Design of Power Electronic Converters
Professor Doctor Shabari Nath
Department of Electronics and Electrical Engineering
Indian Institute of Technology Guwahati
Lecture:19
IGBT Datasheets - I

Welcome to the course on design of power electron converters. We were discussing IGBTs. So, we had seen some basics of IGBTs and then we also saw the switching characteristics of IGBTs. Now, let us look into some of the datasheet notations that are given in the IGBT data sheets.

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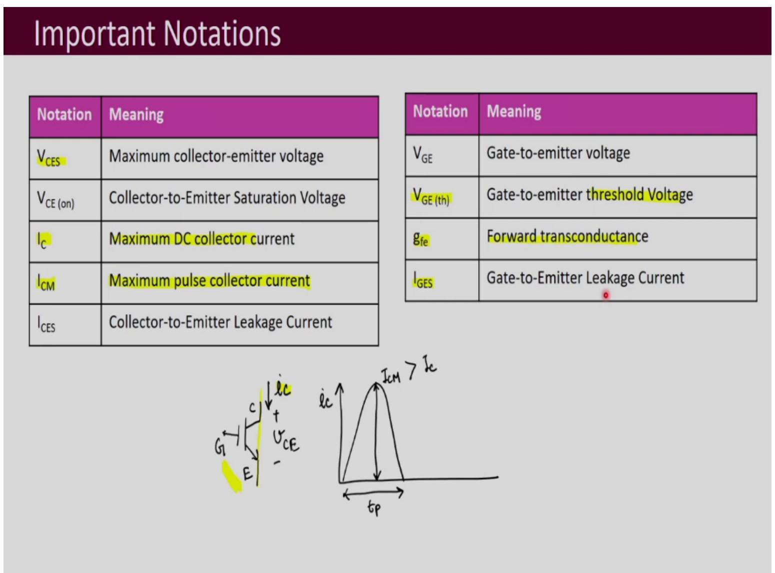
Important Notations

Notation	Meaning
V_{CES}	Maximum collector-emitter voltage
$V_{CE\,(on)}$	Collector-to-Emitter Saturation Voltage
I_C	Maximum DC collector current
I_{CM}	Maximum pulse collector current
I_{CES}	Collector-to-Emitter Leakage Current

Notation	Meaning
V_{GE}	Gate-to-emitter voltage
$V_{GE\,(th)}$	Gate-to-emitter threshold Voltage
g_{fe}	Forward transconductance
I_{GES}	Gate-to-Emitter Leakage Current

So, some of the important notations are first is maximum collector emitter voltage. So, this is the maximum voltage that the IGBT will be able to withstand. So, i_C is the collector current and V_{CE} is the collector emitter voltage. So, the maximum voltage that can, this device can block is your this V_{CES}.

And then when it is in saturation that means, it is in the on state then there will be the drop across it what could be the typical value or the maximum value that is $V_{CE(on)}$ collector to emitter saturation voltage then I_C which is maximum DC collector current. That means, if we continuously keep on passing current through it then based on the temperature what could be the maximum collector current that can flow that is I_C and I_{CM} is the maximum pulse collector current this I have discussed before also in case of diodes and also in case of MOSFET.

So, when you give this kind of a pulsating current I_{CM}, that we can give or the device can withstand can be much greater than this I_C, DC continuous current rating, but this time period may be very short. So, that is maximum pulse collector current and then there can be some leakage current also while this is blocking. So, at that time ideally it should be 0, no current should flow but there is always some current that keeps on flowing. So, that is leakage current which is denoted as I_{CES} collector to emitter leakage current.

Then what could be the gate emitter voltage V_{GE} that is gate to emitter voltage, then what could be the threshold voltage which is the minimum voltage that you require for this part to drive this IGBT and for it to start conducting, so, that is threshold voltage $V_{GE(th)}$. Then forward transconductance this we had discussed before what it is so, that also is usually provided in the data sheets, then gate to emitter leakage current over here also we may be having some leakage current flowing while I mean ideally when there cannot be any current. So, that is gate to emitter leakage current.

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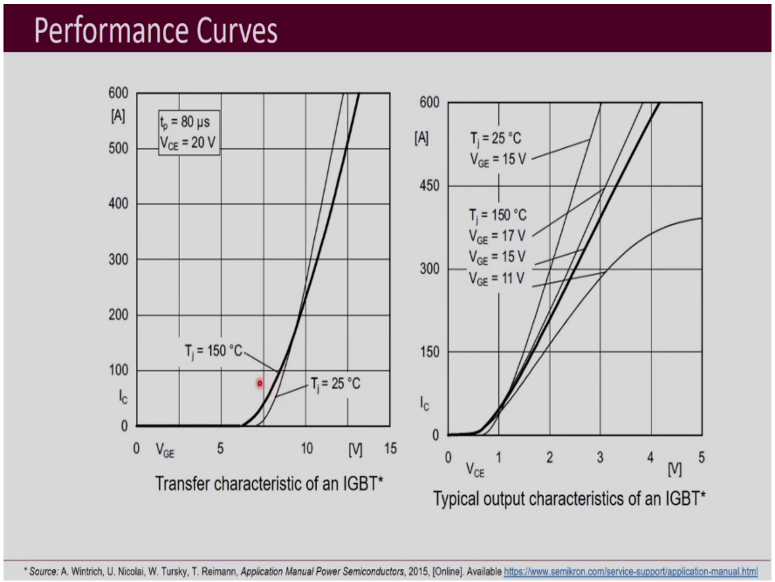

Then let us look into some of the performance curves. So, first one is output characteristics of an IGBT. So, this is between collector current i_C and collector to emitter voltage V_{CE} and it changes with how much gate to emitter voltage we apply and also it can be different depending on the temperature. So, here what you see is that this is for 11 V and then for 15 and 17 V it is provided. So, if we give more than 11 V like if we give around 15 V, that is when it goes over here, which is saturation region and that is what we want in power electronic circuits for it to go into the saturation region.

Then this is typical transfer characteristics which is a graph between V_{GE} gate to emitter voltage and collector current i_C. So, you can see here that till at this point more than 5 V, there is no current that means, this is the threshold voltage and then after that it starts to increase the collector current starts to increase beyond this gate to emitter voltage. So, then after that further it increases a lot. So, the slope of this line is forward transconductance g_{fe} and this also can be different based on the temperature.

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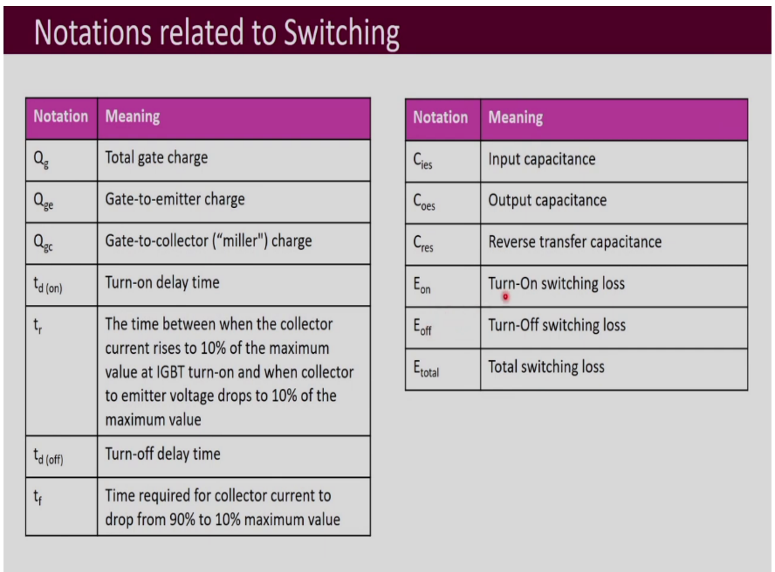

Notation	Meaning
Q_g	Total gate charge
Q_{ge}	Gate-to-emitter charge
Q_{gc}	Gate-to-collector ("miller") charge
$t_{d\,(on)}$	Turn-on delay time
t_r	The time between when the collector current rises to 10% of the maximum value at IGBT turn-on and when collector to emitter voltage drops to 10% of the maximum value
$t_{d\,(off)}$	Turn-off delay time
t_f	Time required for collector current to drop from 90% to 10% maximum value

Notation	Meaning
C_{ies}	Input capacitance
C_{oes}	Output capacitance
C_{res}	Reverse transfer capacitance
E_{on}	Turn-On switching loss
E_{off}	Turn-Off switching loss
E_{total}	Total switching loss

Then notations related to switching, I have shown this before in the last lecture also this is just for the sake of completion I wanted to show you again. That total gate charge, then gate to emitter charge is provided in the data sheets then gate to collector, so Miller charge, then turn on delay time. Now, what it is we have seen during the study of the switching characteristics, then the rise time that is usually defined as the time between when the collector current rises to 10% of the maximum value at IGBT turn on and when collector to emitter voltage drops to 10% of the maximum value.

So, that is like a sum of the rise in current and the fall in voltage. Then $t_{d(off)}$ turn off delay time and fall time t_f, corresponding to the turn off that is collector current dropping from 90% to 10%

of maximum value. Then input capacitances, output capacitances, reverse transfer capacitances these are also usually mentioned in the datasheet plus apart from that in IGBT data sheets they also provide E_{on}, E_{off}, turn on switching loss and turn off switching loss and the sum of these two which is total switching loss.

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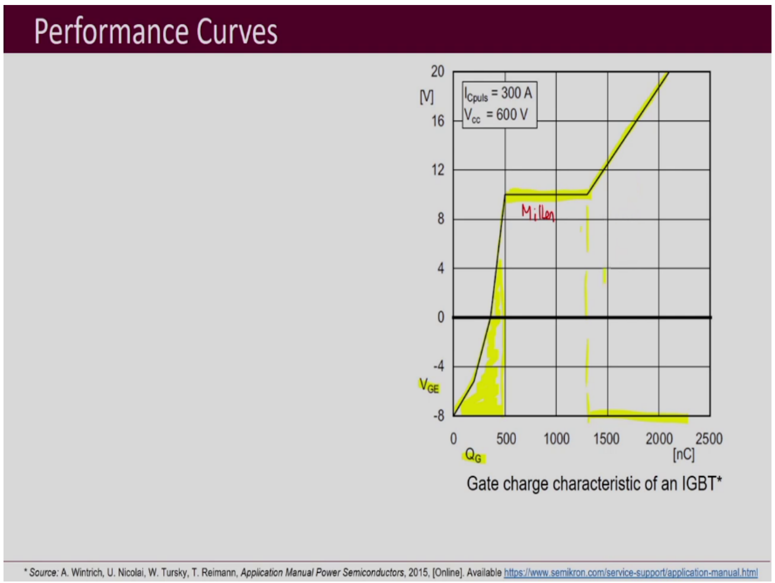

Now, one more performance curve which is of great importance is gate charge characteristics. So, this is between gate charge and V_{GE}. So, usually for IGBTs a negative voltage is given to turn it off. So, let us say if this started from -8 V, then initially when the charge increases, this V_{GE} decreases it becomes 0 and then further it increases and reaches till this point which corresponds to Miller voltage. So this corresponds to Miller voltage.

So Miller voltage and then further what happens is that after the Miller period is over, which is over here, so, this is when our Miller period gets over after that whatever is the leftover voltage which because the gate emitter voltage has to match with the gate drivers voltage. So, that is what it goes up to and whatever is the charge associated with that, it charges also accordingly.

So, basically this region is associated with charging of the gate to emitter capacitance and this Miller part is mostly associated with gate to collector being charged which also acts as the Miller capacitance. And then further again it is the gate to emitter which gets charged after this point over here.

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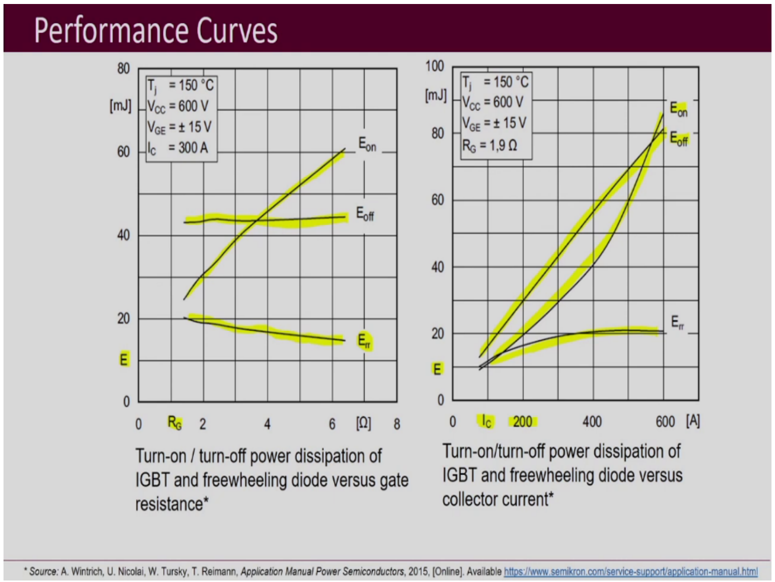

Then other curves that may be provided are these switching losses versus gate resistor R_g. Now, this gate resistor plays a very important role, because if we increase the gate resistor, then the turn on and turn off time increases.

So then correspondingly, what we observe is that as we increase the gate resistor, the turn on losses are increasing a lot you can see over here, whereas turn off switching losses are not increasing so much and this is diode reverse recovery loss E_{rr}. So, this one is associated with diode. So that also we do not see much change, in fact a slight decrease also is observed as gate resistance R_g is increased here.

And this is then how the switching losses change with collector current i_C, now, what we expect is that as collector current increases, then turn on and turn off times obviously are going to increase. And so here we can see that this E_{off} and E_{on} both are increasing as collector current is increasing and that is what is expected. But we do not see significant changes in the diode losses, the turn off loss or the reverse recovery loss that is associated with the diode.

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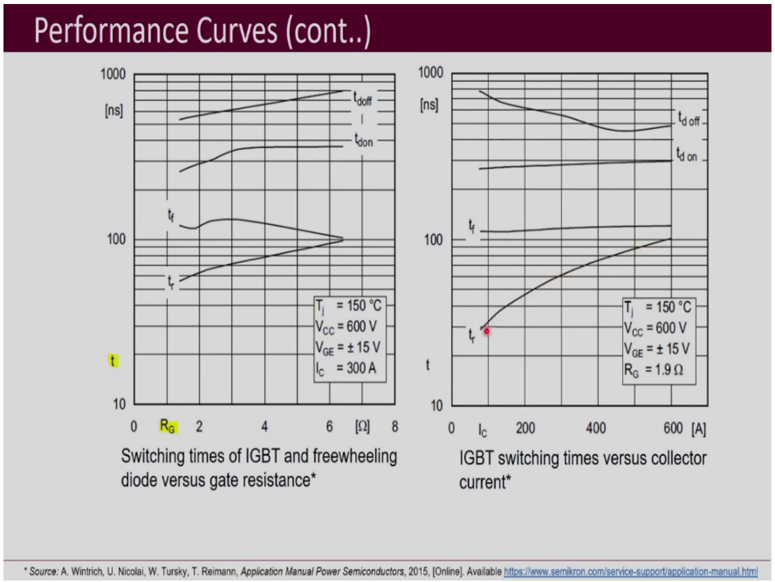

Further in the data sheet, turn on times and turn off times how they vary with R_g and the collector current that also is many times provided. So, this is the graph between R_g gate resistor and turn on and turn off times. So, what we observe here is that the delay on time and delay off time, they also slightly increase with gate resistor. Turn on time, this rise time t_r is increasing significantly with the increasing gate resistor.

Fall time, there is not much significant change with the changing gate resistor. Then further when we observe how these turn on turn off times vary with collector current what we see is that this $t_{d(off)}$ time delay during the turn off reduces little bit and $t_{d(on)}$ delay during the turn on is not much affected. The t_f time for turn off is also not much affected. But however the rise time increases with the collector current.

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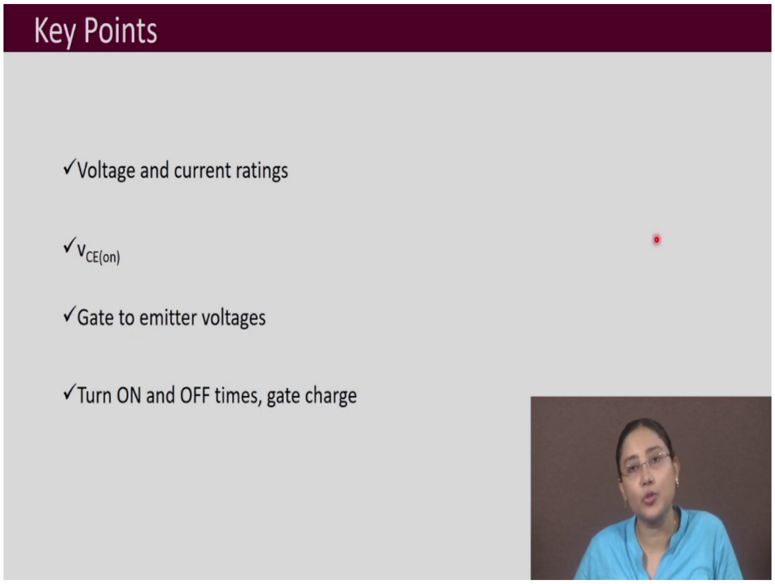

So, what are the key points of this lecture that, the important notations in data sheets related to IGBTs are blocking voltage and the current carrying capacity, current ratings. You can look into the DC continuous rating and also the pulse current rating. And also you should be looking into the on state voltage drop or the saturation voltage drop.

Further it should be also noted down, the characteristics, the notations and the values related to switching and the different performance curves that may be given associated with them and also look into the gate to emitter voltage what is the threshold voltage and what is the typical voltage, that you should apply to turn on the IGBT. Thank you.