Fundamentals of Acoustics
Prof. Nachiketa Tiwari
Department of Mechanical Engineering
Indian Institute of Technology, Kanpur

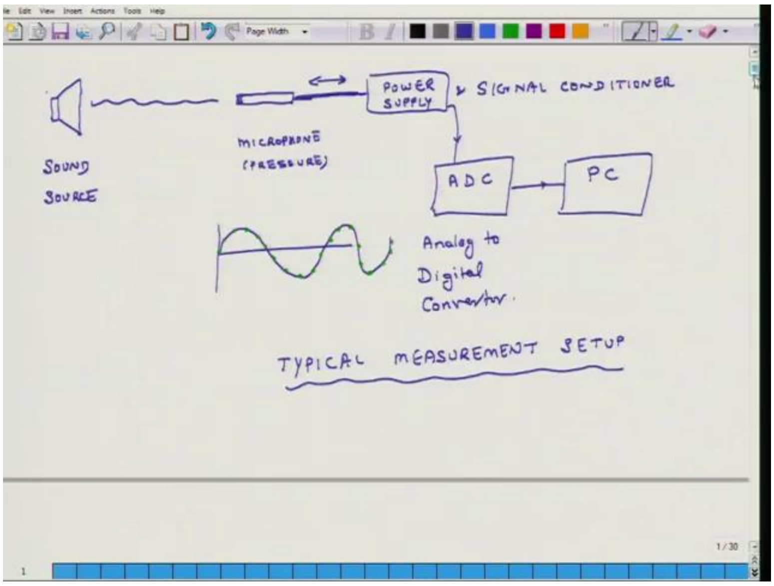
Lecture – 61
Measuring Sound Signals

Hello, welcome to Fundamentals of Acoustics. Today is the beginning of the 11th week of this course and over period of this week we will cover several important concepts as they related to application of the knowledge of acoustics in field work.

So, the first thing we will learn is how do we go around measuring sound in terms of over kind of equipment is needed, what are the important characteristics of the equipment which are as required and what are some of the important considerations which have to be kept in mind as we measure sound. The second thing we will learn is about microphones, their classification, different types of microphones and also about their sensitivity. So, that is another concept and which we will learn about and the third concept we will learn about is known as weighting and essentially it will leads to the difference between an engineering measurement of sound and the human perception of sound. So, that difference is known as weighting and we will discuss this in detail because a lot of times when we measure sound and explicit when we graphical formats, we do not necessarily explicit in terms of decibels, but rather in terms of weighted decibels known as DBA. So, we will learn the meaning of this term called DBA and finally we will develop an understanding of this term called loudness from an engineering stand point.

So, these are some of the important concepts which are required if you work in area of acoustics and your aim is to reduce or manipulate noise so that it becomes; it comes down to some acceptable levels. So, that is all we plan to cover over this week.

(Refer Slide Time: 02:23)



So, we will start with measuring sound. So, let say there is a sound source. Now, here I am making a schematic for a speaker, but it could be anything. So, this is sound source and it when it sound and let say we want to record this sound source so that once we record the sound signal, we can analyze it in detail understand it and take whatever actions we want to do.

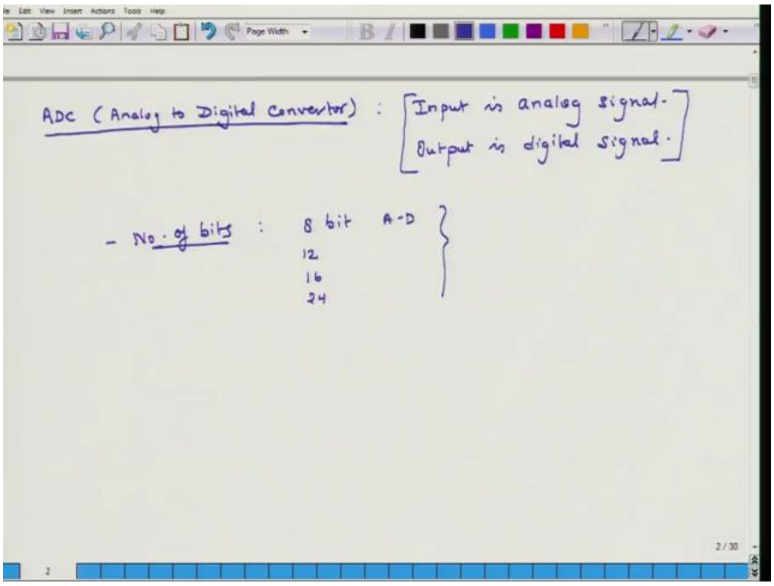
So, to record sound first we have to sense it and it is sensed by typically microphone; now these microphones can sense there are 2 different types of microphones, one category of microphones they sense pressure or pressure fluctuations in the air. So, these are known as pressure microphones and then the second category of microphones are those which measure velocity of that particle in the air. So, they are known as velocity microphones and sometimes they are also known as pressure gradient microphones, but essentially where we do in these microphones is we measure pressure, the difference of pressure between 2 points and using the Newtons law, we convert this difference in pressure into velocity. So, in context of this course we will essentially be talking about pressure microphones, this microphone which I have drawn here will measure pressure.

Now the signal from this pressure, this pressure microphone is connected through a cable to box which. So, in this cable you can have several conductors, may be one conductor is provided with the power, so that the microphone gets excited and it becomes operation and the other conductor provides information which is the signal back and so from power supply and signal conditioner, this box not only provides power supply, but it also conditions the signal coming out of the microphone and this signal goes to another device known as ADC or analog to digital converter.

So, what does this analog to digital converter to do? The input to this ADC is a continuous wave form, I may be getting signal like this, but what this analog to digital converter does not it samples this wave form or this time series signal at a particular sampling rate, so that the output from the analog to digital signal at the converter is a discretize signal, this discretize signal it then finally, can go to a PC and there we can store this discretize signal in terms of one column will be time, another column will be the values of different pressures which are recorded and this signal can later be analyzed in the way we want it to be.

So, this is a typical measurement set up, will be a typical measurement set up. Now we will talk about some of the important components of this set up in detail.

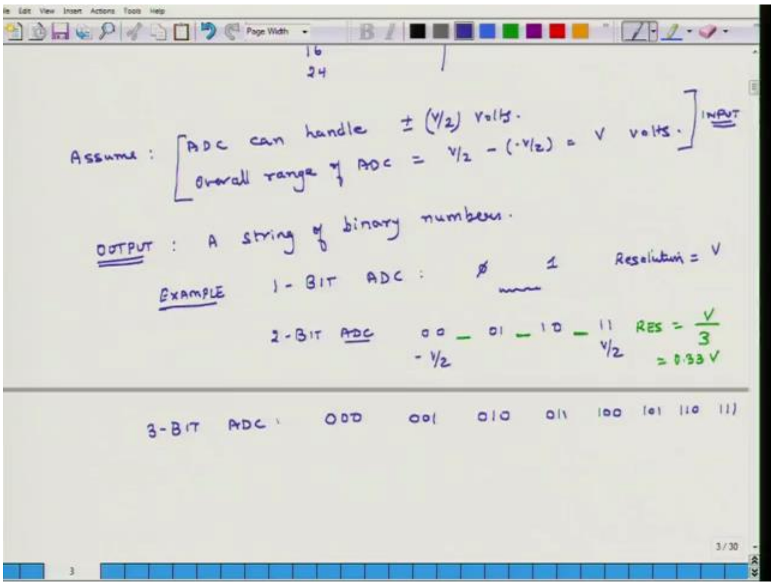
(Refer Slide Time: 07:12)



So, the first we will talk about is ADC, which is Analog to Digital Converter. So, what does it do? In this converter input is analog signal and output is digital signal; and the accuracy of this conversion from analog to digital signal depends on several parameters, but there is one important parameter it is known as number of bits. So, each analog to digital converter if you look at it is specification, it will say how many numbers of bits it uses. So, an example could be an 8 bit, A to D converter or 12 bit or 16 bit or 24 bit and so on and so forth and it is important to understand what is the meaning of this 8 bit thing.

So, we will explain that. So, let us assume that the ADC converter can handle a voltage range. So, what is going into this analog to digital converter? Is an analog voltage signal it go analog voltage signal and output is a string of numbers zeros and ones. So, let say that the input to a particular device. So, it can handle let say plus minus v over 2 volts.

(Refer Slide Time: 09:38)



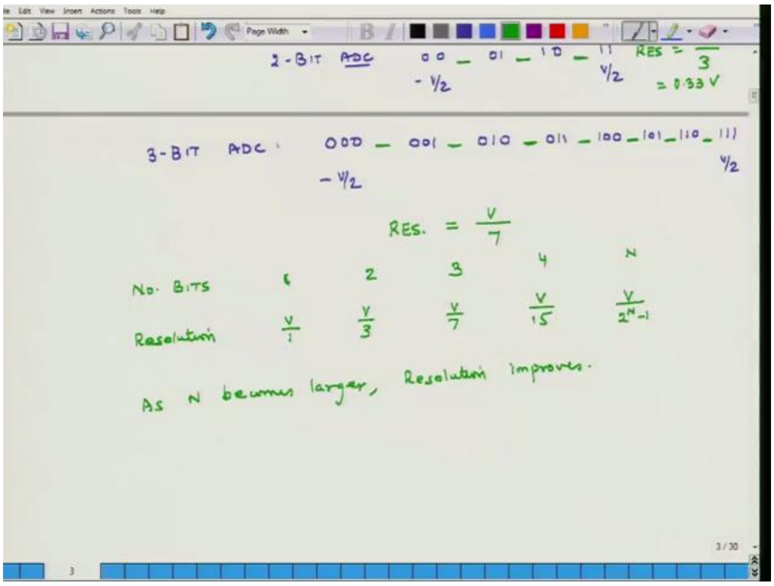
So, the overall range of ADC is what? V over 2, minus v over 2 that is v volts; so, it can handle at the max plus v over 2 and at the min v over 2 volts. So, it will overall range v volts.

So, this is on the input side. Now on the output side what does it give as an output? It gives as an output a string of binary numbers, it gives us 2 of binary numbers. So, suppose the ADC example that supposes the ADC converter is such that it is a one bit device, suppose it is a one bit ADC converter analog to digital converter then what will it give? It will give 2 possible numbers 0 and 1, in this case this entire. So, what is the entire range from 0 to 1? Captures the variation from plus v volts to minus v volts, so it is resolution; so what we can say is that suppose it gives output as 0 volts or not 0 gives it is output is 0 then let say that 0 corresponds to minus v over 2.

And suppose the output is 1 then we say then 1 means plus v over 2 then it is resolution is equal to what? V volts resolution is v volts; let us consider a 2 bit device. So, in 2 bit device it each time it produces an output it as still which has 2 digits. So, what are the 4 different possible digits? One would be 00, other one will be 01, other one could be 10, and the fourth one could be 11, these are the only four possibilities. So, I can say that 00 corresponds to minus v over 2 and 11 corresponds to v over 2, and then how many gaps are there? So, this is one gap, this is second gap, this is third gap. So, resolution is equal to over all range which is v divided by 3. So, that is 0.33 volts.

Let us we see one more example 3 bit device. So, what I say is. So, we will do 1 or 2 more examples, let say a 3 bit ADC, in this case each output will have string of digits where there will be a 3 digits in each string. So, this could be one possibility, this could be another possibility, this could be 010, 011, 100, 101, 110 and 111 in this case if I have to make some sort of a code, I will say that whenever these signal is 000 it corresponds to minus v over 2 and whenever the signal is 111 it corresponds to v over 2.

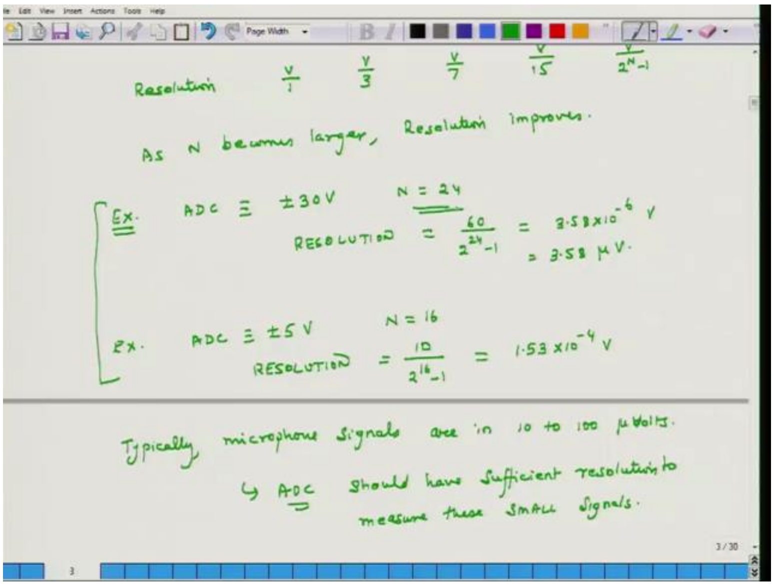
(Refer Slide Time: 14:08)



And how many gaps are there? 1, 2, 3, 4, 5, 6, 7, so our resolution is equal to what? V divided by 7, this is a pattern here. So, number of bits let say 1 bit, 2 bit, 3 bit, 4 bit and resolution is what? V over 1, v over 3, v over 7; in case of 4 it will be if you do the math and do all this type of analysis you will find the that is v over 15. So, I can make a generally and the general rule is it is; so for N bit device, it is v divided by 2 to the power of N minus 1, it is 2 to the power m v divided by 2 to the power of N minus 1.

So, what it means is that as N becomes larger, the resolution improves. So, as n becomes larger I can measure a smaller and smaller amount of signals, so, why is this important?

(Refer Slide Time: 16:11)



So, we will do 2 examples, example 1 let say an ADC device is such that it measures it can handle up to plus minus 30 volts, there is an actual example and the number of bits for it is equal to 24, then it is resolution, it is resolution is equal to what? It is plus 30 minus, minus 30 it is 60 divided by 2 to the power of 24 minus 1 and that comes out to be 3.58 times 10 to the power of minus 6 volts or 3.58 micro volts.

Another example; there could be another analog to digital converter and that measures let say plus minus 5 volts, but it is not 24 bit device, but it is just a 16 bit device, then it is resolution, it is resolution is the range is 10 volts divided by 2 to the power of 16 minus 1 and that comes out to be 1.53 into 10 to the power of minus 4 volts. Now, why is this important? This understanding is important because most of the times when we measure sound, the pressures searched by the microphones are extremely small, one atmosphere is about 10 to the power of 5 pascals and we may be measuring pressures as low as 10 to the power of minus 4, 10 to the power of minus 3 pascals.

And lot of this microphones when these as pressure at low pressures, they converted it into voltage signals, where the voltage signal may be extremely small it may be not milli volts, but it may be 10 milli volts hundred milli volts or I am sorry 10 micro volts hundred micro volts or micro volt. So, typically microphone signals microphone signals are in 10 to 100 micro volts.

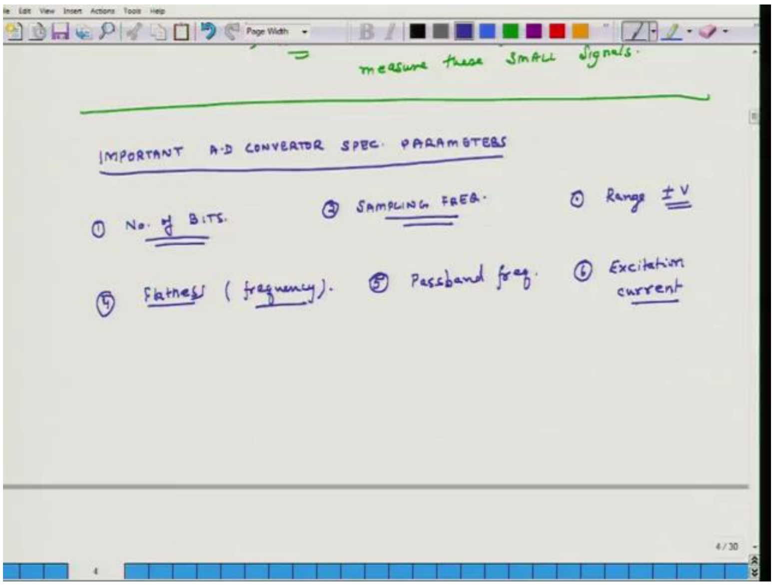
Student: (Refer Time: 18:58).

10 to 100 micro volts; these are the minimum numbers on that maximum side it could be higher. So, our ADC device should have sufficient resolution to measure these small signals. So, if you think that the minimum signal amplitude will be something like 100 microphones; 100 micro volts then it will be good to have measure device which can measure at least 10 times less than that.

So, it is resolution should be at least 10 micro volts or even lesser. So, in that context if this ADC number of bits is not sufficiently large it may not even sense any will to signal and all we will get even though we have a microphone which is measuring when the analog to digital converter converts it in to digital data it will be just sending 0 0 0 0 0 for all the signals if it does not have sufficient number of bits. So, this is a very important consideration when you are taking measurements you should have some idea as to what is the amplitude of the signals and using those and for those signals what kind of bit rate is important. So, that is one thing.

The other 2 important parameters for A to D converter are its sampling frequency and also its range.

(Refer Slide Time: 20:51)



So, important A to D converter specification parameters; first thing we had discussed is number of bits this we have already discussed; the second thing is sampling frequency, sampling frequency we have discussed it in the last week that if I am sampling my data add some frequency f s, then when I (Refer Time: 21:48) that data or do a furrier transform of the data, the maximum possible frequency which I will get will be half of the sampling frequency. So, if you want information on 20000 hertz frequency from my data, then I should sample it at least at a frequency more than 40000 hertz and so and so on and so forth.

So, as we are deciding on an analog to digital converter, we have to make sure that the A to D converter not only as sufficient number of bits, but it also has sufficiently high sampling frequency if it as 100000 hertz or 100 kilo samples per second, then I will get information up to 50 kilo hertz at the maximum. So, that is another important feature. The third important parameter is range; it can measure up to v max right up to what is the range in terms of volts or currents or whatever. So, this is another important because the overall resolution of the system is what? Range divided by 2 to the power of n minus 1.

Fourth important parameter is flatness, what does flatness? In terms of frequency; what does it mean? It means is that if I send, if the noise source is having let say 100 hertz tone. So, there will be some signal in the microphone and it will go to A to D converter. So, the sensitivity of the A to D converter should not change whether it is at 100 hertz or

2000 hertz or 20000 hertz. So, whatever is our operational area of interest in that area the sensitivity of A to D converter should not change it should remain same. So, that is another thing.

So, these are some of the important parameters and then of course, there are some other important parameters, but the first four are really important. So, the other is pass band frequency and what this tells us that what is the range of frequencies in which this device is going to work and finally, does the A to D converter provide us with excitation current or not and I will discuss this parameter later, that it is important to just write in down at this stage. So, that concludes the discussion for today in context of A to D converters, tomorrow we will discuss about microphones in detail and what it means to have a good microphone. So, with that we will conclude the discussion for day and we will meet tomorrow at the same time.

Thank you, bye.