Embedded System Design with ARM
Prof. Kamalika Datta
Department of Computer Science and Engineering
National Institutes of Technology, Meghalaya

Lecture – 25
Experiment with Temperature Sensor

Welcome to lecture 25. So, in this week we will be interfacing a various sensors with STM mode. So, in this particular lecture we will be interfacing LM 35 temperature sensor, LM stand for Linear Monolithic. We look into the properties of this LM 35 temperature sensor and then we will look into the circuit diagram followed by the code that is used to interface this particular device with STM mode and then will show you the demonstration of this experiment ok. Let us move on.

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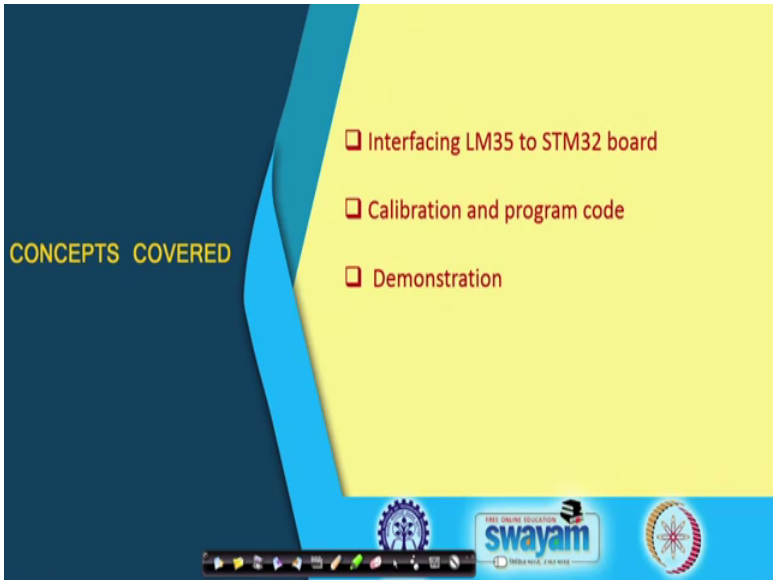

So, these are the few things that we will be doing will interface LM 35 to STM 32 board will also show you how can we calibrate because, for any sensor to work will see that some kind of calibration is required, that we will show and of course, the program code and the demonstration.

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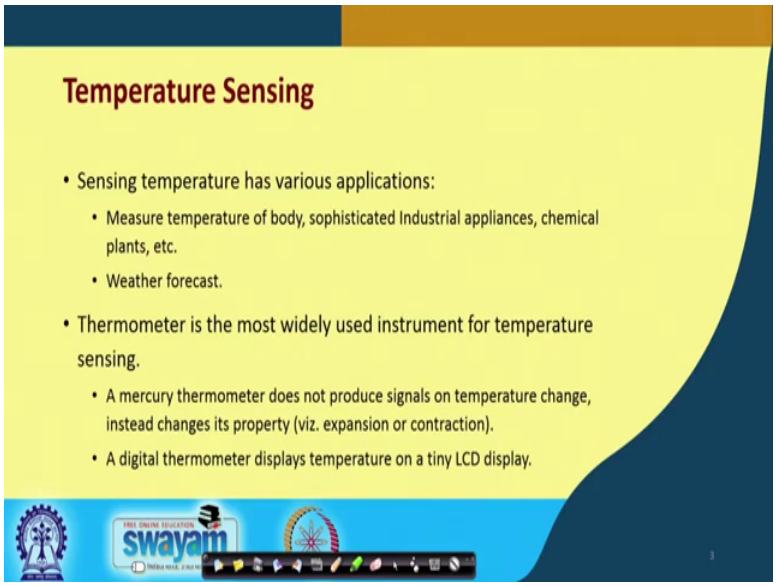

So, what is temperature sensing? Temperature is a physical parameter we all know; sensing temperature has various applications, what are those applications? It measures the temperature of body, it is also used in sophisticated industrial appliances, it is used in chemical plants, where it is needed to monitor the temperature and depending on that temperature certain devices may be required to be made on or off, of course, weather forecast is one of the application. If you think of how do we measure temperature, thermometer is the most widely used instrument for temperature sensing.

So, it is a mercury a mercury thermometer does not produce signals on temperature change, instead it changes its property like it can expand or it can contract this is how a mercury thermometer works. On the other hand, a digital thermometer displays the temperature on a tiny LCD; we have also already seen what is an LCD. So, a digital thermometer, you can actually see the temperature which is displayed in a tiny LCD.

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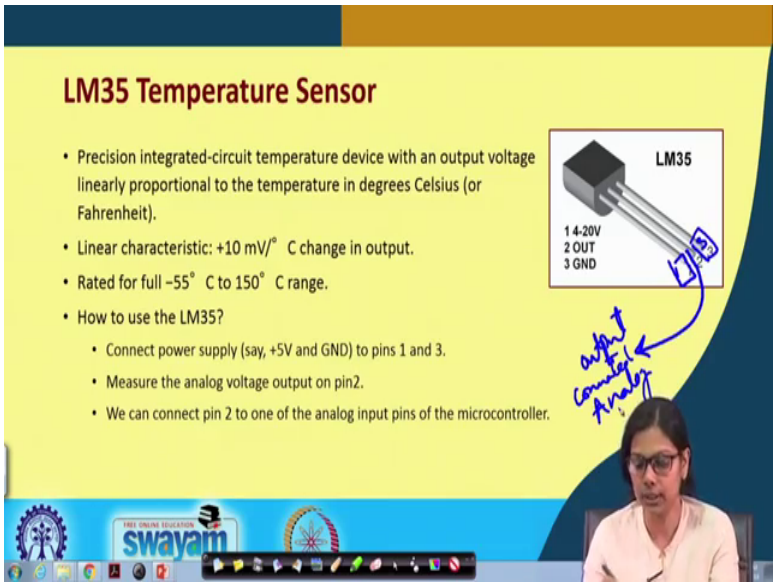

LM 35 temperature sensor, inear monolithic temperature sensor, this is an integrated circuit basically which was developed by national semiconductor, this is a precision integrated circuit temperature device with an output voltage linearly proportional to the temperature in degree Celsius or Fahrenheit ok.

So, what does it mean? It mean that the output voltage is linearly proportional it is linear and it is not non-linear, it is linearly proportional to the temperature in degree Celsius ok. If you think of these linear characteristics, the linear characteristics is like with 10 millivolt change, there is a degree Celsius change in output of the temperature. So, with every 10 millivolt whenever there is a 10 millivolt change then correspondingly, there will be a change in degree centigrade of the output. So, the a full scale of range of this LM 35 is minus 55 degrees centigrade to 150 degree centigrade ok, this is the full range. So, if you have temperature in between minus 55 to plus 150 degree centigrade, that this particular temperature sensor will be able to take that into consideration.

So, how do we use this LM 35? So, this is basically LM 35 there is a flat end and then there is a round and half round end, this way this pin number 1 is basically, this one is the voltage pin, this one is the it should be connected to bcc basically, the number 1 pin number 3 must be connected to ground and from where we will get the output voltage? The output voltage will be available from pin number 2, this is the output voltage. So,

this particular pin must be connected with the analog volt, this will generate a voltage and internally that voltage will be converted to some digital value ok.

So, this is how this connection is. So, one is should be connected to bcc, this one must be connected to ground and from this middle point, it will be connected to the output that is must be connected to the analog volt. Now what needs to be done like how do we use it? First we need to connect say plus 5 volt to the pin of 1 and ground to pin 3 and we can connect pin 2 that is the middle one to one of the analog pin of the microcontroller.

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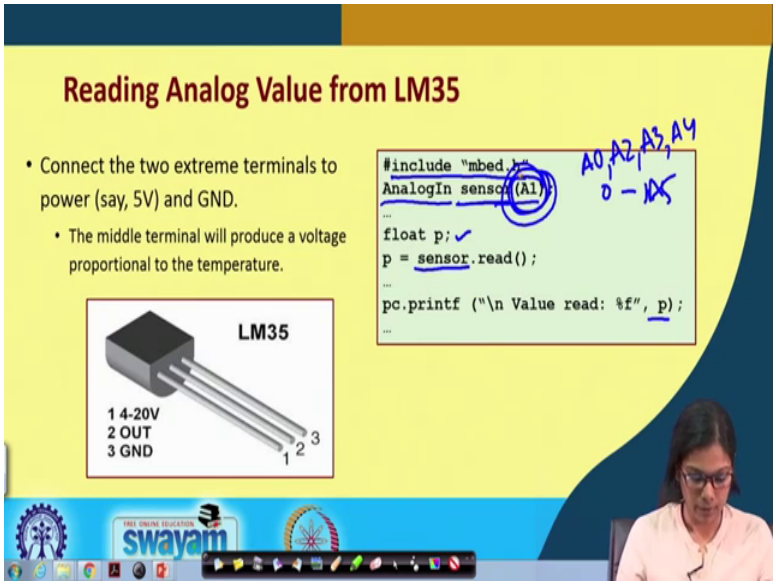

How do we read the analog value? Till now, we have seen that how we will output digital value or we can input a digital value ok. Now we will see that how can we read an analog value. So, for reading an analog value of course, firstly we need to connect LM 35 to ground and to bcc and the middle terminal will produce a voltage proportional to the temperature. The code that is used the mbed c code that is used is first same way, you have to include, first you have to include this header file then we have to initialize a pin analog pin as an input analog pin.

So, analog in this is the name of the pin that we will be using that is sensor and which pin of the board? A1 pin of the board is considered as the analog pin here, we take a float variable because, it will get a value ranging from 0 to 1. So, p we will read the sensor value. So, the function that is used sensor is the name of the port A1 this is the value which we will be using. So, sensor dot read will read the value, which is through this

port A1 connected to this port A1 and you can print it using pc dot print f, the value is percentage f p. So, these are the few lines of code that are required to read the sensor value from the analog port A1, there are other analog ports as well like A0, A2, A3, A4 and A5 ok. In this case, we are connecting to A1.

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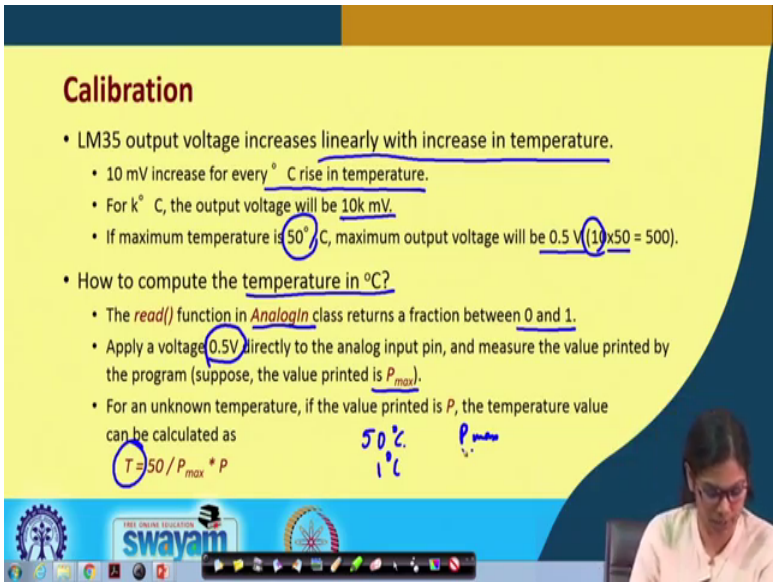

Now, the calibration how do we do this calibration? See current, let us say the current temperature of the room is x for that current temperature, what value you are getting? Ok if we know that now the temperature is let us say 20 degree centigrade, I am getting certain value in my analog output then if the temperature is x then what will if I am getting x value, what will be the temperature?

So, we can do this calibration, this is one way of doing it. Let us let us see how the calibration, we have done in this particular code. LM 35 output voltage as I have already mentioned increases linearly with increasing temperature. So, when there is a 10 millivolt increase for every degree centigrade rise in temperature.

So, k degree centigrade the output voltage will be 10 multiplied by k millivolt, if maximum temperature is let us say 50 degree centigrade and the maximum output voltage will be 0.5 volt. Let us say then this 10 must be multiplied with 50. So, 500 will get the value. Now how do we compute the temperature in degree centigrade? Let us see this, the read function in that analog in class returns a fraction between 0 and 1, I have already told this let us say, we can apply a voltage 0.5 volt directly to the analog input

pin, the analog input pin where we were connecting earlier, the sensor output value I am connecting directly to a 0.5 volt directly to that pin and then we measure the value printed by the program suppose, the value which is printed is P max if that is so; that means, what we are saying the output voltage that is 0.5 volt. For 0.5 volt the value we are getting is P max that for an unknown temperature, if the value printed is P then the temperature value can be calculated as how T will be calculated? 50 divided by P max into that P.

So, basically the thing is that it is basically, 50 degree centigrade then the value which is printed is basically P max, if it is one degree centigrade the value printed will be like ok. So, let us take the opposite one basically, if the value is P max.

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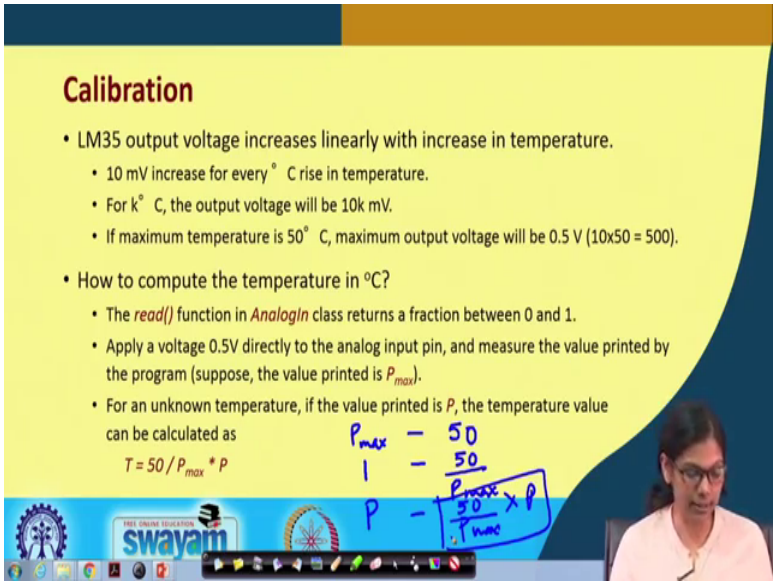

Then it is 50; that means, we are getting a value P max for this 50 degree centigrade.

So, if that is so for one will be getting 50 divided by P max and if it is P then will be getting 50 divided by P max multiplied by P, for this particular scenario ok.

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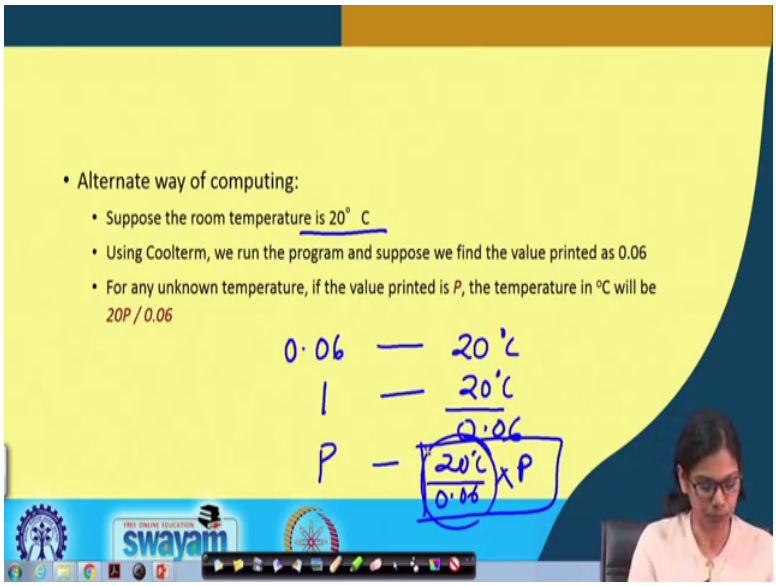

But the one that we have used in the program is little different. So, let me show that the alternate way of computing that we have used it. Suppose, the room temperature I know it is 20 degree centigrade ok. We will see that what value we are getting from that voltage output. Suppose, the room temperature is 20 degree centigrade, we have already discussed about cool term. So, cool term will basically run and suppose we find the value of 0.06.

So basically, if it is 0; 0 0.6 0.06 then the temperature is 20 degree centigrade ok. If the value is let us say 1 then it will be 20 degrees centigrade divided by 0.06 and if we receive the value P then it will be 20 degree centigrade divided by 0.06 multiplied by P that is what we are doing here 20 divided by 0.06 multiplied by P and we have done the same thing in our code. So, we have earlier calculated this using the current temperature of the room that we were getting at that particular time ok.

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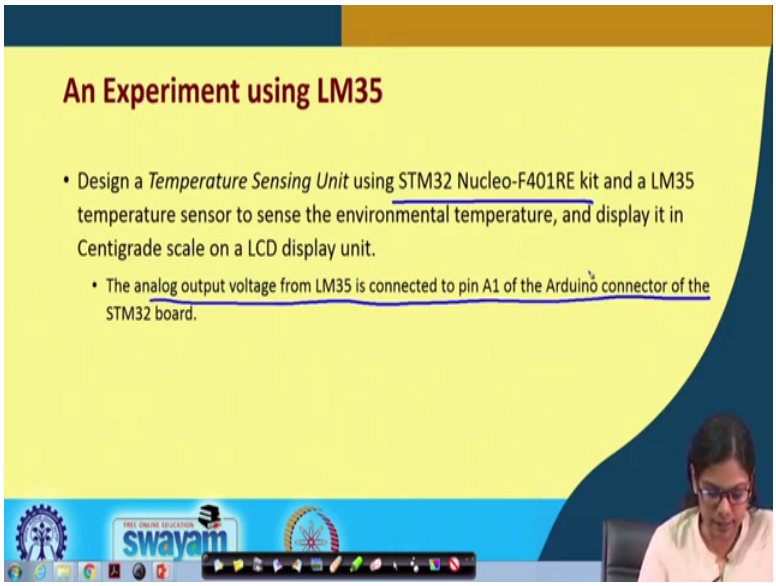

So, let us look into the experiment. Now, I have discussed about LM 35, how do we connect LM 35 with STM and how do we read an analog value from certain port and also how do we calibrate. Now we will design a temperature sensing unit using STM Nucleo-F401RE kit and LM 35 temperature sensor to sense the environmental temperature and display it in the centigrade scale on a LCD display unit. So, the analog output voltage from LM 35 is connected to pin A1 of the of the STM board, which is of course, the Arduino connector ok.

Let us now look into the circuit diagram.

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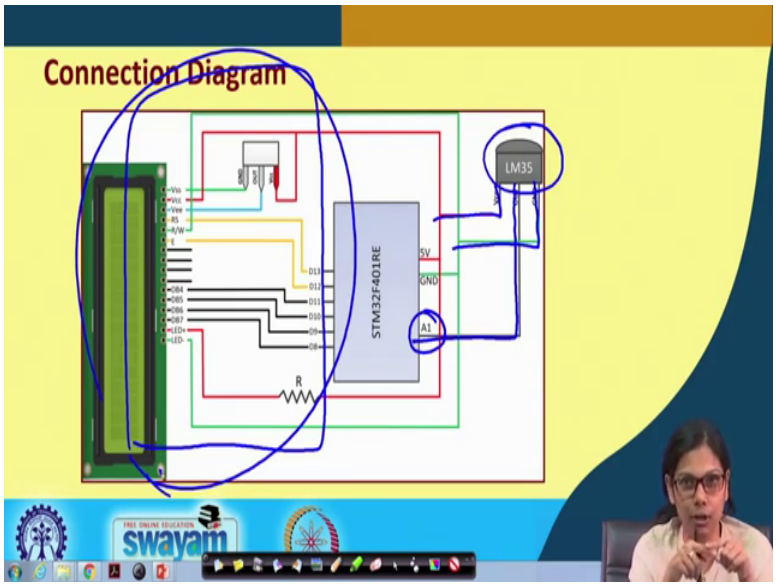

So, if you recall this part of the circuit diagram you already know ok.

So, what we are doing, we are basically connecting from DA to D 13 to various pins of the LCD display, what we are going here to do is that, we are connecting this LM 35 VCC is connected to VCC ground is connected to ground and out is directly connected to pin A1 of the STM ok. This is all about the connection and this part of the connection we already discussed earlier ok. So, it will sense the temperature, do the calibration and display the temperature in this LCD we will be demonstrating this example before that I will be showing you the code that is required to be executed after doing the circuit diagram.

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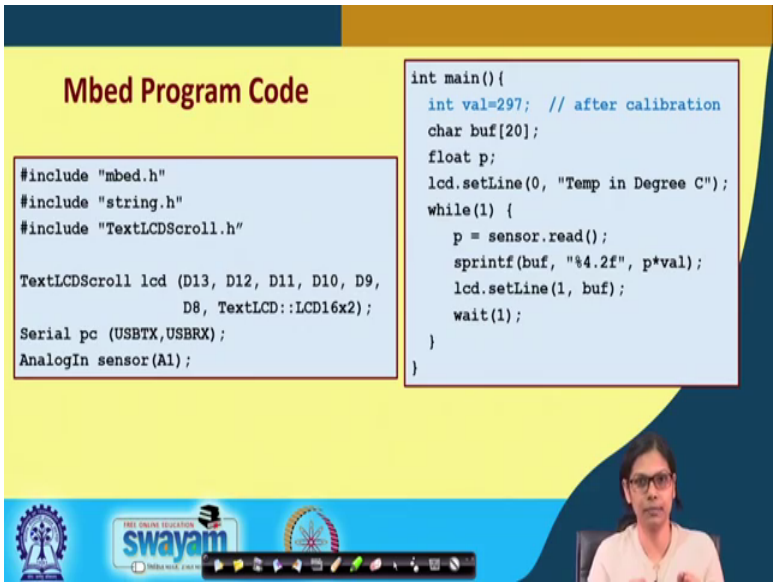

So, this is the mbed program code similarly for LCD, we know that we have to use is text scroll and text LCD.

So, text scroll it is connected to these pins we use here serial pc USBTX RX, this is for the serial communication that we do and such that we can display it in the any of the hyper terminal, which we have already discussed that is one of them are is cool term. This is the analog input value in the name of sensor, we are reading through port A1 and this is after calibration, we get a value like this that is value is 297.

We take a character buffer here and LCD, we are setting the line at 0th the line temperature in degree centigrade and in the while loop, we are reading the value first using sensor dot read and then we are calculating the value that is p multiplied by the val, p is whatever we have got which we are multiplying with this value 297 and we are storing it in this buffer and finally, we are displaying it in the next line LCD dot set line 1 with this buffer, we are waiting for 1 second and again we are doing the same thing repeatedly ok. We can do either of the things we can wait for 1 second or even we can wait for 2 minutes.

So, in the program you have just we done the wait for 1 second here. So, this is all about the mbed programming code ok. So now, that I have already discussed the whole code how do we interface it and how do we display it. Now we will be showing you the experiment the demonstration of this particular code, where will be interfacing this LM

35 with STM and will display the temperature in the LCD ok, let us see that ok. So, we already discussed about LM 35, I already discussed about the temperature sensing experiment that we can do. So now, I will be doing that experiment with LM 35 and what I will be doing in this experiment is that for now? I will be connecting LM 35 with ST microelectronics port and then I will be displaying the current temperature ok.

So, what was the current temperature of this room probably? So, let me tell you the temperature out here the recording is taking place in Shillong. So, the temperature is quite low here. So, the outside temperature currently is 17 degree. So, let us see what is coming here in our sensing unit ok.

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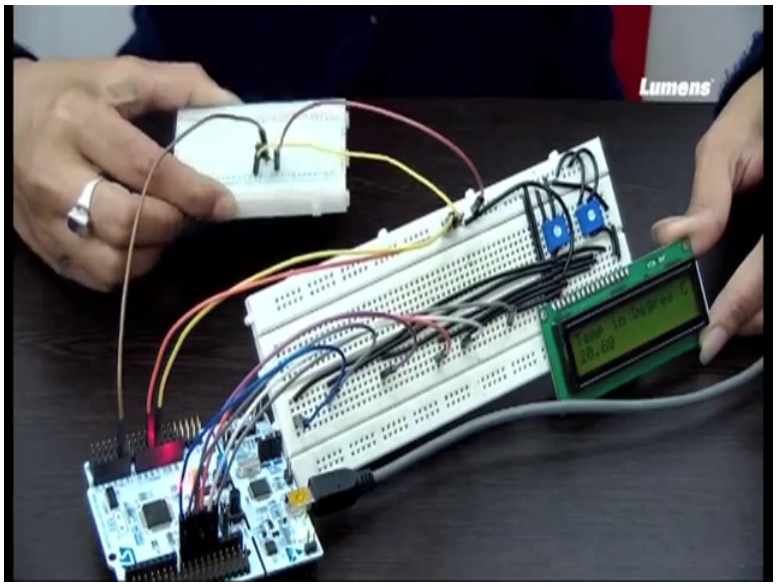

So, this is the temperature sensor, this temperature sensor is LM 35 temperature sensor. Now you see the flat end of this ok. So, the flat end of this the left pin to this flat end should be connected to 5 volt VCC. The right end of this LM 35 will be connected to ground and from the middle position; it will be connected to the analog port ok. Now we already know, how many analog ports are there in STM that we already discussed, we will be connecting this out of LM 35 to one of the analog port, we have already discussed that this analog port internally, it is connected to a AD converter.

So, the value which will be getting from this pin basically, the voltage will get converted into some digital value, we have also shown you how we can see that digital value, you can see the digital value using any of the serial communication thing that is cool term or

tera term there are various others and in Arduino, you can directly see it through serial monitor ok. So now, I will be doing the connection and in doing. So, what I will do basically is that I will be displaying the temperature in the LCD ok. You can also display the temperature in 7 segments, but let me discuss that with LCD. So, this is LM 35 you can see this is the flat end ok, this is the flat end you can see that is the flat end and this is the little bit round end ok.

So, I connect this here, the left side of this will be connected to bcc this is my connection with LCD which is already there with me. So, this particular pin will be connected to bcc, which is the, this one and then I will be connecting this pin that is to ground. So, I have connected this pin to bcc and this pin to ground and from this out the middle one from where this output voltage will come, I will be connecting it to A1 ok. So, we have pins A0, A1, A2, A3, A4 and A5. So, I will be connecting with A1.

So, just see the connection, the connection is straightforward, if you see that this LCD, we already showed you how you will be connecting that is already there, only I have connected this LM 35. So, one there are 3 pins of LM 35, one pin is connected to bcc, the other pin is connected to ground and from the middle point, it is connected to the analog input. So, these are the 3 things that you must know and you must understand. So, this is how we have made the connection ok. I have already shown you the code that you have to dump into this board for displaying the current temperature.

So, we have already done the calibration and as you already know that in this particular sensor that is LM 35, 10 millivolt change in voltage will be equivalent to 1 degree change in temperature. So, we have done the calibration accordingly and now I will be dumping the code, which will display the current temperature of this particular room ok. So, let me connect it ok. So, the temperature what it is showing, you can see this, the temperature in degree centigrade is 18.20 19.40. So, it is little bit fluctuating, you can see with respect to that ok. So, let me increase the temperature a bit and see what value it comes ok.

So, let me do that it increased you can see that it has become 21.60. So, if you can even rub this particular sensor a bit. So, the value actually changes or you can just blow a little bit in front of it to see the change in temperature. So, it has increased again. So, this is a simple experiment with LM 35, where it is reading the temperature and it is displaying

the temperature ok. You can see that the connection with LM 35 is fairly straightforward and fairly simple ah, the thing is only that sensor to sensor things varies ok.

So, the point is you need this calibration, the calibration step is really very important. So, in this calibration step, what you need to see is that you need to read the current value of the sensor, what it is giving and you can see that in cool term and then with respect to that value, what is the current temperature of this particular room ok. So, that particular thing you have to first check and accordingly, you can change that in your code to incorporate this particular scenario ok.

So, this is a very straightforward thing, where we are displaying temperature in this particular display unit that is LCD, but sensing temperature has got variety of application ok. Let us see, if the temperature is beyond certain temperature, beyond certain degree, we will switch on the ac or if the temperature is below certain degree, I will switch on the heater ok. So, these can also be incorporated in a system ok. So, there are various other application of this LM 35, we have shown you one thing, which you can incorporate and do it for other experiments.

Thank you.