Design of Power Electronic Converters
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Lecture 12
Diode Datasheet Examples

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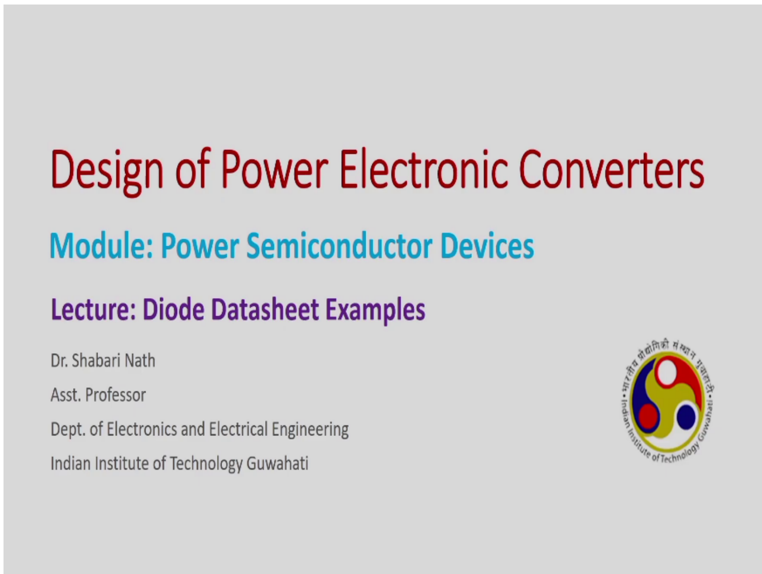

Welcome back to the course on Design of Power Electronic Converters. So, we were discussing diodes and we saw the vi characteristics of the diode. And we also saw the switching characteristics and we also saw few terms, which are important to be noted in data sheets. Now, let us look into some of the data sheets to understand better whatever we have discussed till now.

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So, this is the data sheet of three-phase rectifier and this is actually a data sheet of a series of rectifier diodes. So, this what you can see here is of two sets of ratings 25 A and 35 A and these are the pictures of the diodes. And so, by this you can get an idea of the kind of pins that are used in this kind of packaging just by looking at the pictures. Then these are the primary specifications, the key specifications, that are given here i_o is 25 A and 35 A, that is mentioned over here, the forward current specifications.

Then since this is for a series of diodes this V_{RRM}, this is given as a range 50 V to 1600 V. And then this is packaging information and circuit configuration that means this is a three-phase bridge and is not just a single diode that is there. And then the manufacturers have also specified key features of these diodes. So that also is usually given in any of the data sheets and many times they also write the applications for which that particular device is targeted. So, here there is a description that is provided for the data sheet for three phase bridge rectifier.

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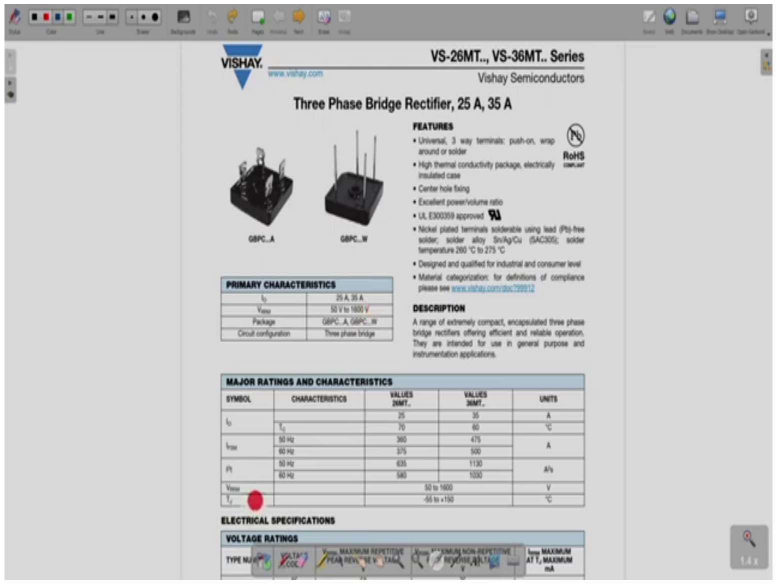

Now, here first of all you see these major ratings and characteristics. So, what you see here i_o and this is 25 A and 35 A for the two series 26_MT and 36_MT. And they have also given the case temperature for it, because forward current is usually specified with respect to temperature. So, case temperature is given as 70^0 C and 60^0 C over here.

Then this is surge current rating I_{FSM}, which is what we have discussed before when I explained you the different notations in data sheets for diodes. So, this you can see here is 360 A and 375 A, that is given for the two frequencies 50 Hz and 60 Hz, which is much higher than this 25 A, that is written. And what is the reason? Because this is related to surge specifications and so that is for a short time interval and so therefore these current ratings are going to be much higher than regular current rating, which the diode will be withstanding again and again.

Then there is a rating which is called as i^2t, which is related to heating and that means fuse selection, because if there is some non-repetitive surge which is coming, then what you need to do is that, you have to disconnect and so there may be a fuse that may be used. So, how do you select the fuse for that this i^2t ratings are given. So, that is what is mentioned over here. Then this V_{RRM} is again repeated over here and this is the junction temperature range, that is -55^0 C to $+150^0$ C, that you can see here.

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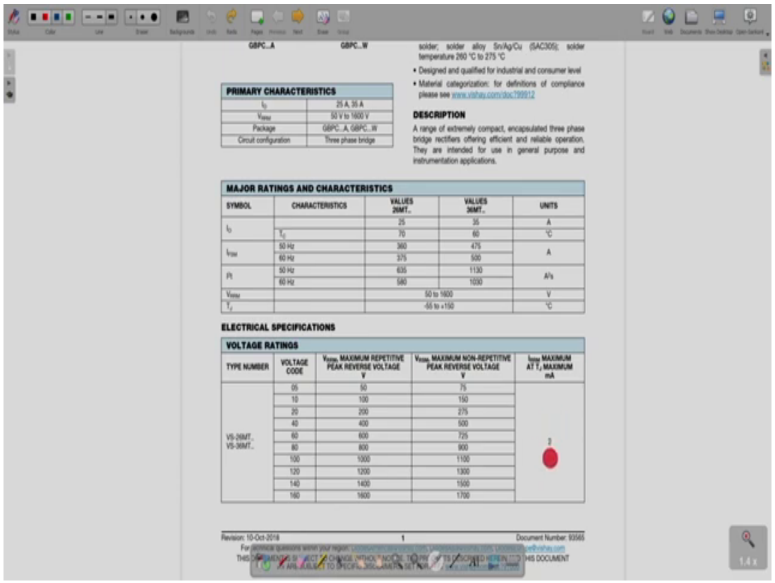

Then you see the electrical specifications in the data sheets. So, again you see here that, as this is for a series of diodes rectifier bridge, diode bridge rectifier, so that is why you see different, different values. There is a whole table which is given over here. So, how much can be the maximum repetitive peak reverse voltage, that is provided and I_{RRM} is basically the leakage current, so that can be equal to 2 mA, that is what this data sheet specifies.

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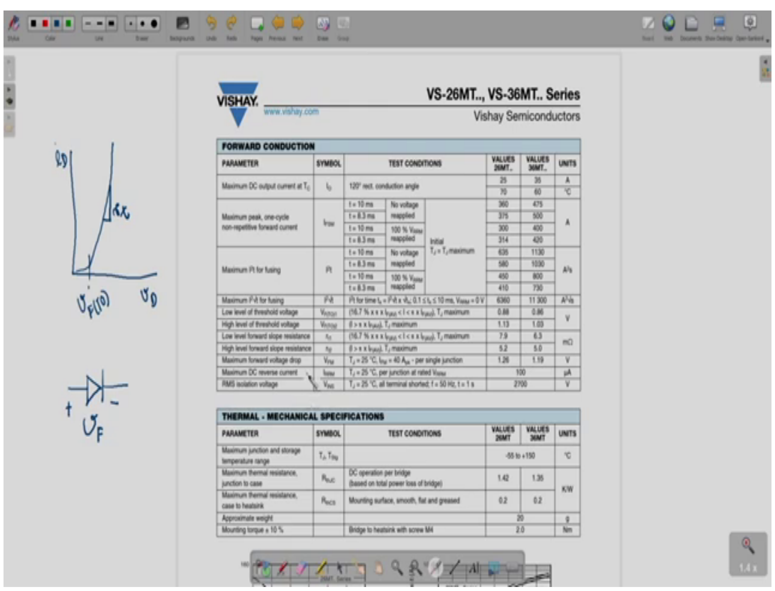

Next what is given over here? This maximum DC output current, so that is i_o which we have seen before also, so there is a forward conduction specification that is provided over here. Then this I_{FSM}, this also we just saw, this is for your 50 Hz and 60 Hz, so that is why corresponding to it half sine wave is 10 ms and 8.3 ms, that is what is given over here. And then what is the condition at which they perform the test for the voltage, that also is given over here and accordingly these current ratings may vary slightly.

And i^2t rating for fusing that also we just saw, so that also for different, different conditions, is provided in this. And the temperature at which manufacturer has provided these values that also is mentioned. So, that is the T_J maximum, maximum junction temperature. Then there may be some other $i^2\sqrt{t}$ ratings that also may be provided. Then this is low level of threshold voltage and high level of threshold voltage forward voltages.

So, what we are telling over here is that, so this is diode voltage, diode current over here and this is v_D versus diode current i_D. So, here there is that threshold voltage, so which is $V_{F(To)}$, that is given over here as the low level and the high level, this also we have seen before. Then the low-level forward slope resistance and high-level forward slope resistance. So, here there is that slope which is r_t, so low level and high level two of them r_{t1} and r_{t2} are provided here.

Then maximum forward voltage drop. So, what is the maximum forward voltage drop? So, this drop over here V_F, that appears while it is forward biased and it is conducting. What could be the maximum voltage, that is given? So, what you can see this V_{FM}, this is mentioned over here for 25^0 C and this is 1.26 V for this 26_MT series. For 36_MT series this is 1.19 V.

So, that is why if you recall I had told you that many of them have this voltage of 1.2 V around as the forward voltage drop. Then DC reverse current maximum that is the leakage current, so that is given as 100 μA. Then there may be other specifications also that may be provided.

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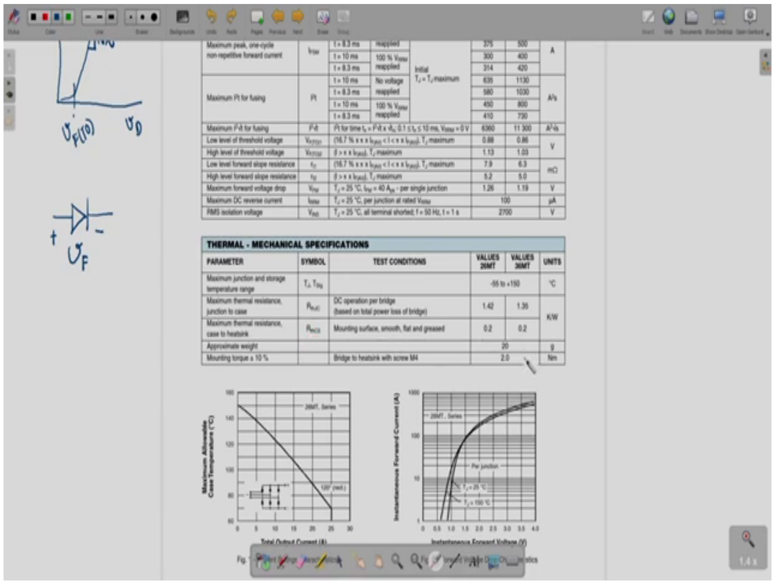

Then you have these mechanical specifications that are given maximum junction and storage temperature range. So, T_J is junction temperature and T_S is basically storage temperature, so that is -55^0 C to $+150^0$ C is what is shown. Then there is this thermal resistance, junction to case this I had mentioned you before what it is, and so that also you can see here that the specified R_{thJC} junction to case it is given in K/W.

Then thermal resistance case to sink, case to sink means case to heat sink. So, that also is given over here and then weight and other mounting torque when you put it on the PCB. So, how do you mount it what should be the torque, that has to be provided, that also is given in the data sheets.

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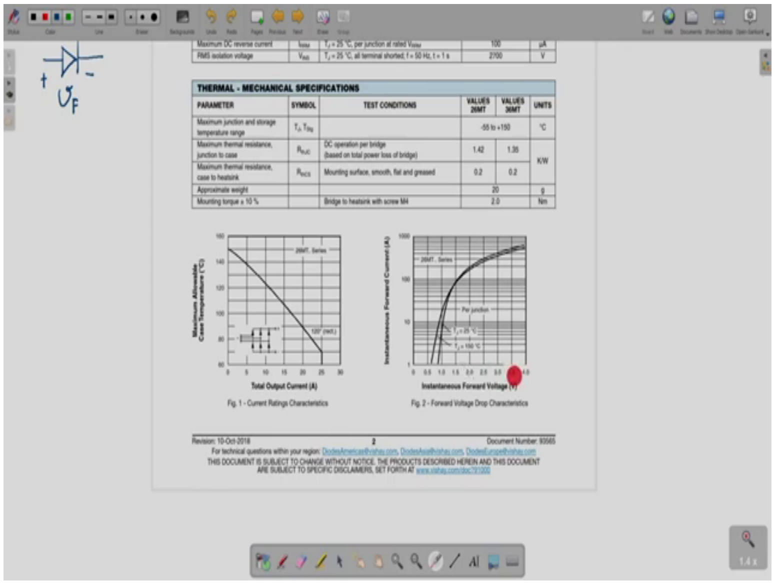

Then next are the performance curves that are provided here. So, this is maximum allowable case temperature. So, maximum case temperature versus output current. So, what do we mean by this is that, case temperature and how much current can flow through, that actually has a relationship.

So, what you see here is that case temperature comes down as current rating, the total output current increases. And that is very much expected, because as current increases heat is going to increase and so temperatures are going to rise quickly and so to protect the device the amount of current, that you flow through and the temperatures, that they can withstand there will be an inverse relationship there. And that is what you see this comes down as the output current increases.

Then, this is forward current versus forward voltage of the rectifier bridge that is provided over here. So, what you see is that two curves are given over here and this 0.5 to 1 V is what you can expect to be initial threshold voltage, because they have started from here, but you can recheck it with whatever that is given above. So, for two temperatures they have provided and as this current increases, then how forward voltage drop increases that is provided, that is what this performance curve is showing.

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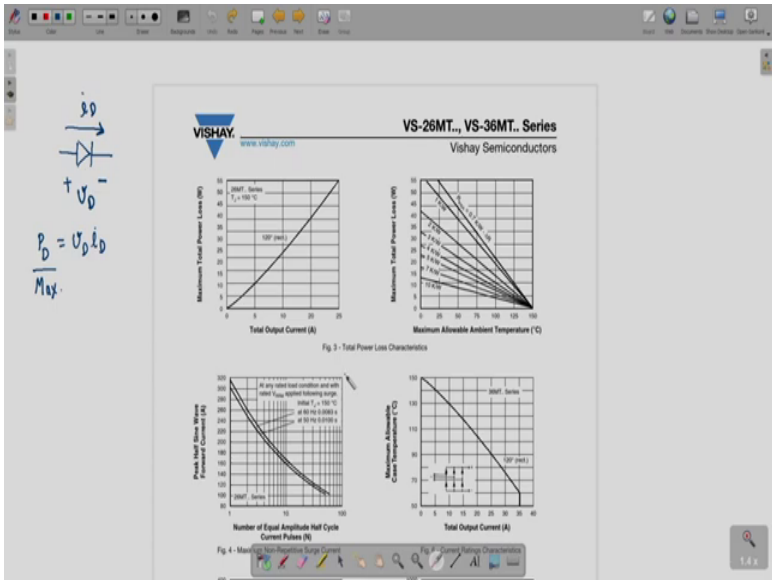

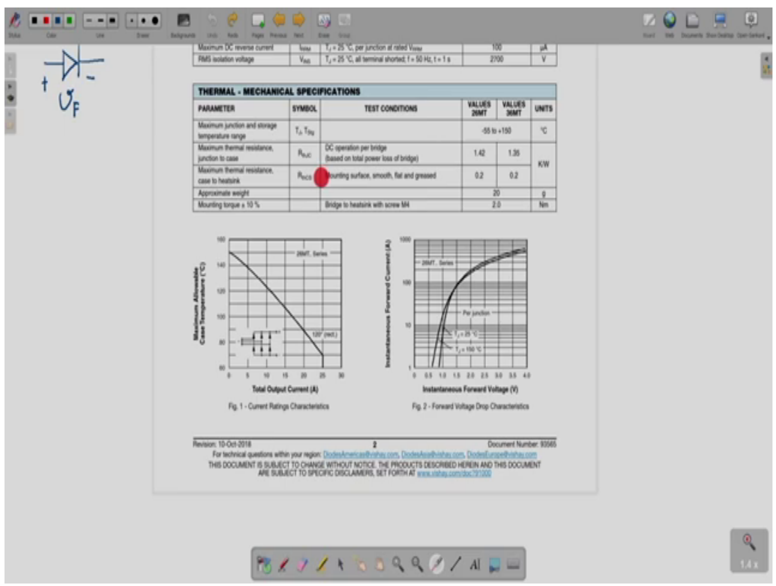

Next the curve, the graph that is shown here is the total power loss versus the total output current. So, when we say total power loss, what is it? This is voltage v_D and then there is this current i_D, so v_D multiplied by i_D is power loss that will be happening and that is P_D. So, there is a maximum that is allowed to protect the device, so that is maximum total power loss, that is provided over here and then there is a total output current with respect to that. So, here you can see that, as current increases power loss is also is increasing over here.

Then maximum total power loss versus ambient temperature. So, you can see here that is coming down over here, it is decreasing as ambient temperature is increasing and that is also what you expect, that as temperatures are going to increase the amount of power dissipation that will be allowed will be decreasing. And these are the several different curves over here which are provided, but this you can see that this sink to ambient thermal resistance, that is mentioned over here.

So, previously we had seen this thermal resistance junction to case and case to sink. Now what heat sink you choose that will also have a thermal resistance and that will be sink to ambient, and that is what the sink to ambient thermal resistances is. As different, different thermal resistances will be used, then how this maximum total power loss versus ambient temperature graph changes that is what is shown here. So, these are total power loss characteristics those graphs are given.

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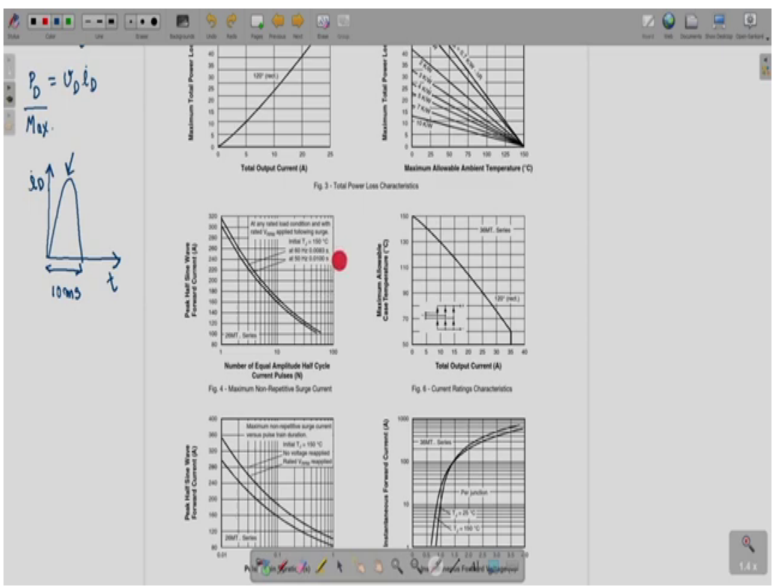

Then next is what we see over here is peak sine wave current, forward current versus number of equal amplitude half cycle current pulse and this is maximum non-repetitive surge current for that this is provided. Now, what it means is what actually I have discussed before. So, for half sine wave if you are going to pass this more current, then what is the usual current rating of the diode? So, this will be corresponding to 50 Hz cycle or 60 Hz cycles, if it is 50 Hz cycle, so this is going to be 10 ms.

So, then how much is this maximum current, that this device can withstand? And then for how many numbers of equal amplitude half cycle current pulses, the numbers that are given while performing the test that is provided over here. So, if you provide a greater number of pulses, this peak half sine wave forward current, that means the surge current that it can withstand is going to reduce, that is what it is showing and it is given for two of these frequencies 60 Hz and 50 Hz.

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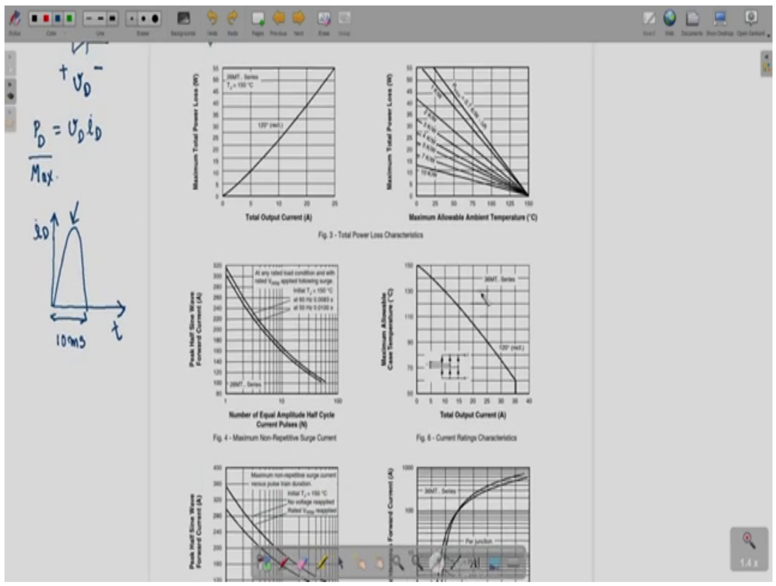

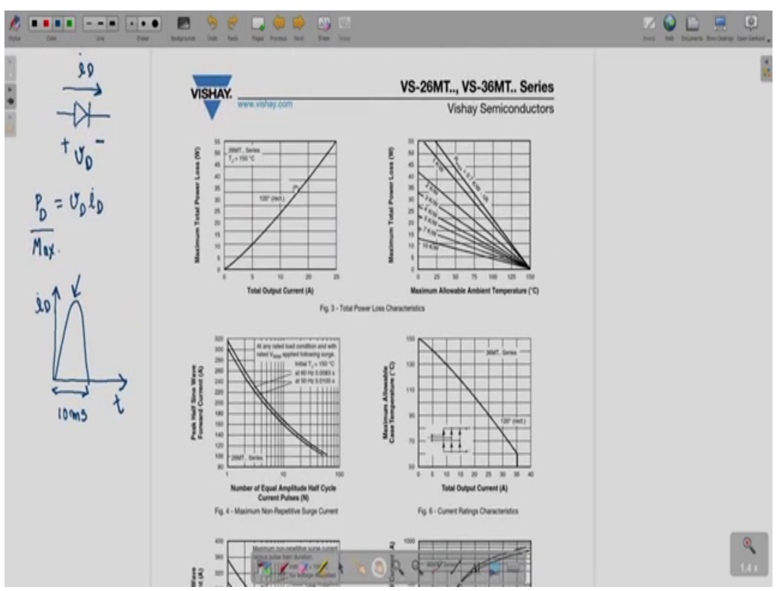

Then next you can see over here a similar graph is given and this graph is again peak half sine wave forward current versus pulse drain duration, it is actually pulse train duration, so that means you are giving a series of pulses. And there is a time duration of it. So, what is the time duration for which it is provided and accordingly how much the values could be? So that is what is given in this data sheet. So, this is again for non-repetitive surge current, you can see that these current values are high initially, but as this pulse train duration increases, then that comes down.

Then next what we see here is maximum allowable case temperature versus total output current. So, you have to note down that this is given for 36_MT series. Till now whatever these ones that we had seen were all for this 26_MT series. So, the same curves they have also given for 36_MT series as well.

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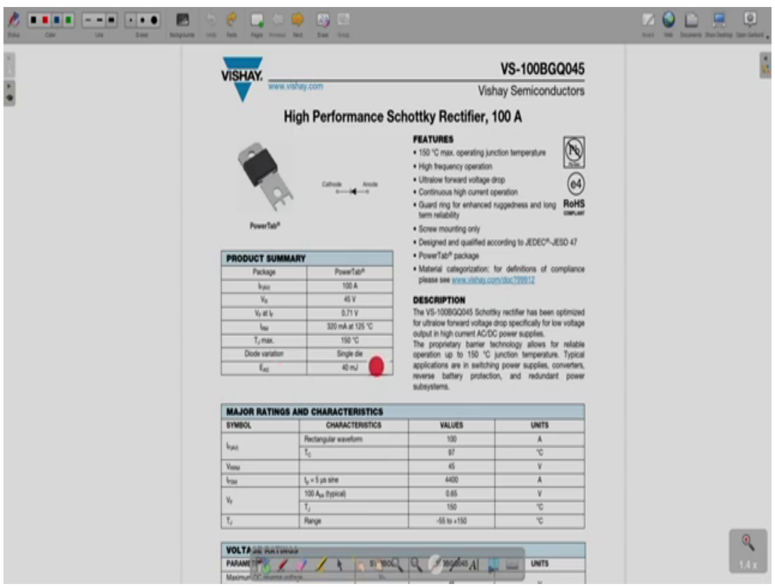

Now, let us look into the data sheet of a Schottky diode. So, high performance Schottky rectifier of 100 A by Vishay Semiconductors is the data sheet that I am using to show you for a data sheet of Schottky rectifier. So, again you can see here some features are given by the manufacturer, there is a small description also provided and this is the picture of that Schottky rectifier you can see here. The packaging is much more different than previously what we saw for that three-phase rectifier bridge.

And these are the key specifications, average forward current is 100 A. Now, you may compare it with, previously it was written as i_o as compared to here it is written as $I_{F(av)}$, because over there it was a three-phase rectifier and the data sheet was for the whole three-phase rectifier and not just for the diode.

Then you have this V_R the breakdown voltage which is 45 V and you can see here that this is much smaller. And why is this much smaller? This I have told you before that Schottky diodes are usually manufactured for less than 100 V, above that it becomes difficult to make Schottky diodes. So, that is why here you can see that the current rating is much higher, it is about 100 A, but the voltage rating is lower 45 V.

And another key thing that you can see here is the forward voltage drop which is 0.71 V. Now, this 0.71 V is much lesser than previously what we saw as the 1.26 V for the rectifier bridge. Then leakage current over here that is given is 320 mA at 125^0 C, maximum junction temperature allowed is 150^0 C. And then this avalanche energy that is also given over here 40 mJ. What is the meaning of avalanche energy that also I have explained before.

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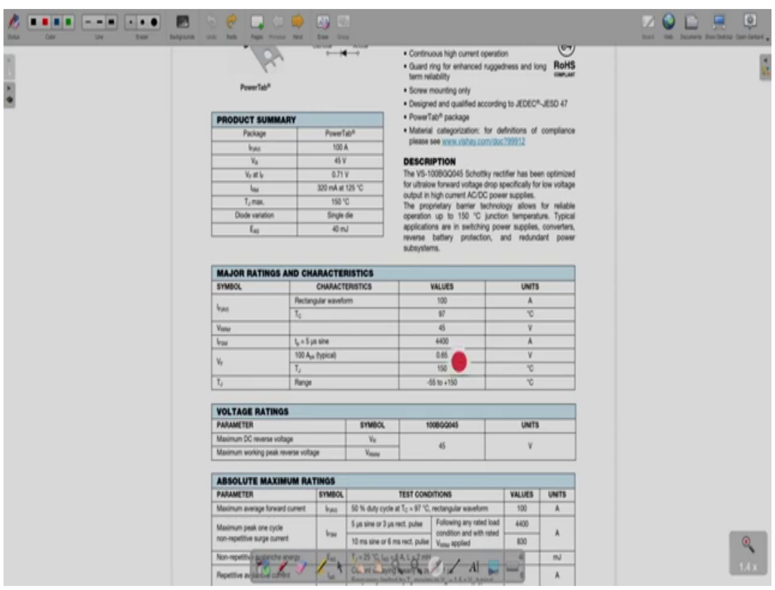

Now, these are the major ratings and characteristics that are provided over here. So, here you can see this average current, that is 100 A and this is at 97^0 C case temperature. And then this V_{RRM} is 45 V and surge current rating, that is for if you provide pulse of 5 µs sine wave, then that is 4400 A, that is what the manufacturer has provided over here. Then a forward voltage drop is 0.65 V, which is given at the temperature of 150^0 C.

Now, please note that here they had provided this 0.71 V, whereas over here they provided it for 0.65 V, so that all depends on what are the other conditions for which they are giving that V_F. Then junction temperature range is also provided.

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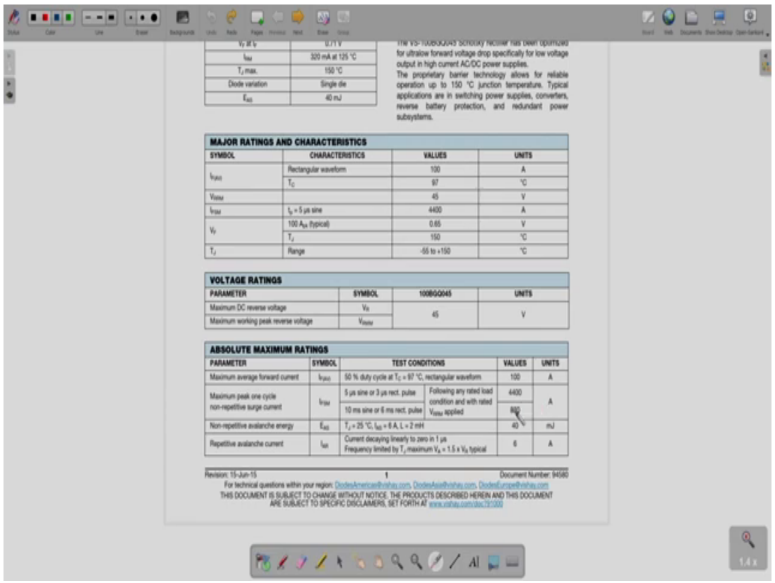

Then DC reverse voltage rating, that is the same as the working peak reverse voltage. So, that is your V_{RWM}, V_R is given as 45 V in this case. Then absolute maximum ratings are provided in this data sheet, you can see this maximum average forward current I_{FAV} is given 100 A for these conditions, they are providing that value.

Then this non-repetitive surge current that also you can see if only 5 µs sine or 3 µs rectangular pulse is provided, this goes as high as 4400 A. Whereas, if 10 ms sine or 6 ms rectangular pulses provided, so that comes down to 830 A. And then avalanche energy and repetitive avalanche current, that also is given here.

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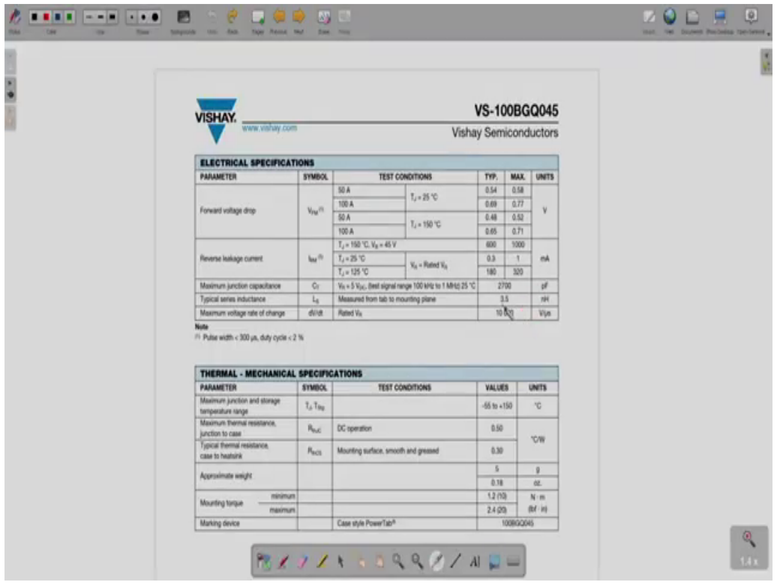

VS-100BGQ045

Vishay Semiconductors

www.vishay.com

ELECTRICAL SPECIFICATIONS						
PARAMETER	SYMBOL	TEST CONDITIONS		TYP.	MAX.	UNITS
Forward voltage drop	V_{FM} (1)	50 A	T_J = 25 °C	0.54	0.58	V
		100 A		0.69	0.77	
		50 A	T_J = 150 °C	0.48	0.52	
		100 A		0.65	0.71	
Reverse leakage current	I_{RM} (1)	T_J = 150 °C, V_R = 45 V		600	1000	mA
		T_J = 25 °C	V_R = Rated V_R	0.3	1	
		T_J = 125 °C		180	320	
Maximum junction capacitance	C_T	V_R = 5 V_{DC}, (test signal range 100 kHz to 1 MHz) 25 °C		2700		pF
Typical series inductance	L_S	Measured from tab to mounting plane		3.5		nH
Maximum voltage rate of change	dV/dt	Rated V_R		10 000		V/µs

Note

(1) Pulse width < 300 µs, duty cycle < 2 %

THERMAL - MECHANICAL SPECIFICATIONS					
PARAMETER		SYMBOL	TEST CONDITIONS	VALUES	UNITS
Maximum junction and storage temperature range		T_J, T_{Stg}		-55 to +150	°C
Maximum thermal resistance, junction to case		R_{thJC}	DC operation	0.50	°C/W
Typical thermal resistance, case to heatsink		R_{thCS}	Mounting surface, smooth and greased	0.30	
Approximate weight				5	g
				0.18	oz.
Mounting torque	minimum			1.2 (10)	N · m
	maximum			2.4 (20)	(lbf · in)
Marking device			Case style PowerTab®	100BGQ045	

Then next you see this maximum forward voltage drop of V_{FM}, that is provided for two different junction temperatures and different values of current and what is the range, that you can see and you can observe, that this is much lesser than what was the range for rectifier diode.

Then reverse leakage current that also is given for different, different temperatures. And then this junction capacitance that also we had discussed before, that is mentioned over here is 2700 pF, then series inductance the stray inductance, because of the package that is giving as 3.5 nH and this $\frac{dv}{dt}$ limit is many times given in the data sheet. So, that is provided here as 10,000 V per µs.

Then you see these mechanical specifications, basically temperature range, thermal resistance junction to case and case to sink, that will be given weight in mounting torque those things are provided.

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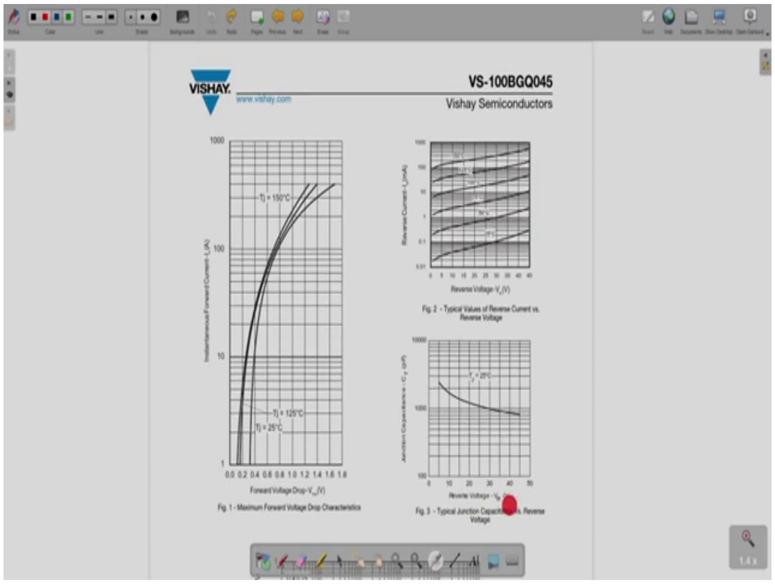

Then further you see this maximum forward voltage drop characteristics, you can see here from where forward voltage drop is beginning, when current is lesser and as the current increases how forward voltage drop also increases and it is provided for three different temperatures.

Then this data sheet gives you this reverse current, that means basically leakage current, that is given for different, different values of temperature and how it changes as reverse voltage, how much reverse voltage you have applied, that is changing. Then how this junction capacitance that is varying with respect to reverse voltages means the negative, opposite voltage, that you apply when the diode is reverse biased.

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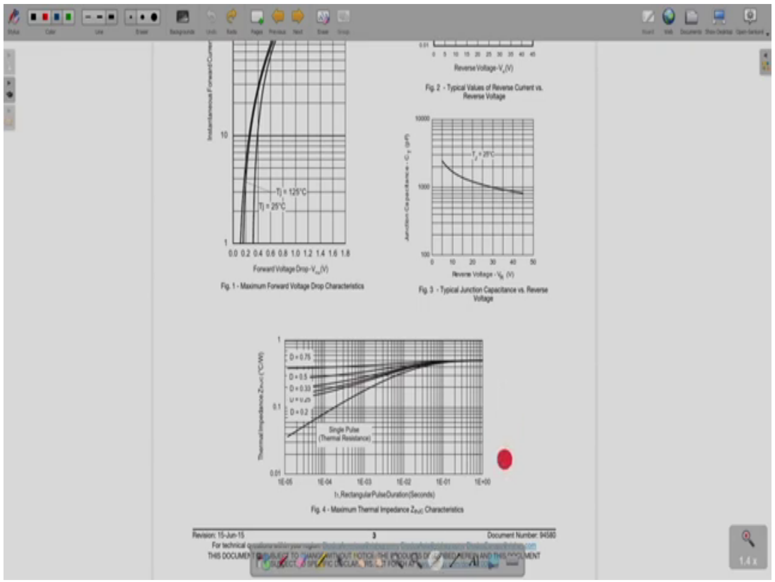

Then there are some thermal graphs, which are also given in the data sheet, this we will not take up now, this we will discuss later on in the course.

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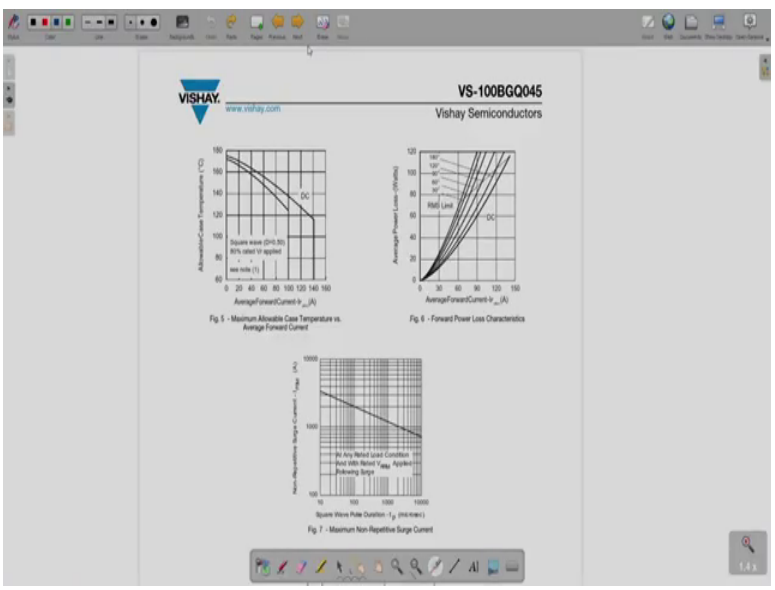

Next you see this allowable case temperature versus average forward current and here you can see that, case temperature decreases as forward current increases. So, that is what we expect normally to happen. Then power loss versus average forward current and that is obviously going to increase as the amount of forward current is going to increase, the amount of loss that takes place that also increases, that is provided over here in this graph.

Then further what you see here in this data sheet, they have provided this pulse duration versus non-repetitive surge current I_{FSM}. So as the value of pulse duration increases the surge current that it can withstand decreases. So, in this data sheet there are some graphs that are provided which were not there in rectifier bridge data sheet.

And also, when we saw the values the different specifications that are given that also are not exactly same as the rectifier bridge data sheet. So, it is depending on the type of the diode and application of the diode, some of the specifications will be given, some will not be given and also performance curves. Some data sheets will have some curves and another data sheets will have different curves, it all depends on the type of the diode and the application.

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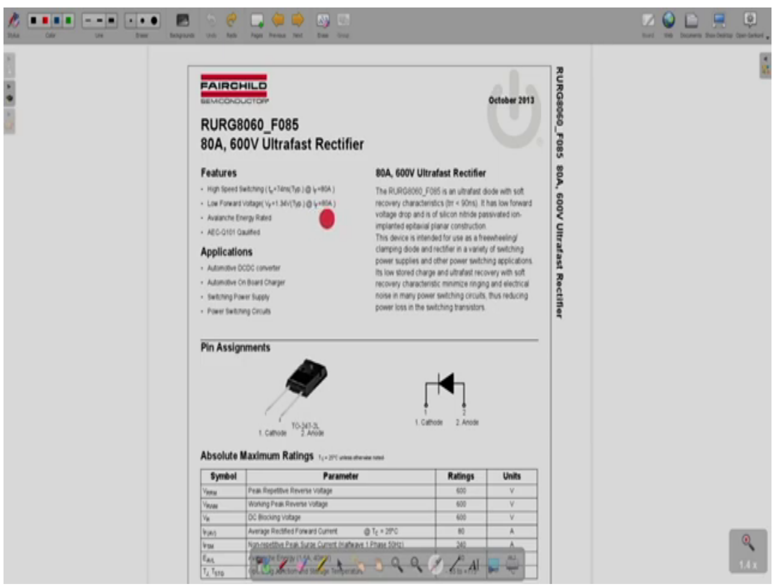

Next, I am taking this example of another diode, this is RURG8060 F085, this is by Fairchild Semiconductor and this voltage and current rating you can see here 80 A, 600 V ultra-fast rectifier, so that means this is a fast recovery diode. And again, you see these features and applications are provided and description is also given over here. So, these key specifications you can see that since this is a fast recovery diode reverse recovery time is provided and that is given at this forward current 80 A, and low forward voltage drop, which is 1.34 V typical at this current rating of 80 A.

Now, this here you can compare it with the Schottky diode, where it was given as 0.7 V, whereas here this is 1.34 V. So, this has a higher forward voltage drop as compared to the Schottky diode.

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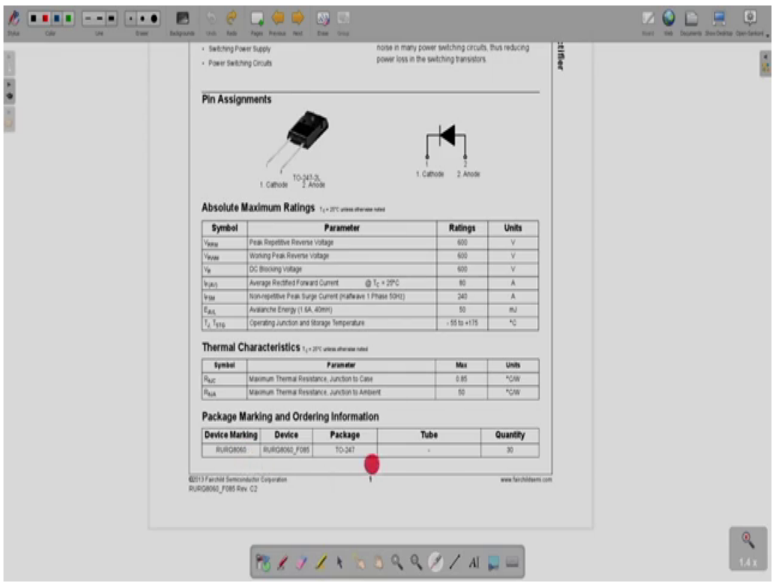

Then next you see these absolute maximum ratings, the peak repetitive reverse voltage, that is given as 600 V, and working peak reverse voltage is same, DC blocking voltage is also same. So, all three these voltage ratings are same for this diode. Then average rectified forward current is given as 80 A for this device and that is for the case temperature of 25^0 C, this is very important, because if case temperature is going to increase, this current rating will come down.

Then non-repetitive peak surge current for 50 Hz half sine wave, so that is given as 240 A. Then avalanche energy in the storage temperatures and junction temperature range are also provided. Then thermal resistances junction to case and junction to ambient, these are given. So, previously you saw the datasheet giving junction to case and case to sink, but here they have provided junction to case and junction to ambient.

So, you can find out what will be the case to sink and then sink to ambient temperature, that is something that you have to choose based on what heat sink that you are using. Then this is package information, this is using this package TO-247.

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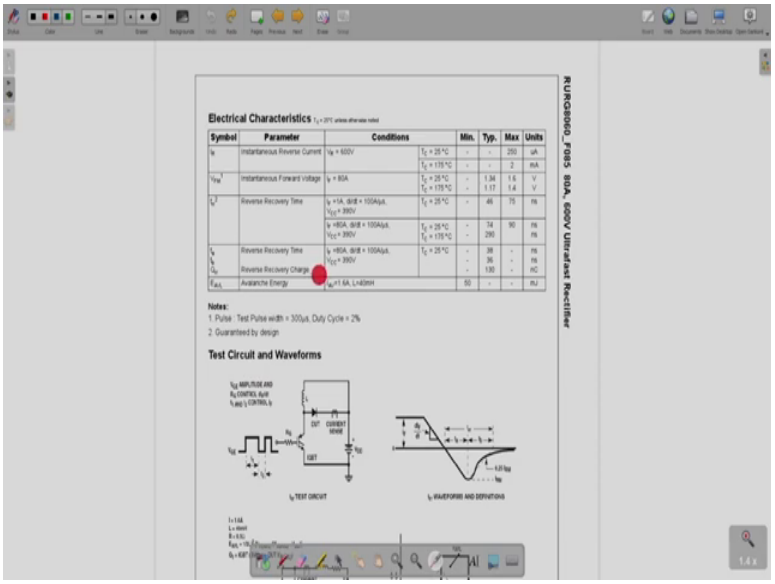

Then next you see these electrical characteristics, given I_R as given is instantaneous reverse current. So, basically that is reverse recovery current, which is very, very important specification, so this depends on the junction temperature, here this is given with respect to case temperature. So, this becomes 2 mA at 175^0 C and it is 250 µA at 25^0 C.

Then instantaneous forward voltage, that also is given for two different temperatures. Then reverse recovery time is provided t_{rr}, that is here you can see for different conditions and this is also given for this $\frac{di}{dt}$ rate what the manufacturer have used. So, this is what I had told you before also, many times in the data sheet this turn on and turn off, whatever specifications they are making they are specified for a particular $\frac{di}{dt}$. So, that is what we see here.

And then reverse recovery time t_a and t_b are these two which we had written as t_4 and t_5, when we discussed switching characteristics of the diode, so that is written over here as t_a and t_b. So, that you can know the softness factor of the diode the S factor and you can see here that this is 38 ns and 36 ns, so it is slightly less than 1, but it is close to 1. So, it is reverse recovery charge that also is given as 130 nC and avalanche energy is also provided.

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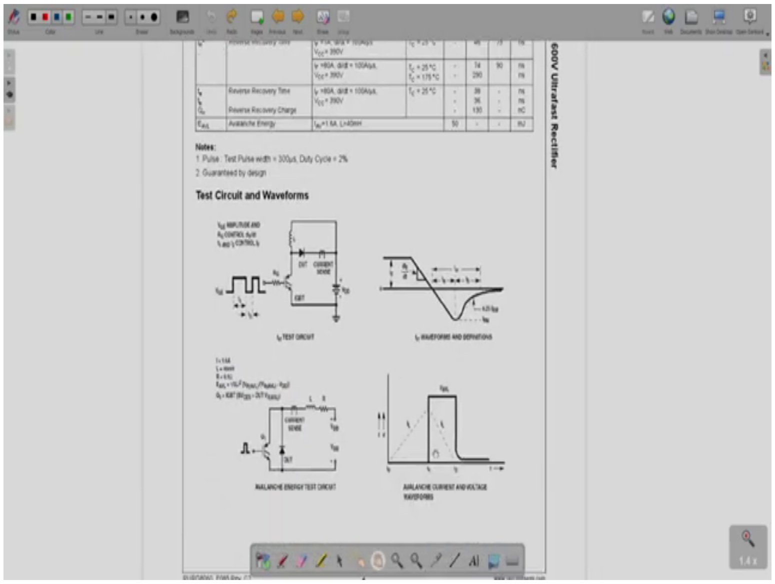

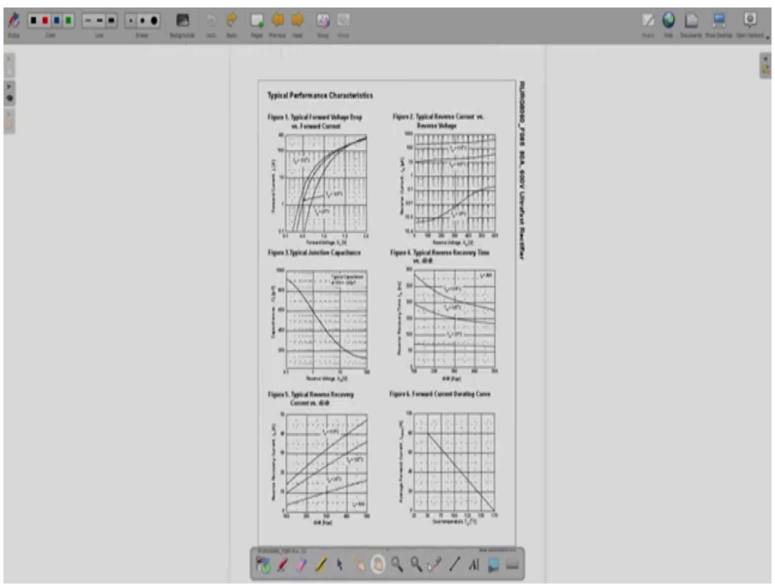

And then there will be test circuits and waveforms, which are given by the manufacturer.

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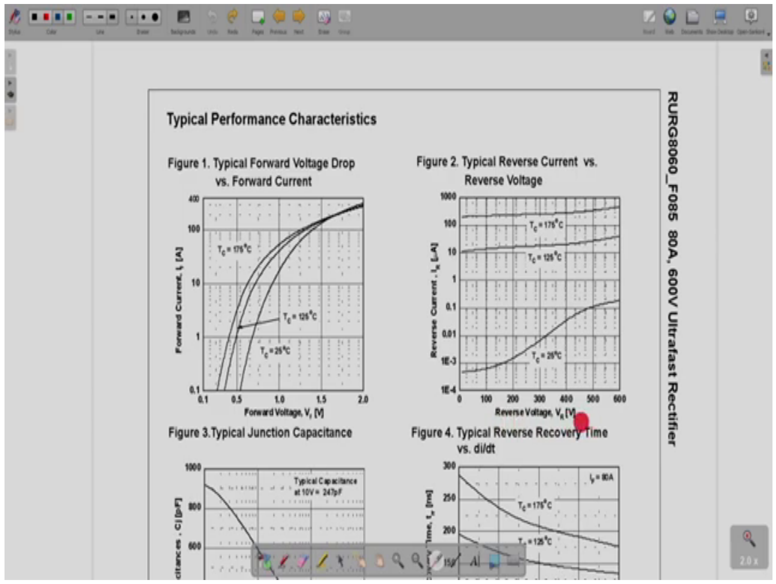

Now, this is forward characteristics, that you can see here in this figure one forward voltage drop versus forward current. These are the thresholds and then after that as current increases the forward voltage drop also increases. Then a reverse current, that is basically leakage current, how it changes with the reverse voltage, that is applied.

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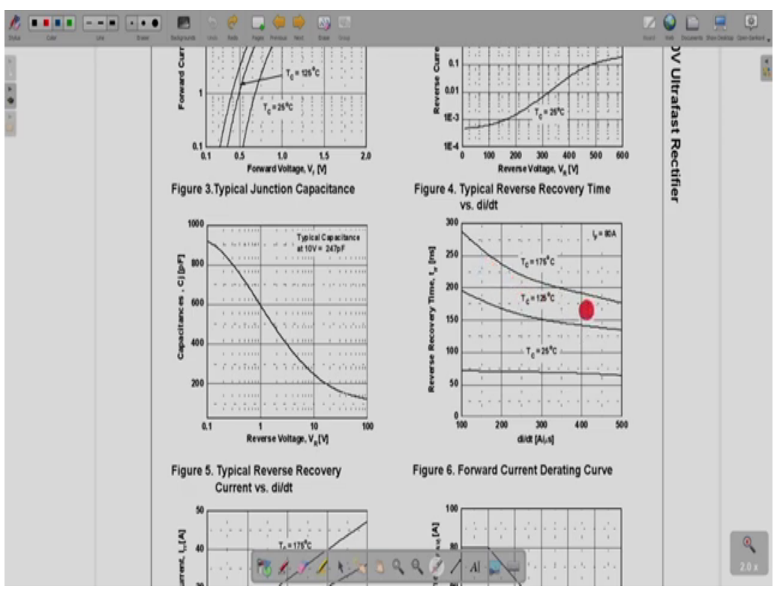

Then here what we see is junction capacitance, how that is changing with reverse voltage, then reverse recovery time how that is changing with $\frac{di}{dt}$. So, as you increase $\frac{di}{dt}$, you can see here that when temperatures are higher than t_{rr}, that tends to reduce.

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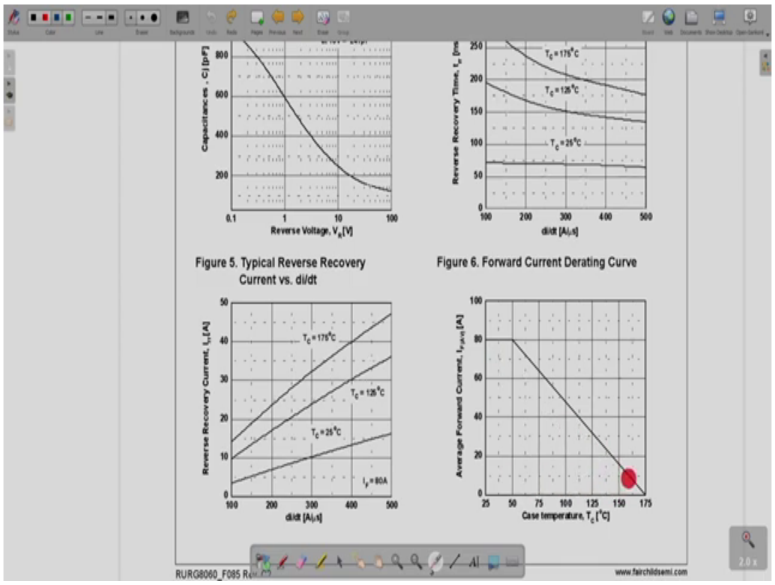

Then what we see here reverse recovery current I_{RR} versus $\frac{di}{dt}$, so $\frac{di}{dt}$ increases reverse recovery current also is increasing. Then this is average forward current versus case temperature as case temperature increases forward current that is allowed is going to decrease.

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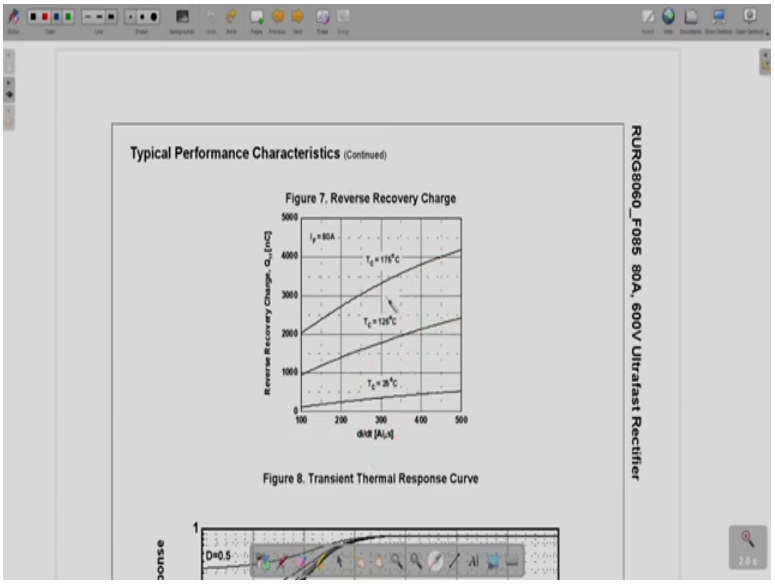

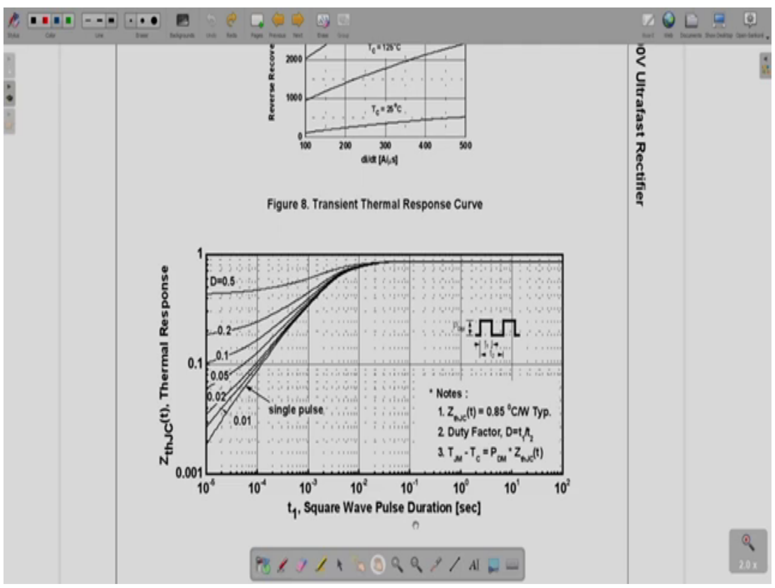

Then next what you see here is a reverse recovery charge Q_{RR} versus $\frac{di}{dt}$, that also you can see that as $\frac{di}{dt}$ is increasing reverse recovery charge Q_{RR} also increases. Further, thermal responses are also given that we will discuss later on in the course when we discuss thermal design.

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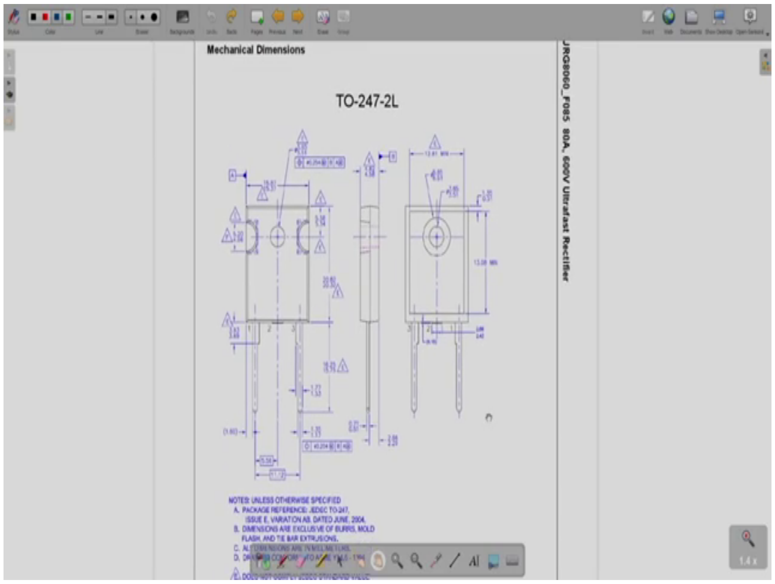

And then you can see here, that this is actually mechanical dimensions, which are given in the data sheet. So, while you are designing your converter, you first analyze the converter and you decide the key specifications that are required and what type of diode that you require. And then basically you go through different data sheets of different diodes and you pick up the one which suits your purpose. Thank you.