Fundamentals of Acoustics
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Lecture – 62
Microphones

Hello. Welcome to Fundamentals of Acoustics, today is the second day of the eleventh week of this course. And what we plan to do today and may be tomorrow as well is detailed discussion on microphones; there different types, there different applications, and how do we go around specifying a microphone. So, the theme of the discussion is microphones.

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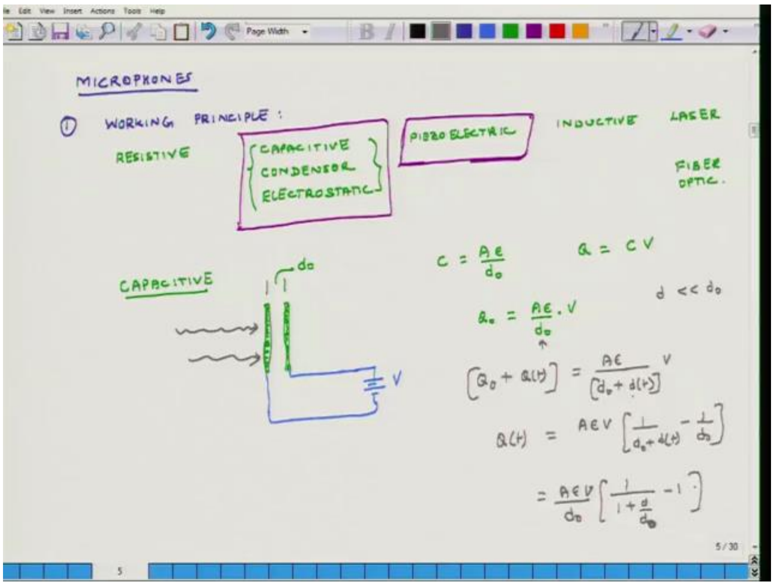

And we can classify microphones in several ways. So, today we will classify microphones in two ways. So, the first way is classification according to the Work in Principle. So, in terms of working principle a several types of microphones, so one category is resistive microphones. And the second category comes in different names so they are called capacitive microphones, sometimes their also called condenser microphones, and them sometimes they are also called electrostatic microphones. So, this is like one set of names. Then we have piezoelectric microphones. Then we can have inductive microphones, then we can have microphones based on laser and there is no space here, but another category is fibre optic microphones.

Most of the times when we take measurements we use either this category of microphones or piezoelectric microphones for doing and (Refer Time: 02:38) measurements. You can learn about these other categories resistive inductive laser fibre optic from references and from the net, but what we are going to discuss somewhat in detail is how these microphones where and how are they is specified. So, this capacity microphone works from the principle of sensing capacitance between two plates. So, what happens? In the capacity microphone essentially what you have is are two plates and they are separated by some distance let say d naught.

Then the capacitance between initial capacitance between these two plates is what, area of the plates times permittivity constant divided by d naught; this is the standard formula. So, let say these are the two plates and I put a charge on these two plates by connecting them to a battery. So, let say apply a voltage V; so this is essentially gives to plates at as a capacitor and when I apply a voltage across it then there is a charge which gets developed across these two plates, and the value of this charge is Q. And what is this Q? Q is equal to C times V capacitance times voltage. So, let say that initially the charge is Q naught and that equals A epsilon over d naught times V.

Now, when some sound wave hits this plate; so one plate is fixed the other plate is flexible it is like a dia form. So, when sound wave hits this other plate this other plate which as dia from it moves back and forth based on the pressure. So, this d naught is the initially distance this changes, so because of this there is Q naught plus some additional charge let us call this Q t, this is their and that is because of d naught plus change in the distance between these two plates, so let us call that dt. And this change is very small compared to d naught its very small compare to d naught times V. So Q t on, because this change is very small; so is Q t Q is also very small.

So, this is equal to A epsilon V 1 over d naught plus d t minus 1 over d naught. And this equals A epsilon V divided by d naught 1 over 1 plus d, so now just start going to write d t this d over d naught minus 1.

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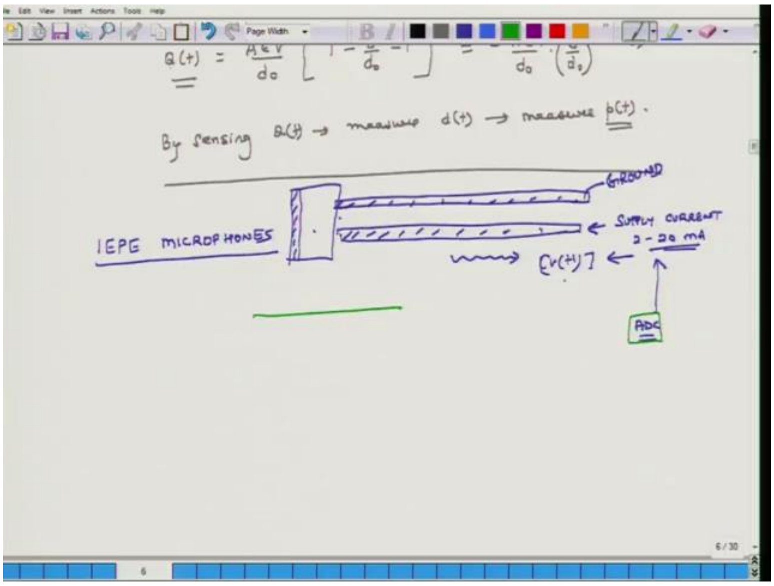

So Q t equals A epsilon V over d naught, and d over d naught is a very small number. I can take its approximation, so it is 1 minus d over d naught minus 1. So this entire term if I take its binomial expression expansion and only if consider the first term I get this thing. So, this becomes A epsilon over d naught V times d over d naught, and this d is a function of time it is actually and of course there is a negative sin there.

The point is that if I can measure this change in Q change. So what is Q? Q is the change in charge, if I can measure this change and charge then I can relate that change in charge to d and this d then can be finally related to the pressure, because if I have double the pressure then d will be double and so on and so forth. So, based on that by sensing Q I can measure d t and from that I can measure p t. So, essentially what I am doing is I use some electronic equipment to measure the charge across these two plates, and by measuring the charge I am able to measure pressure across the capacitor; I am able to measure pressure fluctuation in front of the plate.

So, this is how these condenser microphones work. In piezoelectric what happens is, that you have a piezoelectric crystal and you apply some initial voltage across the piezoelectric crystal so they are little bit compressed because of that, and then when some pressure hits the piezoelectric crystal; the working principle is that when you press piezoelectric crystal or expand it there is some additional voltage generated. So that change in voltages sensed and with that change in voltage you interpret that in terms of pressure.

So, this is how these two devices work. But in both of these two devices what you want is a voltage source here; in case of capacitive sensors or in piezoelectric sensors also you need some excitation voltage. So, now you can provide this excitation voltage in two ways.

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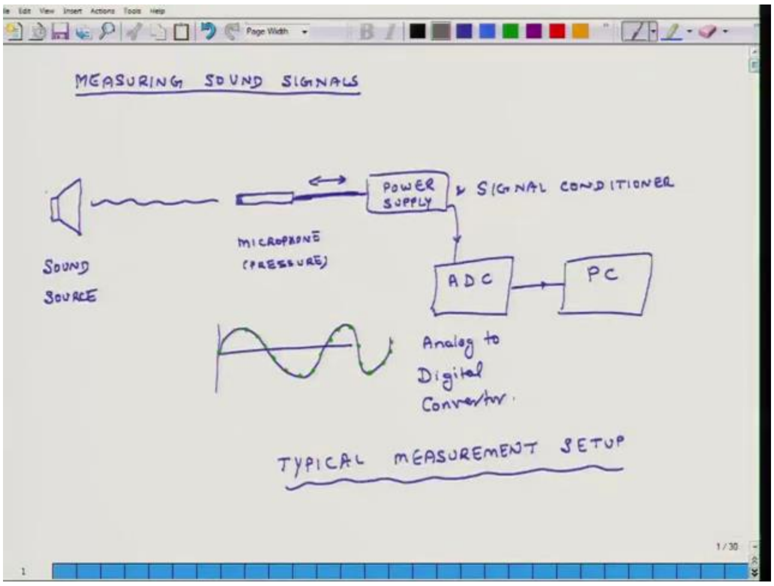

Either you have a power supply, an explicit power supply which excites which provides this excitation voltage. In this power supply there may be two sets of cables; one set of cable is there to provide this excitation voltage, and the other cable is there to sense the signal. But now, there are some special microphones and these microphones are known as IEPE microphones. IEPE as an industries standard protocol and then these microphones what you do is you had just one conductor, and of course there is a ground so there are two conductors. And these two are connected to the microphone, now there may be a pre and between the microphones in the conductor.

So this is your ground, and through this conductor which is the lie wire which is; so this cable I have just drawn it in a schematic wave but in reality a lot of time this cable is a buoyancy cable. So, in the centre there is a copper conductor and outside there is a ground. Through this conductor the signal travels in this direction in terms of voltage. So this is the voltage which we want to cells, and then you excite the system which could be a capacitive sensor or a piezoelectric sensor by putting in some supply current. And this is typically in between 2 to 20 mille amperes. This supply current for IEPE microphones is provided by the ADC itself. So, sometimes you can by ADC is which not only sense the signal, but they also supply the current to the sensor.

So, if that is the case then you do not necessarily need this thing right; you do not necessarily need this thing you can directly connect this to this. So, your overall system becomes simpler. So, a lot of times; so if you have and a to d converter which can provide the supply current in this 2 to 20 mille amperes and if you have a sensor which is IEPE type then you do not need is power supply. You can get read of the power supply, your cabling is also simpler because here in the conventional way you need 7 different cables, but here you just need one single buoyancy cable to connect it. So, this is become more popular these IEPE type of microphones.

But, it depend what kind of microphone meet your needs and if amongst that IEPE type of microphone is there and you also have an ADC which can provide the supply current then that will make your system simpler. So, this is something about microphones. The other thing I want to talk about microphones is their sensitivity.

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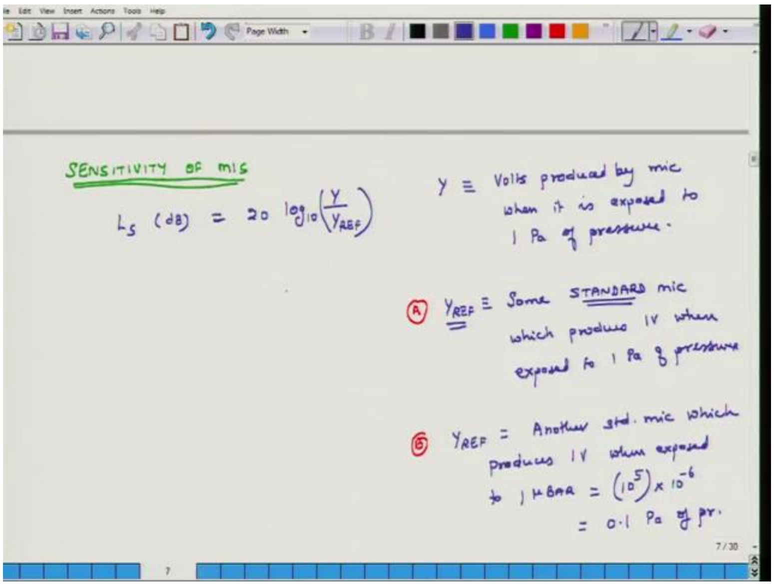

Sensitivity of MIC's; so first we will develop a write the expression for sensitivity and then we will discuss it. So, he designates the sensitivity of microphone as L S and any its units are decibels. So, sensitivity of a microphone in decibels is defined as 20 log of 10 y divided by y ref. So what is y? Y it corresponds to volts produce by mic when it is exposed to 1 pascal of pressure.

So, if I exposed a microphone to 1 pascal of pressure and its say produces 2 volts then y will be 2. Then there is a reference value of y, and what does this mean? It y ref you corresponds to some imaginary mic, some mic and we will call it some standard mic which produces 1 volts when exposed to 1 pascal of pressure. This is 1 value of y ref, but there are in the industry there are two type reference situations. So, this is case A.

So, there could be one type of a standard mic which produces 1 volt when it is exposed to 1 pascal pressure, but then there could be case B where why ref is equal to another standard mic. So, there are two different standards we are using, another standard mic which produces 1 volt when exposed to 1 micro bar, and what is 1 micro bar? So, 1 bar is how many pascals? 10 to the power of 5 pascals is 1 bar and 1 micro bar is 10 to the power of minus 6; so that is equal to 0.1 pascals of pressure.

So, whenever some supplier or some vendor gives us the sensitivity of the mic he will say- oh sensitivity is in decibels, let us say he say sensitivity is minus 20 decibels but then the immediate question is that, what is your reference? Is this reference of type A or is it of type B? So, this is important to know. So, we will just do two examples so that we become clearer on this thing.

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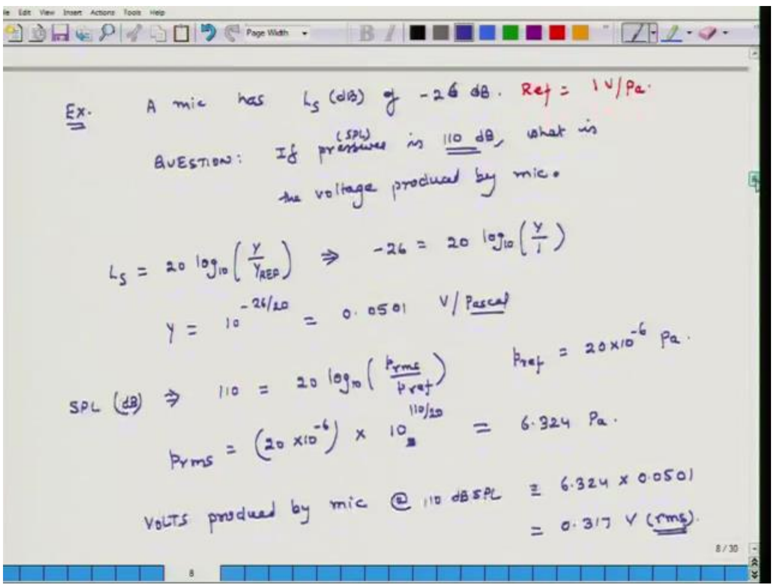

So example: let say that there is a mic, mic has sensitivity and sensitivity is designated as L S, as L S in decibels of minus 26 dB. And then we are saying that reference is equal to 1 volt per pascal, so in that case it is of type A. So the question is, if pressure is 110 decibels what is the voltage.

Student: Pressure is.

Pressure is sound pressure level is 110 decibels, so this is SPL. So, if pressure is 110 decibels then what is a voltage produce by mic. So, the first thing we have to compute is how many volts is produced by the mic when it is produced by when it is exposed to 1 pascal; that is the first step is we have to find this value of y. So, we will do this. So, L S is equal to 20 log of 10 y by y ref, so this gives us what is L S minus 26 equals 20 log of 10 y; and what is y ref, 1. So, this gives us y equals 10 to the power of minus 26 divided by 20 that is equal to 0.0501. And this is what, volts per pascal. Why is it pascal, it is not microbar it is pascal because are reference is 1 pascal because it is the type A.

So, if I expose it to 1 pascal of pressure it will generate 0.05 volts. Now we want to see how many pascals 110 decibels correspond to. So, sound pressure level dB; so this is 110 equals 20 log 10 p rms by p ref. And what is p ref? 20 times 10 to the power of minus 6 pascals. So, p rms equals 20 times 10 to the power of minus 6 times 10 to the power of 110 by 20, understood. So, if you do the math this comes to 6.324 pascals, and this is the rms value. So, volts produced by mic at 110 dB SPL are equal to what, how may volts it is 6.324 times 0.0501 and that comes to 0.317 volts.

Is this peak volt or rms? Volt, this is rms volt. If you have to find peak volt we have to find the ratio of the peak and the rms. So this is one example. And in this example what we have done is we have computed volts produce by this mic which has a 26 decibels (Refer Time: 23:19) if the standard mic is producing 1 volt per pascal.

In the next class we will start our lecture by discussing the other type of mic and see that it produces a different number of volts. So that concludes our discussion for today, and I look forward to seeing you tomorrow. Bye.