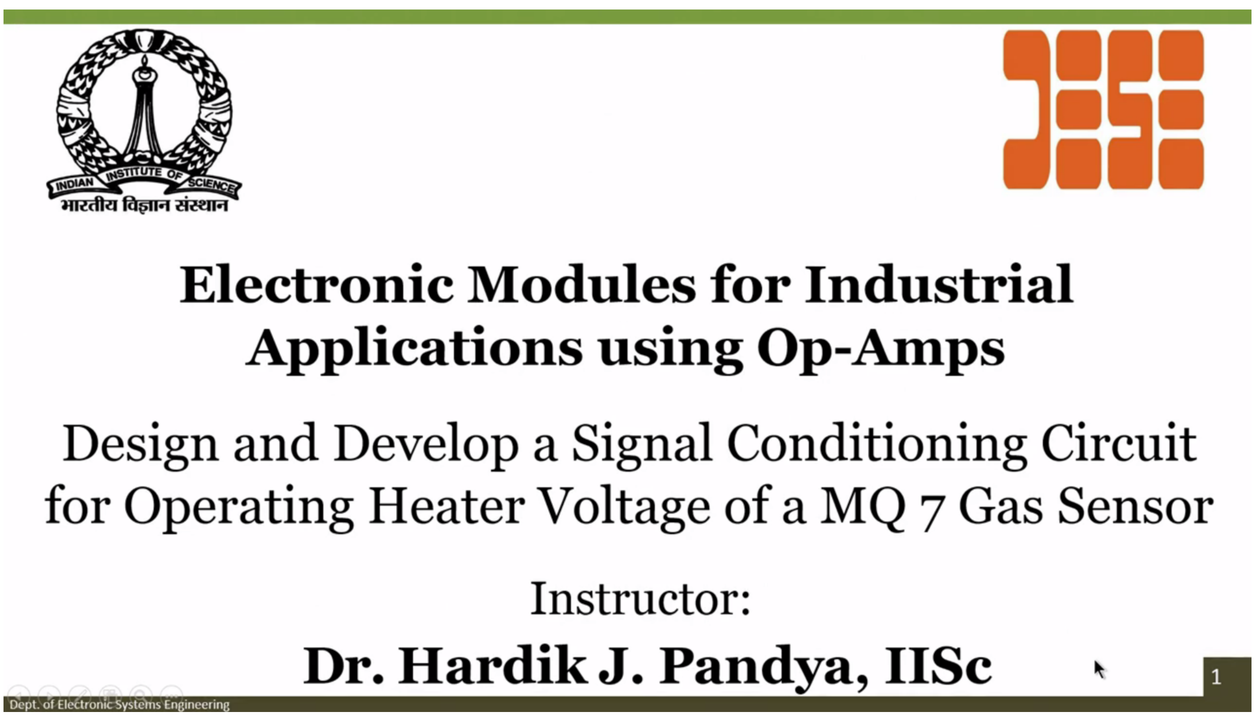
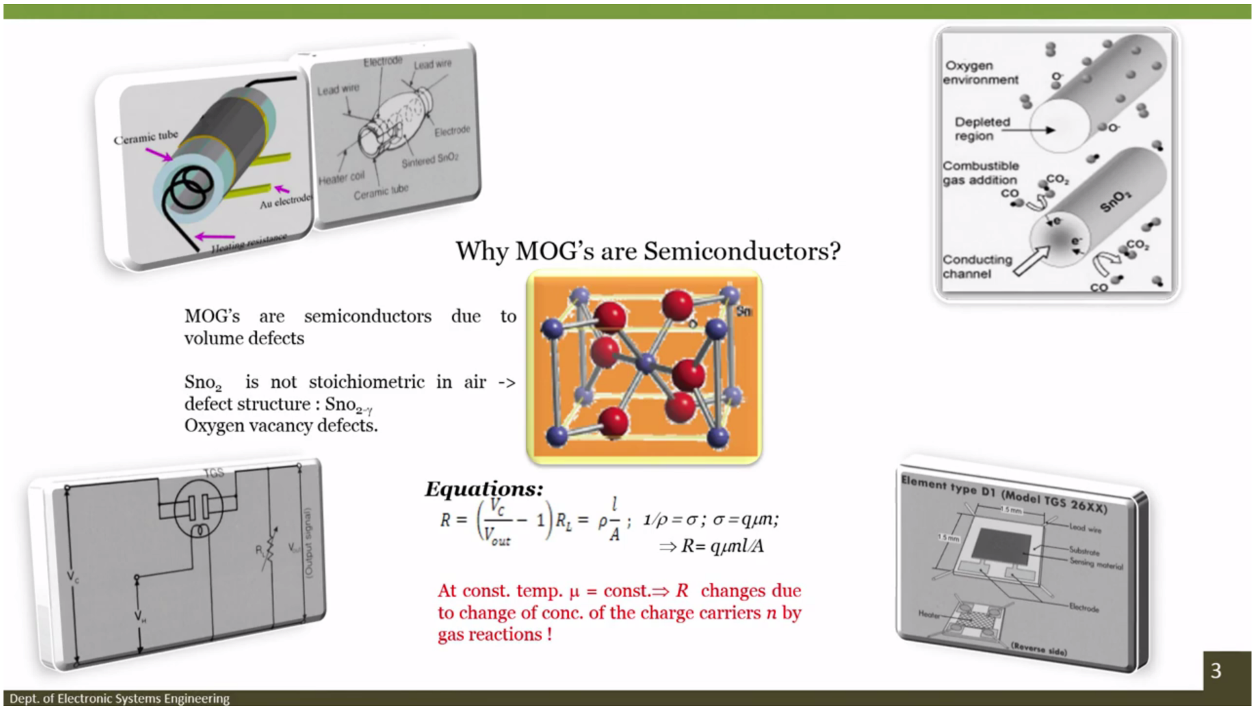
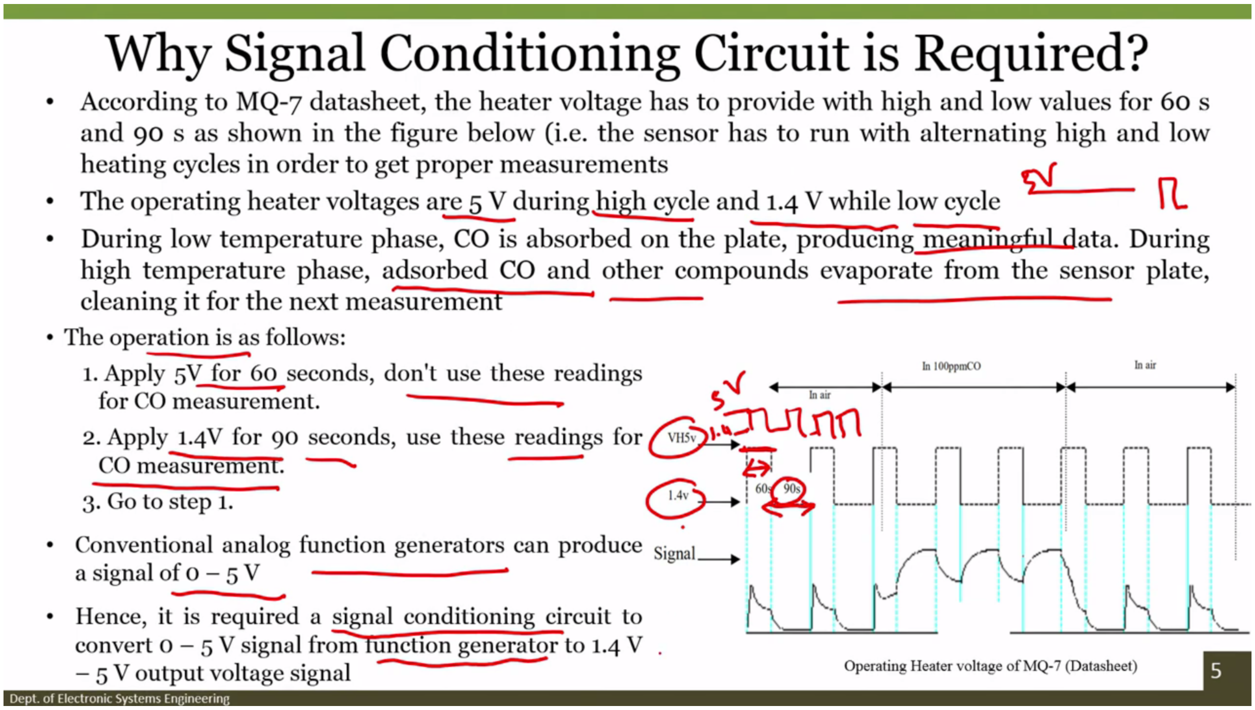
Female Speaker: Hello everyone. Welcome to the course, and let's get into the next module where we study more about how do you design the signal conditioning system for MQ7 gas sensor. Let's get into the details.



So I am sure professor Hardik has covered the fabrication process and what is the purpose of MQ7 gas sensor. It is designed to detect carbon monoxide, but let’s see once the device has been fabricated, let’s see how do you do the signal conditioning, how do acquire data from these sensors once they are fabricated, and how do you modulate these based on the requirements.



So this the details about the MQ7 gas sensor, the different parts of it and how they can be integrated with the other systems. So I am sure this would have been covered in detail.



Now we are talking about the signal conditioning circuit for the MQ7 gas sensor. So why do we have to focus on how specific we have to be regarding the conditioning system? there is a little complexity with the sensor, the choice of sensor. So when we are talking about MQ7 and if you look at the data sheet of this sensor, the gas detecting sensor, to be specific, it is the carbon monoxide. So what does the datasheet tells us, the voltage has to be provided between two-range. So it is 1.4 volts and 5 volts. Ideally what is it? If you just give a supply volts of 5 volts to any device what you buy in the market and then give the rated supply, but the way the sensor operates is between two levels of voltage. So the operating heater voltage is 4 volts, which is the upper voltage during the high cycle, and 1.4 volts when it is a lower cycle.

So the pulse here is having a certain duty cycle. So it is not a constant voltage, say, 5 volts which has to be given as this input to the sensor. Here, the pulse width is constantly -- the pulse width varies, so that is the rise time has to be 60 seconds and the voltage here should be 5 volts, and the fall time, once the pulse falls down, it has to remain there at 1.4 volts for 90 seconds. So this pulse width, the rate at which the pulse is being generated has to be vary between two voltage levels. That is the lower voltage should be at 1.4 and the upper one at 5 volts. So how can we achieve, this is what we will be discussing in detail today.

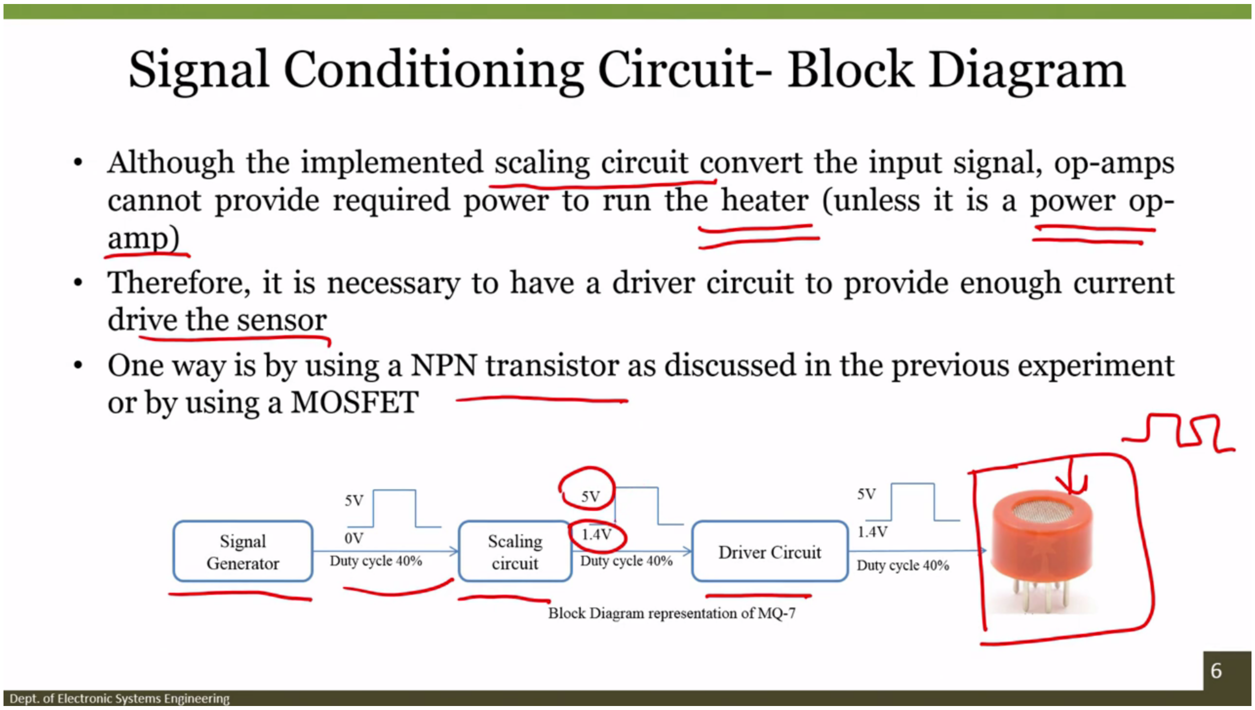
Now this was the requirement of the MQ7 sensor where the detail says that during low temperature phase, the carbon monoxide is absorbed on the plate, producing some data. During high temperature phase, the absorbed

CO and the other compounds evaporate from the sensor late. So there is two phases, at lower temperature CO is absorbed and it remains on the surface, and when the temperature increases, when there is a rise in temperature, the absorbed materials would get evaporated from the surface of the sensor.

So there are two different phases. Hence, you see the details about the operation, it states that when you apply 5 volts for 60 seconds, do not use these readings for CO measurement, and then when you apply. Why are they mention? So this is what the datasheet says. So when it is at a higher voltage, so it means that it is at a higher temperature and it is there for around 60 seconds. These are not junk readings which are not to be taken. That is when the evaporation of these compounds, like the CO and other absorbed materials is happening. So that is the junk data which we don't want, but at lower temperature when you apply 1.4 volts, that is for 90 second. This is the reading which has to be captured in order to get accurate levels of CO, which is being capture by your sensor, and this process repeats.

Now I hope you've understood how the -- what is the requirements of the MQ7 gas sensor. It operates at two different voltage levels. And why does it operate at two different voltage levels? Because we are intending to measure the amount of carbon monoxide using this sensor? But at the higher temperature, the other compounds which are absorbed get evaporated and what we require is basically the 1.4 volts for 90 seconds. So this the pulsating input what has to be given to the sensor ideally when you are working.

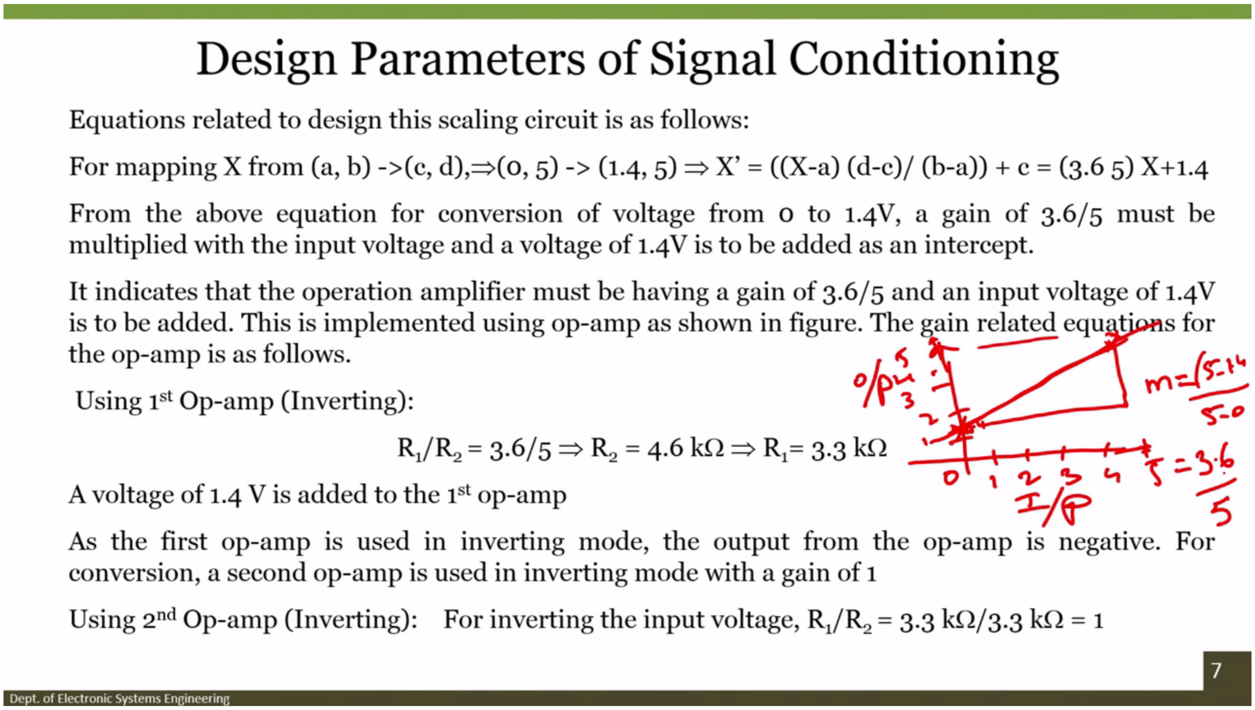
So how do you get the source? Assume you are having a function generator. So what does the conventional function generator can provide you? It can only provide you between 0 and 5 volts. So ideally what you do is just connect your sensor to the function generator and get 5 volts, but how do you get the 1.4, this level of fluctuations, that is 1.4 to 5 volts. This is what we require and that is where a signal conditioning circuit comes into picture. So what we do here basically is to convert the 0 to 5 volts signal what we are getting as an input from your function generator, and convert that to a 1.4 volt to 5 volt output. Now let's see how can we get this voltage range, 1.4 to 5 volts.



What are the different parts -- this is your gas sensor, the MQ7 gas sensor what we are talking about. So what does the PPT here mention is, although the implemented scaling circuit, so we have something called as scaling circuit and a driver circuit, and this is the signal generator or the functional generator, which becomes your input, which is generating o to 5 volts input. So what the line here states is, this scaling circuit converts the input signal, and then the operation amplifier cannot provide the required power to run the heater. So when you understood, when you're studying or maybe you were taught about how the fabrication of he gas sensor works. So there is one portion of the sensor which is nothing but the heater part inside this sensor.

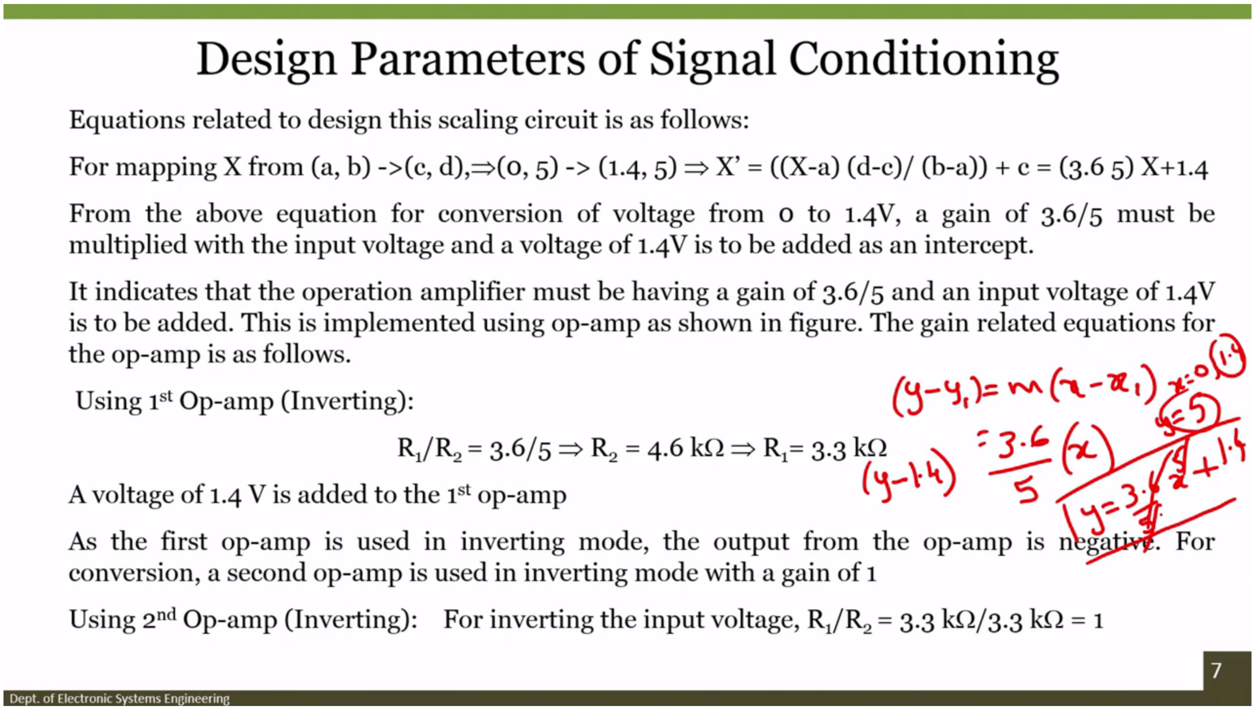
So what happens is in order to drive the heater to the desired temperature, the operational amplifier cannot produce the enough current. Hence, unless you have a power amplifier. So it is exceptional cases. So if you are working with a power of operation amplifier, then it is fine, it can drive your gas sensor, otherwise if you're just working with the IC741 or the ideal, the normal op-amp which cannot drive high currents, then in that case, you'd require something called as a driver circuit. Therefore, it is necessary to have a driver circuit to provide enough current to drive your MQ7 gas sensor. So for that, one way is you use a transistor, I discussed in the previous experiment, or you can even use a MOSFET. So that becomes your driver circuit.

Now let's focus on how do we get this from the source which is o to 5 volts, how do we design a scaling circuit so that we get this 1.4 or 5 volts. I am sure now you would be thinking, why don’t I just use a clipper circuit and then use a clamping circuit and then achieve this portion of the two levels of voltage source what is being required. Well, that is one such condition where you could achieve this, I’ll leave that to you how do you design it, so you could try multiple options and get this voltage range, but I will be discussing about one way, one technique how you could accurately get this 1.4 to 5 volt voltage range in order to drive your sensor.



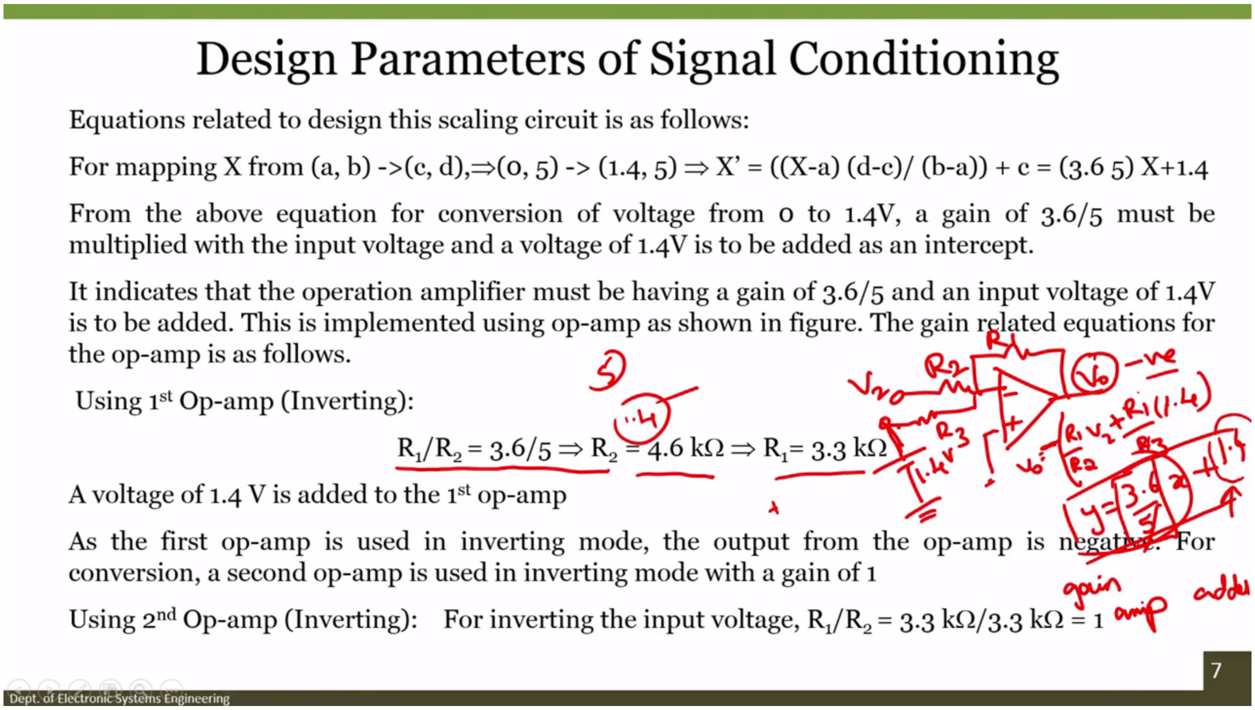
Now here we’ll get into a bit of mathematics here. What is your requirement? The input of your function generator is giving 0 volts and 5 volts, but what is the output that you desire, 1.4 volts to 5 volts. All right, now let’s say this is my input and this remains my output. So this is the input voltage and the output voltage, and how do we go about designing this is what I am trying to tell you. So initially when it is 0, what was the requirement? The requirement was 1.4 which is somewhere here. So I put an x here. So when it is 0, I need 1.4 and when it is 5, I want to have a 5 volts. So when I draw I line like this, I get a line which intercepts between two points, that is 1.4 and here it is 5.

Now if I need to identify the slope of this, what is the slope of this line what I have drawn? It is nothing but (5 - 1.4), this point here divided by 5 - 0, which remans to be 5. So what is 5 - 1.4, 3.6/5. So this is the slope what I get. So if I need -- from 0 to 5 volts if I need something like 1.4 to 5, and if I draw an intercept points, and then the slope of the equation gives me, 3.6/5 is the slope of this equation.



Now let's write the straight line equation, $(y - y_1) = m (x - x_1)$. So what was the slope we got previously? It was 3.6/5, y minus, what was y_1, y_1 was 1.4 is equal to $x - x_1$, x_1 is 0, so I keep this equation this way. So what is the equation I get now? I get $y = 3.6/5\ x + 1.4$. This becomes very important for us to design our signal conditioning circuit. If you can observe, this here is your output and this is the input. So what do you need then your -- so you need this 1.4 volts, then x is -0. So you need here output to be at 1.4 volts, and then when do you get and when you have your input as 5, you will get your output again as 5 volts, two different conditions, okay.

Now, say, x is 0, what happens? This term goes away and you are able to achieve the input. X here is your input from the function generator. So when x is 0, I am able to achieve an output voltage of 1.4 volt, and when my input of function generator goes to 5 volts, what happens, this 5 and 5 gets cancelled, and then I am able to achieve an output voltage of 5 volts. So now we are able to get 1.4 to 5 volt range when we have an input from functional generator, which is nothing but 0 to 5. This was the basic mathematical equation and how you can derive the slope and get the input and output function based on the requirement.



Now let's see based on this equation, y - 3.6/5 x + 1.4, how can I design the entire signal conditioning circuit. So I am just going to keep this equation on. Let's get rid of the other. So now that we have this equation here, 3.6/5 x + 1.4. Now how do we implement this using your different electronic components.

Now let's assume, I have a -- so you have two input voltages. So this is the circuit which I am going to implement based on the mathematical equation, okay. Let's assume we are connecting this to the voltage source, a constant voltage source, 1.4 volt, okay, this input here and this is the other voltage source what we have. This becomes your resister R_1, R_2 and R_3. So this is the output voltage. I am just trying to implement this mathematical equation using this circuit here. Let me explain how does it work.

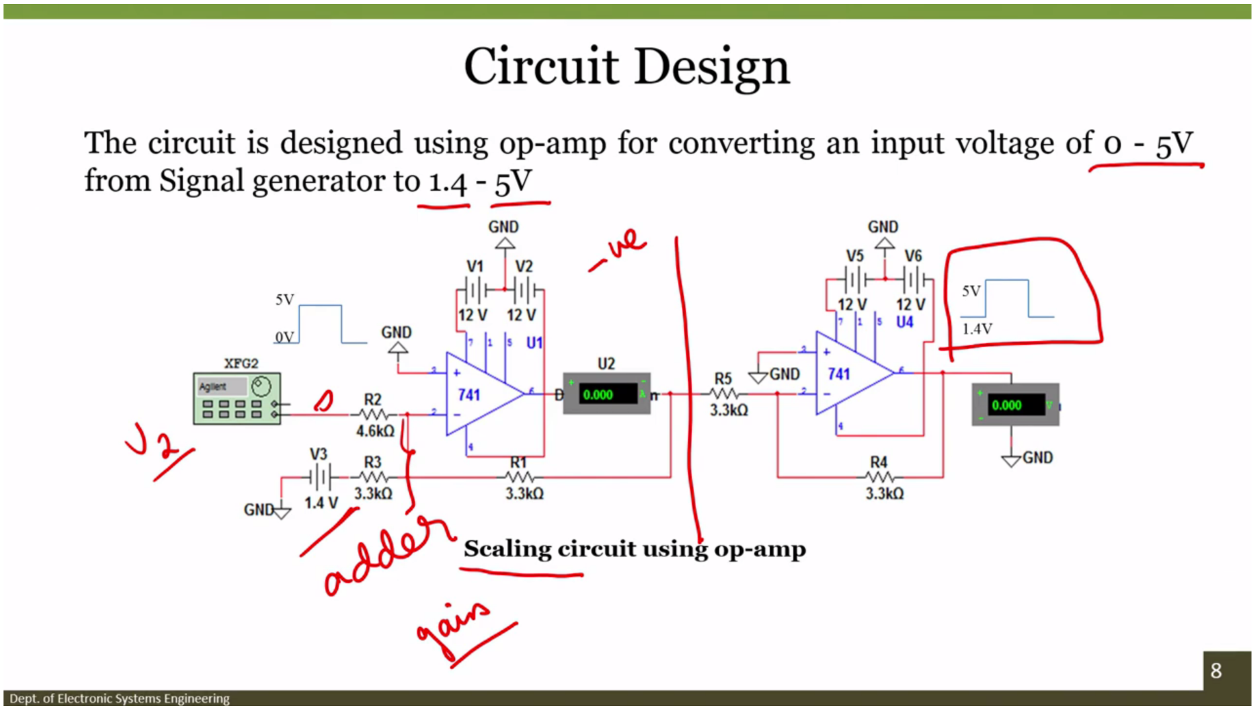
So how do you write the equation for this? V_0 is nothing but ($-R_1/R_2\ V_2 + R_1/R_3$ 1.4), which is the input voltage. Now since the negative term is common, let me take the negative term out and this is your equation, V_0 is nothing but ($-R_1/R_2\ V_2 + R_1/R_3$ 1.4). Ideally, what is it here, it's just the constant 1.4. And how do you get this 1.4? Say, you can -- one way of getting this 1.4 volt here is consider R_1 and R_3 are equal resistance, that is the ratio of R_1/R_2 is 1. So when the choice of resisters here is assume we have R1 and R3. Consider you choose both of these to have a common value, common resistance.

Only then we can make this ratio to be equal to 1, and that's when we can get similarities with the equation what we have written here. So now I know that R_1 and R_3 resistance should be identical, so that my ration of R_1/R_3 gives me 1. Now let's see how do we design R_2. Now you know R_1 and R_3 should be identical. Now the ratio or R_1/R_2 should be equal to this slope. These two resistance when they are connected should give me the slope what I got while I derived the mathematical equation, which was 3.6/5. So when you do this permutation and combination, it can be seen that approximately if you need this slope and this voltage, you can choose the resistance value appropriately.

This here R_1/R_2 in order to get this ratio, 3.6/5, they have chosen R_2 to be 4.5 kilo ohm and R_1 to be 3.3 kilo ohm. And let me be clear, this is one approach. So you are free to implement different values based on your -- I mean if you like to experiment and do something, so you could always go ahead. So this was the ideal choice to get the ratio of R_1/R_1 constant and the ratio of R_1 and R_2 in order to achieve this slope based on the equation.

Now this was the choice of resisters, 4.6 and 3.3 k. Well, now that we have the different resisters, all we have to do is just rig up the resisters, the constant voltage source, the constant voltage source, give the input from the function generator, and you will see the voltage no from 1.4 volt to 5 volt, because this what the minus sign here, if you have noticed, so the output V_0 would be a negative value. So what do you want to do is, just replicate the same circuit again. Give the input of this output to the same circuit when you feed it back to the same circuit, what happens is your negative would turn and then would return and you would get the positive value that is you will get 1.4 volt to 5 volt. So this is in the inverting mode and that is the reason the output, which is negative is given to another, the consecutive, the second circuit, which is nothing but the -- the identical circuit is given as a feedback to the output of this, so that you get the required gain.

This becomes your gain amplifier depending on how you have chosen your R_1 and R_2 and this is your slope, which is nothing but the adder. So 1.4 volt here is the adder and this part works as your gain amplifier. This was the entire part about how do you go about designing a signal conditioning system for a MQ7 gas sensor.



So this is the scaling circuit. Like I said, we have used this circuit to scale the input voltage from 0 to 1.4, and then getting the corresponding voltage, 0 to 5 from 0 to 5 to 1.4 volt to 5 volt. As you can see this is the function generator, the V2 which we had considered in our circuit, and this is your adder, which is the 1.4 volt, constant supply. This was the resister. The ratio of this is what we wanted to be 1, so that our output remains at 1.4 volt when the input from the function generator is 0, and then accordingly you have the resister R_2, which is 4.6. So the ratio of these will help us get the slope, which is nothing but gain of your amplifier. Like I mentioned, the output of this is a negative, because it is an inverting amplifier, and hence you are feeding it back to the same circuit in order to get 1.4 volt to 5 volt.

So this was the discussion about how you go about designing a signal conditioning system for an MQ7 gas sensor. Let's get a hands-on and let's rig up the entire circuit, and see how we can implement this in real-time. So this was about the signal conditioning part, how you can design the scaling system and how you get the desired voltage provided you have a constant analog function generator where the input cannot be altered to the desired range. So it's just a 0 to 5 volt constant range.

I hope this has helped you understand how a signal conditioning circuit with variable input voltages can be used and then based on your application, you can design the circuit by yourself, identifying what can go into your adder portion or what can go into your gain, the desired gain based on the slope or the mathematical equation what we had done. So this is it for today. Thank you.