Design of Power Electronic Converters
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Lecture 16
MOSFET Datasheets-II

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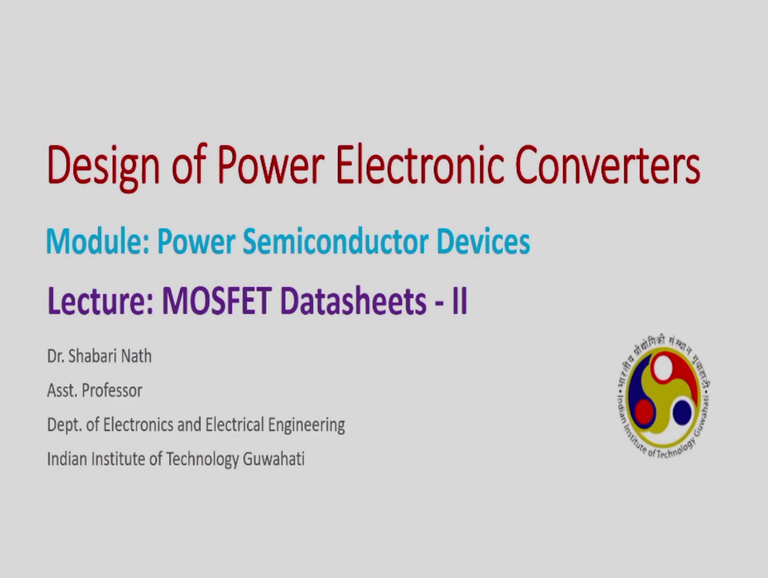

Design of Power Electronic Converters

Module: Power Semiconductor Devices

Lecture: MOSFET Datasheets - II

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Welcome to the course on Design of Power Electronic Converters. So, we were discussing MOSFETs and we had seen some of the basic terms associated with MOSFETs, then we had also looked into the switching characteristics. After that, we had started looking into the datasheet terms of MOSFETs. So, we will continue discussing the datasheet term in this lecture.

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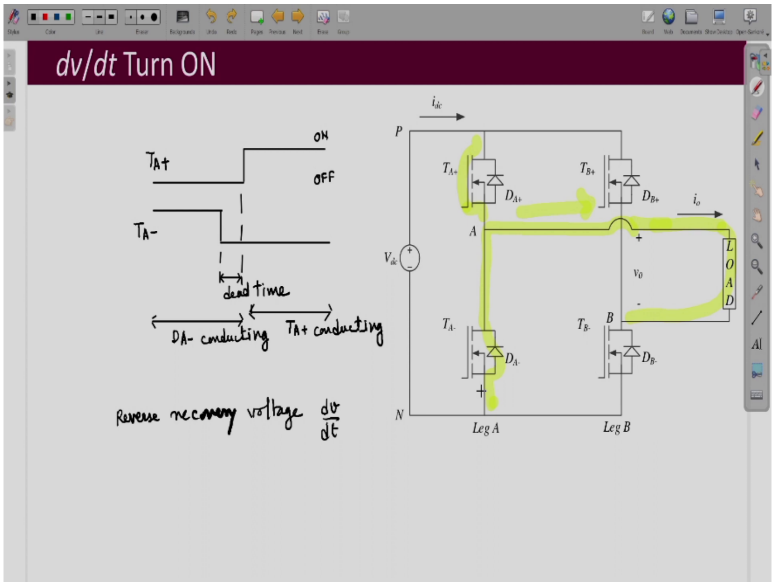

dv/dt Turn ON

There is a term in datasheet that you will be often finding related to MOSFETs and that is $\frac{dv}{dt}$ limit that may be there or in diode data sheets also, we had seen this $\frac{dv}{dt}$ limit that may be provided for diodes. So, now, what is the background of this $\frac{dv}{dt}$ limit that we will be discussing now.

So, for that let us recall the H-bridge converter that we had discussed before. So, in H-bridge converter, when we consider just this leg, then we know that we can either turn-on T_{A+} or we can turn-on T_{A-}. We can never give gate pulses to both of them together because if both of these turn-on together, then that we will lead to a shorting of the source and so huge amount of current will be flowing and that may damage the devices.

So, now for that what is given is what is called as a dead time. So, let us look into this idea of dead times. So, let us say this is gate pulse for T_{A+} and this is the gate pulse for T_{A-}. So, this is for T_{A+} the upper switch and this is for the lower switch T_{A-}. Now, this is on state and this is off state that means it is 0 and 1.

So, initially what we are telling is that T_{A-} is on, that means this lowers switch is on, and then after some time we are making this T_{A-} off. So, when this T_{A-} is off at that time even T_{A+} is not giving the gate pulse. So, this duration in between what we observe is the dead time.

So, here this is our dead time after that, what happens is that this T_{A+} is turned-on. So, this gate pulse is given at this instant. So, now what happens during this dead time interval, let us have a closer look at it. So, let us say for that direction of current is positive. So, this is the direction of current that we are talking about this is the positive direction of current.

So, when T_{A-} was on what was carrying the current in this direction, of course it is the diode which is going to carry the current because this MOSFET will not allow the current flow in this direction in the downward direction, it will only allow the flow in the downward direction it will not allow the flow in the upward direction and with current to be positive that is what is required.

So, the current has to flow like this and we are not considering here that whether the upper MOSFET is on or the lower MOSFET is on something is on either of it we are just concentrating on this Leg A for this moment**.** So, diode D_{A-} is going to conduct. Now, when we turn-off this switch over here at this position T_{A-} is turn-off and T_{A+} is not yet on. So, what will happen during this dead time, this diode will continue to conduct.

So, that means during this whole period it is the diode which is conducting. So, D_{A-} is conducting during this entire period, while D_{A-} is on and also during the dead time. After that what happens is this upper switch T_{A+} is turn-on at this point. So, then what will happen is that this T_{A+} will take over and then the current will be flowing in this direction.

So, now, the current is going to be flowing like this once this upper switch is turned-on. So, after this point it is T_{A+} which takes over from here. So, here T_{A+} is conducting. So, what do we observe then that even though we are providing this dead time over here.

What is happening is that it is the diode which is conducting and when this upper switch T_{A+} is turn-on this diode turns-off and then this T_{A+} is going to turn-on. So, the diodes turn-off is associated with the MOSFETs turned on or vice versa, MOSFETs turn-on and at that time the diode turns-off. So, then the reverse recovery voltage for the diode is very important this reverse recovery voltage and the $\frac{dv}{dt}$ that is associated with it that is very important for to be considered while devices are turning-on and turning-off.

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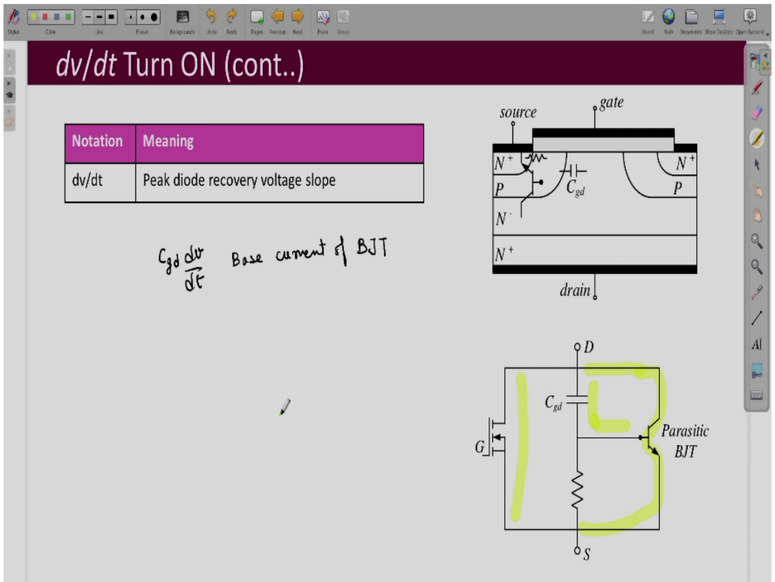
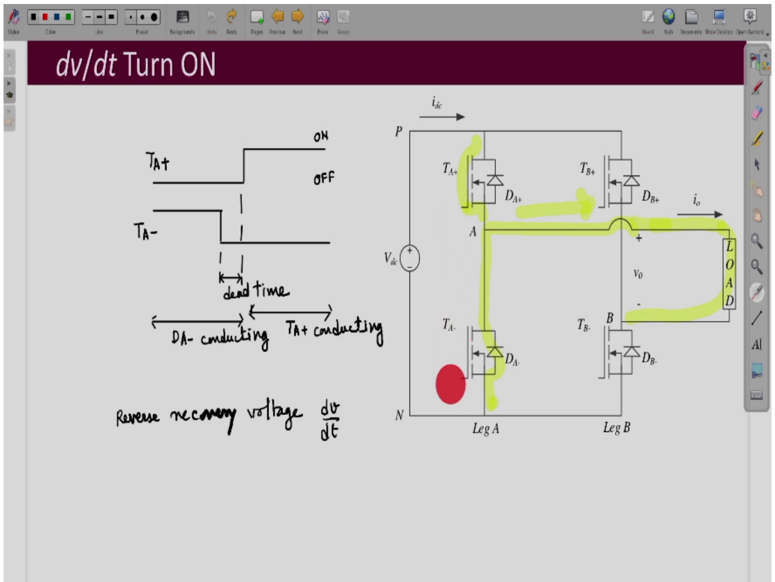


dv/dt Turn ON (cont..)

Notation	Meaning
dv/dt	Peak diode recovery voltage slope

$C_{gd}\frac{dv}{dt}$ Base current of BJT



dv/dt Turn ON

Reverse recovery voltage $\frac{dv}{dt}$

Now, let us see this we have seen before this physical structure and in the physical structure we had observed that that there is a Parasitic BJT in the MOSFET and of course, there is a gate to drain capacitance also associated with it. Now, if a simple equivalent circuit has to be drawn and the effect has to be shown.

So, it can be drawn like this say that this is the Parasitic BJT and here you can denote it by resistor and between this the drain to source you can represent it like a gate to drain capacitance and then followed by a resistor. Because this effect is between this source and this drain that we observe here, and here and this MOSFET is also present.

Now, what will happen is that, while this diode is turning-off, there is a current associated with this capacitor and that current is going to flow to the base of this Parasitic BJT. So, this current $C_{gd}.\frac{dv}{dt}$ this is the base current of the BJT. And, if it is sufficient enough to turn-on the BJT then it may turn-on this parasitic BJT and once this parasitic BJT is turn-on that means this will start to conduct and there will be a path between the drain and the source.

So, it will lead to a shorting of this MOSFET or you can say that this MOSFET the lower MOSFET will also turn-on. So, what we are telling is that because of this diode, if this $\frac{dv}{dt}$ is very high. So, that will turn-on the parasitic BJT and so, there will be a conduction path between drain and source. So, it is like that the MOSFET is turn-on this lower MOSFET, T_{A-} gets turn-on. And so, both of these MOSFET are then on together T_{A+} and T_{A-} and it will lead to a shorting of the source.

So, that is why this limit of $\frac{dv}{dt}$ is given, it is the peak diode recovery voltage slope that is provided sometimes in the datasheets to protect the MOSFET, the lower MOSFET or the upper MOSFET from turning-on, while other MOSFET is being turn-on and the diode is turning-off.

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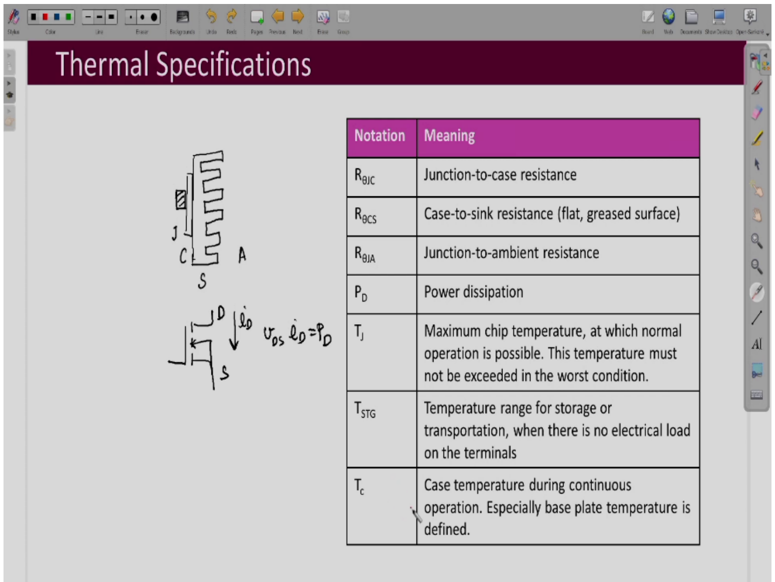

Thermal Specifications

Notation	Meaning
$R_{\theta JC}$	Junction-to-case resistance
$R_{\theta CS}$	Case-to-sink resistance (flat, greased surface)
$R_{\theta JA}$	Junction-to-ambient resistance
P_D	Power dissipation
T_J	Maximum chip temperature, at which normal operation is possible. This temperature must not be exceeded in the worst condition.
T_{STG}	Temperature range for storage or transportation, when there is no electrical load on the terminals
T_c	Case temperature during continuous operation. Especially base plate temperature is defined.

Now, let us look into some other terms in the datasheet one is this $R_{\theta JC}$ junction to case thermal resistance this we have discussed before also that you have got a chip and then after that, you will have the casing and then further is there is a heat-sink, this is the usual arrangement of power semiconductor devices.

So, there is junction over here then there is case and this is the heat-sink and then there is this ambient. And in between them there will be thermal resistance between any two of these and that is what is given in the datasheet this is junction to case resistance then case to sink resistance.

And what may be the condition for which they might have provided flat or grease surface that also, that may be there, means basically the case or the sink on which whether they have provided greasing or not with that they are providing this value that may be mentioned in the datasheet. Then junction to ambient from here to here, what could be the thermal resistance that also is given.

Then power dissipation. So, this power dissipation is just that this is MOSFET and then V_{DS} multiplied by current i_D that will be flowing. So, this gives P_D power dissipation then further what could be the maximum junction temperature over here maximum junction temperature here. So, that also may be provided in the datasheet. Then storage temperature what is the range of temperature in which this device has to be stored and then the case temperature during continuous operation that is also provided.

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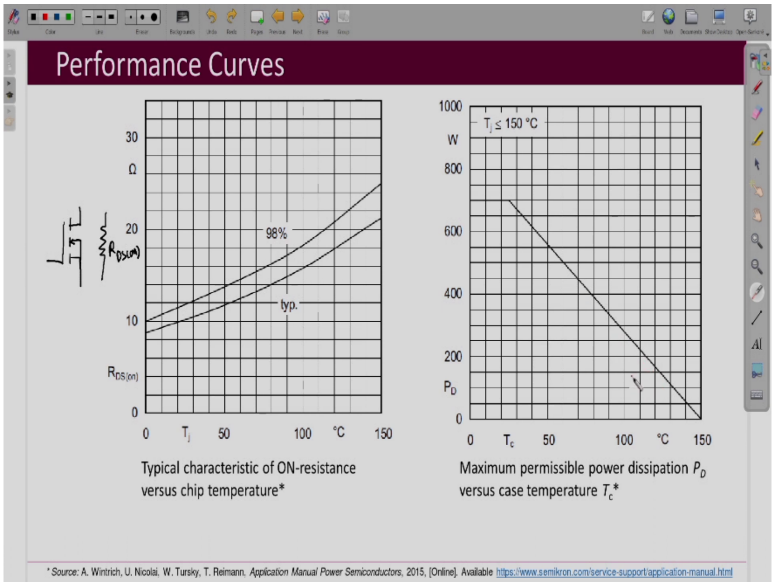

Performance Curves

Typical characteristic of ON-resistance versus chip temperature*

Maximum permissible power dissipation P_D versus case temperature T_c*

* *Source:* A. Wintrich, U. Nicolai, W. Tursky, T. Reimann, *Application Manual Power Semiconductors*, 2015, [Online]. Available https://www.semikron.com/service-support/application-manual.html

Next, let us look into some of the performance curves that are provided. So, one of the performance curves is this $R_{DS(on)}$ versus junction temperature T_j. So, $R_{DS(on)}$ we know that here whatever is the resistance during on state that is $R_{DS(on)}$ and this is a function of temperature, it varies with temperature and that is what we observe here as the temperature is increasing, this $R_{DS(on)}$ is also increasing.

So that is actually, I mean good thing for MOSFET because if this is like characteristics where it increases with temperature, so, that helps in paralleling two MOSFETs. Suppose this one MOSFET here, we want to connect another MOSFET in parallel. So, if both of these resistances increase as the temperature increases, so that helps in the paralleling operation.

So, that is what we see here. And then this is the curve, a typical curve shown for power dissipation P_D versus case temperature. So, what we observe here is that as this case temperature is increasing, this power dissipation what is the maximum permissible that is allowed that is decreasing that is what we see and this is what we expect that power dissipation limit will decrease as temperature is going to increase.

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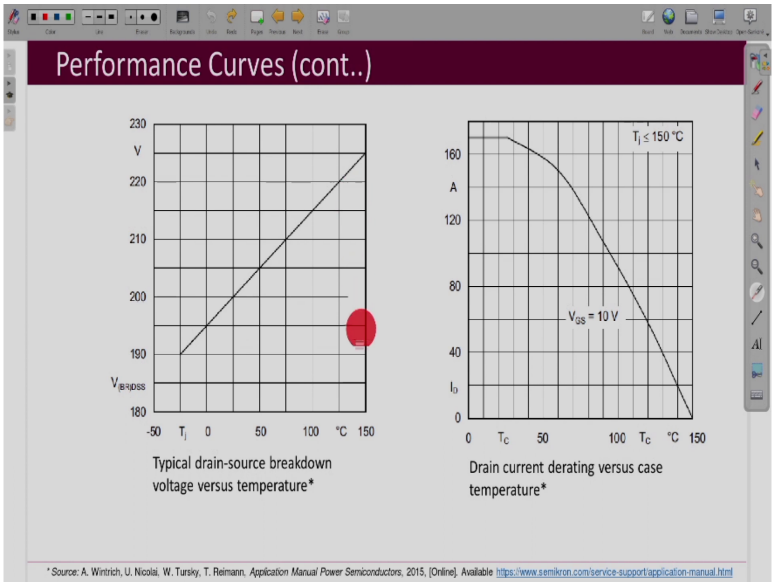

Performance Curves (cont..)

Typical drain-source breakdown voltage versus temperature*

Drain current derating versus case temperature*

* *Source:* A. Wintrich, U. Nicolai, W. Tursky, T. Reimann, *Application Manual Power Semiconductors*, 2015, [Online]. Available https://www.semikron.com/service-support/application-manual.html

Then further this is a graph between breakdown voltage of the MOSFET versus junction temperature T_j and what we observe here is this breakdown voltage slightly increases as junction temperature is increasing. It is not a very high increase, but if it is 190 V over here, then you can see it is going above and it is like close to 225 V that we see at 150^0 C.

Then this is another graph between drain current i_D and case temperature T_c and as expected that as case temperature increases drain current what is the maximum that is allowed that is going to decrease, because it is obvious that losses are going to increase as drain current increases. So, temperatures as it increases how much drain current maximum that can be allowed is going to decrease.

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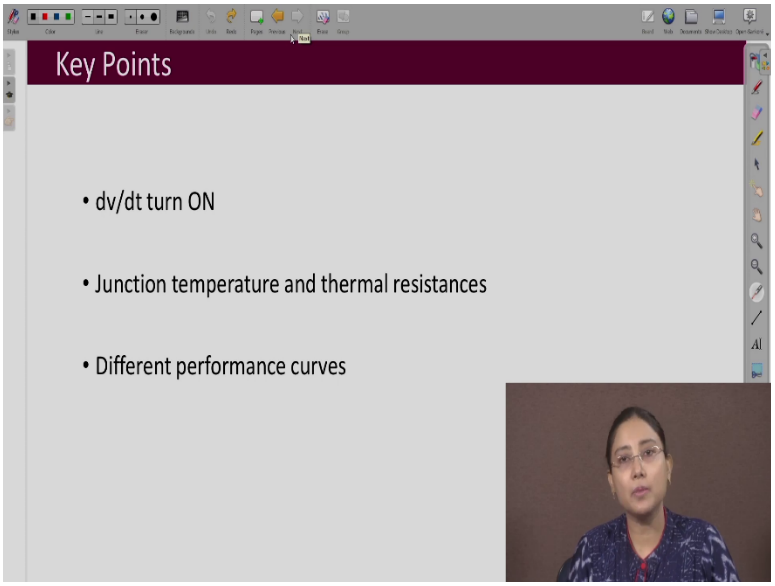

Key Points

- dv/dt turn ON
- Junction temperature and thermal resistances
- Different performance curves

So, what are the key points of this lecture, the key points are that there is $\frac{dv}{dt}$ turn-on that is possible in MOSFETs. So, for that you should be looking into the $\frac{dv}{dt}$ limit in the datasheets that may be provided. And further these days the MOSFET that we get they have good immunity to $\frac{dv}{dt}$ turn-on and different manufacturers like to provide different specifications to show that how good is the immunity to $\frac{dv}{dt}$ turn-on.

So, that you can look into the application notes of different manufacturers of MOSFET and further there is junction temperature and thermal resistance. Those values will also be provided in the datasheets and the different performance curves may be provided in the data sheets. Now, here I have shown just a few of them, there may be several other that may be provided in the datasheets. Thank you.