Power Electronics with Wide Bandgap Devices

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Lecture-2

CHARACTERIZATION OF WIDE BANDGAP DEVICES

welcome to the course on power electronics with wide bandgap devices this is our second lecture in this lecture i am going to discuss about characterization of the wide bandgap devices so this is in continuation with the previous lecture so there i have discussed about different types of wide bandgap devices mainly focused on gallium nitride and silicon carbide their advantage, challenges their current trends and the applications. Also I have shown data sheets of silicon carbide, gallium nitride and silicon and also discussed their comparison. So as you have seen in the data sheet so different parameters are actually given those are required for designing converter So, the important parameters I have discussed in the previous lecture. So, if you want to see more parameters then you can download those data sheets from the website. So, now if you download the data sheets of the same devices which I have shown in the previous lecture that is silicon, silicon carbide and gallium nitride using same part number. then you will be able to see for silicon device there are like much more information given in the data sheet as compared to silicon carbide and GaN.

Similarly for silicon carbide comparatively more information is given as compared to GaN and comparatively less information you will get in the GaN data sheet. So what is the reason? So basically these devices, these wide band gap devices are comparatively new. They are not that much mature. So not all the information related to design are given in the data sheet.

Some information are given which are important and some they may be important, but like they depend on different electrical or thermal conditions. So, that information are not given because those is not known. However, for designing the converter, that information may become very significant for some of the researchers or the users. That is the reason it is important to characterize these devices. So, this is what I am going to discuss in today's lecture.

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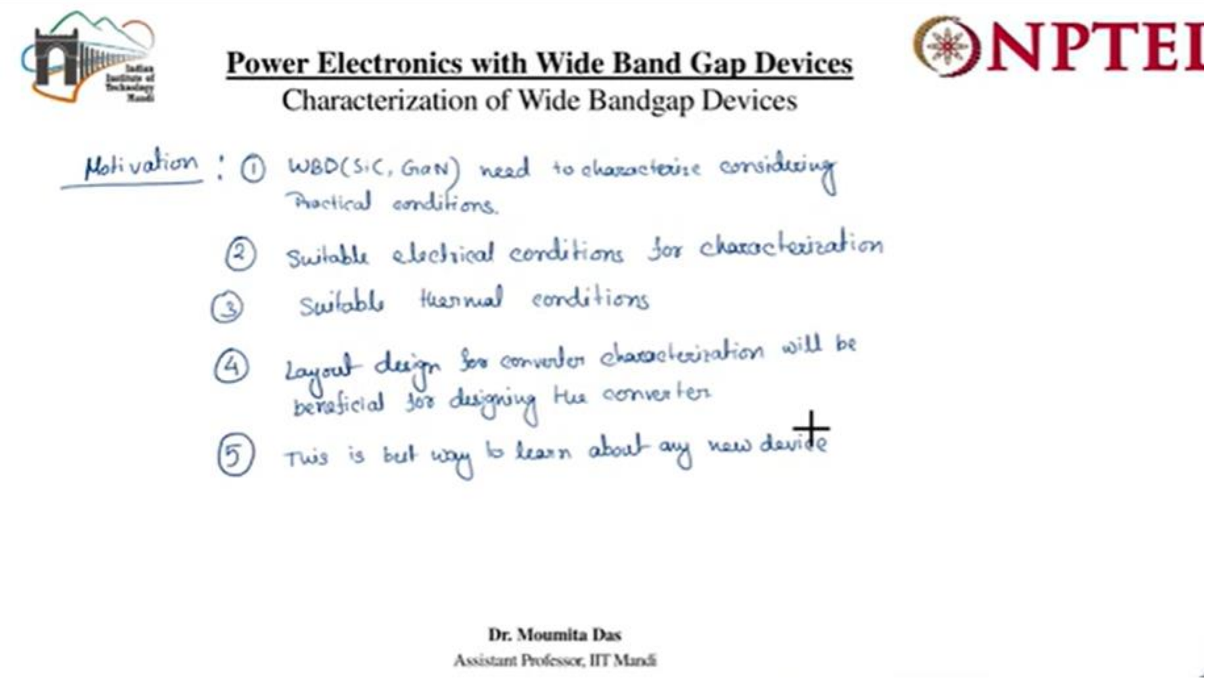

So, basically motivation behind the characterization. So, when I say motivation. So, then there are few points you need to know. So, what are the motivation behind this characterization? So, first is that, so the wide band gap devices such as silicon carbide and GaN, they are comparatively new. and not matured. So, all the information are not available in the data sheet. So, then if we require some information which are not available in the data sheet, then what we have to do? We have to characterize those devices. So, basically what we have to do? We need some practical condition for which we will be designing our converter. So, the wide band gap devices need to characterize considering practical conditions. Second is that So the data sheet is incomplete and not the information is given, all the information are not given with respect to different electrical conditions.

So basically the condition which they have considered for the characterization of the data sheet that may not be the same condition for which you need different parameters. So then you need different parameters with respect to your electrical conditions. So let's say in the data sheet you must have seen different electrical conditions are given. Electrical conditions means different types of voltage, current and the temperature. if you remember I have discussed in the previous class so with respect to different temperature current carrying capability of the device changes means at 25 degree Celsius if the device is capable of carrying 15 amperes current so if the temperature increased to 100 degree Celsius then what happens current carrying capability of the device reduced to let's say 12.

5 amperes same thing happens for all the devices. So, the reduction may be different, but definitely there will be reduction if the temperature increases. Similarly, if the electrical

parameter changes means the voltage for which we are considering the characteristic. So, let us say VDS if it increased from let us say 100 volts to 400 volts. So, definitely the capacitances whatever is present, which I have shown in the last class, input capacitance, output capacitance, reverse transfer capacitance, those capacitance values will also change and same as the with respect to rise time and the fall time.

So obviously if those parameters changes so that is going to affect the converter operation with respect to let's say dynamic characteristics, static characteristics and also to find out losses in the converters. So that is why we need to consider different electrical condition which will be suitable for our application. So suitable electrical conditions for characterization. Similarly we need to consider suitable thermal conditions as well. suitable, so it may happen the converter which we need to design that probably will be used for a operation where the temperature will vary from a range of let's say 25 to 50 degree Celsius.

So then we have to see like at room temperature let's say 25 degree Celsius is the room temperature in that condition what are the values of different parameters and similarly for 50 degree Celsius what will be the changes in the parameters for that particular device. Then we have to design the converter with respect to that. Now these are with respect to different conditions. Now this is not only the only reason why we want to characterize the devices also these devices are suitable for high frequency operation so the layout design of these devices will be different with respect to the silicon device why the design will be different because some parameter which may not be significant for silicon device related design that may become significant for wide band gap devices due to consideration of the high frequency operation. So, then if we are like using these devices or we are designing one PCB for the characterization then we have to consider all these points so in that process what will happen we can extend that knowledge for designing the converter using those devices so basically layout designed for converter characterization will be beneficial for designing the converter.

And another important thing is that whenever there is some new device so then we need to learn about the device so what type of device what are their characterization how we can use this particular device where this can be applicable so this is actually best way to learn a new device by characterizing the device so this is best way to learn about any new device. So, these are the different motivations for characterizing wide band gap devices. So, now this motivation also exist for silicon devices because you know like when silicon devices came in the market. So, then that was also new. So, probably people have spent lot of time to learn about those devices.

So, then why we have to reconsider these points again. So, basically the difference between silicon and the wide bandgap devices causes to learn about these new devices more challenging than that of the silicon device. So, whatever the existing method available for silicon devices to get the characteristics of the silicon, so that may not be suitable directly for wide band gap devices. So, the reason why it will not be suitable is because this device packaging is much different than that of the silicon device. As you have seen in the previous lecture, the GaN packaging is much more different that of the silicon carbide or the silicon devices.

So, basically those are SMD type of devices and they are very thin and also accessing different points gate drain source points of the GaN devices is much more challenging than that of the silicon carbide or silicon devices. So, then the existing kind of equipment whatever is available for characterization of the silicon device that will not be suitable directly for GaN devices. so then we have to find out different method or we have to modify the existing method in order to characterize those new devices so that is one important thing and second thing is that whenever we are actually characterizing silicon device so additional wire length may not cause that much problem because you know the parasitics for silicon device may not be that significant what may be very significant for the wide band gap devices due to high frequency operation. and third thing is that whenever we are going to use any equipment that equipment may not be suitable to test any particular device new device so for high frequency operation so their frequency may be limited considering the silicon device so those are the different devices that cause us to look for new methods or modify the existing methods for the wide band gap devices Okay, now I will tell you about different types of characterization. So what are the characterization you need for your converter design basically what are the different parameter you need with respect to the converter design so when we say converter design the first thing which comes to your mind is that rating of the device so rating of the device means what are the voltage and current ratings so those are the first thing which we look for a device like whether that device will be suitable for this much voltage rating and this much current rating.

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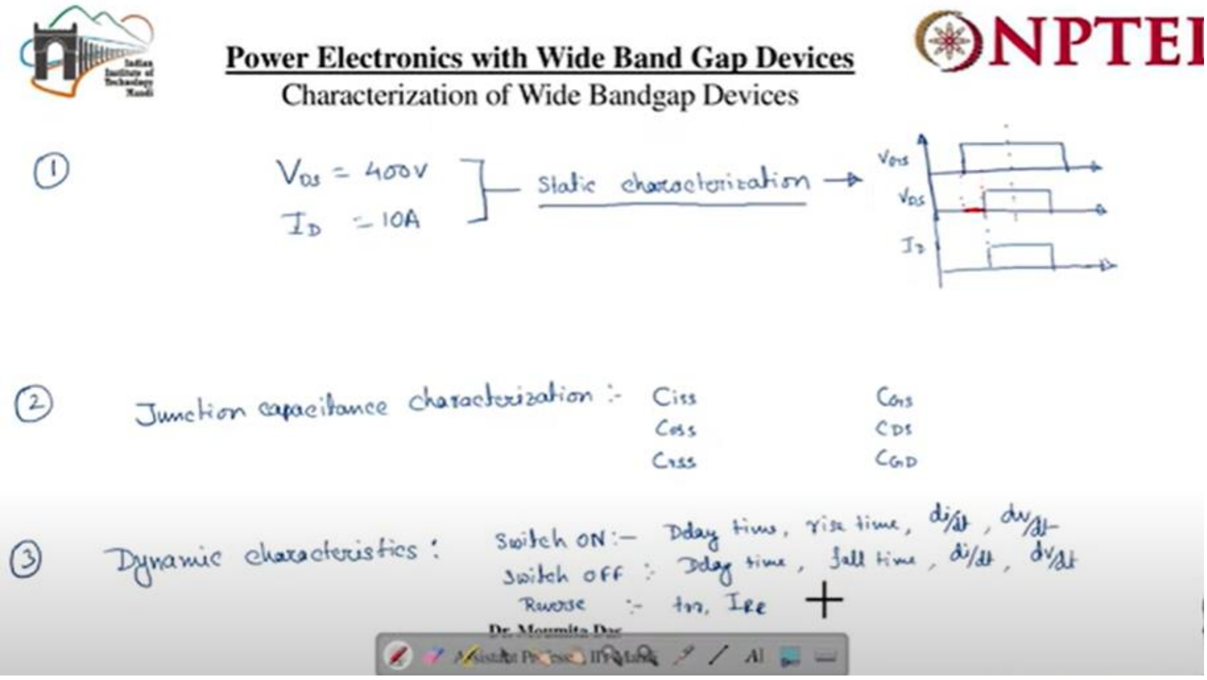

Let's say any device is having voltage rating VDS which is of let's say 400 volts and ID which is of 10 ampere. okay so when we try to design any power electronics converter, any converter buck converter boost converter what we see what is the rating of the device rating in the sense there are two parameters one in term of voltage another in term of current so when the device will be off in that time how much drain to source voltage is appearing across the device and when the switch is on what is the drain current maximum will be flowing through the device so based on that we can actually select the maximum rating and then from there we can select the device which will be capable of carrying that much current or can have that much voltage stress across it so now these two parameters Can we find out from the device characterization? So, when we say device characterization for that we need static characterization. So, this comes under static characterization. So static characterization means the device is basically reaching to steady state. So when we turn on any device, so initially there will be some time required to reach the device to the steady state. When it is turning on it will take some time which I have shown in the previous lecture in terms of rise time and delay time.

That time is required to reach the device to steady state till it is carrying the rated current. So, in steady state it will be probably carrying rated current. So, that rated current we can get from this static characterization. similarly during the turn off condition when the device is turning off so that time is also given in the data sheet in terms of delay time and the fall time so after the delay time and fall time the device will be completely off and the voltage stress across the device will be in terms of VDS so this VDS can also this information we can get from the static characterization. So, what we have to do for this static characterization? So, we have to provide a gate pulse.

So, this gate pulse should have suitable pulse width so that device can reach to steady state. Now, this gate pulse should is very important what should be the pulse width of this gate pulse because you know like if we try to keep width of this gate pulse very small then probably the device will not reach to the steady state then we may not have the actual information of the VDS and ID so then it will be difficult to find out what can be the maximum rating of the device now if this length is very This not length, this width of this gate pulse is much wider. Then what will happen? That will cause high conduction loss because when the gate pulse we are applying, we are expecting device to conduct. so then what will happen the device will be in conduction state so in that time what will happen due to the device conduction state there will be conduction loss so this conduction loss can cause temperature of the device to increase and if the temperature of the device increases so then what will happen then the parameters of the device different parameters it can be current voltage or any other parameters those parameters value will also change so then we will not get actual value of the static parameters so that is why optimizing of this gate to source voltage is very important for this static characterization so once we are applying this gate to source voltage after that we will be able to find out drain to source voltage of the device and similarly we will be able to find out drain current of the device okay so now there will be delay between this gate to source voltage and the drain to source voltage because you know this delay you can see here so this delay it is actually shown in this particular section So let me select different color. So then it will be easier to see so this portion you can see here So the gate to source voltage we are applying here and the drain to source voltage It can be seen after a delay point.

So this delay is very important You know why it is important because by keeping delay we can allow the device Resonant parameter means if the device is turning on and in hard switching mode so then what will happen due to presence of different parameters like capacitors, inductors, the parasitic parameters there can be some oscillation during the starting. Similarly during the turn off condition also this oscillation can present. If the oscillation is present, so then what will happen? That can cause some problem with respect to measurement of the static parameter. So, that is why this delay is provided. So, the device turn on and turn off happens such a way so that there cannot be resonant oscillation present in the static parameter characterization.

so this delay optimization of this delay is very important so this delay we need to provide so that the device can reach to steady state within this duration after providing delay it may not happen that device is not reaching to steady state it should reach to steady state and we can measure different static parameter so this is the first thing which we need to consider the static characterization. Second thing is the junction capacitance characterization. So junction capacitance So, these capacitances you know in terms of Ciss input capacitances, Coss output capacitances, and then Crss reverse transfer capacitance of the device. So when I say input capacitance says so basically this input capacitor is having two different capacitor component of the device. So when you try to characterize the capacitances, the capacitance which we get to see in the device that will be either gate to source capacitance, drain to source capacitance or gate to drain capacitance of the device.

Now this capacitance says are actually give the value of this input output and reverse transfer capacitance so input capacitance will have two capacitances of the gate then output capacitance will have two capacitances of the drain and the reverse capacitance will have only one capacitance between drain to source now these capacitances are very important for designing any converter as I have shown you in the last class these capacitances are the main component which decides what will be the switching frequency of particular converter because you know charging and discharging of these capacitances give us rise time and fall time and that can give us actual value of the switching frequency. If this capacitance values are very high then device operation will be limited to low frequency. That is what I have shown you in the last class. Si devices are generally having higher value of this parasitic or the junction capacitances and it will be actually higher than that of the silicon carbide and GaN and silicon carbide will be having higher capacitance than that of the GaN device so since the GaN is having much lower capacitance much lower junction capacitance that is why this device is suitable for high frequency operation Now these capacitances are not linear they are non-linear in nature and different parameter of the converter can affect the value of these capacitances. Different parameters can be let's say voltage rating of the device.

Let's say some converter probably we are operating at 100 volts some we are probably 400 some at 1000 volts. The variation in the voltage is can cause different value of the capacitance and then variation in the current the drain current so that can also cause the change in the capacitance value and also the temperature So these parameters so basically the static parameter and the temperature affects this junction capacitances So that is why it is important to characterize these capacitances in order to find out exact value of the capacitance from the graph with respect to the particular application So the data sheet what I have shown you in the last class there some values are given with respect to these capacitances but those values are applicable for by considering the electrical parameter that they are given with respect to that particular test so some parameter electrical parameters are given for the test so those parameter if you are considering for your converter design then if you are choosing those capacitance values then it will be perfectly fine but if your electrical parameters are changing so then what you have to do you have to see so generally in silicon device data sheet those capacitances curves will be given with respect to drain current or drain voltage or the temperature so then you have to select the particular temperature particular drain current and the drain voltage. So, then you can choose the appropriate value of the junction capacitances and then from there the frequency can be calculated. So, those calculation we will see in details in the next lectures. So, today I am just telling you the basics of this characterization.

So, why we need characterization and what are the different types of the characterization. So, we will see in details in the future lectures. So, this is about the junction capacitance. Now, third point is the dynamic characteristics. So, dynamic characteristics when I say, so this gives us the information about different dynamic conditions so what are the different dynamic conditions so dynamic conditions means the device has not reached to steady state so either the device is turning on or the turning off so then if the device is turning on so during the switch on condition so during the switch on condition.

So it will tell us about the delay time during the turning on, rise time and what are the other things. Also it will tell us about the di/dt and the dv/dt. Similarly, during the turning off condition means the switch when it is turning off. So, then also we can get all this information. So, delay time will be there for turning off, then fault time, then di/dt and dv/dt.

Are these the only parameters which we can get from the dynamic characteristics? So there is another important thing which we can get from the dynamic characteristics. What is that? That is the reverse characteristics. So if there is any reverse operation in the device, so reverse characteristics we can get what are the reverse characteristics or the reverse parameters so basically reverse recovery time then reverse recovery current and the reverse recovery charge those information we can also get from the dynamic characteristics We will see about these characteristics in details in the next class and also I will discuss about different measurement equipment which are available for this different characterization.

This is all for today. Thank you. See you in the next class.