Design of Power Electronic Converters
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Module: Gate Drivers
Lecture 24
Optocoupler Based Gate Drivers - I

Welcome to the course on Design of Power Electronic Converters. So, we had started with the module on gate drivers and we saw the introduction to gate drivers. So, what is gate driver, what is the need of it, what does it require to do and then we also saw some equations related to estimation of a gate driver requirements means power requirements and current and voltage requirements.

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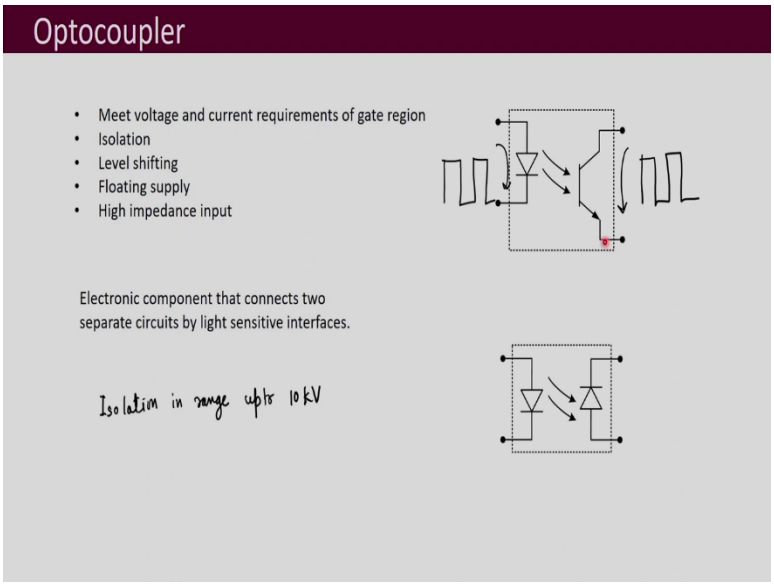

Now, today, we will be discussing the first type of gate driver which is optocoupler based gate driver. So, previous lectures I had told you about the requirements of gate drivers. So, what it needs to do is that it meets the voltage and current requirements of gate emitter or source region.

Then it needs to provide isolation then this isolation can be of different form it may be an optical isolation or it may be magnetic isolation and then it needs to do level shifting, it should be able to work with floating supplies and it should also be able to give high impedance input. So, these were the main requirements that we had seen for gate driver circuits.

Now, so, there are various different types of gate drivers. And in this course, we will not be discussing all of them, we will be discussing only the ones which are widely used and the first among them is optocoupler based gate driver. So, what is an optocoupler? You might have heard this term before, it is basically an electronic component that connects to separate circuit by using light sensitive interfaces.

So, basically you have a photodiode or you can say that a light emitting diode which when turned on is going to emit light and then on the other side, you may be having a transistor or diode which is again light sensitive, a photosensitive device. So, for example, here this kind of an optocoupler, what is going to happen is whenever this light is emitted over here, then this transistor starts to conduct because it falls into its base region and then it conducts.

So, what we have there is when you give a gate pulse like this, so, whenever this is high this gets turned on it starts to conduct and then because of this light emitting diode, this transistor gets forward biased and this also starts to conduct. So, that is how you get also a signal over here.

Now, this is one configuration, there are other configurations as well this is another configuration where the coupling is via two photosensitive diodes. Now, these are photosensitive diodes, these usually operate in the reverse biased region. Now, we will not be discussing too much about this optical isolation and about the photodiodes details, you can read all these things on your own. If you google you will get a lot of information about all these things.

So, just know that what is important for this course to understand is that this optocoupler based gate drivers they use optocouplers and these are optocouplers which are generally used and they provide optical isolation and this isolation usually is in the range of up to 10 kV.

So, the first requirement of voltage and current requirements of gate region that yet does not seem to be satisfied just by using this kind of an optocoupler, but optical isolation can be provided and when we say level shifting, this can be connected to different voltage levels. So, level shifting should be possible that you are able to see somewhat, but you do not see the voltage and current requirements of gate region can be made by just this kind of a transistor or diode. So, then what has to be done for that?

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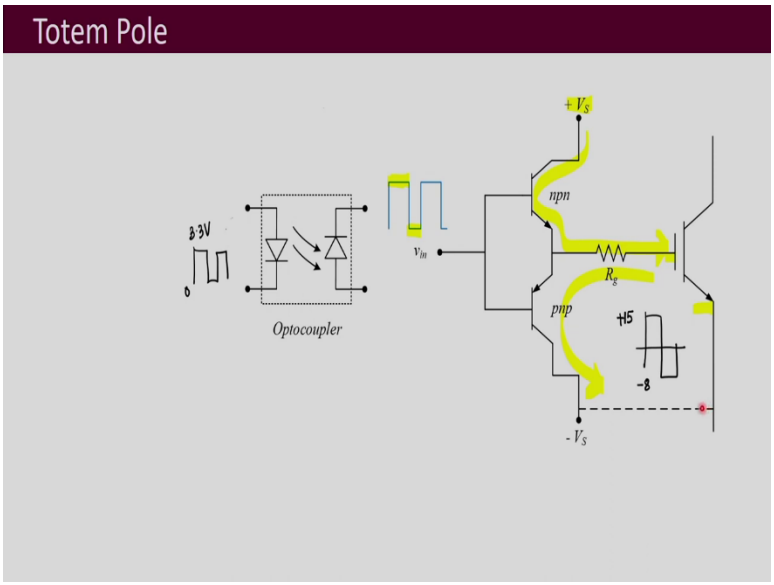

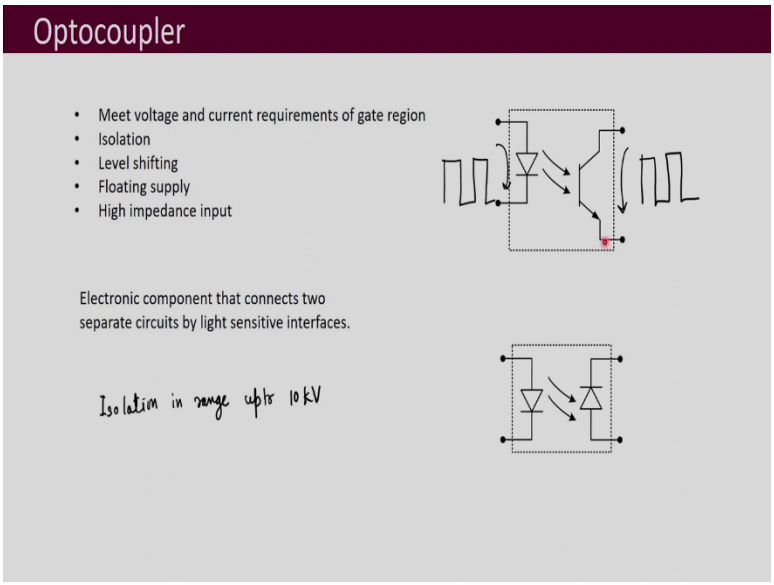

So, for that what people use is what is called as a totem pole. So, you have this kind of an optocoupler and then this optocoupler's pulse whatever it comes on the output side that is given to this totem pole, it is a combination of a npn and pnp transistor. And so, you can see here that whenever this pulse is high, it is given to both of them since, this is npn, npn means whenever this is high, this is going to conduct.

And pnp if the base is high then that is not going to conduct it will be in the cut-off. So, therefore, then what will happen is that whenever the gate pulse is high, this is high. So, this

starts to conduct and the current flows like this. So, that is how we can turn on this IGBT and then we can connect we can make this V_s as whatever is required by this gate emitter region.

And this can be a transistor which have the ability to supply the current that is required by this gate emitter region. Then next when this gate pulse goes low over here, so, at that time what happens is that, low means pnp will start to conduct and npn will go into cut off. So, then what will happen if pnp conducts means the direction of the current is going to be like this, that means, when we want to turn off this IGBT then the pulse goes low and this pnp will be able to sync whatever was this gate emitter region charge that was there with the help of this gate current I_G.

So, if we just choose proper totem pole transistors npn and pnp as per the requirement of the gate emitter regions, I_G requirements, the gate current requirement then we have the current source and sink ability and we also have to choose the $+V_s$ and $-V_s$ according to the gate emitter regions requirement.

So, then we are able to meet the voltage and current requirements of the gate emitter or gate source region. So, the first requirement of driver is also met and we also have the optical isolation and plus another thing is that the level shifting that over here levels may be very small it may be let us say from 0 to 3.3 V and over here we may require something like let us say +15 V and - 8 V.

So, that also is obtained. So, level shifting is also obtained and this usually will not be needing very large amount of current. So, high input impedance is also obtained. And over here this is whatever is the supply that is given that is with respect to this emitter in this then if we have a separate floating power supply then this kind of a driver will also be able to work with floating supply.

So, all these requirements that we saw can be met by these kinds of an arrangement with optocoupler plus totem pole combination. So, over here now, what we see is that this voltage that we provide that has to be with respect to this emitter or the source in case of MOSFET. So, we need floating supply.

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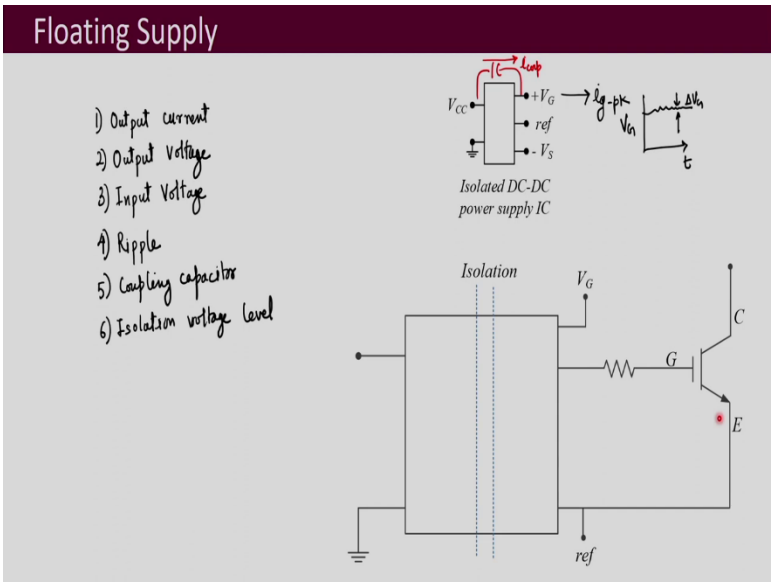

So, then we have to have an arrangement to be able to obtain floating supply. So, that is again shown here. So, this is isolation. This is basically gate driver which provides in case of optic optocoupler based gate driver you have the optical isolation plus you will be having the totem pole.

And then this is gate emitter region and this IC will be given the supply using a floating source whose reference will be this emitter region, then there are different ways by which floating supplies are obtained. One of the ways is using isolated DC to DC power supply IC's. So, what are these IC's these basically contains isolated DC to DC converters inside them, you might have studied them before flyback converter, forward converter, push pull and so forth.

So, those kind of isolated DC to DC converters may be inside one IC and then those ICs are available as power supply ICs and you can use them for gate drivers. This is one of the ways, another way is that you may not use ready-made IC but you can make a floating power supply of your own, you can make a small isolated DC to DC converter of your own using half bridge configuration or full bridge configuration, whatever is suitable for based on auxiliary circuits whatever may be available for your design.

And then there are other methods also where the floating supply may be generated using what is called as a bootstrapping method which we will be discussing later on. So, there could be various ways of obtaining the floating supply and but for this optocoupler based gate drivers you have to

have an arrangement to generate the floating supply if converter has position of IGBT's or MOSFET such that the emitter or the source point floats for some of the IGBT or MOSFET.

So, now, what are these isolated DC to DC power supply IC? Usually, they will have input side where you can give whatever supply that may be specified in the data sheet of that IC, this may be a low voltage or medium voltage whatever voltage 5 V, 10 V that will be specified by the manufacturer.

And then usually they will have this kind of 3 output terminals, where you have $+V_G$ that means +15 V or 18 V, 20 V whatever is required by this power electronic device. Then it will have the reference that is common with respect to this $+V_G$ and then usually they may be also having a negative output with respect to the reference. Because many times these IGBTs or MOSFETs they are given a negative voltage to turn off. And these power supply ICs are especially made to be used for drivers.

So, now, let us look into what are the important specifications of these floating power supply ICs. So, one important specification is the output current. Now, output current, why is it important? Because whatever is the output current that this will be providing that is what should be sufficient to be able to meet the $I_{G(peak)}$. So, output current specification of this IC should be greater than $I_{G(peak)}$ that you will estimate for your gate driver.

Then the output voltage. So, when you choose this power supply IC the V_G should be sufficient enough to be able to drive this gate emitter region. So, you should also check for the output voltage then of course, this input voltage V_{CC} also you should be checking because this also has to be given by some means to the PCB that you are going to use. So, this also has to be checked in.

Then further, what is important is to look for the ripple in the output voltage. Now, why is this ripple important? Because if you have this V_G and let us say this V_G has got some kind of ripple. Now, whatever is this ripple that is there that is going to affect this driver circuit and this is usually a very sensitive circuit. Driver is actually the most important part of the power electronic design, if in the driver's design in that PCB layout everything is not proper, then it leads to lot of electromagnetic interference issues and you will see lot of unexpected things happening sometimes it starts sometimes it suddenly turns off.

So, I mean it becomes very sensitive to noise. So, that is why this ripple in the voltage plays a very important role of this floating supply it should be as stable as possible as much ripple free as possible. So, the ripple content in V_G you should be checking for the power supply ICs, whatever you are going to use.

Then next one is coupling capacitor. Now, what happens is that you have a coupling between the input and the output. Now, this is coupling capacitor then is a parasitic, it is unwanted, but it is there you cannot really 100% get rid of it, but it should be as low as possible.

And this is a problem and it leads to a lot of common mode currents and interferences. Those things we will be looking into later on in the course, but note that this coupling capacitor is what appears between the input and the output and it should be as low as possible. Because there is always going to be a coupling current you can call it as I_{coup}. So, that is an unwanted current and it basically is going to reduce the isolation level and it will also lead to interference problems.

And next one is isolation voltage, you have to check for the isolation level 10 kV, 5 kV what is the isolation voltage level up to which this IC that you are going to use it provides the isolation.

Because then if it is not going to give you isolation for the voltage range for which you are going to use IGBT's then basically you have an isolated power supply IC but it will not be useful for you. So, that isolation voltage level also you should be checking for. And there may be several other parameters that may be given in the datasheet of these power supply IC. So, that you can look into it but these are the important ones, which you should be looking for while choosing that power supply IC for your design.

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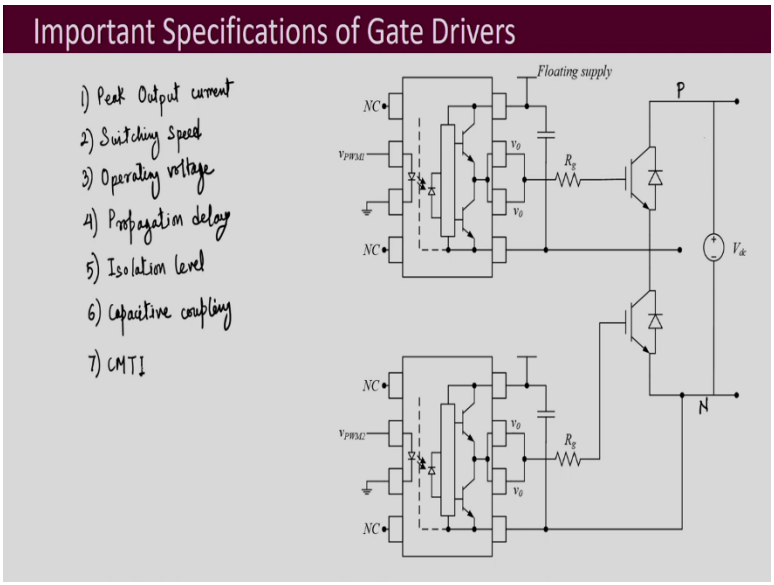

Next, let us look into the important specifications of gate drivers. For that I have taken this example of one leg of an H bridge and this is optocoupler based gate driver where you have this optocoupler and then this totem pole arrangement is also there. Now, what you have over here on this side is the PWM inputs that is going to be coming, PWM_1 and PWM_2 for these two IGBT's.

And then the output is going to be appearing on this v_o point. Now two of them have the same v_o this is how usually the ICs are made, two of them have output voltages and they have to be connected together. And then using this gate resistor this is connected to the gate of the IGBTs.

And they know one of this is reference, this is N the negative bus and this is P the positive bus now, this is not floating. So, reference of this lower driver is fixed it does not float. So, you do not need a floating supply over here, a fixed supply will do. Whereas, over here for this point you have emitter point to be floating this we have seen before. So, you need a floating supply over here.

So, for this driver you need a floating supply. And as we had also seen before this is called the high side driver and this is called as the low side driver. Now, what are the important specifications that you should be looking for choosing this gate driver? So, those the first one is of course, peak output current. Peak output current last lecture we saw how to calculate the peak output current requirement for turning on or turning off this IGBT's and MOSFET. So, gate

driver whatever you choose should be able to supply the peak output current. So, peak output current of this driver should be greater than what you obtain here as $\frac{V_G}{R_g}$.

Second is the switching speed, you have a certain requirement of switching frequency let us say 50 kHz or 100 kHz whatever. So, drivers should be able to switch at that frequency, those bridging speeds specification of the gate driver should be greater than the switching frequency that you will be choosing for your design.

Next is operating voltage. Now, operating voltage this V_G level that whatever you provide here that should be sufficient enough for this gate emitter region to be driven. So, this voltage has to be proper. Next is this V_{PWM1}, whatever the voltage it can allow it should be compatible with whatever controller you are using that controller whatever voltage it is giving as output 3.3 V, 5 V or whatever other voltage it is giving that much input voltage this driver should be able to allow.

So, operating voltages of the gate driver IC also you should be checking for. Then next you should look for propagation delay, this is something which will be explained to you little later. Then is isolation level. This of course is going to be important because for optocoupler based driver or any other driver you are using if you are providing isolation what is the level of isolation that you should be checking for.

Then is capacitive coupling. Now, as I told you for floating power supply IC similarly for optocoupler based gate drivers also you will be having this coupling capacitor between this input side and output side. So, that also you have to check what is the capacitive coupling it should not be too high. And next one is CMTI common mode transient immunity this also I will explain you little later. So, these are the important specifications of gate drivers of which you should be careful for while selecting the optocoupler based gate driver IC.

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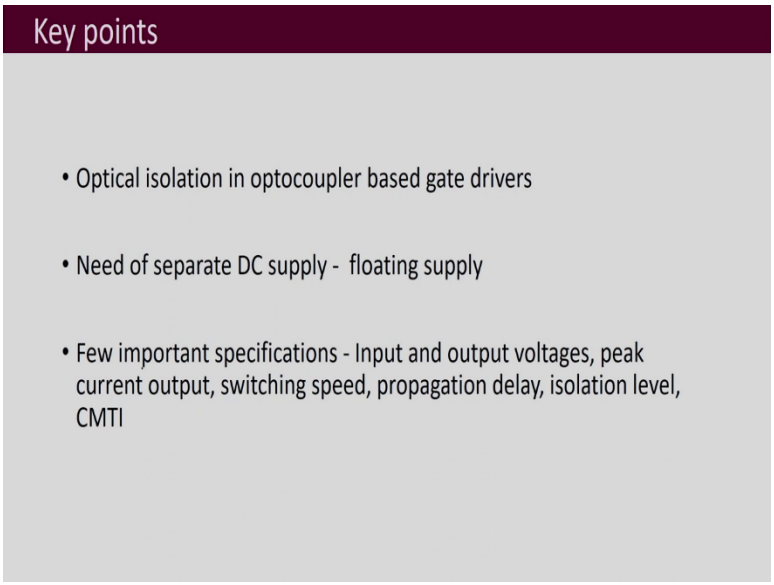

So, what are the key points of this lecture? Optical isolation is provided by optocoupler based gate drivers. Next is that it needs a separate DC supply and if you have floating emitters or floating source in your power electronic circuit then it also will be needing floating power supply IC but it needs a separate DC power supply.

So, that is actually what you can say the disadvantage of optocoupler based IC because it makes it a little expensive. But overall optocoupler based gate drivers give very good performance and are very widely used. And then the other important specifications that you should be looking for is input and output voltages, peak current output, switching speed, propagation delay, isolation levels and CMTI. Thank you.