Electronic Packaging and Manufacturing
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Lecture – 35
Electronic Packaging Reliability – 1

Yeah welcome back, we will continue today with our course on Electronic Packaging and Manufacturing. And today, we start a new topic on Electronic Packaging Reliability. Extremely important and probably it is very critical as you know that if we buy a component or an electronic product, a gadget then it is not just essential for it to function as per our expectations today, but to retain that performance over its lifetime. I do not want a smartphone that is extremely fast efficient when I buy it, but then 6 months later I get frustrated with its performance because it has not been able to perform with the same efficiency over it over the time.

So, it is very important that it is not just it is very important not to have good performance at the beginning right when you buy it which is known as beginning of life, but also retain that performance ok. It is like a you know a cricket player somebody can have a very glorious debut probably it scores a double 100 on debut, but then over the next 10 tests and the rest of his career it is his performance is quite ordinary. So, this is something that you know example of a performer who had who showed a lot of promise at the beginning, but was unable to live up to up to those standards.

On the other hand, you have other players who whose debut may not be as glorious, but it is quite decent, but to hold on to their performance and performs consistently over their entire career all right.

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So, let us move on to that one and the topics that we are going to cover as part of this module is why is reliability important. I think we already took an example, then quality versus reliability, and then reliability matrix ok. We are going to cover these concepts as part of this lecture.

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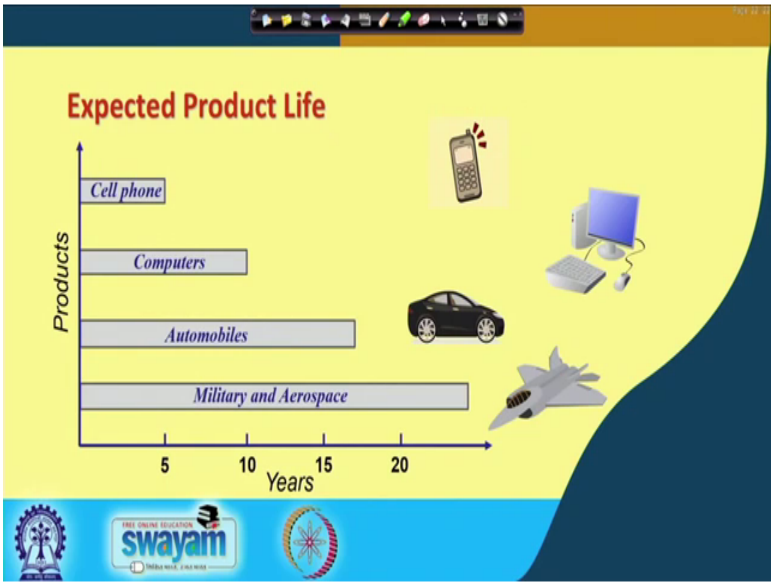

So, let us start with this slide where we are looking at when we talk about reliability and define it as the ability to hold its performance over its lifecycle. So, then we also have to consider that what is that lifecycle? What is the lifetime or the life of a product? Now that life of a product really depends on the application and its performance its ability to retain the performance over its entire life also depends on the conditions in which it operates.

So, let us take a cell phone looking at product life. If you take a cell phone, I do not think too many of us retain a cell phone over more than 5 years. So, typical life time of a cell phone probably is 5 years. So, if I can design a product such that it does not its performance does not degrade over a period, it does not degrade appreciably or perceptibly over its period of 5 years, then I think it is a good design. After 7 years later say it is not performing as well and somebody is complaining you will ask how old is your phone we would say 7 years, oh! my phone is 7 years old and you would say hey come on 7 years it has it has served you what else do you want how much more do you expect right.

So, that is the expectation that is the expected lifespan and that is how the product is going to be designed. Computers if you think of a desktop, I do not think 10 years is very unreasonable is that unreasonable ok. You may get newer models, but we really do not discard it we would just say we would still say that you know I have an old desktop which is decent I mean if you want to do some emails and web surfing I think you can go to that one that is good enough.

Automobiles I would say 15 to 20 years and even more sometimes. But again I think what I am trying to say is beyond the certain age you do expect its performance should degrade, but the lifecycle of a typical automotive product or an automobile is about 15 years even when you know when we in India for example, when I registered my car the registration is valid for 15 years ok. And after that, you may be allowed to renew the registration for another 5 years, that is the that is the rule in the state and I think in many states over India right.

So, 15 years it is expected that not many cars are going to last beyond 15 years or at least last with that owner who can still take pride and say I have this car for much longer than 15 years probably much lesser ok. That is that is a trend that we have today. It was not there before, I mean in earlier days I think when my when our fathers used to buy a car, it was probably they bought it with the expectation that it is going to serve them for the rest of their lives ok. Expectations have changed. Military and Aerospace yes Military and

Aerospace maybe 30 years or so, when you when you actually build a build an aircraft and the electronics that goes into it the aircraft is supposed to function for definitely more than 20 years ok.

Military vehicles, Military airplanes so these products have much longer life cycle. The other thing that we need to note is each of these products and product categories operate in a different set of operating conditions. A cell phone is primarily going to be in a protected environment probably indoors most of the time sometimes outdoors, even though outdoors we normally keep it on our holster in our pockets and sometimes if a call comes we will take it up; we will pick it up.

Computer desktops mostly indoors even more. So, automobiles on the other hand yeah it is supposed to function over a wide range of weather conditions over a wide range of road conditions in the in maybe it may be raining it may be snowing it may be scorching hot outside, automobiles are supposed to last in such conditions or function reliably in under such conditions.

Military and Aerospace even harsh even more even more rugged even more adverse conditions. If you think of down hole drilling, there is electronics inside ok. So, deep sea drilling, down hole drilling these are also very adverse conditions in terms of pressure in terms of temperature in terms of corrosive environment right. So, the expected product life is one and also the conditions under which they operate is another.

So, all these actually when we design an electronic product all these have to be kept in consideration. That is why, if you recall at the beginning of these when we are talking about at the beginning of this course when we are talking about first level packaging, we were talking about plastic packages, we are talking about ceramic packages. And we said ceramic packages much more expensive, but much more reliable and typically goes into Military Aerospace type of applications where your where your product life cycle is much longer and the product operating conditions is also much harsher.

But for computer or for a cell phone, we normally do not go for ceramic packages, because number 1 the conditions under which the operate are not that adverse and number 2 the life cycle expected life cycle is also not that not that long all right.

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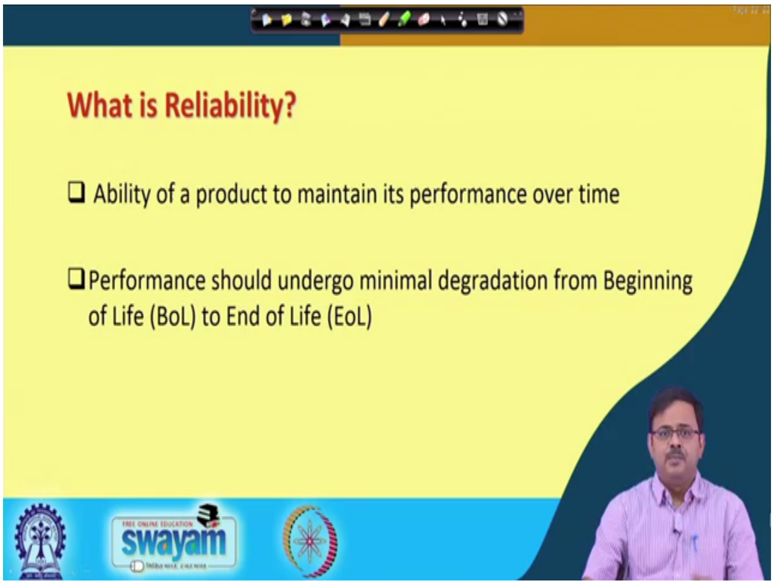

So, what is reliability? We have I think mentioned it several times ability of the product to maintain its performance over time and performance should undergo minimal degradation from beginning of life to end of life this BoL and EoL is often used under in the reliability jargon and they stand for beginning of life end of life. Beginning of life means when it just comes out of production it is also sometimes called end of line, but sometimes that become, but it at times becomes confusing because both them stand for EoL. One is end of line; the other is end of life. End of line means, it is an assembly line and as it is comes out of the assembly line fully assembled and ready to be shipped to the customer then that is end of line that is when the quality check happens. Is it performing as per specs? Yes, it is ready for shipment right.

So, but beginning of life probably is another term and probably more widely used, but many times if you come across our end of line do not do not get confused because that is what it means, what it means is it is just out of the factory having done gone through the quality check and ready for shipment all right ok.

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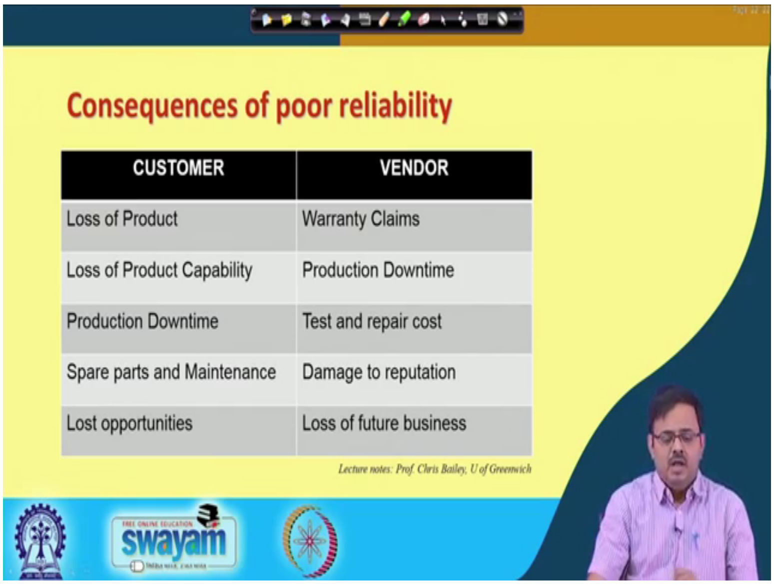

Now what are the consequences of poor reliability it has consequences both for the customer who is using it as well as the vendor and I have listed some of these thanks to a course that I attended from Professor Chris Bailey from University of Greenwich.

For the customer it is a loss of product, loss of product capability, loss of product is if it fails its gone. Loss of product capability if it is degraded it is not failed, but it is so slow that it is almost unusable. Production downtime, because if it goes bad and then you have to then you have to call the technician and once by the time he or she comes and fixes it, then it is for that time it is it is not operational and that is the loss to the customer.

Spare parts and maintenance if something goes bad too often and you have to repair it or replace it then that is that is a you know that is not something desirable. So, from the customer point of view and lost opportunities and that all relates to lost of product capability production downtime everything. For the vendor, so this is the person who is the customer is a person who is actually using it and bearing the brunt of the degraded performance or the failure. But for the vendor also even though he has sold the product and made his money. A poor reliability means there are more warranty claims if the product fails within the warranty period then he has to give the service and replacement parts for free and that is the cost right that is a that's an added cost to the vendor that is a loss right.

Same for production downtime test and repair cost which comes to him if it is under warranty is damage to reputation right that is very important the brand image and loss of and this leads to loss of future business. So, for both ends it is poor reliability is a matter of grief concern right.

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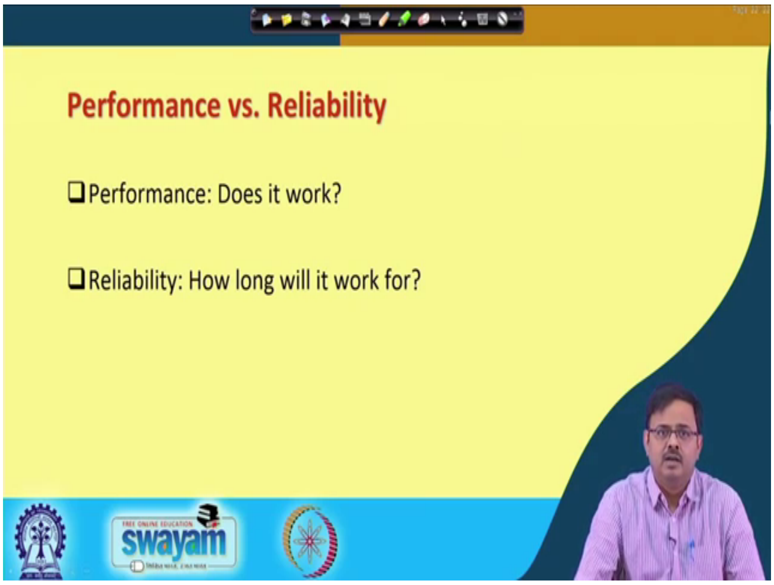

So, performance versus reliability again we have talked about performances does it work yes does it work according to expectations that is according to specs it is, but how long will it work, how long will it work for; that is reliability.

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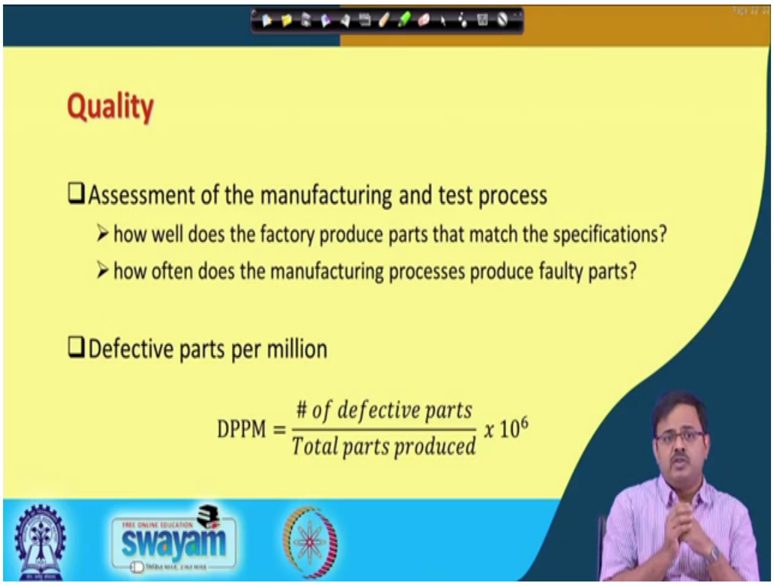

What is quality? Quality and performance are often used interchangeably, but quality is assessment of the manufacturing and the test process is. What is, how is the quality of the product? How well does a factory produce parts to match their specifications. And how often does the manufacturing processes produce faulty parts.

So, when you talk about quality, what it means is from the factory and the production point of view it is what is the probability. Probability being used in loose terms here. What is the likelihood? Let us say of a certain manufacturing plant following a certain set of processes produce faulty parts and that has to be very low. So, what it does is the part that is the way it is characterized is DPPM which is defects part defective parts per million DPPM.

So, what is that? It is the fraction of the defective parts over the total amount total number of parts that is being produced and since it is per million it is 10 to the multiplied by 10 to the power 6. So, if I produce 100 parts and two of them are defective, then it is 0.2 right. They are just the ratio, but parts per million its 0.02 times 10 to the power 6 which is 2 into 10 to the power 4 that is a very long number very very large number sorry.

So, therefore, if you have a good process your defects defective parts per million or defect per million parts should be very very small per million parts all right

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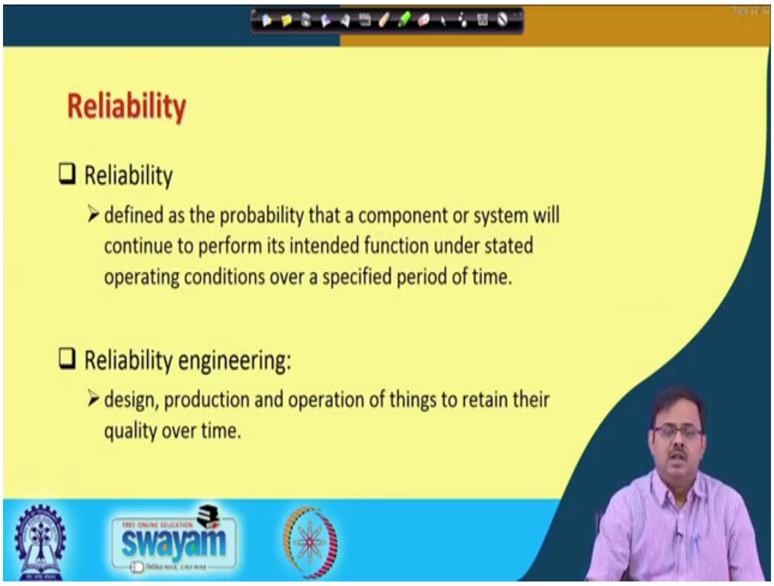

Now that is quality. What is that? That is when the product is produced or manufactured is it defective, is it satisfactory. If it is defective, it is not sold it is not shipped. If it is not effective, it is ready for shipment. Many a times, you would see quality some stamp on. If you buy a new computer or a or a new cell phone you would often see that sticker quality check tick or quality ok, I mean different companies will have different stickers, but what it says is it was tested for quality after production and found to be.

Reliability on the other hand is defined as a probability that the component or the system will continue to perform mark the words continue to perform its intended function understated operating conditions over a specified period of time. So for a cell phone it should perform as per the expectations as per the promise and the specs that is given under a under indoor and outdoor conditions over a period of let us say 5 years. If it is a desktop under the indoor conditions over a period of 10 years.

So, that s reliability it is not just good enough to have the performance today, but have that performance satisfactory performance after a period of let us say x number of years where x depends on the type of product that we are talking about. So, therefore, if I am a reliability engineer in a company what am I supposed to do?

My responsibility to is to design, produce, and operate to order the or to ensure that the design production and design production is such that the operation of the parts, or the components, or the gadgets, or the products that I am producing retain this quality over time. That is reliability engineers job all right.

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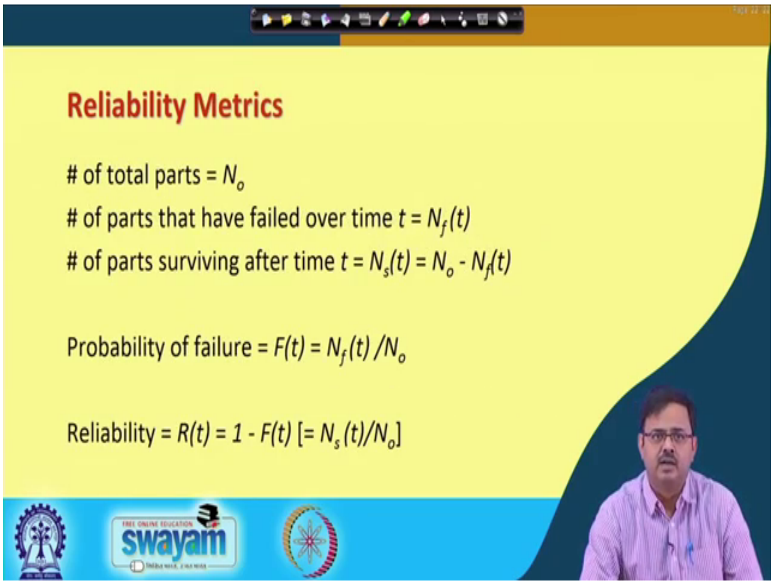

So, now that we know what is performance, what is quality, what is reliability and the importance of reliability. Let us look into some of the theory or some of the metrics of reliability. How do I measure reliability?. Is it just a physically loose term? Oh he is very reliable we say that right or is it a mathematical term? You can put a number and say reliability is so and so much. So, from the in the mathematics or statistics field reliability is actually a numerical number; it is a numerical quantity. What is it? It is the probability of survival of parts.

So, if you have N number of parts N naught number of parts to start with and they have operated after a for a period of time t, let us say t maybe 10 years t maybe 1 year whatever. And then number of parts that has failed over that period is denoted by N f; N f of t where t n f is the function of time. Therefore, the number of parts that survives after time t is going to be N naught minus N f that is what is shown there.

So, the probability of failure from the very basic definition of probability is N f over N naught and the reliability is 1 minus probability of the failure. Therefore, N s over N naught or 1 minus N f over N naught clear. So, that is what reliability is. Now at this juncture let me just make a mention of when I say a product has failed or a part has failed what do I mean? When I say it has failed, it means that it is unable to perform as per expectations.

Now, the failure can be of two types one can be catastrophic which is the product just does not work at all for example, if a connection has snapped due to whatever reason your product will not function so that is the failure that is a catastrophic failure. The other one or let us say it has become so hot that the silicon has got charred, it has burnt your product is not going to perform.

On the other hand, the failure can be in terms of degradation. You started with a certain performance, but over a certain time, but over a period time period of t that performance metric has undergone a degradation. And depending on what that metric is it can go up or go down and when it goes above or below depending on what we are talking about if it goes above or below the threshold acceptable limit then we say it has failed.

We have studied thermal before if I say that the acceptable junction to ambient thermal resistance is 2 degree C per watt. When I buy a product and do some testing I see that the junction to ambient thermal resistance is 1.5 degree C per watt. So, therefore, that is below the acceptable limit of 2. But then, I operate that product for 1 year or one and half years and then I decide to measure it after; let us say 18 months and I see that it has now gone to 1.9 from 1.5. 1.9 degree C per watt, it is still below two degrees c per watt which is the limit. I test it after 6 months again and I see that it has now gone above 2, so I would say it has failed, so that is failure.

On the other hand, it may be just a connection which is going loose with time as long as it is holding its performance it is good, but then one day it does just does not work. It has snapped the condition has been broken and in such a case it is a failure, it is a catastrophic failure all right. So, that is the definition of failure here.

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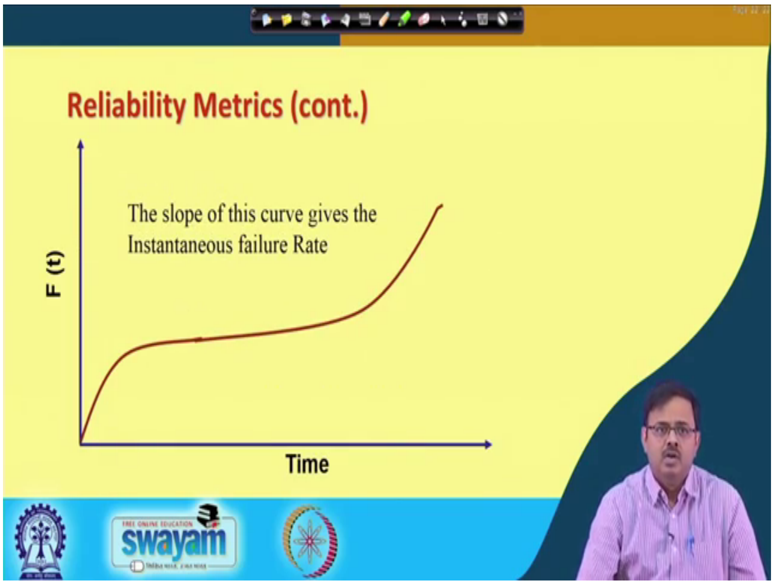

So, if you look at F t which is the failure, probability of failure, then this is how it looks. So, this is reliability matrix this is the probability of failure with time and let us say this is a typical curve. Now if I take this mathematically speaking, if I take the slope of this curve at any point of time that gives me the instantaneous failure rate what is the rate of failure at that point of time, how many products are failing. Remember if we go back to the previous slide, this N f is a function of time definitely, but N f is increasing, correct. This N f is increasing.

Let us say in the first month 1 part has I produced 1000 parts in the first 1 month one part has failed. The in the second month, another 2 parts have failed. 6 months, every month there was an increase. So, if I take N F t it will be an increasing number right which is what I am showing here. It will keep on increasing, it may be high at some point and then over here may be the number of failures per unit time is less, per month is less. But it is if you just take F t it will keep on growing and R t it will keep on decreasing right. But then, what you see is the number of failures the way I have drawn, this curve the number of failures is high at this part and it is quite low beyond I mean again per unit time it is quite low over here.

So, if you take the slope, if they see that the slope is quite high over here, but the slope is quite low over here D f D t. So, that is the instantaneous failure rate all right.

So, we will stop here today and just to recap what we discussed today, we started with the discussion on what is reliability and how is it diff, why is it important and how is it different from quality and performance.

Reliability as we see it is the ability to hold that performance over time ok. And then we came, we just started with some reliability some discussion on reliability metrics as to how do I quantify reliability in the in the field of mathematics and statistics reliability is quantifiable is a quantity right. It is quantifiable, you can attach a number to that and that is what we are going through right now so.

Thank you very much and that is the end of this lecture. When we come back, we will continue our discussion on reliability matrix.

Thank you.