Course name: EMI /EMC and Signal Integrity: Principles, Techniques and Applications.
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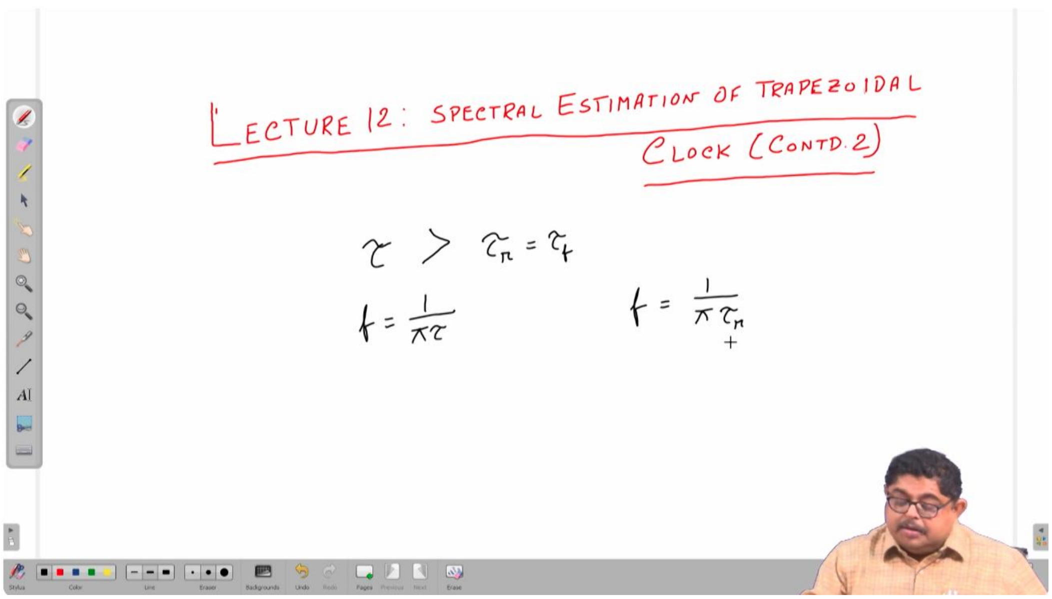
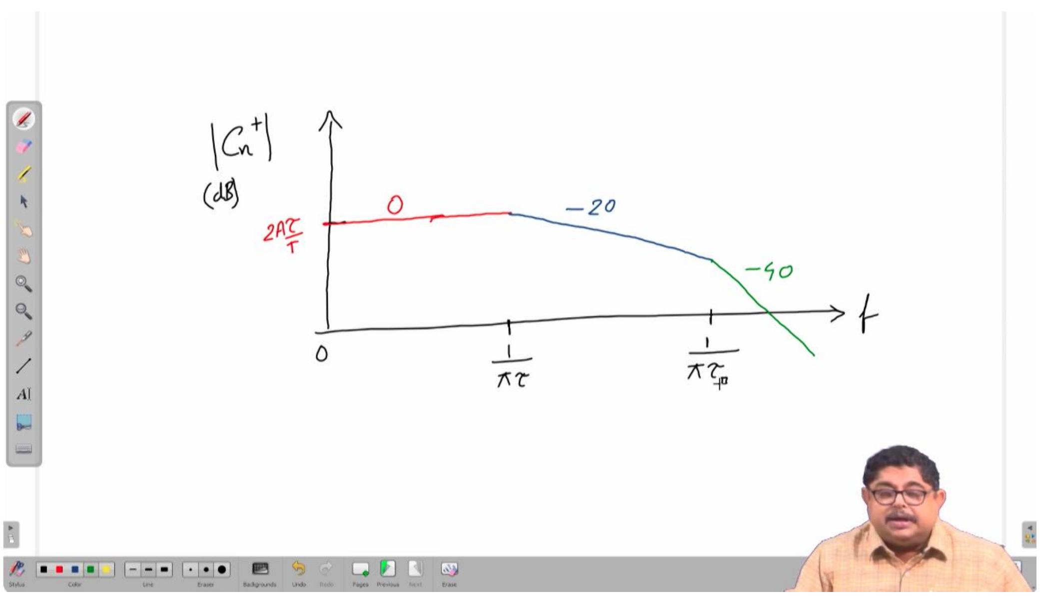
Week :03
Lecture 12: Spectral estimation of trapezoidal clock

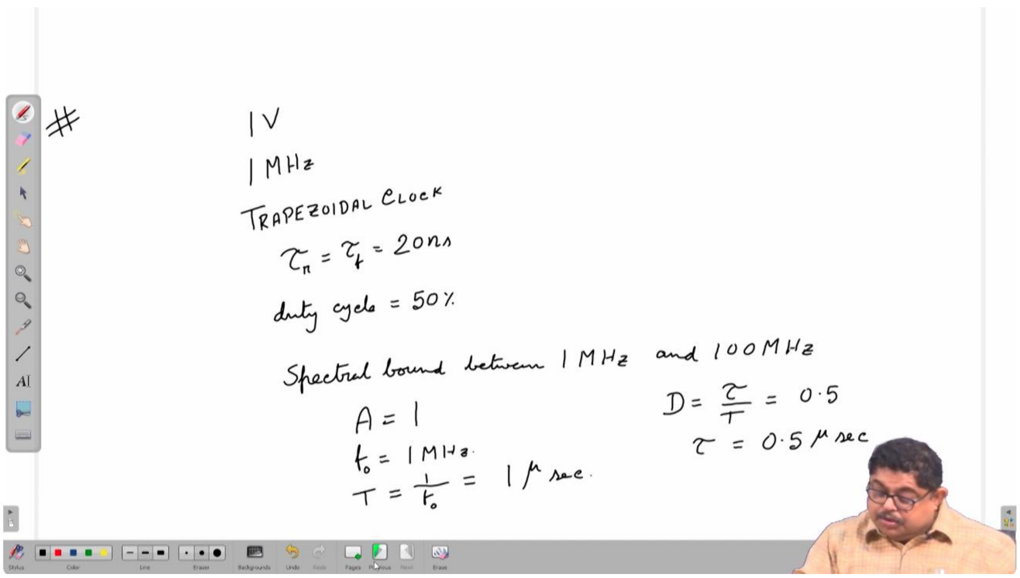
Welcome to the 12th lecture of the course on EMIMC and Signal Integrity Principles, Techniques and Applications. We were seeing the spectral upper bound of trapezoidal clock in the previous class that we will continue now because we have not yet summed the 3 plots that we have got. So, we start that. Now, here to plot or to sum the 3 plots we will have to assume one thing assume or what is the reality that what is the relation between tau and tau r. You see that tau is the pulse width, tau r is the rise time or fall time and we are assuming tau r is equal to tau f. Now, generally tau pulse width is much larger than tau r. So, we can say that f is equal to 1 by pi tau will be much smaller than 1 by pi tau r that means f is equal to 1 by pi tau will come earlier than f is equal to 1 by pi tau r that means the first break point in frequency in the bode plot will be governed by tau the second break point will be governed by pi tau r.



So, we can now add the 3 plots and it will be. So, this is our c n plus this is our frequency this is 0 let us take this is 1 by pi tau and this is 1 by pi tau r. So, this is in dB scale. So, I think let me see the plot 1. So, plot 1 was in red colour. So, let me sorry put it in red colour, but it will go up to 1 by pi tau its value we have said is 2 a tau by pi tau obviously in dB and its slope is 0 then I think there will be a break. So, the second plot will start from 1 by pi tau you can look at your notes that it will start from 1 by pi tau with a minus 20 dB per decade slope and then there will be another break point. So, this is continuing, but the you see that this is continuing, but the green plot that means, the plot 3 that is coming from 0 dB and from here it is also having a from 1 by pi tau r it is having a minus 20 dB per decade slope. So, this is minus 20 that is also minus 20. So, from here we can say that it will be minus 40 dB per decade slope. So, that will go on. So, that is the meaning you see going to negative is no problem because it is in dB scale. So, that can go to dB that will only mean that it is actually all these are you see less than 0 dB. So, they are negative. So, you can see that high frequency spectral contents that depends on tau r because the placement of tau r is important because after 1 by pi tau r that means, after this frequency the components are suppressed at a rate minus 40 dB per decade. So, if this 1 by pi tau r this break point comes closer then much of the high frequency come closer to 1 by pi tau then much of the high frequency components will be attenuated sufficiently. But if the second break point moves further to the right then many of the high frequency components will suffer only attenuation at the rate of minus 20 dB per decade. So, high frequency spectral components in that case would not be much attenuated. So, this is an important thing that where you are placing your tau r. Now tau r is in the designer's hand because rise and fall time of the clock is his choice. So, he should have to make it judiciously that choice so that he can get sufficient attenuation.



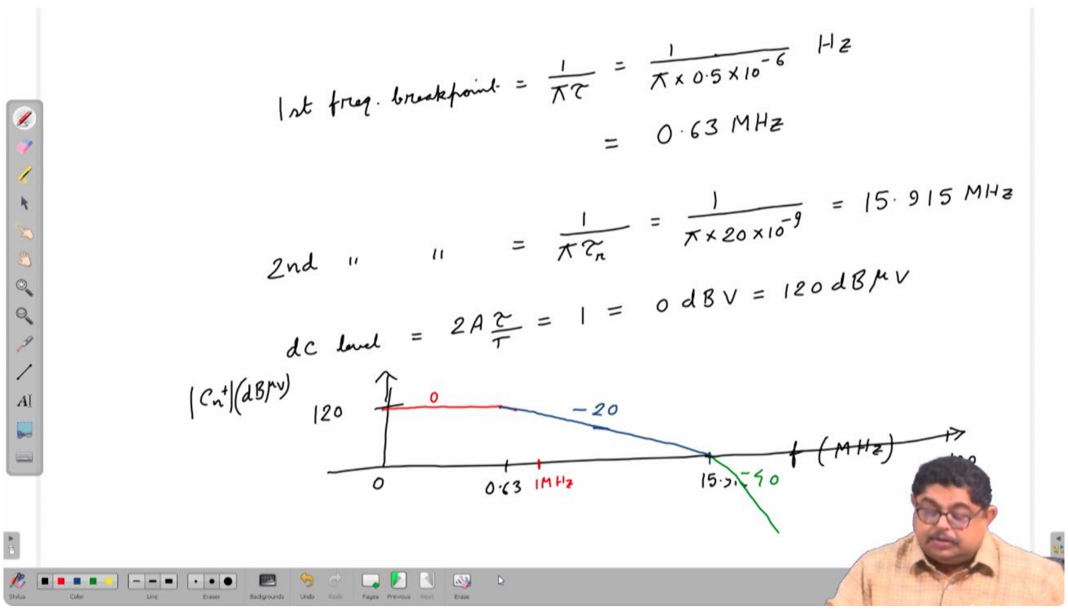
So, let us take an example that consider a 1 volt. So, a example I am taking 1 volt 1 MHz trapezoidal clock rise fall time is let us take 20 nanosecond duty cycle in industry these are the terms they specify. So, that is why we are taking that let us take 50 percent first. Now, draw the spectral bounds between that means what is the spectral bound between 1 megahertz and 100 megahertz that means the clock is at 1 megahertz that means fundamental frequency that means f naught is 1 megahertz and up to 100 thermonic we want to see what are the spectral bounds that means up to. So, if someone says that at 78th harmonic what is the clock that means at 78 megahertz what the maximum the harmonic can be I will be able to say that. So, let us solve this. So, what are given you see now in our terms the means we have done the analysis in our some specified notations of the parameters. So, in that one what will be a a is given as 1 volt then f naught is given as 1 megahertz . So, what is our, but in our expression there was no f naught. So, but we had t. So, what is t? t is 1 by f naught and that is 1 micro second it is given duty cycle D duty cycle is tau by t that is 0.5 50 percent. So, that means from here we are getting what is the value of tau? Tau is 0.5 micro second. Now what is tau r that is already given 20 nanosecond. So, we have all the parameters are given pulse width given pulse width is given rise fall time is given amplitude is given. So, we can now determine.



So, what is the first frequency break point that will be here also you can see that what was our assumption that tau is much less than much greater than tau r. So, here you see tau is 0.5 micro second tau r is 20 nanosecond. So, it is much bigger. So, first break point will be determined by tau. So, 1 by pi tau. So, 1 by pi into 0.5 into 10 to the power minus 6 second that will give you the sorry this is in frequency because 1 by pi tau. So, this tau is in second. So, this will be a hertz. So, if you do you know pi is value 22 by 7. So, that you put you will get it is 0.63 megahertz. Similarly, what is the second frequency break point that will be 1 by pi tau r. So, it is 1 by pi into 20 nanosecond and if you do that that will be 15.915 megahertz. What is the DC level? That means, at 0 frequency what is the level 2 a tau by T. So, tau by T is half 2 into half. So, it is 1. So, in dB I can convert this.

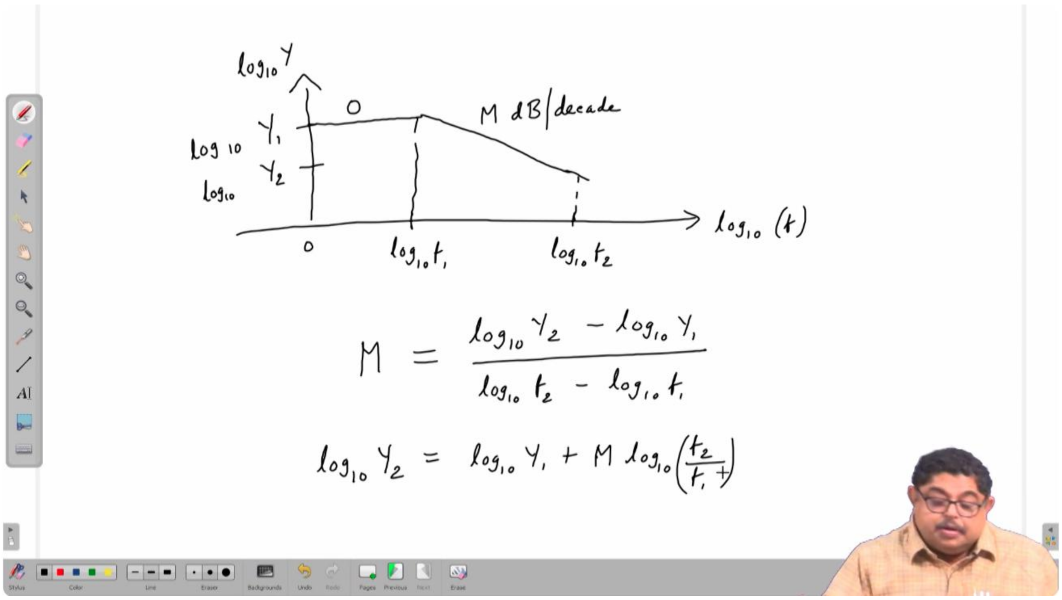
So, let us convert it in micro volt. So, I can say that it is 0 dB volt and that is 120 dB micro volt. I think you are by now got familiar with this. So, it is 120 dB micro volt. But you see that so, we can draw the spectral upper bound. So, it is 0 then 0.63 and this is 15.915, f is in megahertz. So, this value we know this will be 120 this side we are putting C n plus in dB the unit is dB micro volt. So, in that 120. So, we know that it will go like this then sorry then it will go like this then from here it will be minus 40 dB.

So, I have drawn some extra part let me clear that. So, let us take this is I think and from here it will be. So, this is minus 40 this was minus 20 this was 0. But the question asked us that draw it from 1 megahertz to 100 megahertz. So, we will have to find you see this is 0.60 megahertz they are not bothered about this part, but what is the value at 1 megahertz similarly this thing is going down. So, at somewhere 100 megahertz what is the value that we will have to calculate.

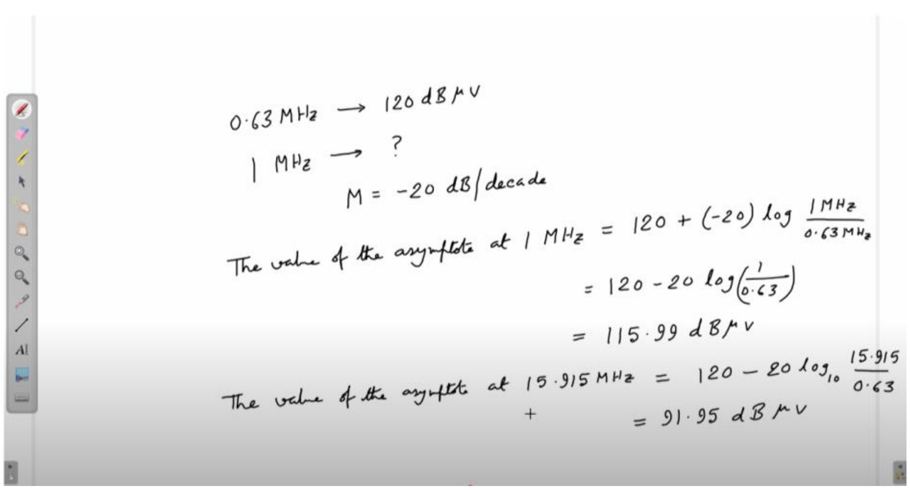


So, that is something we will have to now attempt. So, there we will have to recall one property of line that suppose I have log 10 y in the y axis and log 10 f in the f axis this is the bode plot. So, let us say that these are all logarithm. So, if I have y 1 here log 10 y 1 some and for that point let us say I have log 10 f 1 similarly at some other frequency log 10 f 2 I have y 2 log 10 y 2 log 10 base y 2 ok. So, suppose I am having that from here it is going like this then the thing is having a slope the slope is let us call it in general m d b per decade and this is 0 d b per decade. So, that means, suppose at one point I know the value here also I know the value that at f 1 frequency the value is log 10 y 1 at f 2 frequency the value is y 2. So, what is slope of a line m is equal to log 10 y 2 minus log

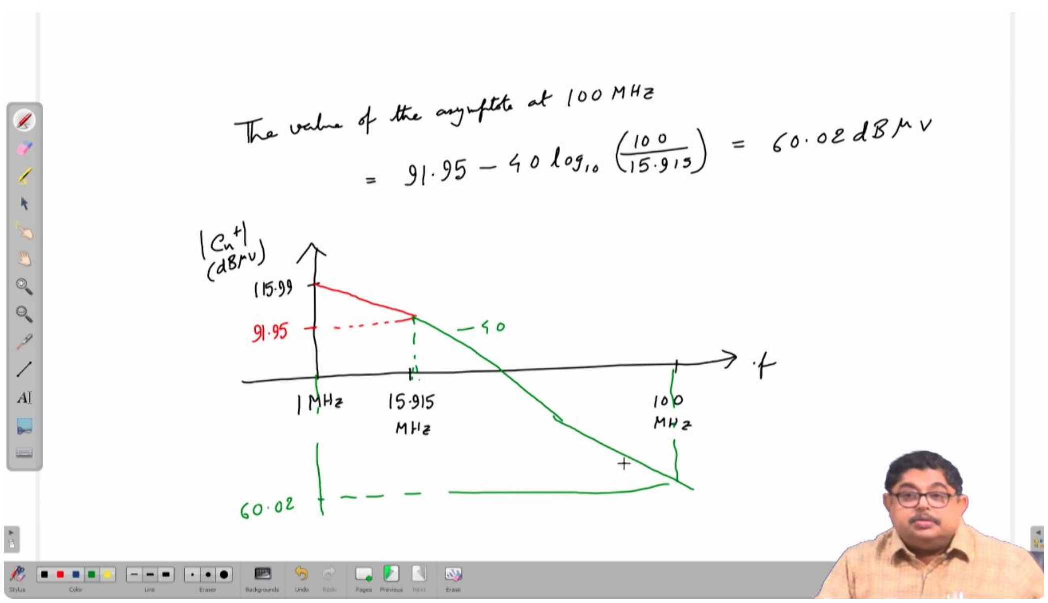
10 y 1 by log 10 f 2 minus log 10 f 1 you know this from your coordinate geometry that slope is equal to y 2 minus y 1 by x 2 minus x 1. So, just I have converted it into log. So, log 10 y 2 will be what can I say log 10 y 1 plus m log 10 f 2 by f 1.



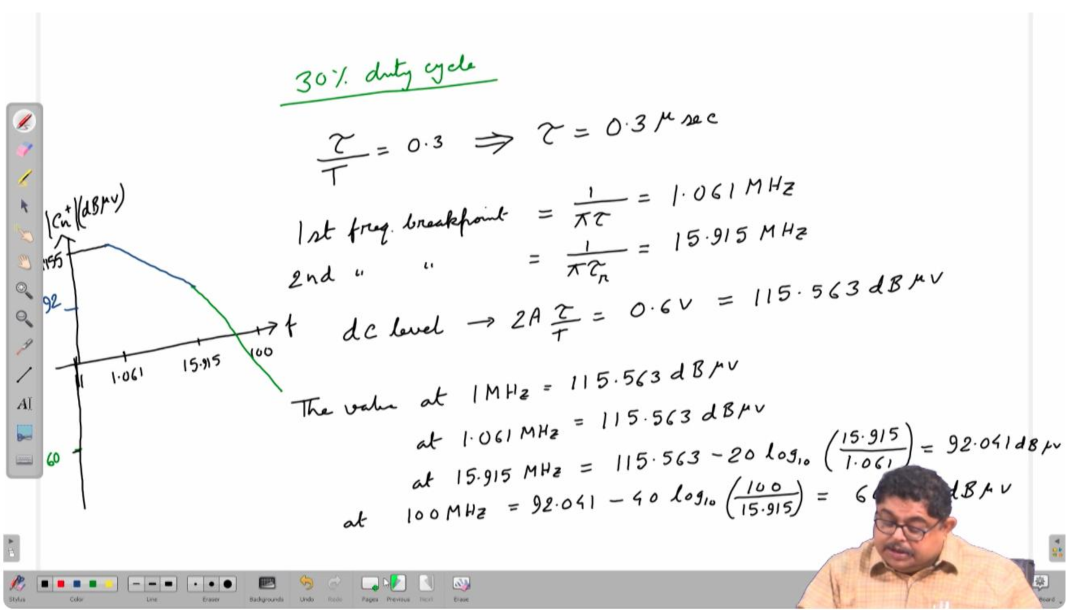
So, with this formula we can easily plot that I know that for our plot at 0.63 megahertz what was the value the value was 120 dB micro volt. So, what is the value at 1 megahertz what is the value the from 0.60 megahertz the slope m is minus 20 dB per decade.So, can I say the value of the asymptote at 1 megahertz is 120 plus slope is minus 20 into log 1 megahertz by 0.63 megahertz. So, it is basically 120 minus 20 log 1 by 0.63. So, if you do it you can find it from your calculator it is 115.99 dB micro volt. Now, it will go with this minus 20 dB slope. So, what is its value the value of the asymptote at up to what it is going the second frequency specific point that is 15.915 megahertz. So, what is its value? So, that you can easily say that 120 minus 20 log 10 15.915 by 0.63. So, if you do this you will get 91.95 into 0.95 dB micro volt and after this we know the slope will change to minus 40 dB per decade.



So, we will have to calculate that the value of the asymptote at 100 megahertz that will be 91.95 minus 40 log 10 100 by 15.115 into 0.915. So, that is 60.02 dB micro volt. So, now, I am in a position to answer the question that I have here that f is 1 megahertz f you see 0.63 is outside. So, I need not show that this is 15.915 megahertz and let us say this is 100 megahertz. So, it will start at 1 megahertz value is 115.99 all these are in plus in dB micro volt. Actually to accommodate these small values I have gone to dB micro volt which is now significant 115.99. So, it will be up to here this value is 91.95 dB micro volt and then from there it is going down with a minus 40 d b slope. So, it is going down and these value if I draw this will be 60 point how much 60.02 dB micro volt. So, I think I have shown all. So, at 1 megahertz the value is 116 dB micro volt at 15.915 it is almost 92 dB micro volt and that 100 megahertz at 100 thermonic of the clock it is 60 dB micro volt ok. So, this is one. Now, let us see that if we change various parameters of the clock how this upper bounds they change. So, first we will change that let us change the duty cycle which is a very frequently this duty cycle is changed because duty cycle actually depends on your electronics that how fast you can generate a pulse and then again generate another one pulse and then another pulse how frequent you can do that that depends on your duty cycle. So, 50 percent I said is a fairly good some designers may, but suppose someone says no no I will not have that much faster. So, we let us say that it is 30 percent duty cycle. So, let us say 30 percent duty cycle let us redo this problem that 30 percent duty cycle.

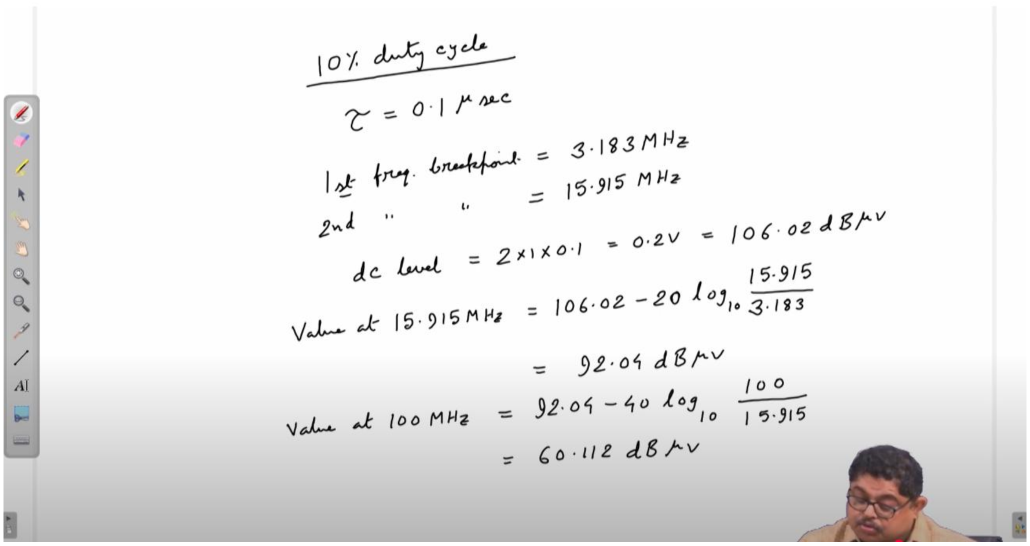


That means, now tau by t is 0.3. So, that will make that pulse width has changed. So, it is 0.3 micro second I have not changed rise time fall time anything. So, first frequency break point will change because I have changed tau. So, first frequency break point is determined by tau. So, that will be 1 by pi tau and that will change. So, it will be 1.061 mega if you do this that means, put tau is equal to 0.3 micro second you will get this almost 1 megahertz. The second frequency break point is 1 by pi tau r now that would not change. So, that is as before 15.915 megahertz. Any other thing will change? Yes, the DC level will also change because DC level has this duty cycle in it. So, 2 a tau by t now you have this. So, 2 a is 2 into 0.3. So, it will be 0.6 volt. So, in dB micro volt if you change it, it will be 115.563 dB micro volt. So, we can now see that the DC level is going up to that means, this with 115.560 it is going up to 1.061 megahertz. So, what is the value at 1 megahertz? So, the value obviously, value means I mean the C n plus magnitude the value at 1 megahertz will be 115.563 dB micro volt. Then at 1.061 megahertz it is same 115.563 dB micro volt at 15.915 megahertz from here it has started a minus 20 dB fall. So, it is 115.563 minus 20 log 15.915 by 1.061 that is 92.041 dB micro volt and at 100 megahertz ,the value will be 92.041 minus 40 log 10 100 by 15.915. So, if you calculate it will be 60.113 dB micro volt. So, I can draw. So, what is the value? Sorry it is not coming 115.5 ok. Then it will now start a fall. So, this value will be 92. So, the space is not there I am not writing the decimal point. So, 92 dB micro volt and at 100 megahertz it is 60 dB micro volt. So, you see that changing the duty cycle from 50 percent to 30 percent did not change much previous case also I think we have 60.02 dB now also we have 60.1 dB micro volt. So, it did not change much.



Let us see another that if I make it 10 percent duty cycle 10 percent duty cycle. So, tau will be 0.1 micro second first frequency break point first frequency break point will be you can calculate 1 by pi tau that will give you 3.183 megahertz the second frequency break point you have not changed the tau r. So, it will be still that 15.915 megahertz the

DC level that will be 2 into 1 into 0.1. So, that will be 0.2 volt that will be 106.02 dB micro volt. So, now you what will be the value at value at 15 first frequency break point is 3 megahertz. So, that means, this DC level at 1 megahertz also this DC level will come, but let us see what happens in 15.915 megahertz because there it is coming with a minus 20 dB per decade slope. So, that will be 106.02 minus 20 log 15.915 by 3.183. So, that will give you 92.04 dB micro volt and what is now the value at 100 megahertz that will be 92.04 minus 40 log this log I have meant this is from the base 20 log t t log 10 then I will have to make 100 by 15.915 that will give you 60.112 dB micro volt.



So, if we plot it is 1 actually I am writing a if you can say that why I have the formula I have derived for log 10 actually here we are assuming that you are plotting everything in semi log graph paper. In semi log graph paper this side you are making log that is by your calculation and this side the frequency will be already in logarithmic scale. So, that x axis if you take with a that is why we are doing like this actually the frequencies are in logarithmic scale semi log graph paper. So, we are assuming that all these plots are on semi log graph paper where y axis is normal axis and x axis is log, but we are making y axis in logarithmic by calculation we are making and these while plotting it will be taken care of. So, that is why I am writing is a, but the formula when I derive that how to make at any value any particular frequency what is the thing that is both side it should be logged.

So, this graph will be something like this and something like this this one is 60 and let me know make this point is 100 it is continuing, but my interest is 100 then my interest is 15.915 f is in megahertz my interest is 3.183. So, this value is 106.02 then this value is 92.04 and this value is 60. So, here also you can see that at 100 megahertz my spectral component spectral coefficient is still 60 dB micro volt. That means, duty cycle does not affect the high frequency components 100 megahertz is with respect to a 1 megahertz clock 100 megahertz is a high frequency 100th harmonic. So, it is not affecting that. So, we can conclude that duty cycle change does not affect the high frequency components 100 megahertz. Why? Because due by duty cycle changing fundamental frequency is fixed you see that with respect to that we are doing everything.So, duty cycle changing means basically you are changing the pulse width. So, that will affect the first break point you see first break point is changing, but our high frequency components attenuation will be given by second break point. So, that we are not changing. So, that is why high frequency components are more or less same. Who will be then doing the high frequency components attenuation that I said the second break point and second break point is governed by rise fall time. So, effect of rise fall time will have to see to see the high frequency components attenuation. So, that we will do in the next class. Thank you.