polar EEG waveforms which has been generated, these are the different types of montages which has been used in practice there are many more almost 20 to 25 kind of montages and each and every montage has its own significance why it has been used, mostly you should know when you take anything as a reference from area it is just too mostly to nullify the common mode noise.

Now, one more interesting thing we will see here is if you see here F3 is subtracted from FP1, C3 is subtracted from FP1, C3 is subtracted from F3, P3 is subtracted from C3, so I just want to show you a few things on fascinating thing FP1 minus F3, so I can draw it like this, F3 minus C3, similar way I can draw it like this, C3 minus P3, like this P3 minus O1, so it is like from frontal, prefrontal to frontal to central to parental to occipital.

Similar way it will come in this like it is like bidirectional, in both the direction if this thing is constant, like this, same way if I go here FP1 minus F7 then it will be like this FP1 minus F7 (())(08:21) F7 minus T3, T3 minus T5 and T5 minus O1. Similar way if you go here FP2 minus F8, F8 minus T4, T4 minus T6, T6 minus O2 and finally the midline electrode where is for midline electrode, you pull not, FZ minus CZ, CZ minus PZ.

So, now if you see this shape which has been generated here, it looks like two bananas that is why this used bipolar montage is known as double banana. So, it is just fascinating to see the different kind of montage have been used and named it different manner, so I just want you to

people to come to know that this is also one of the important parameter while acquiring or EG you should not only know where electrodes have been placed and how many electrodes are used, you should also know while analysing or while acquiring which kind of montage is you are referring.

So, further if you move ahead one more very important parameter is shielding. Now, these wires if not shielded can act as an antenna and can surely deteriorated by electromagnetic interference. So, very important to shield it with different layers of either copper or aluminium foil and that should be finely grounded, this is a very important concept because mostly most prominent noise which deteriorate the signal quality is power line interference.

So, please make sure whenever you are in using or whenever you are performing any kind of experiment make sure your device whichever is you know affected to or kept it in an open environment you can shade it properly and you use enough number of layers for your wires, one more thing is this power adding and addition to power line interference you should also take care about the crosstalk which happens in between two nearby wires.

So, that also should be taken care and properly whatever why are you select make sure it is properly shielded and efficient enough to reduce or to eliminate the crosstalk between two nearby wires. Further if we move on let us say now we know how many electrodes are used where you are going to put the electors what montage is to use and your entire thing every experimental setup is also prone to any kind of interference like sorry experimental setup is also like you know free from any kind of noise or EMI's electromagnetic interferences.

Now, once you start your recording you should first check with known artefacts, so this is what we generally follow, if you see here, here is the this is very well-known eye blink artefact, so kept on a proper polarity are this upswing are you know this positive cycle tells you about eye closed and this is eye open. So, this thing is very prominent and like while pre-process your signal is a signal eye blink removal is the very first step is any cognitive neuroscientist will do as well as these are the clenching of chores and eye movements.

So, these are three of the basic checks which we perform before recording any ERP or any event related potential or any EG related bio-potential. So, you should also check and these are kind of all these things eye blinks and all our artefact which does not have a significant easy information

for any particular applications, but still it is good that if we can use it for as a dry run proof of whatever the system one which we are working it is working perfectly fine.

So, another very important step before performing any kind of experiment is you should check with the known artefact that if I cleanse the zoo it should look like a high frequency burst which you can see here, if you move your eyes it should look something like this but smaller than eye blinks. So, this most of the thing holds in all their acquisition device, so I would encourage you to know more artefacts and check if you can do this kind of experimentation.

So, further if we move ahead you can check the functionality of your sound level meter of your stimuli generator unit and if you have put a response unit like in most of the cognitive a neuroscience experiment you need subject to respond, you need subject to press the key, you need subject to you know move his hand or something like there should be some response unit based on the bio potential received.

So, before you start the experiment you should check whether that response unit is working fine, as well as in case of it is written sound level meter, but you can check it that is specific to auditory experiment, so before you start your experiment you should check the intensity of your stimulus using sound level meter, you should also check that whether the trigger switch has been generated triggers which has been generated is conveyed properly or reach properly to your recording system or not.

This kind of ignore all these pre-experimental checks you should perform before you start any experiment. It is very useful for any cognitive neurophysiology study that you click all these boxes before performing a successful experimentation. So, I hope this will enhance the understanding of yours and you will have proper happy experimental session after following all this.

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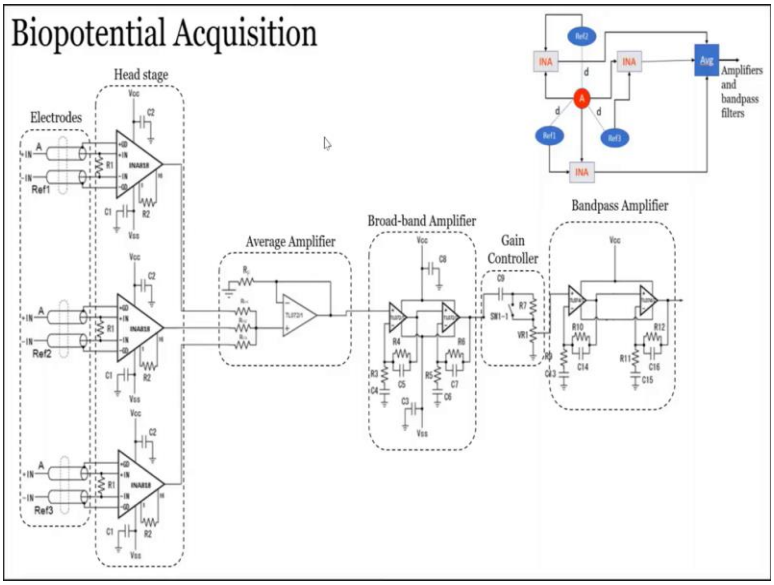

So, now you guys have an idea about the criticality or the care you should take while performing any experiment, we will see how we are going to record some bio potential and in this subsection we will see different circuits which has been used to generate are acquired by a potential as well as the modern day instruments or equipment that is been used as well.

So, this is one of the circuit that has been used. Now, consider A is your active electrode which is placed and three nearby references have been taken, this entire circuit is explained in a separate module in detail, so I would like all of you to first understand that and then you take a look at this video still I will just give some brief overview of the circuit. So, this part is nothing but your electrodes, A is the same active electrode which is used with three reference electrode and this is the head stage which is comprising of instrumentation amplifier.

So, instrumentation amplifier one of the most important equipment or one of the most important circuit that has been used for bio-potential acquisition not only EG for any kind of bio-potential, bio-potential you consider you will find instrumentation amplifier why because it magnifies even a millivolt or microvolts of signal. So, very important the first stage is your instrumentation amplifier, once you get this output of your instrumentation amplifier it has been averaged out.

The final output is averaged out in order to get exactly the same value for instrumentation for bio-potential, one more thing to note here note down here is, this reference are kept in such a way that distance from your active electrode remains the same, so there is assumption that the

noise level which is there at reference 1, reference 2 and reference 3 should be similar. So, once you average it you will get the most signal or most you know kind of fidelity in terms of bio-potential.

One more thing here is to use instrumentation amplifier the another use is it will eliminate the common mode noise between references and your active electrode. So, once it is averaged out then it remains a broad band amplifier and gain controller, so this circuit which is already covered in one module if you change your switch from ON to OFF or OFF to ON then you will you can use the same circuit to record ECG as well as EEG.

Topology wise I will tell you that this is an active electrode which has been used with three reference electrodes and three instrumentation amplifier as you can see here and response of instrumentation amplifier is averaged out using this averaged amplifier or path. For those who are not much familiar with op-amps and instrumentation amplifier I would recommend it I would recommend to first have a look at the detail and a description of this circuit in the course and then look at the video.

Further, there is one alternative to this mostly this INS are very useful tool for bio-potential acquisition at the same time it is used somewhat chip area. So, if you want to make your device timing if you can reduce the number of instrumentation amplifier it would help, but at the same time it might affect the fidelity. So, let us see that variant of bio potential acquisition.

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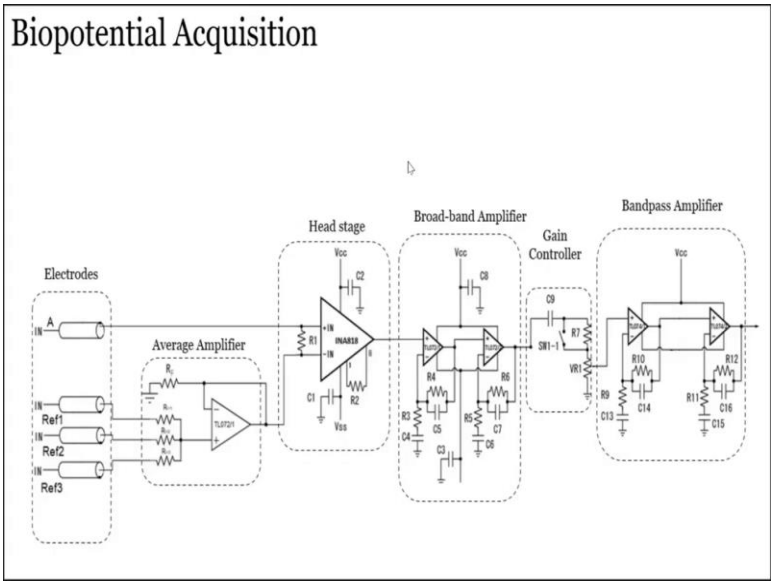

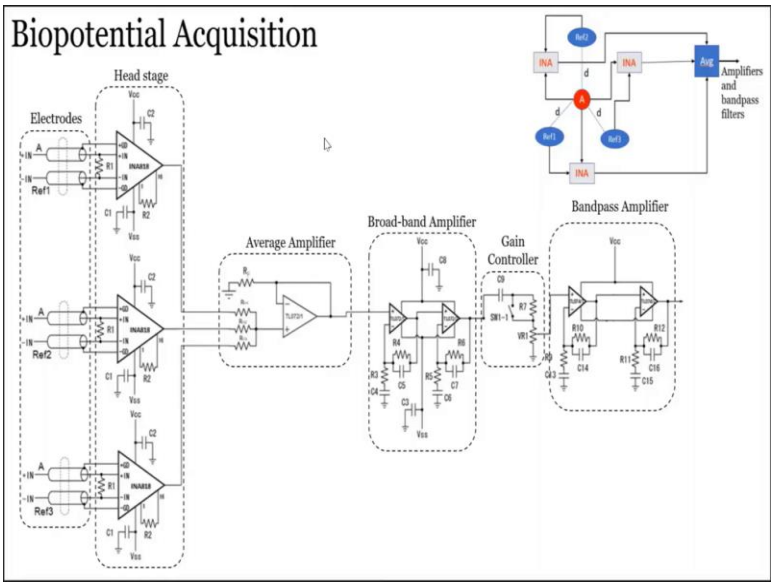

So, this is the this circuit also does the same functionality which has been done by this circuit. But in this case what is changed is that earlier we were using head stage first and average amplifier, in this case we are averaging out the reference here only and we are using only one instrumentation amplifier. So, this is a kind of a classic case of electronic circuit design, you have to make a trade-off between the chip area as well as your quality or fidelity of your signal.

So, once this reference values which has been placed if you can see here all the reference are kept at the same place from your active electrodes of this all three reference values been averaged out, then it will be given to your instrumentation amplifier to check with respect to

your active electrode and then you can further the same story they spread band amplifier gain controller and all remains the same.

But this is the case of you know trade-off between your signal fidelity and your chip area or your cost, so I thought I should include this and this is the circuit which are already seen and it is a very low cost EEG or ECG signal conditioning circuit and it works for both, so it is a kind of a very generic bio-potential acquisition circuit. So, I thought I should give you people some idea about which kind of circuit is being used. But these are like very primary labelled EEG and ECG acquisition device.

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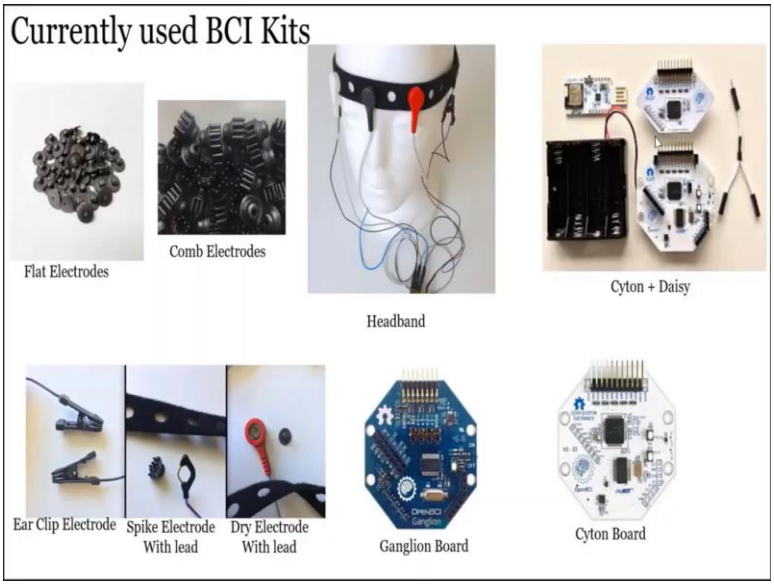

If I talk about modern day tools or modern-day components which have been used then we can see that currently used open BCI I just show you one open BCI get here. So, basically it will have a different electrode along with the leads to connect that electrode. Now, in the first image here whatever you can see is known as flat electrode.

So, those electrode has a flat edge towards the scalp where it has like this flat edge will be placed on the scalp and the small part bottom part that is used to acquire the bio-potential, so this kind of leads are provided with flat electrode, so you have to just place this electrode here and from here the bio-potential can be conveyed or can be transferred to your acquisition device.

Now, this one type of electrode, there is one more type of electrode, let us say this, this is a Comb electrode, so in case of I have mentioned I guess that in case of hairy person where it is

difficult to get the potential with flat snap electrode we go for spike electrode or comb electrode, this is also the case of spike electrode, so like I say it that lead was used for flex nap electrode this kind of leads, this kind of leads are used for spike electrode.

One more type of electrodes which can be placed on your earlobe that is called clip electrodes. So, these electrodes are mostly used as a reference because it is far away from your scalp, so this kind of electrode can be used as a reference and further if we see how we can place the electrode or you know there is a headband for open BCI, so how open BCI headband looks like? So, here is a good image of mannequin in which open BCI headband and electrode are placed.

Once you place this thing here if you can see the ear clip electrode is also placed you are can directly connect this thing to your open BCI boards for signal acquisition. Now, which kind of boards open BCI have and how does it look like, how to operate in that board? So, these are the three modern day boards which have been used with this 4 1.5 volt supply, it is a very affordable acquisition units this first I will talk about ganglion, ganglion is a 4-channel board with wireless transmission this is the updated higher version that is Cyton which is an 8-channel board with wireless transmission and finally this is Cyton with a guy Daisy.

So, if you place the Cyton on Daisy and configure it you can use it for 16 channel as well. As well as this small part here is nothing but a dongle, a receiver, it should be connected using USB to your laptops, so once you connect this thing to USB and you have to download open BCI software, you can get this output or final your brain potential going on.

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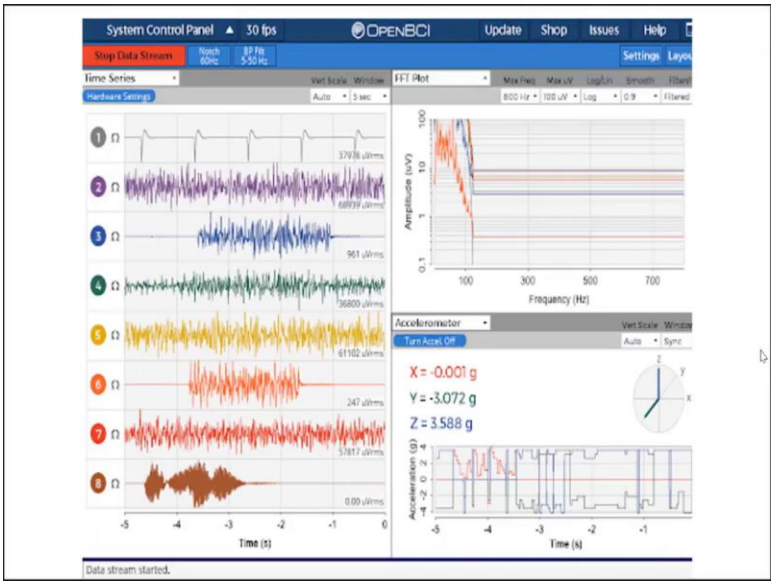

So, once you are open BCI Cytone or software is programmed and connected with wireless link and you start your data stream, the screen will look like this. This is for Cytone, it has a 8 channel as you can see here, you can select the notch filter and band pass filter settings from here, you can also see the FFT which frequencies are prominent in particular channel as well as this is an accelerometer, it shows the movement of your Cytone board.

So, if board has moved a bit it will tell you that this is because of some movement your EEG is deteriorated or some artefact presents. So, this is basically idea an idea about how open BCI a whole home software is look like and how you can use it further for bio-potential acquisition. Now, if I talk think in terms of system, what are the kind of components are included in Cytone board?

So, we will not go into the detail as circuit itself is very complex, but I will quickly tell you about the different modules and functionality of the same, so you will get an idea that previously one circuit which we have this discussed in detail has similar kind of flow when I talk about bio potential acquisition. So, I will show you the circuit which I have simplified in order to make all of you understand I have reduced the complexity of the circuit and I have removed some of the sub-units which are not useful in the context of this course.

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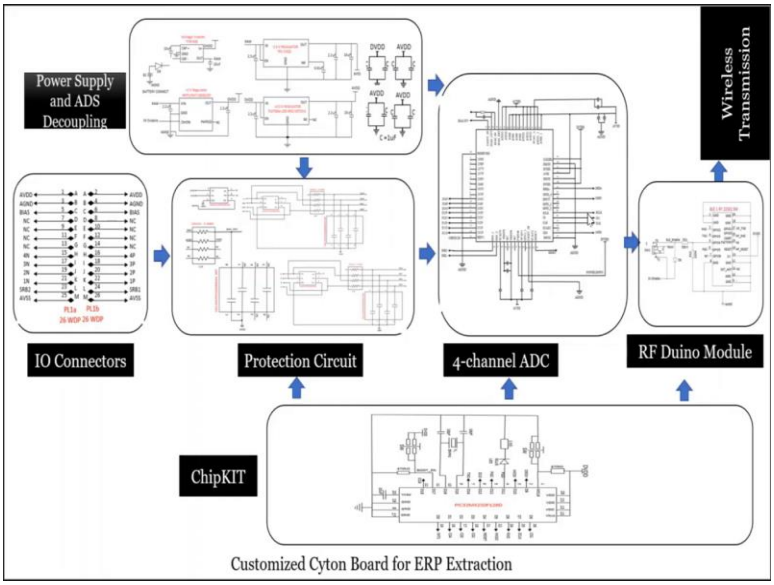

So, this is basically a customized Cytone board for event related potential extraction. So, here if you can see at the top there is a power supply and radius decoupling unit, we have used different analog and digital ground because like this is the big signal electronic system design, so we have used that on the left centre part you can see this all the connectors which have your channels and your reference and many things.

As well as here you see this 1, 2, 3, 4 positive ion channels where SRV 1 is your preference, you can go to the open BCI official site you will find a design files, you can check out and you know analyse it further this will be a protection circuit, it works in both way it we will see a subsequent circuits from any current search appearing from input connector side as well as it will save a human being in on which the electrodes have been placed for bio-potential acquisition.

So, this protection circuits is the resistive bank and capacitor array which has been used and further it will the values or potentials after this protection circuit is given to INA instrumentation amplifier 1299, so it is a ADC with very high precision the 24 bit ADC ADS 1299 is been used for I have shown here for 4 channels, so all this part is disconnected and further once this ADC convert the analog bio-potential which have been obtained using electrode to a digitized form it the values will be given to RF Duino module.

Now, this chip kit is basically a bootloader whenever you start your experiment I have shown you the home screen, so home screen as well as some like in laptops in your system there is a

once you open it, it booting happens, similar way chip kit serves as a bootloader and initialize all the variables and logic in order to get the home screen et cetera. So, this is just an idea, basically they this system also use instrumentation amplifier and ADC like this is basically ADS 1299 is a multi-channel ADC.

So, that is what it is very powerful multi-channel ADC is being used and further it will be transmitted like I said this is also a similar kind of acquisition system like earlier what we have used, so this is basically what bio-potential acquisition is all about and I hope you guys have understood it and basically this experimental setup and acquisition, so how you strategize and how you design your board it is very important and I would encourage all of you to go through this official site of open BCI, and you can explore it more based on your requirement. So, I will see you in the next module, till then all of you please take care, stay safe, bye-bye.