Design of Power Electronic Converters
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Module: Gate Drivers
Lecture 26
Desat Protection with Optocoupler Based Gate Drivers

Welcome back to the course on Design of Power Electronic Converters, we were discussing optocoupler based gate drivers. We saw what is optocoupler based gate driver, then what are the important specifications of optocoupler based gate drivers. Further, I also showed you one data sheet example of one optocoupler base driver.

Now, there is one feature which is many times incorporated in your optocoupler based gate drivers, it is what is called as the Desat protection, some of the optocoupler based gate driver IC's have this special feature included in them. So, let us understand what it is and what is the need of it.

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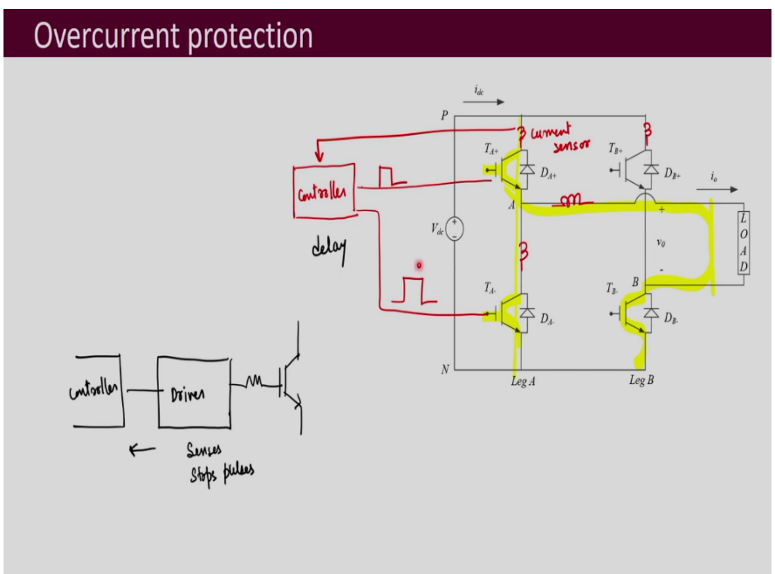

Now, overcurrent protection is something that you may be familiar with that when different types of faults happen, then that leads to overcurrent and that is something from which your converter has to be protected from. So, let us look a little bit more into it. So, there may be different types of faults that may occur is let us say you have this kind of a short by mistake you give gate pulses to both of these two and there may be a short of these. So, when there is a short then what will happen there will be a huge current that will be flowing through these two IGBT's, that may be one source of overcurrent another is that let us say this load somehow got shorted.

So, if this load somehow got shorted at that time also huge amount of overcurrent will be flowing through these two IGBTs or there may be some other shots that may be happening in some other part of the circuit, which also may lead to let us say if this is shown for your H bridge, where it is a single phase, you can have three phase then when you have three phase then also you may be having line to line shorts or line to ground shorts, different types of shorts may be happening in the circuit in different ways then that will lead to overcurrent.

Now, when it leads to overcurrent that means what the device is supposed to carry huge amount of current and also a lot of voltage will appear. Basically huge amount of heat is going to be generated and the IGBT or the MOSFET is then expected to go into your active region and that may damage the device.

So, we have to protect the device your power electronic devices against this overcurrent that may arise. Now, when you want to protect it, how do you do that? First of all, you have to sense that there is an overcurrent that has happened and once you sense that there is an overcurrent that has happened you have to inform the controller about it.

So, the controller stops giving the gate pulses and then you can shut down the system or you can stop pause the system for a while and then once the fault is clear, you can again continue with the systems operation. So, now, how to sense the current one is that you can put current sensors over here, you can put current sensors at different places over here, hall effect sensors can be put in different different places and then from that hall effect sensor, what will happen your this current sensor, so this is the symbol of the current sensor.

So, this current sensor is going to give information to the controller and then this controller then accordingly maybe stop giving the gate pulses to these different IGBT's. So, but obviously there will be a delay that is going to be involved here. Because it takes some time for the current sensor to sense the sensor itself will have its own delay, then your controller will decide what to do that also will have its own delay and then for you to shut down the or stop the gate pulses that also will take some time.

So, this kind of thing arrangement will have some delay and this IGBT or the MOSFET that you are using, it may its protection times are usually very small, they get damaged very quickly, they cannot withstand over currents for very long time. So, if these delays are more than the it may damage the device, before the controller shut downs the gate pulses or removes the gate pulses.

So, that is why faster protections are better. I am not saying that this kind of sensing method and then using the controller and then accordingly stopping the gate pulse or giving off gate pulses to all of them is not done, this is also one of the protection method which is used, but it is (())(06:17) delay and it is a little slower then the other method which we are going to look now.

So, the other method is that what could be a very good method is that you are this IGBT this is connected to the driver and if this driver is then connected to your controller, now, if this driver itself senses it and stops the gate pulses then that is very quick and after that further it can inform the controller that this has happened I have stopped the gate pulses. So, this could be faster this method is faster than this approach this first approach.

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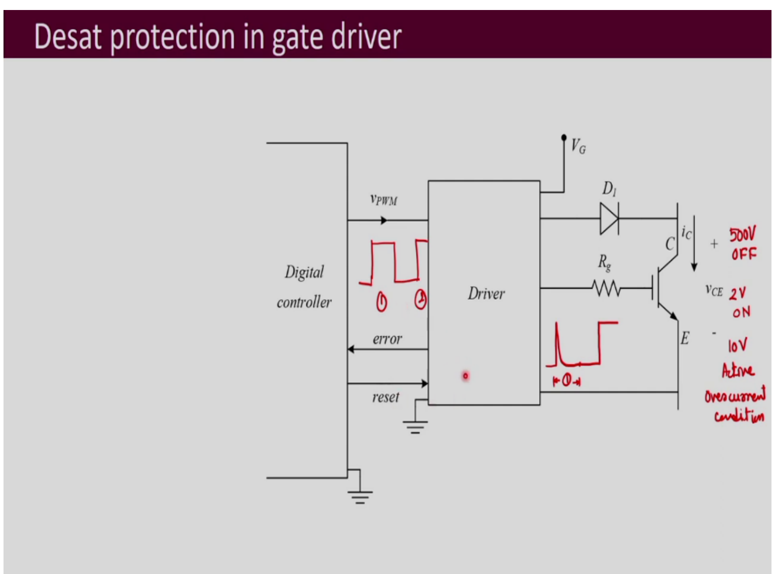

So, that is what is shown in this diagram that is your desat prediction in gate driver. So, what is done over here is that you use a diode, this diode is connected between your driver’s one of the terminals and the collector or the drain terminal of the MOSFET, collector terminal of the IGBT and drain terminal of the MOSFET it is connected in between them.

So, this is used to sense the voltage of this point. Now, how does this desat protection works? It is basically on the principle that if your this IC current becomes very high then your this drop VCE will also become high. So, you can say that the device has entered into active reach. So, VCE is going to be higher than when it was in your saturation.

Now, if we can sense this voltage VCE then and we can compare with what it is usually for yours when the device is normally operating that means it is in saturation. If it is greater than that, then we can know that that your device is facing overcurrent and it has to be switched off. So, using this diode D1 this is your this collectors point with respect to this emitter is sensed.

Now how do we say that with respect emitter is sensed. Because your voltage of the output side of the driver is all given with respect to this emitter, this is the reference. So, you already have this point connected you also have the gate connected, now you connect one of the terminals with the collector terminal and using this diode we sense the this voltage VCE.

Now, why are we using a diode? Why do not we just simply shot it and that way also we can sense the voltage that means we can connect this VCE point to this driver and then inside we can have a sense sensing. We can have a differential amplifier to further see what is the voltage that is coming up.

But what happens is that they when this device is blocking, that means when it is off state, off state means gate pulse has not given. At that time this collector to emitter voltage is very high. So, let us say your voltage your VCE voltage was about 2 volt when it is normally in the on state and when it is going to block let say it has to block a voltage of 500 volts for the normal off state operation. And when it is going into active region let us say the your VCE goes to 10 volts, that means when it is in the active region, so, it is on and then overcurrent has occurred, overcurrent condition it will give VCE as 10 volt.

So, these three are distinct. So, when it is off, it has to block very high voltage and that we cannot give to this driver and then this driver will get damaged. So, then this diode does the job then even it is blocking that means it is an off condition this diode is reverse bias it does not conduct and so, there is no connection between the driver and the collector point and when this is on stage gate pulse is given. So, at that time this diode is on and it forms a connection between the driver and the collector.

So, this diode is just like a connection forming between the driver and the collector point when it is off it is reverse biased no connection means on but then it is forward biased and it forms the connection and because of which we are able to sense the VCE voltage. Then further what the driver does is it that if it senses an overcurrent that means a higher VCE voltage then it will shut down the pulses it will stop the pulses and it will switch off this IGBT although there may be vPWM1 here.

So, what I want to say is that let us say this is your vPWM1 signal that is coming and in between when this pulse was there, this first pulse was there, at that time it sensed an overcurrent. So, what it will do is that, so, it will shut down like this. So, first pulse will actually not be given to this. So, this is your first pulse which will not be given to the IGBT as if it is sense the overcurrent over here.

So, although there is gate pulse given from the controller, it is not going forward to the IGBT. And after it has switched off, then its sends the error signal to the controller and then the controller knows that this has been this device has been switched off by the driver. And after that, if the controller decides to reset it that means clear the fault it can send a reset command to the driver. So, this is how your desat protection in optocoupler based gate drivers is incorporated.

Now, one more thing that I would like to mention here is that that I am telling that it is included in your optocoupler based gate driver, but it is also included deset prediction feature is also included in other types of drivers that we will be discussing later on. So, do not think that only with optocoupler based gate driver you get deset protection feature you may be getting deset protection feature in other drivers also.

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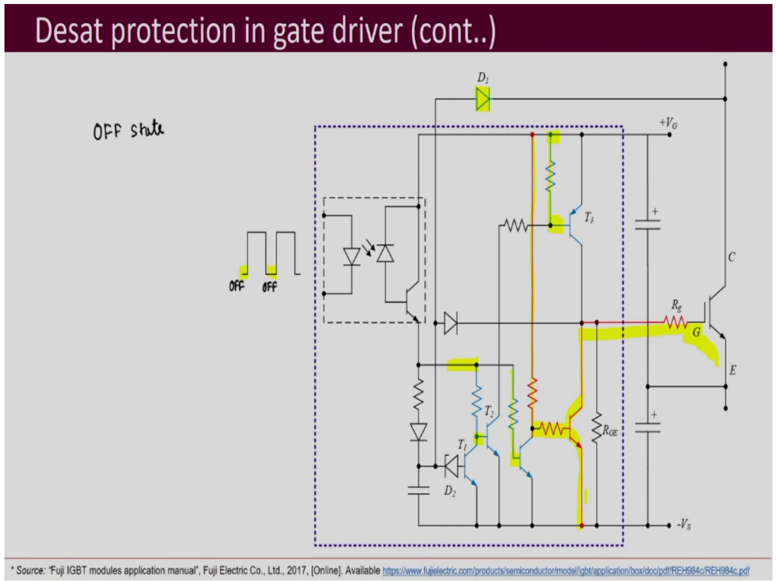

Now, let us look into this how this whole thing works, just an example is given here. So, this circuit is taken from Fuji IGBT modules application manual. So, here it shows what type of circuit can be inside to provide the desat protection. So, here you have this optocoupler. So, this blue box actually is the optocoupler based gate driver.

So, you have this optocoupler over here and then and this is this diode D1 which is used to sense the overcurrent and it is connected to this collector point. And then these are the two capacitors which are connected between your supply the floating supply VG and the other negative reference of it the negative supply which is minus Vs and E is the ammeter reference.

Usually you connect capacitors to absorb the ripples in the voltages and then there is this gate resistor Rg. Now, let us look into or what is inside this gate driver which is inside the blue box blue dotted box. So, you see that there are these transistors T1, T2, T3, apart from that there are other two transistors are also there.

So, this is a pnp and this is npn. So, this is pnp, npn arrangement. So, that is the totem pole arrangement, which provides the current source and the sink ability to drive this gate emitter region plus we have this one another resistor RGE then there is this Zener diode D2 is there. Now, this diode itself is like us I mean you can say that a reference voltage it is you can choose the Zener diode according to how much Zener voltage that you need for this T1 to turn on that can be decided by the choice of the Zener diode and this is connected to this diode D1 which is basically your sensing diode to form the this connection with the collector point.

So, how it works, first let us see what happens, why it is off. So, first one is when your gate pulse is not there, so, off state. So, this is your off state that means the voltage is low. So, voltage is low this is not going to operate and what will happen is that then your this is your high. So, this is that high that comes here. So, this is high that is going to come and this is pnp. So, this will be off. So, blue is shown as whatever is shown is blue is off. So, this is also shown in blue this diode D1. So, this is also off because it is in the blocking state.

Now, further what happens is that you can see here that this resistor in this to this acts as potential divider and now, this is npn. So, if this is high this point is high. So, this is going to conduct that means this conducts and then Rg is getting connection to this. So, this is what conducts and so, that is your gate emitter region can be discharged through transistor to this lower transistor and what is the status of these other three transistors, we can see here. So, this point is low as this is low.

So, this is low point. So, if this is low or what happens is that this is npn. So, this point is low. So this is going to be off, then again here as well same thing this is low, because this potential is low. So, this will be also off. So this is like an open here. So, whatever is the potential divider that is getting formed, which is actually leading it to the high side and so that is going to turn on this npn transistor. So, that is what happens when it is in the off state.

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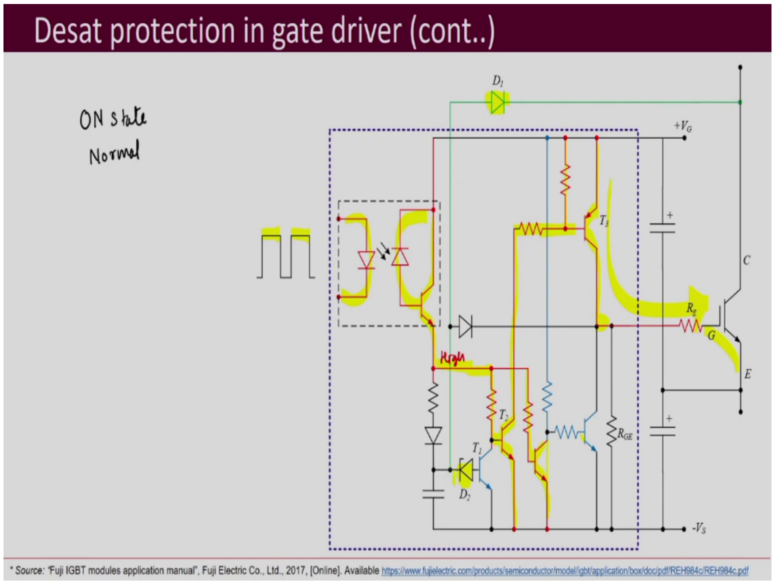

Now, when it goes into the on state normal on state that means no fault has occurred. So, no fault has occurred this is your high. So, this is going to conduct this will emit the light and this also then further starts conducting and then this transistors well conducts. So, that means this also is now high, this is now high potential. So, what will happen if this is high, this is high. So, this is npn this turns on T2 turns on this is shorted, this is shorted means this is going to be pulled down.

So, this is again going to be pulled down here because of this T2 and we just pulled down this is pnp. So, this is also going to turn on and so this is going to conduct. So, we see here this conducts and so this provides the current the gate current to turn on this gate emitter region. Further what we see this is high, so, this is high npn, so, this turns on. So, this is pulled down, if this is pulled down what will happen this lower transistor will turn off, so, it does not conduct. And here what we see is that this diode is going to be conducting now, it is forward biased, but it is normal operation.

So, whatever the Zener diode that we had selected the Zener voltage it is not this potential which is connect of this collector potential is not greater than your what it should be for fault condition. So, then what will happen this T1 will be off then, because this will not allow the high to be coming here. So, then this is normal off state.

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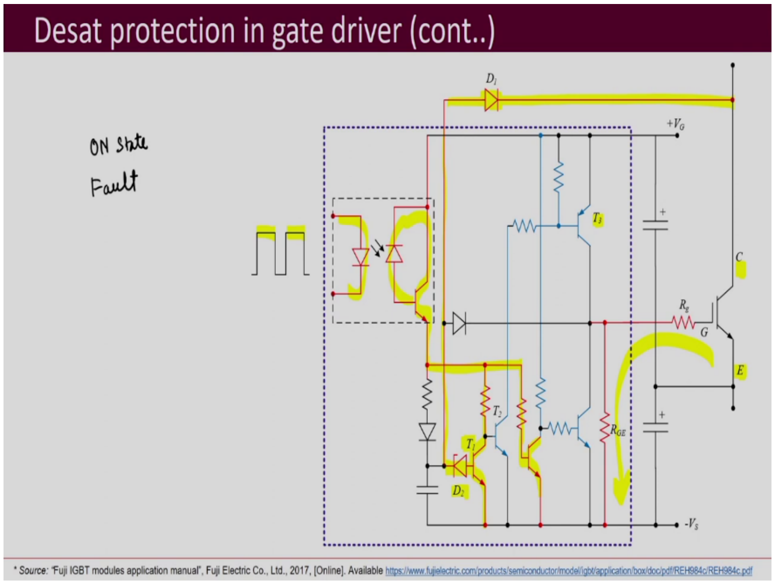

Now, let us see what happens when you are having on state but there is a fault condition. Overcurrent fault is there. So, here this is high, this is high, so, this conducts again this conduct, so, this is all as usual as the on state that we saw just now. So, this is at high so, this is high. But, now, what is going to happen is that this diode, which was connected to this collector point, because there is a fault this collector emitter region voltage is high enough and it is sufficient for this conduction to happen over here for the Zener diode.

And so, this T1 turns on so this T1 turns on turns on it is pulled down, if this is pulled down, what will happen this T2 will become off, T2 goes off, that means, what we saw this T2 goes off means T3 will also go off because it gets connected to the high potential now and this is pnp and then further else is the same. So, this is high, so, this is high, so, this is also shorted, this is pulled down, so, this is also off. So, now, we have to turn it off. So, we saw that this T3 is now blocking, it is not conducting.

So, if it is (())(22:32) not conducting this is also off. So, there has to be something to take care of this gate to emitter to turn off the IGBT. So, this RGE actually absorbs this gate emitter charge whatever was the charge associated here and it turns off the IGBT. So, this Zener diode D2 and T1, using them we are able to sense and detect that there is an overcurrent that means it has gone into the D saturations active region and so, this is this upper totem pole transistor T3 is turned off and the charge that is present in the gate emitter region of the IGBT is absorbed by this resistor

RGE, this is how it operates. And this is one example of what is the nature of the circuit that is inside your optocoupler based gate driver IC's which have the desat protection included in them.

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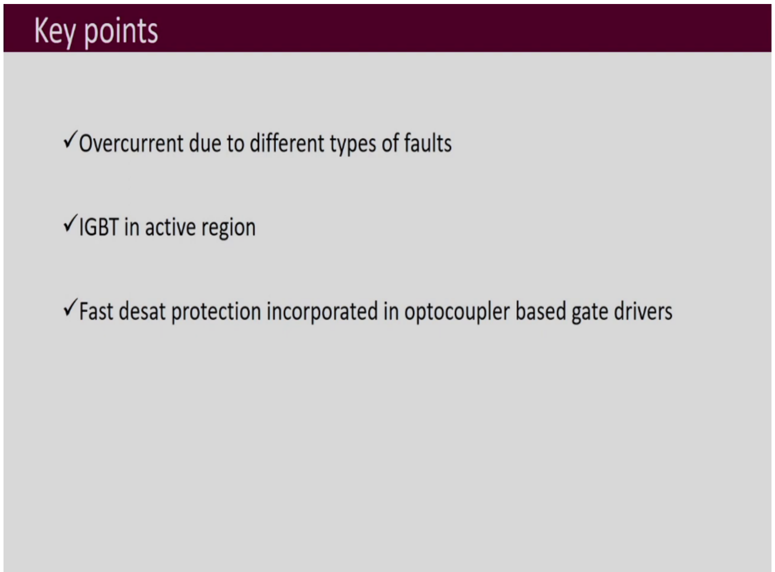

So, the key points of this lecture are that there may be over current due to different types of faults in power electronic circuit and that means your MOSFET and IGBT has gone into the active region when you have the overcurrent and they can withstand these over currents for very short time periods before they get damaged. So, as fast as possible protection system to be there.

So, one of the very good ways of detecting overcurrent and protecting the devices is having desat protection included in the drivers, not all drivers have the desat protection inside them. But some of the drivers and they have it and if you need for your design, you can use those drivers which have the desat protection in the drivers. Thank you.