Machinery Fault Diagnosis and Signal Processing
Prof. A. R. Mohanty
Department of Mechanical Engineering
Indian Institute of Technology, Kharagpur

Lecture – 16
Computer Aided Data Acquisition

In this class, we are going to talk about computer aided data acquisition. As you know in the previously when we talked about signal analysis, particularly finding out the features of the signal beat the RMS value, beat the mean value, we are certain integrations to be done where we required a mathematical function for a signal as simple as that you know.

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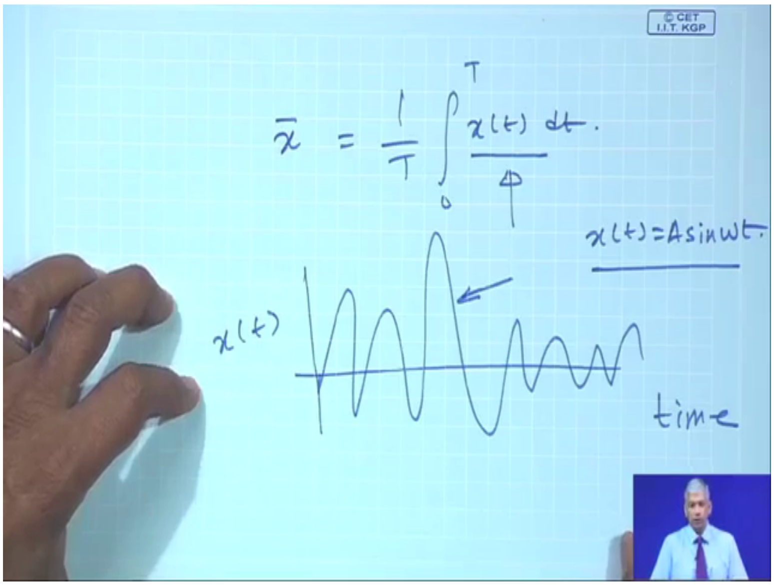

Suppose I want to find out mean of a signal, I need to integrate the signal over a time period. Now the problem there lies that if I have a signal of this nature which is coming out of my machinery, I do not have an expression or a mathematically equation to this curve. If you it has a nice sig wave where xt was equal to a sin omega t, I am sure all of us have done the such integrations even; first a electrical circuit courses and we have very happy and comfortable to find out features of the signal ok.

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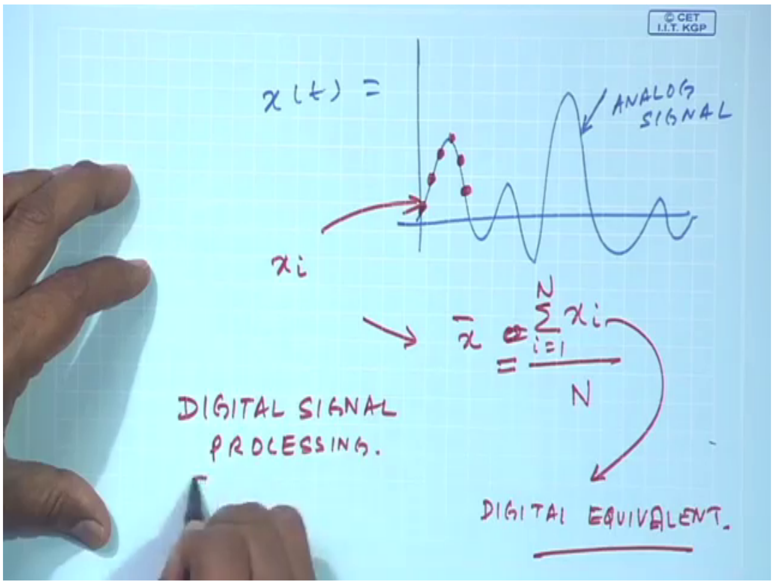

But then this could be done in a better way instead of x t representing this signal, I have closely spaced point x i.

So, if I have such sequence of x i I can analyze them like nothing, but i is equal to 1 to N divide by N. So, this is a simple example how if we have this as an analogue signal, and here I have a digital equivalent of that signal. So, the job of us right now is to how to convert this analogue signal into a digital signal. So, that all this numerical computations bit just finding out the features, even finding out the frequency domain coefficients of such signal we can do that and that is actually what is done in digital signal processing, and just to recap as you know in CBN or machines condition actually depends on what we infer from the signal obtained by this transducer xt.

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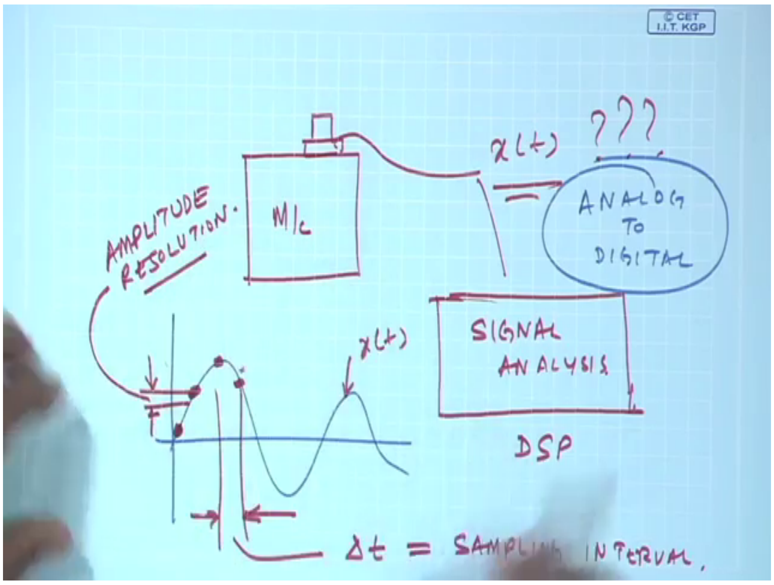

What do we understand from this as signal xt and. So, that is why we have on a nice module of signal analysis, but to do any mathematical signal analysis or DSP, I need to convert this signal from analogue to digital.

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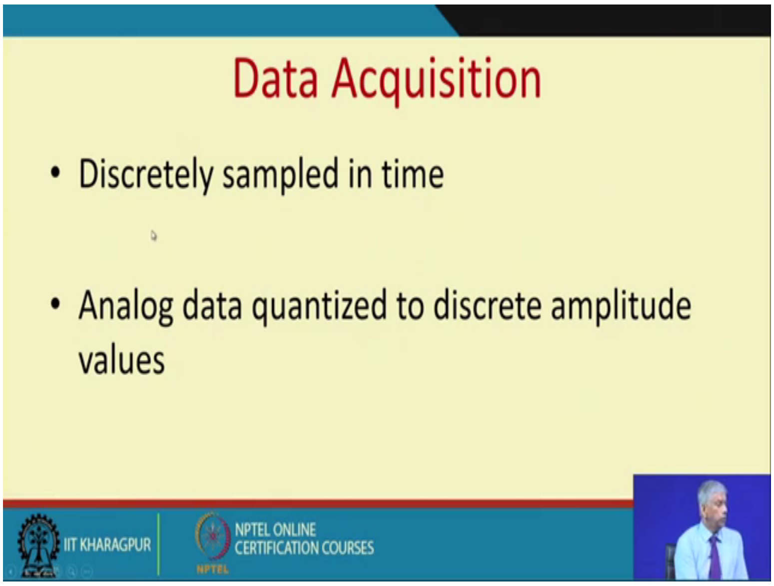

So, this is what we are going to focus on introduce class. So, data acquisition is values which are discreetly sampled in time, discreetly means there is a definite time interval between the signals. So, this delta t is known as the sampling interval, a device hardware device does this. So, it will give you and corresponding analogue value to digital signal xt and that is this hardware which we are going to talk about.

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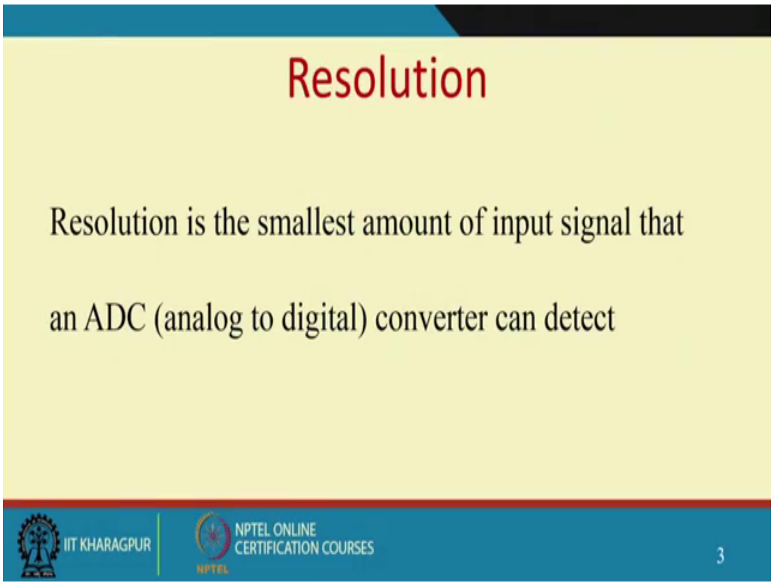

And then another quantity is resolution, what is the minimum value the signal can be sensed I will give you an example here, because see all the signals which are digitized I have an analogue domain and then I have a digital domain.

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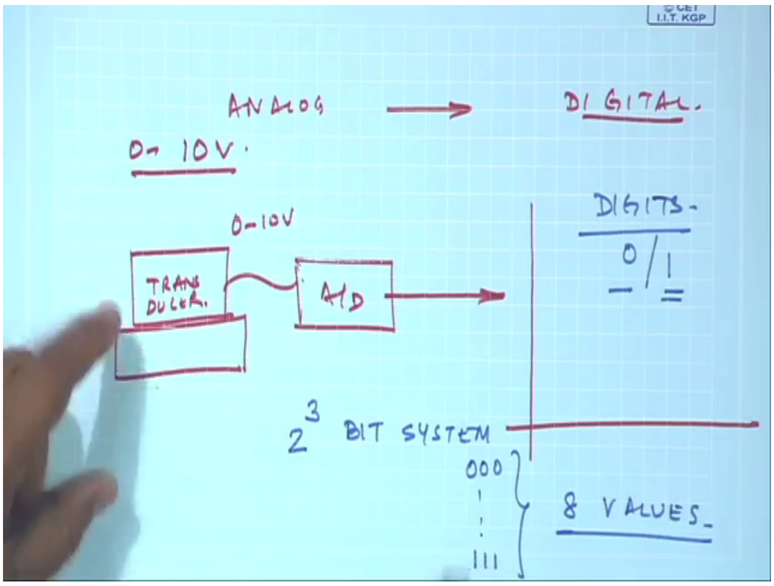

So, in analogue domain I have a analogue voltage may be from 0 to 10 volts this is my transducer output. So, in transducer gives me maximum value it can give to 0 to 10 volt analogue signal.

Ok, but then once I do in A to D conversion, I should be able to store this n digits as you know in digital domain I can store a value either as a 0 or a 1. So, there are 2 options. So, if this is a 2 to the power 3 bit for the sake of discussion system. So, the possible values of zeros this guy can have is all the from 0 0 0 to 111 So, I will have 8 values. So, whatever be the analogue signal which is coming to the system my A to D is only been able to convert into digital values and only have 8 positions or locations.

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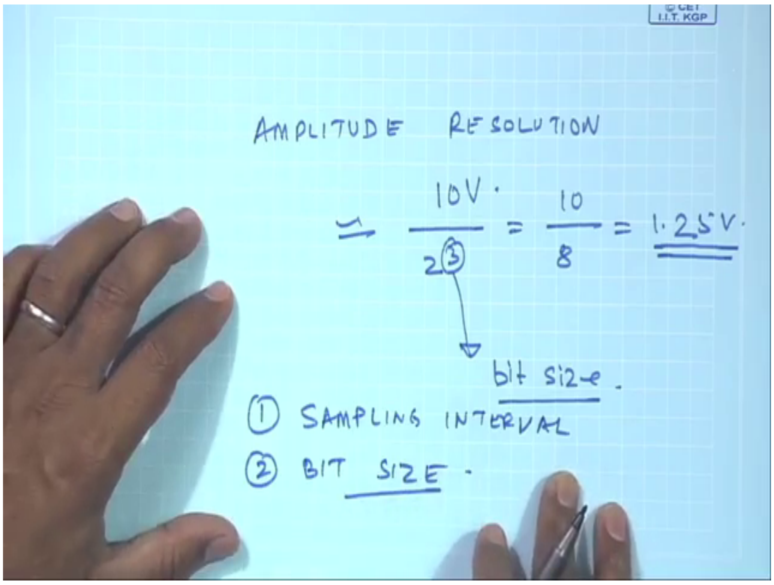

So, store this value. So, this amplitude resolution is nothing, but your total voltage. So, in our case 10 volts divided by 2 to the power 3, 10 by 2 to the power 8 is 1.25 volt. You see this bit size plays an important role in the resolution of this A to D converter. So, one thing that keep in mind, one is the sampling interval I will give an example of the sampling interval and other is the bit size apart from few other things.

So, today if I go to by hardware for the analogue to digital conversion.

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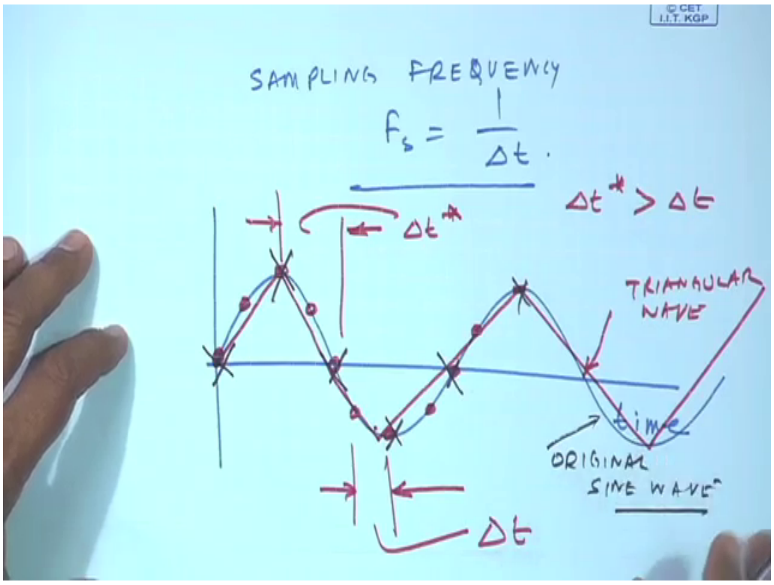

These are the 2 important features one has to look for all the specifications, and by the way sometimes the sampling interval is related to the sampling frequency F s is nothing, but 1 by delta t. So, this also creates another problem imagine, I have an analogue signal of this nature and I sample at few points shown by this red dots; that means, what I n peaking values equally spaced sampling intervals. So, if I join this red dots I will get my original white signal, but instead of delta t suppose I pick another sampling interval at a different sampling rate one is this x and so on. So, you see if I join this I am getting straight triangular wave.

So, and this is the new sampling interval delta t star, where delta t star is greater than delta t. So, I have got this triangular wave as opposed to the original sine wave. So, I have created by inadequate sampling frequency I have created are or an aliased or pick made a signal wrongly represented in the frequency domain.

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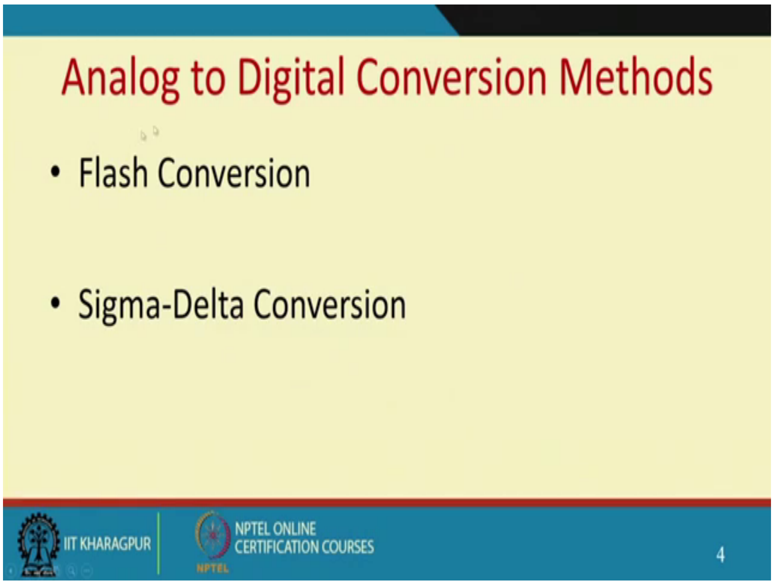

I will continue this discussion, but just to tell you this analogue to digital conversion methods there are 2 methods, one is the flash conversion, another is the sigma delta conversion will not go in the details of this just to know that when you specify you have to specify either of these 2 processes.

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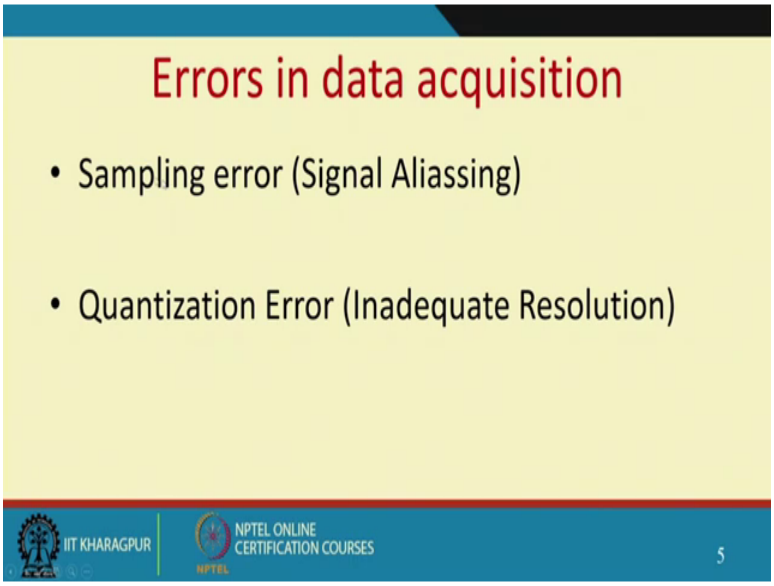

So, the errors because of data acquisition one is the sampling errors, which we discuss is known as signal aliassing and other is the quantization error because of the inadequate resolution I will explain it through a better diagram here.

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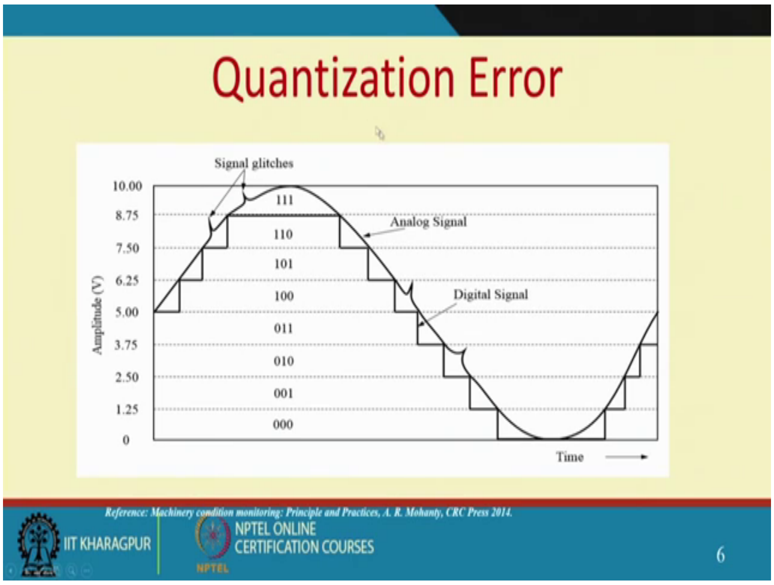

So, if you see here the same signal, this is my black line or continuous line in the original signal ok.

Now, because of a defect in this machinery, I have got some glitches in the signal which could be because of some machine faults and this has to be captured by me, but if you see if I have a 3 bit computer. So, these are the actual values 0 0 0 to 111. So, if I have the amplitude resolution this is nothing, but 10 divided by 2 to the power 3 or 10 by 8 this is 1.25. So, the data acquisition system only understand 0 to 1.25, 2.5, 3.75 and so on volts. So, in this case of 5 volt analogue signal is represented by this line, and the next point it comes here which is only 6.25. So, it is not able to decide the minor variations between 5 to 6.25, because the least it can senses only 1.25. So, in that token what I get is a jacket wave like this, which is my digital representation of my analogue signal which is quite different well how could this be improved this could be improved if I had final resolutions.

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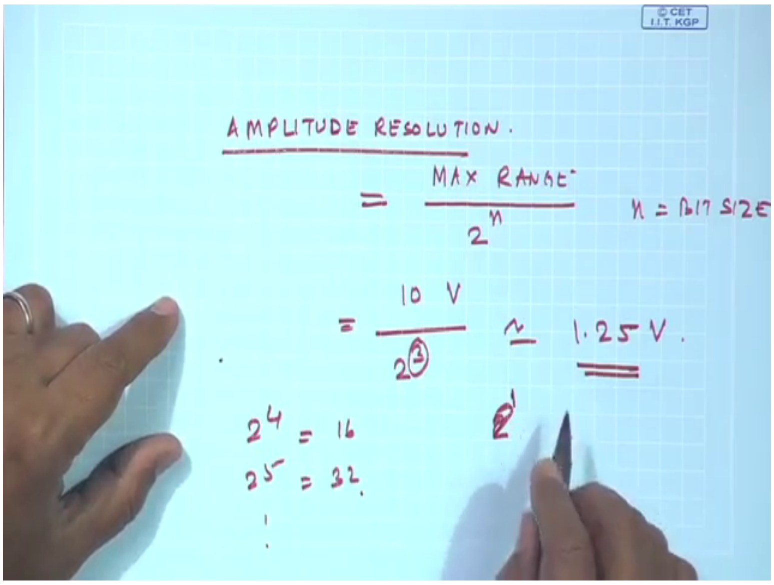

So, this amplitude resolution which I am talking about is nothing, but the maximum range by 2 to the power n where n is a bit size, if maximum range of 10 volts and 3 weight we saw this as 1.25 volt.

If I increase this in bit size you know 2 to the power 4, 16 2 to the power 5, 32 and so on this is with increasing bits are the denominator increased. So, this will reduce. So, one way to improve this amplitude resolution is to reduce the quantization error. So, quantization error in a data acquisition system can be reduced by increasing the bit size.

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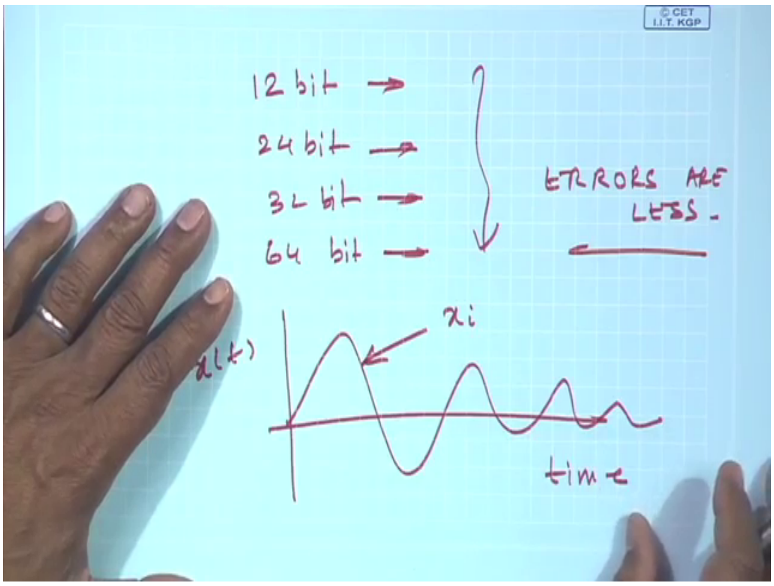

So, if you see the numerical accuracy of a 12 bit laptop is less compared to a 24 bit or a 32 bit or a 64 bit, and you have seen nowadays in the market if you buy a computer system with higher bit size they are highly priced because they have give you a better resolution errors will be less as we increase are less. Because my objective is to faithfully represent my machine signal whatever I do, I need to get back my original signal after the data acquisition system and this is known as x I this is one case we have to do.

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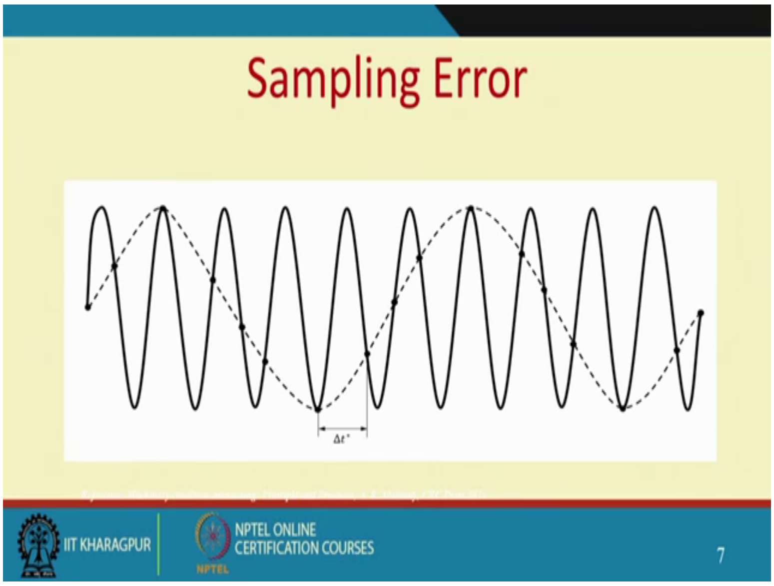

Now, another related to the sampling error is this case here. So, you see I have the original black signal, if I now sample it at lower rate of the time period is high, I will get back get my dash line this is actually a low frequency signal.

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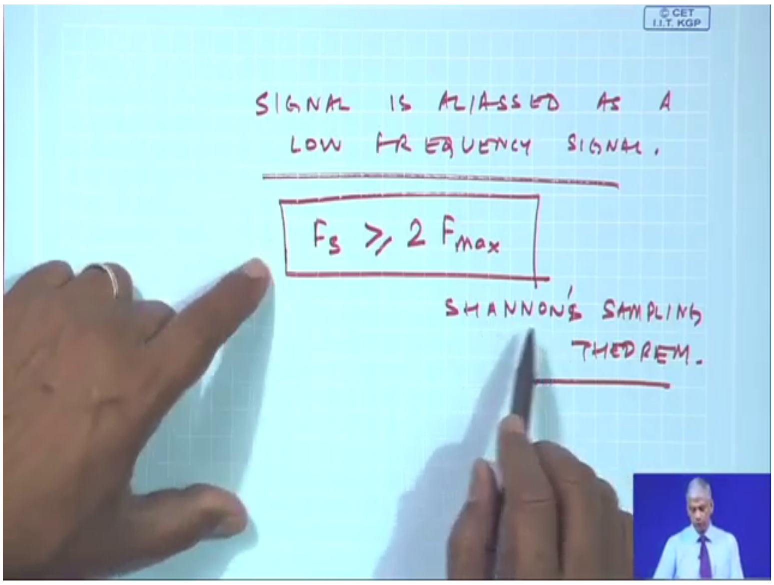

So, signal is aliassed as a low frequency signal so in fact, there is a theorem which says your sampling frequency should be greater than twice of f max to prevent signal aliassing. So, this is the Shannon's sampling theorem. So, to prevent signal aliassing we have to do this.

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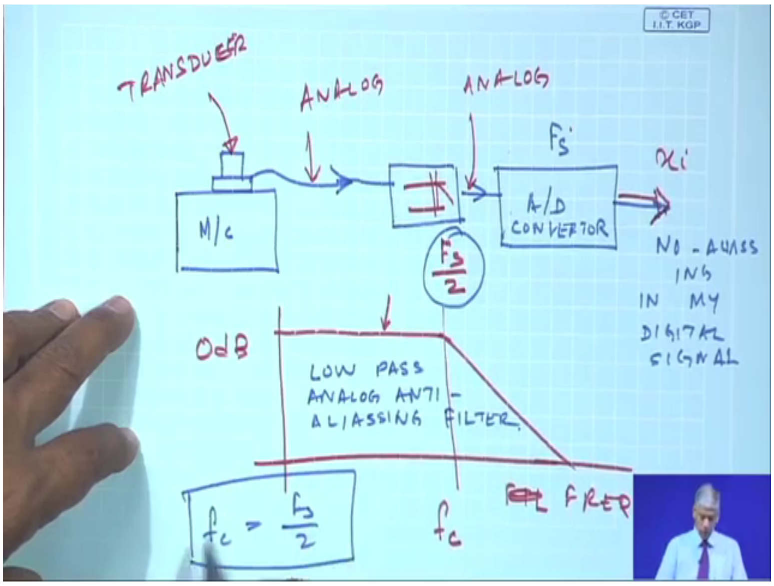

But the question is many a times in this A to D devices, I have my machine here and I have a transducer, I am giving an analogue signal and I have one A to D converter, which comes in the market the sampling frequency and then I have to put some device here so that I get no aliassing in my digital signal. So, this is of course, a digital simpler x i, and this is this is the analogue, this is also analogue and this is my transducer. So, what we can do is if I put a filter. So, that it does not allow this is the certain role of cutoff frequency of this filter.

Such that it does not allow any frequency beyond Fs by 2 to pass on to the analogue filter because this is known to me. So, I can set the this is a low pass analogue anti aliassing filter. So, if I go to the market and if I by an A to D converter with the sampling frequency, I can always have the low pass anti aliassing filter put as a front and before that A to D process some of them have some of the A to D converter is have such filters before them or I can put an additional low pass analogue anti aliassing effected with the cutoff frequency f c is equal to F s by 2. So, that any signal with comes in which I get x i here is never aliased, this is very important thing which we have to keep in mind. So, as you know in CBM there are many signals for example with time with this is a temperature signal as opposed to time for a vibration signal.

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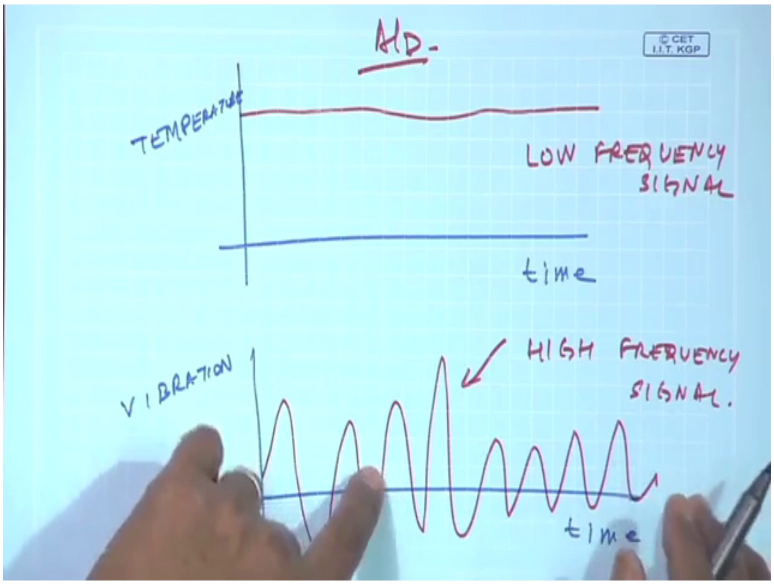

Temperature signals do not change so rapidly unlike a vibration signal vibration signal could be changing very fast, but a temperature signal is very slow slow. So, this is a very very low frequency signal, and this is a visually high frequency signal. So, the data acquisition system A to D converters, for temperature recording conversion is actually I can have a low frequency signal sampling frequency. In fact, they are much much cheaper compared to the data acquisition devices used for dynamic signals which are vibrations.

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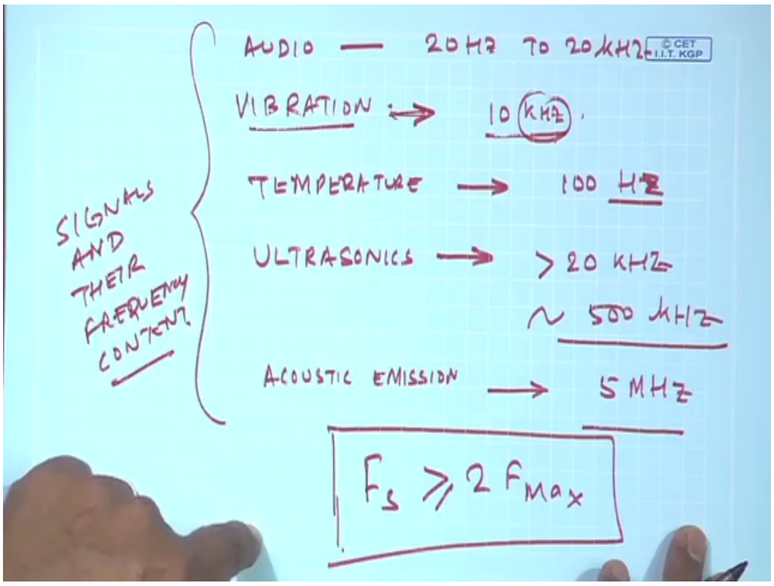

So, you know; obviously, people sometimes ask me what is the typical frequency range of vibration signals for CBM, I say you know if you look into ic engines and motors you know though the if I talk about the audio range from 20 hertz to 20 kilohertz. Vibration signals are good after 10 kilohertz; there is enough information to do any CBM temperature even less than around 100 hertz, 10 kilo hertz very high. Now there are few other devices for example, you will see lot of ultrasonics which are used for in radars etcetera sonars etcetera this is greater than 20 kilohertz depending on some underwater acoustic applications they can go up to you when even you know 200 500 kilo hertz, particularly some they underwater sonars and. If we look how acoustic emission is something which will discuss later, on the maximum frequency of the signal could be around 5 megahertz see you can see different signals, and there frequency content because is to get a meaningful representation, they are all have a sampled at F s is greater than twice F max.

So, this has to be kept in mind. So, if today if you go to the market to buy data acquisition systems, we will see data acquisition systems to different sampling frequency is because of this obvious reasons one is to prevent signal aliassing and other is 2 have higher bit size so that the amplitude resolution is fine enough.

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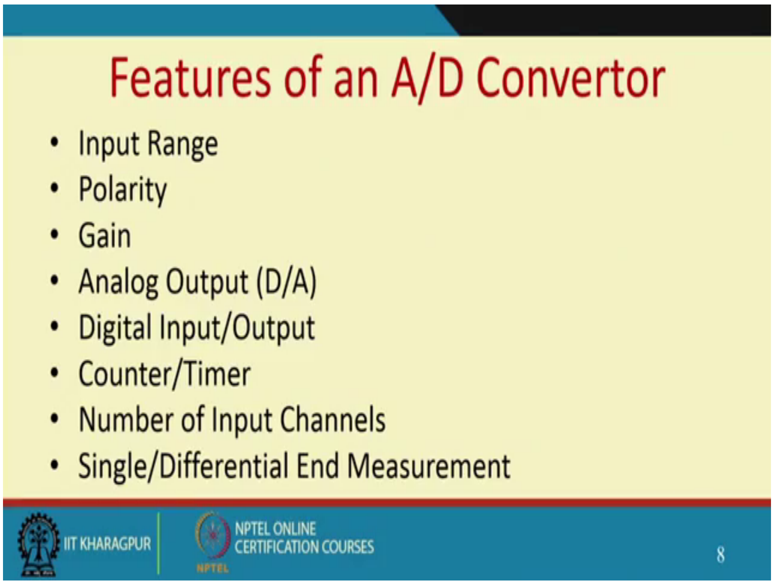

But then there are few other features of A to D converter, one is this maximum input range its usually you know 0 to 10 volts polarity, sometimes you know whether they will be bipolar or unipolar gain sometimes some of this data acquisition units the least sensitivity or amplitude resolution is so low, that even a thermocouple signal giving few millivolts cannot be sense.

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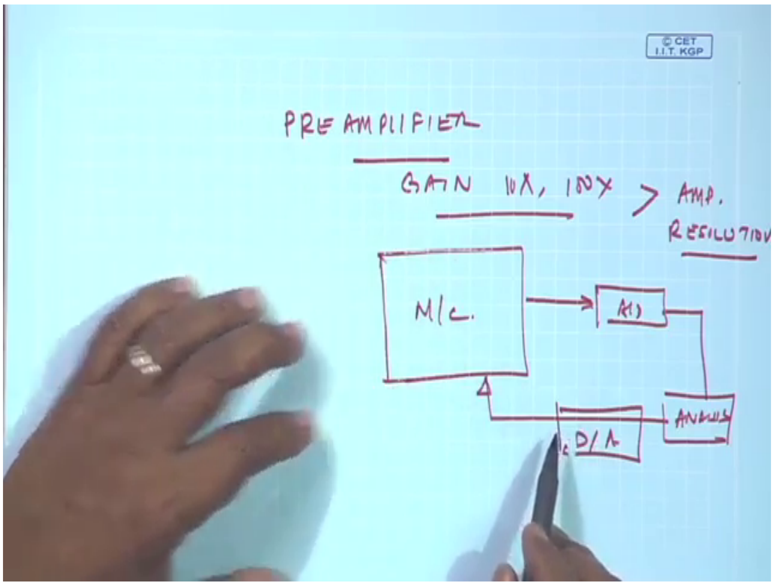

So, we need to have a pre amplifier to give a gain some gain 10 x or whatever 100 x. So, that they are greater than the amplitude resolution of the unit of course, nowadays you know this one open loop process in which we are doing in CBM, but may of the closed loop operations wherein after you take the signal through an A to D converter, you get do an analysis and you want to control through an mechanical feedback and actuator. So, we need to have what is known as the digital to analogue.

So, some of the units have d 2 one that is for a closed loop control system and so on.

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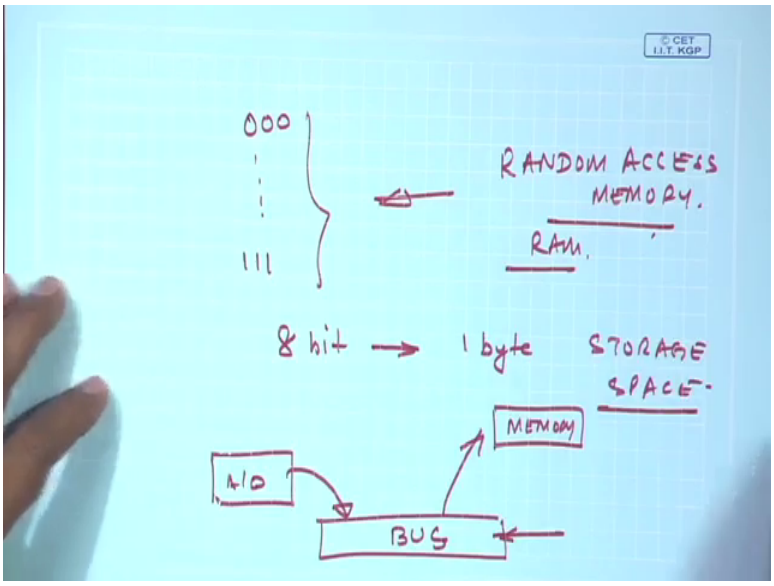

Some of this because you know finally, this system has showed the values 0 0 0 to 111 where they have store them, I store them in the random access memory of my computer systems some ram memory is require. So, this was an 8 bit system. So, each digital sample will take one byte of storage space. So, memory also comes with the cost. So, if my have higher resolutions the storage space would increase and then that would lead to having more number of ram required because you know finally, this digital data needs to be stored somewhere . So, I have a bus digital bus on to which I put my A to D converter digital and from this bus I can have a memory location or I can put on board memory. So, and this bus is an architecture which is prevalent in today's computers you know started, I will talk about this is different bus architectures which are available today and then there are provisions we just talked about one channel.

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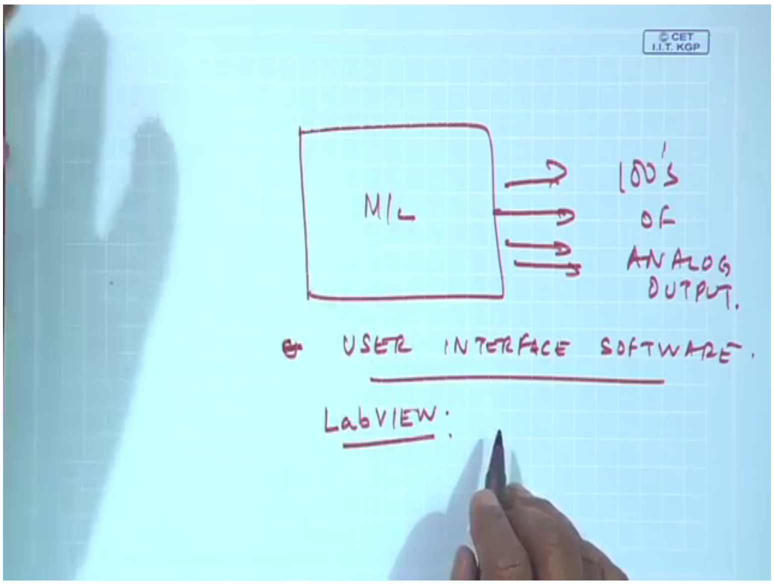

Imagine I have a machine where there are hundreds of analogue output. So, some of them have to be acquired simultaneously some after them one by one. So, in an A to D converter simultaneously how many channels I can digitizes also function and so on. Because the data storage would capability would reduce by having more channels and many a times you will see later on only we talk about wireless data acquisition how this signal can be transported through Wi-Fi to another device and; what are the limitations of signal transmission over Wi-Fi frequency range in soon.

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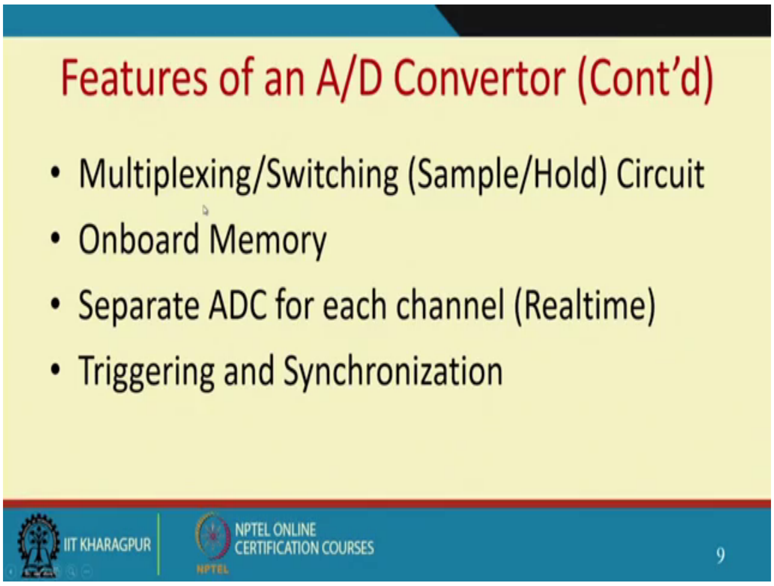

Sometimes you know when you have want to converter one digital converter, but there are many input and we can have a analogue or digital switching circuit which is known as the multiplexing and then sometimes you know we will trigger and synchronize, and end of the day we have who is who is controlling all this. So, there has to be a user interface software to control already.

So, in in the universities or in IIT is we have a very popular software lab view which is of the company, and then this is used to control the data acquisition units and communicate with the computers and then today it was analogue signals for CBM, it could be vision signals it could be in you know motion signals and so on. And another thing is a program any other features, which are available in data acquisition unit one is triggering when at what time do I need to sample a signal.

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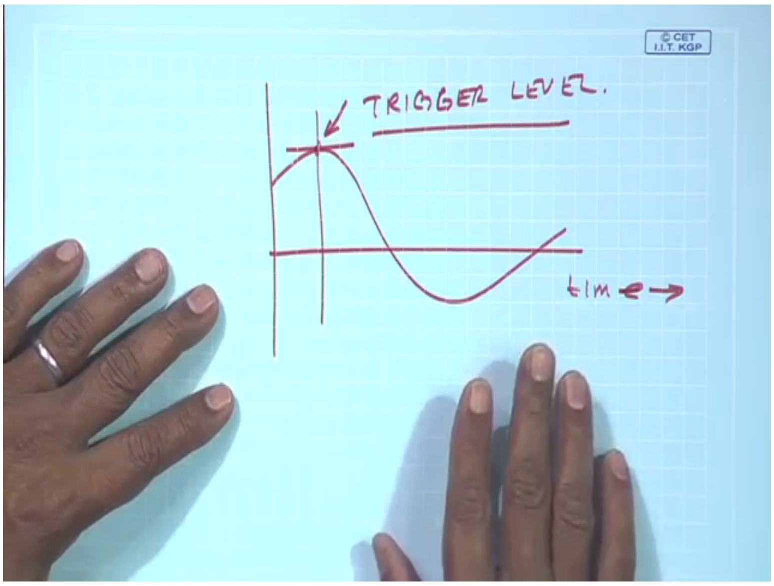

So, only when a max has occurred I will start acquisition. So, this is called as a trigger level, only when I max has occurred or even does occurred I will acquire the acquire the signal. So, this has to be taken into account when you are doing data acquisition. So, just to recap you know there are lot of features in data acquisition units, but most important is quantization error which can be improved by increase in the bit size, and other is the aliassing error which can be improved by increasing the sampling frequency or having a low pass into aliassing filter.

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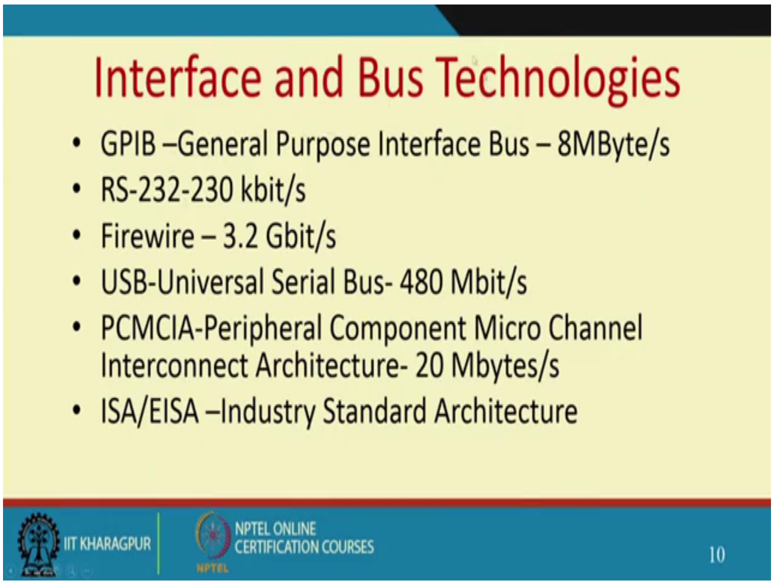

Now, coming to this bus that is once I have the digital data I need to transfer them of course, we use to have the Gpib transfer protocol, which had a speed of 8 megabytes per second.

We had the RS 232 it is very slow, but still people use it 232 kilobytes per second firewire is a 3.2 gigabits per second you know which is very popular in the max systems today we have the USB systems, and then there is to be PCMICA at 20 megabytes per second. So, faster computers have you know faster speeds you know we have 3.2 today when in the data transfer when in wireless communications we are talking about 3 g 4g you know people are talking about 5 g. So, this is only how fast we can transfer the data if you can transfer the data first you can acquire data large number of datas store large number of datas and process dynamic signal through will talk about data recording and data transfer ha later on.

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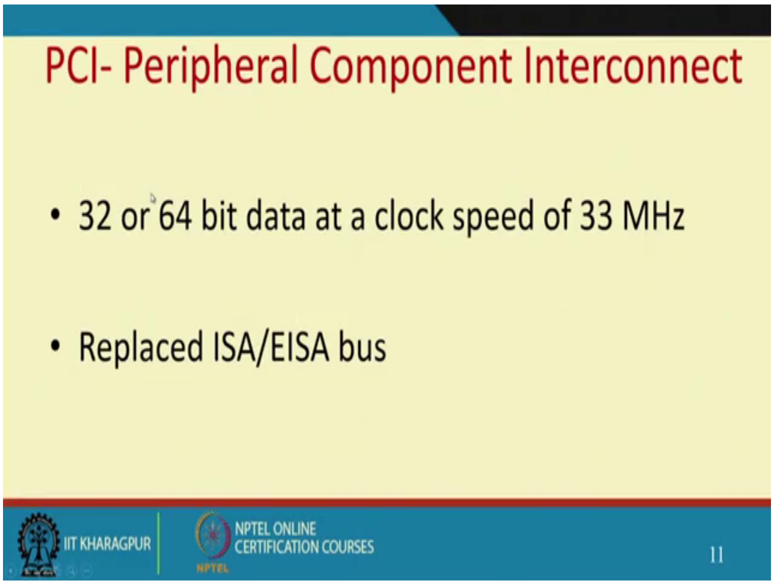

And then PCI a interconnect it is a clock speed of 33 megahertz, which is replaced the ISA EISA bus.

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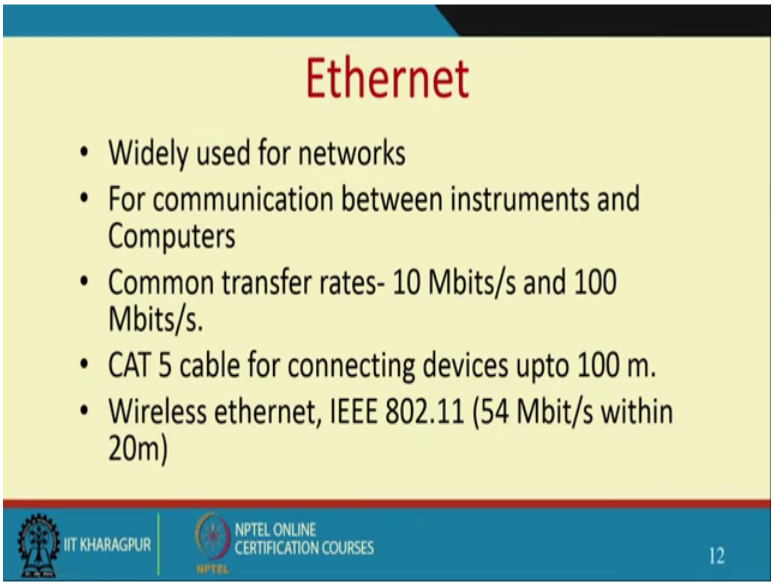

We also use the Ethernet once the data is in digits and of course, we have the CAT 5 cable connecting devices we have the wireless Ethernet and so on. So, today is world in a bit machines computers mobile devices we need faster ways of transferring digital data through this protocols which are available and then we can do our processing and make an analysis.

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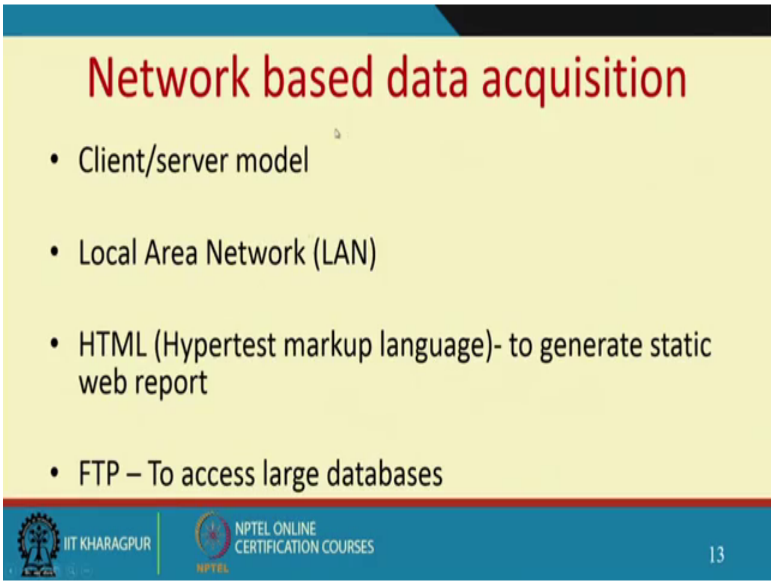

Of course you know there are network based data acquisition system. So, unlike a client server in a model. So, you could be sitting server and controlling your acquisition and so on.

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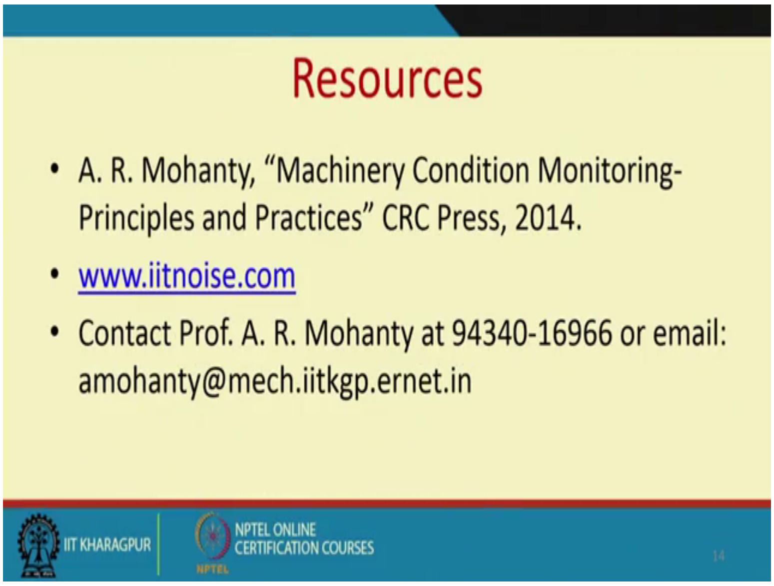

We will continue more on this and then subsequent classes.

Thank you.