Machinery Fault Diagnosis and Signal Processing
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Lecture – 18
Data Recording

In this lecture we are going to talk about data recording. You will remember in the substitution or one of the earlier classes we talked about computer aided data acquisition. But in machinery condition monitoring you will come under instances where the signal analysis cannot be done in SITU just because of the inconvenience of the environment of. I will give you an example.

So, for example, you are just recording vibration signals from a gearbox close to a very dusty environment like cement plant or a coal mine etcetera. So, we always will not find it convenient to do a signal analysis in situ. So, that means, we have to record the data right then and there and then bring it back to the lab for analysis. So, in this lecture we already see what are the different aspects of data recording available, and you know what are the different formats of data recording, what are the different devices available today for data recording and so on. So, that the signal because if you if you again recall CBM.

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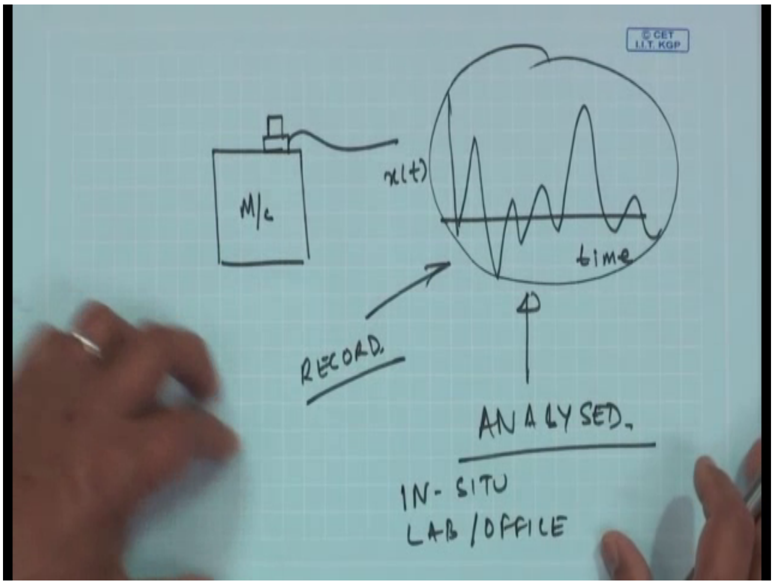

I have a machine on which I put a transducer, it will capture a signal in time and this needs to be analyzed. So, where do I analyze? Sometimes in SITU, sometimes in a lab or an office.

Where and less are there and so on. So, what is this how to record, now if you will know that in CBM, our signals are dynamic.

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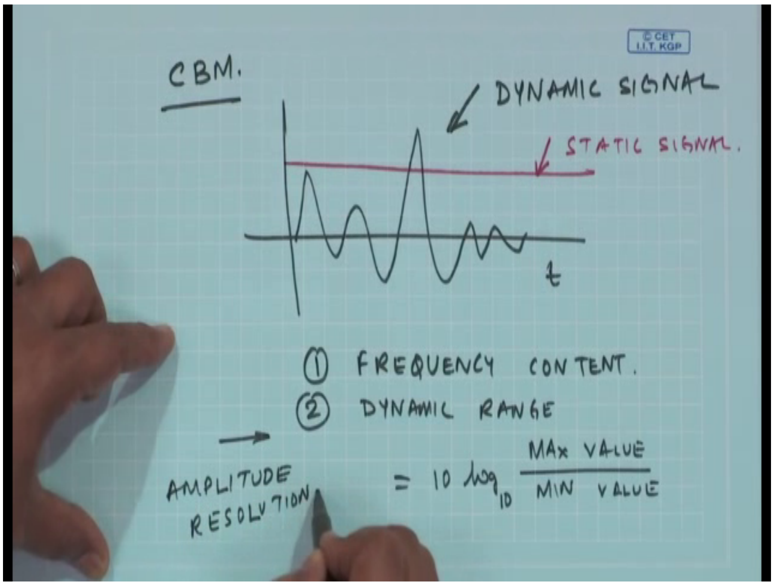

This is an example of a dynamic signal as opposed to maybe static signal. So, if you consider the dynamic signal, you will see that there are few important features of dynamic signal. One is the frequency content, other is the dynamic range or a dynamic range, I mean what is the in a logarithmic scale 10 log to the base 10 of maximum value to the minimum value present in the signal.

So, for example, I will give you a dynamic range and signal I could have a maximum of 10 volts or a minimum of point one volt. So, we should have adequate dynamic resolution to accommodate such high varying signals. You would have seen this would relate to the amplitude solutions, which we talked about during data acquisition. And you will recall that this amplitude resolution was nothing but the maximum input voltage to in a dynamic signal 2 to the power n.

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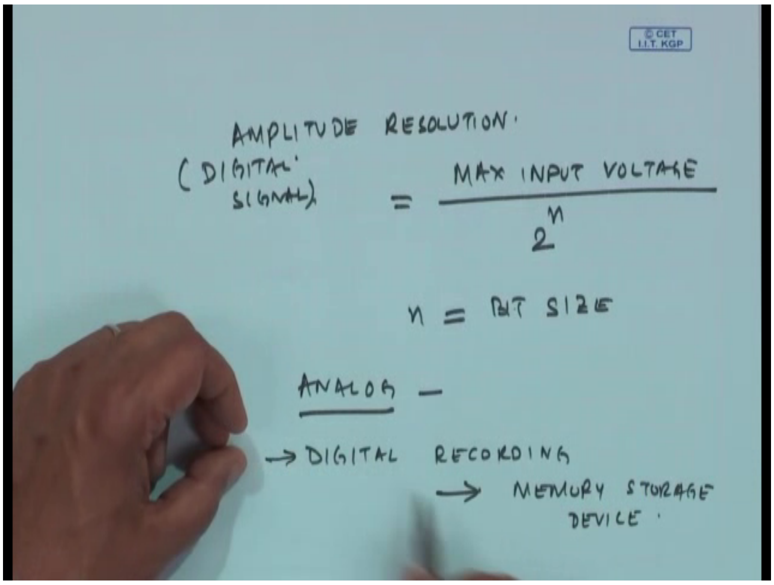

Where n is a bit size.

This is of course, for a digital signal. Now well before I come to the digital signal. So, a signal which is occurring out of a transducer is actually analog. So, I can do some analog recording. So, what are the different modes of analog recording?

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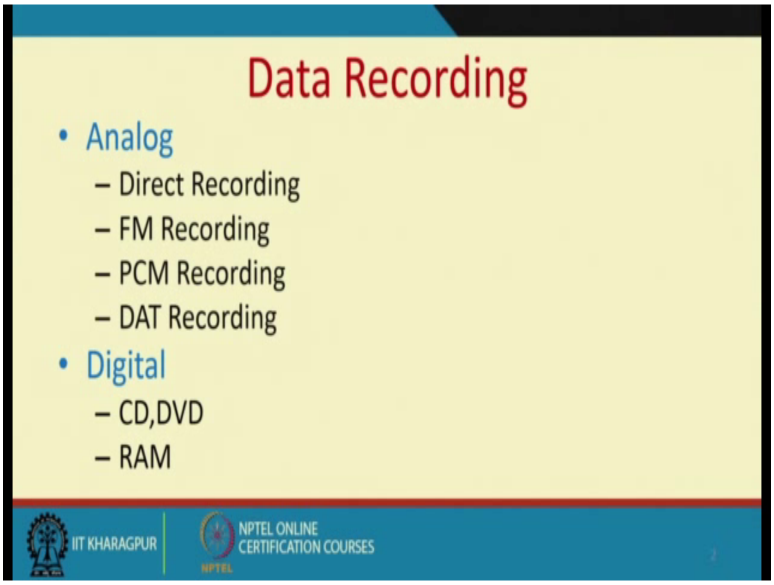

One is a direct recording or a frequency mode listen recording or a pulse code recording or a dat recording. We will see how these are done. And of course, today if you have digits. We can do them in digital recording; that means, we have nothing but a memory storage device. Even a data which you record in your pendrive, or your flash drive is actually nothing but a digital recording. But the I will throw some light into this analog recording and so on, you will recall earlier we have this tape recorders.

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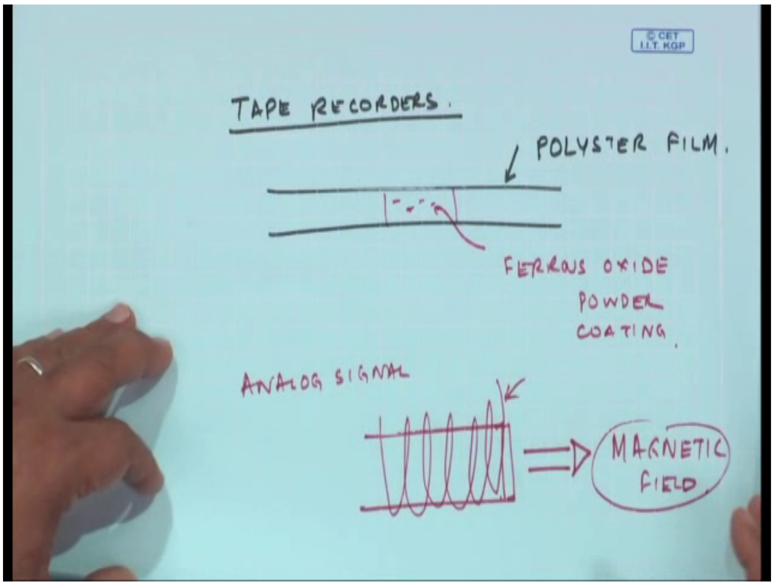

Basically, the tape is nothing but a polyester film on which it is coated with some ferrous oxide powder coating. So, if I have an analog signal given into is an iron core. This will create magnetic field, the variations in this magnetic field will be proportional to the variations in the signal. And because there is a magnetic field, the ferrous oxide will be accordingly because of their hysteresis will record this magnetic field which has happened because of an analog signal.

So, the analog tape recorder actually have 2 spools, you know.

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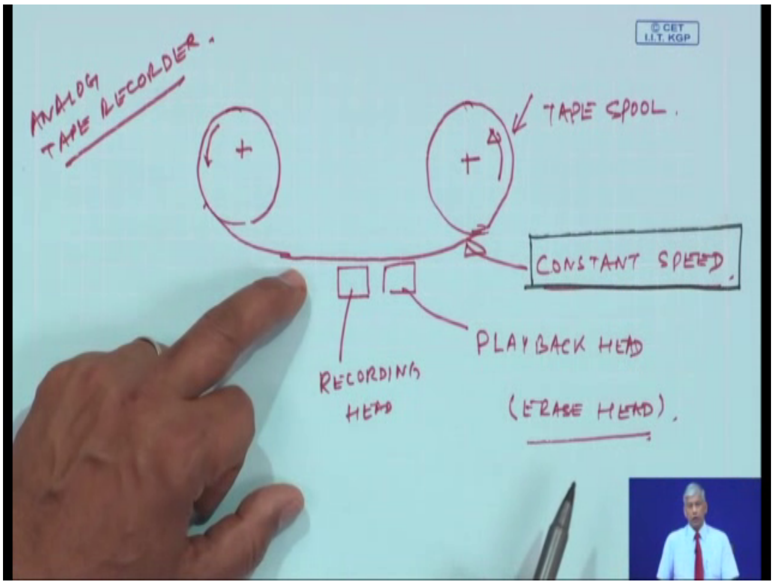

And then there is a tape, and this is what is known as that recording heard. And then you know another head could be here a playback head. In one case I am from a signal I am producing a magnetic field in another case, from this magnetic field which is there in the tape I am trying to generate the signal. So, that is what and then also there is an erase head also. So, with the strong magnetic field I can nullify whatever is stored in the tape by an erase head. And this was actually and this is the tape spool. And this is actually goes at a constant speed.

So, this is the arrangement of an analog tape recorder. Of course, which time the formats of the tape have changed. You know, we had you know the spool tapes, we have the cassette tapes and so on. And of course, you know similarly in your video recording we have the you know vhs tapes the betamax tapes etcetera, they are nothing but different formats and it depends on the speed, and imagine from the signal processing one of you if I have a high-speed phenomena which I am recording.

This tape speed also needs to be at a frequency or at a speed higher than the phenomena which I am recording. So, there were you know speeds which are possible, and then you know and of course, I want to ensure that this is constant that the speed is constant. And then of course, there are many control mechanisms you know control closer controller circuits to ensure that such tapes have constant speeds otherwise there will be variation in the signal.

In fact, there is some provision that if I have recorded a signal at a speed one in x if I play it back at 10 x I am artificially increasing the frequency 10 times.

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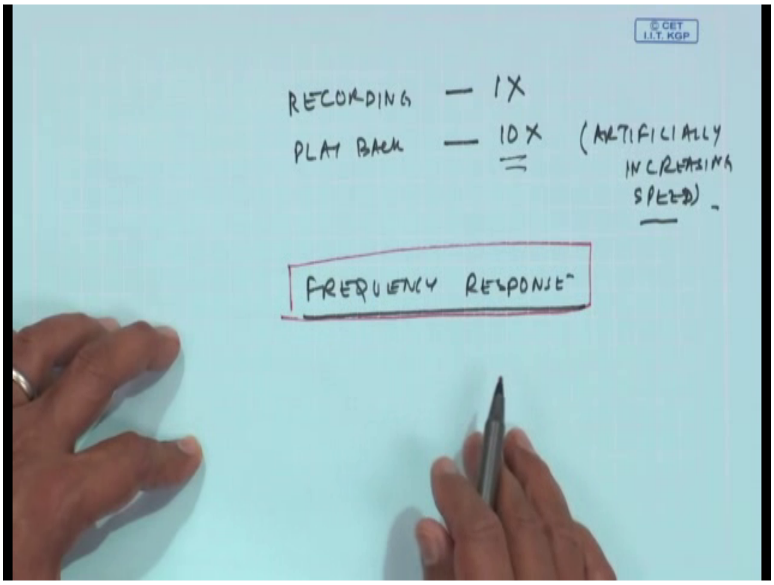

This was the earlier provisions were there in the tape recorder, because many of the analysis equipment either did not have a very loop or lower frequency response. So, they had to record at a higher speed, and played back at a recorded of speed and played back 10 times and then of course, you can do the other way also. So, you could do some amount of frequency scaling by such varying the speed between recording and playing back.

But the problem with this cassette tapes or the analog polyster tapes is their frequency response, by the way at this point I would also tell you how do you determine the frequency response of a normal tape recorder for that matter frequency response of any system. And in particular that of a tape recorder. Because that is very, very essential. Because the frequency response is an important parameter as you know. I need to have a frequency response higher than my maximum frequency of interest in the signal to have any meaningful analysis. Now this is done. For example, so, what if you have a tape recorder?

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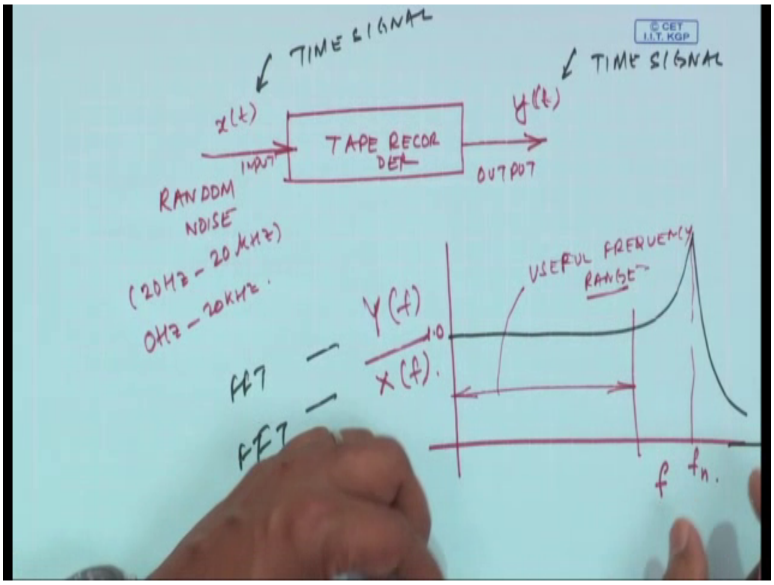

You record with an random noise; that means, for example, if you are talking about an audio frequency maybe from I mean, a though it is 20 hertz to 20 kilohertz. You it is no harm if you give a signal from 0 hertz to 20 kilo hertz. So, this is my input signal.

So, this is my x t of course, the generator random noise you need to have a random noise generator. So, if this gives a corresponding voltage. And the playback is there output and this input. So, I have a signal yt. So, what I do I just plot as a function of frequency y f by x f. So, as you know this is in this is a time signal. And this also a time signal. So, I have to simultaneously acquire both of them and do the FFT. FFT of these 2 signals and plot them. So, this may so happen that it may look like this. So, that means, this frequency and this will be actually 1. So, this is nothing but the natural frequency of the tape system. So, maybe this is my useful frequency range.

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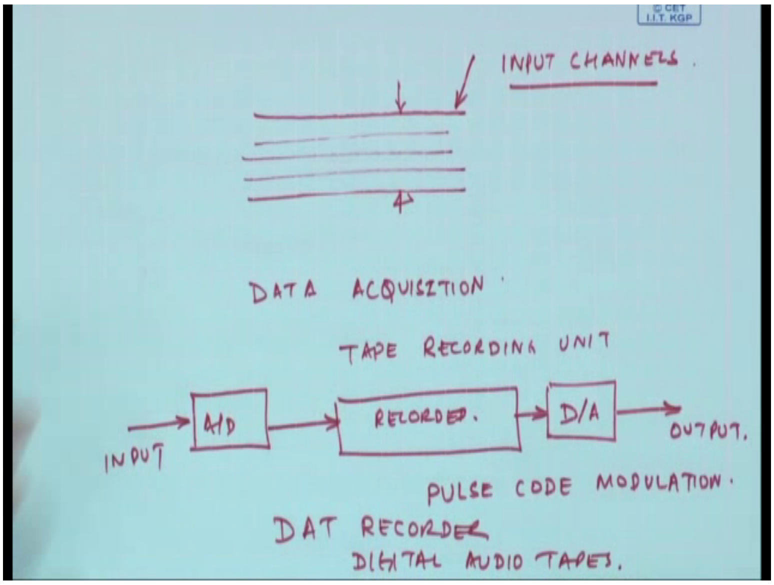

Now when I talked about the tape I did not say anything regarding. How many numbers of inputs are there in the tape. So, I could have varying input channels. So, you know maybe a 4-channel tape recorder or an 8-channel tape record. That depends on how much space you are allocating physically to such a signals in a tape of a certain width and these are standard tape widths are available. But the problem with this such analog tape recorders is. First of all there are some issues. Main is you cannot maintain a constant speed sometime because of your drive mechanism, because of a moisture or fungus contamination in the tapes they need to be stored in an environment where it is in a humidity control.

So, these are practical issues and then the which time this ferrous or ferric oxide which is coated may come off the polyester films polyester films themselves have a life. So, this gave rise to an problem with analog tapes. And then with the evaluation of technology people have slowly moved from analog to a digital recording medium.

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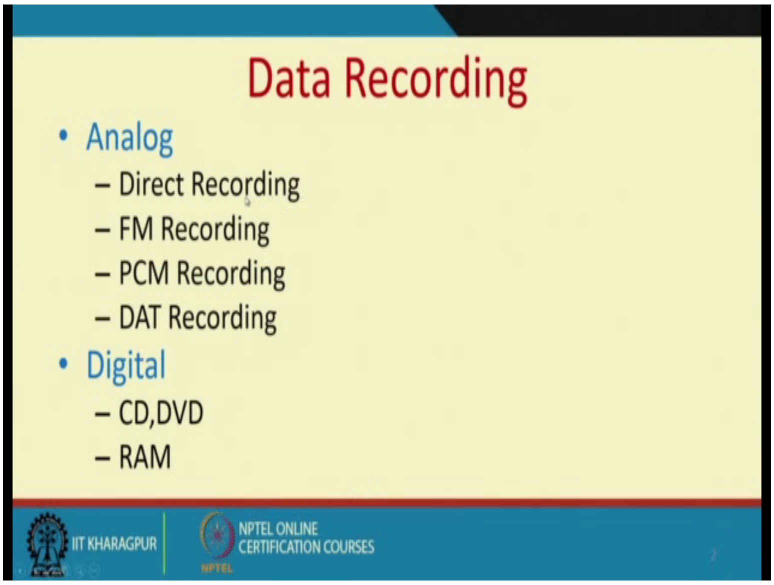

And then of course, one was a direct recording and then we had the frequency modulation recording, where the high frequency signals can be very easily recorded. It has a very low frequency response and a high frequency response as well. And then now that we know about data acquisition we can also see how this data acquisition you will help convert this analog signal to a digital signal.

So, to do that, what we could do is before the tape recording unit, I have an A to D converter. And this this digital data is recorded, you know through what is known as an PCM technique pulse code modulation. And at the output, I can have d to a digital to analog and then I will get my output signal as. So, this is my input signal. So, this is the convention of this data recorders which is known as the digital audio tapes.

So, such is also a recordings are also available. Now before I come to the digital recording let me show you what the limits of this frequency limits when you have the lower frequency limit upper frequency limit and what is the noise floor and the dynamic range and so on.

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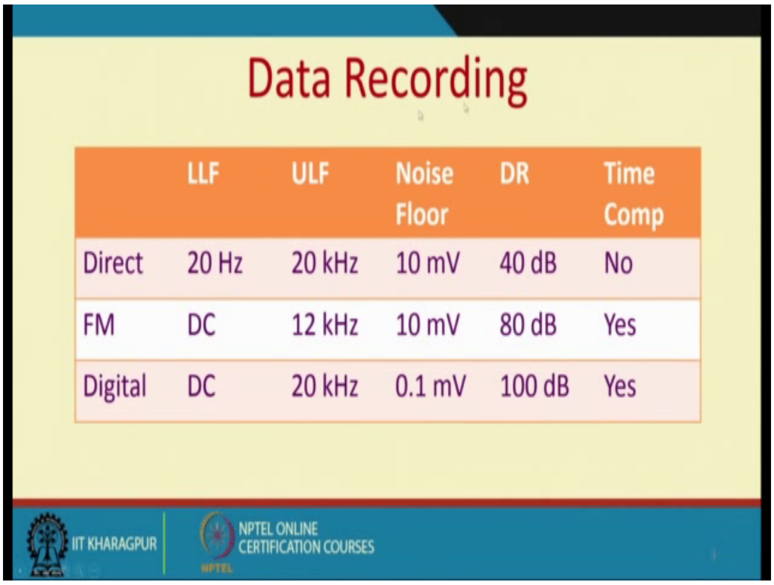
Data Recording

	LLF	ULF	Noise Floor	DR	Time Comp
Direct	20 Hz	20 kHz	10 mV	40 dB	No
FM	DC	12 kHz	10 mV	80 dB	Yes
Digital	DC	20 kHz	0.1 mV	100 dB	Yes

So, if you look at a direct recording the original cassette tape or tip it can go from 20 hertz to about 20 kilohertz. And noise floor is the minimum signal strength which it conducts sense is about 10 mini volts similarly with fm though it has a very good frequency response. The noise floor is still only 10 millivolt, a dynamic range is somewhat better than the direct recording. But if you come to digital recording of course, today the limits beyond 20 kilo hertz are also possible. The noise floor is very, very low and the dynamic range this is very, very high and if you recall again this amplitude resolution nothing but input 2 to the power m.

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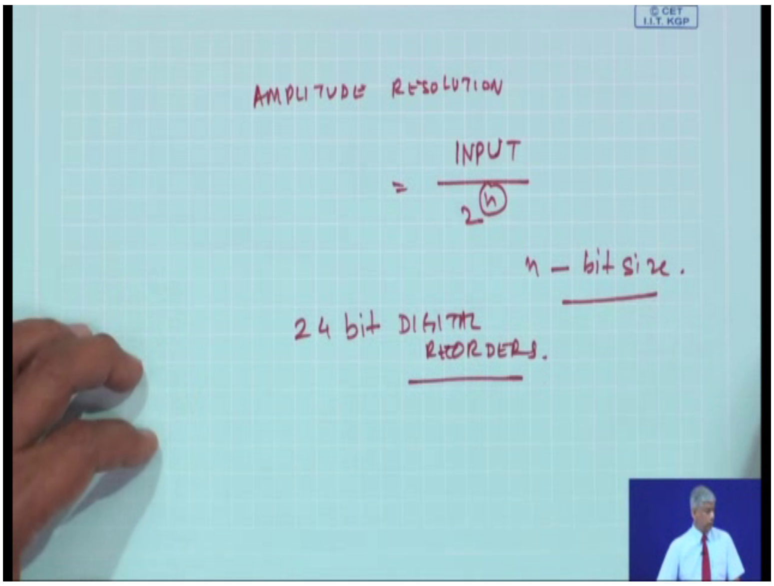

So, if I increase the bit size my dynamic range will occur. Today in the market you will have 24-bit digital recorders and so on. And, but I get the question is if today the technology is such that everybody is doing digital recording, let us find out the limits of digital recording and so on.

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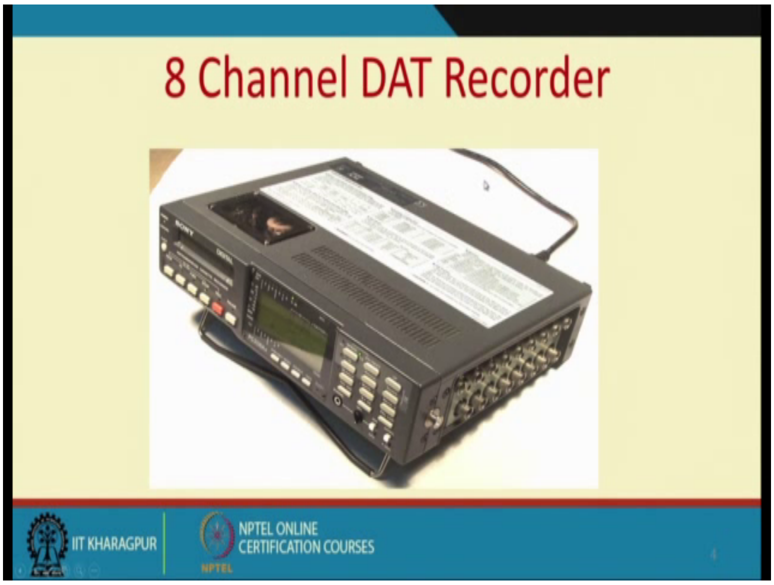

Well this is a view of an 8-channel analog that recorder. If you will see here we can have 8 analog inputs, and 8 analog outputs. Of course, the digital conversion is done inside. And by 8 channels I mean 8 inputs can be taken in simultaneously. And then it this comes with a digital audio tape.

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But the present digital recorder comes with certain modules, and this is a view of a digital recorder where there are many modules. Now when I talk about modules, let me tell you what I mean by that say when we talk about inputs from signals for CBM.

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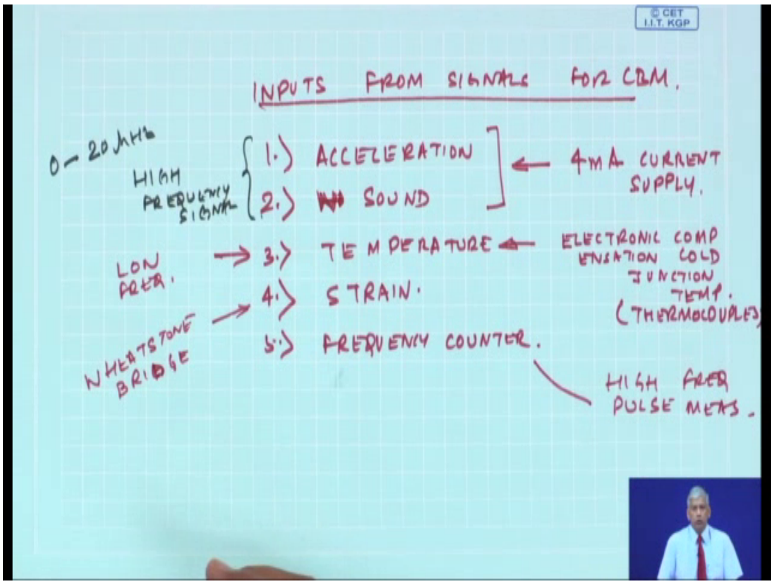

One is of course the acceleration. Another is maybe noise or you know size or sound, temperature. Then we have a strain, maybe a frequency counter. So, typically one would come across such input signals. So, we will cover about this later on, some of this sensors require a 4 milliampere current supply to drive the sensors. And as you will see these are very, very high frequency signal may be of the order of from 0 to 20 kilohertz. And of course, if should doing ultrasonics it will be low.

And this is a thermocouple some of those thermocouples require an electronic compensation for the cold junction temperature. You know there are different types of thermocouples and each one of them produces different it requires a different electronic voltage to compensate for the cold junction temperature. And depending on the type of the thermocouples I mean particularly this is for the third case of thermocouples we require such. And, but then these are low frequency signal.

Similarly, for strain gauges what will happen? I will require a wheatstone bridge wheatstone bridge arrangement. And for frequency counter there is nothing but pulse high frequency pulse measurements. So, you see I just gave you a list of generic signals which are possible in the case of CBM.

So, my data recorder which I need to have to record such varying signals also need to have features as to they can accommodate all this type of signals. Because you know when I am going to do CBM on a machine, I am not going to have one type of recorder only for accelerometers one type of recorder only for thermocouples or one type of accelerometer sorry data recorder only for you know frequency cantors. So, I need to have a varying composite inputs. So, you will see today in any of the digital recorder there are different input modules.

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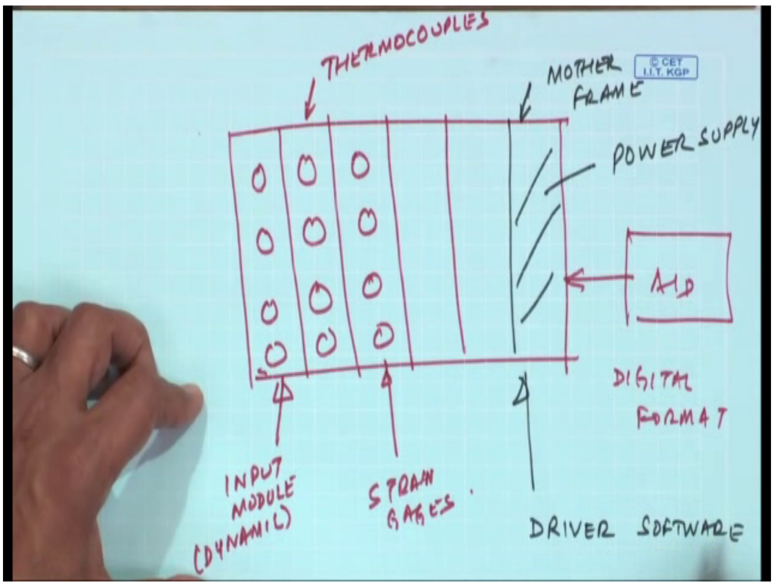

And if you look at the view of any data recorder the input model is what matters. So, input model 1 2 3 4 and there will be some connectors like this and so on. So, this is an input model. May be an input model for dynamic signals for all terms of thermocouples, for maybe strain gauges and so on. So, all of these go into their corresponding A to D, which is inside this and then they get recorded you know digital format.

So, we have a mother frame on to which we have these modules. And is mother frame there may be a power supply, which you may require to power all the units and the processors. And then this will this may have a driver software. So, that you know and then it can have a keyboard mouse USB LAN wi fi interface normal thing.

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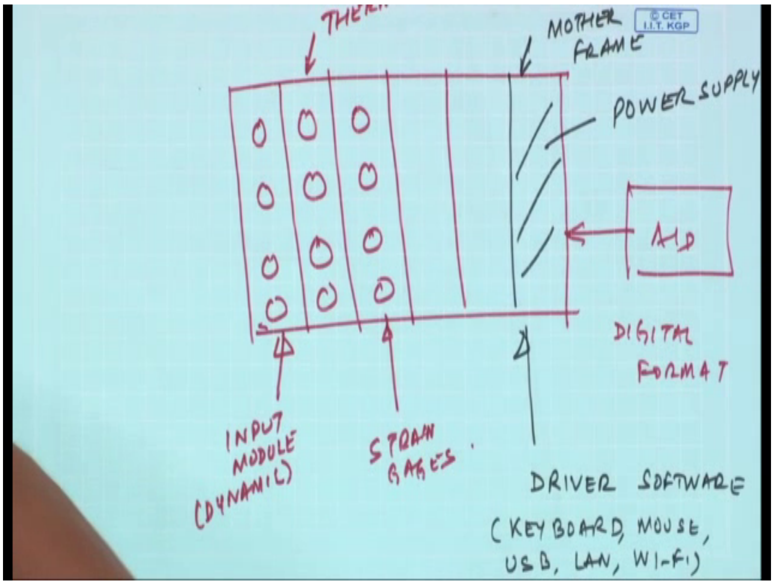

So, this is what a data recorder is and if you look here. This is one such data recorder where actually there are 16 different channels, you know one to 16 channels and I think all of them are will being used, but for one. So, I can have even if you will see here these are the input ends you know different cases of different types of signals could be used and such is the availability of a digital recorders today, which are available.

And they could be you know 16 channel 32 channel; I can stack them up from module to module. So, I can have an integrated daq system which is portable which is mobile, and I can record many signals of different type in such an unit store everything in the memory of this unit. And then I can pull it back whenever I need.

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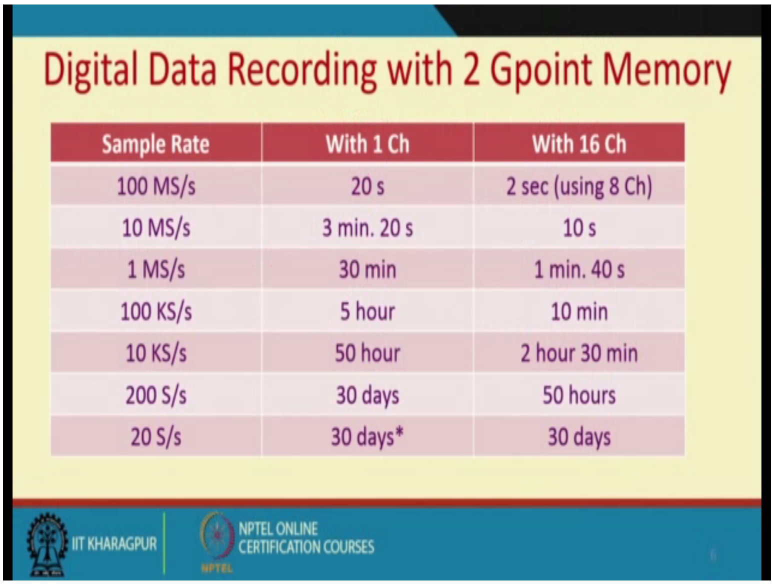

But one thing we must keep in mind is this data transmission rate.

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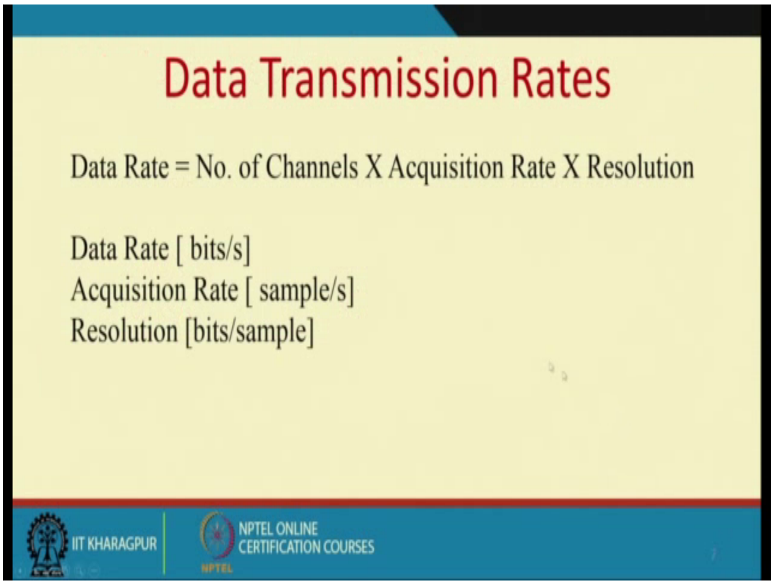

Because you recall this which we discussed during our class on data acquisition that the number of channels is nothing but the number of inputs into the system, acquisition rate is samples per second and if you recall to avoid aliassing I have to acquire these signals at a rate where the frequency is at least twice that of the maximum frequency contained in the signal. And every data requires certain bits.

So, if it is a 16-bit recorder. I will have 16 bits per sample or 2 bits per 2 bytes per sample now; that means, every digital data which is stored will require 2 bytes of memory space. And then if simultaneously I am capturing many channels, I can see what is the data rate and so on. So, if I go back to my this if my available memory is 2 giga point you will see by varying this sample rate with single channel with using 16 channel. So, you see this kind of data time will increase if my sampling rate is slow. Now you know see 20 samples per second.

So, your phenomena is happening at 10 samples per second; that means, it is a very, very slow changing signal wherever you have 100 mega samples per second. So, the sampling rate is very, very high 100 mega hertz. So, this is may be when you require ultrasonics and so on. So, this kind of size sampling rates are equal. So, it is you who decides depending on your type of signal which you have.

You know disk we will later on we will discuss about some other very, very high frequency type of signal like ultrasonics which are more than 20 kilohertz some of the you know sonars which are used in submarines, they actually you know give out signals at around 100 kilohertz. So, if you want to capture the sonar signal we have to sample. And store the data at a very, very high sampling rate.

So, these calls for such high sampling rate, we get an idea of what analog recording is and how analog recording has given way to digital recording and the present format of digital recording; is you know today we have cds dvds in a blue rays, we are nothing but the track density and storage space has increased. So, I can store in more data in a given space. And that is what is the requirement. And of course, they are becoming smaller and smaller and being digital recording now they do not lose their fidelity and we can store them for a long time.

Thank you.