Electronic Packaging and Manufacturing
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Lecture – 36
Electronic Packaging Reliability - 2

Welcome back and we will continue our discussion on Reliability of Electronic Packages. So, in the last lecture we had just started with reliability matrix.

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So, if you look at the slide here we will continue with that and then talk about a few of those including failure rate bathtub curve which is also called the infant mortality curve. And something called MTBF we will see what that is ok. Alright, so let us move on and in the last class we were talking about what is failure rate and what is reliability.

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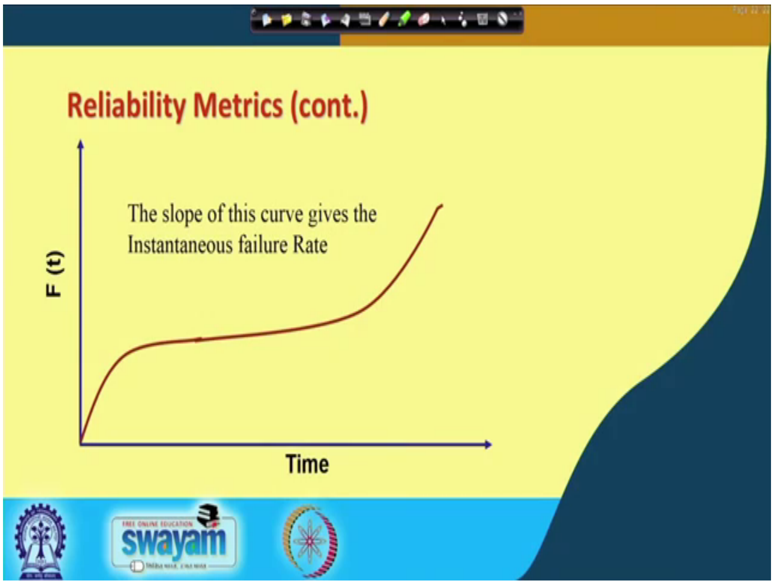

We said that this was the curve that we were looking at the probability of failure F t defined as number of failed products over the number of original number of failed parts of an original number of parts with time this is that is what is plotted on the y axis and the x axis is time. And we said that the slope of this curve gives you the instantaneous failure rate.

And if you look at this curve what you see is at the beginning the slope is high, then the slope goes down and then towards the end it again catches up ok. This is not an arbitrary curve that I have drawn this actually is very very representative of typical failures you know you know in any electronic product. So, now as I say that if you take the rate of failure is basically the derivative of F t with time.

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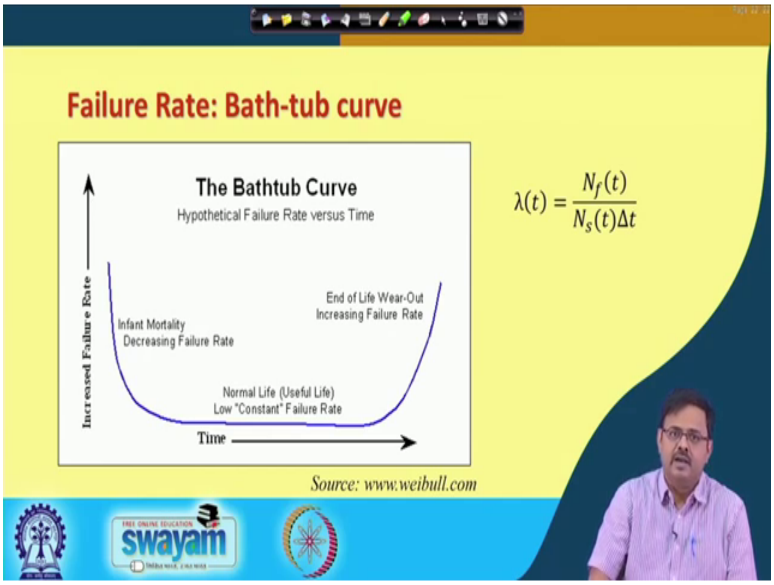

So, if you look at that; if you plot such a curve that I had drawn before. And plot that now the slope this is what you will get. The instantaneous failure rate often given by lambda t is given by this alright. So, it is N f t divided by N s which is the number of surviving parts divided by the time interval I am talking about ok. So, what do I see here this by the way we will spend some time on this curve.

This is a very famous curve known as the bathtub curve bathtub because of the shape that you see here. The y axis is the instantaneous failure rate. And I think it is written wrong here in I do not know why it is called I took this picture from weibull dot com and the y axis is shows increased failure rate I do not know what that means. But it is it is actually the instantaneous failure rate there lambda t as is shown there the failure rate let us say the rate of failure.

So, what is the number of parts that is failing per unit time at a certain point in time ok. So, that is the failure rate that is what is plotted on the y axis and what you see is the shape is like a bathtub. So, that is why it is very it is a very famous curve known as a bathtub curve. Now, what do we see here and we are going to look at it visa v the earlier plot that I had shown here for the F t the probability of failure ok.

So, likely what we see is at the beginning the failure rate is very high ok. So, if you take a certain time interval the number of failures in that time interval is very high towards the beginning. And then after some time it so with time it comes down and reaches a very low value and then it remains constant over that range and then finally, again towards the end. So, when sufficient time has passed it again goes up.

So, why is this? This is because and so before that so these three phases that we see at the beginning where it is high and then it is coming down then the second phase is where it remains constant. And the third phase is again when it rises up these three are given three different these are zones or regimes. The first one is what is called the infant mortality stage ok.

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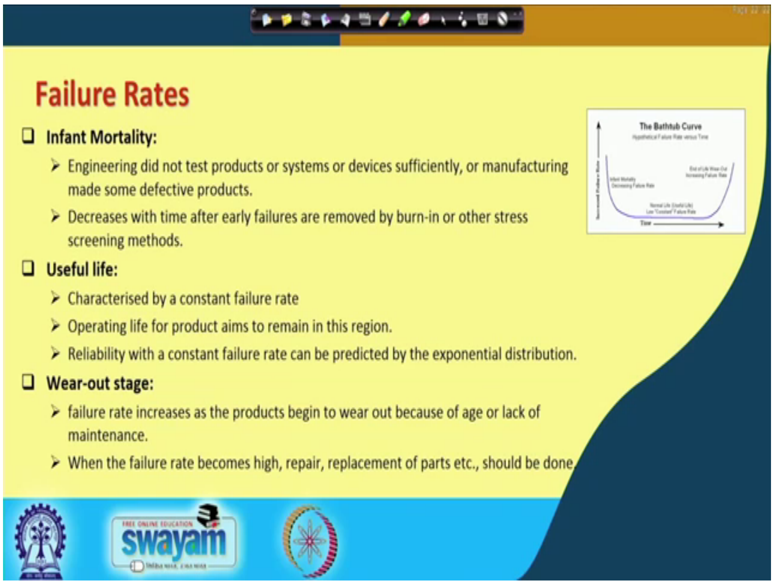

So, what happens in the infant mortality stage? The number of failures are high as you see here, why? Because, either engineering did not test the products or systems or devices sufficiently and manufacturing you know manufacturing produced some defective parts or products. So, therefore, I had ship end result is the company had shipped defective parts to the customer ok. And which was detected right at the beginning. So, it is a defective part it happens right.

So, why because they did not test the products or systems sufficiently the quality check was not good enough ok. Now, what happens is if such detect defective products actually went then those will be detected very early. So therefore, you will have a high number of failures at the beginning, but then something that has survived the first few operations or cycles is likely going to survive several more ok. So, this is where this is known as the infant mortality stage ok.

Now, let me tell you why this is also called the mortality curve; because if you look at the human life expectancy then the curve is very very similar. Infant mortality is number of infants the human small babies who die within the first one year ok. Many of them are born with such defects that they do not survive beyond a few days or weeks. So, if you take any population you will see that the infant mortality the and calculate the mortality rates you will see a high number at the very early age ok.

And then a baby or a child who has survived probably, the first 2-3 years of his or her life is likely to live much longer right. You do not apart from some accidents or something very unexpected we do not here deaths do not here about deaths very often between the age of let us say 2 or 3 till maybe 40 right. After that yeah there are some where you will still see some more some deaths, but then we see deaths again at an old age where you know it is automatically where your body does not function and the organs does not function as well as they were supposed to and you see that to happen and then you see deaths ok.

So, therefore, even if you take a human population you see any at any part of the world the numbers will vary definitely, but you will see that there is a the depth number of deaths and the rate is high at early age and at a at old age right. So, that is why this is also known as a mortality curve. Now, as a nation develops what do we have to do if you look at a not so developed nation versus the developed nation the first thing is the mortality rate it is very low. So, I have to this should be as low as possible this value should be as low as possible and also this sharp decrease this curve should leave at this stage should be as much to the left as possible that is one.

And that happens with proper definitely proper care during pregnancy and then proper neonatal care when the child is born even if he or she is born with some illness then the care in the hospital post birth care is so good the new natal care is so advanced and so good that the child can be brought out of that right. You fix the problem right at the beginning ok, but in many not so develops areas of the world or even within a developed nation there are certain population who do not have access to those developed facilities.

And that can be you know like if a child is born t here is no baby warmer there is no incubator right premature birth so. So, therefore, you see deaths because of that. So, developing developed nation a develop population must have must reduce must strive to reduce this number and also move this infant stage as to the left as much as possible ok. And also reduce this number as much as possible. So, again this part again if it is a very developed nation where you know traffic is smooth, accidents are low, there is even if there is a certain sudden illness the access to advanced healthcare facilities as such that is so good that this rate is very very low ok. So, this next thing is this line should have as low a value as possible ideally 0.

And what else; the life expectancy for human beings should be as high as possible. So, again this finally, end of life part the aging part must shift to the right as much as possible. Now so that is for a human population that is why this is also called the mortality curve. And that is what when a nation is trying to call itself developed these are some of the things that it must try for ok. Now, if you talk about an electronic product or for any product that way it is very uncanny and what is very surprising, but yet probably expected that the same curve is followed right. So, the first one just like birth defects is defects at the factory during the production stage that were went undetected.

So, decreases with time after early failures are removed by burn in or other stress screening methods. So, this is important what do I mean by that a good company which cares for it is brand value the brand image and does not want to ship defective products should be able to screen out those defective products at the factory itself and remove it. And this is not just doing a sanity check after the production it is also to make sure that if you will make it go through certain cycles of operation it does hold it is performance it does not show some degradation so that is called burn in.

So, many companies or in several good companies before shipping a product not every product maybe, but from a certain production lot will take some products and make them go through certain tests repetitive tests to make sure that the product holds it is performance. So, that stresses screening methods burning methods and only after that will the ship. So therefore, they think what are we trying to do we are trying to remove this infant mortality part as much as possible this left part as you see over here, then this is a useful life.

So, if a product has survived for a certain number of months or years depending on what it is maybe one year. Then it is probably going to survive for most for a reasonably good period of time maybe for the next few years ok. But then there will be some failures you know just like in a human life there can be some accidents maybe some sudden illness and unavailability of medical facilities whatever certain conditions that force you.

So, anyway so characterized by a constant failure rate ok; so, for an electronic product it can be an abusive handling look I mean your cell phone is performing nicely and then it just drops in water it slips from your hand and drops into water or it falls on the ground and breaks apart. So, these are failures, but this a company cannot you know really design a product for such you know such catastrophic consequences is difficult right my car is performing well, but I suddenly wish to take my passenger car in the racing track it is not meant for that ok.

So, abusive handling it can be which can be intentional which can be unintentional it can be an accident right alright it can be for example, your product is your charging your cell phone or your TVS plugged in and suddenly there is a big lightning and thunder and many a times products have failed right it can be 110 volts product you plug in into a 220 volts supply you got this from somebody gifted you from your friend gifted you something from us a way where the line voltage 110 volts and instead of using a step down transformer you directly put the plug into your 220 volts it will burn off ok.

The product will get burnt catastrophic failure, but that is not what I mean the company cannot really design your product for these things such scenarios, but such scenarios are rare. So, there will be a calculus by a constant failure rate and apprec and that will be a very low value or that should be a very low value. So, that is the operating life alright and the wear out stages when it has become so old.

So, that is age old because of aging there is a certain degradation you cannot help it just like the human body ok. So, that is wear out due to age or it can be due to lack of maintenance and again aging even for a human being somebody who is fit who does exercise regularly maintains a very disciplined life a good diet etcetera is going to live longer hopefully. But as long, but definitely as far as long as he or she lives they are going to live a healthy life because they have maintained themselves well on the other hand if somebody leaves an in discipline life.

And then he is going to develop these symptoms of aging at a much earlier stage right and which may lead to end of life eventually at an earlier age compared to let us say a healthy individual right. So, when the failure rate becomes high at that time you have to repair replacement of parts maintenance has to be done more regularly correct. So, this we have seen for example, if you are driving a car once.

For example, my car is right now 8 years old and I do see this things are failing you know something it is the sound is not great I have to go for more regular maintenance if I if I want to maintain the car or retain it is performance and so on and so forth alright. So, if you now look at it when a company gives you warranty for one year one year warranty it is its supremely confident that it is going to last that one year without any defect. Because, if it fails within that one year you will send it for free for the free replacement or free service and there is a cost to the company ok.

So, most likely a product that has survived for the first year is going to survive unless except for certain catastrophic scenarios it is going to survive for some time. So,, but then beyond a certain warranty period it is it is beyond a certain life expectancy which is probably about five years for a cell phone you are going to see this the performance going down things degrading with time that is because of wear out correct alright

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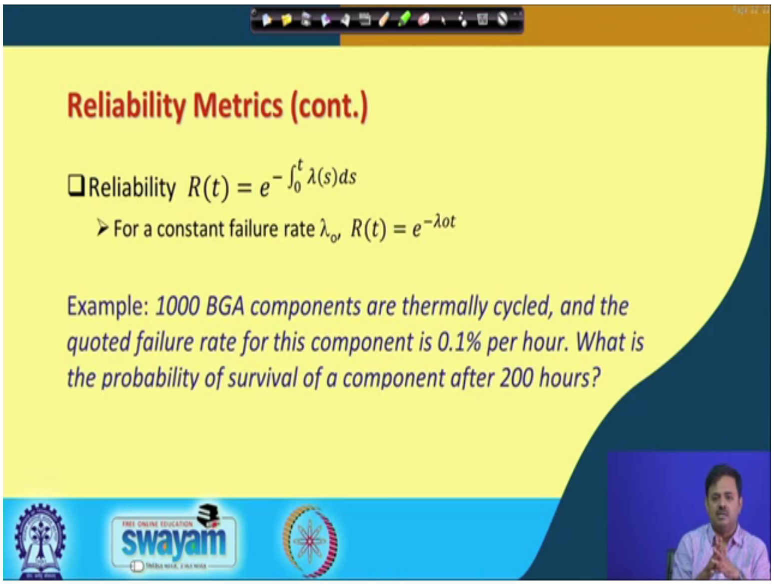

So, if you continue with reliability metrics the reliability R t is given by this expression; it is exponential of minus integral of lambda d t or lambda s ds from 0 to t. And what was lambda? Lambda was this failure rate clear. Now, let us say if the failure rate is constant which is where what we are seeing in this useful life for a constant failure rate which is let us say lambda naught in R t the reliability becomes e to the power minus lambda naught t ok. And it escaped can be easily proven from the definitions ok.

So, now let us take an example that I have 1000 BGA components and which I thermally cycle them thermal is thermal cycling means I put it let us say in an oven and make them go from let us say whatever minus 40 to plus 40 degrees repeatedly. Over and the cycle time is let us say several minutes. And the quoted failure rate for this component is 0.1 percent per hour.

So, every hour when I am testing them for functionality I see that 0.1 percent. So, 1 in 1000 parts have failed. So, what is the probability of survival of a component after 200 years? So, what is probability of survival? Probability of survival is nothing, but reliability correct. So, probability of survival is reliability so R of t and this is a constant failure rate therefore, reliability is e to the power minus lambda naught t.

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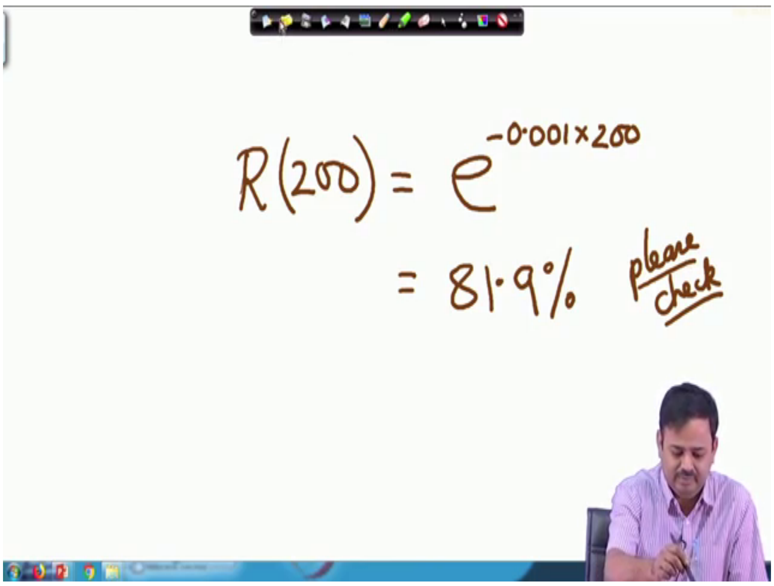

So, in this case if I want to come here it is going to be reliability of 200 is going to be e to the power minus. And what was my reliable the rate of failure was 0.1 percent. So, therefore, 0.001 and they said this is 0.001 per hour and they said what is the probability of survival after 200 hours is so I will put it as 200 ok.

So, simple this is going to be my reliability it is a non-dimensional number e to the power minus of lambda naught t because this is a constant real failure rate. And if you do that I think this comes out to be around 81.9 percent or so ok. You can check this most likely so I will write again. Now, that I am on camera I would write please check alright. Ok let us come back to the slide, so this was the expression that I am getting.

So, let me tell you a little story here or maybe a little anecdote here. So, we saw this and we found that the rate of failure is much less beyond a certain period of time. Here also we saw the failures are very high at the beginning and then it kind of becomes I mean the number of failures per unit time is quite low. And again with when we attain with aging and we are out again it goes up. So, many a times it is said that if somebody is selling you up if you are looking for a second hand car I can use car and if somebody is selling you a one year old car and it is good then that may be one of the best buys.

So, what you need to ask is why do you want to sell a one year old car and if the answer is something convincing and not related to that it is not functioning well then just go ahead and buy it grab it ok. So, for example, when I was after my PhD in the USA I was I worked at Intel in USA for about 2 years and then I was moving back to India. And I had a car which was about one and half years old absolutely new car that I was that I had bought it was one and half years old and of course, I cannot bring it to India.

So, I had to sell it and it was bought by one of my lab mates over there and everybody was teasing him that; man his name was Dennis and said Dennis you got the best deal because for a car of any product actually. If you look at the selling price it depreciates very high at a very high rate towards the beginning. So, one year old car versus a new car the price difference is going to be substantial, but then a one year old car which is performing very well it is as good as new ok. Something that has in USA for example, is something that has been driven for 1000 to 1200 miles.

Actually that is one of the best buys because it has gone through all the initial defects if there was any it has gone for any nitty gritty defects etcetera it has gone for regular servicing and it has been all sorted out ironed out all these kinks and all. And then it is now ready to serve you for probably in the next without any problem for the next 7-8 years maybe for the next 10 years ok. And you are getting it at a much cheaper rate at least 30 percent 20 to 30 percent lower so that is what it is alright. So, now, this was reliability metrics that we are talking about.

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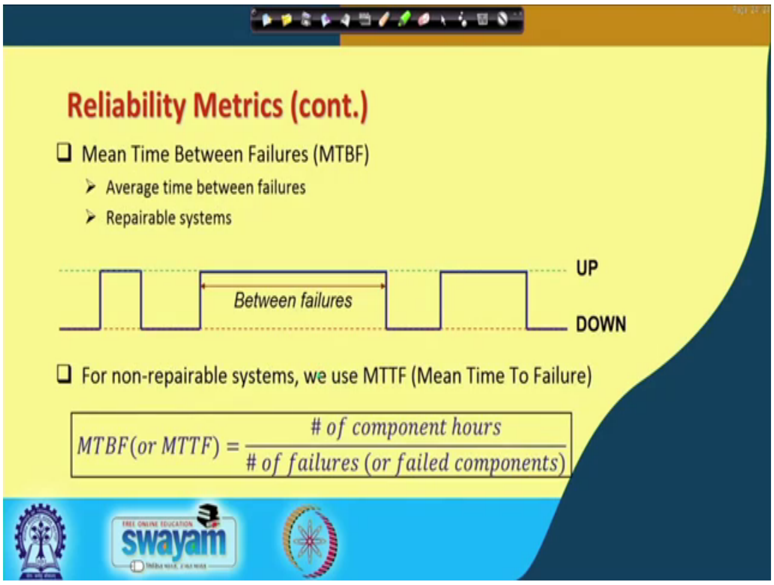

So, let us quickly now wrap up this lecture as well as our discussion reliability metrics by one final one which is called the mean time between failures MTBF. So, the mean time between failure is basically defined as the average time between two failures. So, if it is a repairable system then what happens if you look at this slide let us say this is your system which is running. So, this is uptime and then there is a defect.

So, there is a downtime then it gets repaired again it becomes up then again it develops a problem it is down for some time it is serviced or repaired and so on. So, this is a time between failures so where it is functioning. So, mean time between failures is given by the number of component hours divided by either number of failures or failed components. If you do not have a repairable system it is you know where something fails you have to discard it and get something else.

So, depending on whether it is a non-repairable system versus repairable system we use mean time to failure for a non repairable system where you have to throw out and get a new one or mean time between failures where you actually where you can actually service and repair and make the same system work. For example, my washing machine sometimes now it is like 6 years old sometimes it fails I call the technician he does come something it comes does something and again it is working ok.

So, mean time between failure or mean time to failure, but for our case we will come they are almost equivalent alright. So, this is the final reliability metric that we wanted to talk about ok. So, that kind of wraps up our discussions on reliability metrics and that kind of also wraps up our discussion on for this lecture alright. So, reliability as we see there are several mathematical concepts that are involved.

The last one I want to mention is if it is a constant failure rate where we saw an exponential distribution the reliability function was an exponential distribution e to the power minus lambda naught t you can you can finally, try this out actually. This lambda naught is actually one over MTBF mean time between failures you try it out you will see that is exactly what it is correct. So, keep that in mind. And, so to wrap up what we have discussed today we started with the discussion on the failure rate instantaneous failure rate.

And that if you look at and that led us to the discussion on something very very important which is the bathtub curve or the mortality curve. And using analogy between the product and defects that is found in a product that is that is produced in a factory. And drawing an analogy with human life and mortality of a human population we saw that they are so similar right. The only difference I would say is when we are talking about in the aging limit.

And we said that in case of a human life through that as a nation gets developed we say that one of the metrics of a developing nation of development is the average life expectancy ok. So, the number of age related deaths occur at a higher age. So, life expectancy is let us say more than 70 years alright. So, average human life expectancy goes up as a nation for a developed nation. that; however, you cannot draw a direct analogy with an electronic product for example, because the life expectancy depends on the product.

And let me end with an interesting note over here yes a cell phone is expected to last for 5 years and a manufacturer like an Apple or a Samsung would like it to last for 5 years to for their brand image reputed for their reputation everything. But they also have to sell products, but they do not want it to last ideally even 1 day above 5 years ok. So, that is where you know I was just I was listening to some lectures from somebody who is very well known in this field.

And he was saying that; earlier we talked about in this light in this lecture is or in the previous lecture we talked about design for reliability a reliability engineer should design for it is reliable performance over a long lifetime ok. Now, they are saying there is also this concept where designed for failure. And failure when? So, that it fails right maybe the day after it is expected lifecycle of expected product life if it is 5 years let it fail on the first day after the fifth year.

Because then the customer is going to go and the user is going to go and buy a new product otherwise you know if Samsung or Apple or Motorola they start making cell phones or smart phones that unless there is a catastrophic failure that is under normal conditions will keep on performing then how are they going to survive right. So, they also have to sell their products and get the cash inflow so that is also one thing. So, that is what also helps them to keep their prices down so that the sales and to keep the sales at the expected level ok.

So, therefore, though just to wrap it up an average life for a human being we would like to increase the life expectancy, but for an electronic product maybe not. So, much if you would like the mortality rate to be as low the failure rate to be as low as possible during it is useful life. But thereafter after what is the expected useful life whether it is 5 years for a laptop whether it is 10 for a for a laptop or cell phone where, there is 10 years for a desktop where there is 15 or 20 years for an automobile after that yeah I think the manufacturers do want it to fail so that they can sell new products ok.

Thank you very much, and when we come back in the next class we are actually going to talk about testing for reliability and physics of failures.

Thank you.