Principles of Communication- Part I
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Module No 6
Lecture 35
Analog to Digital Conversion of Signals and Introduction to Sampling

Hello welcome to another module in this massive open online course, so in this module we are going to start looking at new topic that is conversion of analog signals into digital signals, alright. And the first step to convert an analog signal to a digital signal one has to make the signal discrete in time, alright. So we have to sample the signal, alright. So we are going to start looking at sampling to convert analog to a digital signal, okay.

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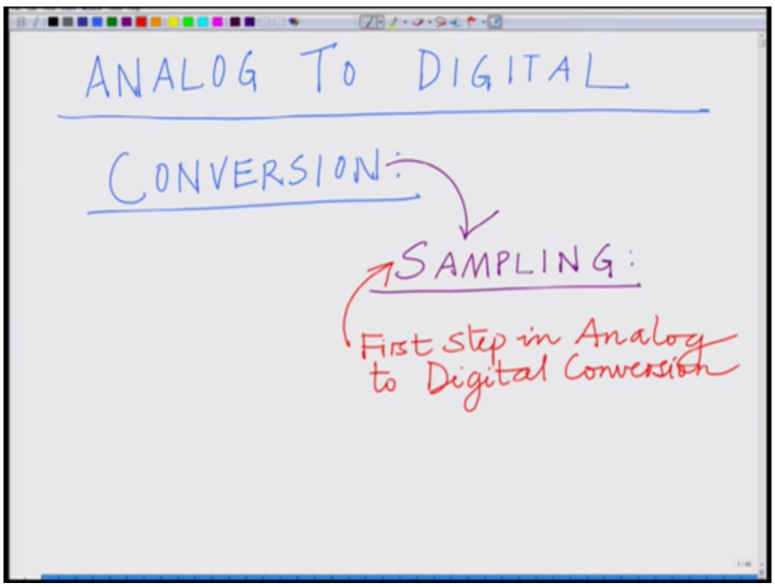

So we are going to start looking at analog to digital conversion, alright. To convert an analog signal to a disc discrete signal and the first step towards this is sampling, okay. And what does sampling do sampling converts sampling converts, so sampling is the first step in analog to digital conversion this is the first step in analog to digital conversion and what does sampling to sampling converts a continuous time signal into a discrete time signal, okay.

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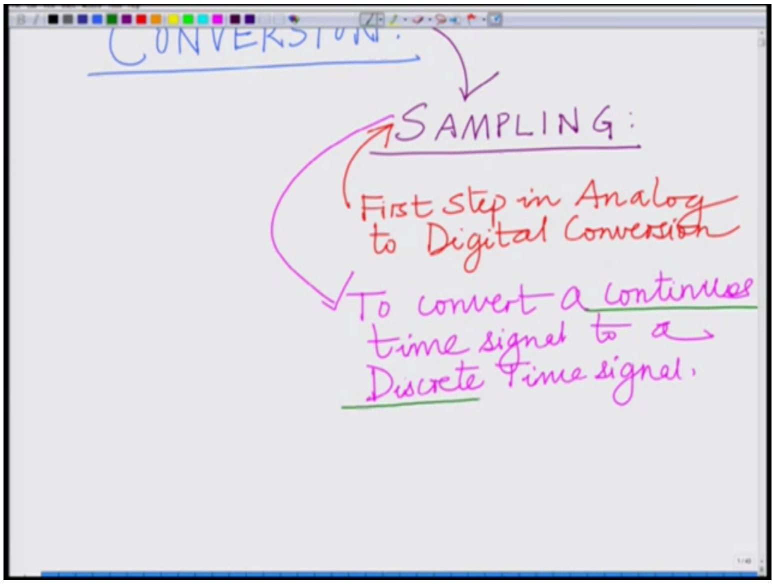

So sampling the basic idea behind sampling is to convert an analog converter a continuous time signal to a convert a continuous time signal to a discrete time signal, okay.

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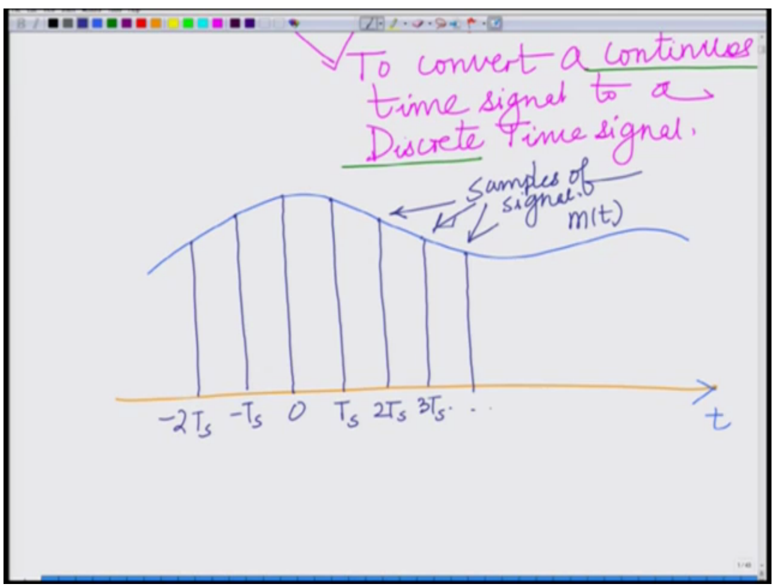

For instance let's say we have our signal let us draw a simple signal here to illustrate this point so we have this signal, alright which is continuous time signal now I want to sample it, alright. So I am going to sample it at certain specific discrete time instance which are also known as the sampling instance. So let us say the sampling frequency or let us say the sampling time is 0 that I sample it at Ts, second sample at 2Ts 3Ts and so on then minus Ts minus 2Ts, so this is my signal let say m(t) and these are the samples of the signal, okay.

These are the samples of the signal and you can see that the samples of the signal are extracted at every Ts or multiples of Ts this quantity Ts is basically they are sampling the sampling interval, alright. Once every sampling interval we extract a sample of the signal m(t). That is the signal to be sampled, okay.

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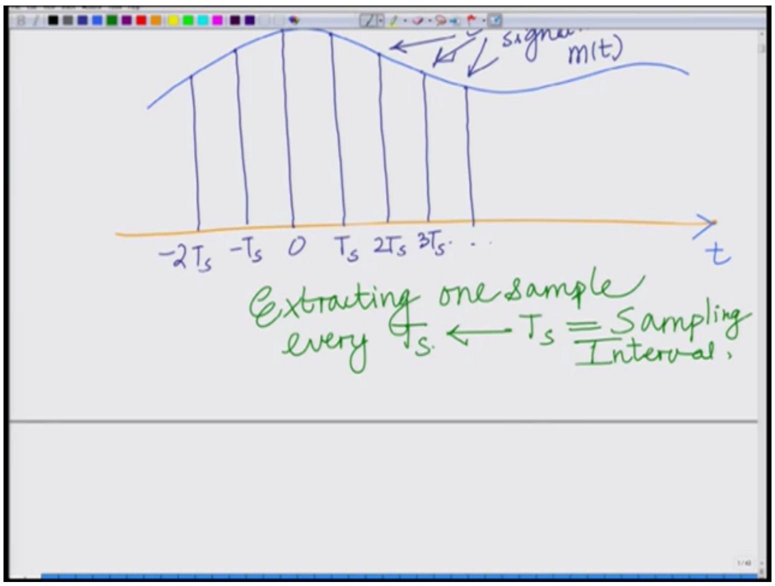

So we have our signal so we are extracting one sample every Ts so you are Ts equals the sampling interval, okay. So this quantity Ts is a sampling interval and you can say this is a periodic process it's a repetitive that is after every Ts you extract a sample, so minus 2s minus 2Ts minus Teleshopping 0 Ts to, so at every multiple of Ts you are extracting a sample this is periodic repeats once every Ts. So Ts is a sampling interval that is a period of sampling and 1 over Ts is a sampling frequency, alright.

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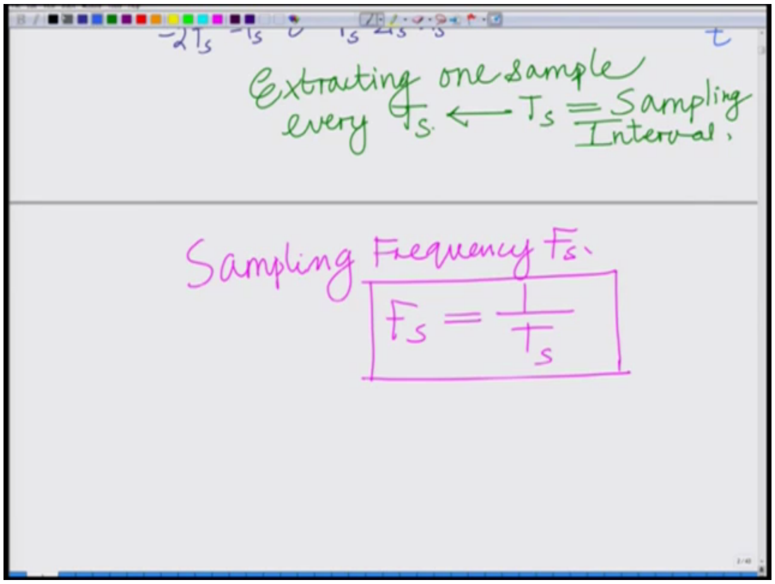

So correspondingly since this is a periodic process sampling frequency which will see is a fundamental quantity of this sampling process Fs equals 1 over Ts, so your sampling frequency is Fx sampling interval is Ts and therefore sampling frequency Fs is 1 over the sampling duration or the sampling interval a Ts and therefore this is basically you are sampling this at sampling frequency when you are extracting since you are extracting samples once every interval of duration Ts, alright. The sampling interval is Ts the sampling frequency is 1 over Ts which is denoted by Fs.

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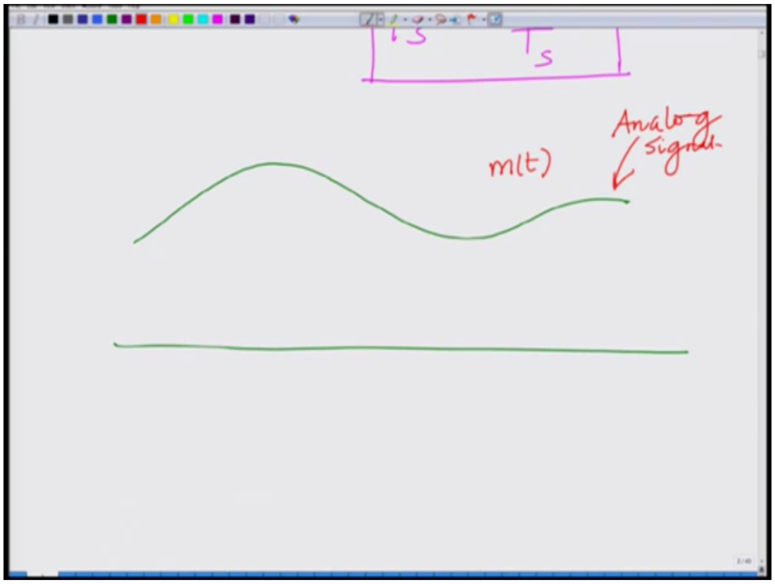

And naturally the sampling process can be represented as follows, so I take my signal again, okay. This is my m(t) this is my continuous this is my analog signal I can multiply it by an impulse train, now what I am going to do I am going to take an impulse train, okay.

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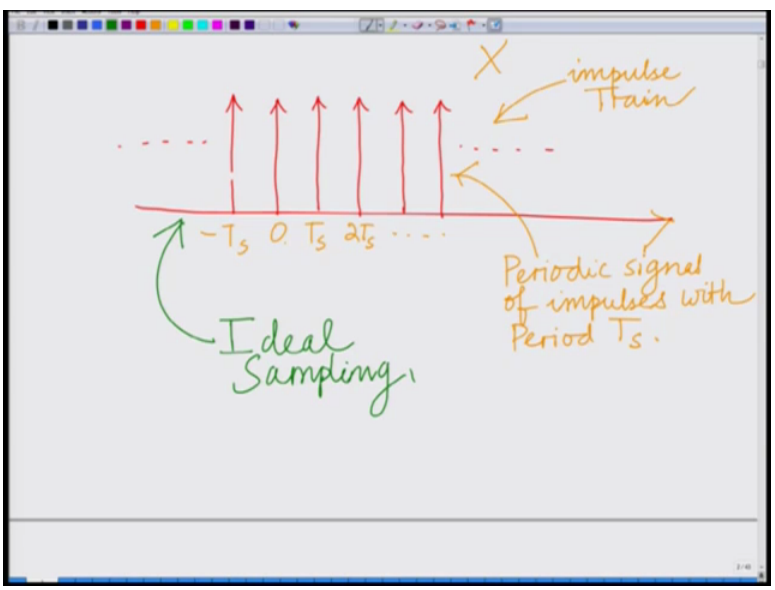

So this is my impulses which are spaced so I take the product of this with this which is my impulse train, now if you look at this, this has an impulse at 0 for instance this is an impulse at 0 Ts, 2Ts and so on minus Ts, so this has this is an impulse train this is a train of impulses which is one impulse that is it is a periodic signal of impulses with period Ts, so this is a periodic signal of impulses, periodic signal of impulses with period that is you have basically one impulse every Ts. So when you multiply this impulse train with the signal what you can see is each impulse at the point of that impulse for instance impulse at 0 will pick the magnitude will pick the level of the function of the signal at 0.

Impulse at Ts will pick the level of the signal at Ts therefore they are creating basically a modulated train of impulses the height of each impulse once you multiply the impulse train with the signal the height of each impulse or the or basically the scaling of each impulse will be proportional to the signal level at that particular time of that impulse, alright. So one way to sample is basically by multiplying the original signal to be sampled with an impulse training this is also known as ideal sampling or impulse sampling. This is also multiplying this by a train of impulses this is also known as ideal sampling, okay. Ideally we want to multiply it by a train of impulses, okay.

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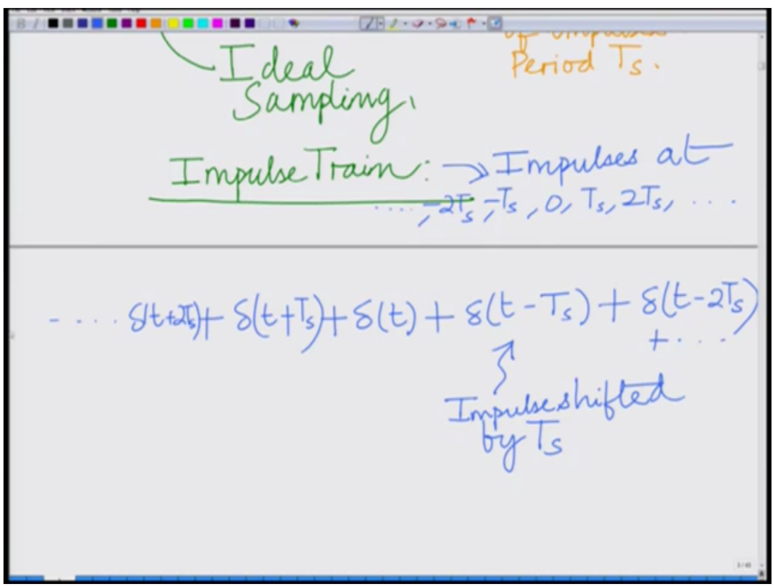

Now let us characterize this impulse, train of impulses we have an impulse at we have the impulse train let us look at impulse the impulse train if you look at this impulse train we have impulses at well, they have impulses once every Ts so you have impulses at 0 impulses at Ts impulses at 2Ts so on. And you also have impulse at minus Ts minus 2Ts and so on and therefore if you look at the corresponding signal that is going to be impulse well, impulse at 0 Delta t plus impulse at Ts Delta t shifted by Ts this is impulse shifted this is your impulse shifted plus Delta t minus 2Ts plus also impulses at minus Ts that is Delta t plus Ts and this is continuous so on Delta t plus 2Ts and its continuous so on and therefore if you look at this signal train of impulses.

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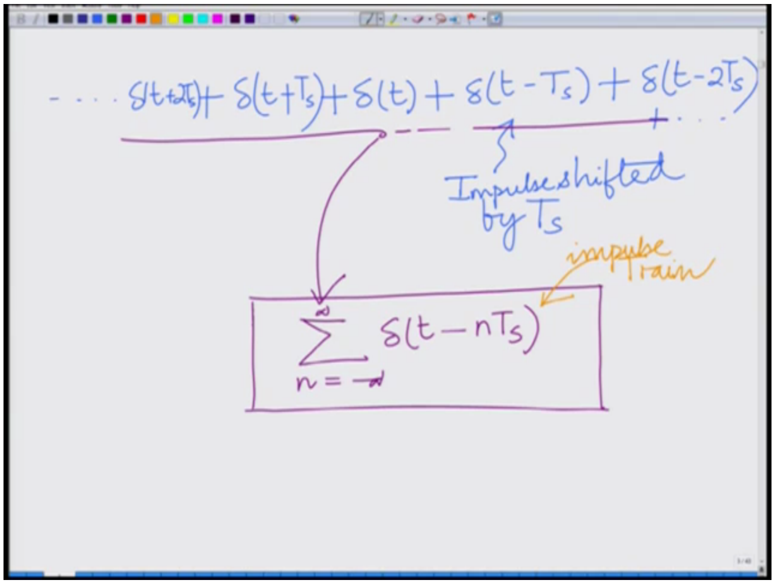

This can be represented as summation n equal to minus infinity to infinity Delta t minus nTs this is basically your impulse this is basically your impulse train that is basically you have this sequence of impulses 1 impulse at every Ts or multiple of Ts that is impulse at 0 Ts, 2Ts one impulse at minus Ts minus 2Ts so on. So each impulse shifted is at nTs where n can be any integer is 0, positive, negative each impulse shifted to nTs is Delta t minus nTs your (summa) you are considering the summation of all these impulses from n equal to minus infinity to n equal to plus infinity this is your impulse train.

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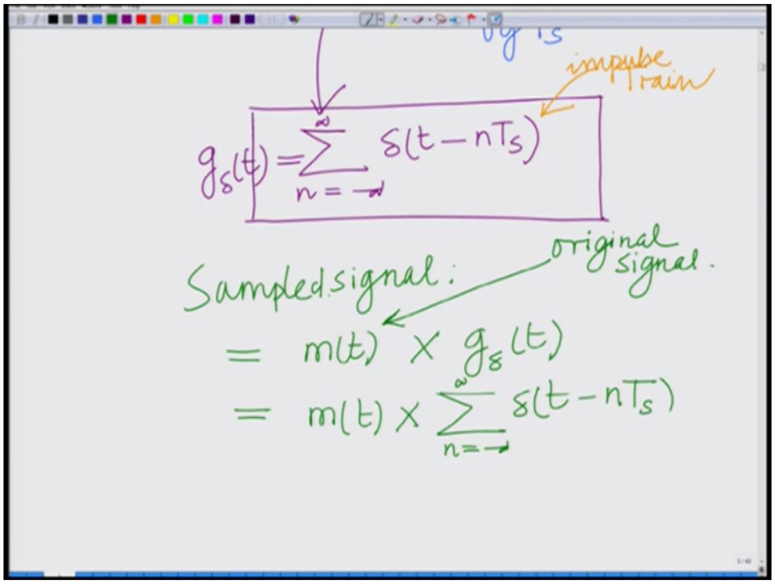

Let us denote this by g delta of t this is your impulse train g delta of t, okay.

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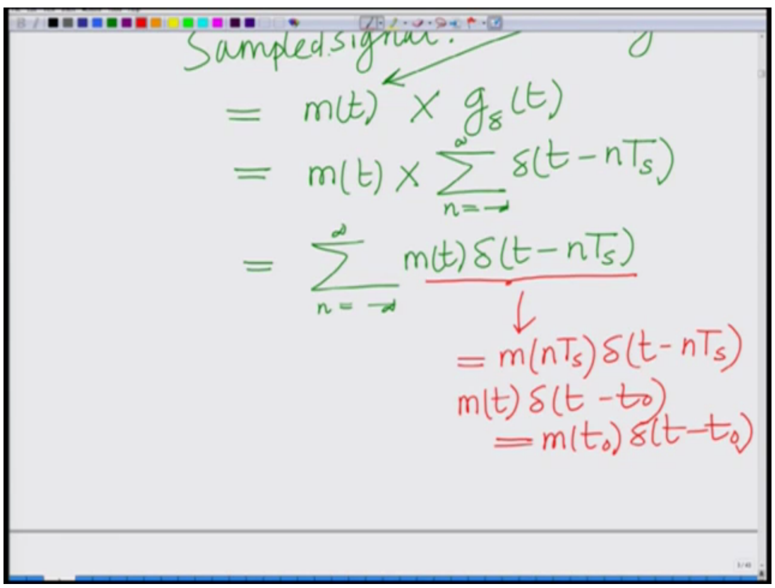

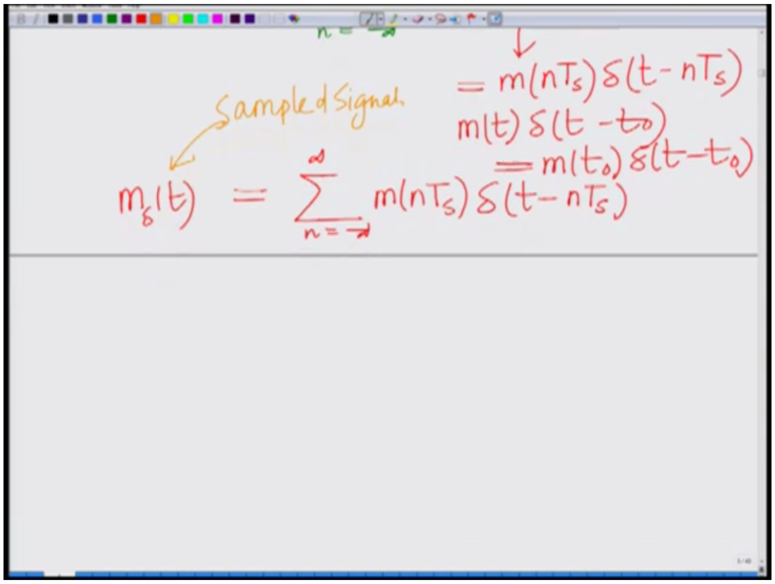

And now the sampled signal as we are saying the sampled signal now the sampled signal can be generated this is your m(t) into g delta t that is product of original signal this is your original signal, signal to be sampled and g delta t is your impulse train which is m(t) times summation n equal to minus infinity to infinity delta t minus nTs which is equal to summation n equal to minus infinity to infinity m(t) delta t minus nTs.

Now you can see m(t) into delta t minus, now you can use the property that m(t) into delta t minus Ts is equal to m of nTs into delta t minus nTs where we are using the property m(t) into delta t minus t not equals basically m t not into delta t minus t not. It is when you multiply a signal by impulse shifted to t not then it simply picks the value of the signal at t not, alright. That is how we are basically sampling this segment, alright. So we are able to extract at each nTs we are able to extract the sample or that level of the signal at nTs that is your m of nTs, okay.

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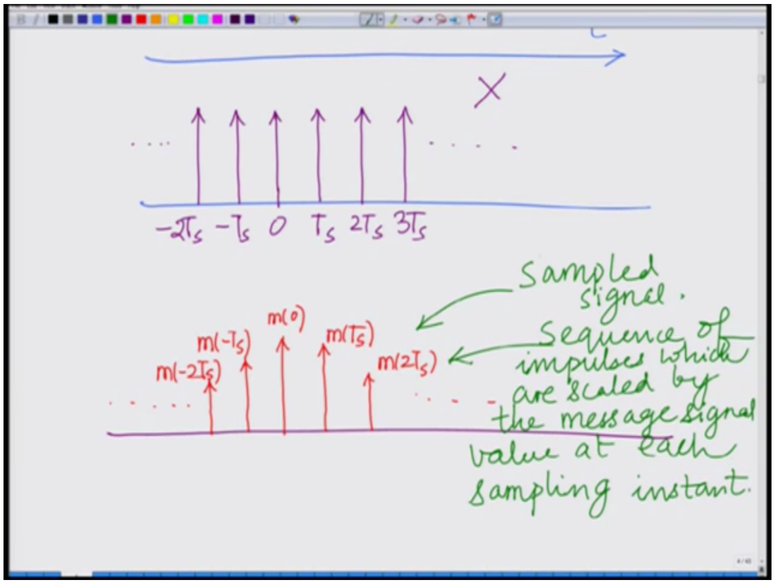

And therefore this gives us n equal to minus infinity to infinity m of nTs delta t minus nTs this is your m delta this is your m delta t, okay. This is basically your sampled signal, okay. So their sampled signal is summation n equal to minus infinity to infinity m of nTs into delta t minus nTs and what we are doing is basically very clear we have this original signal, alright which is varying with time.

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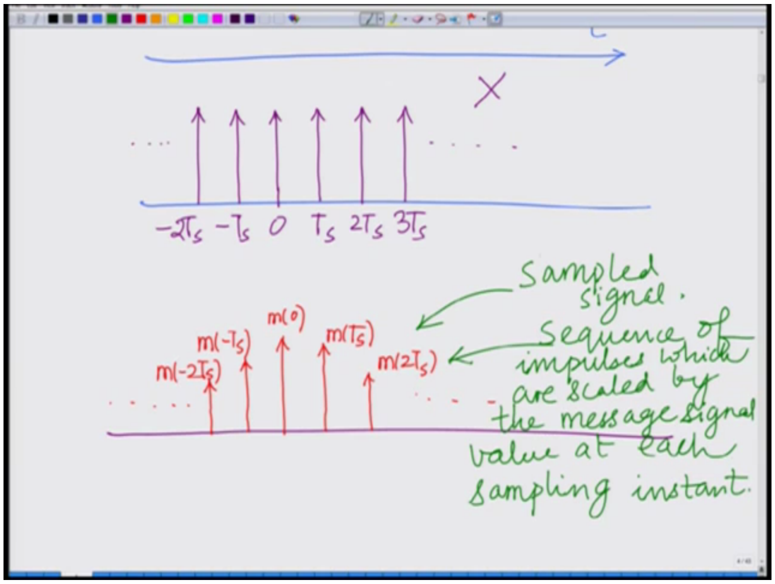

And now you have this impulse train you have this train of impulses at T at 0 Ts, 2Ts, 3Ts and so on similarly minus Ts minus 2Ts so on, so you have this impulse train which is at 0 Ts,2Ts, 3Ts minus Ts minus 2Ts so you take the product basically what you do what you are doing is you are taking the product of the original signal with this impulse train and therefore what you are going to have is basically the signal at 0 will pick m of 0, so you will have basically you will have signal at 0 picking this value corresponding to this is your m of 0, so at 0 you will basically pick you will basically pick m of 0.

At Ts you will pick m of Ts, At 2Ts you will pick m of well, whatever is the value here that would be over m of 2Ts and of course at minus Ts you will pick this value that is your m of minus Ts at m of 2Ts at minus 2Ts you will pick m of, okay. So this is basically your sampled signal, okay which is basically again your sequence of impulses this is basically your sequence of impulses this is your sequence of impulses with the amplitude of the impulse, correct?

The amplitude or each in sequence of impulses with which are scaled proportional which are scaled by the which are scaled by the message signal value, value of the message signal at the sampling instant at each at each sampling which are scaled by the message signal value at each sampling instant.

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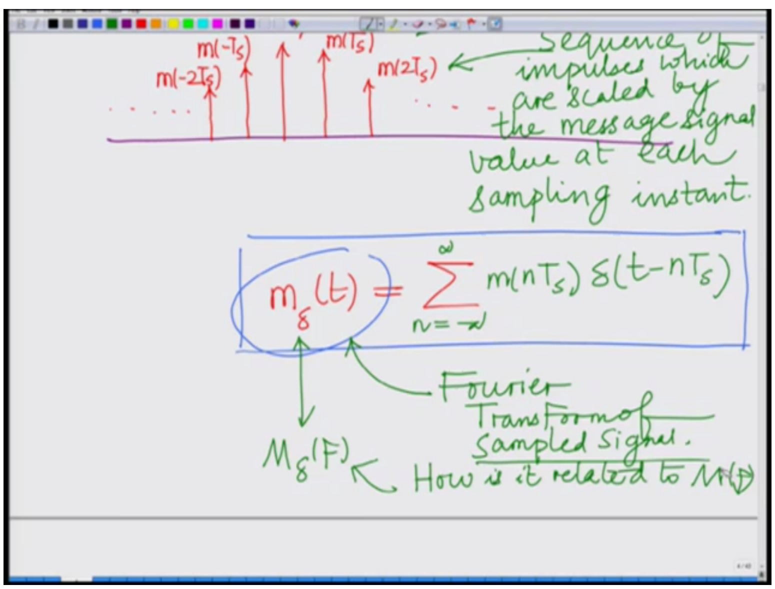

So we have this sampled signal, okay that is your m delta and that is the expression that is given by this expression remember m delta T equals summation n equal to minus infinity to infinity m of nTs delta T minus nTs this is your this is the this is the sampled signal that we obtained, okay. So this is basically the sampled signal that we obtain and now we want what we want to do? We want to look at the Fourier transform we want to look at this behavior of this in the Fourier domain. So want to look at the Fourier transform we want to look at the Fourier transform of the sampled signal that is what is the Fourier transform M delta F of the sampled signal and how is it related to M of F? Where M of F is the spectrum of the original signal, alright?

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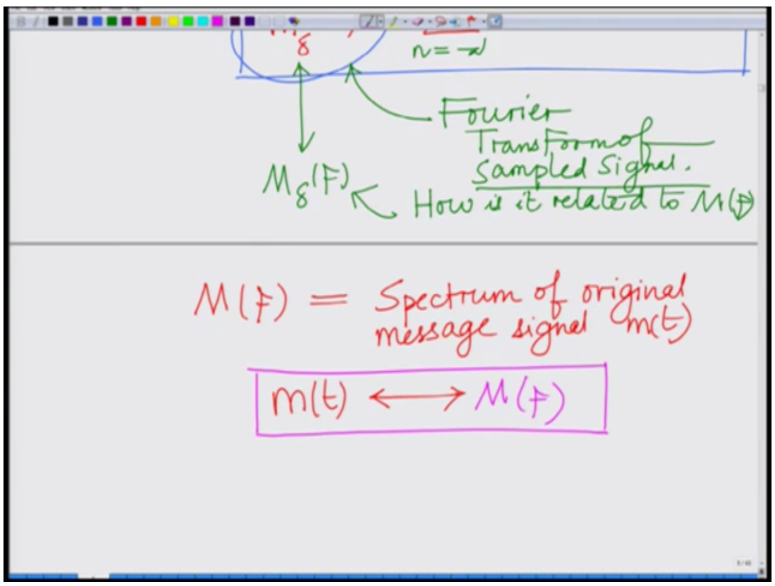

Remember M of F M of F is the spectrum of the original message signal m(t) that is M of F is a Fourier transform of m(t), alright. So we know the spectrum of the original signal, alright. M of F that is m of t is the original message signal which spectrum is M of F, we know that we are sampling it with an impulse train at sampling frequency Fs that is sampling interval Ts, alright.

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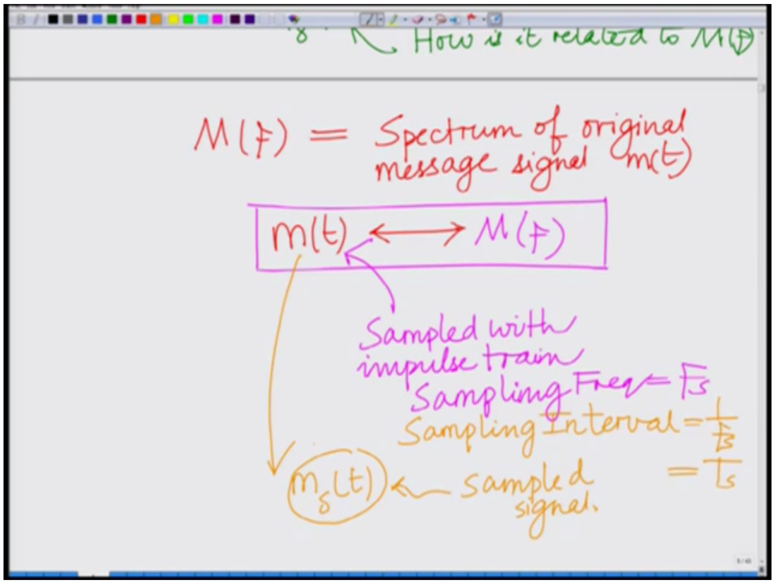

Let us say this is sampled with the sampling frequency is Fs sampling interval equals 1 over Fs that is equal to Ts, now we get m delta t which is your sampled signal which is your sampled signal. How is the Fourier transform of m delta t? That is if you call the Fourier transform of this as your m delta F, how is it related to M of F? Alright, what is the relation in the, what is the relation of the spectrum of m delta F to M of F? And remember also more importantly when we are sampling we are losing the information because we are only extracting the information of the symbols, alright or the signal original signal at the sampling instance that is multiples of Ts 0Ts, 2Ts, minus Ts, minus 2Ts so on. So we are losing the information contained in the signal in in the intermediate duration, alright.

In the intervening (inter) in the intervening duration that is we are losing the information corresponding to the interval 0 to Ts, alright. The information in that particular interval, alright and that leads to distortion, alright. That can lead to distortion, alright. So we are going to see when does that lead to distortion? And what kind of distortion?

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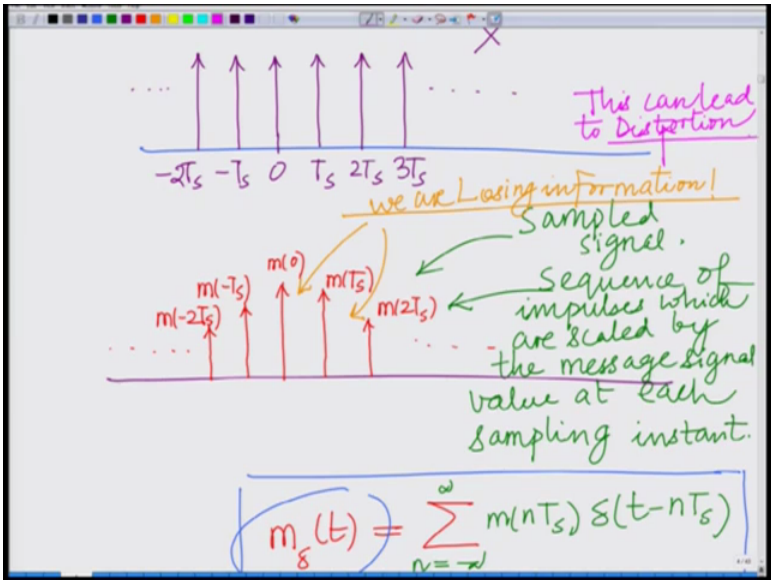

So basically if you look at, go back and look here you can see that basically we are losing information, in sampling we are losing information because we are extracting only the information at the sampling instant so we are losing information this can cost of distortion which means this can lead to this can lead to distortion, alright. It can lead to distortion if you are not able to recover all the information from the signal that is information has been lost then this can lead to distortion, alright. So we want to see under what conditions what is the type of distortion? And under what conditions, that is what is the, what can how can we fix the nature of sampling? Such that the distortion is minimize and if possible there is no distortion at all, right?

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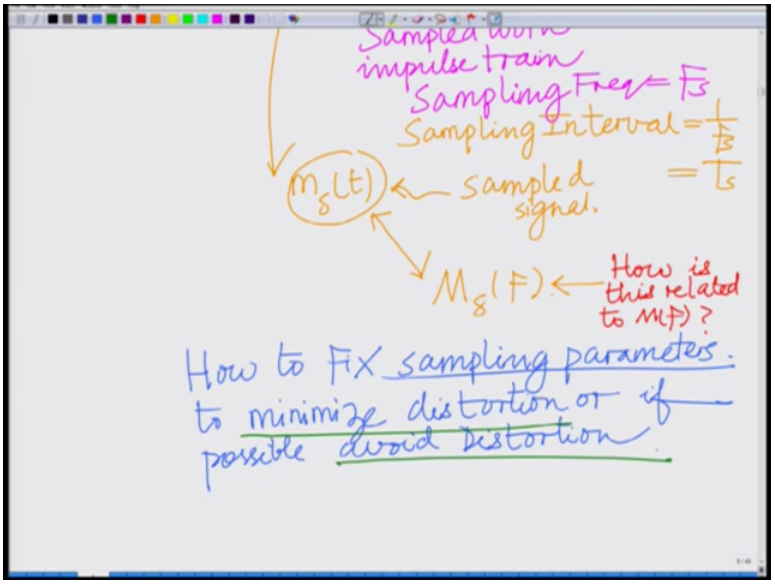

How to fix the parameters of sampling to avoid to minimize distortion or possibly no distortion? So the question we want to answer is how to fix the parameters of sampling? How to fix sampling parameters to minimize or if possible avoid distortion? Either we would like to well ideally we would like to avoid distortion, correct? Ideally we would like to avoid distortion but if avoiding distortion that is making distortion completely 0 is not possible then at least we would like to minimize the distortion.

That is caused by loss of information which is arising due to this sampling process, alright. So these are some of the questions that we want to answer while sampling while considering the sampling of this analog signal which we will consider in the subsequent modules thank you very much.