Design of Power Electronic Converters
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Module: Gate Drivers
Lecture 27
Bootstrapping

Welcome back to the MOOC course on Design of Power Electronic Converters. We were discussing the module of gate drivers and we had looked the basic concepts of gate drivers, then we had also looked into optocoupler based gate drivers, we had also seen the data sheet of one optocoupler based gate driver. Then we also saw over current protection and how it is incorporated in gate drivers which is your DSAT protection. Now, today we will look into another thing associated with your gate drivers which is called as your bootstrapping method. It is a method which is again very widely used for your gate drivers for driving MOSFETs and IGBTs.

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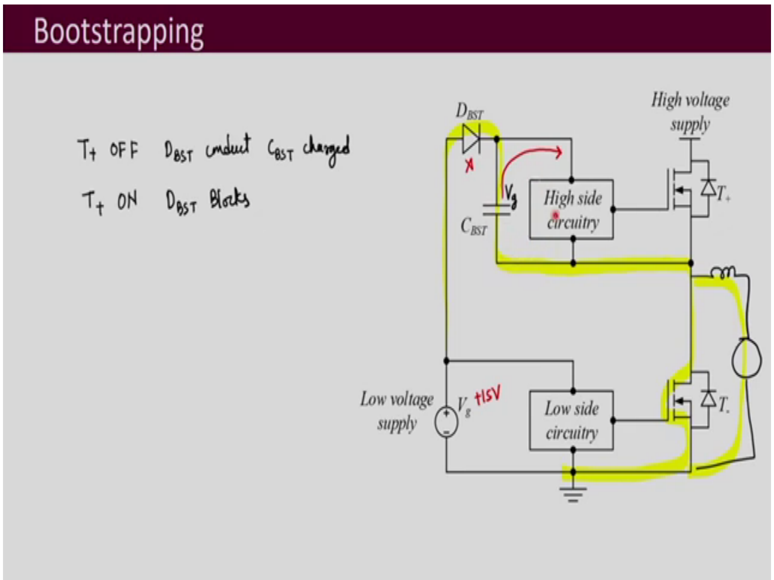

The bootstrapping can be explained with the help of this one leg of an H bridge. Now, this we have been taking as an example again and again. So, here we had seen that for this lower MOSFET the source of it is non-floating that means it is fixed it does not changed, as we turn on and turn off the device we have to apply gate pulse over here and that is with respect to the source whose potential is fixed.

Whereas, we had seen that when we look into the upper MOSFET which is also called as the high side gate drive. So, for this the problem happens is that this source point it is floating. And why it is floating that also we had seen. So, when you turn on this lower MOSFET this point gets connected to this reference and when this upper MOSFET is on at that time the same point gets connected to this DC bus rail, this is usually going to be a high voltage.

So, this points potential is going to be changing from your high supply voltage to your this reference voltage. And whatever gate we have to apply here that has to be with respect to this floating source. And so, driving this MOSFET and providing the supply for this a high side driver circuitry is a problem.

And for that we had seen we need the floating supplies and we can use isolated DC to DC converter ICs which are available and specifically they are designed for driving the, for using with drivers. Now, that is a very good method although using an isolated DC to DC converter IC. And providing the floating supply using that it says very good levels of noise immunity.

But the problem that happens is that that it is little expensive method. We have to separately use a isolated DC to DC converter and all the components associated with them whether you are using ready-made IC or you are making of your own, there is a cost associated with it. So, could there be any cheaper method of getting the same floating supply. And Bootstrapping method exactly does that.

So, how it works is that it uses this diode which is your bootstrapping diode, it is called as D_{BST} is the name that I have given and then there is another capacitor which is your bootstrapping capacitor, it is denoted by the symbol C_{BST}. And now we have this low voltage supply Vg which is providing the supply to this low side driver circuitry. Now, this can be of the level of your 15 volt or 18 volt whatever is required for driving this MOSFET.

So, now what will happen is that this D_{BST} is going to turn on whenever this is off. That means, whenever this is on the lower one is on at that time the D_{BST} is going to conduct. So, if your T_{plus} is off that means your T_{minus} is on, your D_{BST} this is going to conduct and then what will happen is that that your, it will charge this capacitor C_{BST} through this path and here it will come and then if this MOSFET is conducting it can complete its path through this or there may be some inductor or load that may be connected over here.

So, in that case if this diode is conducting and the MOSFET is not conducting in that case it can also complete it path through this load or the inductor. So, then that is how your C BST is going to get charged. So, your C BST is charged and it is charged to the voltage Vg, it is going to be charged to the voltage Vg.

And now at that time you have to note down that as I told this is off so this is not playing any role. Then when your T plus turns on at that time what happens is that your this one starts to block. Because say here your voltage becomes very high this is supposed to turn on so this is already off and this voltage is going to be higher, so over here you will have, I mean your D BST stop conducting that means it will start to block, so D BST is blocking.

So, as a result now what will happen is that that your this capacitor, now this is off, this is not present, so the C BST will now supply this high side driver circuitry. So, that is how then this Vg whatever voltage that is required this high side driver receives its power from the charge that was stored in C BST and that is how this high side driver and this MOSFET is driven.

So, what we observe here is that that this same floating supply is now obtained using this bootstrapping method and we do not have to connect an external floating supply. So, that is that inexpensive method of bootstrapping. Now, let us look into it little bit more of the details that how this kind of a circuitry can be realized.

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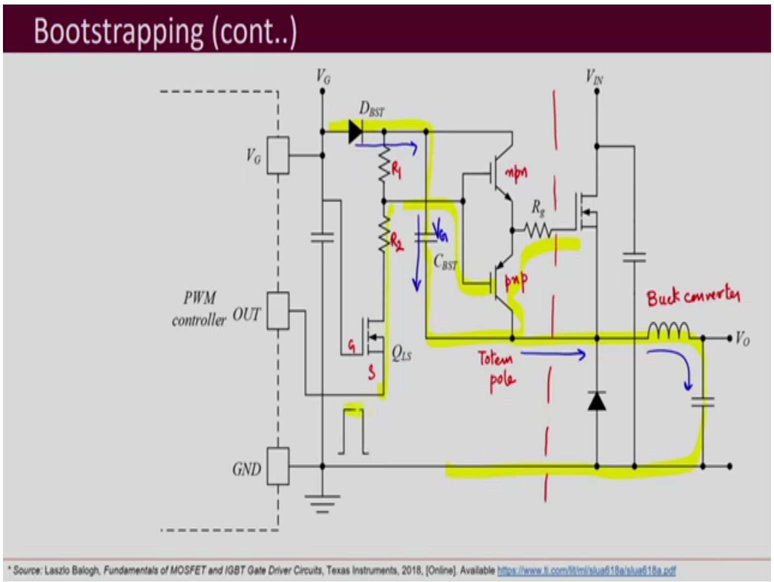

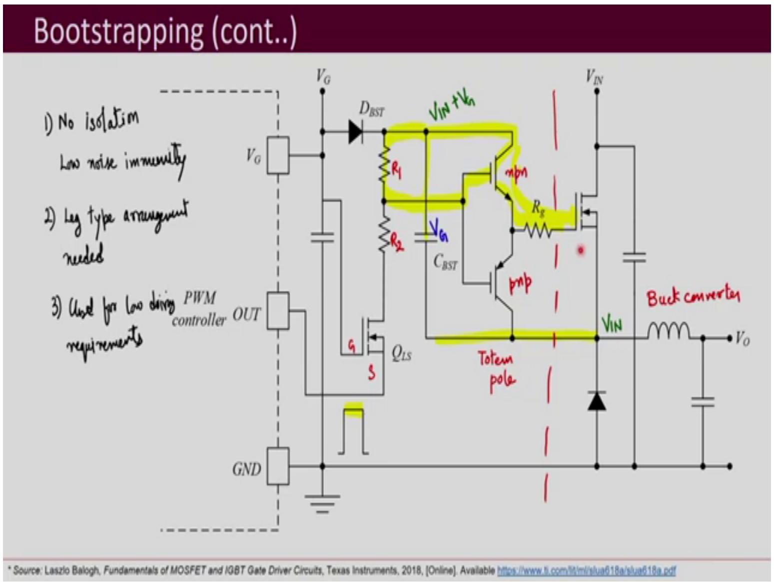

So, this is an example that is shown of how this bootstrapping plus this driver arrangement all that can be realized in an electronic circuit. So, here what we have is this one leg which this is actually a buck converter and this is also like a one leg of an inverter of an H bridge, but however the MOSFET is not required because this is your buck converter, so this part is your buck converter.

You can see over here this is your buck converter circuit, you have the LNC you have the diode over here and then this is the MOSFET. And this there is the capacitor associated with your input and on the output side you have the LC filter of the buck converter. Now, on the driver side what we have is this gate resistor, then this is the totem pole arrangement, so this is your totem pole, so you have this npn and your pnp connected together.

Then further what we have is this bootstrapping diode D BST and this bootstrapping capacitor C BST and here we have got two resistors let us give them the name R1 and R2 and further we have got a MOSFET Q LS and this is your PWM controller which is going to give the gate pulses. And there this Vg is the supply voltage that is required to drive this MOSFET and then we have this another capacitor which is just to absorb whatever transients and noises that may be there, one capacitor that is connected to Vg. Now, this point, this Vg point is connected to the gate of this MOSFET.

Now, you can see that this is an n-type MOSFET so that means if this is high with respect to your source then only this will be on, else it will be off. So, let us see the operation now how this circuit works. So, this is let us say is your gate pulse, this is your when it is low and when this is high.

So, initially let us say this is low that means this MOSFET is supposed to be off, at that time what will happen is that at this part is low and here this is connected to high so that means what this is substantial voltage between this gate and source of this MOSFET. So, between your gate and source there will be sufficient voltage and that voltage will turn on this Q LS.

And so, when your Q LS is off that means this is you can consider it to be like a short so R2 is shorting that means this is being pulled down. So, if this is being pulled down because this is already low, because this is off state, off state this is low so this is pull down using R2. And so here what we see is that if this pull down now npn is not going to turn on, what will turn on is pnp, so pnp is going to turn on and so this will discharge whatever was the gate to source region capacitances and whatever was the charge associated with it that is going to discharge through this pnp.

So, what we have is this is going to conduct like this and this is what is the connection and this is pulled down. Now, that is to turn off the MOSFET. Now, what happens to this capacitor? So, this capacitor then is going to be, this D BST is on and it charges through this capacitor, this charges the capacitor C BST and it completes its path through this way. So, here we have our charging current for the capacitor C BST and this capacitor gets charged to your Vg voltage.

Then further what happens when this goes high? So, this is going to go high now, so when this goes high this is already connected to high that is Vg and the source is also high so then this gate to source the difference is not going to be significant, so this is going to be off, so this is off and then so there is no path.

So, now what will happen is that this C BST will start to discharge and it has the path through R1 and then this points gets connected to Vg and so as it is getting connected to Vg this is going to be turned on npn and so this is on and so your this is turned on and so here this is what is the path for your, this is what is the path for your MOSFET to turn on through npn.

And what we observe is that now this C BST is this other potential is connected to this point. As this MOSFET is on this is going to be at the potential of V IN, this is at the potential of V IN now. And here this is this points potential is V IN plus V G and over here the potential is just V G, so we can see that this D BST will then start to block. So, this is how your the C BST then supplies the whatever is the driving power the gate drive power that is required to turn on this upper MOSFET, and this diode D BST is blocking at that time.

Now, from this few things that we can note down is that first of all there is no isolation, we are not giving any isolation between the driver's side and the power electronic side and also what we observed is that when this device was off at that time the C BST was getting charged and it was completing its path through the power electronics circuit. So, whatever was the noise that was that will be present here the power side noise that will also enter into the control side as well as the driver side and this may disrupt the functioning of the controller and also the driver. So, the problem is that your low noise immunity.

Then one more thing that you can see is that a leg type arrangement is needed, you can observe here that it completed its path, this charging path, it completed to through this. So, then this kind of an arrangement is needed if this type of a MOSFET and diode or both of these has one leg this kind of an arrangement is not there then your this bootstrapping method cannot be used, so you cannot use it for any power electronic circuit blindly, you have to look into it whether bootstrapping method can be used for that particular circuit or not.

Of course, it is true that many many power electronic circuits it can be used but still there may be some circuits where it may not be applicable, so that is why you have to be cautious where your if this H bridge type arrangement is not present then you have to be careful whether this bootstrapping method can be used there or not.

Then next thing that you can observe is that it can be used for low driving requirements. What I mean by that is that if whatever is the gate current that is required to turn on this MOSFET if this gate drive requirement is very high as the ratings of your MOSFET or of IGBTs they are available for 1700 volts and many times their current capability is also very high and we may need very I mean little bit higher levels of gate currents so that cannot be supplied using this kind of a bootstrapping capacitor arrangement.

So, there we have to have floating in supply separate isolated DC to DC converters to supply the gate drive requirements. So, but for your low power range or your medium power electronic applications this bootstrapping method can be used. So, it has some limitations but still it works and it is used in many practical circuits and it is a very inexpensive method of driving your power electronic devices.

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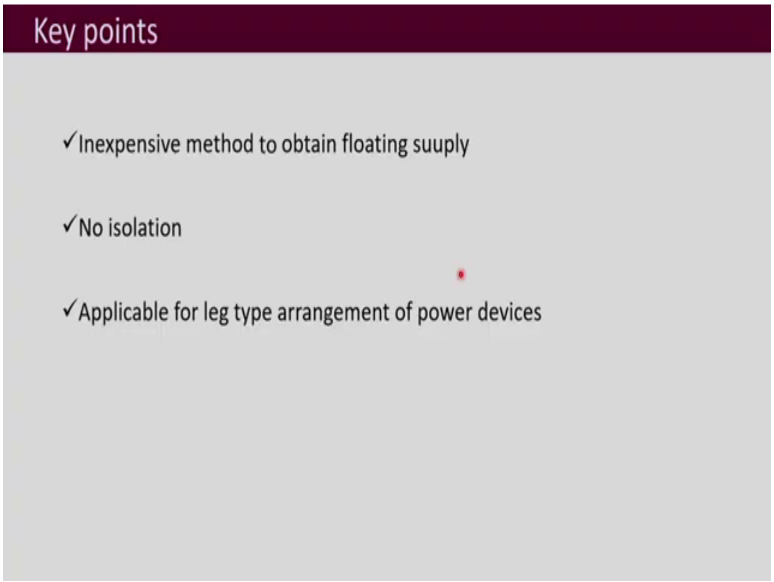

So, the key points of this lecture is that bootstrapping is an inexpensive method to obtain the floating supply and it can be used with your optocoupler based gate driver ICs and other gate driver ICs can also have the bootstrapping involved in it to obtain the floating supply. But there are some issues like it does not give any isolation and low noise immunity and it is applicable for a leg type arrangement only. So, you have to be careful while using bootstrapping method in your driver circuit. Thank you.