Design of Power Electronic Converters

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Lecture 22

Introduction to Gate Drivers

Welcome to the course on Design of Power Electronic Converters. Today, we will begin now with the next module and that module is of gate drivers. So, the first lecture I will be just introducing gate drivers.

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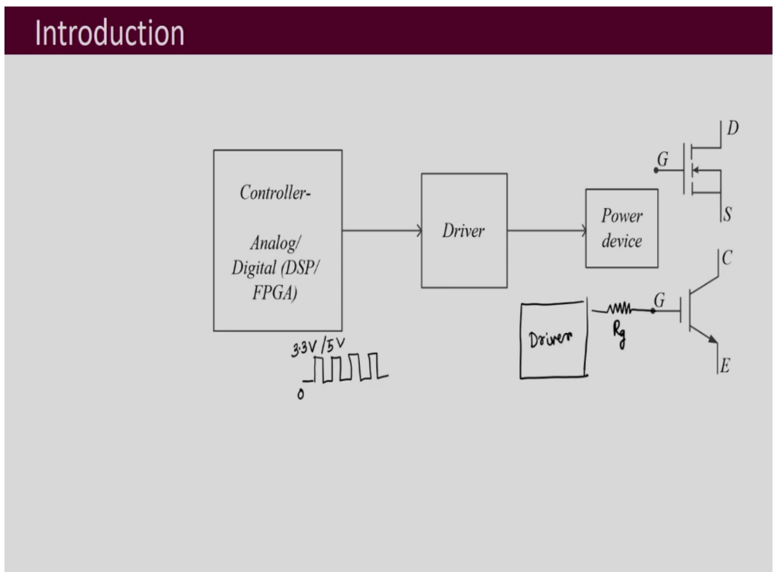

Any power semiconductor device, basically MOSFETs and the IGBTs that which we use very frequently. They are connected with a driver and then that driver gets the signals from controller. So, the controller may be an analog controller or a digital controller and in terms of digital controller, it may be microcontroller DSP or FPGAs. So, then, what happens is that you have these kind of PWM gate pulses, which are given by these controllers, and these are usually of lesser voltages, let us say of 0 to 3.3 V or 5 V like that.

And then, so, these cannot drive these MOSFETs and IGBTs, because their voltage levels are usually low and also these controllers, they do not have the ability to sink that much current or supply that much current, which is sufficient enough to drive these MOSFETs or IGBTs.

So, in between we require another circuitry, which is called as the gate drive circuit. And this kind of acts as an interface between this controller and the power semiconductor device. And usually, you will be having a gate resistor in between. So, this is like this kind of a gate resistor, which is there it is usually denoted by R_g, and that gets voltages or signals from this gate driver. And there are different types of drivers which are used. So, now, let us understand it in little bit more detail.

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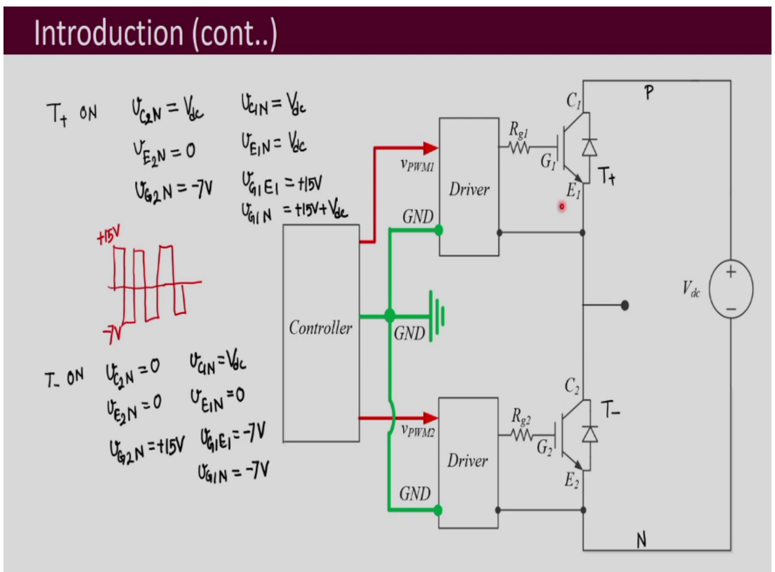

So, here I have taken an example of one leg of an H bridge. So, this is the DC supply, which is connected to this one leg. And then we have these two IGBTs with anti-parallel diodes and then there are two gate resistors R_{g1} and R_{g2} and we have two gate drive circuits this is driver one and then this is second driver two.

And these two drivers are receiving gate pulses from this controller and let us say those are named as V_{PWM1} and V_{PWM2} and then here there is a common ground because this controller will have its own reference with respect to which it will be giving these PWM gate pulses.

So, this is the common ground which is denoted in this green color and that ground is also connected to these drivers' input side, both the input side of driver one and driver two. So, let us see what is the picture over here in terms of the reference that we are using. Now, we have studied this while discussing semiconductor devices that the voltage that we have to provide is with respect to the emitter on the gate and then we can drive the IGBT or the MOSFET.

So, then the emitter has to be the reference with respect to which the voltage has to be applied on the gate terminal. Now, we have to understand how voltage of this emitter point E_1 and this emitter point E_2 changes or it does not change. So, for that, let us give some name to these transistors. Let us call this transistor as T_+ and this transistor as T_-.

So, when T_+ is on i.e., this upper switch is on. So, then what will happen is that, let us assume it to be ideal. So, at that time, this we can consider it to be a short and so, when it is a short, this voltage over here at this emitter point E_1's potential with respect to this bus will become equal to V_{DC}. So, let us call this terminal as N and this bus as P.

So, we will be having voltages, V_{C2N} will be equal to V_{DC}. This is V_{C2} the potential over here with respect to this is equal to V_{DC} and your V_{E2N} that is equal to 0 because this is always connected to this endpoint. Now, what is the potential of V_{G2N}? So, V_{G2N} will be equal to whatever is the voltage that is required to turn this IGBT off because when T_+ is on T_- is off. Now, let us say that, typical voltage of +15 and -7 V is what is applied to turn on and turn off the IGBTs. So, that means, this is +15 V that is given to turn on the IGBT and -7 V that is given to turn off the IGBT.

So, in that case gate voltage over here will be -7 V, this point's potential will be -7 V with respect to E_2 or with respect to N. So, what we will be having is this voltage will be equal to -7 V. Now, let us see the status for the upper IGBT. So, V_{C1N} will be equal to V_{DC} and this point's potential will always be equal to V_{DC} because this is always connected to this bus P.

Then next is V_{E1N}, this emitter's potential with respect to this bus N that is V_{E1N}. So, that is equal to V_{DC} because, we assume this is on and so, this is shorted. After that you have V_{G1E1}, we should find out what it should be. Now, with respect to this emitter, to turn it on, G_1 has to be 15 V, that is what we have taken here to turn it on. So, then this will be equal to +15 V. And if we see V_{G1} with respect to N, so, that will be equal to +15 V plus V_{DC} because, over here this E_1 itself is at the potential of V_{DC}. So, with respect to N, E_1 is at V_{DC} and with respect to E_1, G_1 is at +15 V.

Now, let us see the potentials when T_- is on, that means lower switch is on. So, when T minus is on, V_{C2N} this becomes equal to 0. This is because if T_- is on this is shorted, so, C_2 also gets connected to N point. And V_{E2N}, that will be equal to also 0 and this will be always equal to 0 because this is always connected to N, then we have this V_{G2N} that will be equal to +15 V, because here we are turning it on.

So, this has to be +15 V with respect to E_2, then we have V_{C1N}, now, this will be always equal to V_{DC}. Then V_{E1N}, now, this is going to be equal to 0. Now, this is why this is 0 because this is shorted. So, E_1's potential is now connected to here, which is N. Further V_{G1E1} now will be equal to -7 V because this is off, so, G_1 has to be -7 V with respect to E_1 and V_{G1N}, this will be equal to also -7 V because, you can see that E_1 itself is at 0 potential. So, therefore, G_1 is also at -7 V.

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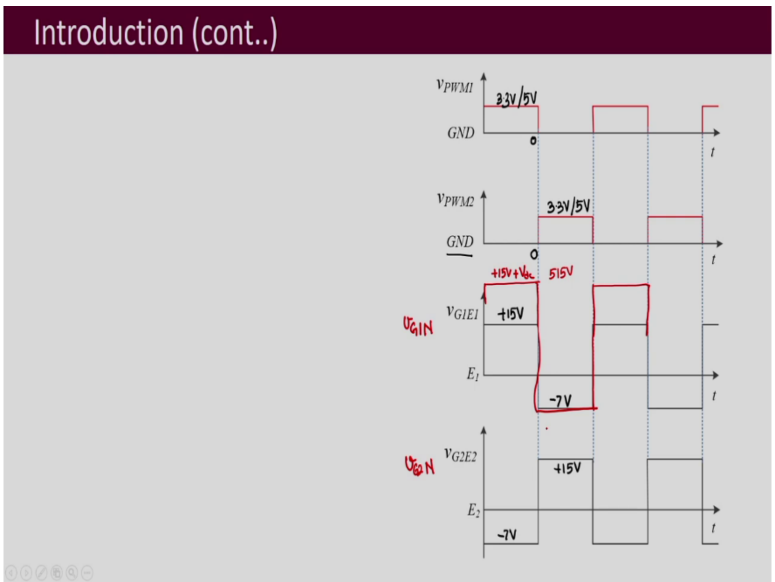

So, if we plot it, this is how the plot will look like. So, V_{PWM1}, these are with respect to ground. So, that means with respect to this ground V_{PWM1} and V_{PWM2}. So, that is let us say equal to 3.3 V or 5 V whatever small and it is 0 here. And similarly, V_{PWM2} will also be like that with respect to the same reference which we have denoted as ground. Further G_1E_1 with respect to E_1, that means, this point G_1E_1 with respect to E_1 that is going to be equal to what we have taken as typical voltage of +15 V and -7 V is what is going to come, and similarly, here for V_{G2E2} as well, what we observe is that this G_2E_2 this will be also +15 V and -7 V with respect to E_2.

So, this is going to be +15 V and this is going to be -7 V. But, if we would have plotted this as V_{G1N}, and here V_{G2N}, means with respect to the common negative reference bus N. So, there this would have gone from +15 V plus V_{DC} and this would have remained at -7 V whereas, say for V_{G2N}, it remains the same.

So, this would have become V_{G1N}. Now, if V_{DC} was let us say 500 V, so, this would have become 515 V and -7 V. So, what we observe is that since emitter's potential is floating or for E_1 the upper IGBT, gate driver's potential that changes by huge amount as you turn it on and turn it off. So, this kind of voltage with respect to reference bus N, it will be very difficult to generate for the upper IGBT whereas, for the lower IGBT it should not be that difficult because the emitter is not floating for the lower IGBT.

So, what we observe from here is that it depends on the position of the transistor in the circuit and what kind of circuit you may be having, different types of topologies are there and depending on that, IGBT or MOSFET whatever transistor you are using its location in the circuit and how it is turning on and turning off and how the potential of the emitter or the source are changing whether it is floating or non-floating depending on that gate driver's voltages also has to be changed.

So, then this is a problem. So, that means, we have to have an interface circuit in between which can do the isolation and which can give voltages with respect to a floating reference. So, that is what one of the jobs of the driver because of which we use it.

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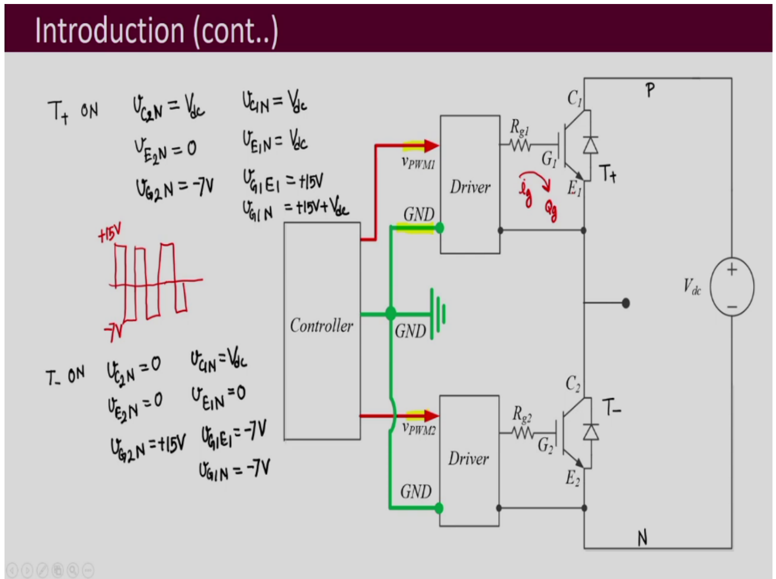

Then, one more thing that you should note down is that this gate emitter region has its own requirement, now here I have taken +15 -7 V, now always it may not be +15 -7 V. Different voltages may be required to push it into the ohmic region or the saturation region. So, the driver should be capable enough to be able to give that much voltage.

And also, there may be a driving current requirement whatever is this gate requirement I_G over here, it should be sufficient enough to drive this gate emitter region, it should be able to provide the charge Q_G that is required to turn on the gate emitter region and also it should be able to sync that much of current when we are turning it off. So, that is also something what the driver does and is what why we need it.

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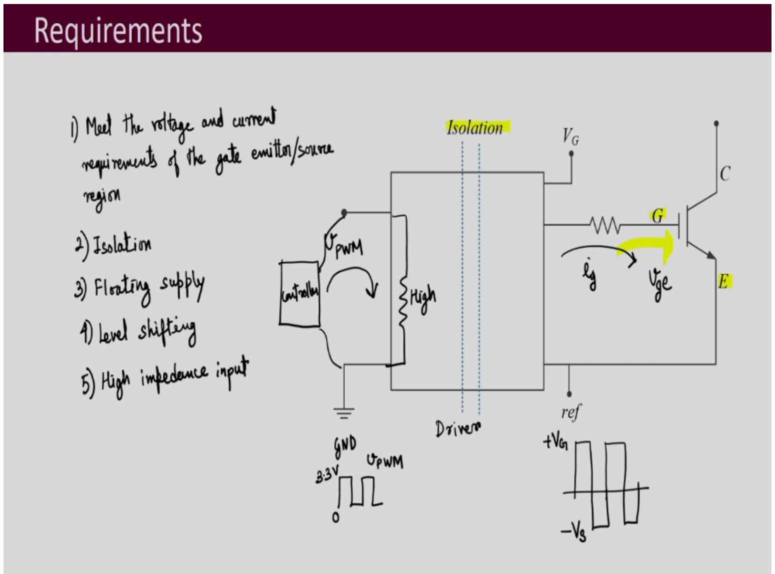

So, now, let us look into some of the requirements of the driver, which the driver has to satisfy. So, this is the driver which is represented by a box here. So, what we understood from the one leg of the H bridge example that, the driver should be able to provide isolation. Why? Because here this reference which is ground, this may be connected to the controller and it is a fixed potential. Whereas here what we will be having is that this reference is with respect to this emitter and this may be floating.

So, it should be able to provide the isolation and next is that it should be able to meet whatever the voltage requirements that may be between the gate and emitter and also provide the current requirements of the gate emitter or the gate source region. So, first requirement is that it should meet the voltage and current requirements, of the gate emitter or source region. Second it should also be able to provide isolation. Now, this isolation may be a magnetic isolation or it may be an optical isolation sometimes isolations are not given also but usually we will take it that some kind of isolation is good to have.

Then next is that it should be able to work with floating supply. Now, why we are talking about floating supply over here, because here this point, emitter point this may be floating. As we saw in the H bridge one leg example the lower IGBT's emitter is not floating but the upper IGBT emitter potential is floating.

So, the drivers should be capable of working with floating supply that means whatever is giving supply to this driver on this output side. So, let us say that is V_G that is going to give its voltage with respect to this reference, which is emitter or source which may be floating. So, it should be capable of working with floating voltages and floating supplies.

Next, it should be able to do the level shifting. Now, what do we mean by level shifting? It is just very simple that it should be able to shift the voltage level. So, if let us say this is 3.3 V, which is V_{PWM}, which is applied over here, this is what comes to the input side of the driver and the output side of the driver it may be a different voltage that may be given and that may be $+V_G$ (+15 V, 12 V, 8 V) whatever is the requirement of that particular IGBT or MOSFET and you may give some small negative voltage also depending whether it is a MOSFET or an IGBT.

So, it should be able to do the shifting in the level. So, that is level shifting. And next it should give a high impedance input. Now, why we are telling that it should have a high impedance input? Now, note that this side of the driver is connected to the controller and this usually does not have very high current syncing or supply ability. So, then what will happen is that this is connected to this over here and if it is going to draw a lot of current or sink lot of current, so, then that will load the controller which is not desirable.

So, over here whatever is the resistance that we see this should be high enough. So, it should provide high impedance input and of course, at the same time on the output side it should be able to provide whatever is the gate current requirement or whatever is the gate to emitter voltage requirement. So, low impedance output and high impedance input that is what the drivers should be able to provide.

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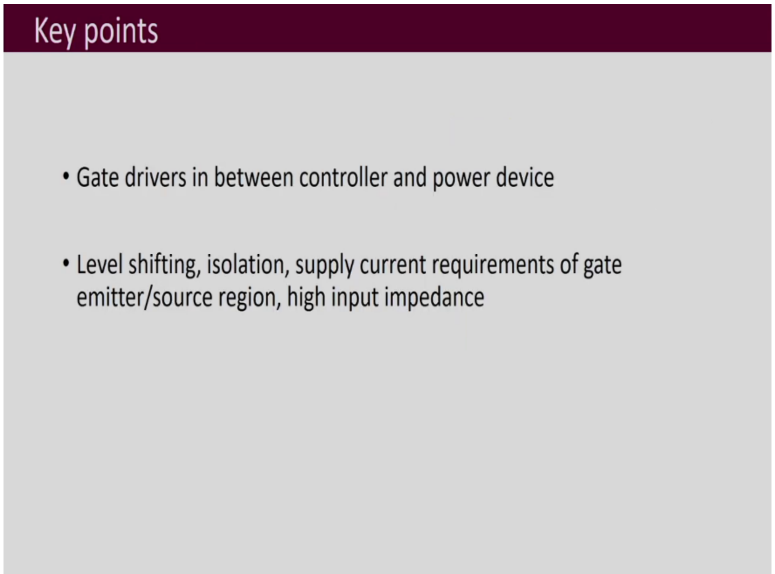

So, the key points of this lecture are that we require a gate driver circuit in between the controller and power electronic device. And what are its main job? It should do level shifting; it mostly provides isolation and it should be able to work with floating supplies. And the most important is that it should be able to supply the current requirement and the voltage requirements of the IGBT or the MOSFET and it should also provide a high input impedance. Thank you.