NOISE CONTROL IN MECHANICAL SYSTEMS

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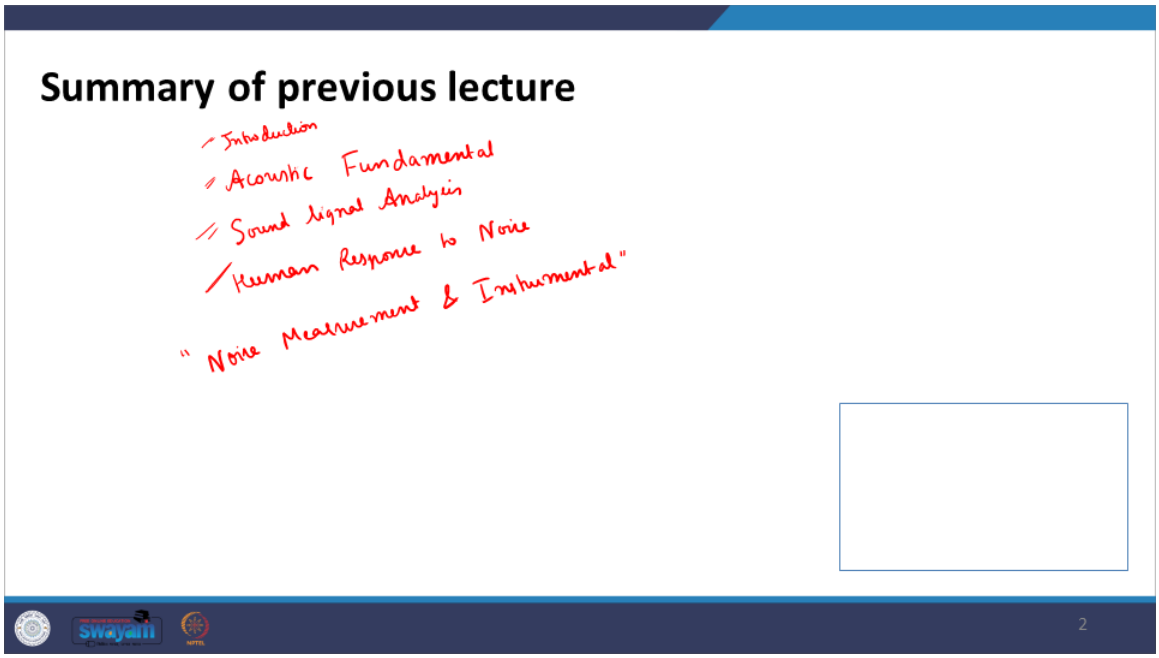
Week: 05

Lecture: 24

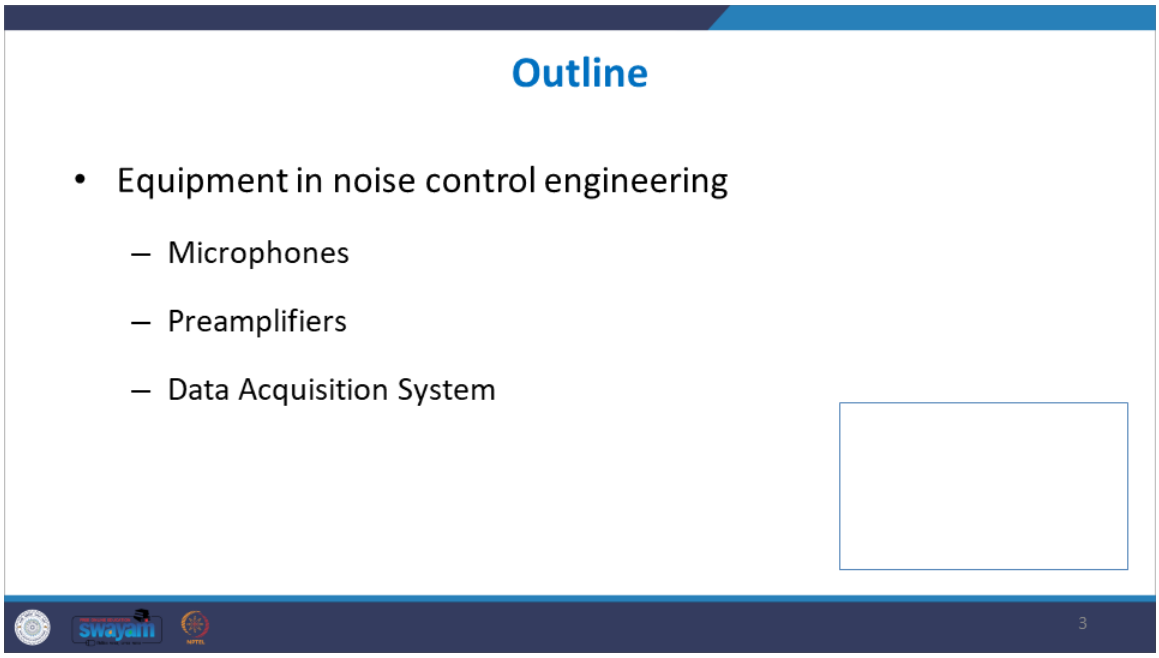
Lecture 24: Equipment for noise control engineering: 1

Hello and welcome to lecture number 24 in the course on noise control in mechanical systems. I am Professor Sneha Singh from IIT Roorkee. So, we have covered various things in this course so far. We began with an introduction to this course, noise, and sound in general. Then we covered acoustic fundamentals because, for entering into the

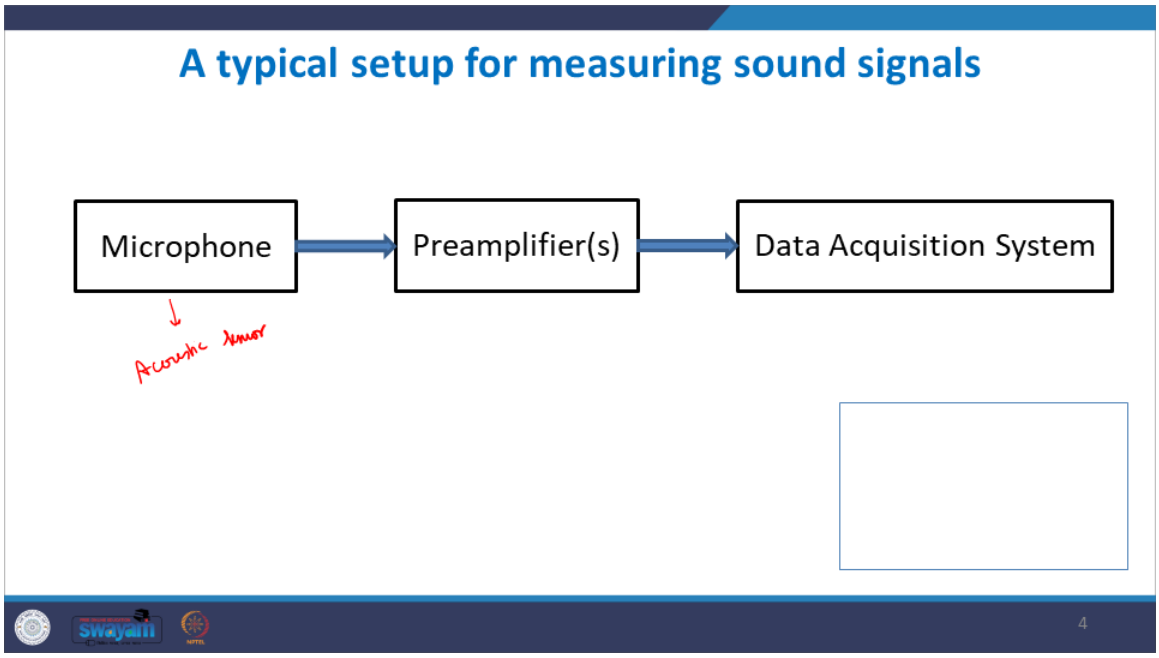
field of noise control, the fundamentals of acoustics are definitely required. Then we studied some of the ways in which sound, as a signal, is analyzed for noise monitoring. Then we studied the human response to noise. Because, the very basis of noise control is that it is harmful to human beings, and humans want to control the noise. So, what is the response of a human being to noise or the sound signal? That was also studied. And so far, we have covered these key modules. Now we will begin a new module on, noise measurement and instrumentation. So, before we explore the key principles and methods for noise control and some case studies, we need to understand what instrumentation to use and what measurement techniques are available for noise control engineering.



So, the title of this lecture is obviously Equipment for Noise Control Engineering Part 1. So, we will study the basic equipment, which includes microphones, preamplifiers, and data acquisition systems in this course in this particular lecture.



So, let us see a typical setup for measuring sound signals. So, nowadays we have various kinds of advanced, complicated, sophisticated, and compact devices that are coming up to measure sound and display the information in the form of some signal. So, basically, a device is able to measure sound and display it in some form of signal and some kind of readable values. But traditionally, you know, be it any kind of device, essentially it is made up of three sorts of components. Whenever sound signals are measured, we have a microphone, which is, you know, the main acoustic sensor that we use, that senses the pressure and converts it into acoustical signals. Then we have preamplifiers because, as you know, sound acoustic pressure is a very small value compared to atmospheric pressure. These are very minor fluctuations which are perceived as very loud by human beings. So, whatever signals that are acquired are weak in nature and need to be amplified to come up to a readable value, so some pre-amplification is needed. Then we have a data acquisition system which connects all these together, and finally, data is acquired and stored in a readable format. So, let's see these devices one by one.



So, microphone, what is it? It's a type of acoustic transducer or sensor. So, what do you mean by transducer? It is any device that converts one form of energy into another form. So, acoustic transducer, what do they do? They convert sound energy from sound energy to some other form of energy and then some other form of energy back to sound energy. So, these kinds of conversions they can do. So, a microphone is one such device. It is an acoustic-to-electrical transducer. It converts the sound energy that is incident on it into electrical energy. Okay, so you can see various kinds of microphones. This is a typical mic which you must have seen in various kinds of events where the host is using a mic. What is it doing? It's amplifying the sound so that the audience can hear it louder.

Microphone

device that converts one form of energy into another form of energy

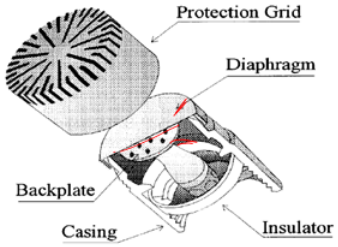
- Microphone is a type of acoustic transducer or sensor.
- A microphone is an acoustic-to-electrical transducer that converts sound energy incident on it into electrical energy.

Source: Google image

So, what are the basic components of a microphone? You know, you have the protection grid because the things inside the microphone are very sensitive. They have to, you know, they should be able to sense these small and very minute variations in the acoustic pressure in the fluid medium. So, these extremely small fluctuations, they should be able to sense. So, they are very sensitive devices. So, everything has to be protected. So, a protection grid is used. And behind that, we have a diaphragm, which is the main device of a microphone, and we have a back plate, the casing, and the insulator.

Basic Components of Microphones

- The basic components of microphones includes:
- **Protection grid**: Protects the microphone diaphragm and makes final adjustment of the frequency response.



Source: Interactions of Flow Field and Combustion Characteristics in a Swirl Stabilized Burner September 2011
DOI: 10.14279/depositonce-2964

So, what does the diaphragm do? It is a kind of membrane that is suspended around its edges, a kind of membrane or sheet. So, whenever sound is incident, it vibrates the membranes and the diaphragm; then the vibrations of the diaphragm Whatever is created is proportional to the incident sound pressure, and this acts as one plate of the capacitor. So here, you know, there are different techniques of converting sound to electrical energy. One such technique is the use of a capacitor microphone, where the diaphragm And the back plate is one part of the capacitor; this is another part of the capacitor, and the amount of electrical charge or the amount of voltage that is stored in the capacitor depends on the spacing between the plates of the capacitor. And as the diaphragm vibrates, one plate is fixed, the other one is vibrating, and the spacing keeps continuously changing. So, there is a change in the voltage, which is then converted into, you know, if you have a circuit that completes this, then you get an electric current, and here the value of the electric current is going to be proportional to the sound pressure that is incident on the diaphragm. Then you have the casing, which encloses the entire body, and some insulation is also provided because, you know, it is a sensitive device that needs to be protected from unwanted noise, ambient wind, weather conditions, and various other reflections from unknown devices.

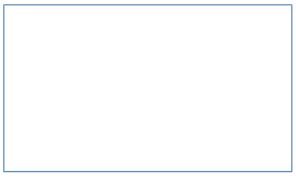
Basic Components of Microphones

- **Diaphragm**: A membrane or sheet suspended at its edges. Converts sound energy to the diaphragm vibrations, where vibrations are proportional to the incident sound pressure. Acts as one plate of capacitor.

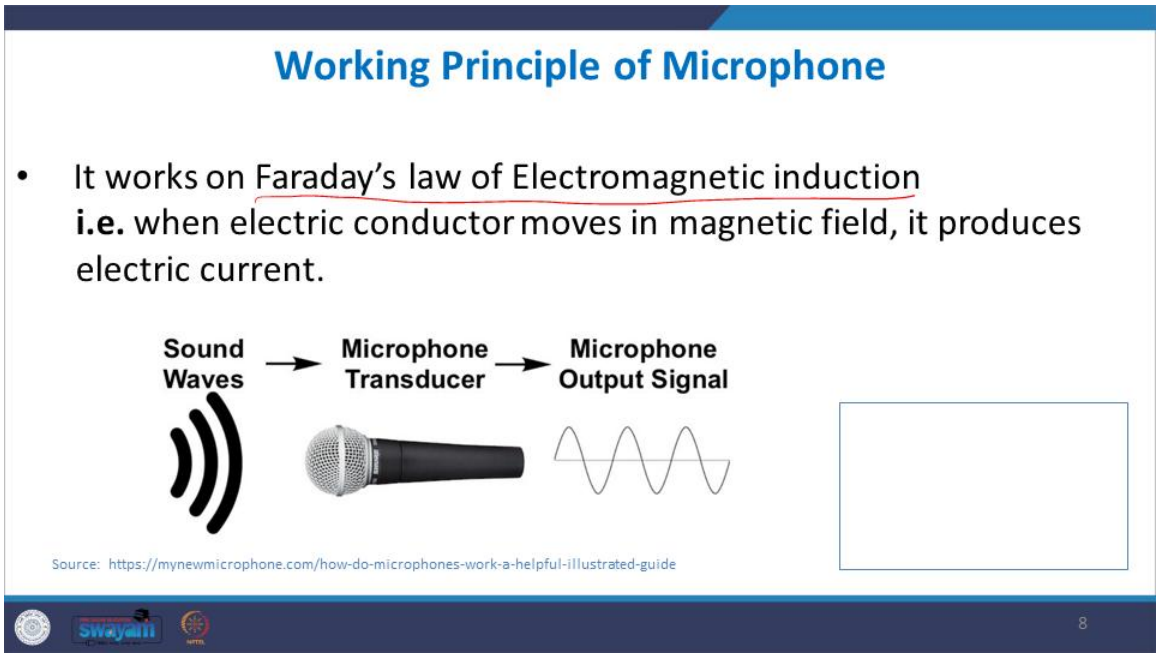
- **Backplate**: Acts as other plate of capacitor. Stays in place so that as variations in air pressure move the diaphragm closer or farther from the backplate, the voltage varies.

- **Casing**: Encloses the microphone.

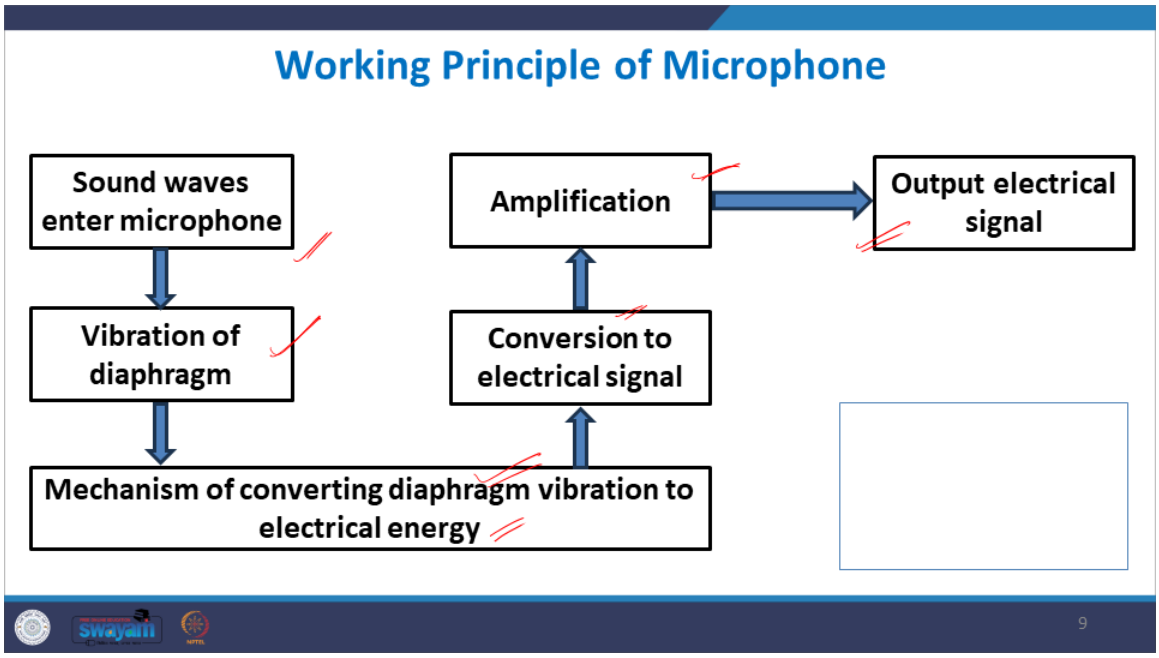
- **Insulator**: Reduces unwanted noise, ambience, and sound wave reflection.



So, what is the working principle of a microphone? Essentially, you know, most microphones work on Faraday's law of electromagnetic induction. So, what happens is that, you know, the diaphragm or there is some kind of element—basically, you can see now there are so many microphones that are coming up, but if I have to explain it in a very simplistic way, what happens in literally every microphone is that you have some kind of element that vibrates in proportion to the incident sound energy. It could be a diaphragm that is like a thin membrane, you know, suspended around its edges. For example, imagine a drum, you know. So, when you play the drum, the membrane of the drum vibrates. In the same way, you know, the sound wave is incident on it, and the membrane vibrates. So, you have some element that vibrates in response to the acoustic pressure that is incident on it, and those vibrations are then converted into electrical current through some mechanism.



So, essentially, for every kind of microphone, what happens is that sound waves enter the microphone, they hit the diaphragm or the thin membrane, which is very sensitive to acoustic pressure. Based on the amount of acoustic pressure applied to that membrane, vibrations take place, whose amplitude is proportional to the amplitude of the acoustic pressure. So, the value of the vibration would definitely correspond to the value of the acoustic pressure. Then, you have some mechanism for converting these vibrations into electrical energy. What is that mechanism? It depends on the microphone. We have various kinds of microphones. Each of them uses some different mechanism to convert these vibrations into electrical energy. Then, from that, the conversion to an electrical signal happens. Then, amplification happens, and finally, we get the output electrical signal.



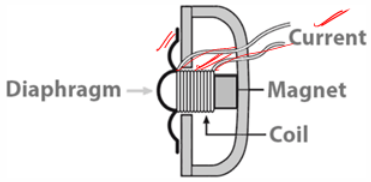
So, let us see some of the types of microphones that are used. The first one is the dynamic microphone. It works on the principle of electromagnetic induction. So, while the rest of the components remain the same, the difference is what I am illustrating here. So, here you have a diaphragm which is, you know, which is surrounded by, you know, a coil. So, this coil acts like a solenoid and it works on the principle of electromagnetic induction, and there is a magnet that is placed. So, whenever the diaphragm is moving, it sort of acts like, you know, moving, you know, it is. So, you know, what is the principle of electromagnetic induction? When you, you know, move a conductor in a magnetic field, it creates electricity. So, here the diaphragm becomes a conductor, and when it vibrates, it is moving in this magnetic field created by this coil, or, you know, And then, you know, whatever happens, you have the wire circuits. So, the current is generated by this mechanism.

Types of Microphone

- The three main types of microphones, commonly used in various applications are:

1. **Dynamic Microphone:**
- **Principle:** Uses electromagnetic induction.

- **Components:** Diaphragm, coil of wire, and a magnet.



Source: https://www.teachmeaudio.com/recording/microphones/dynamic-microphone

Then, with the dynamic microphones, what are some of the features? They are more durable and robust in nature, and they are capable of handling very high sound pressure levels. So, they are usually used for, you know, live performances, vocals, and instruments like drums and guitar amplifiers. So, wherever you know you have to deal with loud noise, high-frequency noise, they are less sensitive to such high frequencies, which makes them very ideal for such loud sound sources.

1. **Dynamic Microphone:**

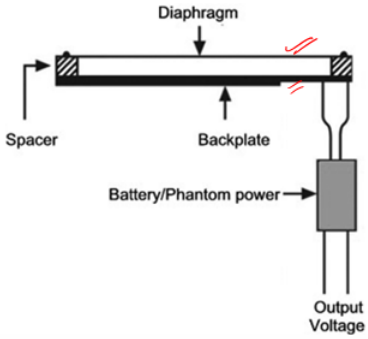
- **Features**:

1. Durable and robust, capable of handling high sound pressure levels (SPL).
2. Typically used for live performances, vocals and instruments like drums and guitar amplifiers.
3. Less sensitive to high frequencies, making them ideal for loud sound sources.

The other type of microphone is the condenser microphone. It is also called the capacitor microphone. So, the very first diagram I showed was of a capacitor microphone. So, here it uses a capacitor or a condenser to convert the sound into electrical signals. You know that in electrical technology, in the basic electrical technology classes, you must have studied about what a capacitor is. It is a means of storing electrical potential. So, this is when you have two parallel plates with some charge and separated by a certain spacing. They can act as a capacitor and store electric voltage. So here, the diaphragm becomes one plate of the capacitor, and then you have a steady and fixed back plate. The upper plate is moving, and therefore the voltage, due to this capacitance, is changing. The capacitance changes, and hence the overall voltage that it is storing changes. Then you have some circuit or some means by which we can tap this into an output voltage. So, the overall output current that is created. So, the current would be proportional to the voltage, and the voltage would be proportional to the capacitance, which then depends upon the spacing between these plates. So, obviously, the spacing depends on what? The spacing depends on the pressure, the acoustic pressure that is incident on the plate. So, ultimately, you get an electrical signal which corresponds to the variations in the acoustic pressure.

2. Condenser microphone: / Capacitor Microphone.

- **Principle:** Uses a capacitor (condenser) to convert sound into an electrical signal.
- **Components:** Diaphragm, backplate, and a power source.



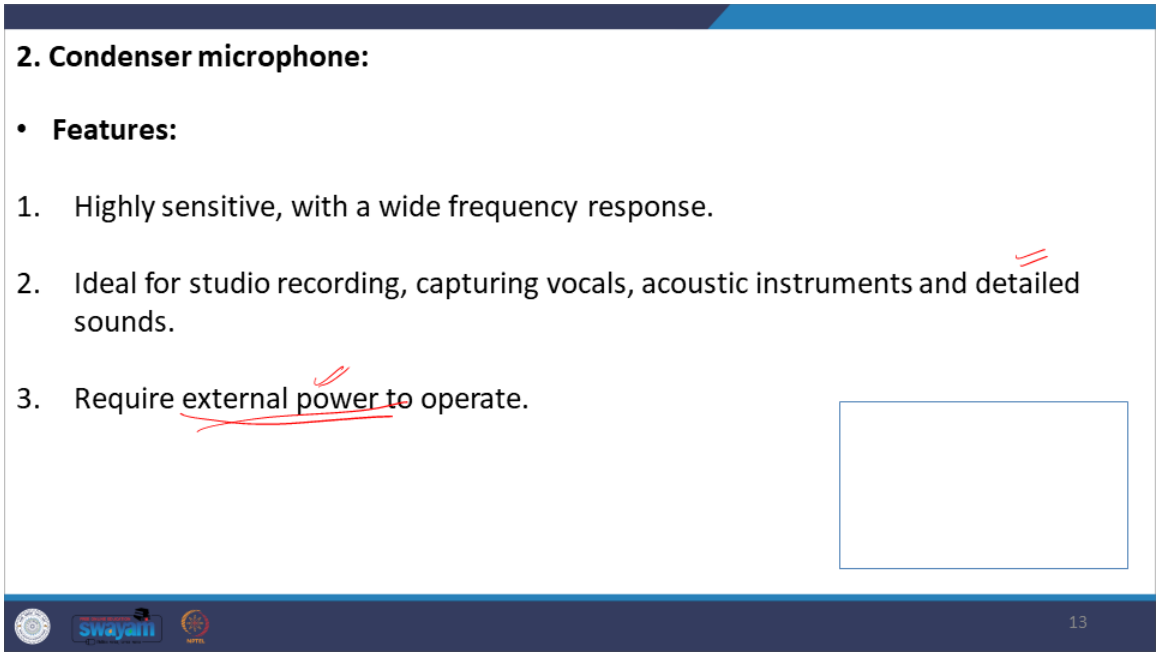
$I \propto V$

$V \propto C \propto \frac{1}{\text{spacing}}$

$\text{spacing} \propto \frac{1}{P}$

Source: https://www.teachmeaudio.com/recording/microphones/condenser-microphone

These microphones are more sensitive, very highly sensitive, and have a wide frequency response. They are more ideal for studio recording rather than open-air performances and live concerts. They are more used for studio recording, capturing vocals, and whenever you need to record sound in detail, so more detailed sound, low-key sounds. It requires some external power to operate.



We also have something called a ribbon microphone. So, what happens here is that a thin metal ribbon is suspended in a magnetic field, again, this also uses electromagnetic induction. So, just like in the previous case where I discussed it, you had a diaphragm which becomes the moving conductor in the magnetic field, and a coil is creating that magnetic field. Here also, you have a similar concept; there is some kind of coil which is creating the magnetic field. but you have Instead of a diaphragm, now you have a thin metal ribbon that is suspended in the magnetic field, and as the acoustic pressure is incident, the ribbon moves, and the movement of the ribbon then induces electrical current by the principle of electromagnetic induction. Usually, these ribbon elements are made of aluminum or other such light metals. They are bi-directional in nature, so they can capture sound both ways.

3. Ribbon Microphone:

- **Principle:** Uses a thin metal ribbon suspended in a magnetic field to generate an electrical signal by Electromagnetic Induction.
- **Components:** Ribbon element, magnets.

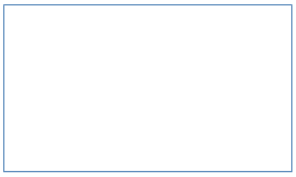
Source: https://www.gear4music.com/blog/what-is-a-ribbon-microphone-benefits-applications/

They are more delicate and sensitive to handle because, obviously, they have these thin metal ribbon elements which can very easily get damaged or broken. Suppose when the microphone falls, it can damage the ribbon element, so they are more delicate and sensitive, but they give a warmer and natural kind of sound recording, often used in studio settings for recording vocals, strings, and brass instruments, okay. So that is essentially what a microphone is. If you are interested, you can study about microphones in detail. These days, we also have piezoelectric microphones where we have a diaphragm and there is a piezoelectric element that is in contact with the diaphragm, and by the principle of piezoelectricity, the vibrations are then converted by these crystals into electricity. And various other things which you can take time and study on your own if you are interested, but in this course, we will limit our discussion of microphones to this point itself.

3. Ribbon Microphone:

- **Features:**

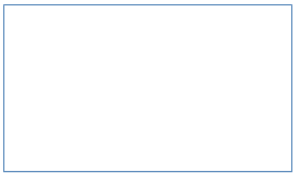
1. Delicate and sensitive to handle, but provides a warm, natural sound.
2. Often used in studio settings for recording vocals, strings, and brass instruments.
3. Naturally bidirectional, capturing sound from both the front and back.



The second kind of device used in noise control engineering is a preamplifier. So, what is that? It is an electronic device that amplifies weak electrical signals, typically from a microphone, to a level that can be processed further by other audio equipment. So, as I told you, the signals picked up by these microphones are very weak in nature because acoustic pressure fluctuations themselves are extremely small. Even the minimum pressure fluctuation perceived is 20 micro Pascals, which is a very small value. Just reaching 1 Pascal, considering our atmospheric pressure, is significant. Even 1 Pascal is considered as 93 dB sound, which is very loud. So, these are very minute pressure variations, and hence the signals created are weak. For further processing and readability, they have to be amplified to a larger value. So, a pre-amplifier is needed; it converts the weak signals into a more readable format. So, these are the key functions of a preamplifier.

Preamplifier

- An **preamplifier** is an electronic device that amplifies weak electrical signals, typically from a microphone, to a level that can be further processed by other audio equipment, such as power amplifiers, recording devices.
- Without preamplifier, weak signals from sources like microphones would be lost or drowned out by noise, making the preamplifier a crucial component in any professional audio setup.



First of all, amplification of these low-level signals. So, these low-level signals from microphones are converted into line level or strong enough to be processed further. Various preamplifiers can also be used for signal conditioning, where they can shape or condition the signal. For example, they can filter out some unwanted frequencies, adjust the signal tone, add gain to adjust the volume level, and so on. So, some kind of frequency weighting can also be done, and you can remove the unwanted bits.

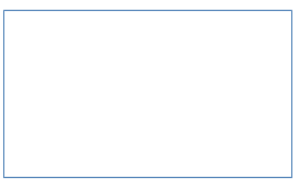
Key Functions of Preamplifier

1. **Amplification of Low-Level Signals**:

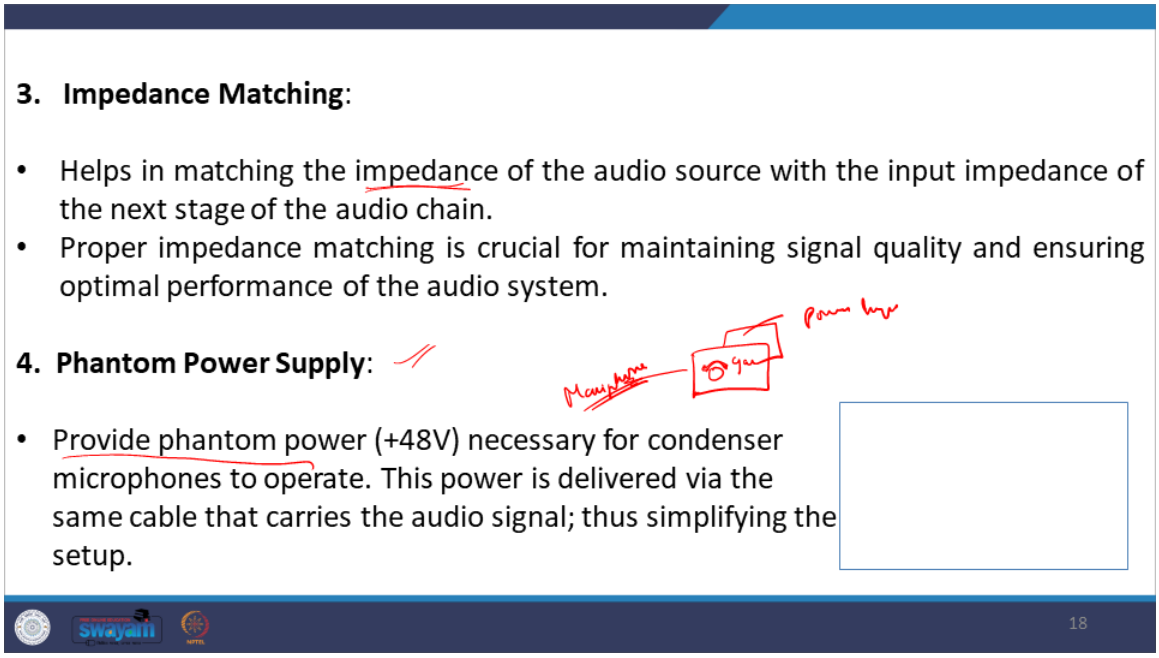
- Take low-level output signals from microphones, or other audio sources and boost them to a "line level" that is strong enough to be processed by other audio equipment.

2. **Signal Conditioning**:

- May also shape or condition the signal. E.g. filtering out unwanted frequencies, adjusting signal's tone, or adding gain to adjust the volume level.



Then, impedance matching. Essentially, all the devices we are discussing are various mechanical systems. So, these are electromechanical systems, electronic plus mechanical, and we have these signals flowing from one part to another. Each of these components should offer the least resistance to the flow of the signals so that we can get high-quality signals. For that, the impedance of one part needs to match. So, let us say the impedance of the microphone cables should match the impedance of the data acquisition system should match the impedance of the other forms of cables that might be connected to some other signal analyzer. So, the impedance of the various components should match. So, we offer minimum resistance to the flow of the signals we have captured, and we get high-quality signals. So, that is also sometimes achieved using these preamplifier devices. Then, the phantom power supply. So, sometimes the preamplifiers are built in such a way that they are devices which have knobs to control the gain of the signal, and they are also connected at the back with some power supply and then to the microphone, which is the sensor. So, they are supplying power. To this whole system, and in the case of the microphone, such as the condenser microphone, they need some external power to operate. So, this can be supplied indirectly from the preamplifier; it can be a source of supplying power and can be delivered to the device for operation.

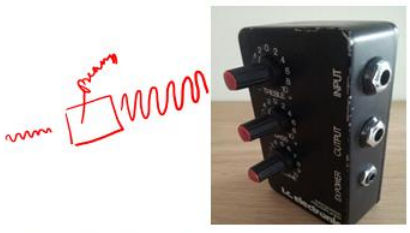


So, let us see some of the common preamplifiers that are available. So, several types are available, and they have their own features and benefits. In the market, you can find all of these kinds of devices. Let us see integrated preamplifiers. They are some of the most basic or rudimentary kinds of preamplifiers that can be found in the market. So, they are built into the actual amplifiers or receivers. And they offer the very basic functionality, which means that they may not be able to do, you know, some advanced signal conditioning or some kind of, you know, advanced filtering. They can only perform the basic function, which is whatever signal is being received, add some factor to it. So, the amplitude of the signal expands, okay. So, if this is the signal that is being received, you have the preamplifier. This basic preamp. So, no other conditioning, but just adding some gain value to convert it into a more, you know, signal with a higher amplitude can be achieved. So, usually, for example, a kind of integrated preamplifier could be where you have your own loudspeaker. You have a microphone. You are speaking as a speaker. I have a microphone. I am speaking, and directly, you know, the cable of my microphone is connected to some kind of loudspeaker, and I adjust the volume of the loudspeaker. That itself acts as an integrated preamplifier. Even the amplification provided by these receivers here, the loudspeaker being the receiver to my sound signal, which is playing it back to the audience, that becomes an integrated preamplifier. So, you cannot condition your signal using a loudspeaker, right? You can only adjust the gain.

Types of Preamplifier

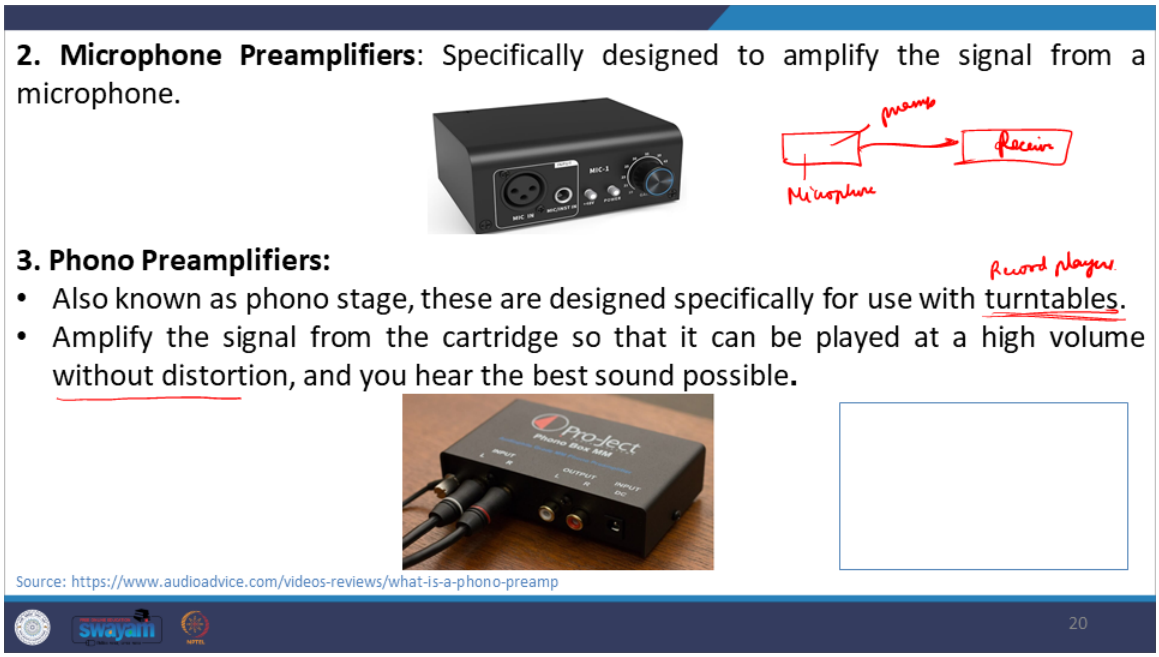
There are several types of preamps available on the market, each with its own set of features and benefits:

1. **Integrated Preamplifiers:** Are built into amplifiers or receivers and usually offer basic functionality. These are ideal for entry-level systems or for those who want simplicity.



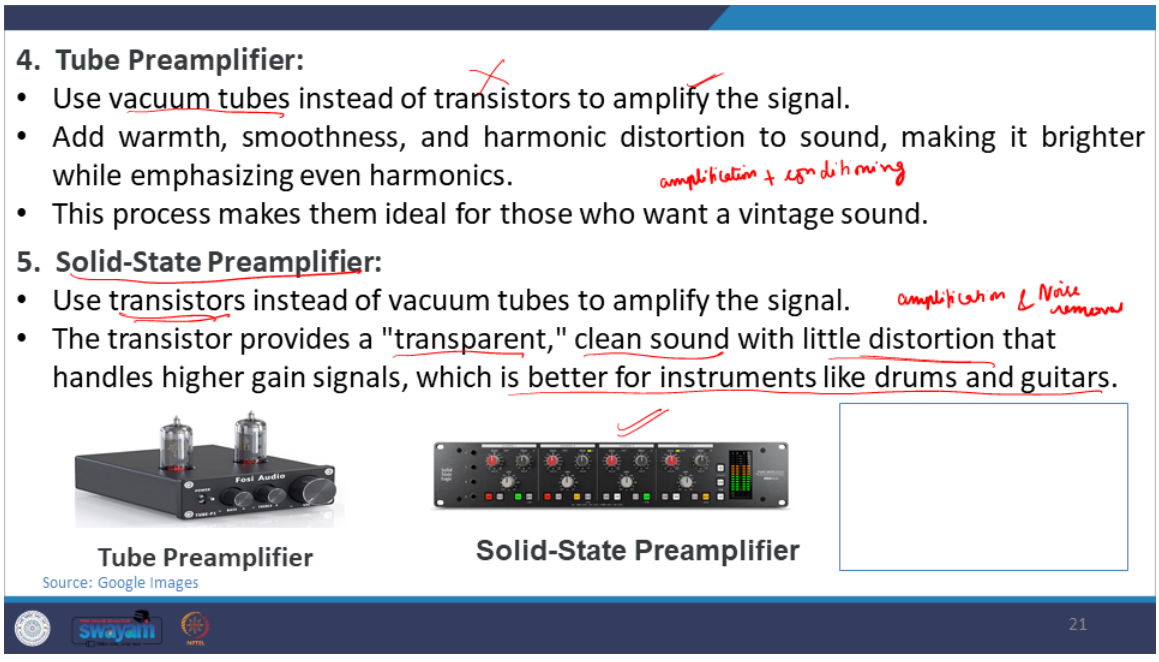
Source: https://en.audiofanzine.com/guitar-bass-booster/tc-electronic/integrated-preamplifier/medias/pictures/

Then we have some microphone pre-amplifiers. So, in the modern day, what happens is that many of the microphones have pre-amplification inbuilt within them. So, sometimes, you know, you have this microphone, and then you have the receiver, let us say. Some receiver or speaker. So, within the microphone itself, you have got some preamplifier inbuilt into it. So, as soon as the signal is received, it is amplified within the microphone and then sent over to the various devices for processing. Then phono preamplifiers, so this is usually used when you are using these kinds of turntables or you can say, you know, record players. Nowadays, it is hard to find, you know, phono preamplifiers. So they are specially used for record players, and you can adjust the gain volume of the sound that is playing through this record player, and with the minimum distortion, you can hear the best sound possible.

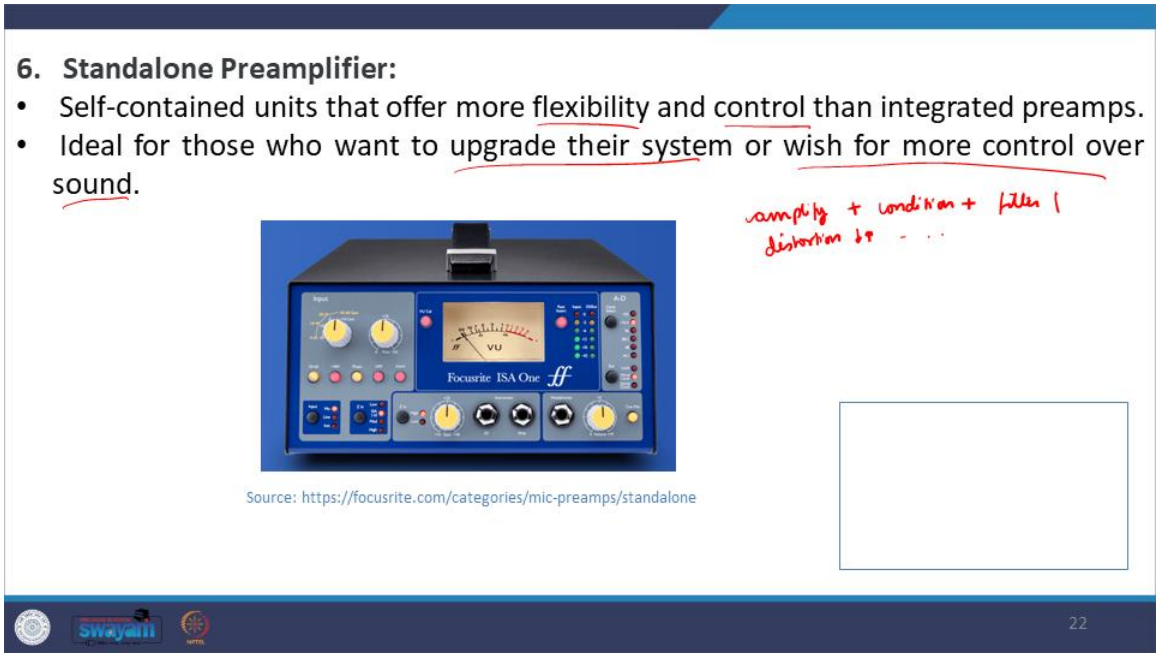


Then you have two other kinds of preamplifiers. We have the tube preamplifiers and the solid-state preamplifiers. In the tube preamplifiers, you use these vacuum tubes. Instead of the transistors, and they are used to amplify the signal, and when this mechanism is

used, it adds more warmth, smoothness, and more harmonic distortion to the sound, making it brighter while emphasizing even harmonics, and it makes it ideal if you want to hear some kind of vintage sound. Where a solid-state preamplifier It uses transistors. This does not use transistors and instead uses the vacuum tubes, and it amplifies the signal. So here, what happens is the transistor provides a more transparent, clean sound with little distortion that handles higher gain signals and is better for instruments like drums or guitars. So, suppose you know you are making some recording, and you want to amplify it, then a solid-state preamplifier could be best if you want to hear the sound as it is without any added kind of distortion or without any added conditioning, as it is, you want to hear them without any unwanted noise. You can use, you know, the solid-state preamplifier, which is usually found with most of them, you know, musical recording instruments. Whereas with, you know, various kinds of, you know, you have these record players, you have these gramophones, and these kinds of devices where sometimes, you know, it adjusts the music or it adjusts the sound signals so that, you know, it adds more bass or it adds more harmonic components to it. So some conditioning is provided here. Amplification plus conditioning happens. And here, mostly it's amplification and noise removal. So, no signal conditioning happens.

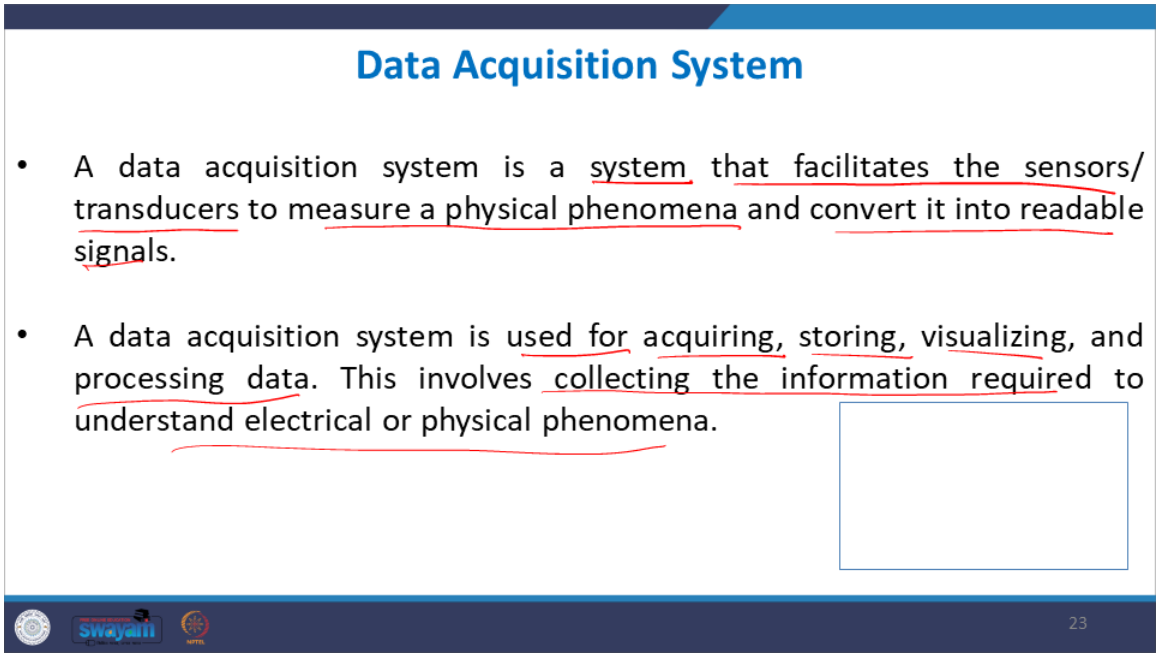


Okay, then we have the standalone preamplifiers. They are one of the most advanced in all the categories, and they offer more flexibility. You know, they have more flexibility and more control than the integrated preamplifiers. They are ideal for people who want to upgrade their music system or want to upgrade their sound recording device and wish for more control over the sound. So here, they can provide a lot of options like they can amplify the signal. They can condition, filter, then you know, various kinds of distortions can be added or removed, and various other kinds of signal manipulations. So, more options are provided by such preamplifiers. You can manipulate and condition the signals with more options here.



So, the third kind of, you know, device we want to talk about is the data acquisition system. So sometimes, you know, if you buy a data acquisition system, sometimes people say that I bought a data acquisition system for, you know, my noise control setup. And sometimes, you know, people say that the entire setup, which means including the microphones, the cables, these preamplifiers, this entire setup becomes like a data acquisition system. These terms are used interchangeably. So, essentially, a data acquisition system is any kind of system that can facilitate the sensors or the transducers

to measure a physical phenomenon and convert it into readable signals. So, not just for sound signals, you can have a data acquisition system to acquire thermal signals. So, let us say you are doing research and making a study of, you know, some kind of, you know, heater or heating ventilation system, and you want to see how the heat transfer takes place. You can make use of a data acquisition system which can have, you know, you can have some thermocouples for measuring, which can be connected via some wires and circuits into a hardware from which the signals, these heat signals are converted into electrical signals, they are pre-amplified, they are conditioned, and converted into some readable output. So, that will also become a data acquisition system. So, basically, any system that can facilitate all of this measurement of a physical phenomenon and conversion into a readable output. So, they are used for acquiring, storing, visualizing, and processing of that data. And information is collected, and you know, to understand this phenomenon. So, in terms of noise control engineering, how does the data acquisition system be inbuilt or integrated with a microphone and preamplifier?



So, you can have your sensor, which is a microphone, and then you have a DAQ device. So, DAQ device, which is, you know, short form for data acquisition device, okay. This

is a short form for data acquisition. Acquisition, okay. So, you have sensors followed by the signal conditioner, you know, sensors, then you have the preamplifiers. I can add here, post the sensors, you have some preamplifiers. But sometimes the preamplifiers are inbuilt into the sensor itself, and then you have some signal conditioner, which can be again part of the preamplifier or part of the DAQ device. But signal conditioning happens, and then analog signals are converted into digital, and this all happens in a DAQ device. And then you have some software, which then locks the data and, you know, creates beautiful visuals to visualize the data. So, the data acquisition system facilitates, first of all, taking the input electrical signals from the sensor, doing some signal conditioning. So, what are the functions it does? First of all, you know, taking in the acoustic signals. You can say the electrical signals from the transducer because whatever the acoustic signal, thermal signal, or whatever, it gets converted into electrical signals. So, taking in the electrical signals from the sensors, then doing, you know, conditioning. Sometimes even pre-amplification and conditioning can be done using a DAQ software or a DAQ device. So, pre-amplification, signal conditioning, then conversion from analog to digital, digital conversion of the data. And then finally, what happens is that, you know, processing of the received digital data and creating visual representations. So, you have hardware that takes the signals and does this pre-amplification, signal conditioning, and analog-to-digital conversion. Then you have the software integrated with a DAQ device, which then processes it and creates these nice visual representations. Okay. So, with this, I would like to end the lecture, you know, and in the next lecture, we will see some of the more advanced devices used for noise control engineering.

Components of a data acquisition system

- **Digital data acquisition systems** consist of four essential components:

1. Sensors
2. Signal Conditioner
3. Analog-to-Digital Converter
4. Computer with DAQ software for data logging and analysis

} DAQ device

DAQ block diagram and elements of modern digital DAQ

Source: https://dewesoft.com/blog/what-is-data-acquisition

So, thank you for listening.

Thank You