Embedded System Design With ARM
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Lecture – 16
Output Devices, Sensors and Actuators (Part II)

Now, continue with the discussion, we shall be talking about some of the sensors that we can use for interfacing and for building some embedded system applications in this lecture. So, this lecture is titled to continue with the previous one Output Devices Sensor and Actuators the 2nd part.

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So, here we shall be very briefly talking about some of the sensors like speaker temperature sensor LM 35, light dependent resistor, microphone which we shall be showing as part of the demonstration. We shall not be going into detail, but very brief working principle. So, that you actually understand how the thing is working first let us talk about a speaker.

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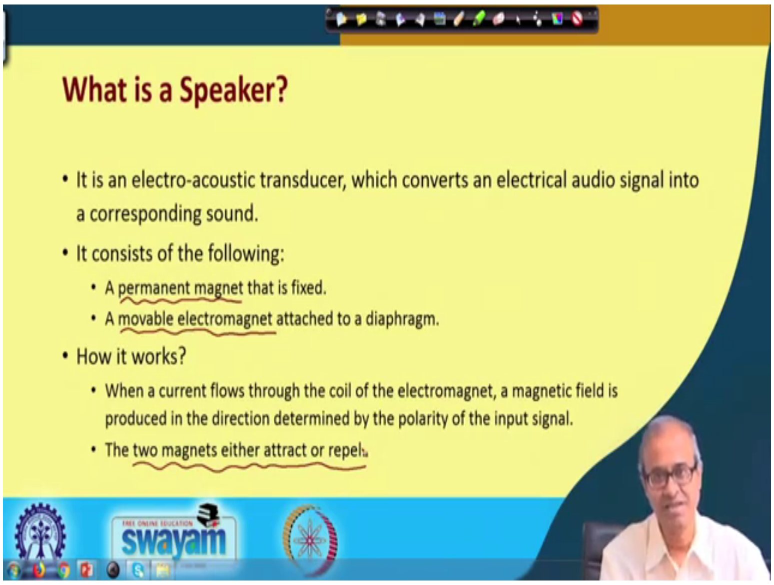

Well you all know what a speaker is a speaker is a device through which we can generate some sound we can get an audio output right.

Now, a speaker essentially we call it as an electro acoustic transducer, which means is converts an electrical audio signal into a corresponding sound; that means, you give an electrical signal a waveform as the input and the speaker will generate a sound as the output you can hear with your ear ok. Now, what is there inside a speaker? Inside a speaker there is a permanent magnet and there is a movable electromagnet.

Well what is a electromagnet? Electromagnet is constructed out of some ferromagnetic material with a coil around it whenever there is a current flowing through the coil that material becomes a magnet. So, the idea is like this there is a permanent magnet and the coil around the ferromagnet is movable, whenever there is a current flowing this will become a magnet. So, it will either be attracted towards the permanent magnet or it will be repelled from the permanent magnet depending on the kind of current we are passing there will be a vibration this is the basic idea.

So, when current flows through the coil of the electromagnet due to the magnetic field produced this material becomes a magnet and the two magnets either attract each other or there will be a repulsive force there will move away from each other this will happen depending on the polarity of the current, which direction the current is flowing.

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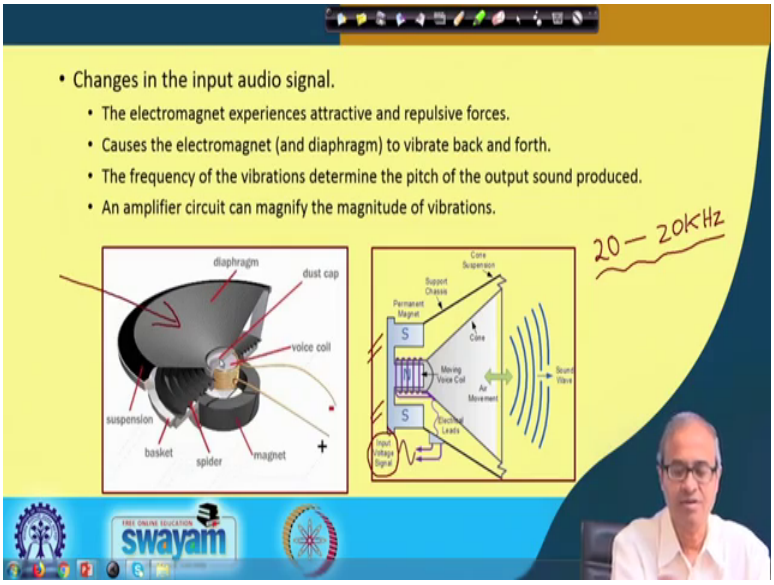

So, just looking into the diagram yes you see I have shown a diagram here the permanent magnet is shown in the back this is the permanent magnet. And in the coil, coil is wound around a middle point this can be connected or attached to the permanent magnet or this can be a separate movable part also there can in two different kind of speakers you can manufacture.

And when there is a current flowing depending on the input voltage signal there will be some current flowing in the coil. So, this coil will be moving forward and backward depending on the attractive or repulsive force and there is a thin diaphragm connected to that coil. In a speaker you must have seen there is a diaphragm like this on top a thin soft material that also starts moving back and forward there is a vibration.

Now, if that vibration is in a frequency range that our ear can hear we will be hearing a sound. Now, you know that the typical audio range is 20 hertz to 20 kilohertz. So, human ear is able to hear between this frequency range. So, if there is a frequency with which the diaphragm is vibrating in this range, we will be able to hear that sound right this is how it works. So, you see here you mentioned this electromagnet you can see here it experiences attractive and repulsive forces depending on the direction of current that is flowing through it.

So, the electromagnet as well as the diaphragm will be moving up and down there will be a vibration and the frequency of vibration will generate a sound well in most audio systems we also have a good amplifier circuit with very low noise. So, that we get a very clear and nice sound in all our music systems and other audio systems we have a very sophisticated amplifier which is connected through this to connect to the speaker. So, that you get a very clear sound right.

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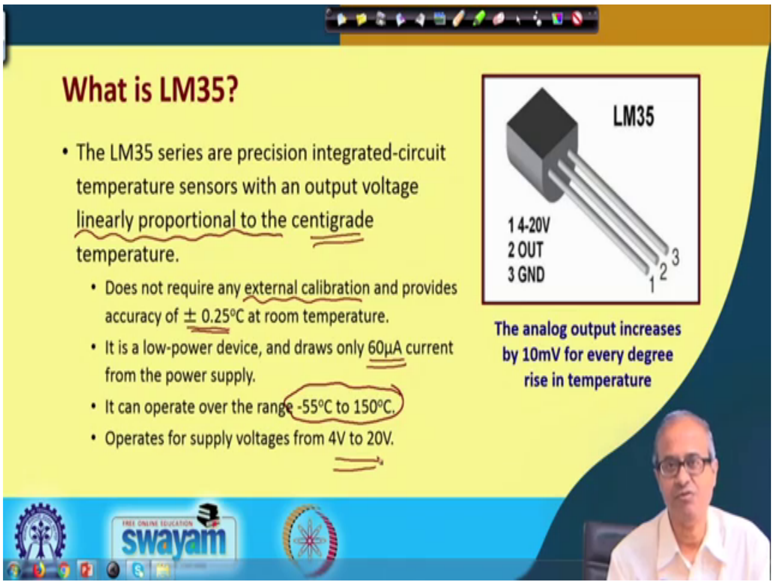

So, next let us talk about one kind of temperature sensor this is a very popular temperature sensor which many of us use in our experiments this is called LM 35 ok. This LM 35 is a very convenient kind of a temperature sensor it looks like this you look at this diagram there are 3 pins; pin number 1 and pin number 3 are the power supply pins. Pin number 3 you connect to ground and pin number 1 you can connect a positive power supply depending on the type number of LM 35 this power supply voltage can vary between 4 and 20 volts.

And the middle point pin number 2 will be generating some analog voltage which will be proportional to the external ambient temperature there are two versions of LM 35 available some of them can directly generate a voltage proportional to the temperature in degree centigrade or Celsius there is another version which can also give in degree Fahrenheit ok.

So, some of the notable thing is that as I said the output voltage is proportional to the temperature in these sensors the kind of sensor that we shall be showing you it will be proportional to the degree centigrade of the temperature. And this has all this circuitry built inside it you do not need any kind of external calibration to be made very convenient to use. And it has an accuracy of plus minus 0.25 degree centigrade which is often sufficient in most applications and it also consumes very low power 60 microampere current during this operation. So, it is also a very low power device very convenient it can operate over a wide range of temperatures minus 55 to 155 degree Celsius typically and of course, as I told you the power supply range is also 4 to 20 volts.

The other point to notice that the middle point is generating an analog output voltage I told you and it is proportional. So, what is the constant of proportionality the constant of proportionality is such that there will be an increase in 10 millivolts in the output voltage for every degree centigrade rise in the temperature, this is how this device has been built.

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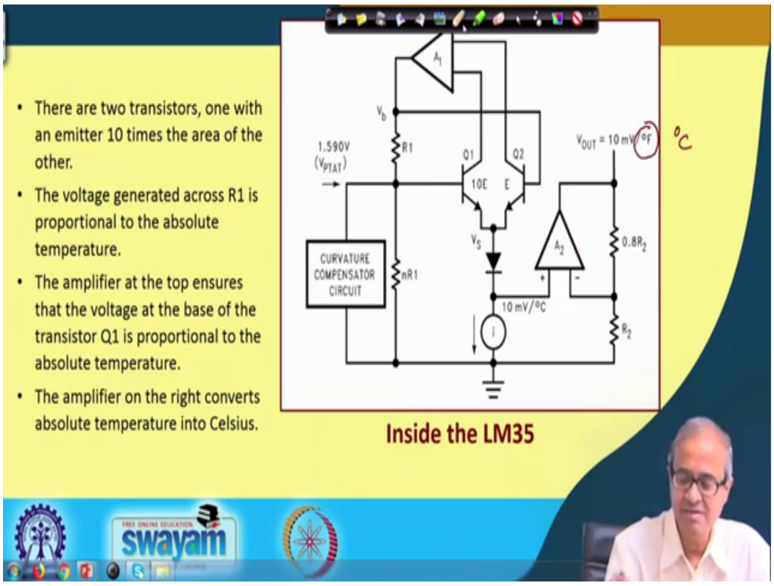

So, internally I am not going into the detail explanation internally this device looks like this, you see there are two transistors some diodes there are some amplifiers there is a constant current source. And these two transistors are very peculiar one of them has an emitter which is 10 times larger than the other. You see I am not trying to explain how this circuit works, but the idea is that the currents that are flowing through the transistors there is a strong dependence on the ambient temperature that is how the temperature sensing is done.

And the difference in the current that is flowing into these two transistors that is amplified and the voltage across this resistance R1, this is actually becoming proportional to the absolute temperature. And on the other side this absolute temperature value this voltage is through some other circuitry the other amplifier is being converted into a voltage which can be made proportional to either degree Fahrenheit or degree centigrade both kinds of amplifiers can be designed. So, there are two families of LM 35 device I told you one gives you the output voltage proportional to degree centigrade other proportional to degree Fahrenheit. So, in sight this circuit is like this ok.

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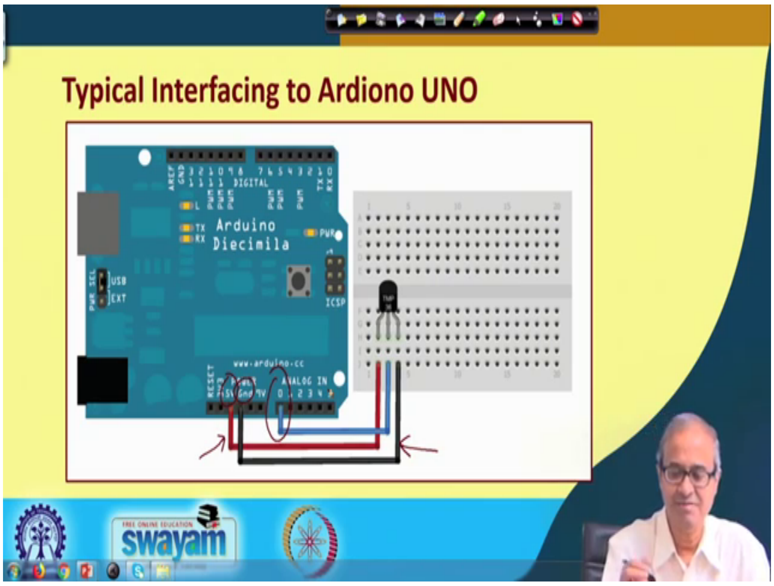

But to use it is extremely simple well here I am showing a diagram where with an Arduino UNO board we are trying to connect you see this is a LM 35, now which were put on a breadboard these vertical lines are all connected ok. Now, the leftmost terminal we are connecting in to 5 volts this is the terminal which is generating 5 volts we are connecting it directly to 5 volts the rightmost wire this black one this is connected to ground you see this is the ground terminal this is connected to ground.

And the middle one which is supposed to generate the sensed analog output proportion of the temperature this is connected to one of the port lines. You see we have connected to one of the analog inputs because, it is an analog voltage you can read the value of the analog voltage through an AD converter built in AD converter, you can read the data and you can make a calculation what is the actual temperature outside right ok.

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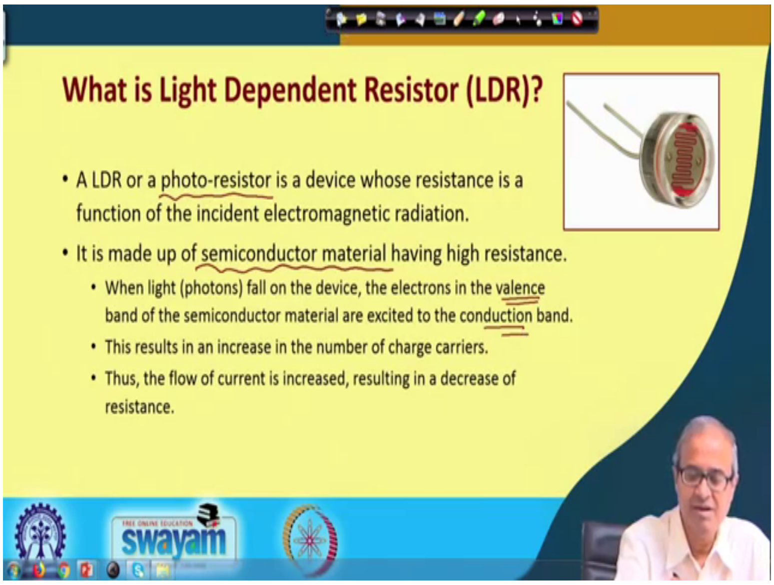

Now, let us talk about a sensor called light dependent register which can sense light. Now, LDR is a very small device. So, it looks like this it is a two terminal device and there is a transparent window on top you can see some this kind of zigzag pattern inside it this is how an LDR looks it is very small in size. This LDR is sometimes also called a photo register it is a resistance whose resistance value changes depending on the light that is being incident on it this is how LDR works depending on how much light has been incident the value of the resistance changes. So, you can measure the resistance that will give you an idea about what is the intensity of light that is falling on it ok.

So, so, so, internally it is made out of some semiconductor material because semiconductor materials have this kind of photo resistive property when light falls on them the resistivity changes ok. So, here some explanation is given when light or photons fall on the device the electrons inside the device they move from one state to the other typically they are called valence bond, they move to the conduction band. Valence band to conduction band if they move; that means, electrons become more mobile resulting in a reduction in resistance because flow of electrons result in a flow of current right. So, more mobile electrons are higher will be the current lower will be the resistance this is how roughly an LDR works.

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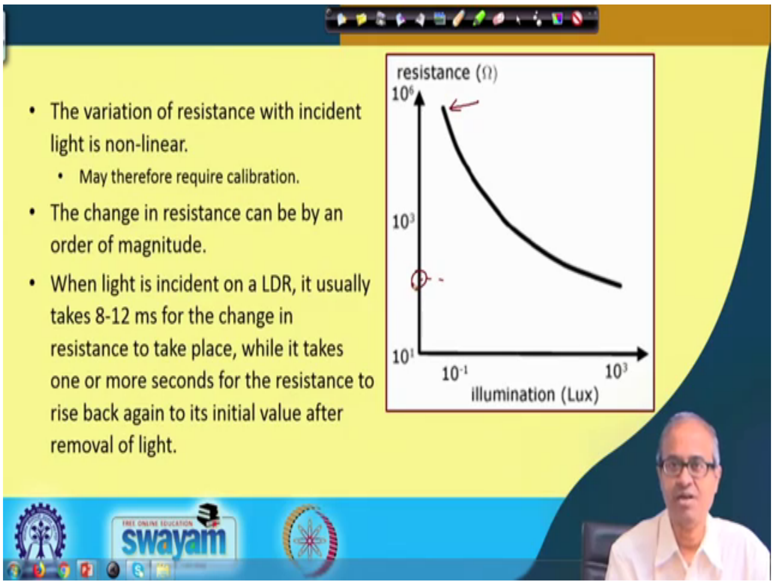

And the other properties, that as the illumination increases the intensity of light well the unit of illumination is Lux you may be knowing. So, as the illumination increases the resistance decreases exponentially. So, one point in notice that you see we unlike LM 35 this is not a linear device the resistance is not proportional to the intensity level it follows this kind of exponential curve.

And the other point to notice that the difference can be quite significant you see in this typical curve here we have a resistance of the order of mega ohms and on this point we have a resistance of the order of hundreds of ohms. So, from mega ohm to hundreds of ohms this is a huge difference. So, if you have a proper circuitry to sense this change in resistance you can very faithfully and accurately sense the level of light intensity ok.

And the other point you notice that these devices are not lightning fast it takes a little time for them to generate the output. Like when light falls on these devices it typically takes of the order of tens of milliseconds for the device to respond and the output to settle down. And when light is withdrawn again you put it in a dark place, then it can take a couple of seconds also much longer time for the resistance to again go back to that high resistance state ok. So, this you should remember; that means, the response time is not of the order of microseconds or very lower milliseconds like that it can take a little time all right fine.

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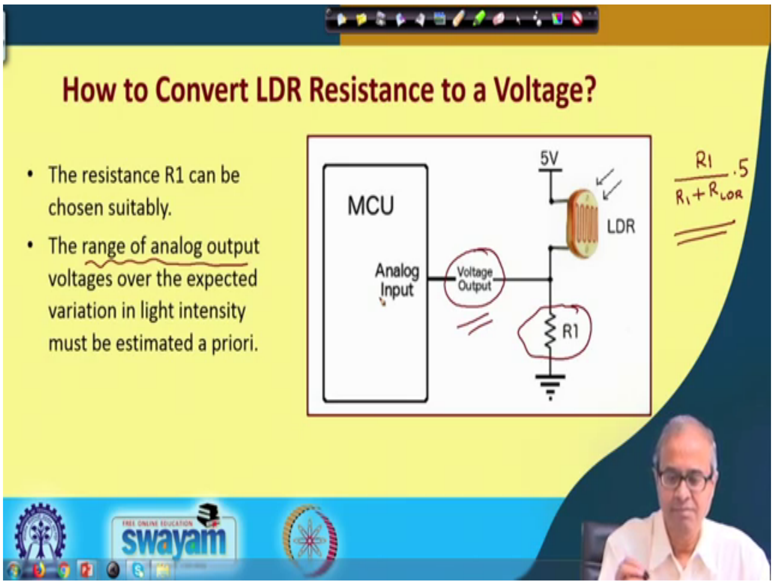

Now, talking about interfacing while interfacing very typically we use some kind of a resistance divider circuit like we can use an LDR we can use a resistance R1 with a 5 volt supply let us say and this we can feed it to one of the analog input pins of our microcontroller either Arduino or STM 32. So, here this voltage output what will be the value it will be this R1 divided by R1 plus resistance of the LDR multiplied by 5 volts this will be the value of this output voltage.

So, you will have to first find out the range of analog output voltage in the expected environment let us see you may be using the LDR to check whether the light intensity has fallen below a threshold. So, you will have to do an experiment and find out what are the resistance values in the dark state and in the light state. So, this R LDR this value is changing. So, accordingly you will have to choose the value of R1 so, that the change in the voltage output can be significant. So, that you can read this analog input in the microcontroller and take a decision what to do with that right ok.

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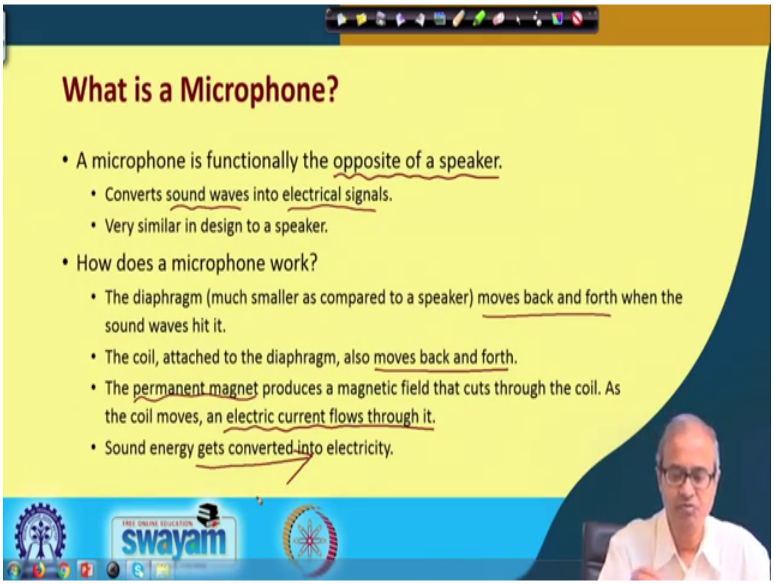

Now, the last kind of sensor that we shall be talking about in this lecture is a microphone. Microphone you all know is something where you speak well in our mobile phone there is a microphone when we give a talk or a presentation we have a microphone sometimes I also have a microphone connected in my collar here I am speaking to you are able to hear this is also a kind of sensor a sound sensor some sound is being generated that is captured by the microphone and it is stored somewhere in electronic format ok.

So, essentially what is a microphone? In terms of functionality while internally the arrangement is very similar to that of a speaker, but it works in exactly the opposite mode a speaker converts an electrical signal to sound microphone converts sound into electrical signals design is very simple similar there here also there is a diaphragm. But, microphones are much smaller than a speaker typically speakers at large you have also seen very large speakers the sound boxes you have seen the speakers are pretty large.

But in contrast microphone there are microphones inside your mobile phones also there are very small in size there is a very small diaphragm inside. So, when you speak on it that the diaphragm vibrates there is also a coil around the diaphragm around that permanent magnet, now you are not passing a current through the coil rather you are allowing the diaphragm to vibrate in response to the sound.

Now, as the coil vibrates inside a magnetic medium a voltage will be induced in the coil and you can measure that voltage it is reverse from sound you are generating an electric voltage and that voltage will give a measure of the vibration that is being carried out in the diaphragm in response to the sound ok.

So, this is actually how it works the diaphragm moves back and forth the coil which is attached to a diaphragm will also move back and forth just like a speaker there is a permanent magnet there will be magnetic field in which the coil is sitting. So, as the coil moves a an electric current will be flowing through it because of a voltage that will get induced. So, sound energy gets converted into electrical energy or electricity. This is how a microphone works.

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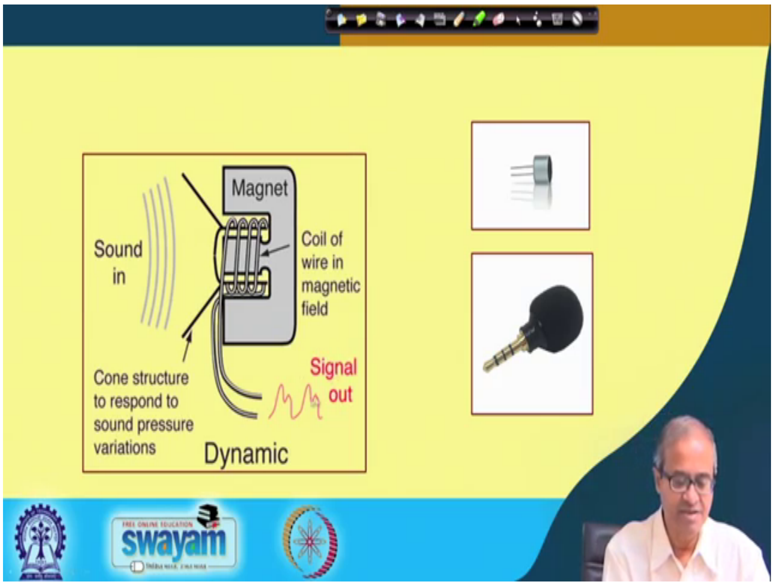

So, inside you see the smallest microphone can be very small and here I am showing the basic microphone of a typical those bar kind of microphone you use while giving some lectures or some presentations this kind of microphones are also used and inside as I told you there is still a permanent magnet and there is a coil which moves. And as it moves there is a signal, which is generated in speaker it was a reverse I was applying a current and because of that the coil was moving the diaphragm was moving, but now because of the sound I am giving in front the diaphragm is moving first a voltage is being generated that is my signal right this is how it works.

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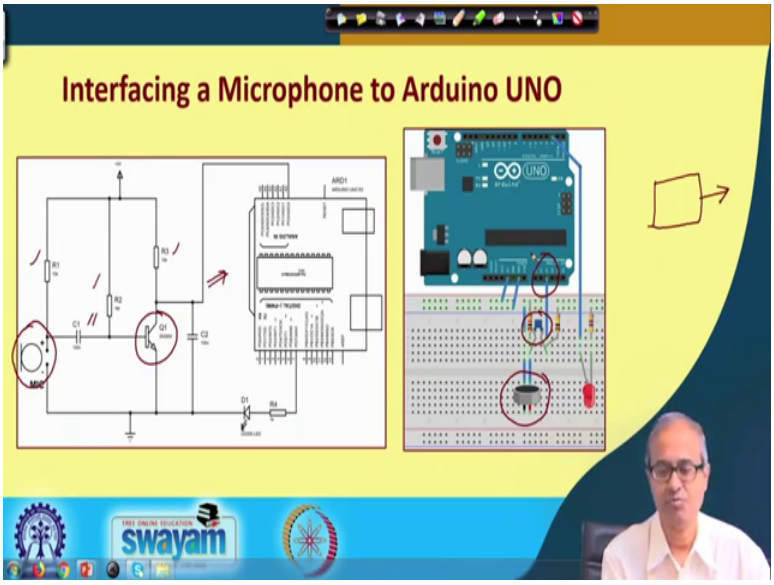

Now, interfacing is also not quite difficult I am showing a typical interface there can be simpler ways of doing it also you see here this is the symbolic diagram of a microphone here I am showing you a transistor level amplifier which consists of some resistances and some capacitances actually. So, whenever you are speaking that is being converted into a voltage which is in the 0 to 5 volts level in that range. So, here the typical interface is shown where here you can see the microphone sitting here and the other circuitry you can see here this is your transistor right and you have made the connection with this Arduino UNO this is how you can connect it.

But you see let me also tell you when you want to buy a microphone of this type for some experiments you will find often that there are some products available which already have this circuitry built into it. So, if you buy it you need not have to construct this circuit directly this unit will give you a voltage that will be proportional to the sound you are making you can connect it directly to the analog input port like here it at connected to an analog input port here. So, you can connect it directly to the analog input port. So, with this we come to the end of this lecture in the next lecture we shall be continuing with some more of these devices that we will be using to show you or demonstrate the interfacing experiments.

Thank you.