Design of Power Electronic Converters
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Lecture 17
MOSFET Datasheet Example

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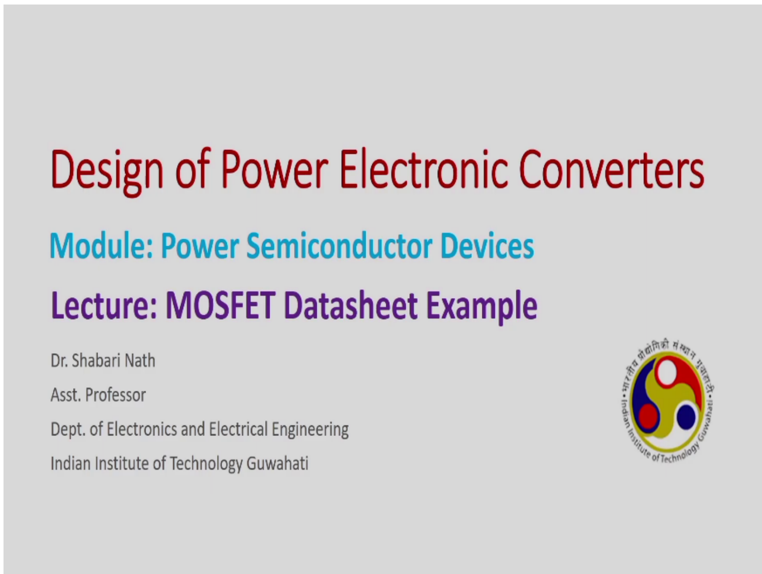

Welcome to the course on Design of Power Electronic Converters. And we were discussing MOSFETs and we had looked into several terms associated with in the datasheets of MOSFETs. So, now, let us look into an example of a MOSFET datasheet.

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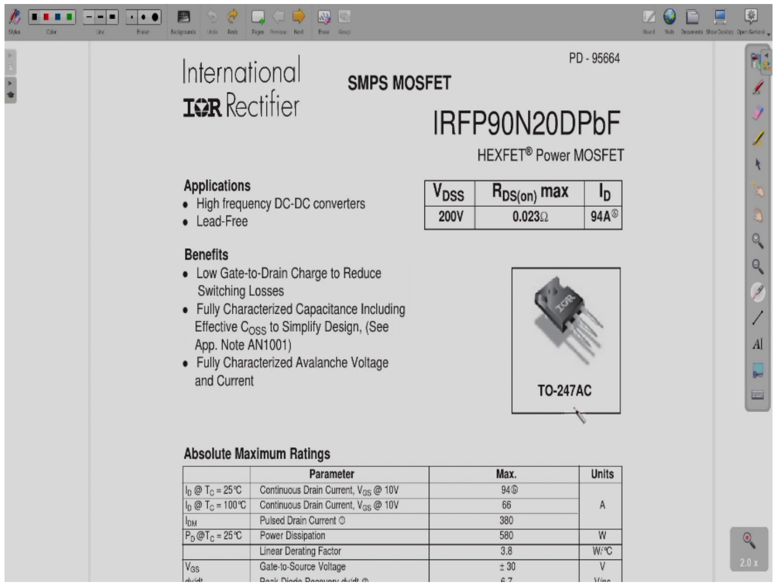

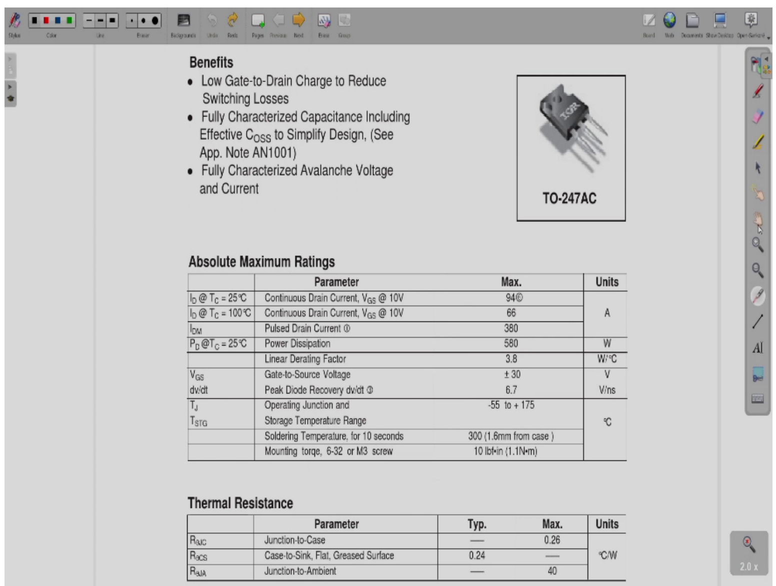

The example edition that I have chosen is by International Rectifier. So, as you can see here that this is a 200 V MOSFET and $R_{DS(on)}$ provided is point 0.023 Ω and then the continuous current rating is given us 94 A. And these are some of the applications, then the key features of this MOSFET are also highlighted by the manufacturer.

And this is picture of the MOSFET, in here what it shows is this is the package that is used TO-247. Now, let us look into some of these ratings that are provided by the manufacturer. So, you can see here that, this is your i_D value, which is at 25^0C, continuous drain current is given as 94 A. This is what we had seen before at 100^0C the value that is given is 66 A.

So, there is a decrease in that value and this is what we had discussed before also. Then pulse to drain current this I had also explained you in the diode datasheet example, that there will be pulse to drain current, pulse to drain current means basically for short time if you want to apply a pulse, so, then that rating will be much higher than this i_D rating which is being passed continuously.

So, that you can see here this is given as 380 A and the power dissipation at 25^0C this is given as 580 W. Then further gate to source voltage maximum rating is given as ± 30 V. Now, this is what is the maximum it does not mean that this is what you are supposed to apply, this is what it can withstand gate to source voltage. Then peak diode recovery $\frac{dv}{dt}$ this we had also discussed when we discuss the datasheet terms.

So, this $\frac{dv}{dt}$ limit also you can see here this is provided 6.7 V/ns, then operating junction temperature and storage temperature range is given as - 55 to 175^0C. Then further you can see here that there are some other specifications that also may be provided, basically soldering temperature and mounting torque those specifications.

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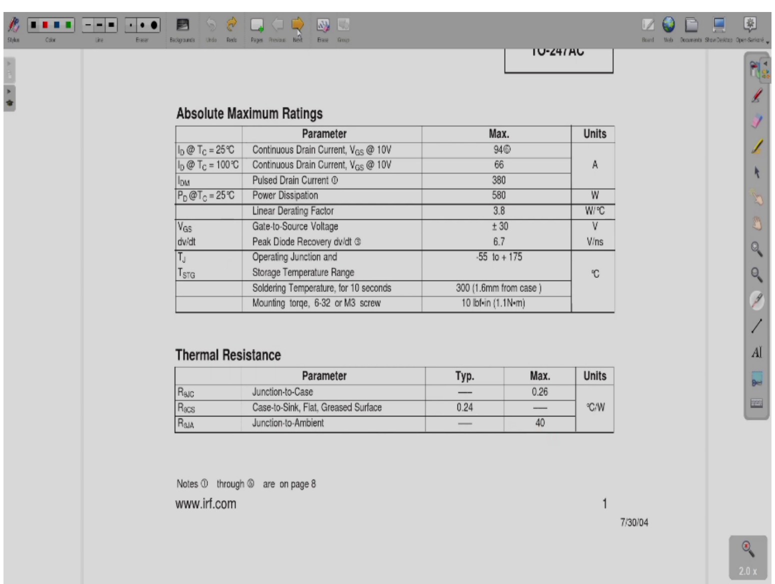

TO-247AC

Absolute Maximum Ratings

	Parameter	Max.	Units
I_D @ T_C = 25°C	Continuous Drain Current, V_{GS} @ 10V	94⑥	A
I_D @ T_C = 100°C	Continuous Drain Current, V_{GS} @ 10V	66	
I_{DM}	Pulsed Drain Current ①	380	
P_D @ T_C = 25°C	Power Dissipation	580	W
	Linear Derating Factor	3.8	W/°C
V_{GS}	Gate-to-Source Voltage	± 30	V
dv/dt	Peak Diode Recovery dv/dt ③	6.7	V/ns
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to + 175	°C
	Soldering Temperature, for 10 seconds	300 (1.6mm from case)	
	Mounting torqe, 6-32 or M3 screw	10 lbf•in (1.1N•m)	

Thermal Resistance

	Parameter	Typ.	Max.	Units
$R_{θJC}$	Junction-to-Case	—	0.26	°C/W
$R_{θCS}$	Case-to-Sink, Flat, Greased Surface	0.24	—	
$R_{θJA}$	Junction-to-Ambient	—	40	

Notes ① through ⑤ are on page 8

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Then thermal resistances they are also given here junction to case is 0.26, this is over here given in ^{0}C/W. Previously I had shown you data sheets where it is given in K/W. So, here they have provided in ^{0}C/W. And then case to sink thermal resistance that is also given in the junction to ambient thermal resistance what could be maximum that is also given by the manufacturer.

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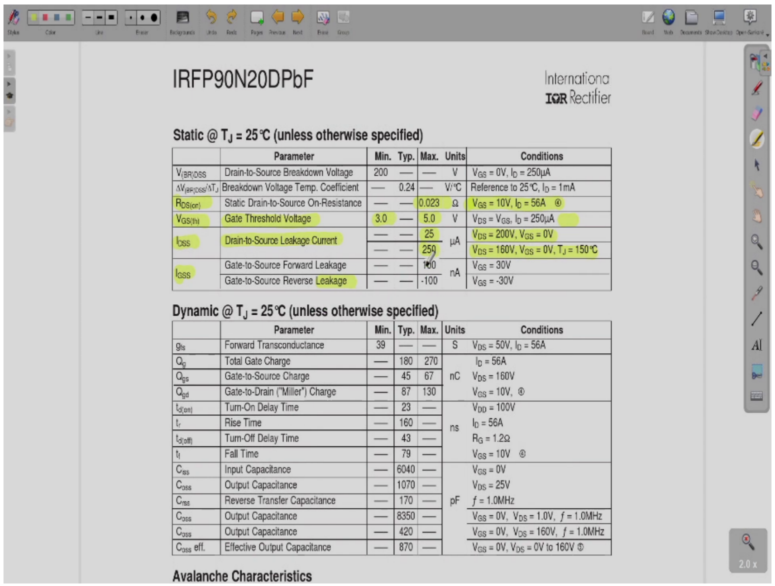


IRFP90N20DPbF

International IOR Rectifier

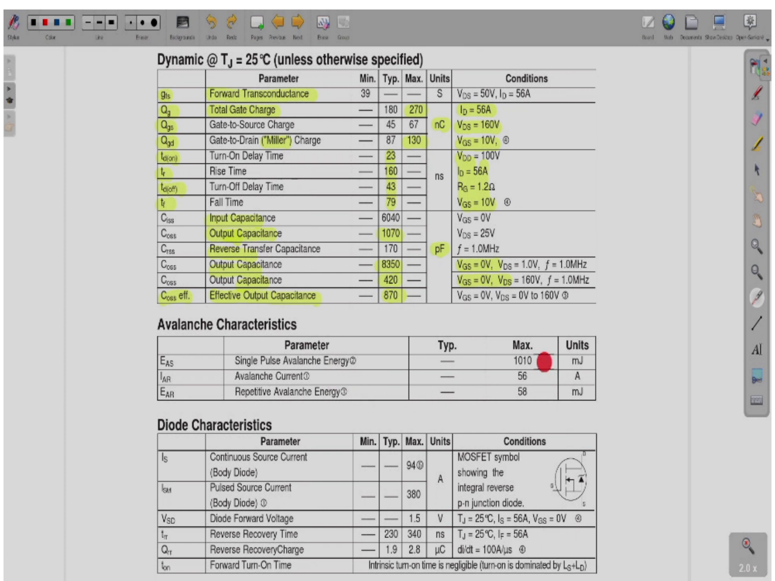
Static @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions
$V_{(BR)DSS}$	Drain-to-Source Breakdown Voltage	200	—	—	V	V_{GS} = 0V, I_D = 250μA
$\Delta V_{(BR)DSS}/\Delta T_J$	Breakdown Voltage Temp. Coefficient	—	0.24	—	V/°C	Reference to 25°C, I_D = 1mA
$R_{DS(on)}$	Static Drain-to-Source On-Resistance	—	—	0.023	Ω	V_{GS} = 10V, I_D = 56A ④
$V_{GS(th)}$	Gate Threshold Voltage	3.0	—	5.0	V	V_{DS} = V_{GS}, I_D = 250μA
I_{DSS}	Drain-to-Source Leakage Current	—	—	25	μA	V_{DS} = 200V, V_{GS} = 0V
		—	—	250		V_{DS} = 160V, V_{GS} = 0V, T_J = 150°C
I_{GSS}	Gate-to-Source Forward Leakage	—	—	100	nA	V_{GS} = 30V
	Gate-to-Source Reverse Leakage	—	—	-100		V_{GS} = -30V

Dynamic @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions
g_{fs}	Forward Transconductance	39	—	—	S	V_{DS} = 50V, I_D = 56A
Q_g	Total Gate Charge	—	180	270	nC	I_D = 56A
Q_{gs}	Gate-to-Source Charge	—	45	67		V_{DS} = 160V
Q_{gd}	Gate-to-Drain ("Miller") Charge	—	87	130		V_{GS} = 10V, ④
$t_{d(on)}$	Turn-On Delay Time	—	23	—	ns	V_{DD} = 100V
t_r	Rise Time	—	160	—		I_D = 56A
$t_{d(off)}$	Turn-Off Delay Time	—	43	—		R_G = 1.2Ω
t_f	Fall Time	—	79	—		V_{GS} = 10V ④
C_{iss}	Input Capacitance	—	6040	—	pF	V_{GS} = 0V
C_{oss}	Output Capacitance	—	1070	—		V_{DS} = 25V
C_{rss}	Reverse Transfer Capacitance	—	170	—		f = 1.0MHz
C_{oss}	Output Capacitance	—	8350	—		V_{GS} = 0V, V_{DS} = 1.0V, f = 1.0MHz
C_{oss}	Output Capacitance	—	420	—		V_{GS} = 0V, V_{DS} = 160V, f = 1.0MHz
C_{oss} eff.	Effective Output Capacitance	—	870	—		V_{GS} = 0V, V_{DS} = 0V to 160V ⑤

Avalanche Characteristics



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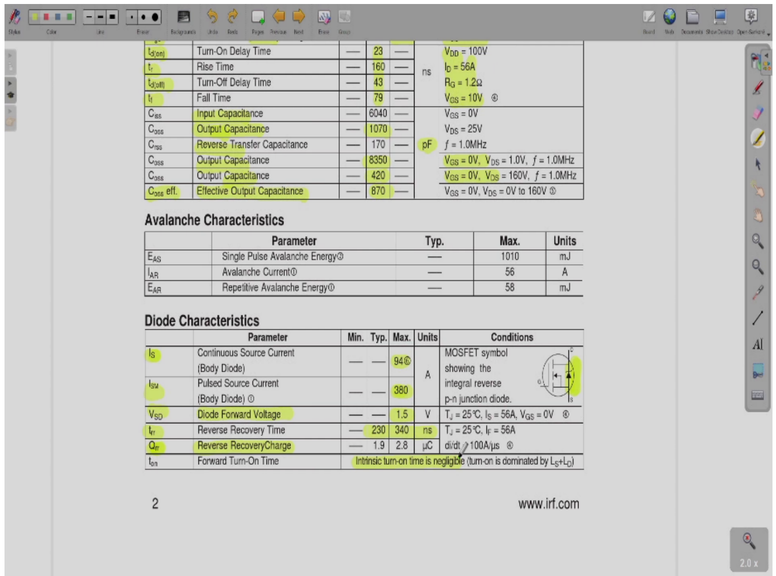
Avalanche Characteristics

	Parameter	Typ.	Max.	Units
E_{AS}	Single Pulse Avalanche Energy②	—	1010	mJ
I_{AR}	Avalanche Current①	—	56	A
E_{AR}	Repetitive Avalanche Energy①	—	58	mJ

Diode Characteristics

	Parameter	Min.	Typ.	Max.	Units	Conditions
I_S	Continuous Source Current (Body Diode)	—	—	94⑥	A	MOSFET symbol showing the integral reverse p-n junction diode.
I_{SM}	Pulsed Source Current (Body Diode) ①	—	—	380		
V_{SD}	Diode Forward Voltage	—	—	1.5	V	T_J = 25°C, I_S = 56A, V_{GS} = 0V ④
t_{rr}	Reverse Recovery Time	—	230	340	ns	T_J = 25°C, I_F = 56A
Q_{rr}	Reverse RecoveryCharge	—	1.9	2.8	μC	di/dt = 100A/μs ④
t_{on}	Forward Turn-On Time	Intrinsic turn-on time is negligible (turn-on is dominated by L_S+L_D)				



$t_{d(on)}$	Turn-On Delay Time	—	23	—	ns	V_{DD} = 100V
t_r	Rise Time	—	160	—		I_D = 56A
$t_{d(off)}$	Turn-Off Delay Time	—	43	—		R_G = 1.2Ω
t_f	Fall Time	—	79	—		V_{GS} = 10V ④
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C_{oss}	Output Capacitance	—	1070	—		V_{DS} = 25V
C_{rss}	Reverse Transfer Capacitance	—	170	—		f = 1.0MHz
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Q_{rr}	Reverse RecoveryCharge	—	1.9	2.8	μC	di/dt = 100A/μs ④
t_{on}	Forward Turn-On Time	Intrinsic turn-on time is negligible (turn-on is dominated by L_S+L_D)				

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Now, let us look into the other specifications. So, here you can see that this is drain to source breakdown voltage, which is given this 200 V that we saw initially also and what is the condition at which they measured it that is also provided. Then further this $R_{DS(on)}$ this we have seen before.

So, maximum it is 0.023 Ω that is given and at what condition they measure it that is also provided for gate to source voltage of 10 V and i_D is equal to 56 A that is what the datasheet shows. Then gate to source threshold voltage you can see here that this is minimum is 3 V maximum is 5 V and then they measured the threshold for this condition.

Then drain to source leakage current there will be some small leakage in the drain to source also. So, that also they have given here is 25 μA, 250 μA and you can see here that, that is provided for two different conditions one here is V_{DS} is 200 V and another one here V_{DS} is 160 V and V_{GS} in both these cases is 0 V. And here the junction temperature is also specified.

Similarly, this I_{GSS} gate to source leakage that is also provided and that is also given here and this is in nano amperes. Then dynamic characteristics, basically that means switching characteristics of the MOSFET that is also provided here. So, what do you see is the Forward Transconductance g_{fs} this graph we had seen.

So, that is provided then total gate charge, total gate charges is maximum is 270 and for what conditions they measured it those are also given here and it is given in nC. Then gate to source charge then gate to drain charge, this is basically Miller charge, which plays important role during switching.

So, that is also given as maximum 130 nC. Then turn-on delay time, rise time and turn-off delay time and fall time what do all these mean, this we had discussed before. So, this also you can see here that all of these typical values are provided and at what conditions they have tested it they have measured it that also is given by the manufacturer.

Then input capacitance and output capacitance, reverse transfer capacitance, this is provided. Now, you can see here this output capacitance is provided 3 times and you can compare the condition for which these values have been given that you can check.

So, accordingly you can see here that these values, different output capacitance values are given in pF. And so, there is an effective output capacitance that is given, which is given as 870 Pf. Then some avalanche characteristics, avalanche energy, avalanche current and repetitive avalanche energy those things are also given in the datasheet.

Further, what is given is the diode characteristics. Now, diode characteristics is important because the current is going to flow in both the directions and that is how it is used in power electronic circuits. So, diode also carries the current so that continuous source current is given. Now, it is not written as forward current because you know that the current is going to flow in this direction from source to drain.

So, that is why it is written like as continuous source current. So it is also 94 A, which is same and that is important because if the diodes rating is lesser than that also we should be careful about that limits for use of the MOSFET. Then pulse to source current if for short time pulse current is applied then that rating is much higher. So, that we can see is 380 A, again same as the MOSFET rating.

Then diode forward voltage drop V_{SD} because this drop is going to be from source to drain. So, that is given as 1.5 V and reverse recovery time of the diode this is important because the diode should also switch as quickly as the MOSFET. But this may not happen all the time because the diode turn-off time actually dominates the entire switching process. Then reverse recovery charge Q_{rr} that is also provided here and forward turn-on time is not given it is just saying that intrinsic turn-on time is negligible. And that is we had discussed before that usually turn-on times of diodes are very small.

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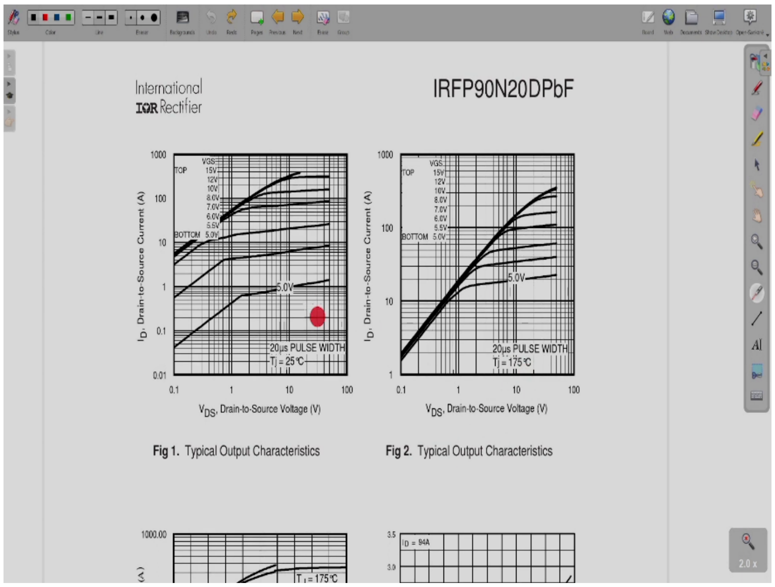

Now, let us look into some of the performance curves that are provided in the datasheets. So, here what is given is drain current, drain to source current versus drain to source voltage, which is output characteristics. So, what you see here is that this is as gate to source voltage is increased, it is going into this ohmic region. And then so, from here what we see is that as we start applying above 10 V or above 12 V that is when it starts to go into ohmic region. So, that much is the gate to source voltage that then we should be providing. Then this is given for 25^0C this output characteristics then they have given another one which is at 175^0C, the same output characteristics at 175^0C and you can see that these characteristics there is some difference in that.

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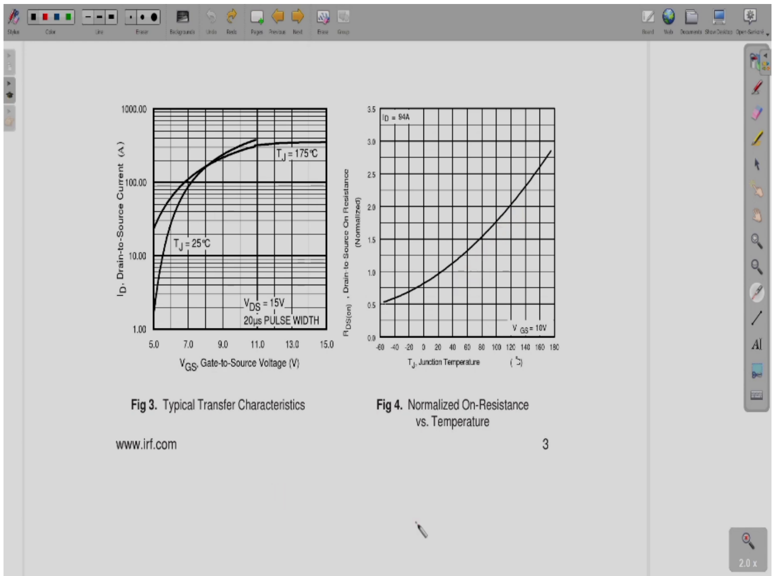

Then further this is drain current versus gate to source voltage, which is transfer characteristics. And that also you can see here two graphs are given, one for 25^0C and one for 175^0C. And from this graph, what you can observe is that the minimum the threshold is going to be about 5 V gate to source voltage, above which actually the drain current starts to increase.

Then $R_{DS(on)}$ versus junction temperature this we had discussed before. So, what you can see is that, that as temperature increases this $R_{DS(on)}$ also increases.

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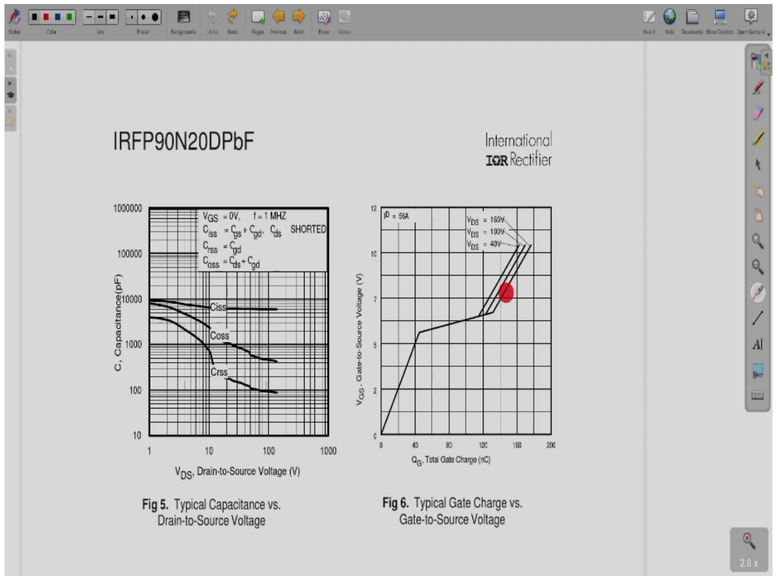

Further this is capacitance versus drain to source voltage. I had told you this before that these capacitances they are not constant, but they vary with this drain to source voltage and that is what is shown. So, this is input capacitance you can see not much effect is there on the input capacitance, but output capacitance and this reverse transfer capacitors they are varying a lot because as drain to source voltage changes and that is why we see the Miller effect also.

Then, further this is gate charge characteristics. So, gate charge versus gate to source voltage. So, here you can see that, that initially as the gate to source voltage increases charge is increased that means the gate source region is being charged the gate to source voltage builds up after that there is the Miller effect and then although the charge is increasing the gate is being charged, but you do not see much increase in the gate to source voltage and after that whatever is the leftover voltage with respect to the what is the voltage applied in the gate by the driver.

So, that is where to gate to source voltage increases and this is the rest of the charge that will be associated with the gate to source region. And you can see here that this, here this graphs they separate out and they slightly vary depending on what is the drain to source voltage that is applied.

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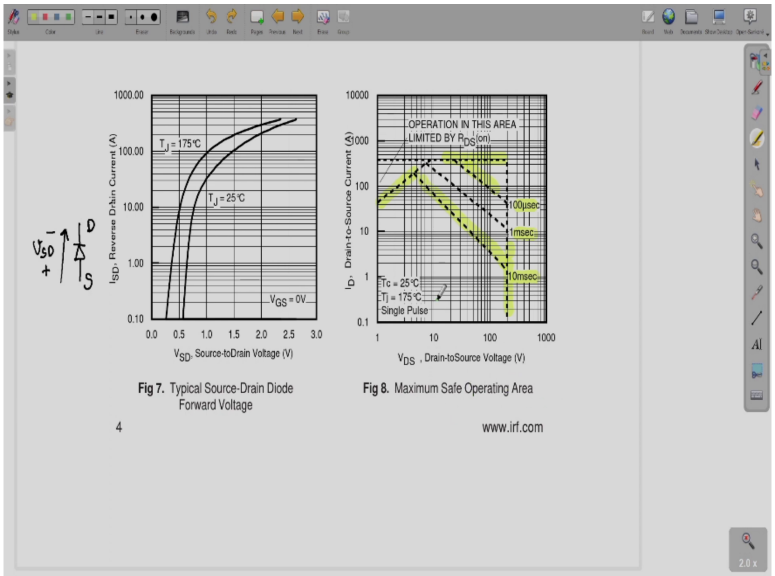

Next, this is diode current versus source to drain voltage, means basically this is forward characteristics of the diode, which is shown here. So, this is the diode. So, whatever is this, which is flowing from source to drain that is this I_{SD} current and whatever is the voltage associated with here that is V_{SD} voltage.

So, that characteristics is shown here. The forward characteristics and you can see that the threshold voltage for the diode is around 0.5 over here. And then this is safe operating area. This also we had discussed before. So safe operating area you can see these 3 limits one this limit is because of the ohmic characteristics ohmic region and then this is limited by maximum power dissipation limits and this is current limit and this part is voltage limit and as pulse duration decreases power dissipation that increases. So, that is safe operating area for the MOSFET.

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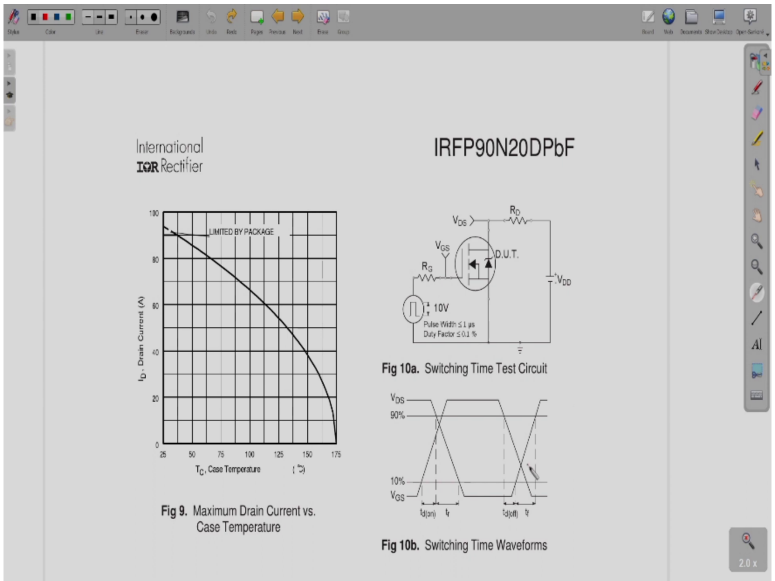

Further what you see here is drain current versus case temperature and that derating has to happen as temperature increases drain current is going to limit i.e., it is going to come down and that is what this graph shows. Apart from that the manufacturer has also given some tests circuits, which they have used for doing the measurements.

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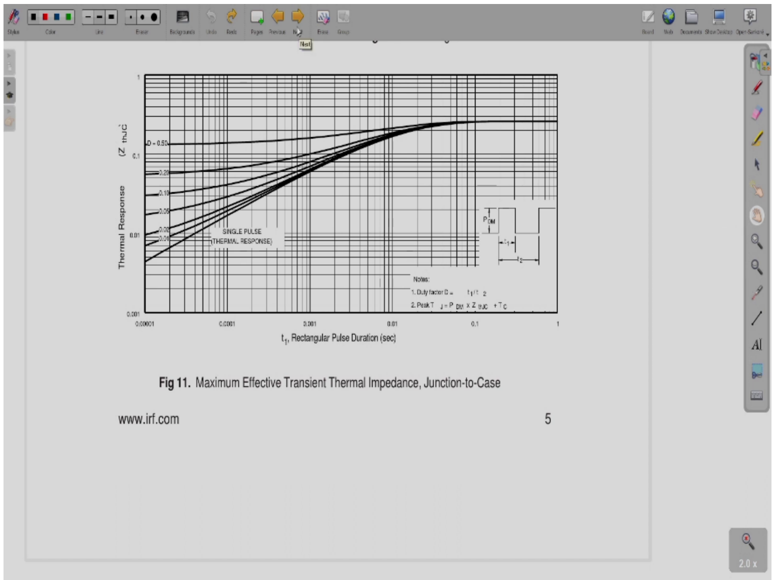

Then further the manufacturer has also provided this thermal impedance graphs the thermal response. So, this we will not discuss now, we will discuss it later on in the course when we go for thermal design.

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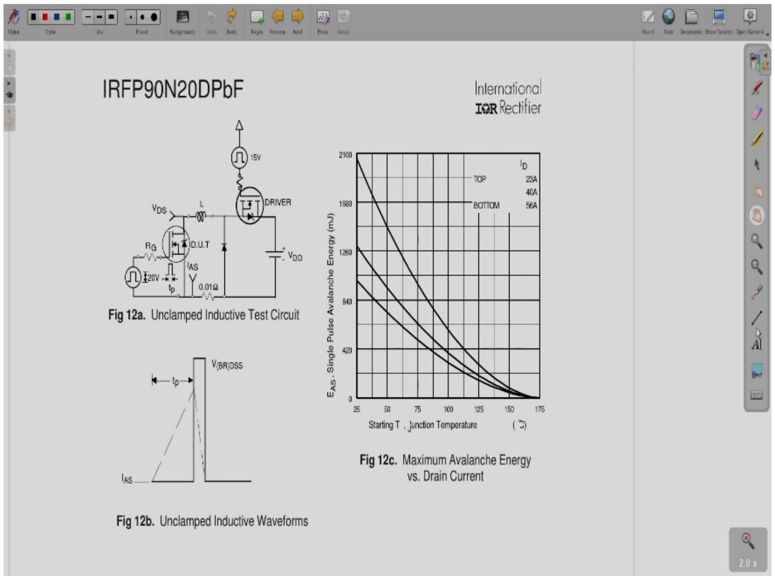

Then further there may be several other these kind of performance graphs that may be provided by the manufacturer and different test circuits and application circuits may also be provided by the manufacturer.

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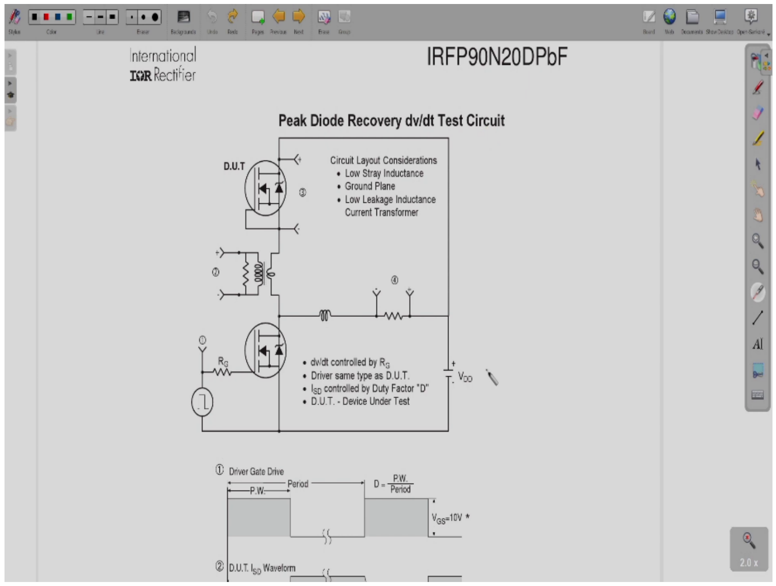

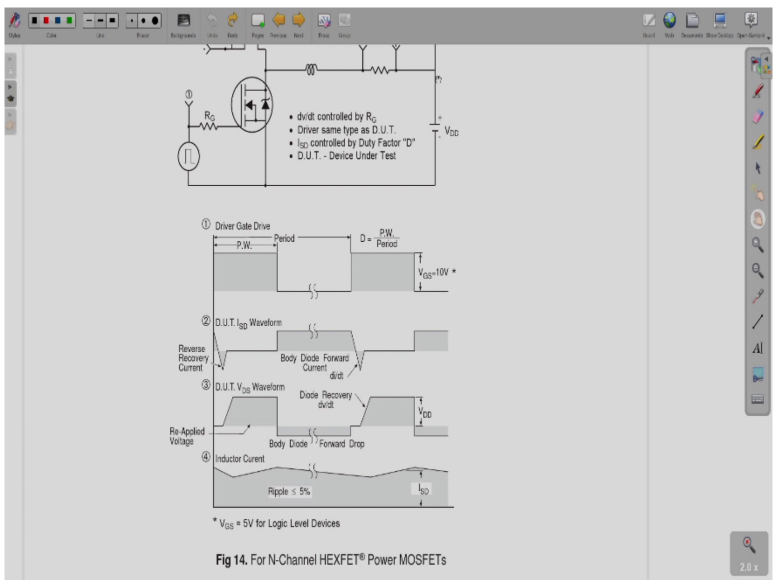

Now, here you can see that the manufacturer has also provided this peak diode reverse recovery $\frac{dv}{dt}$ test, how they have performed it and then some of the waveforms associated with it that also is given by the manufacturer. So, these kind of lot of information may be given by the manufacturer. Different manufacturers provide different types of information. So, you can look into it and usually they are self explanatory and suppose you are not able to follow them. Then you can go into the application notes by the manufacturer and there you will be finding all that information.

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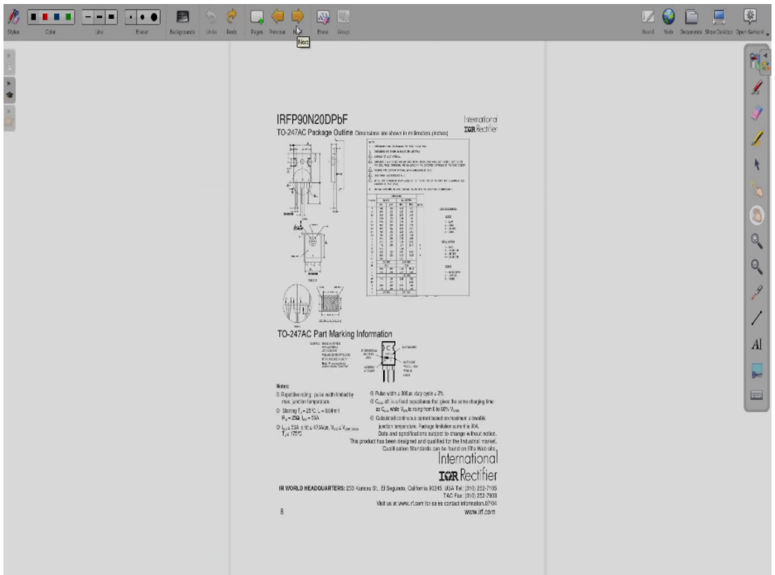

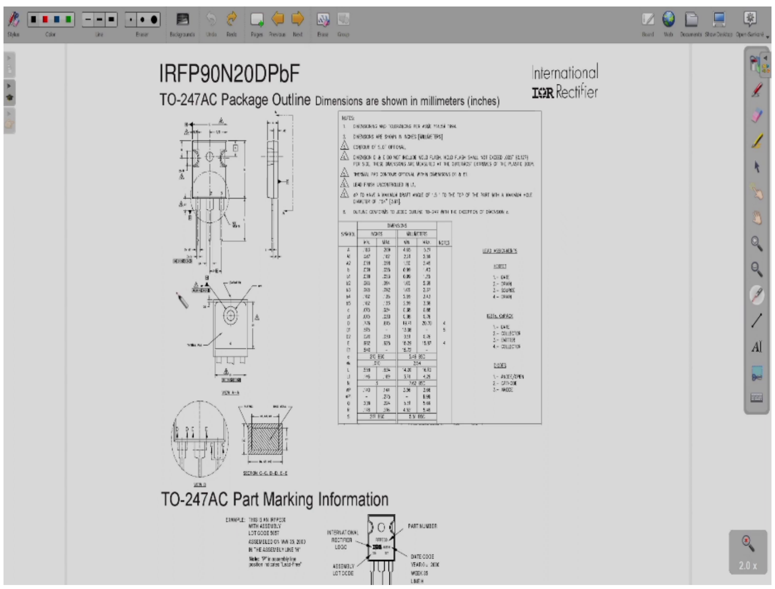

Next, this is packaging information that is given, so basically the dimensions are provided, you can see here that this is the package and the dimensions also usually in this part, they will be giving the dimensions of the package that are used, which you can refer to while you are making the PCB footprints for PCB design. So, as you saw here that, this is an example I have taken and it is International Rectifier's MOSFET. So, they have given certain set of performance curves and test circuits and different information apart from the usual notations that are provided in most of the datasheets. So, like that you can look through it and then based on it, you can choose the MOSFET that is going to be suitable for application. Thank you.