Power Electronics with Wide Bandgap Devices
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Lecture-7
GATE DRIVE FOR DYNAMIC CHARACTERIZATION

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Welcome to the course on power electronics with wide band gap devices. Today I am going to discuss about gate drives and their requirement for power electronic systems. So gate drives is the main link between the control and the power. So world of control means the voltage level is very low and also the current level. In case of world of power the voltage and current both are very high.

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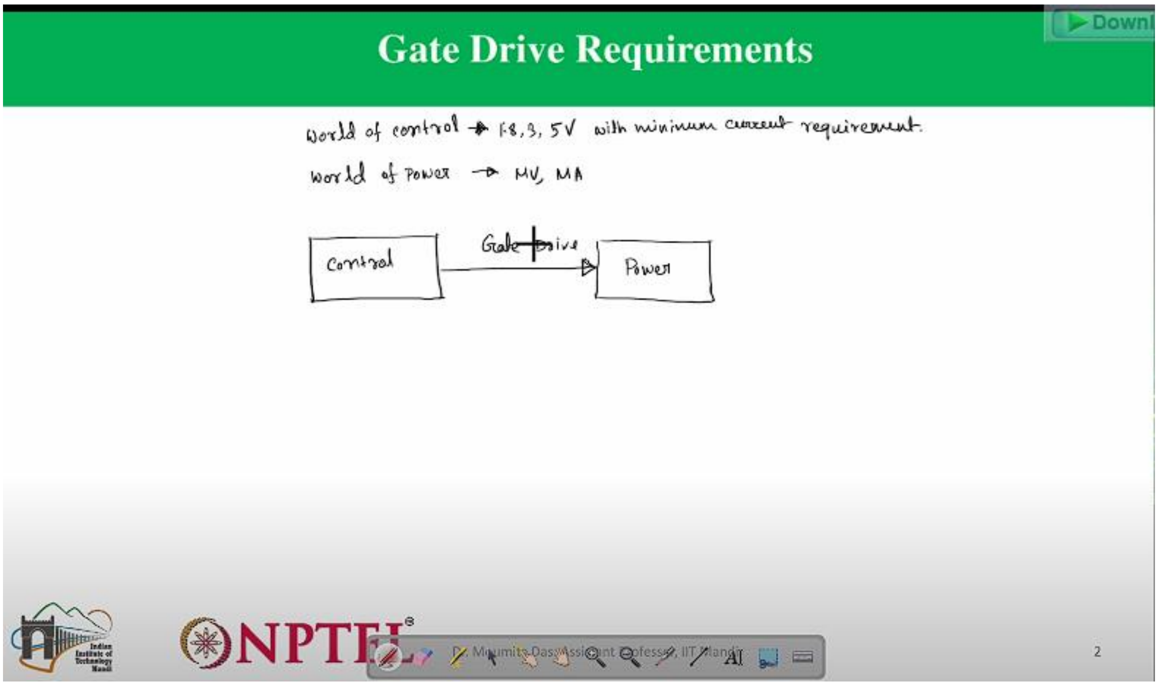

So if I try to quantify it, so then world of control defines voltage in the level of 1. 83 and maximum of 5 volts and the current level is very low. In case of world of power, this voltage level can be either millivolt, sorry not millivolt, megavolt, kilovolt or volts. So, world of power defines voltage level maximum few millivolts, and current level can similarly also be in mega ampere sorry not millivolts it is mega volt and mega ampere. So, then you can understand the difference between world of control and world of power. So, the power level in world of control is very less in power level in world of power or the power electronic systems it is very high and this gate drives it is providing link between world of control and world of power. So that is why it is very important to understand the gate drives requirement for power devices and power electronic systems. So in case of power devices what we need to do? We need to provide some medium so that it can amplify the signal generated from the microcontroller to the level where it can be provided to the power electronic system. So now in case of power electronic system the requirement can be much higher than that of the requirement that of the signal which is provided from the microcontroller. So that is why I can tell you here, so basically this gate drive plays the link between, this is control and this is power. So, it goes to the power device. So, gate drives output it generally goes to the power device and that that is actually part of the power electronic system or the power conversion system. So, now why we need gate drives? So, gate drives is required in order to provide the gate signal to the power devices so that we can get dynamic characteristics properly. So, in the previous lectures I have already told you about the DUT basically the DPT test for the devices which we will be using. So, if we have to implement DPT so then we have to provide gate signal and that gate signal need to be provided properly otherwise we will not be able to get dynamic characterization properly for any device for that purpose this gate drive is required and it is very important to implement this gate drives gate drive circuit properly. So now in case of silicon and other devices also we have gate drives. So let's see how that gate drive circuit looks like.

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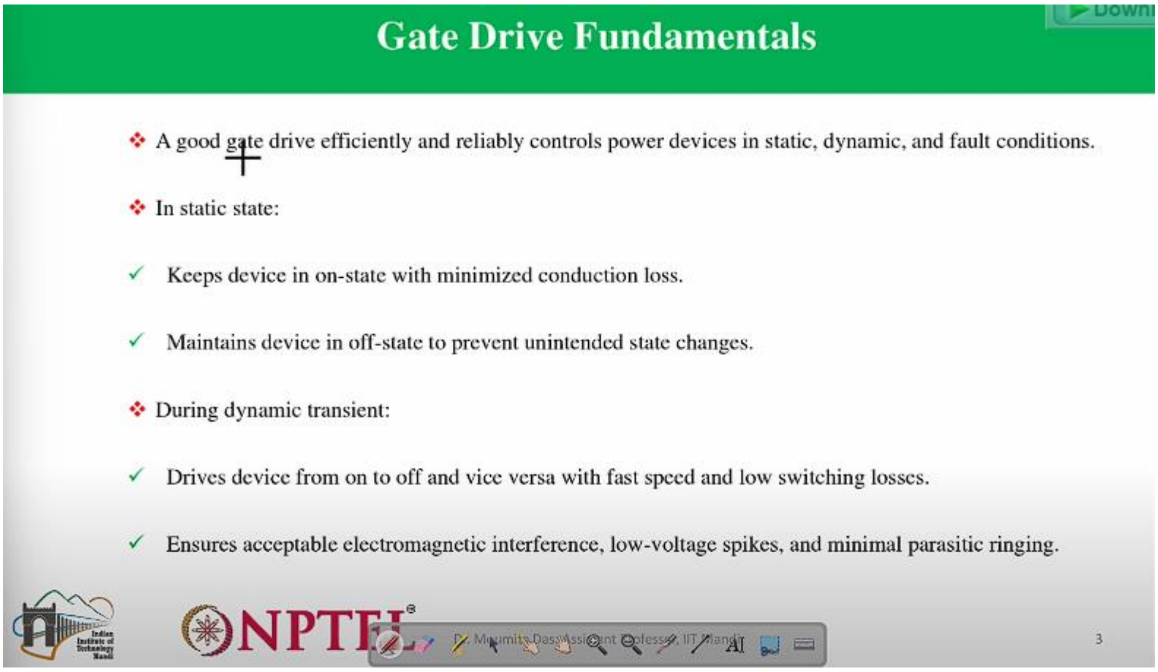

So what are the main component of the gate drives? So any gate drive it is Basically, it should be able to operate efficiently and reliably, control the power devices in static, dynamic and faulty condition. So, static condition there will not be any problem. Dynamic condition there can be some dynamic characteristics that can be part of either gate drive circuit or it can come from the power conversion circuit. And there can be also faulty condition which we don't want transfer either from control to the power system or it should not transfer either from power to the control system. So, that is why we have to develop a gate drive so that it can actually identify the faulty condition and it can separate out control signal from the power signal. So, in static state, what we need to do? We need to keep the device in on state with minimized conduction loss and maintains the device in off state to prevent unintended state changes. So, these are the conditions we have to maintain in static states and during the dynamic states, what we have to do? We have to provide the driving signal so that devices either turns ON to OFF vice versa with fast speed and low switching losses. So the important thing is that we have to focus low switching losses during the dynamic condition and low conduction losses during the static condition. So this ensures acceptable electromagnetic interference low voltage spikes and minimal parasitic ringing. So these are the things which we desire from the gate drive circuit. So we have to provide the drive signal so that we have these components with minimum value.

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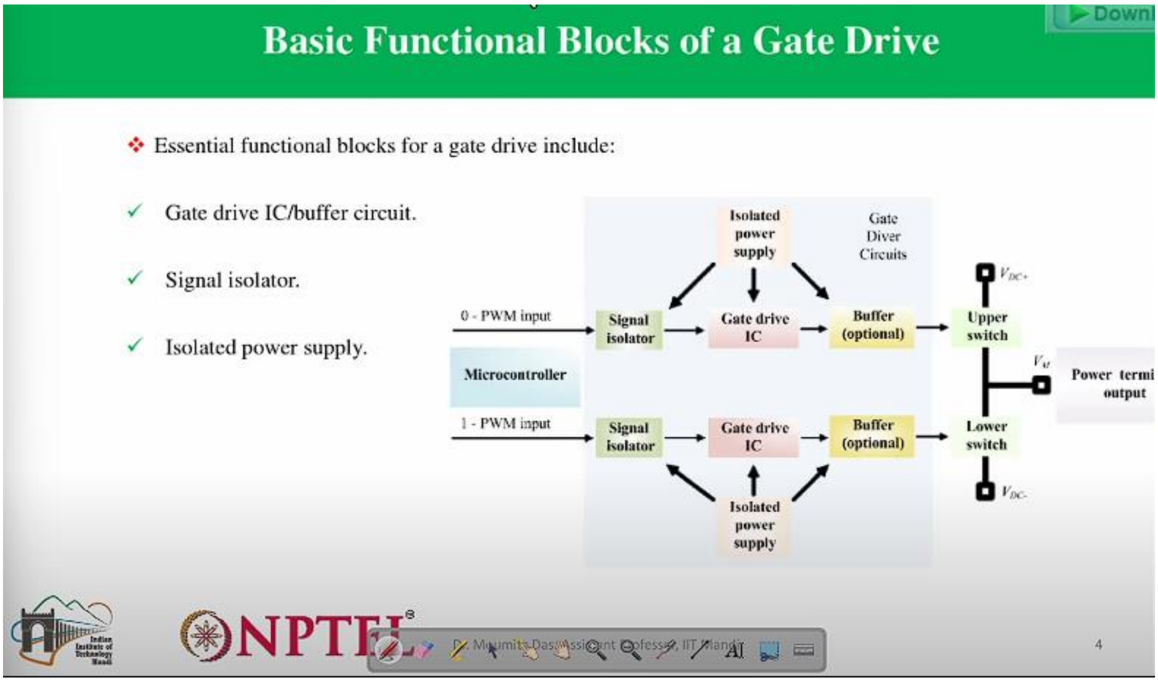

Now these are the basic functional blocks of a gate drive circuit. So what are the components which are present in any gate drive circuit? You can see here so there is a microcontroller. So microcontroller it is a very low voltage kind of device. So it provides the output which will either be 3.3 volts or 1.8 volts. And now this microcontroller output which will be basically pulses to be provided for the gate signal. Now this microcontroller output we cannot directly connect to the gate terminal because you know the microcontroller output voltage level will not be suitable to connect to the gate voltage of the power conversion system because that voltage level will be different. So that is why what we need to do we have to provide this microcontroller output through a gate drive circuit to the gate of the power conversion system. So now this is the gate drive, which is shown in the shaded portion so now this gate drive block what it shows so it shows that microcontroller output, so basically it is providing the pulse width modulation input to the signal isolator so it is going to the signal isolator. Now this signal isolator is one of the important component of the gate drives, and this provide isolated signal so whatever input it will be getting at the like basically microcontroller output. So that output will pass through the signal isolator and the output of the signal isolator will be isolated from the input signal. So that is the function of the signal isolator. Now this output of the signal isolator, it is going to the gate drive IC. So what it does the gate drive IC, it provides suitable voltage and current required for driving the gate terminal of power device. Now this gate drive IC output can directly be connected to the switch or it can pass through another buffer, a block if the gate drive output is not suitable to amplify the required voltage level for the power devices, so this buffer that is why it is written here optional. So for some cases buffer is mandatory for some cases buffer is not required so that is why there are like main components, which we will be needing, so that is signal isolator and gate drive IC, so these are the two main components of the gate drives and buffer is optional. So this is the entire gate drive circuits, so now there are basically three components you can see here, it is written here so basically gate drives or buffer circuit signal isolator, so this gate drives and buffer circuit is shown in one point now all this three components so if we have signal as a signal isolator and gate drives then the two components will be provided supply from isolated power supply. So, both signal isolator input and gate drives input should come from isolated power supply. So, that their voltage level should not be affected by control or the power signal and there should not be any noise transferred because of the voltage supply to these devices. So, that is why isolated power supply is very important for gate drive circuit. so these are the main components of any gate drives now these components are also used for silicon device or any device which are in use for power conversion system. So you can see here this buffer output is directly going to the switch, which is part of power conversion system or power electronic system. Now this switches you can see here it can be any kind of switch It can be silicon switch, silicon carbide, gallium nitride. So any kind of switch can be placed here. So the basic functional block diagram remains same. So we are not changing anything there. But there will be some additional requirement for wide bandgap devices. So why there will be additional requirement. So that we need to understand first so additional requirement comes because of the different structure of this wide bandgap devices or different properties of this devices.

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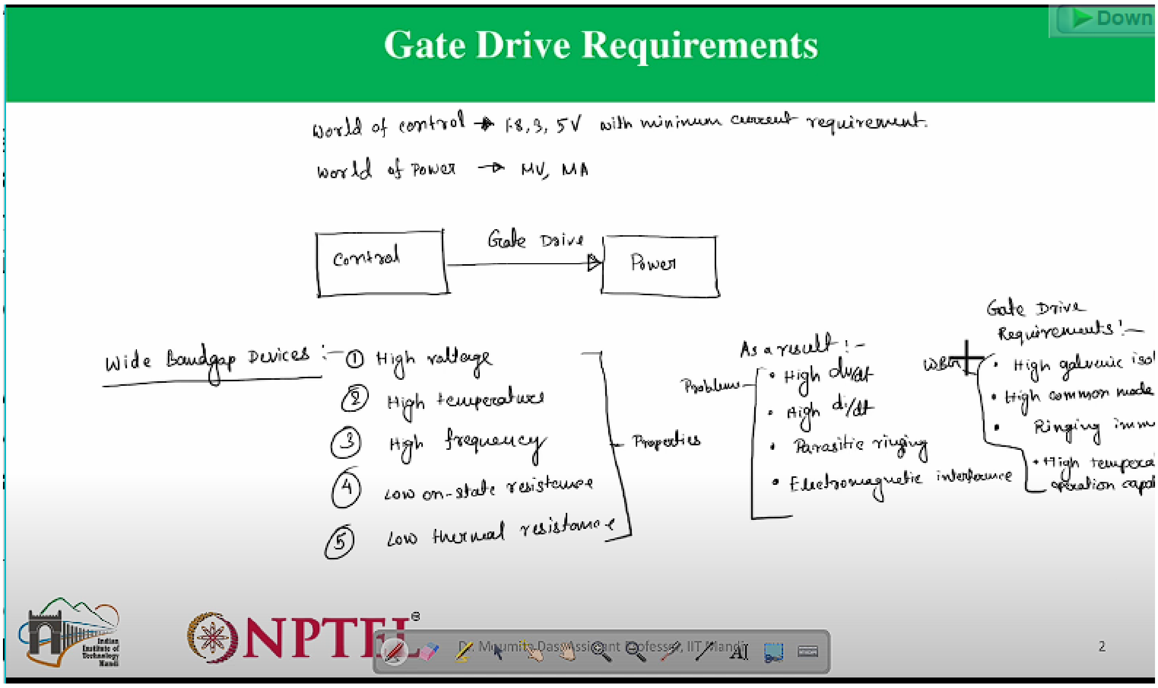

So what are the properties that makes the main difference, so let's see that particular point so if I try to write down for the wide bandgap devices So wide band gap devices, so they are different from the silicon devices. You already know what are the properties that are different from the silicon devices. So the property, in terms of properties if I tell you, so basically the main things comes, so it is capable of operating at high voltage level. So high voltage operation capability, also high temperature operation capability, also high frequency and it has property of low on state resistance and low thermal resistance. So these are the properties which we get to see in wide bandgap devices. Now these properties are different than that of the existing silicon devices. Now if these properties are different then what will be the problem. So because these properties are different, so then what is happening, the due to this factor we have some additional thing which can be part of the power electronic system, so as a result following things arises. So, what are the things? So, due to this high dv/dt problem occurs. Similarly, high di/dt problem occurs. Parasitic ringing occurs. electromagnetic interference. So these are the problem arises due to this, these are the properties due to these properties these different problems arises, these different problems arises. So these are not problems in case of silicon devices. So then what we have to do? We have to provide solution or look for the solution which can tackle these problems. So then what we have to do? We need special requirement for designing gate drive circuit. That is why this gate drive circuit is or understanding of gate drives is very important. For any wide band gap device or any new device if you are trying to use it for the first time or trying to use it in any application for the first time. So that is why new requirements for this device says is we need high galvanic isolation capability gate drive. So, now we also need high common mode transient immunity capability. And also we need ringing immunity capability in gate drive and along with all this additional thing is required, so mostly the gate drive you have already seen basic functional block diagram. So it is having signal isolator gate drives buffer and power supply. So these are the components basic components. Now these components are suitable to operate for like the temperature where silicon device can operate properly. But if we try to use this wide band guide devices for high temperature operation because these devices are suitable to operate at high temperatures. Then we need suitable gate drives component which will also be able to perform properly at high temperatures. So high temperatures capability. High temperature operation capability. So these are the requirements for wide band gap devices for along with basic functional block diagram these components will be additional component which we need to incorporate for wideband gap device applications in power conversion system. Now all these things you can see here I haven't included protection part yet. That will be that also included in the gate drives. But that I will be discussing later. Today I am discussing basic requirement for any gate drive circuit.

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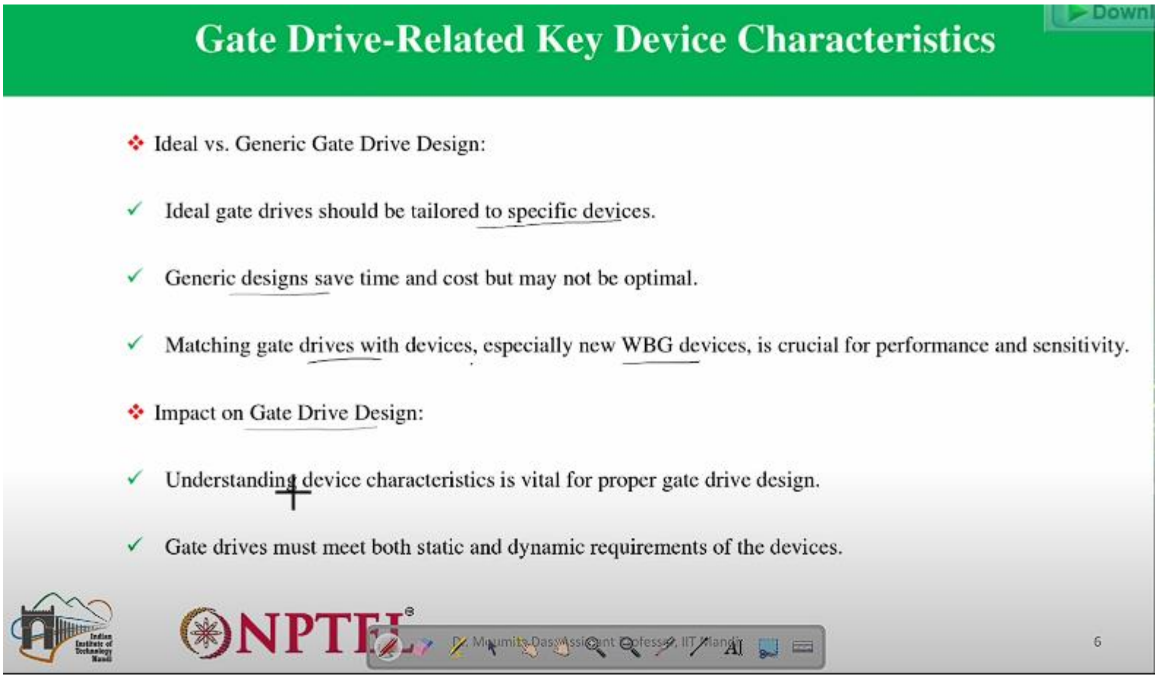

So now you can see here so this is the basic block diagram and all these component should have those capability which I have discussed. Now this is the thing will be different in wide bandgap devices. Now as I already mentioned why wide bandgap devices so basically it is having superior property so this superior property requires additional things for gate drive implementation.

Now this gate drive how it should be, how the ideal gate drive we desire so ideal gate drive should be tailored to specific devices, means each device is different each device is having different rise time different fall time different delay time different parasitic capacitances and other parameters they are also different. Although they may come under let's say GaN or silicon carbide their properties will be similar to that of the that material what we are going to use but based on the device rating all the parameters will change, so that's why gate drive requirement or ideal gate drive we should design as per the requirement of particular device, if we try to use general gate drive, so then we will not able to optimize the operation of the that particular device. So that is why this generic design can save time, cost, everything, but the operation may not be optimal. So matching gate drives with devices, especially new wide bandgap devices is crucial for performance and sensitivity. And also when we are actually trying to implement DPTs, so then what we need to do we need to implement this gate drives, but properly for that particular device otherwise the characteristics which we will be achieving that may not be proper. So now impact on gate drive design. So we have to like understanding device characteristics is very important for proper gate drive design. So this characteristics means static characteristics. So initially we will be getting static characteristics and from there only we have to design this gate drives. So once we design the gate drives we can provide gate signal to DPT to get the dynamic characteristics. Now these gate drives must meet both static and dynamic requirements of the devices.

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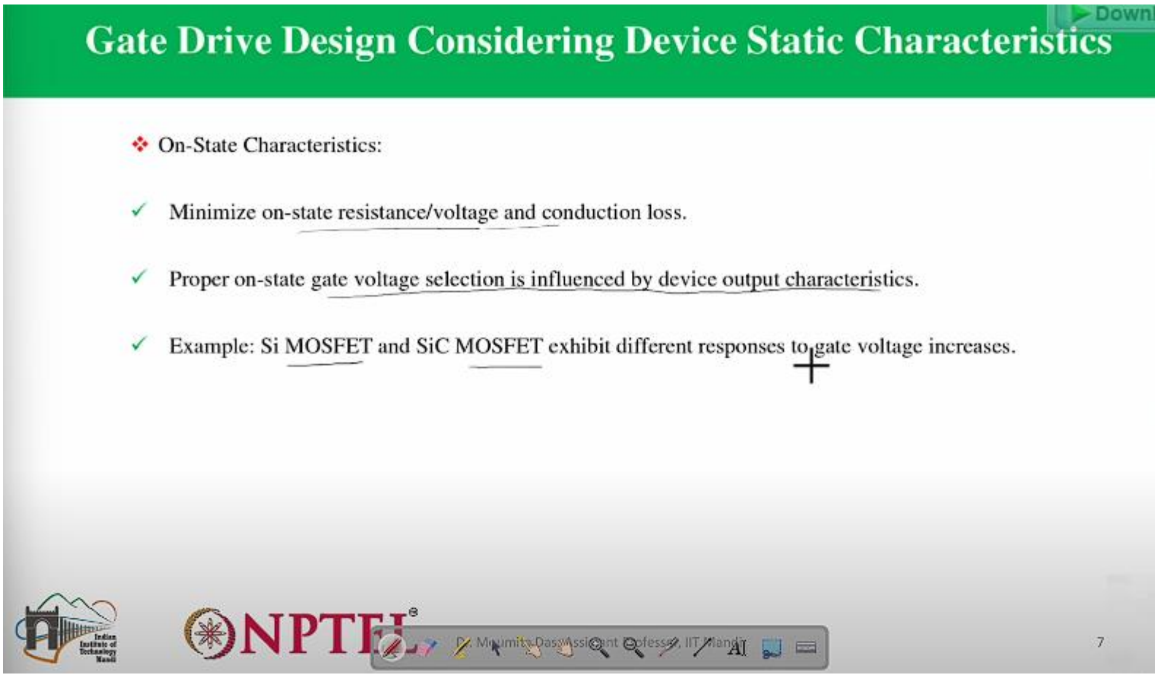

Once we have dynamic characteristics then what we have to do? We have to again optimize the design of the gate drive so that we can get optimal performance of the device. Now this gate drive on state characteristics should be such that it should minimize on state resistance or voltage so that conduction loss will be minimum. Now proper on state gate voltage selection is influenced by device output characteristics. This on state gate voltage selection is very important for any gate drives. For example silicon MOSFET and silicon carbide MOSFET exhibit different responses to gate voltage increases. That you have already seen from the static characteristics, dynamic characteristics, from everywhere you have seen how the characteristics looks like. So for each device the characteristics will be different. So based on that our design should be such that it should match that particular device.

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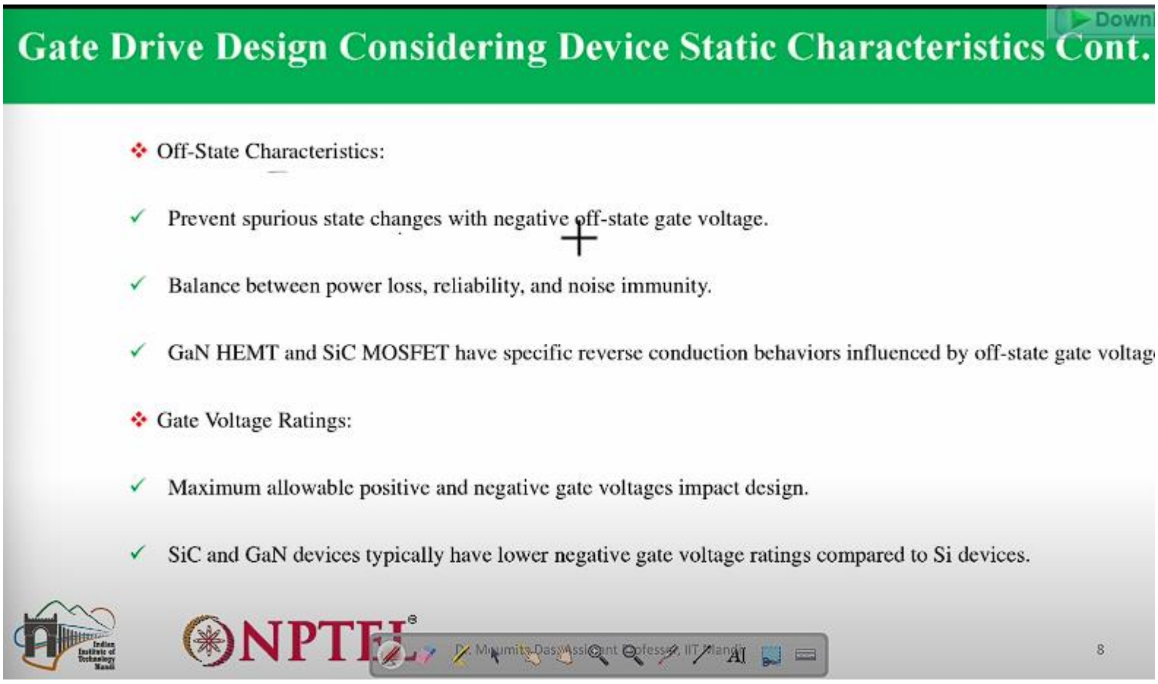

Now, OFF state characteristics, how it should be? So, to prevent this various state change with negative OFF state voltage, we have to actually design this gate drive signal properly. So, we have to balance between the power loss, reliability and noise immunity. This GaN device and silicon device have specific reverse conduction behavior which is influenced by OFF state gate voltages. So you have already seen so OFF state gate voltage we can either keep 0 or negative in case of GaN and silicon carbide. So now you have seen that if we keep 0 how this voltage or the characteristics will be during the reverse conduction and if we keep negative voltage then how it will be different during the reverse conduction. So based on that characteristics you can decide whether you want to keep OFF state voltage as zero or negative for any particular application. Now gate voltage rating, so basically maximum allowable positive and negative gate voltages it impact the design. So then we have to if we have only the positive voltage then the design will be different if we have like both positive and negative then the design should be such that it should be able to provide this both the power supplies. Then silicon carbide and GaN devices, it basically provided in the data sheet that it requires negative gate voltage as compared to silicon device which requires only positive gate voltage. So that is where main difference comes so basically the first thing is that power supply how much it should be during the on state and off state During ON state, for silicon and silicon carbide devices, they have the similar type of voltage level. But during OFF state, silicon carbide requires negative voltage, whereas silicon they don't need to provide, they don't have negative voltage requirement. So, there the difference is coming. And in case of GaN, anyway the voltage level is much lower than that of the silicon and silicon carbide and it requires negative gate voltage.

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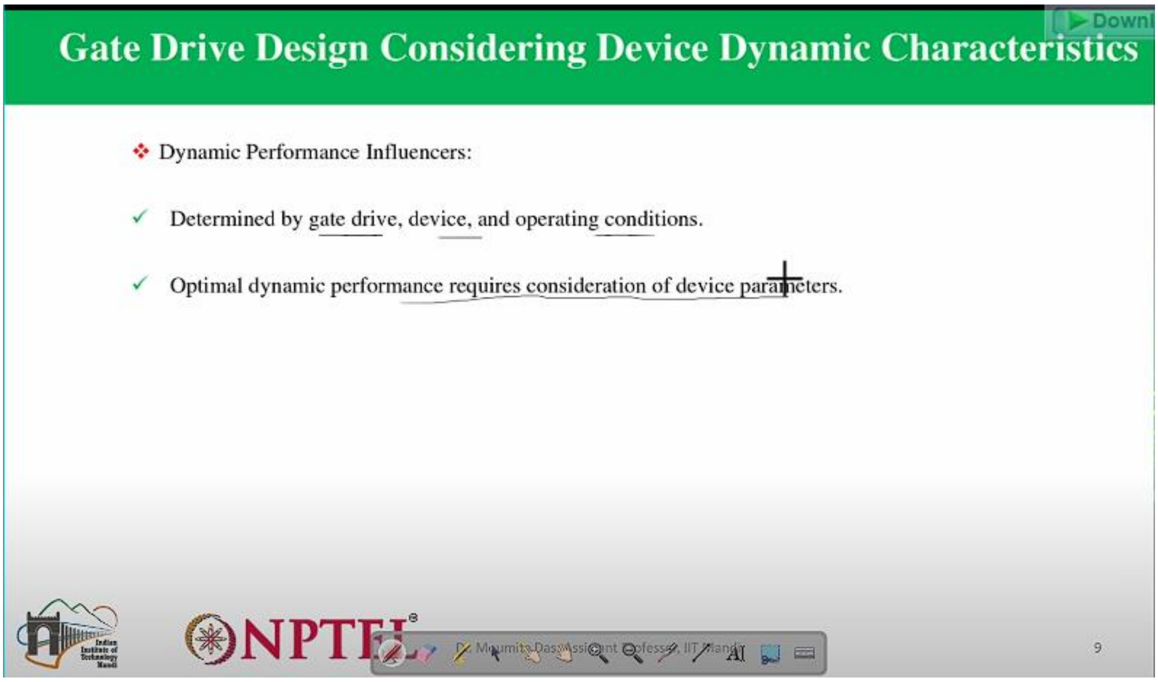

So, now the dynamic performance when we try to consider, so then what are the components effects and dynamic characteristics. So, this is determined by gate drive, device and operating conditions. Optimal dynamic performance require consideration of the device parameters. So, until and unless we have device parameter, we cannot have the optimum type of operation.

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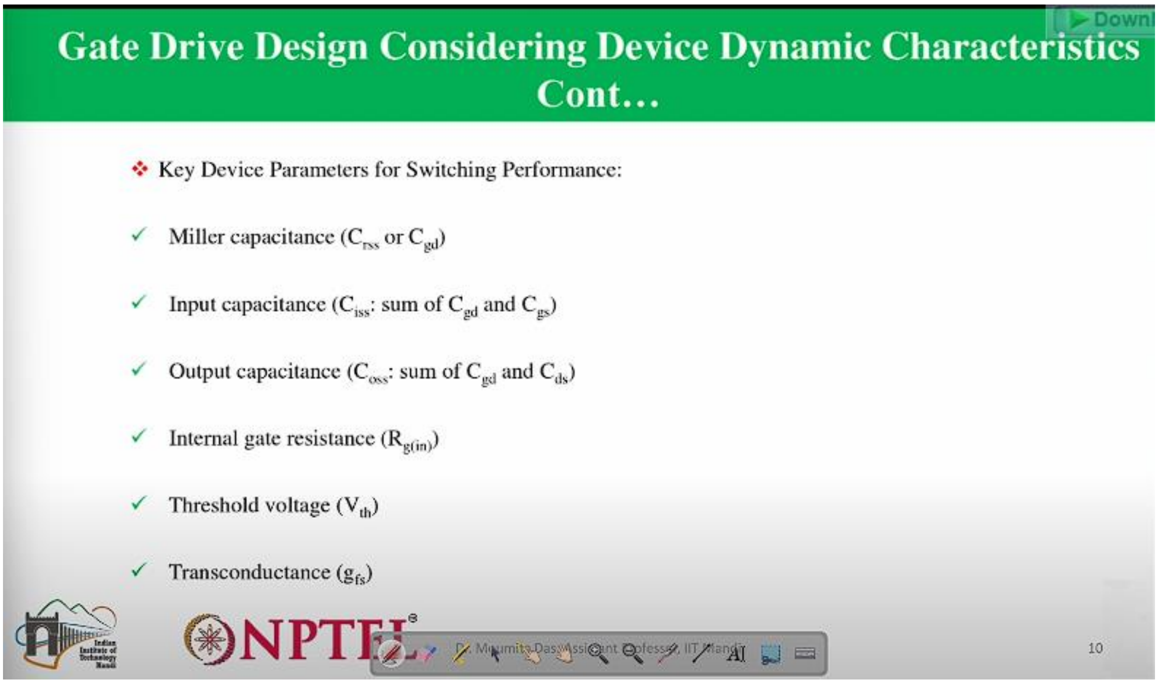

Now, these are the key parameters that we need for designing gate drives. So, what is this parameter? So, Miller capacitance, you have already seen Miller capacitance. So, basically that is the capacitance between gate to drain. So, this capacitance, you can actually get from that either from data sheet or you can actually also get your own capacitance. So, you have already seen how to get the value of the capacitance from the capacitance characterization. So, you can get input capacitance, so basically which is sum of the miller capacitance and gate to source capacitance and then output capacitance which is sum of the gate to drain and drain to source capacitance. So, there are three different capacitances are generally given in the data sheet, which you can you which you will get to see in terms of input capacitance, output capacitance, or reverse conduction capacitance or miller capacitance these are the three capacitors such capacitances are generally given in the data sheet. Now these capacitances you can take from data sheet, if it is given then very good, otherwise you characterize your device to get those capacitances. You can characterize based depending upon the temperature and suitable temperature you can select to get the appropriate value of the capacitor. So this capacitor then you can use for designing the gate drive circuit. So and another thing is the internal gate resistance, So what will be the internal gate resistance that also you can get from static characteristics, then the threshold voltage level and transconductance. So, these are all these components I have already discussed how to get these components. So, these components you need in order to design the gate drives. Once you have these components, then what you need to do?

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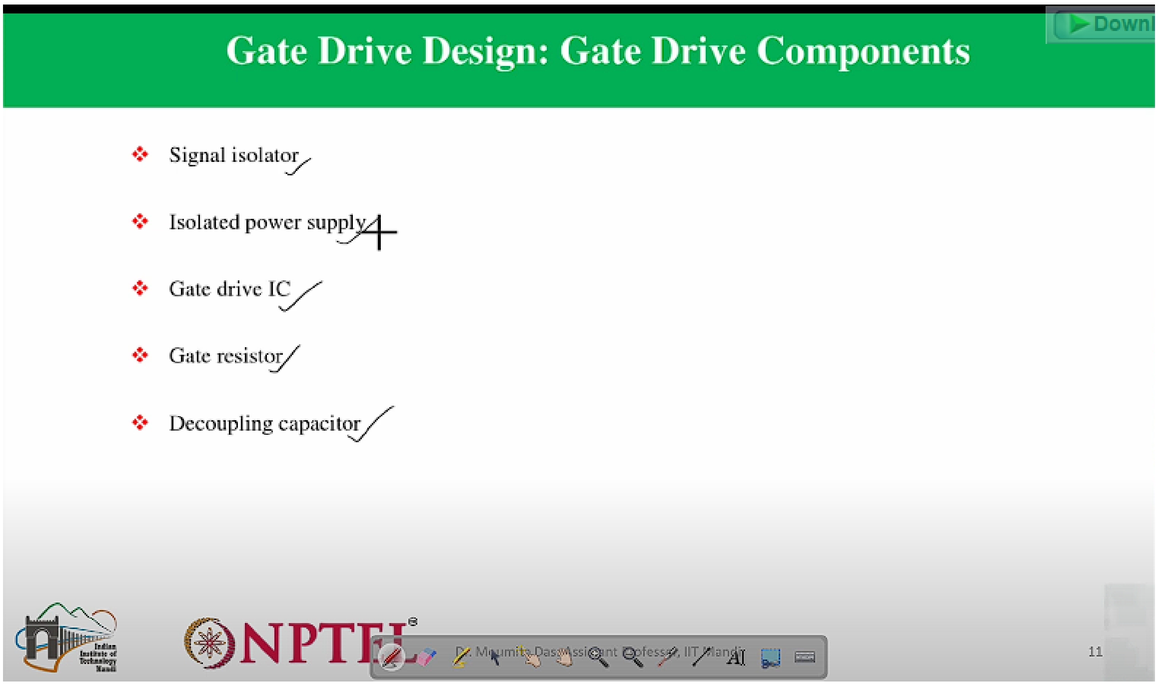

You have to design the gate drive and then you need these these different parameters. So, you can see signal isolator you have seen, isolated power supply and gate drive IC. These three components you have seen in basic block diagram. Then there will be gate resistor. and decoupling capacitor. So decoupling capacitors so that you can see in terms of the buffer circuit or other places wherever decoupling capacitors will be required that there you can connect. So these are the components of the gate drive and the parameter which you need from the particular device that I have shown in the previous slide. So, these things are required for designing the gate drives. So, how to design these different components of the gate drive like signal isolator, isolated power supply, what should be their rating that I will be discussing in details in the next lecture. Thank you. This is the reference for today's lecture.