Design of Power Electronic Converters
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Module: Gate Drivers
Lecture 28
Pulse Transformer based Gate Drivers

Welcome back to the course on Design of Power Electronic Converters. We were discussing gate drivers. And today we will look into another type of gate driver which is called as the pulse transformer-based gate drivers. So, before this we had discussed your optocoupler based gate drivers, now optocoupler based gate drivers are based on optical isolation and they give you capacitive coupling between the input and the output. But when we want isolation which I said is one of the primary requirements of gate drivers is isolation.

So, that isolation when we want to have it the first thing that will come into your mind is magnetic isolation and that is of using a transformer. So, you may be wondering that why not use a transformer for gate drivers. So, of course, it is used for your gate drivers as well, your magnetic isolation and so it will be giving you an inductive coupling between the input and output. And so how it is used, what are the challenges in it and what are the advantages of it, let us look into it.

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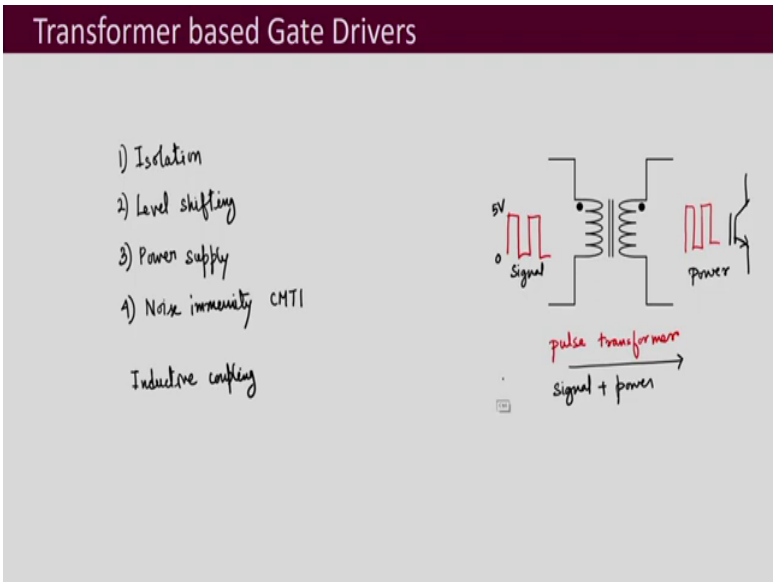

So, transformer-based gate drivers of course you will have a transformer and on the input side you will be giving pulses like this and output side also you are supposed to obtain pulses of this nature and so that is why this is also called as a pulse transformer. Now, when we use

transformers there are several things that come inherent with it, that is one is that, that is it gives you isolation, it gives you magnetic isolations between the primary and the secondary.

Next requirement of your gate drivers is level shifting so that also is something very easy to do in case of your transformers. You can have one voltage levels on the primary side, you can have another voltage levels on the secondary side, you stepping up and stepping down is very easy if we use transformers. So, level shifting is very easy.

Then next is that your power supply you do not need another power supply, you do not need a separate DC to DC converter to supply your gate drive requirements. You can transmit signal as well as power using this transformer. So, that means you have this, this is your signal plus whatever is the when you have your this kind of a MOSFET or an IGBT whatever is the gate drive requirement the power requirement here. So, both of it your signal plus power that can be transferred through this transformer. So, your power supply you do not need I mean the separate one is not required if you are using transformer.

Then next is that your noise immunity is also something which is needed, good noise immunity is needed that is your CMTI levels that is something a requirement for your gate drivers, so that also is good for your transformers. So, it has got several advantages and instead of capacitive coupling as in case of optocoupler based gate drivers here you have inductive coupling.

Well, there may be parasitic capacitances involved based on the frequency, switching frequency but usually you will, I mean inductive coupling is what you expect more in case of your pulse transformers. Now, when we are using transformers one of the problem with transformer is that it only allows AC to be passed through it, if you are going to give DC to a transformer so then you know that it is going to get saturated.

And the very basis of operation of transformers is that AC is given in the primary and that is what then stepped up, or step down and we obtained on the secondary side. But when we see these kind of signals that has to be given to the gate they have your DC also in them. So, just may be from 0 to 5 volt let us say so this has got DC also inside it, but DC is not allowed. So, then what is the solution, what can we do?

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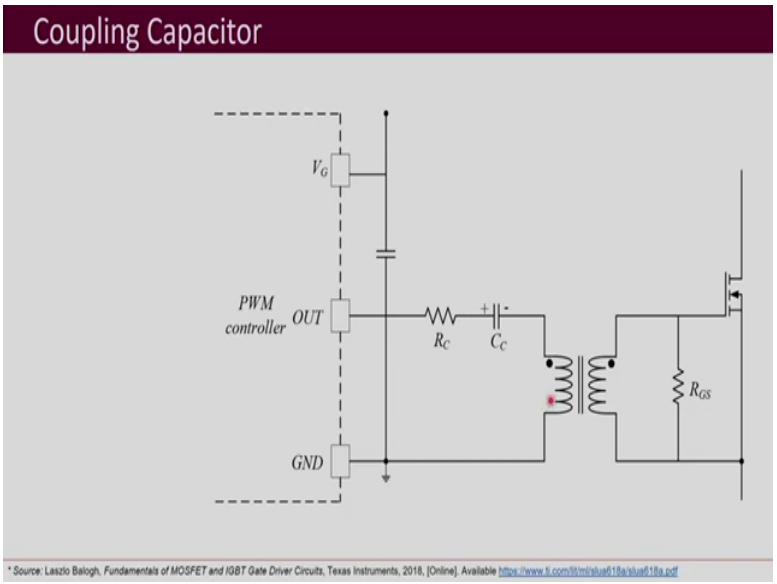

So, for that what is done is that people use this capacitor, this coupling capacitor. So, if we have a capacitor before this primary side of the transformer what will happen is that that only the AC this will be passed, this capacitor will not allow the DC to go on and applied to the primary side only AC will be applied. So, your this problem of DC going into the transformer is solved by this coupling capacitor. But now there is a another problem that comes up when we use this coupling capacitor that is there it becomes a dependent, this operation becomes dependent on the duty ratio what is the level of the duty ratio.

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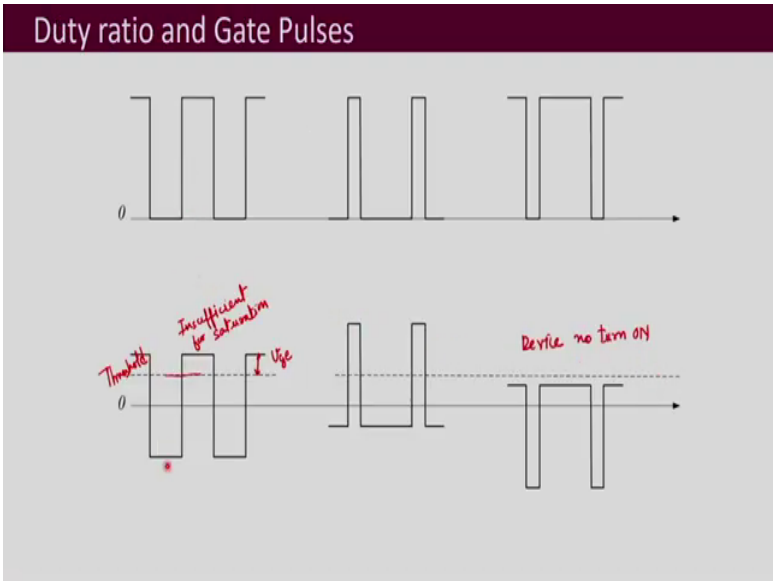

So, let us see that. So, let us say these are your gate pulses and here you see a 50 percent duty ratio. Now, what will happen is that when you subtract the DC out of it so if you are

subtracting the DC out of it this is what it is going to become. Now, here somewhere here you may be having your threshold, so if this is your level of your threshold and this so what is left out after the threshold is this much.

Now, this voltage, gate to emitter voltage whatever we are going to give, this may not be sufficient to drive the IGBT or the MOSFET into saturation. So, insufficient for saturation, this may happen. And if it is insufficient for it to drive the MOSFET or the IGBT into saturation then it will tend to work in active region and then huge amount of losses will take place.

So, this is one problem that we see and is something dependent on the duty ratio. Then let us say if your duty ratio is small, less, and then if you subtract the DC out of it then this is what is you may be getting and here you may see that then everything is okay, it may be sufficient enough to drive it into your saturation region and things may work all right.

Now, let us say if you have high duty ratios, it is much greater than 50 percent. Then if you subtract DC out of it and if you just want the AC in it so this is what you may be getting and here you can see that this is smaller than threshold, so your device may not turn on at all. So, here device no turn on and that means you will be not getting the turn on and turn off as you are, as you want because of your high duty ratio.

So, what we observe here is that that your operation is becoming duty ratio dependent when proper operation will take place and when proper operation will not take place that is something dependent on what is the duty ratio that is provided by the PWM controller, when we use this capacitance to remove the DC and pass the AC to the transformer. So, this is a problem and how to solve it?

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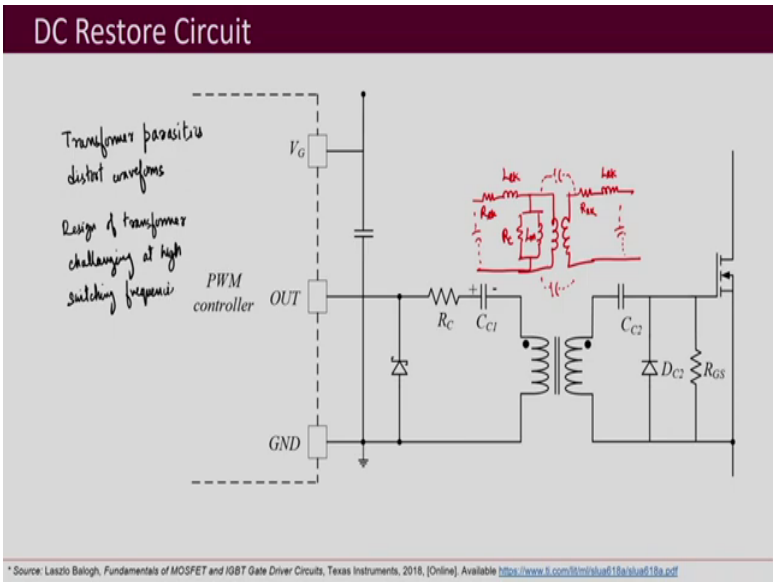

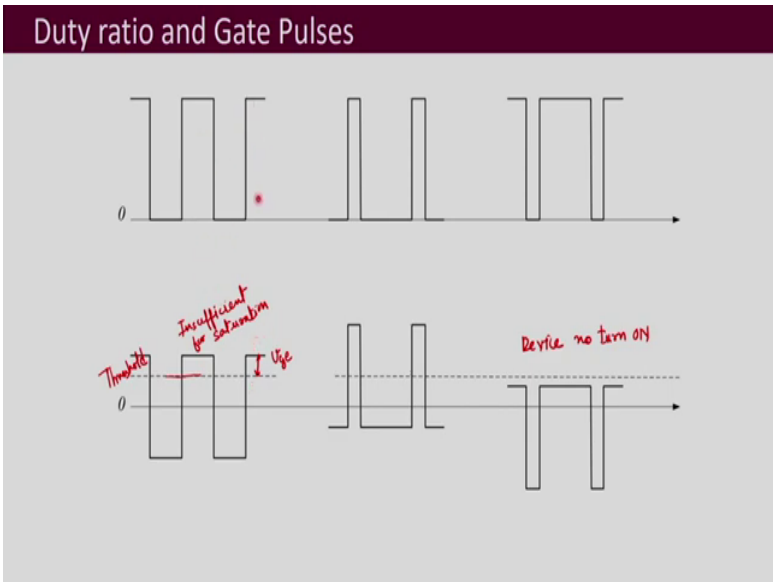

So, people have solved it by what is called as the DC restore circuit. So, what they do is that on the other side they again put a capacitor and you can also have a diode and so that will restore the gate pulse back to its original shape. So, here you have this arrangement after removing the DC and then the DC restore circuit will make the gate pulse similar to what it was originally.

So, that solves the problem and eliminates the issues that arise and the limitations that happens because of the value of the duty ratio. So, by this arrangement your pulse transformers are used and it works very well and as I told you that there are several advantages of using pulse transformer based gate drivers that you do not need a floating supply, you do not need a separate DC supply both the power and the signal can be

transferred through the pulse transformer itself and you get a very good noise immunity also because your transformers have that good levels of noise immunity.

But then there are certain challenges as well and that challenge is associated with the design of this transformer. As the power levels increase especially when your switching frequency increases this parasitics of the transformer they tend to dominate. You have studied the equivalence circuit of transformers and you have seen that that it has got your inductances and your resistances if you have forgotten that you may recall your 50 hertz transformer this is the equivalent circuit that you might have studied.

These are your leakage inductances on the primary and the secondary side, this may be different. And then this is your core resistance and then this is your magnetizing inductance LM and then you have also got the parasitic resistances there. And as your switching frequency increases if it becomes very high then we may also get capacitive, parasitic capacitances also inter winding capacitances may be there.

So, that also may be coming but that usually happens at much higher frequencies then for which presently the converters are being used. So, capacitive, parasitic capacitances still are not given that much importance for pulse transformers but as your this silicon carbide devices and gallium nitrate devices are taking over your power electronic converters then your switching frequencies may become so high that your capacitances may also, parasitic capacitances of transformer may also become important.

So, overall what you have is your switching frequency is increasing your effect of parasitics are going to increase and that may distort the gate pulse waveforms and that is undesirable. So, designing the transformers such that these parasitics are very less that is a challenge.

So, that is one of the main challenge of using your pulse transformer, your design has to be very good. So, let me just write down here. So, transformer parasitics, this can distort your waveforms and that is undesirable and so design of transformer is a challenge especially at high frequencies.

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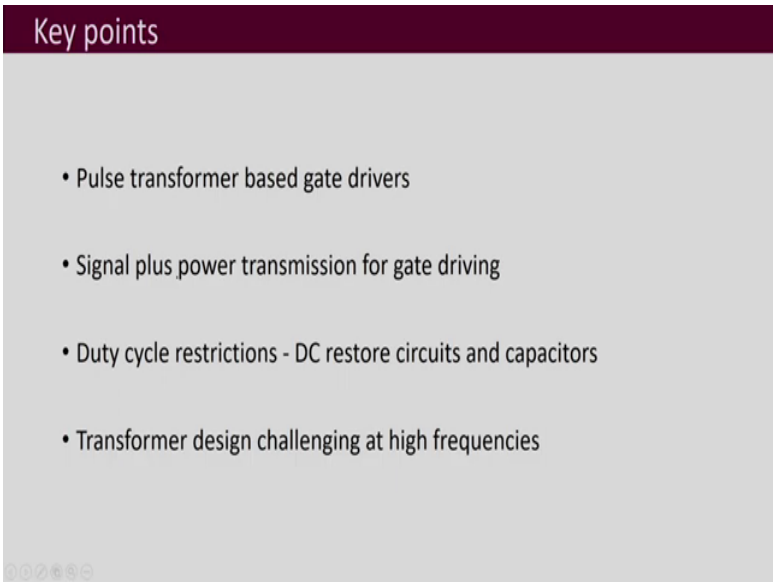

So, the key points of this lecture, your pulse transformer-based gate drivers are also used for power electronic applications and they have several advantages like signal plus power both can be transferred, transmitted through the driver, through the transformer, you do not need any separate floating supply. And then it can have duty cycle restriction if you do not use the capacitive coupling and the DC restore circuit but usually they are used and so that eliminates that problem. But it has also that challenge of designing the transformer properly so that parasitic effects do not dominate for high switching frequencies. Thank you.