Design of Power Electronic Converters
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Module: Gate Drivers
Lecture 29
Gate Drivers - Few Other Requirements

Welcome to the course on Design of Power Electronic Converters. So, till now we had covered several things about gate drivers, we discussed your fundamentals of gate drivers, your waveforms associated with gate drivers, how do you choose the gate resistor and also the power that is required for driving the gate emitter or the gate source region of the MOSFET or the IGBT. Then we looked into different types of driving, one is using optocoupler base gate drivers, then we also saw how we can incorporate protection inside gate drivers and then further we also saw bootstrapping method which is an inexpensive method of obtaining the floating supply. Then further we also looked into pulse transformer based gate drivers.

So, mostly this is what is required for you to design the gate driver region. Now, there are some other few things that you should be knowing before gate drivers designing and there are lot of information that you may be obtaining from various application notes and even if you google. So, there are a lot of things that you can go into it and study on your own but these are whatever I have covered are the things that you will require for your first design. Now, let us look into some of the other aspects which is important for your knowledge of gate drivers.

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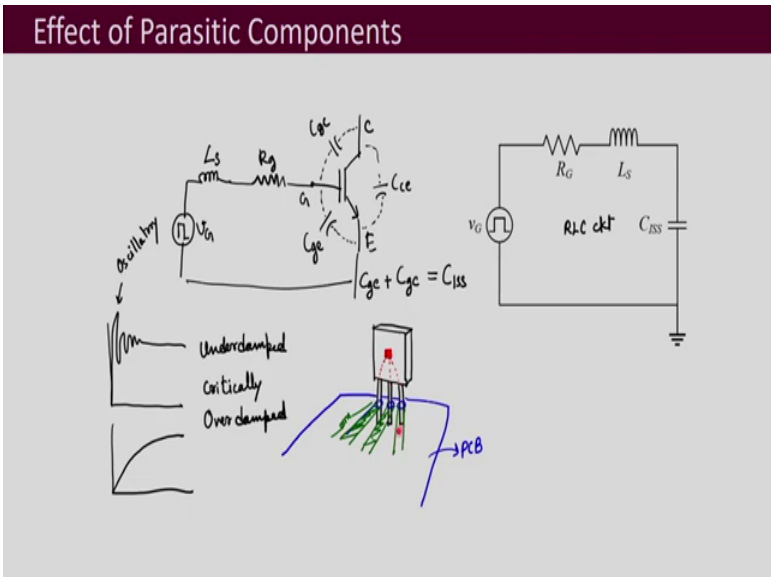

So, there are some parasitics that are associated there in your gate drive region. So, for that first of all a recall this IGBT or the MOSFET arrangement. So, here you have your this capacitor gate to emitter and then you have another capacitor between gate to collector, so this is your collector emitter and gate.

And then you also have a parasitic capacitance between your collector and emitter and over here you have your gate resistor R_G connected for driving the gate emitter region. Now, this is what we had drawn before many times and I had also shown you the pictures of MOSFETs in IGBTs and one of the simple ones let us say the discrete ones pictures that I had shown you, it some, it looked something like this.

So, you can see here there is these three legs are there and inside here you will have the chip of the IGBT inside and then through this lead wires this will be connected to these legs. So, obviously there will be some parasitic inductance that will be involved in this connections, in forming this connection and also this leg.

And then further what will happen is that that this is going to be let us say if it is being mounted on a PCB, let us say this is your PCB. So, here there will be these soldering pads will be there through which your MOSFET legs will go inside and then it will be soldered and it will be connected to these different different traces, PCB tracks that will be there.

So, this will have its own inductance and parasitic resistances, these connections. So, that means will have parasitic inductances associated with all of it. And so there will be parasitic capacitance which is what we are writing as L_S. And you can also further recall that your input capacitance was the sum of C_{ge} plus your gate to collector C_{gc} which is what we can call it as the C_{ISS}. So, that is your this C_{ISS}.

So, if we had to draw this as an equivalent circuit. So, here we have our whatever is the driver, the gate driver is going to give that is your V_G that is going to come and this is connected to the emitter. So, here what you see is that if you draw the equivalent circuit you can draw it like this, an RLC circuit.

And you know that RLC circuit you can have this kind of a response, an oscillatory response, if it is underdamped. And you know that your RLC circuits they can be underdamped or critically damped or they can be over damped as well.

So, if you have critically damped then or if you have over damps so the responses are like this. Now, this critically damped is something very difficult to achieve because that means your L_S and C_{ISS} values with respect to the R_G value are perfect enough to achieve critical damping. But usually what happens is this L_S cannot be determined very accurately, it is just estimated, this values are very difficult to estimate also. And your this C_{ISS} also we had seen it that this is something dependent on this voltage this is a variable, this is not a fixed value.

So, critical damping is something you do not expect practically. If you increase this gate resistor R_G value too much then you may be able to achieve over damping but then the moment you have over damping what will happen is that this your this circuit will become slow, because your, it will take more time for it to go to its steady state value.

So, this is a slow response under damping is fast response but then there is going to be oscillations. And depending on these values of your R_G, L_S and C_{ISS} how much is, what is the frequency of oscillation and how high these oscillations are going that will be all dependent on that. And so, then we have to be careful that this oscillatory response is not damaging but this region first of all the spikes should not be very high and second these oscillations are not distorting the power electronic circuit operation or the other turn on and turn off waveforms. So, now how you can do that?

You can do it by changing this gate resistor R_G value what you have in your hand is the control of the R_G. Of course, this L_S and your C_{ISS} are not in your hands but R_G is something you can change, you can play with it to some extent. So, there you have to balance that this oscillatory response is not too much and at the same time you are not making the turn on and turn off slower. So, this is something you should be aware of.

And one of the ways of reducing this L_S is that this gate emitter region the PCB design the layout that is to be performed that has to be such that the driver is placed as close as possible to the gate and the emitter points, the wiring there that means the length of the traces should be as small as possible and as small and as straight as possible so that your L_S is small enough.

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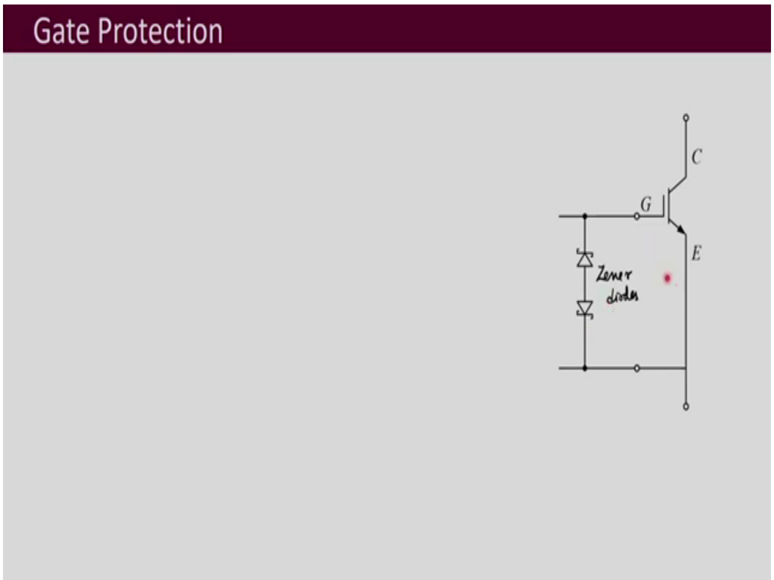

Now, as I told you that there can be oscillations in this gate emitter region and then there may be some spikes also, some transients that may be coming up which may damage this gate emitter, so we should also think of some protection. And one of the protection that is given is by using these Zener diodes. So, your this Zener diodes are used, two back to back Zener diodes. So, you have to choose the proper voltage of the Zener diodes. And then that will be able to chip off any of those spikes that may be going to the gate emitter region.

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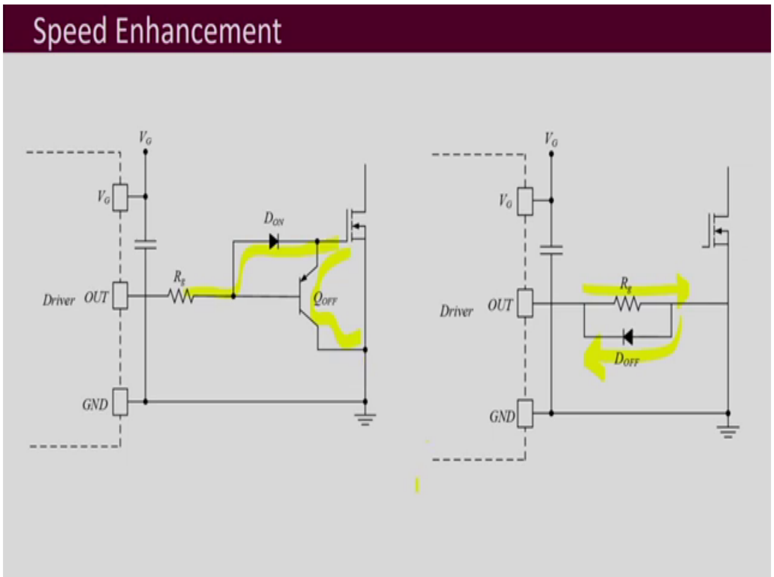

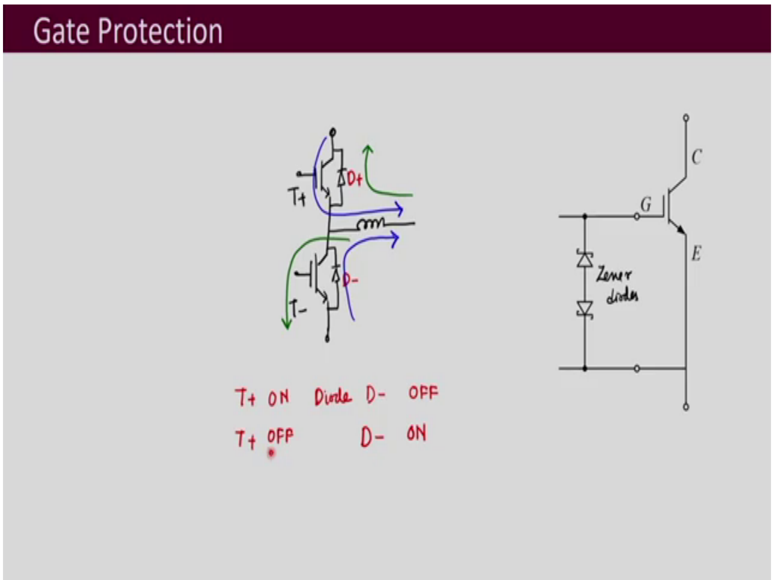

Now, let us look into some of the ways of enhancing the speed of turn on and turn off. So, for that recall this one leg of the H bridge, let us call this as T plus and this is T minus now this I had discussed before as well but for you to be able to connect what I am telling let us look into it again.

So, you may recall that I had told you that when your T plus is going to be on at that time your diode, this diode let us give this the name D minus and this is D plus, your D minus is going to turn off. So, what is happening is that when T plus is carrying the current if this current direction is positive when T plus turns on at that time this the positive direction of current is carried by T plus.

And when T minus is turned on at that time the positive direction of current is carried by D minus and when the direction of the current is opposite that means if it is negative if T plus is turned on at that time the current is carried by the diode D plus and when T minus is turned on at that time the current is carried by T minus if it is negative direction of current.

So, what we observe is that that turn on of T plus is associated with turn off of diode D minus and similarly your T plus off is associated with D minus on and so forth. So, your transistor on is associated with diode off or transistor off is associated with diode on. Now, if you recall that when we had discussed the switching characteristics I told you that it is the turn off process which is slower than the turn on process for almost I mean most of the devices for the diode as well you have the reverse recovery current in the reverse recovery charge which has to be wiped out.

So, it is little slower than you turn on, it is the turn on diode is not a problem it is a turn off of the diode which is more of a problem. And similarly, for your IGBTs also you saw that you have the tail currents during turn off and then your turns offs are slower. So, when we are using gate drivers for your MOSFETs or IGBTs even if you speed up the turn on, you do not get much benefit because it is going to be dominated by the turn off of the diode.

Now, turn off of the diode you cannot do much about it. Once you have selected the diode, so whatever is it is done of times are there so that will be there. So, even if you are increasing the turn on speed it will not help because it is dominated by the diode turn off. So, turning is increasing the speed of turn on is something is not done in gate drivers.

Whereas, when we see the turn off of the transistor then it is in associated with turn on of the diode and turn on times are usually smaller, so it is the turn off of the IGBT or the MOSFET which will be dominating and so if we increase the speed of turn off by using a proper gate circuit so then that will have some benefit.

So, that is why when we do speed enhancement using gate drivers so we enhance the speed of turn off and not of turn on. So, what are the arrangements that can be used there are many many different arrangements that people use I am giving you examples, so two simple examples of how you can increase the turnoff speed.

So, here what is being done you can see here in this simple case this R_G is going to be used while turning on and at that time this diode is going to be off and when this device is going to turn off at that time this diode will conduct and this current will flow through this diode D off, it is the gate resistor which usually slows down the turn on and turn off, if you increase the value of gate resistor then your turn on turn offs will be a times will be higher, if you reduce it then it will be lower.

So, that is why here if you use diode you get rid of this R G then your turn off will be faster, many times we will also use another value of gate resistor also, higher value of gate resistor in turn on and lower value of gate resistor during turn off. So, that is one of the simple ways of increasing the turn off speed.

Another way is that you can have this kind of an arrangement where this R_G is being used and it flows through during turn on this current flows through this diode D on this is the path of turn on and while it turns off it actually discharges quickly through this transistor Q off and so that is how this R_G is eliminated during turn off and it leads to faster turn off, so these are two a very simple methods of enhancing your turn off.

But you have to be careful that your whatever arrangement that you are using that is not creating other issues during your turn on or turn off or they are not reducing your noise immunity, so all those things you have to be careful before using this speed enhancement method, there are various other methods are there and some of the gate drivers that you can buy, so they also have those features incorporated inside them. So, study the data sheets look into it what is the arrangement inside it and it is not creating any other issue I mean for your normal operation and it is beneficial enough for you to increase your turn off speed.

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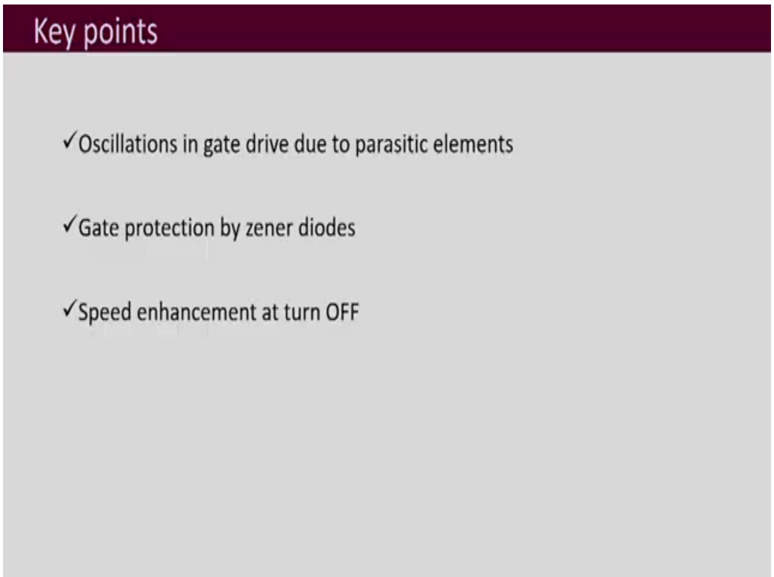

So, the key points of this lecture is that there are oscillations in gate driver region because of the parasitics and to some extent you can control it by changing the value of R G and these what are the values of this parasitic, how do you determine this parasitic inductance and capacitance values.

One is capacitance of course you get some idea by looking into the data sheet of the IGBT or the MOSFET and this L_S to some extent you can get an idea by actually using some value of R_G and practically doing the experiment and seeing on the oscilloscope the nature of the waveform and then you can measure the frequency, there of the oscillations and from there you can estimate what could be your parasitic inductance and capacitance values. And then you can change this R_G value and then see how much does it has an effect on the oscillations.

And then you also should be protecting the gate region and it is usually done by connecting to Zener diodes in the gate region. And to increase the turn off speed you can do some special arrangements. So, you can use some speed enhancement method, it is the turn off time which can be decreased by using your gate drive arrangements, but the turn on times are not decreased, that means speed is not increased, turn on speed is not increased by gate drive arrangements. Thank you.