**Electronic Systems for Cancer Diagnosis**
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**Lecture – 63**
**Electronic Module for Gas sensor**

Hi welcome to this particular lecture. Now, in this lecture we will look at electronic module or signal conditioning circuit for gas sensor. Now when you talk about sensors there are several kind of sensors. So, starting from thermal sensors right we have pressure sensors, force sensors then we have piezo resistive sensors for strain gauge, we have VOC sensors which stands for volatile organic compounds we have gas sensors right and so on and so forth there lot of other sensors as well that we I have not talked about, but there is a slide which will explain variety of sensors available in market.

And, from those sensors we will pick one which is the gas sensor will understand what kind of gas sensors are available, we will understand what is a principle behind the gas sensor and then we will see how can we design an electronic conditioning circuit for that particular sensor. Now then I am talking about gas sensor if you think from engineering point of view or from the industry point of view in fact, then you can use this sensor for sensing CO 2 right which is a leakage in our industry or you can use the sensor for understanding the leakage in a pipeline, which is a chemical pipeline and there is there is a importance of measuring that particular leakage in an industry.

Now, when you talk from medical point of view if I have a group of sensors, i.e. I can delineate a particular volatile organic compound from the breath and that is called a studying the breath signature now of a patient. For example, if a patient is suffering from a particular disease the some of the world organic compounds will be in higher concentration compared to other VOCs. So, if a person suffering from ketosis which is a diabetes then the its also our breath has several kind of VOCs along with gas the VOCs stands for volatile organic compounds like I said for example, we are using petrol diesel right.

Now, I do not say we exhale a VOCs which are similar to petrol diesel and just give you an example of volatile organic compounds. So, if you drop a petrol on the table, it will evaporate same we drop a diesel on the table it will evaporate. Drop acetone on the table it will evaporate, drop ethanol on a on a table it will evaporate all things which are volatile in nature at room temperature are called volatile organic compounds. So, what I said is that we exhale several VOCs like acetone, methanol you know IPA and similar kind of VOCs along with CO 2 and humidity in a in a in our breath.

Now if a person is suffering from particular disease, certain VOCs are of higher concentration compared to remaining VOCs. If you can detect or if you can delineate those VOCs from the breath: then what you can say, you have a developed a non-invasive way of measuring disease. That the point that I am making is that if it is a cancer, then also you can detect a certain VOCs in higher concentration compared to a person who is normal and if you check the best signature of the and the person suffering from cancer and person who is not.

So, the point here is that if I can design and fabricate a sensor and I can use two sensor or one or area of sensor along with electronic indistinct circuit, then I can understand what is going on and how can I see the change in resistance corresponding to the particular VOC. So, if it is a resistive sensor, when you expose the sensor to a gas the resistance would change that resistance we need to convert to a readable format for a changing from the change in resistance to a readable format what we need to use? We have to design the signal conditioning circuit.

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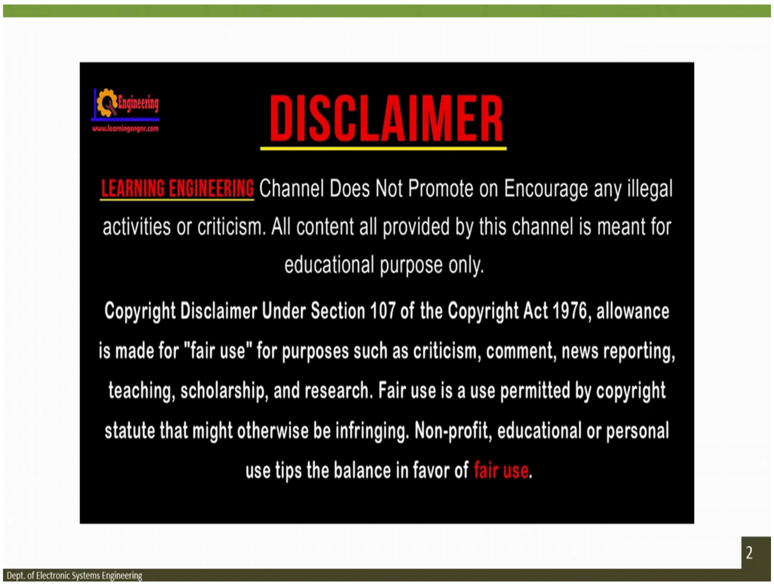

Now, let me play the first video for you. So, you know what kind of sensors are available in market.

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In our normal life we used different types of sensors that are commonly used in various applications.

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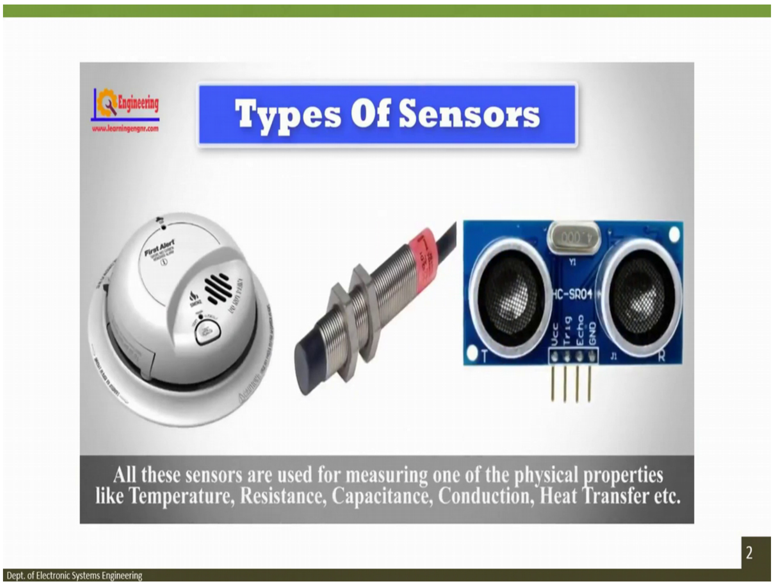


All these sensors are used for measuring one of the physical properties like temperature resistance, capacitance, conduction, heat transfer etcetera.

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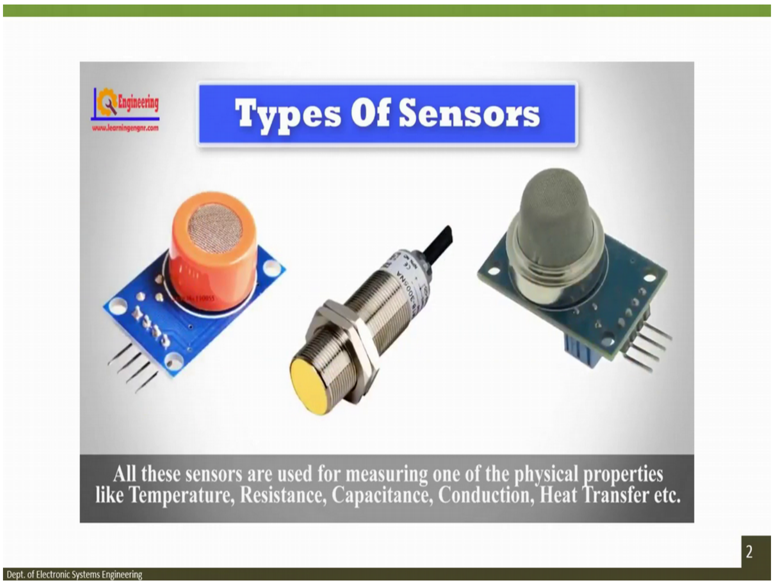


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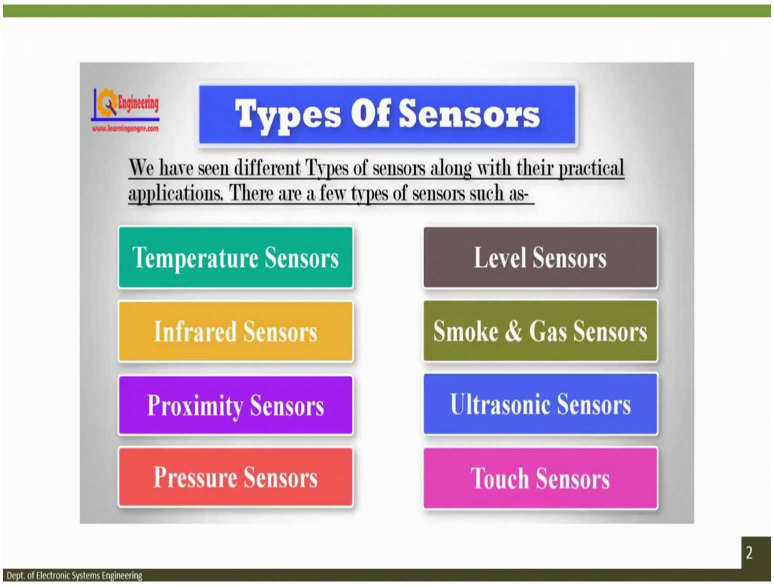


In this video we have seen different types of sensors along with their practical applications. There are a few types of sensors such as temperature sensors, infrared sensor, proximity sensors, pressure sensors, level sensors smoke and gas sensors, ultrasonic sensors and touch sensors are commonly used in most of the electronics applications.

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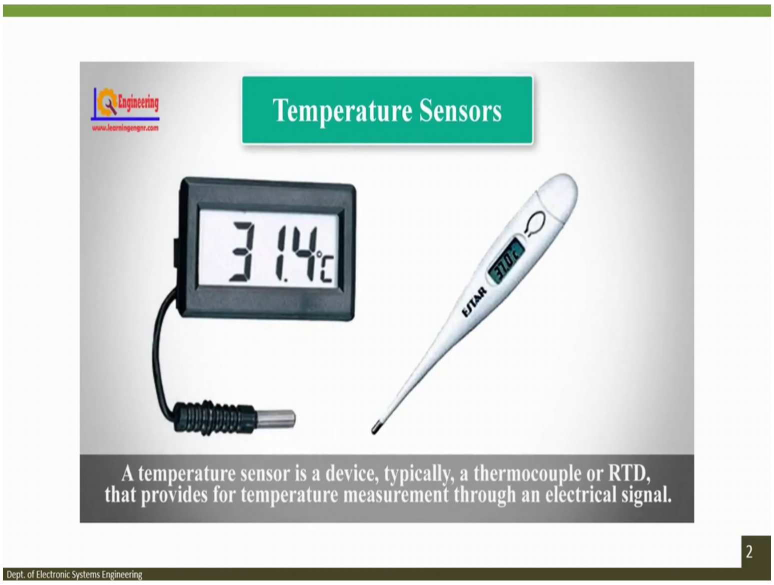


Temperature sensors; a temperature sensor is a device typically a thermocouple or RTD that provides for temperature measurement through an electrical signal.

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In other word a temperature sensor is a device, that detects and measures hotness and coolness and converts it into an electrical signal.

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There are different types of temperature sensors like LM35 IC thermistors thermocouples RTD etcetera.

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Temperature sensors are used everywhere like computers, mobile phones, automobiles, air conditioning systems industries etcetera.

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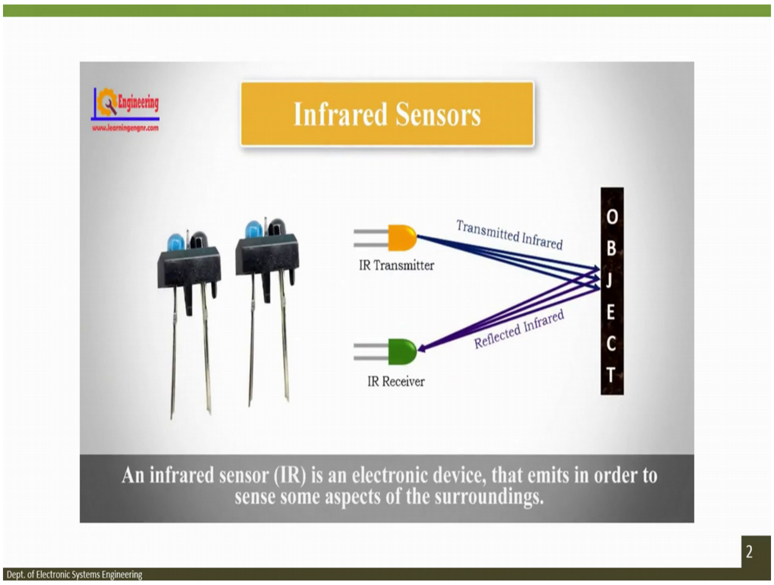


IR sensor an Infrared Sensor IR is an electronic device that emits in order to send some aspects of the surroundings.

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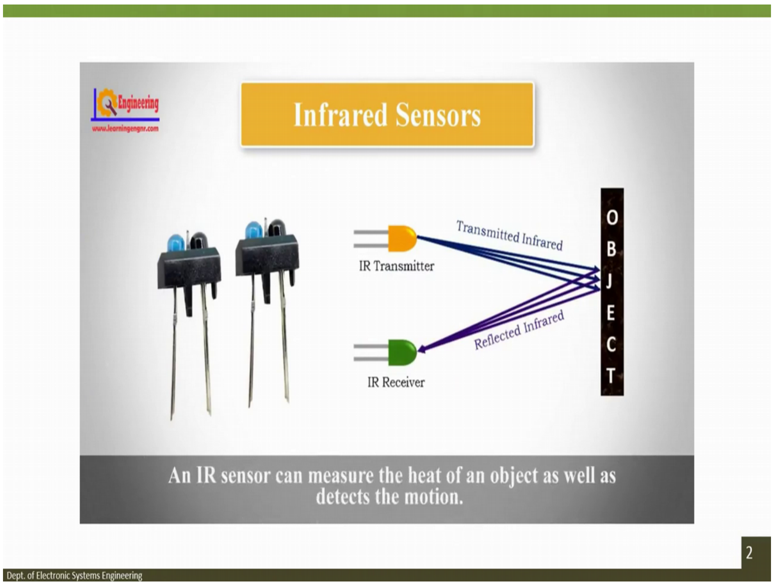


An IR sensor can measure the heat of an object as well as detect the motion.

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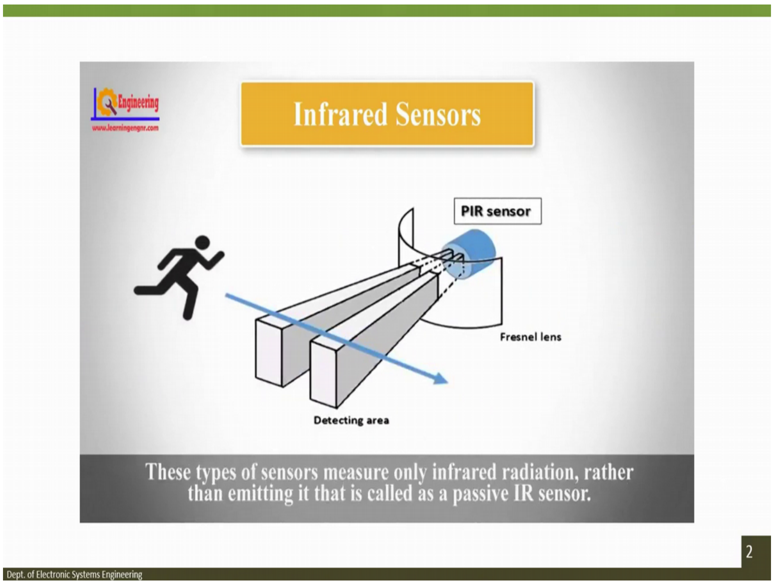


These types of sensors measure only infrared radiation rather than emitting it that is called as a passive IR sensor.

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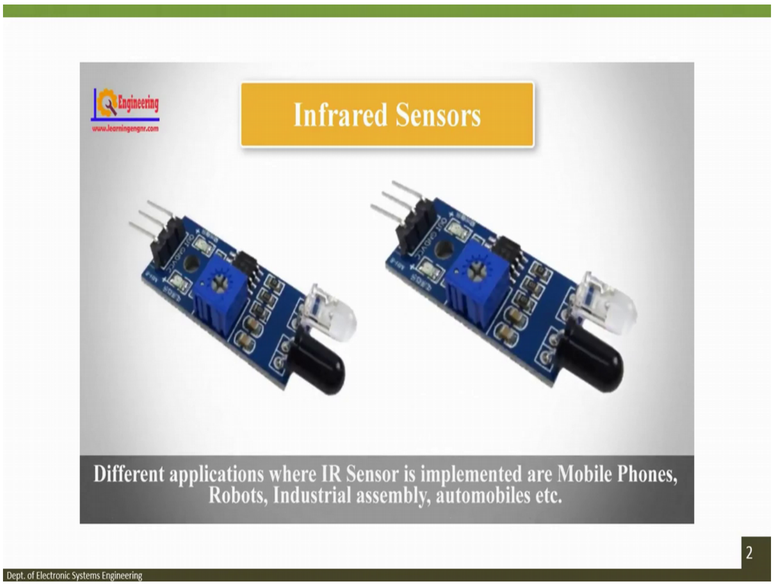


Different applications: where IR sensor is implemented on mobile phones, robots, industrial assembly, automobiles etcetera.

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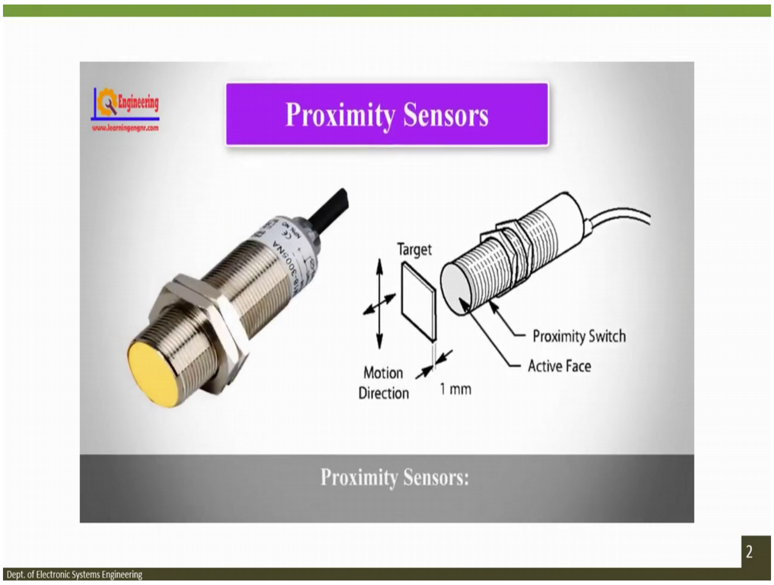


Proximity sensors.

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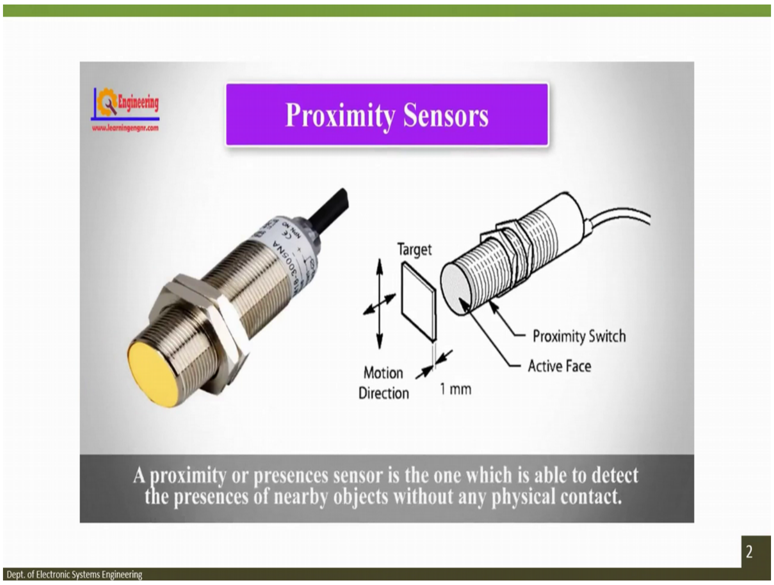


A proximity or presence a sensor is the one which is able to detect the presences of nearby objects without any physical contact.

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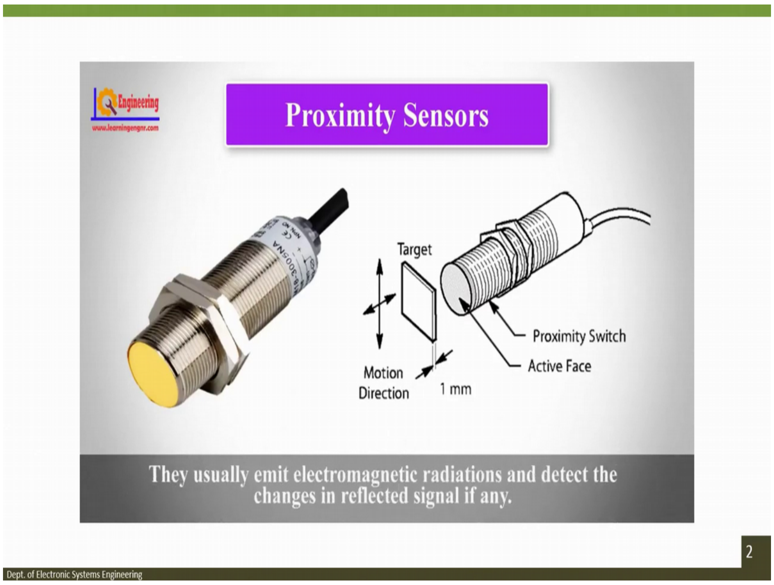


They usually emit electromagnetic radiations and detect the changes in reflected signal if any.

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Proximity sensors are also used in machine vibration monitoring to measure the variation in distance between a shaft and its support bearing.

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This is common in large steam turbines compressors and motors that use sleeve type bearings.

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Pressure sensors.

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A pressure sensor is a device for pressure measurement of gases or liquids.

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Pressure is an expression of the force required to stop a fluid from expanding and is usually stated in terms of force per unit area.

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A pressure sensor usually acts as a transducer; it generates a signal as a function of the pressure imposed.

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Pressure sensors can also be used to indirectly measure other variables such as fluid or gas flow speed, water level and altitude.

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Level sensors.

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A level sensor is one kind of device used to determine the liquid level that flows in an open system or closed system.

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The level measurements can be available in two types namely continuous measurements and point level measurements.

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The continuous level sensor is used to measure the levels to a precise limit. But they give correct results.

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Whereas, point level sensors used to determine the level of liquid whether that is high or low.

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Ultrasonic sensors.

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An ultrasonic sensor is an instrument that measures the distance to an object using ultrasonic sound waves.

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An ultrasonic sensor uses a transducer to send and receive ultrasonic pulses that relay back information about an objects proximity.

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Ultrasonic sensor can be used for measuring wind speed and direction tank or channel fluid level and speed through air or water.

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Smoke and gas sensors.

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A smoke detector is a device that senses smoke typically as an indicator of fire.

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Commercial security devices issue a signal to a fire alarm, control panel as part of a fire alarm system.

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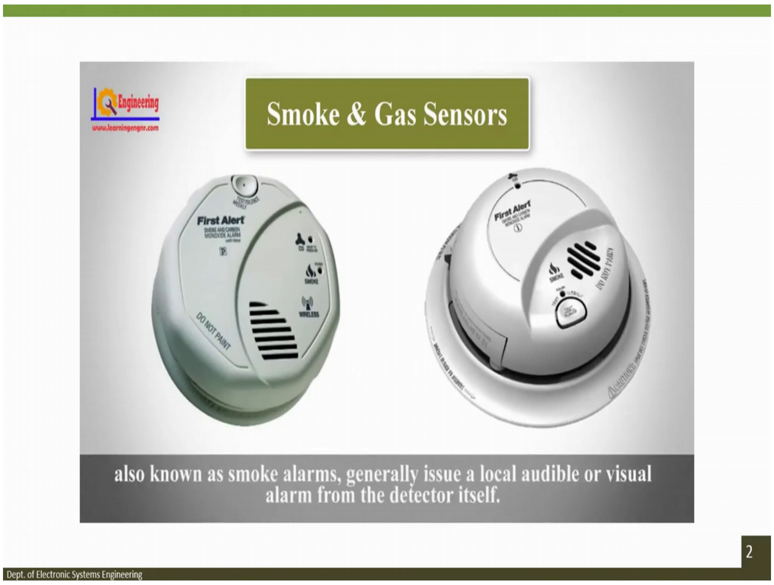


While household smoke detectors also known as smoke alarms; generally issue a local audible or visual alarm from the detector itself.

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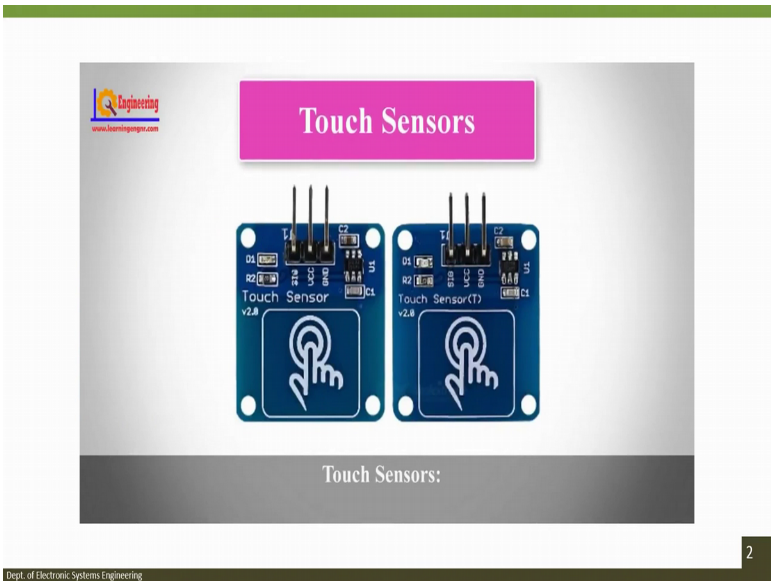


Touch sensors.

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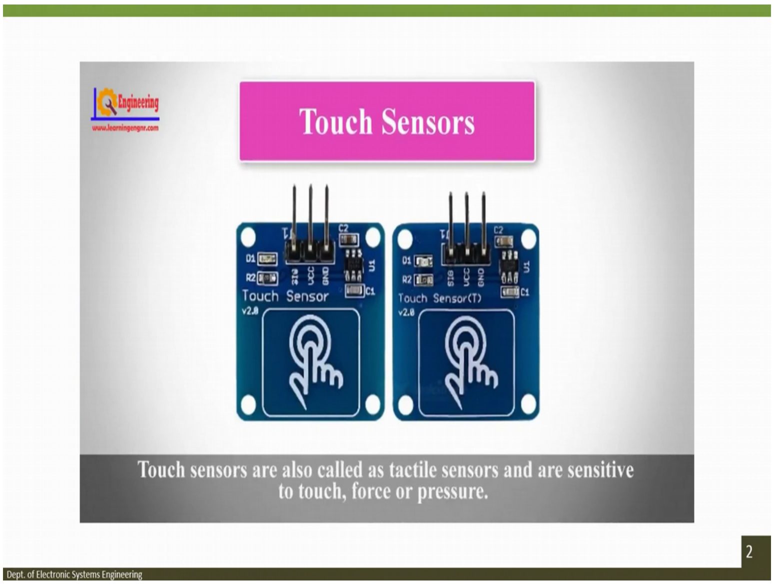


Touch sensors are also called as tactile sensors and our sensitive to touch force or pressure.

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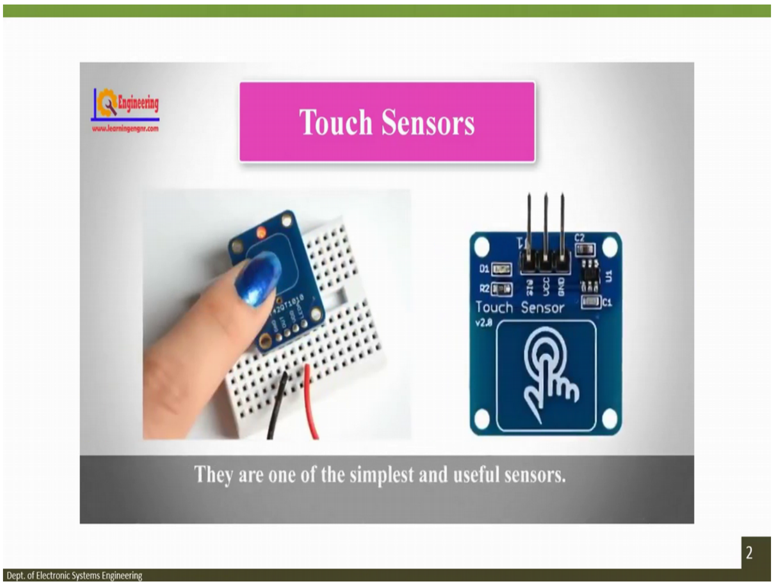


They are one of the simplest and useful sensors.

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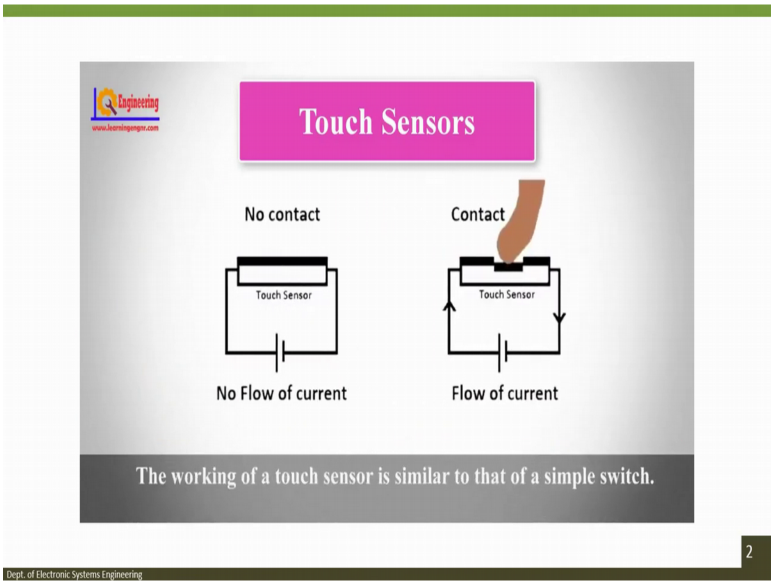


The working of a touch sensor is similar to that of a simple switch.

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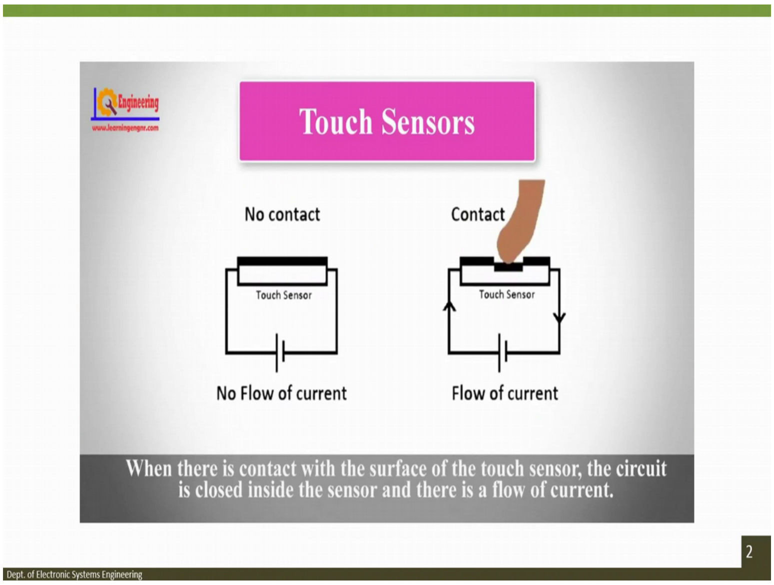


When there is contact with the surface of the touch sensor, the circuit is closed inside the sensor and there is a flow of current.

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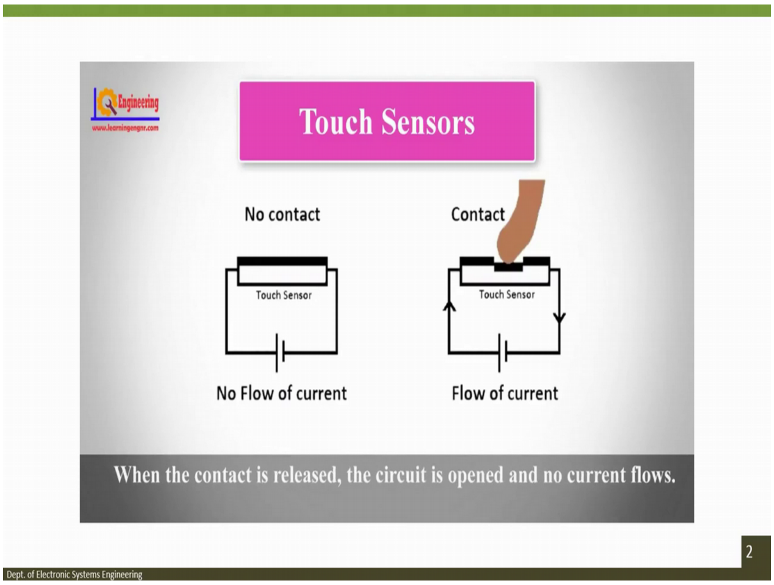


When the contact is released, the circuit is opened and no current flows.

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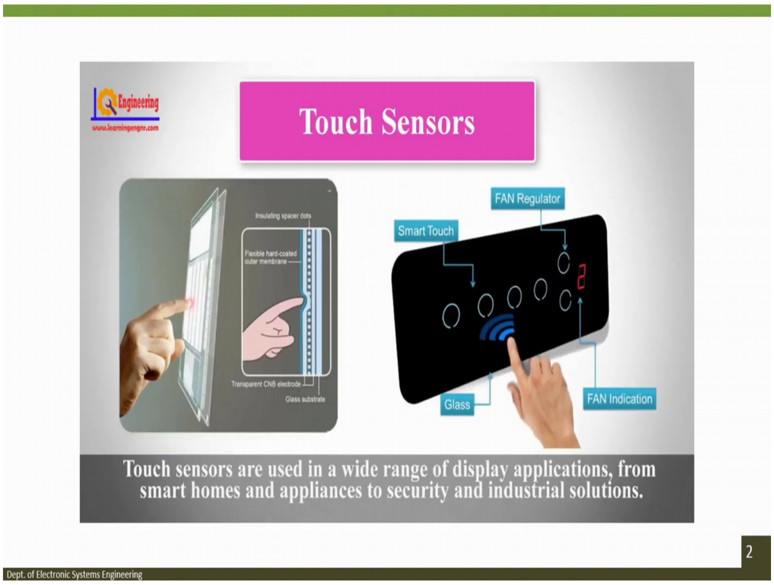


Touch sensors are used in a wide range of display applications from smart homes and appliances to security and industrial solutions dear viewers, thanks for watching the video. So what you have seen in the video is, that there are several kind of sensors and then from those kind of sensors we will be talking about metal oxide gas sensor.

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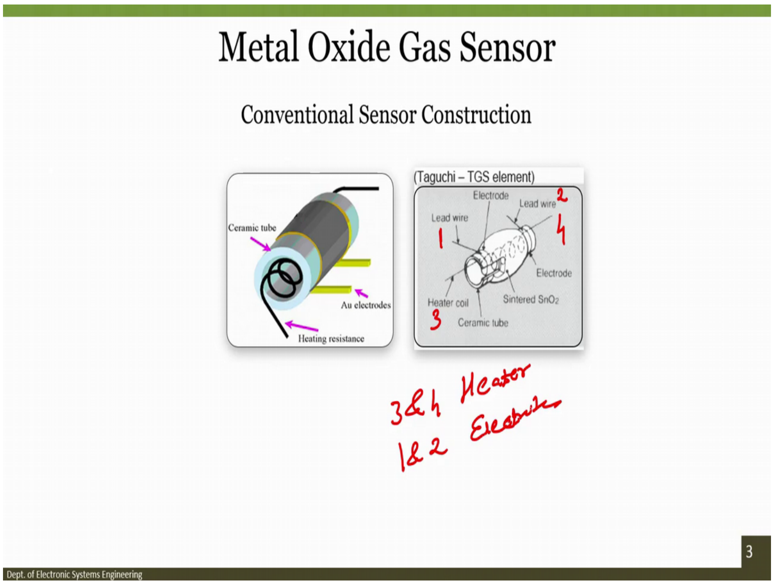


So, when you talk about material oxide gas sensor, this is the conventional sensor construction where you can see a ceramic tube and the ceramic tube has a sinter SnO 2 what does SnO 2 stands for? SnO 2 stands for tin oxide all right and then there are electrodes. So, let me first show you few of the sensors and then we talked about the sensor construction it will be kind of easier. If I want to show you the sensor I have brought few of the sensors which we have bought from Taguchi. Taguchi is a company in Japan. So, if I show you the first sensor the first sensor if you can see it has a four different terminals as you can see in my hand, and this four terminals is having n in the front there is a mesh. It is a there is a cover there is a roll of having four terminals and a cover. So, we will see what is the roll, I will I will open the second sensor.

So, you will understand and actually I will show it to you few of the sensors there is a second sensor again you can see here there are four different pins which you can see and in the front there is a mesh right. There is a mesh in the front and if you see there are four different terminals which are here, now there is a role of this four different terminals and I will show it to you in the in the slides now what each terminal role is there all right.

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Same way if I show you another sensor, I can show it to you right over here right and here what you see is again there is a casing and the top and there are four terminals in the bottom.

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Again what is the role of these four terminals we will check in the in the next slide right and each sensor is meant for a particular application. Now let me show you a sensor with a kind of signal conditioning circuit.

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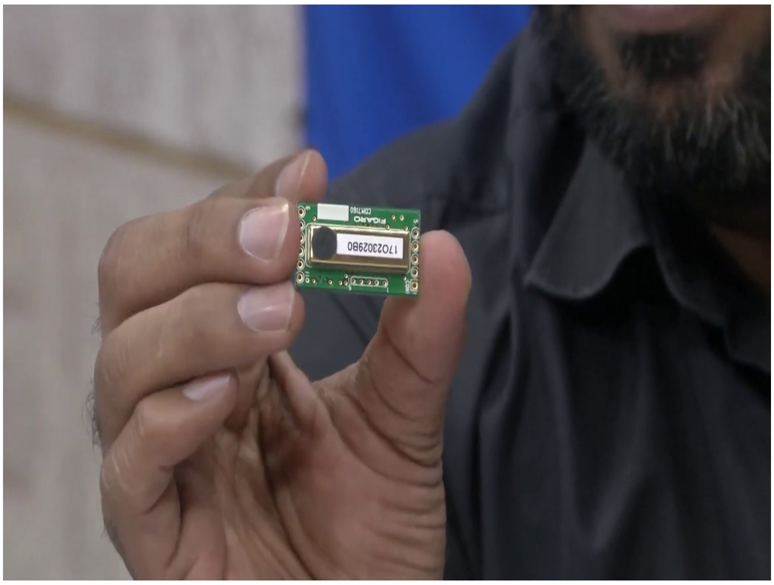

So, now I am holding a CO 2 sensor which is right over here. So, if you see the CO 2 sensor yes.

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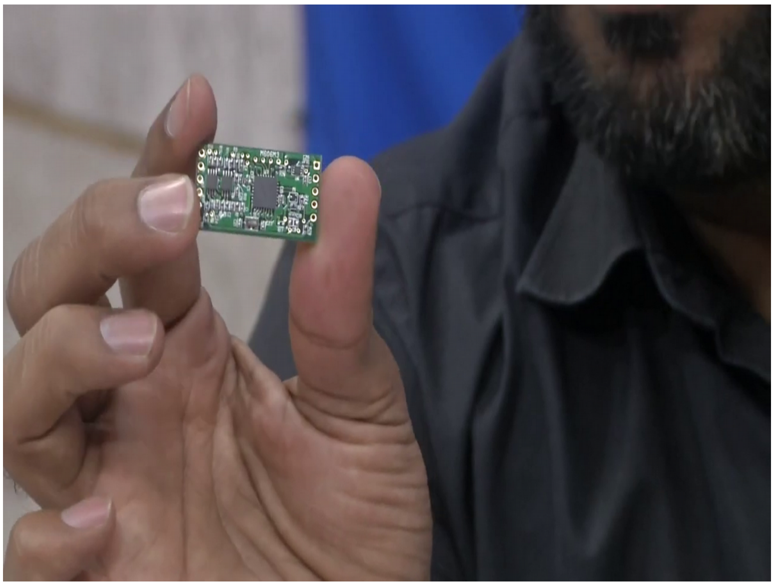

And in the back side there is a whole signal conditioning circuit, which you can see here right. So, this comes with a signal conditioning circuit, but if I talk about other sensors they do not come by signal conditioning circuits.

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For example if I am showing it to you the earlier sensors that I have shown they do not come with similar conditions circuits these 3 sensors right all 3 sensors they do not have any similar conditioning circuit. But this one has its own signal conditioning circuit which is on the back side this is the front side right. So, it is kind of very easy to understand easy to see how the sensor looks like. Similar sensor if I want to design a signal conditioning circuit using Arduino or using raspberry pi 3 what kind of circuit we can design we will see in the slides. Now if you focus on the on the slide what we see is there is a sintered SnO 2 SnO 2 sense for tin oxide right now there are lead wires.

So, let me write down or give the number to each of the wire the so, lead wire 1, lead wire 2 heater coil is 3 1 here and the second and half coil is given number 4. Now you can correlate why we have four different terminals at the backside of the sensor or we have four different pins for each sensor, the two pins pin number 3 and 4 are meant for heater; while pin number 1 and 2 are meant for electrodes alright. So, we have 4, then that is why each of those sensor were having 4 different terminals.

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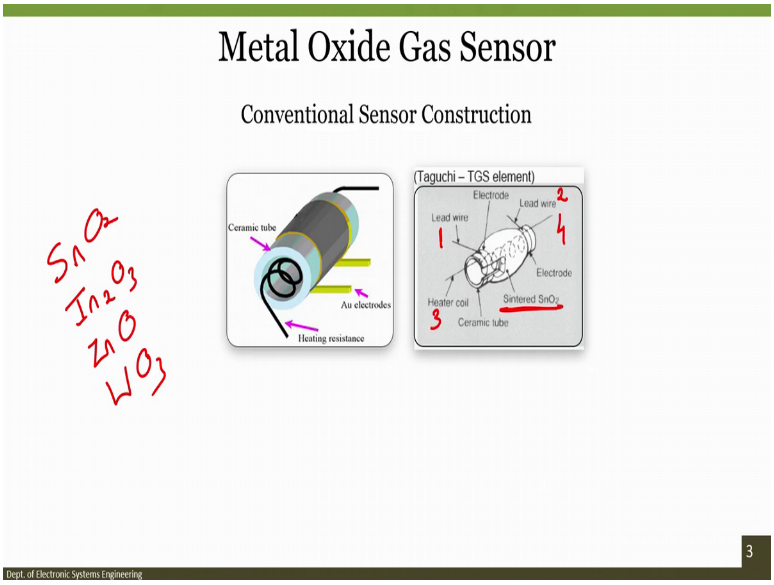


Now, there is a ceramic tube and within ceramic tube there is a sintered tin oxide. Why it is called metal oxide? Because you see this is tin this is indium this is zinc this is tungsten.

If I want to have metal oxide, then I will have tin oxide, indium oxide, zinc oxide, tungsten oxide all right. So, this is how the metal oxide semiconductor uses sensing material, they use the we had to use a metal oxide semiconductor as a sensing material in the sensor, while you require a heater to increase the sensitivity. Here you will see why heater and how heater can help in increasing the sensitivity in few slides, for now this is a conventional way of fabricating a sensor.

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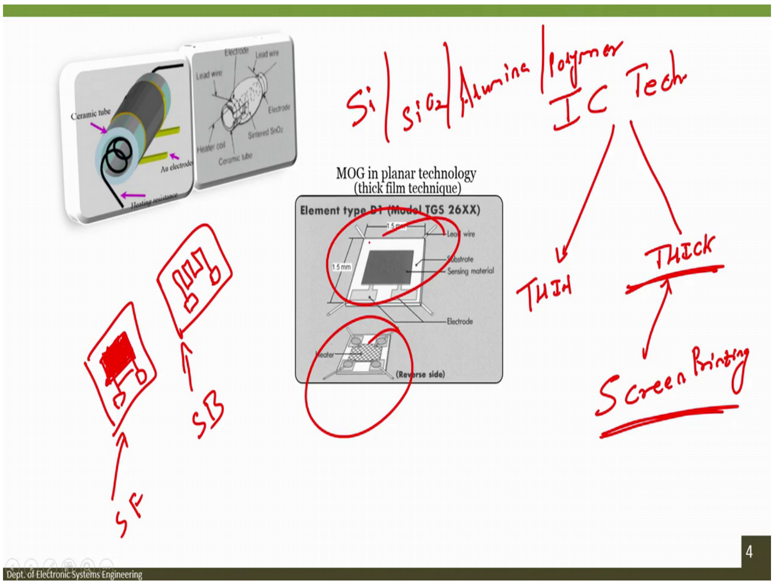


If I see a second way of fabricating a sensor it is using a thick film technology. Now if you know integrated circuit technology right then you will understand, that there are several kind of technologies one is thin film technology and another one is thick film technology. In thick film technology we use screen printing screen printing right. So, using the screen printing technology using the thick film technology, we have fabricated a sensor and that is why it is called thick film technology. Now again the front side of the sensor right if you see if you take a substrate can be substrate can be silicon, substrate can be silicon dioxide, substrate can be alumina right substrate can be polymer also.

So, if I take this substrate this is a substrate and this is the substrate front side, this is substrate back side, then if I have a electrode right like this and on that electrode if I if I use a sensing material, which is my metal oxide semiconductor right on the back side I have a heater on the back side I have a heater this is the back side this is a front side ok. So, now, what is the advantage of screen printing is that, we can have a high throughput we can fabricate lot of sensors very quickly right.

The disadvantage is that we cannot miniaturize it beyond a certain point we cannot make it tiny all right. So, there is a disadvantage. Again after you do the screen printing you have to sinter the material you have to heat or anneal the semiconductor metal oxide or metal oxide semiconductor to certain temperature so, as to form the sensing layer. This is an example of that type D1 right which is model 2 g a at 2 g sorry TGS 26 xx which is again from Taguchi.

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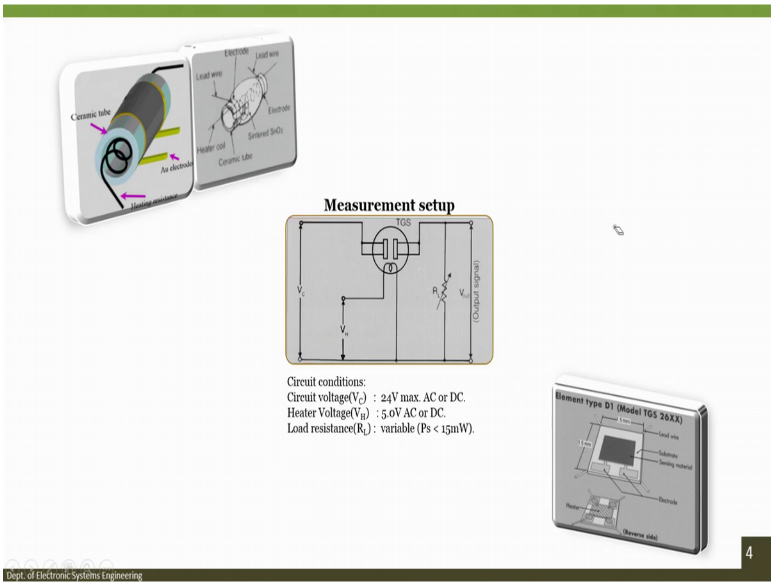


And then let us see the circuit electronic circuit or conditioning circuit for using these sensors. So, the first thing is we have to apply a voltage, we will apply a 24 volts AC or DC which is your voltage across the semiconductor and then we have a heater voltage which is your 5 volts and then finally, you have a load register which is variable in nature all right and the power consumption should be less than 15 milli watt.

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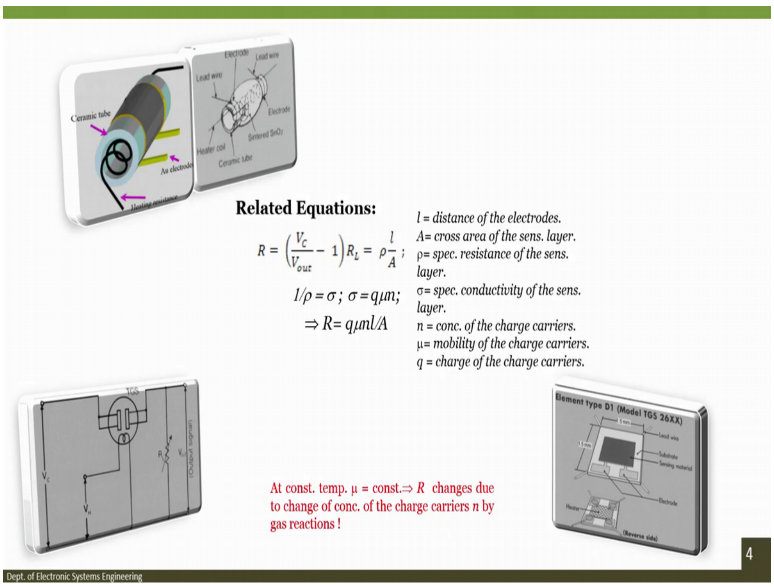

If I go for the equations, then this is how the equations are placed where we have R equals to Vc by V out minus 1 into RL equals to rho by l by A rho l by A is nothing, but the resistance, resistance and rho is the resistivity l is your length and A is the cross sectional area. If you if you increase, the length the resistance will increase if you decrease the area resistance will increase, if you are increase the resistivity resistance will increase if we decrease the resistivity resistance would decrease you cannot change the resistivity, if I using the same material, but you can always change the length you can always change the area thus the resistance is depending on length and area and it also depends on resistivity, but for a single metal you cannot change the resistivity.

So, depending on what kind of resistance you want for a final heater, you need to select that particular material or a metal for fabricating that particular heater. So, if you see the slide where the l is equals to the distance of electrode, A is cross sectional area of sensing layer rho is specific resistance of the sensor then we have specific conductivity, we have mu mobility we have n concentration of charge carriers and finally, q is a charge of the charge carrier. So, in a constant temperature we have mu constant; that means, R changes due to change of concentration of the charge carriers and by gas reactions.

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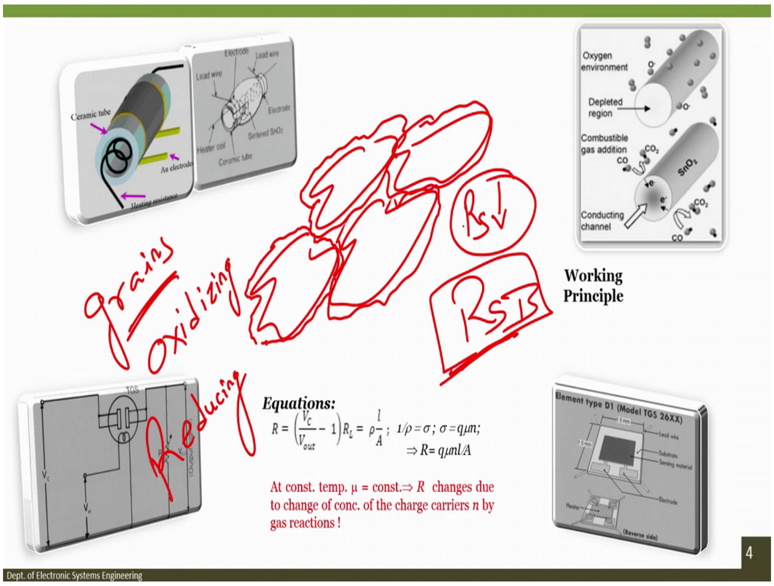


So, if I talk about the working principle, what happens is if I just zoom it out this gas sensor sensing material is consisted of several grains we called grains g r a i n s ok. And each grain will lose some electron and will cause a depletion layer a depletion boundary around it. While losing some electron it will have a depletion boundary around it right in presence of the oxygen in air right and this causes this depletion layer, that I have drawn across the grain will cause some kind of resistance value, which we call as a base resistor. Now if I if I inject oxidizing gas. So, there are two type of gases; oxidizing and reducing if I use oxidizing gas, then the electrons will be depleted further from the depletion layer and the resistance of the sensing layer would increase.

While if I use a reducing gas then the electrons will be donated and the depletion layer width will reduce causing the resistance of the sensing layer to decrease all right. So, based on what kind of gas we are using whether it is oxidizing gas or reducing gas you will see the change in the resistance. This initial is a base resistance or our sensor base resistance this is sensing resistance which is different than the base resistance either this resistance would decrease or it would increase right.

So, that is what is a basic principle behind the gas sensor or metal oxide gas sensor in particular the same thing is shown here then in the presence of oxygen there is a creation of depletion layer if you have a combustible gases like CO 2 then the depletion layer would increase resistance would increase.

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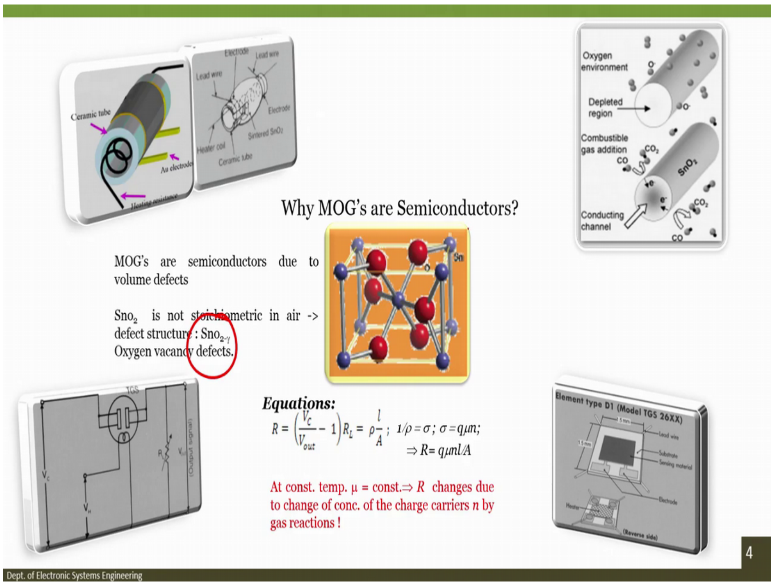


So, the question is why we have to use metal oxide semiconductor gas sensors this is because of the volume defect SnO 2 is not stoichiometry in air, but different structure

SnO 2 whereas, this one right shows the oxygen vacancy defects. So, that is why we can use the SnO 2.

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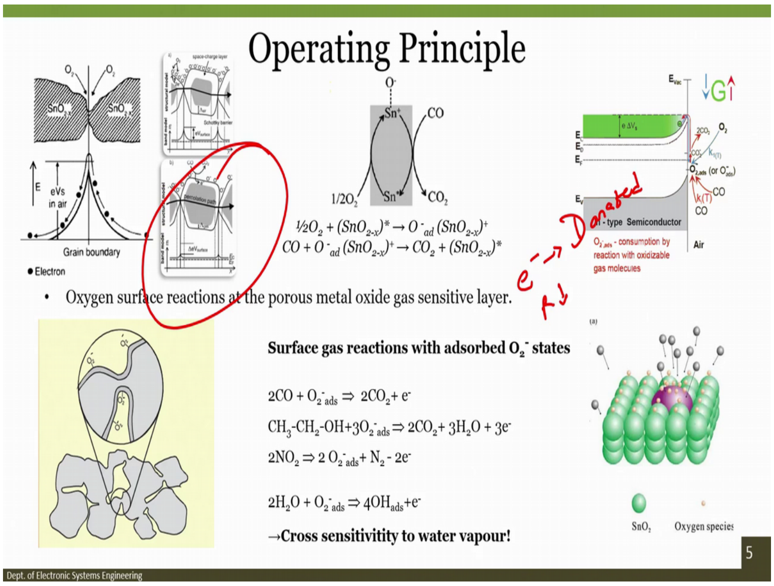


Same way if we are talking about the operating principle like I discussed each is consists of a few grains and there is a depletion layer which is a space charge layer, today that is created in presence of oxygen and on inducing oxidized gas or a reducing gas, this depletion layer width will change. So, if I talk about just CO 2 then you can see here that my energy band diagram also changes with respect to the reaction of the CO 2 onto the semiconductor oxide and here you can see that O 2 minus adsorption consumption by reaction with oxygen oxidizable gas molecules, how the energy band diagram changes.

Where if I talk about the SnO 2 then this is our reaction occurs that with SnO 2 if there is a the sensing material is of SnO 2 and if I use CO 2 as a gas to be sensed then this is a reaction that is involved. So, oxygen surface reaction at the porous metal oxide sensitive layer, surface gets reaction with adsorbed O 2 minus states and the reaction occurs as 2 CO plus O 2 minus two CO 2 plus electron; again you can see that we have CH 3 CH 2 OH plus 3 O 2. So, CH 3 CH 2 was is nothing, but your ethanol and if you have that then again you have electron that is released you have NO 2 electron is you know released it is absorbed while you have H 2 O then you have electron which is released. So, when there is a electron is released what happens is that, the electron is released, I mean into the into the material the depletion layer would reduce and that depletion layer reducing of depletion layer will cause change in the resistance which is the reduced resistance.

So, you understand by this, if the electrons are donated then what will happen? Resistance reduces right, but if the electrons are taken up from the material, resistance would decrease this is what is there.

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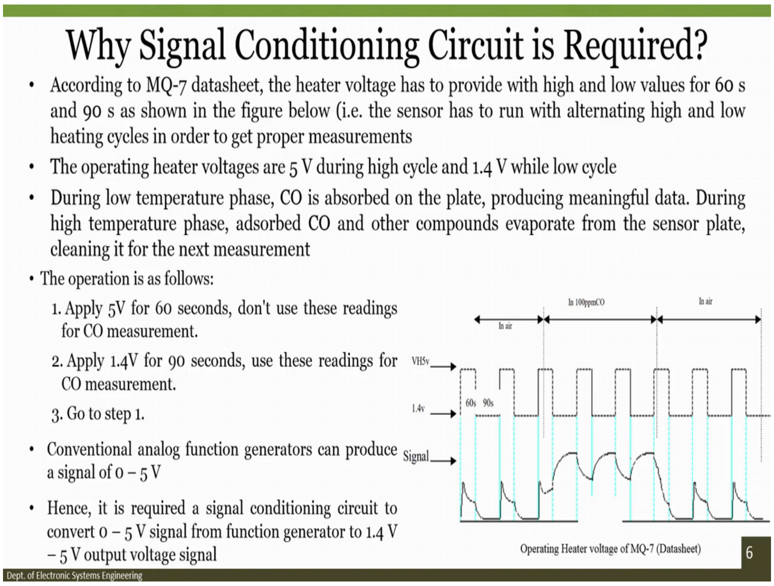


Now, we need to know why we had to use signal conditioning circuit if you have such kind of sensors right. And then I will show it to you one example where I will show it to you how the process flow for fabricating such kind of sensor can be designed all right so, that you know that in your laboratory any design such kind of sensors as well or not. So, if I see why signal conditioning circuit is required, then first is we are talking MQ-7 and MQ-7 stands for gas sensor. So, if you see MQ-7 gas sensor datasheet the heater voltage has to be provided with high and low values for 60 seconds and 90 second as shown in figure below.

Now before we go here let me just talk one more thing which I forgot if I see this particular thing what happens you know, that when you heat the material when you heat the semiconducting oxide material, the you have a higher sensitivity because a depletion layer also increases and you have more available sites for the gas to react. At a lower temperature you have these sites which are reduced, but at a higher temperature you have a increase in the reaction sites.

So, the gas molecules can react better at a higher temperature compared to a lower temperature. Now the absorption and adsorption will also be different at a different temperature also if I use the sensor at different temperature, I can also use the sensor as selective sensor. Using all the sensors any sensor that I have shown you would be sensitive to one or different gas is it selective that is very important. But when you operate and when you use the sensor you will find that these sensors are not selective to make those sensors selective, we need to change the temperature that is one way of increasing selectivity.

Second way of increasing selectivity is by using the sensor in array, and then you use machine learning technique or you can say artificial neural network to delineate that particular VOC. So, the role of heater is to increase the temperature of the semiconducting oxide and by increasing the temperature of semiconducting oxide you are increasing the sensitivity of the sensor all right. So, coming back to the slide the role of signal conditioning circuit so, that the heater has to provide a high and low values at 60 and 90 seconds as you can see from here right and then what will happen the sensor has to run with alternating high and low heating cycles order to provide proper measurements.

The operating heater voltage are 5 volts which you can see. Now you can see here we require from 1.4 volts to 5 volts ok. So, that is why you need to have a signal that you can convert from 0 to 1.4 and maximum 5 remains 5 we will see how we can design this, but anyway the operating voltages are 5 volts during high cycle while it is 1.4 volts while low cycle. So, during low temperature phase CO is absorbed on the blade, producing meaningful data. But during the high temperature phase CO is adsorbed adsorb is it will come out adsorption absorb is it will be absorbed in the sensing layer, it will have reaction with the molecules ok. And other compounds you operate from the sensor plate cleaning it for the next measurement; that means, that whenever we apply 1.4 volts there will be absorption change in sensitivity, change in resistance not sensitivity change in resistance, and when we apply 5 volts the gases that were absorbed would be adsorbed all right.

So, the operation is as follows apply 5 volts for 60 second do not use this readings for CO measurement, apply 14.9 well then use this readings for CO measurement geo go to step 1 and do and follow the step conventional analog function in under can produce a signal from 0 to 5 volts. Hence, it is required that we design a signal conditioning circuit to convert this 0 to 5 volts for functionality for 1.4 volts to 5 volts for the output signal.

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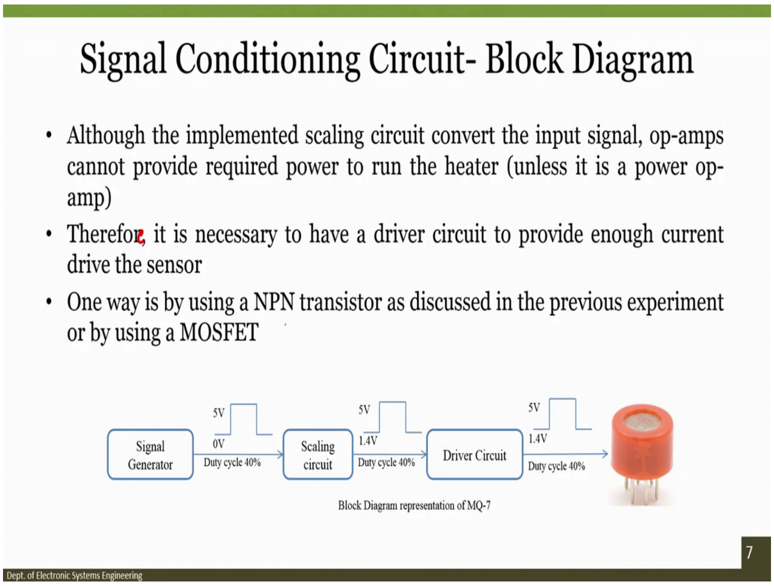


And if you can see the block diagram, the block diagram is that there is a signal generator there is a skilling circuit driver circuit and finally, you can see the this is a sensor that we are using although the implemented scaling circuit convert the input signal op amps cannot provide the required power to run the heater unless it is a power open. There is another disadvantage that until we use the power op amp, it cannot be used to run the heater or drive the heater.

Therefore, sorry for the mistake in this padding therefore, it is necessary to have a driver circuit to provide enough current to drive the sensor, one way is by using NPN transistor, as we have seen in the earlier experiments and we will see in the later experiments as well or by using a MOSFET.

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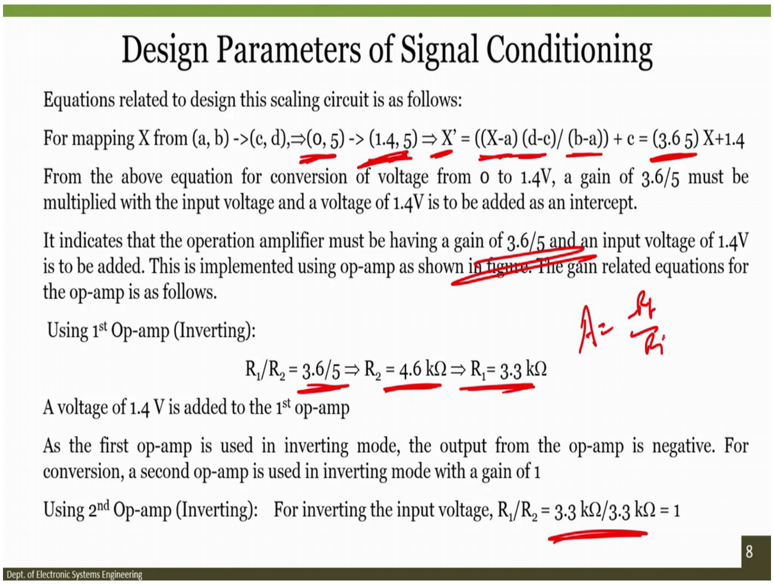


So, how can be equation how can we design the circuit and what kind of equations we need to follow? So, you see for mapping x from a b to c d that is from 0 to 5 volts, we do convert to 1.4 to 5 volts what we require? We require X there should be equals to X minus c d minus c divided by b minus a plus c. So, it should be 36.65 X plus 1.4. If x is 0 if X is 0 then we will have output as 1.4 volts right if X is 1 then we have output close to 5 volts right.

So, from the above equation for conversion of 1 0 to 1.4 again I have 3.6 by 5 must be multiplied with input voltage and voltage of 1.4 to be added, as intercept indicates that operation amplifier must be having a gain of 3.6 by 5 it is very easy to understand.

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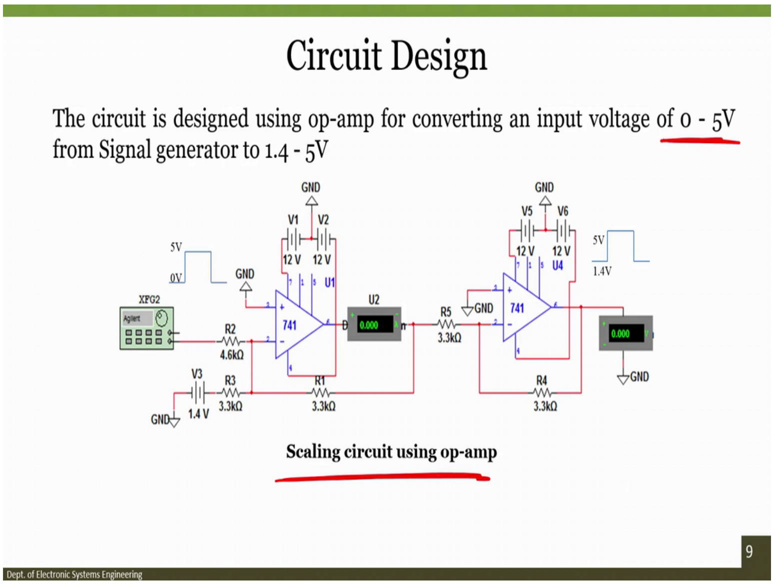


And an input voltage of 1.4 volts is to be added this is implemented in the next figure which is right over here right. So, this figure if you see and you can use a multi seem to understand whether the circuit can work according to what we are looking in that in the theory class, then what we have is that the gain related equations for the op amp is as follows. For inverting R 1 by R 2 is 3.6 by 5.

So, R 2 equals to 4.6 kilo ohm and R 1 can be 3.3 kilo ohms right. So, if I use this particular circuit then if I have R 2 equals to 4.6 and R 3 equals to 3.3 then only I can have my gain of 3.6 by 5, right. So, a voltage 1.4 is added to the first op amp if you again see, what we are done is we have added 1.4 volts to the first operational amplifier from the two operation amplifier shown in the figure, and as the first op amp is used inverting mode the output from the op amp is negative for as conversion a second op amp is used in a inverting mode with a gain of 1. So, if you see this one where this op amp has a gain of 1 and its just to convert the input signal which is out of phase 2 in phase.

So, there is a at the at the output there is a the phase will be shifted because of the inverting op amp and here again if we use inverting op amp, the phase will be shifted which is similar to phase at the input signal. So, that is the reason of using a two stage operation amplifier, again this can be act as a buffer or unity gain amplifier because the gain is 1 right. So, using second op amp we have inverting input R 1 by R 2 equals to 3. So, inverting input you already know for inverting amplifier our gain would be equals to minus Rf by Ri right that is why we just consider R 1 by R 2, if I have both the resistance value same which is 3.3 kilo ohm what will happen? I have gain of 1. So, if I have gain of the if I have values 3.3 kilo ohm and 4.6 kilo ohm for op amp 1 and 3.3 kilo ohm for op amp for R 1 R 2 for op amp 2, then I can design my signal conditioning circuit right and this circuit can be used to convert the input voltage from 0 to 5 volts to 1.4 to 5 volts.

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Now, let us see a video how we can use the gas sensor with Arduino alright. And then I will show it to you how you can use gas sensor with raspberry pi and then we will see how we can fabricate the gas sensor we will see the process flow. So, let me just show it to you let me run this video first.

Hi, these little guys are MQ-2 and MQ-5 gas sensors, they look identical and you can probably tell them apart only by the labels.

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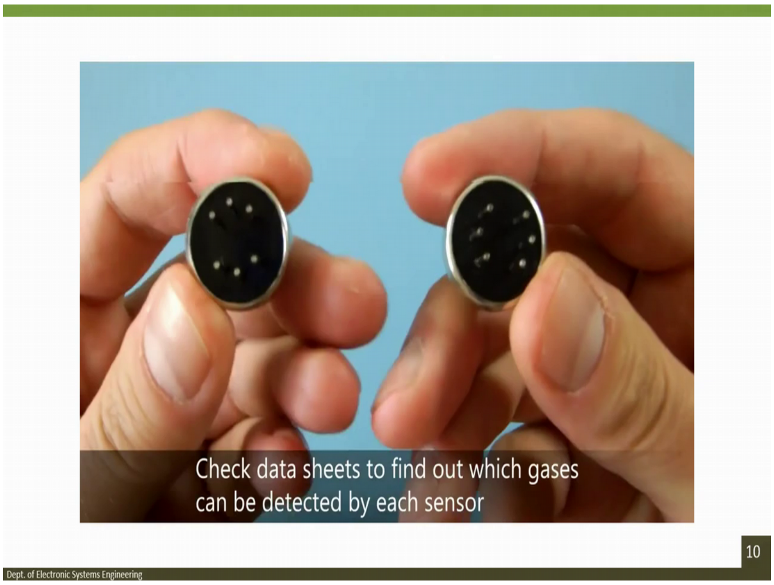


Both require exactly the same connections, but they detect different gases in this tutorial I will show you how to use one of them with Arduino.

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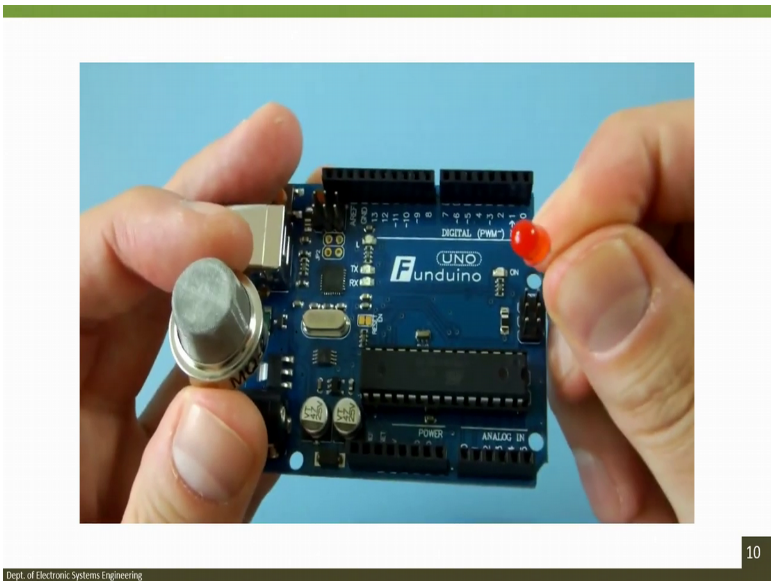


We will be reading values from the sensor and make the Arduino light an LED when gas concentration rises above certain level to build this project you will need a few things.

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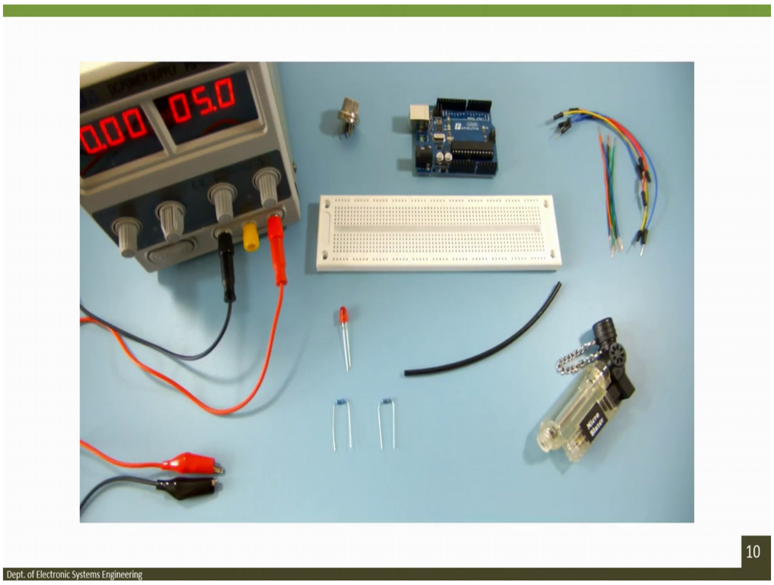


A 5 volt dc power supply that can deliver at least 0.3 amps an MQ 2 or MQ 5 gas sensor an Arduino board a breadboard a few wires an led a 120 ohm resistor a resistor close to 20 k a piece of heat shrink tubing and a gas lighter or torch let us start playing with the sensor. A gas sensor has 6 pins.

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These two middle legs are heater coil pins, do not worry about polarity it is not important in this sensor. The next two legs are a pins and they should be connected to each other the last pair is named b; and these two pins should also be connected to each other.

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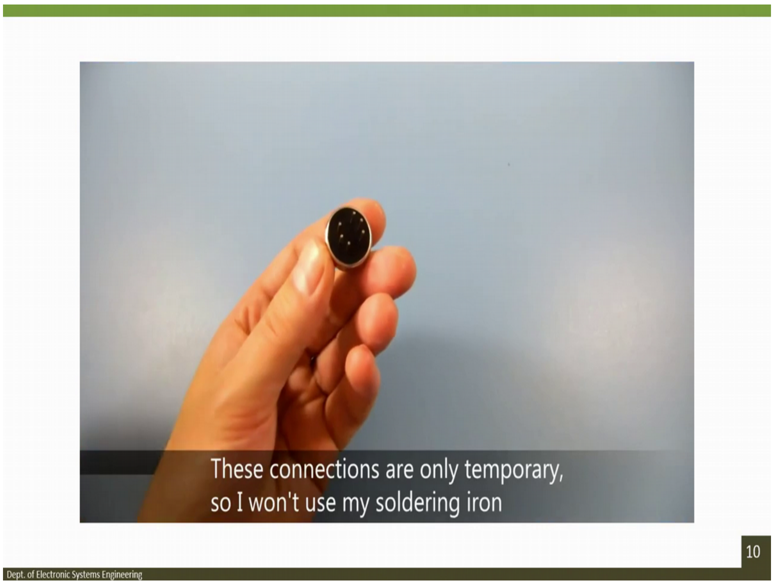


I will connect my wires to the sensor using heat shrink tubing.

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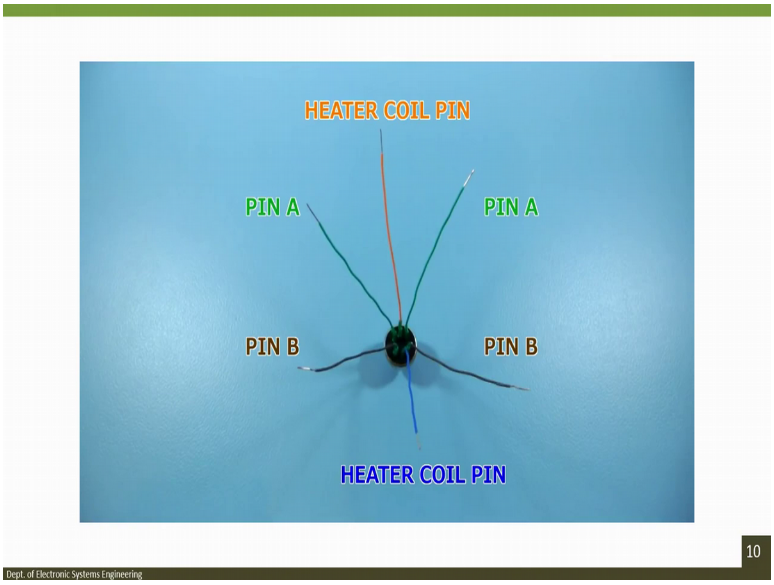


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Now, let us connect the sensor to the breadboard; one of the heater coil wires goes to the positive rail and the other one to ground. Connect both a wires to the positive rail on the breadboard, hook up the b wires to the same row and to ground through a 20 k resistor.

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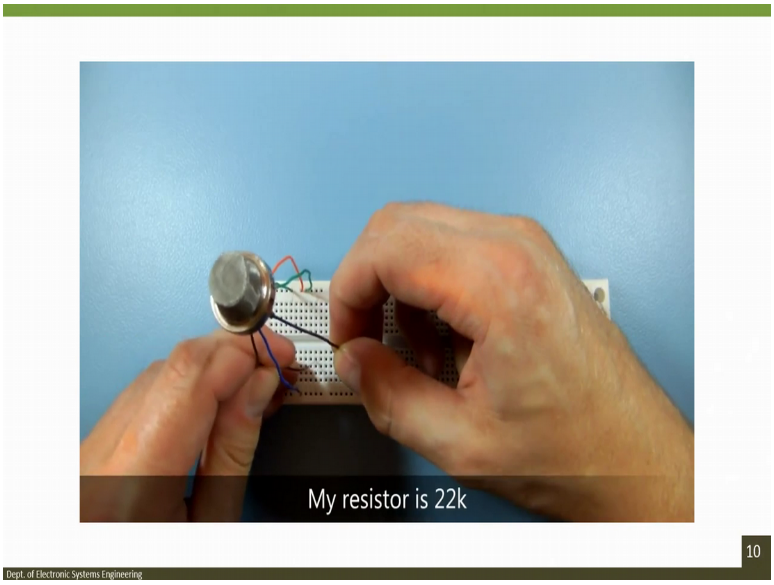


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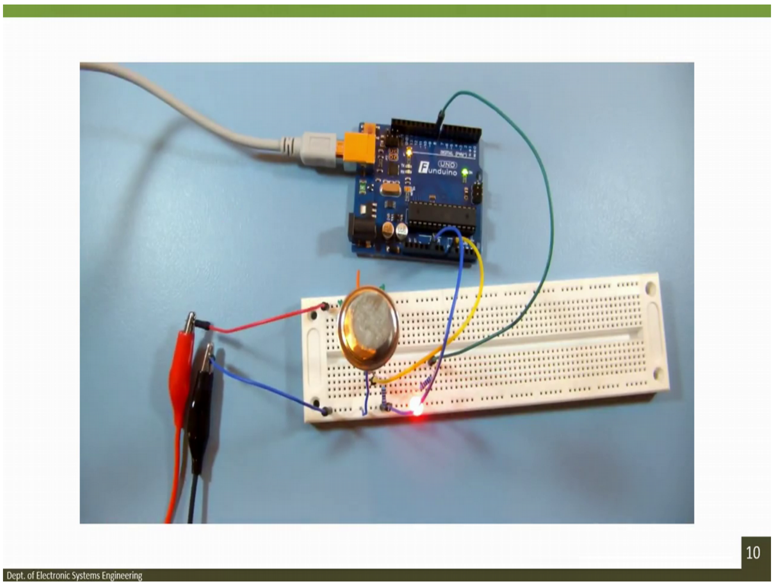


A jumper wire goes between the b pins and a 0 pin on your Arduino board, connect your breadboard ground rail with the Arduino ground pin. Hook up your LEDs negative lead to ground and the positive lead to one of empty rows on the breadboard. Connect a 120 ohm resistor to the positive lead of your led and the other end of the resistor through a jumper wire to your Arduinos pin number 8. Connect a jumper wire to the positive rail on your breadboard and another one to the ground rail hook up your power supply to these jumper wires and the Arduino to your computer. Download the code from my website and upload it to your Arduino you will find a link in the description below.

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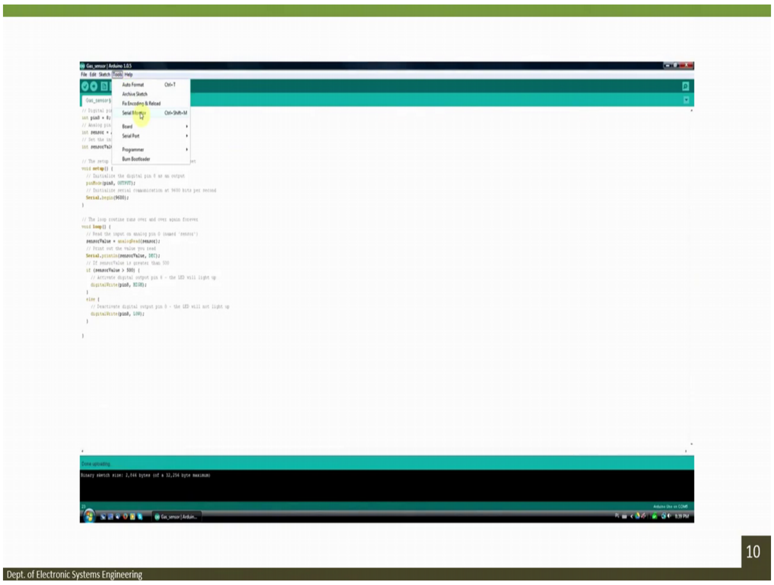


Now, go to Arduino IDE select tools serial monitor.

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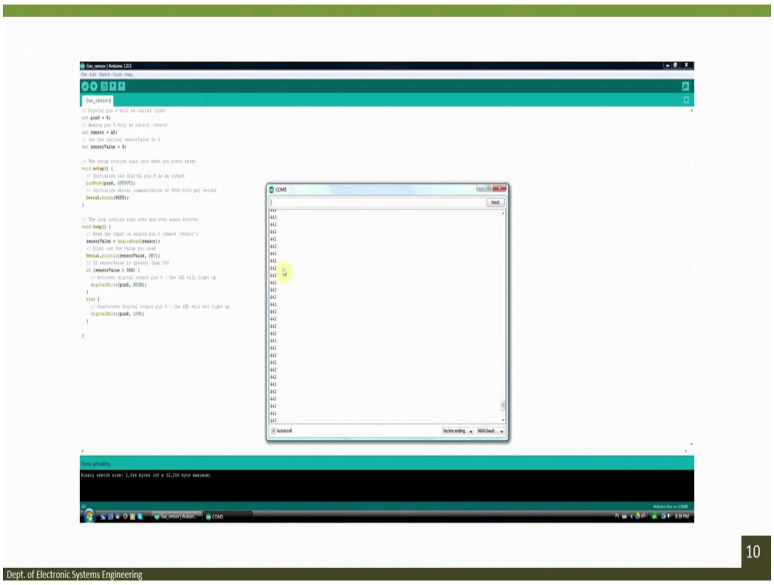


And you should see a value between 0 and 1023 if your sensor detects gas, the value goes higher. Readings from the sensor are reliable after about 2 to 3 minutes after powering up; after about 3 minutes you will notice the readings will go lower and stabilize at a certain base value.

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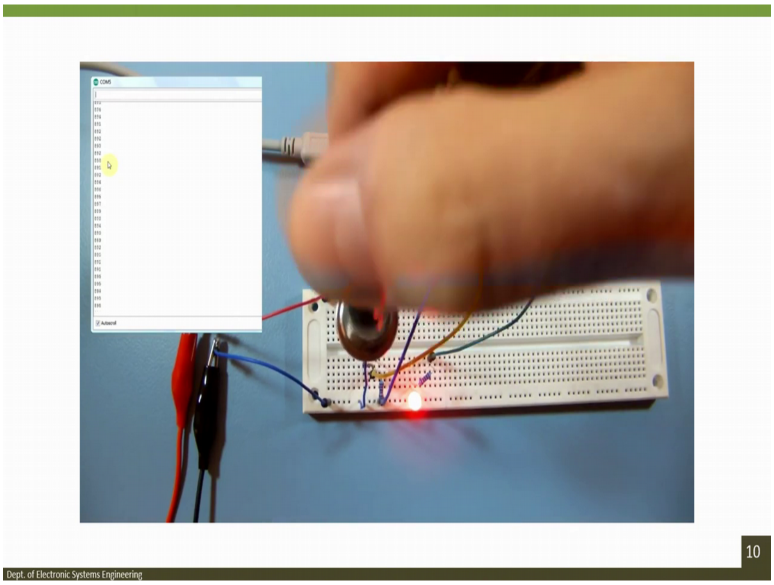


Now, I will try to give my sensor some gas from a mini torch, as you can see the value increases instantly. When it reaches 500 the LED lights up you can adjust sensitivity by changing the sensor value in the code to match your needs now you know how to use a gas sensor with the Arduino. Now, let us see another video where we are using raspberry pi let me play the video.

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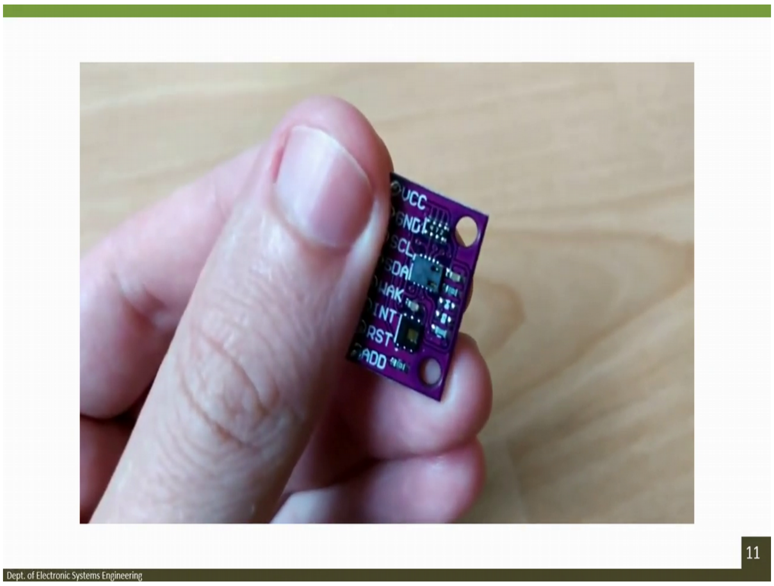

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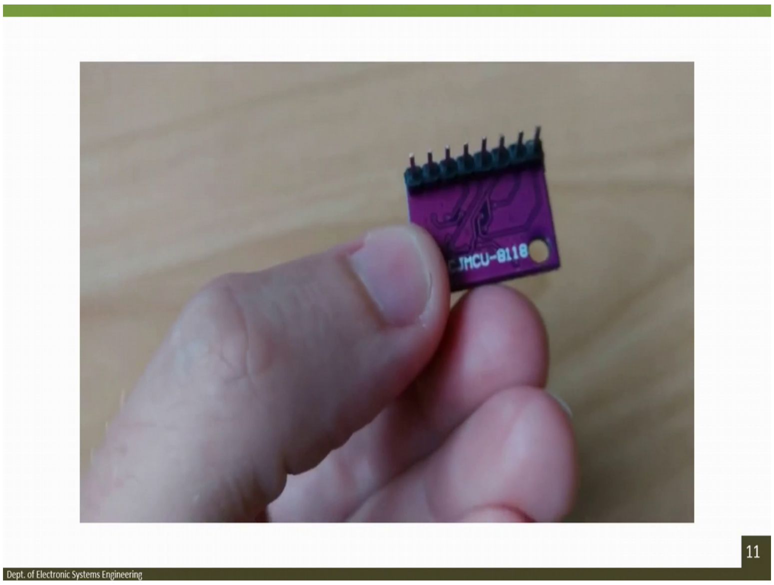


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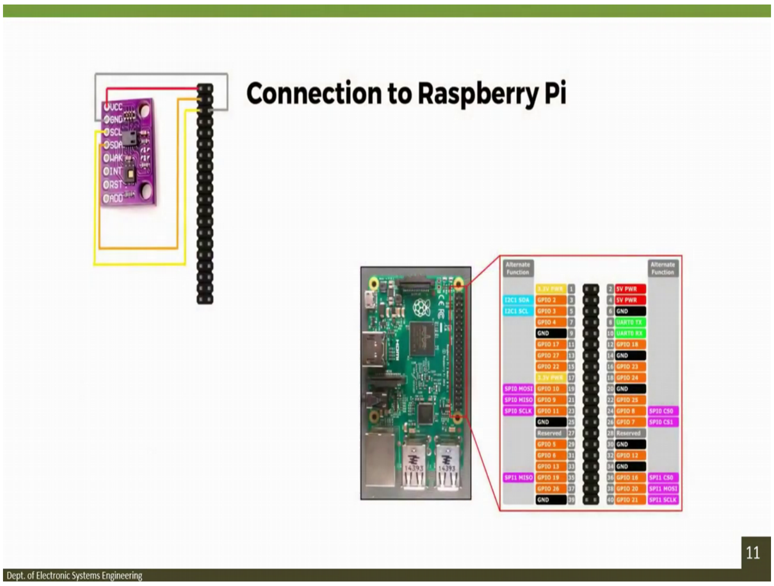


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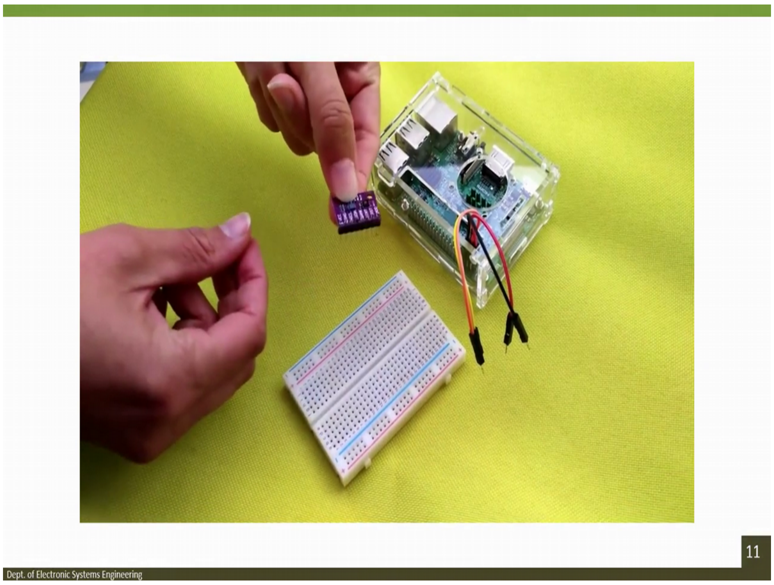


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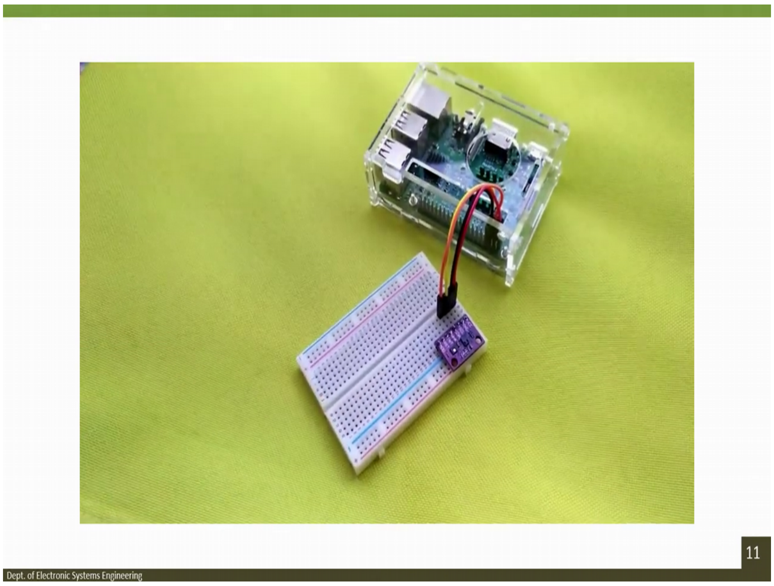

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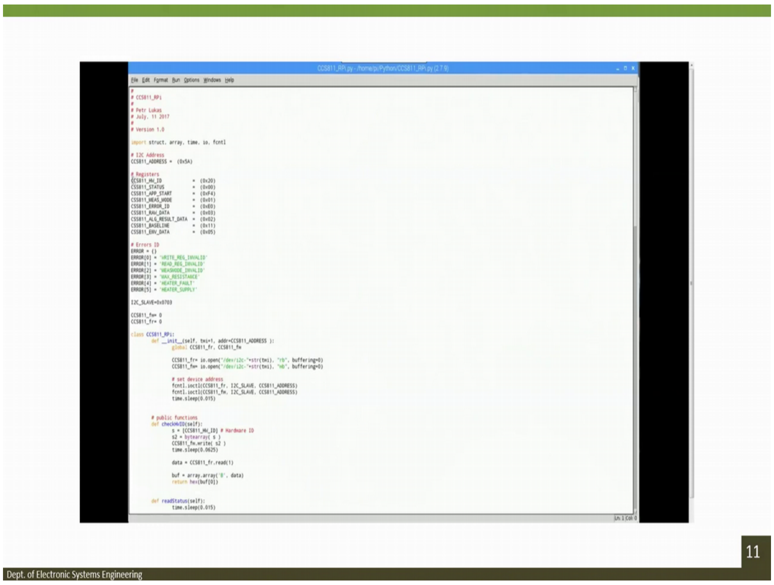


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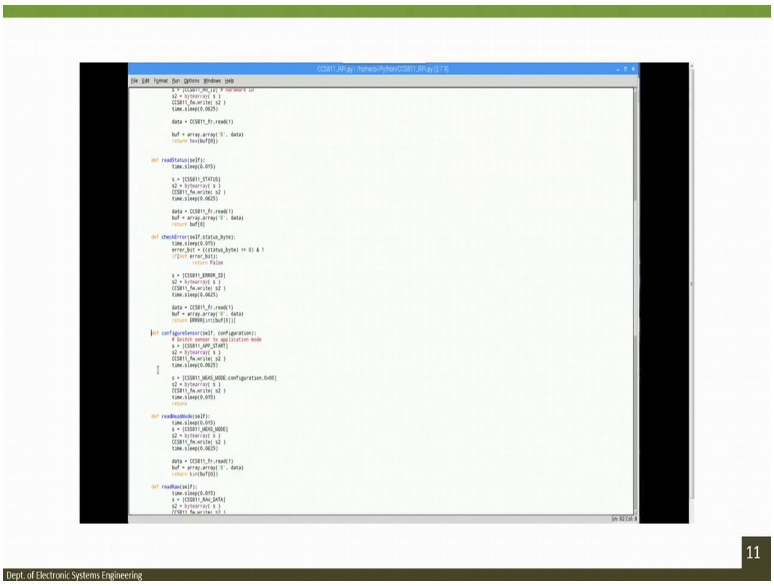

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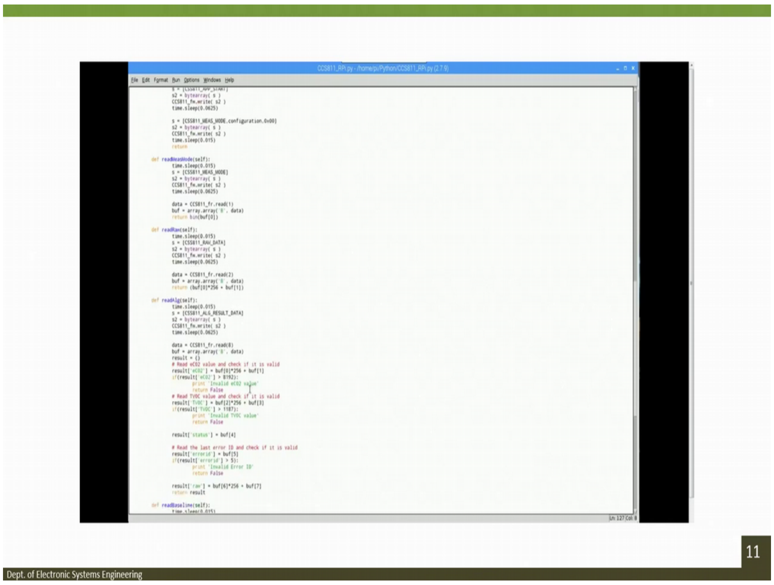


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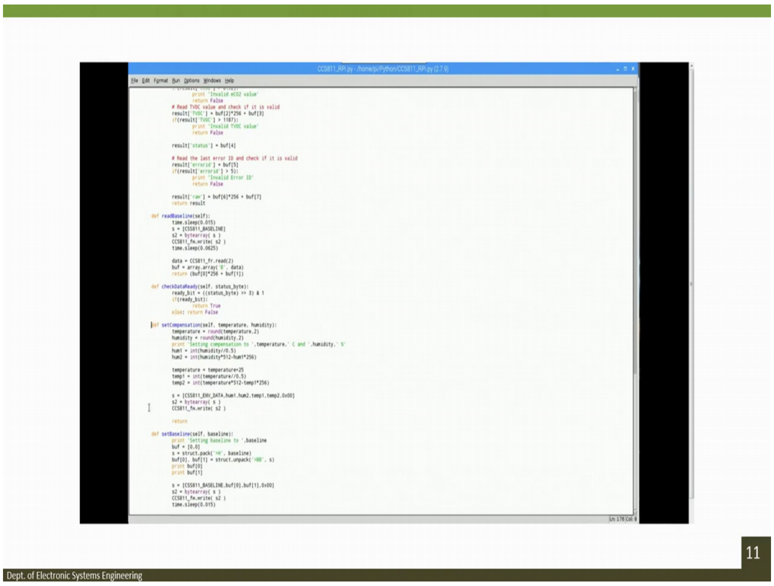

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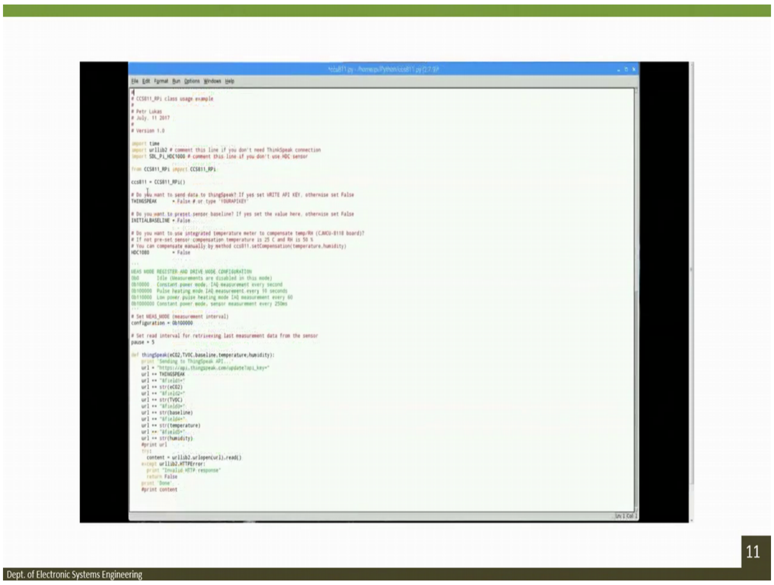


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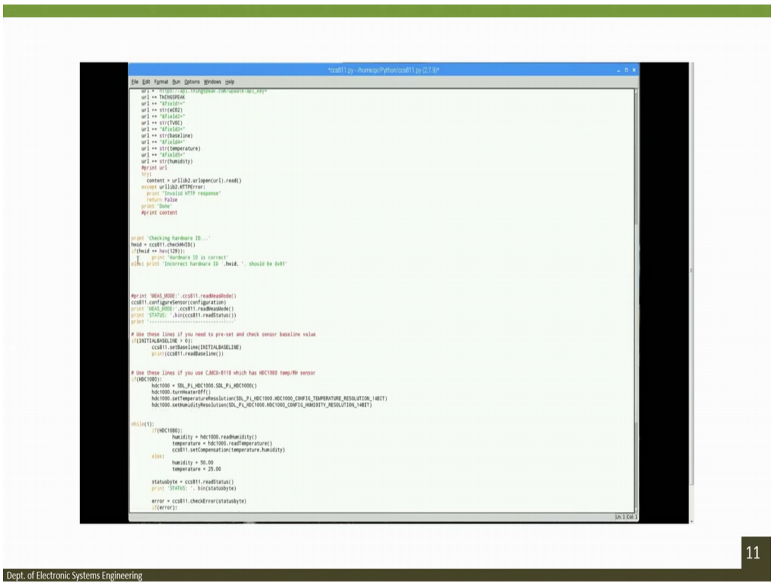

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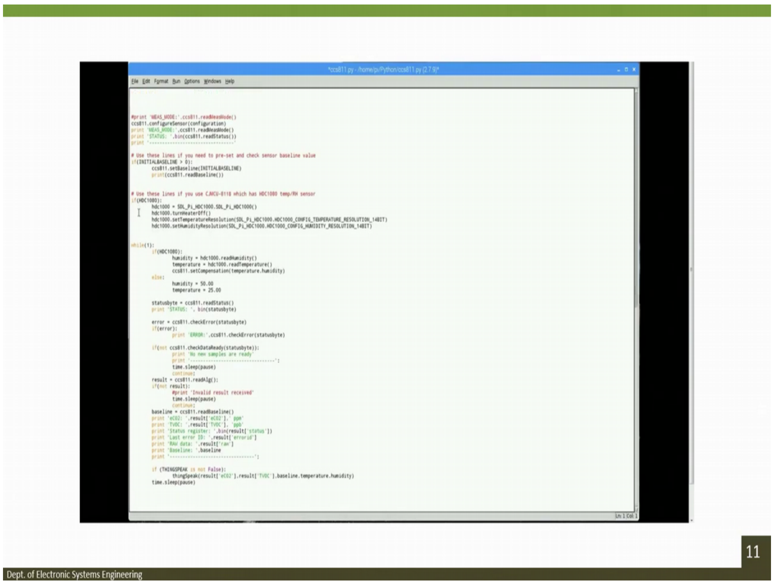


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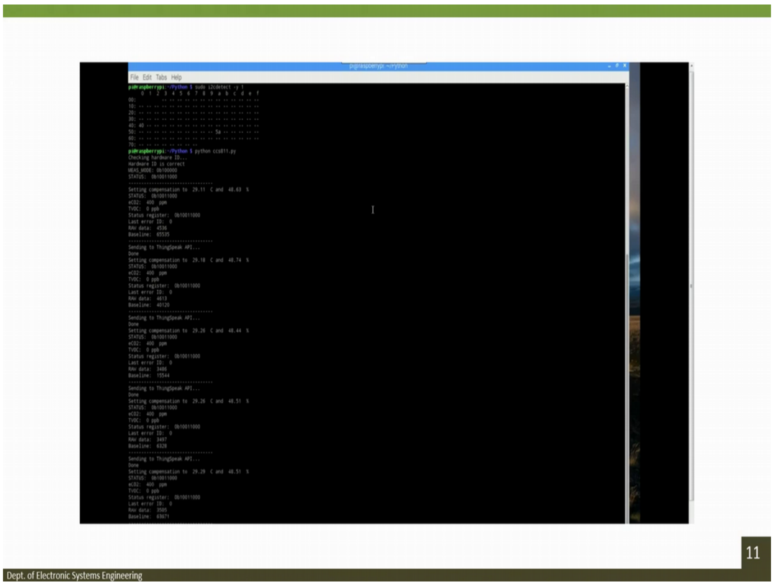

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**List of available sensors and combo boards**

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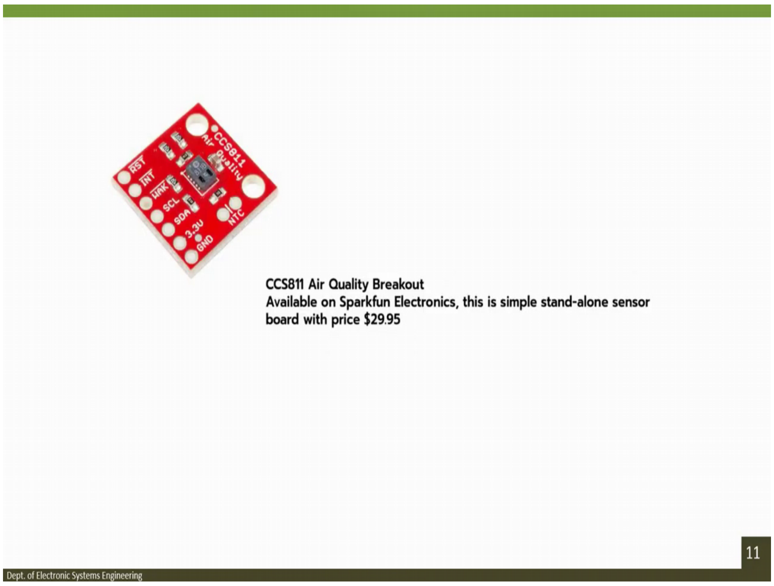

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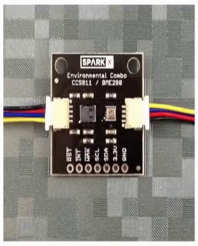


**Qwiic Air Quality Combo Board - CCS811 + BME280**

Available on Sparkfun Electronics - this board it combines CCS811
and high precision temperature, humidity and air pressure meter
BME280 from Bosch Sensortec
Price of this board is quite high: 54.95 USD



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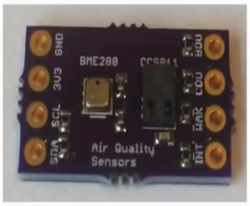


**Air Quality Sensor**

Available on Tindie for 35.95 USD,
this one is very similar to Qwiic Air Quality Combo Board,
it contains CCS811 and BME280 sensors.

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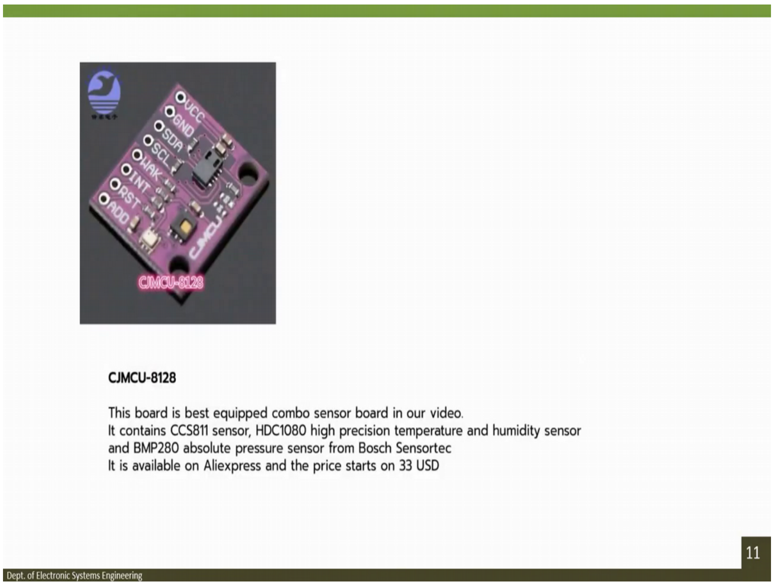


Now if you see what we had to do is that, I will show it to you how can we design a gas sensor, and what are the process flow for designing that particular sensor ok. Alright now till then you take care, I will see you in the next class; bye.