Advanced Neural Science for Engineers
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Lecture 36
Design of Wireless Biphasic Pulse Generator

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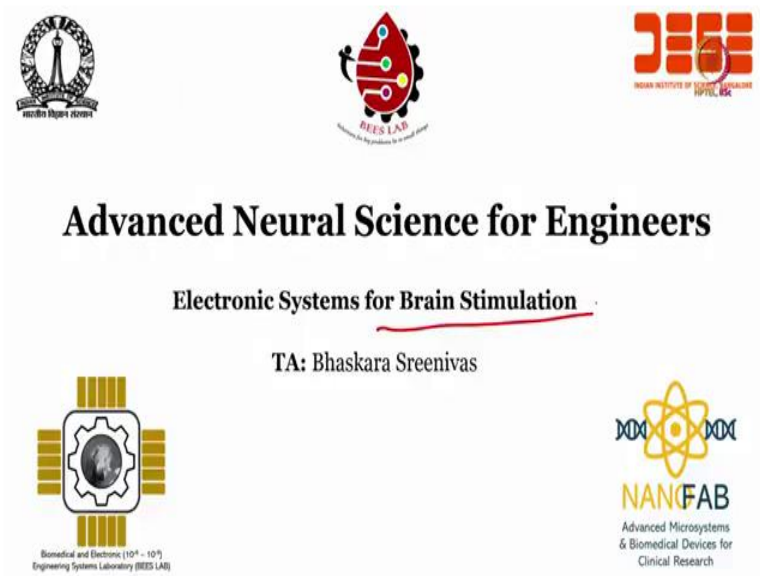

So, welcome students, let us look at one more lecture on electronic systems for brain stimulation in the series of lectures on advanced neural science for engineers.

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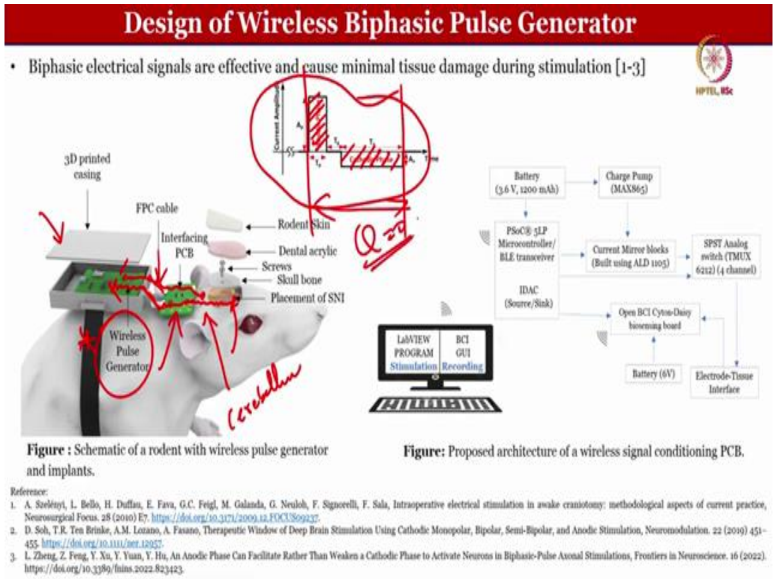

So, initially, if you look at it, we have seen fabrication. So, we have seen how to do fabrication of this neural implant, then we have seen the different characteristics that it has to satisfy to be a fairly good neural implant, if it is recording, if it is for stimulation and all those things, then once everything is ready, now, you connect it to the electrode interface board, EIB, then there is a FPC cable now, from there you will give the connection to electronic systems.

Now, this is a wireless pulse generator. So, let us in this lecture I think we will not discuss much details about it, but I will just want to give you an emphasis or how does it look like. First of all, what is that you want to stimulate, this brain region.

Now, these electrodes connected via this FPC connector and that goes to this and that goes to the electronic system. So, you have direct access to the brain and you have ground also which generally we now put it in the cerebellum area, this is the cerebellum area. And that ground also will be available for the electronic system between these you apply the potential and you know there is a current flow.

This is a global stimulation what generally people do is they will take 2 electrodes that are present now, we have 5 electrodes 1 2 3 4 5 out of them, one they will make it as active another one as a ground and then they stimulate only this particular area, anything is fine does not matter, the concept remains same for engineers the concept remains same, the application could be different.

Now, we already discussed in the previous lecture about why biphasic, because you should not damage the tissue, when you will damage the tissue if you deposit excess charge. So, this is how the biphasic pulses look like the current and time if you look at the current and time the area under this graph will give you in the charge, the area under this graph will give you in the charge after the end of the application of the pulse you have the charge to be 0, the total charge that you apply is 0.

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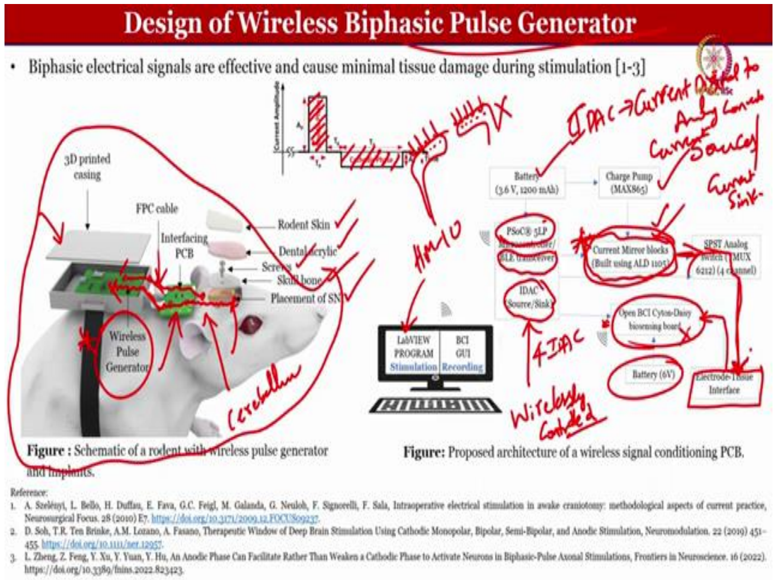

And also I just showed you some images here. If you look at it this is how surgery will take place I am excited to show you. So, we have seen neural implant and we have seen the fabrication I mean fabrication of the neural implant, then we will see the electronic systems. I will also show you how we will do surgery by using the equipment that is available. I am going to give you a demo on stereotaxic operators how does it look like for your information.

So, generally you see this rodent skin is removed and then there is a skull bone that you have to be drilled and then we need to fix the screws for dental acrylic to sit in you know why dental acrylic is required because you need to have the implant in place there sturdy, and then placement and all those things these are all just typically how does it look like.

Now, if you look at it, this is a typical the wireless architecture that I am proposing, but there are many other ways also to do. Now, there is a microcontroller here you see this is from PSoC i Cypress semiconductors and this microcontroller can be wirelessly controlled the PSoC microcontroller as such does not have a microcontroller.

But when it is integrated with BLE modules like HM 10 all those things by which you can communicate with the PSoC 5 microcontroller by using the lab view. Then, this piece of microcontroller has something called as IDAC pins, current digital analog converter these are IDAC current digital to analog converter this will act as a source current sources or current sinks.

So, why am I talking about current source and current sinks so, here if you see look at it, there is electro tissue interface here. Now, you want to have something which is for generation as well as recording, even though the slide says pulse generator, the emphasis is more on generation, because we are not going to discuss about the acquisition part because we that is not the objective of this course.

So, we do not talk about biosensing board because this is a commercially available and then you supplied with the battery now, for this you can choose a switch, if you connect the switch SPST switch single pole single through switch, if you connect it to then the current mirror block outputs will be in contact with the electro tissue interface otherwise, they are in contact with this by default it is in recording mode the architecture right now, if you switch it then that particular output blocks of current mirror will be passed to the electro tissue interface and this currents may not destroy this open BCI system so, let us worried about it.

Now, what is this concept of current mirroring here, why we are doing this? Now, if you look at this there are 4 IDACs that are present in this microcontroller. And I have 5 electrodes, one 5 electrodes on the right, 5 electrodes on the left let us say I want to stimulate all the electrodes at a time can I be able to do it, I cannot be able to do it.

So, that is why the concept of current mirroring coming into picture. And this charge form bundle is required for voltage complaints with current mirror blocks and then increase the range of current mirroring.

So, the here the basic blog that is very much important was is current mirror, why current mirror and all not, because we want to stimulate many electrodes at a time if I want to stimulate many electrodes at a time we need to have current mirror.

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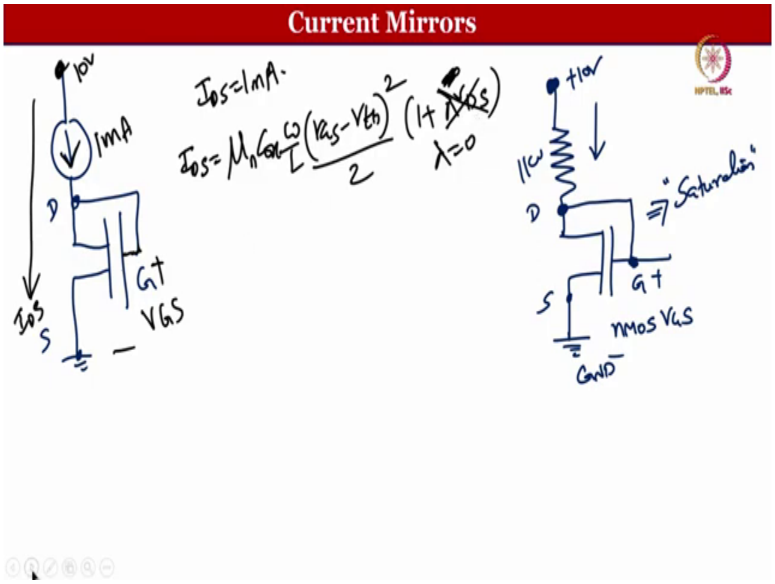

So, let us look at it how does it look like. So, how does the current mirror works is the basic current mirror I am discussing. So, you have this resistor for example, and there is a transistor. Now, when let us say this is n MOS transistor, there is a drain there is a source and there is a gate.

Now, we connect these 2 drain and gate and we apply sufficient voltage let us say plus 10 volt something and sources connected to ground, this will be pushed towards saturation and of course, this transistor will be in saturation there is a current that flows if you choose very minimal resistance let us say 1 kilo watt or something. Now, because of that, this transistor is in saturation with some V_{GS}.

Similarly, if I have a current source coming out like this, and you connect it to the transistor, something like this, which is configured to be in saturation. Let us say some voltage, something now this current let us say this is around 1 milliampere current, current source when it is connected in series with this transistor, which is connected to be in saturation, it developed some voltage V_{GS} whatever is our voltage is let us choose, let us now call it as V_{GS}.

And the current that is flowing through is nothing but I_{DS}, let us say assume I_{DS}, now this I_{DS} is going to be 1 milliampere. Now, how I_{DS} and V_{GS} are connected:

$I_{DS} = \mu_n C_{ox} (W/L) [(V_{GS}-V_{th})^2/2] (1+\lambda V_{DS})$. Now for simplifying our discussions, this lambda to be 0, there are no saturation effects.

So, I am not saying V_{DS} to be 0, I am saying lambda equal to 0. Let us assume that for simply discussion simple discussion because here you need to understand the cycle of electrophysiology labs.

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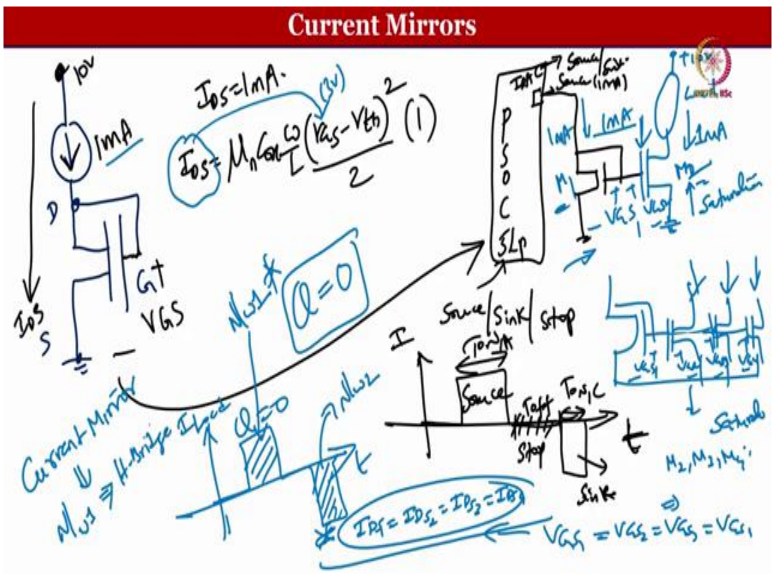

So, now what will happen is now this current let me erase this part, the right part. Now, the PSoC that we have, the PSoC 5 LP microcontroller has IDAC pin and this I can program it as a source or a sink let us say this is acting as a sink source with 1 milliampere output current. Now, this I will connect it to on n MOS transistor same thing same story you can visualize and the source when you talk about source now, there is a provision in the PSoC 5 microcontroller that I can make it as a source or a sink or stop it completely.

So, if I take I versus t for example, I can make it as a source, I can make it as a sink, I can stop it also I can stop it, I can make it as a source, I can make it as a sink whatever it is, I can play around with that and this on time T on time of this anodal pulse t on time on the cathodal pulse and t of time anything can be programmed anything can be programmed and in real time.

So, now, what happens is instead of directly supplying this to the brain, I am trying to supply through something so that I can have multiple sources at a time. So, next what happens is this now since I have this V_{GS}, your I_{DS} instead of supplying directly to the brain now, what we do is we copy these ideas in the form of V_{GS} because 1 milliampere can have some voltage let us say 3 volt or something depending on V_{GS}, here now that I can copy across this resistor, this one more transistor this let us say this V_{GS} 1 for m1 then I can have V_{GS} 2 for m2.

If I can make sure this transistor is in saturation then the current that flows here is 1 milliampere. If this is 1 milliampere, obviously this also will be 1 milliampere. So, plus 10 volt and this is where the load comes here, are you getting? So, 1 milliampere, if you pump you will get 1 milliampere of course, there are some nonlinearities will be there that also can be addressed using different current mirror configurations or slight non linearity will be accepted as soon as well as soon as you maintain as long as you maintain this charge neutrality.

Now, I talked about only sourcing there can be sink also as soon as you maintain the charge neutrality. Now, what is this, this is current deliver to the load, you have one more network that delivers the current which in terms of sink. So, there is a m1 m2 like this, not only m 1 m 2, I can have m 3, I can have m 4 like this, I can have multiple outputs at the same time because this VGS is going to be same V_{GS} 1 is equal to V_{GS} 2, this is V_{GS} 3 V_{GS} 4 according to the network configuration V_{GS} 1 is equal to V_{GS} 2, that is equal to V_{GS} 3, that is equal to V_{GS} 4, if we can maintain M 2 M 3 M 4.

If you can bias this into saturation then I_{DS} 1 is equal to I_{DS} 2 is equal to I_{DS} 3 is equal to I_{DS} 4. So, this is how we can just do the current mirroring on a overview. Now, you have one, the issue with this is actually you have 1 network that is generating the source, this is one let us say network 1 generates a source, network 2 generates a sink some other network let us say that is made of p mos and all those things.

And again the output is connected to the load, little tricky, I am not getting into details of that. So, the point here is network 1 and network 2 may not have exact matching transistors to maintain the charge equal to 0. So, what people can do generally is you have current mirror, you have current mirror configuration you take only network 1 and you connect the output in the H bridge manner.

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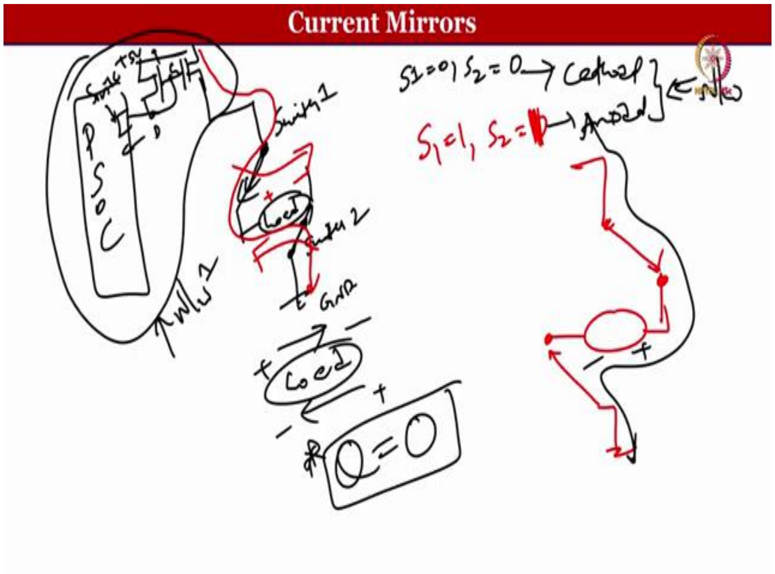

So, when I say hedge bridge, how does it look like is this, because two networks are generating one network is generating cathodal, one network is generating anodal pulse, that is why the problem is coming because charge neutrality will never be maintained as you know the important thing is the charge neutrality.

So, what do you do right now is different tricky, little tricky. You have PSoC then you have source. Now, what you do is let us say this is a heat sink, you have an n mos transistor, p mos transistors that are coming into picture sorry, let me redraw this. Okay, let me erase all the ink, our idea is to maintain the charge neutrality now.

So, let us say we have P SoC and we have a sink pin, sink means your current flows inside now you have P Mos that is connected because this is a drain, this is a gate and source is connected to plus 5 volt or something. Now, output is coming now this is a load now, let us say there is a switch here switch 1 and there is a switch 2 and this is connected to ground. Now, let us say switch 1 is 1 switch 2 is 0 means the switches are connected like this.

So, how the current flows, current flows assuming that transistors and everything is in so this is the direction. Now, you reverse it let us say switch 1 is 1 switch 2 is 0, switch 2, switch 1 is 1 switch 2 is 1, let us say for example, that means that you have a switch here which connects like this and there is a load and now the switch will connect back to this, it has switch positions has been changed like this and these are analog switches, you can just program them and then accordingly it will switch they are also called SPDT switches single pole double throw switch.

So, now what is the current direction, if you look at the current direction, now, you are not changing this network it is the same network, this is the same network, this is the same network 1. So, now the current will flow in this direction positive negative earlier if I take this as a load this is positive negative, it is going like this. Now, in the second phase, it is going like this.

So, there is a very high chances or at least electrical point of view, there are other issues also involved in this, but at least on the electrical point of view the charge that is delivered between the I mean during the cathodal and anodal pulse generation, this is cathodal let us say this is anodal it is okay whatever it is. Since the same network is generating both cathodal as well as anodal there is a very, very, very high chance that now the charge neutrality will be maintained that is very much important.

So, I am stopping it here, in the next session as I told you in the next session, so the next is going to be a video where I will show you how the surgery is performed on the rat, I will show you the rat stereotaxic operators and microscope and the various other tools that are required for the surgery and how the little bit of Faraday cage looks like and then how the environment there looks like. So, let me show you the video now.