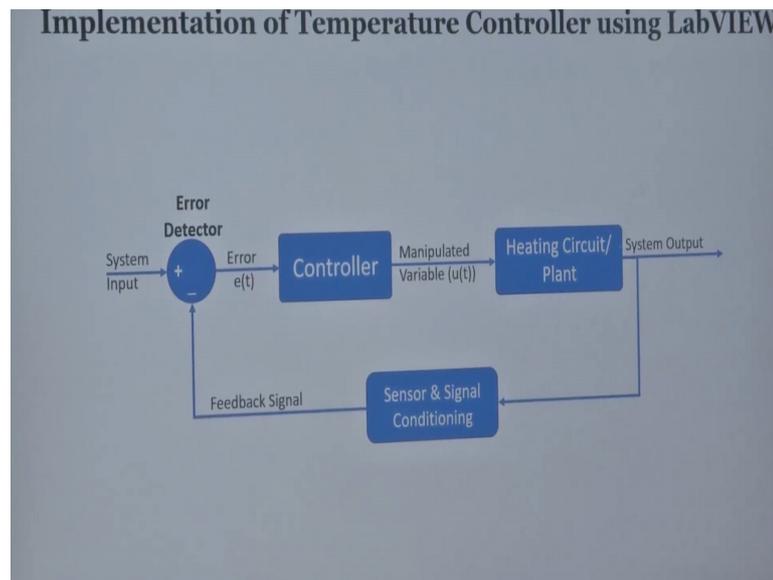


Op-Amp Practical Applications: Design, Simulation and Implementation
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Lecture - 48

Case Study: Implementation of a Software Based Temperature Control Using LabVIEW and CDAQ

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Welcome to the module, now we will be discussing about implementation of a temperature controller using Lab VIEW. In last modules we have seen the use of Lab VIEW data acquisition device and we have also seen about what virtual MEMS that we have in our clean room facility. So, to just make you understand about how to make use of a data acquisition unit using Lab VIEW as well as a cDAQ I just developed a case study. So, before going into the case study I would like to you know make you understand about how exactly this works and what exactly that I am going to do in this case today.

So, the idea of this case study is that I have a plant which was equipped with a temperature sensor by using software that is by using a Lab VIEW. And by using a data acquisition unit you know we will be controlling the temperature on the plant to be as a set as our required set point. So, in order to understand what do you mean by set point, how exactly it works we should understand about a closed loop control system.

So, to give you brief understanding about what is a closed loop control system, how does it look like this is if you look into the screen here we can understand how a closed loop control system looks like, what you mean by negative feedback everything. So, how exactly it works in the sense here you will have an error detector which is nothing, but which finds the difference between the system input and your actual input actual output; that means, that if I say the temperature on the plant to be a 50 degree centigrade the error detector finds out what is the required temperature meaning 50 degrees and what is the current temperature on your plant.

So, if there is if the plant temperature is below the required temperature value; obviously, the error detector will gives you a positive input voltage right. So, by passing through different controllers right different controllers in the sense either p controller, pa controller, PID controller or on off controller by passing through the on off controller based upon the quantity of an error it will generates a manipulated variable. This manipulated variable is responsible to provide power to the heating circuit such that it heats to the required set point. So, as a result because of that reason it starts heating and as long as the system output as long as it is heating it the system output will starts increasing meaning the temperature will starts increasing.

So, why when the temperature starts increasing the error value starts decreasing it. So, this is a general way of understanding about a closed loop system and the representation of a block diagram of a closed loop control system. But, in this case what I am going to do is that as you have already seen in an hardware part how do we you know realise a p controller, on-off controller, PID controller everything using operational amplifier, but in this case what I am going to do is that this complete controller we will be developing using software. Meaning in this case we are going to use Lab VIEW which is nothing, but laboratory, virtual instrument, engineering workbench.

So, using this software we will be developing the required controller logic which is nothing, but a p controller, pa controller, PID controller even in case if you want you can also go with the different other compensator circuits to inside the controller. And since it is in a software we have to provide a system which converts a real world signal into digital because since the controller is realizing in a software, software will understand only digital data. But, as well as the real world signals are completely analog we should

also have to have a converter unit which converts your real world signals into digital signals.

As a result what we are going to do is that we will be using a data acquisition device. So, the data acquisition device that I am going to use here is a compact DAQ which we have already seen in our previous sessions. Now, I am going to show how do we connect that the same circuitry what we have discussed using data acquisition device right. And, I will also give you the brief understanding about the data acquisition device and the chassis as well as the signal conditioning modules that we have and to where we are connecting it. And as a part of it I will also make you to understand about what logic that I am going to develop in Lab VIEW, how exactly it is going to work.

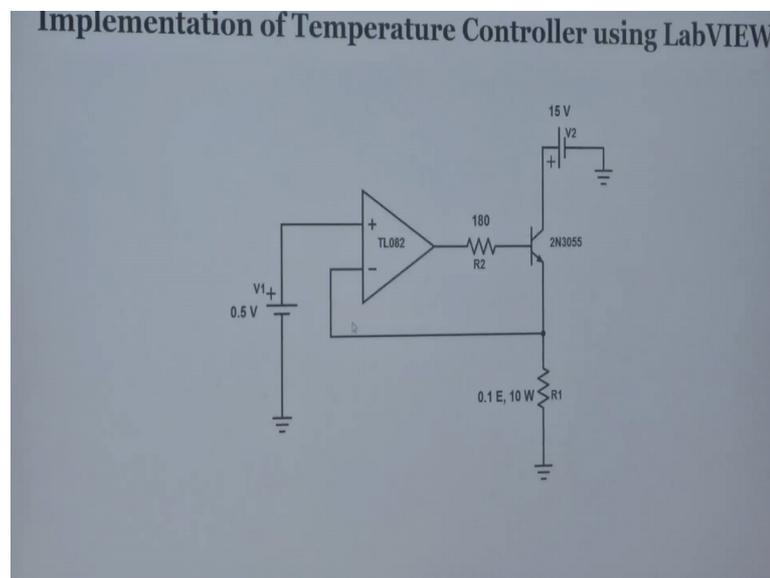
Also in order to you know set the gains of a controller one thing we should also have to understand is that the plant circuit. As we have already seen about the plant circuit again I would like to know in you know make you understand about how exactly it works. And depends upon the plant circuit the manipulated variable the range of the manipulated variable and will be completely set. And the manipulated variable is nothing, but an output of a controller that entirely depends upon the tuning parameters that you are going to sit set on your p, pi, PID controllers.

So, as a result the understanding of an heating circuit is must. And where as when I say temperature it is not sensible in terms of r. Since, it is a temperature and since we are interfacing to an electronic unit it is very hard to you know realise there is a change in the temperature by looking. So, we required to have some sense by using by either by using touching or by using some kind of a sensor which converts this temperature change into electrical output voltage. Since, we are completely realising using an electronic unit we also require an sensor.

So, we will be using an LM 35 sensor which will be you know stick on top of a plant so, which senses the temperature. And since the sensitivity factor of the system input the meaning that since it is an electronic unit the input that we are going to set should also be in form of voltages. So; that means, we should know what is the sensibility factor signal you know the sensibility factor of your system input, meaning if I say if I apply a 5 volts what it means that how much temperature that it should be there on top of a plant.

So, in this case I am considering 0.1 volt per degree centigrade; that means, if I give 1 volt it means that it has to maintain a 10 degree on top of a temperature. If I keep 10 volts it should maintain 100 degree centigrade that is nothing, but the sensitivity factor in this case. And whereas, the signal conditioning circuit is important in case of a sensor because whatever the output quantity that it is going to provide by a sensor may not be exactly match with respect to a system input. As a result you have to convert the output of a sensor data into the system input quantity or a scaling factor; so, we the in this case I am going to use a scaling factor of 100 such that the both the system input factor as well as the output factor will match right.

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So, let me brief you briefly explain you about the working of the plant unit. So, we will be using an operational amplifier. The purpose of an amplifier I will make you understand about the purpose of an amplifier operational amplifier too. And we will be using a you know Darlington pair transistor. The purpose of going with Darlington pair transistor is that since, we will be working on heating of a plant the temperature entirely depends upon the power that we are going to supply in this place.

As a result we will be working with a higher currents higher currents the power is of really higher, the current is also really higher. So, that is the reason your transistors should be capable of withstanding such a higher currents as a result we required to go with a Darlington pair. So, 2N3055 is an on inbuilt Darlington pair which has a

Darlington pair configuration exist. So, that it can withstand up to a current of 10 amps of current.

Now, if we recall as we as we already know the working of an operational amplifier. So, how does exactly it works in the sense this is the input to the plant which is nothing, but the manipulated variable which we are getting from the controller will be connected to the positive terminal. Let us take we have a manipulated variable of 0.5 volts since, the positive terminal is connected with a 0.5 volts, the negative terminal will also be at a 0.5 volts. As a result the voltage drop across it is r one resistor will be also as 0.5.

And since this is a transistor if you recall your transistor working right, the current flowing through the collector is almost equal to the current flowing through the emitter. And the relation between the both things is a proportional and the proportionality constant is called alpha right and which is will be almost equal to 0.99. So, as a result I can say the current flowing through I_C as well as I_E we can almost make it as equal.

So, if you know the current flowing through this emitter leg we can easily understand the current flowing through the collector. Now, in this case since we are applying 0.5 the voltage drop across this R_1 resistor will also be a 0.5. And since the resistance since we know the resistance value and since we are forcing the voltage drop across the resistor is also a fixed value, we can find out the current flowing through this emitter leg right. So, if I want to calculate so, 0.5 divided by 0.1 which is nothing, but 5 amps of current will be flowing through this emitter leg when we are applying input of 0.5 volts right.

So, because of the forcing see, because of the negative feedback connected to the operational amplifier it forces the voltage drop or it forces the current flow through the transistor to be of 5 amps in this configuration right. So, whenever we change the voltage across the positive terminal as a result the voltage drop across this resistor will also changes right.

Since, the resistor is fixed, the current flowing through this also changes, that is why this is also called a voltage controlled current source. By looking by up by changing the voltage controlling the voltage at the input we can also control the current flowing through the circuit. So, that is why this is also called voltage controlled current source.

But, you may ask, you may not understand how exactly it is going to generate a temperature on top of a transistor right. So, in this case what I am doing is that I am generating temperature on top of a transistor, how? So, if you understand if I do not have this negative feedback if you see it is not in a forced condition. So, whatever the voltage that you are applying the complete voltage will be dropped across this particular resistance value and the drop across this collector emitter will be 0.7, 0.7 in a normal case where you do not have a negative feedback.

But, in this case you have a negative feedback. Because, of this negative feedback it forces the voltage drop across this resistor to be 0.5 and the input voltage applied is of 15 volts. As a result what about the rest of 17 14.5 volts right, an energy neither be created nor destroyed. As a result the voltage drop the remaining voltage will be dropped across collector and emitter junctions of a transistor. So, the amount of current flowing through and the voltage across collector and emitter both together the power across the transistor at collector and emitter leg will be too higher, it causes the transistor to heat.

Right so, higher the current higher the voltage drop higher the current flowing through right, higher the power, higher the power higher the temperature generated on top of it. If you want to understand how much temperature is going to generate if you look into the data sheet of 2N3055 you can understand about the relation between power and the temperature generated right from the data sheet. So, as a result as this voltage is keep on increasing, the current flowing will be keep on increasing even that the voltage drop across this will be keep on decreasing the overall the power will be multiple times will be a multiple.

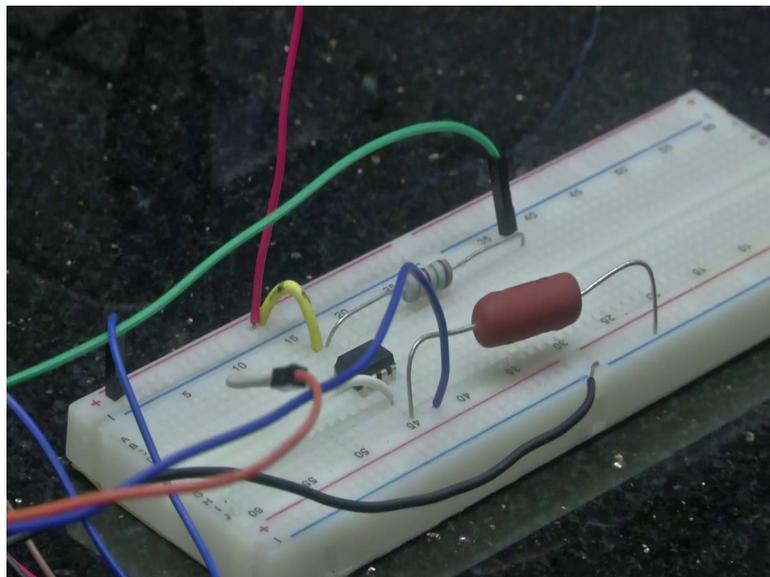
As a result the power across this collector and emitter will be too higher which will starts hitting the transistor. So, this is how we have you know used the plant circuit using operational amplifier and the transistor as an heating unit. Now, since our idea is to control the temperature on top of the plant what we are doing is we are we are using a controller.

So, as I discussed previously the controllers that we are going to see is of p or pa controller and this is completely realised or completely you know developed using a Lab VIEW software. So, this is also called as software in loop, meaning your controller will

be a software which is in the loop where as the plant is in hardware which is in external right.

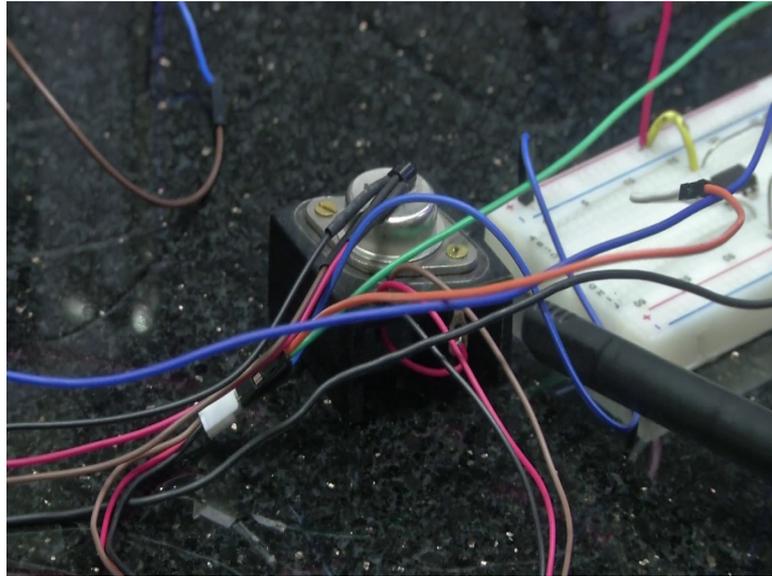
So, we are constructing the plant on the real world I mean on the outside and the controller as a in software. As a result it looks like an simple like software in loop configuration. In order to communicate between your software to your external world you require to also have a data acquisition unit. So, even for acquiring the data into the system event for generation of data from the system we will always require DAU data acquisition unit which performs both acquisition as well as a generation too I will show you how exactly that we are going to do using a Lab VIEW. So, first in order to make you understand I would like to show the circuit that we are going to use in this case.

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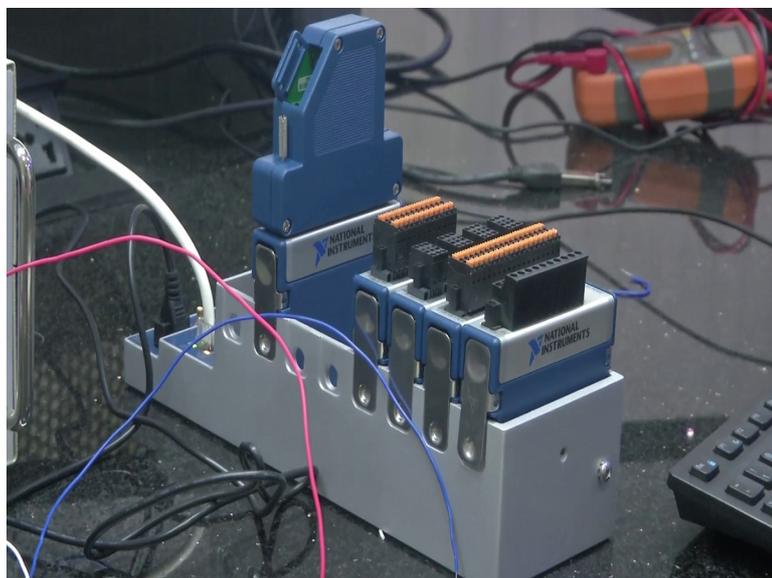
So, if you look into the bread board that is a circuit that we are using. So, this is an Op-amp 741 Op-amp that we are using and this is an 181 resistor which we have seen in the circuit and this is 5 watt 1 ohm resistor in this case, sorry 5 watt 0.1 ohm resistance 0.1 ohm resistance and this is connected as shown in the previous figure.

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Whereas this is our 2N3055 transistor right and on top of it the I have attached LM 35 which is a temperature sensor. Now, by using this power source I will be powering the complete circuit as well as powering the LM 35 unit too.

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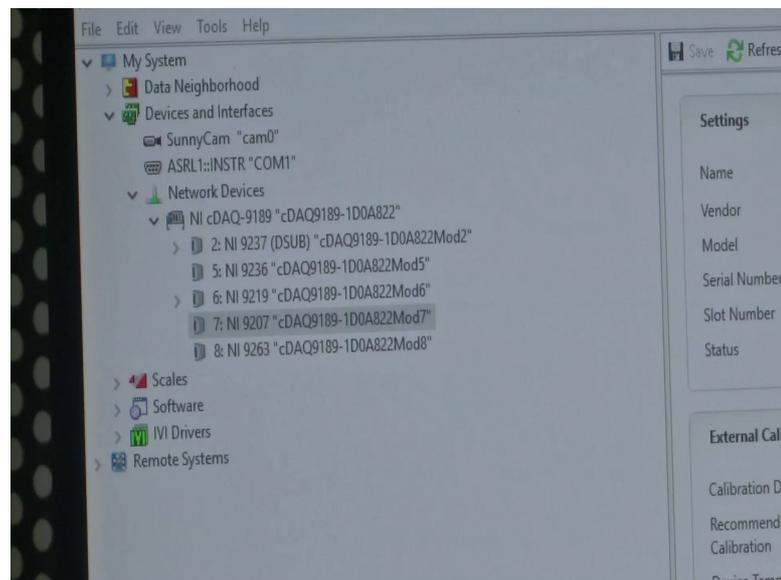


And whereas, here you can see that data acquisition unit this is called compact DAQ. So, this is connected through LAN connected through LAN. So, that using LAN the data will be transferred between the PC as well as to this device. So, it has a different signal conditioning modules. So, this is different signal conditioning modules you can see here.

So, one for different different applications, one to generate analog voltage other one to acquire analog input data to acquire the signals analog voltage as well as current anything can be acquired using this particular chassis. This is ni sorry this particular signal conditioning this is NI9207 whereas, this one is NI9263 by using these 2 modules signal conditioning modules whatever the data it is being generated from the from temperature sensor will be acquired will be acquired and as well as.

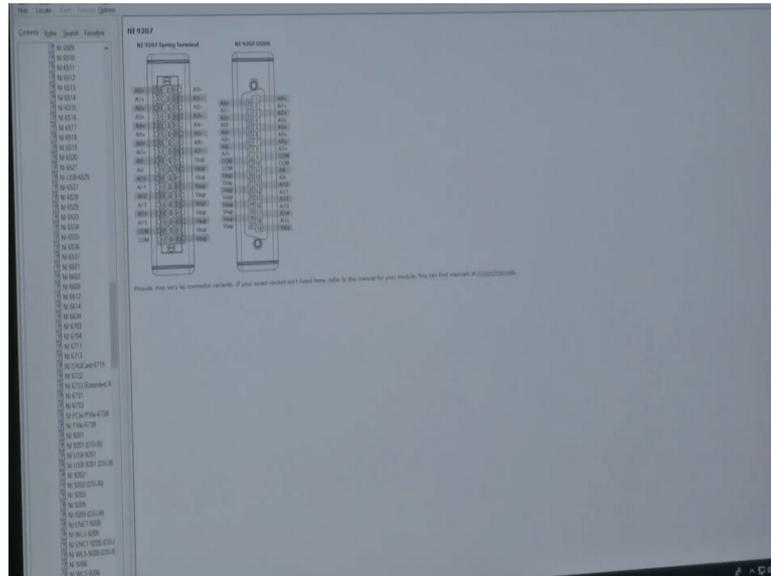
Since, it will be compared with an with a set value by using a differentiator right. The error output signal will be pumped to send to your controller. The controller it generates a manipulated variable based upon the error signal that we have and that the signal whatever we are generating will be generated using this 9263 and that will be given as an input to input to the positive terminal in the plant. Right, so, in order to understand that let me show you. So, let me show you how do I construct the system the whatever the chassis that we are using is cDAQ 9189.

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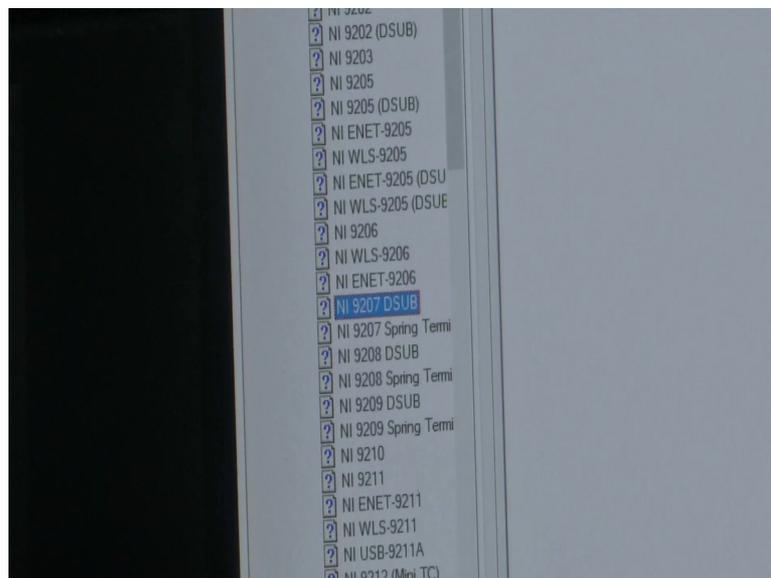
And we will be using module 7 as well as module 8 now, to understand about module 7 and module 8.

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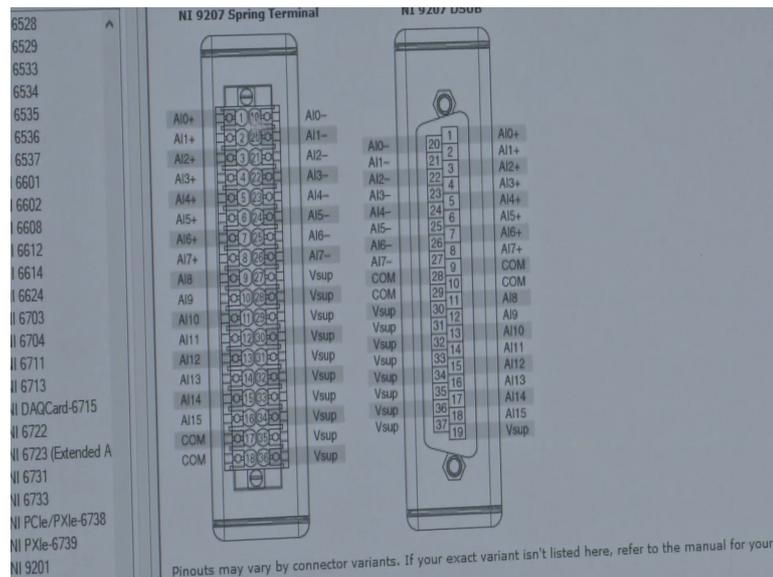
Here we can see so, 9207 is the module whatever we are using.

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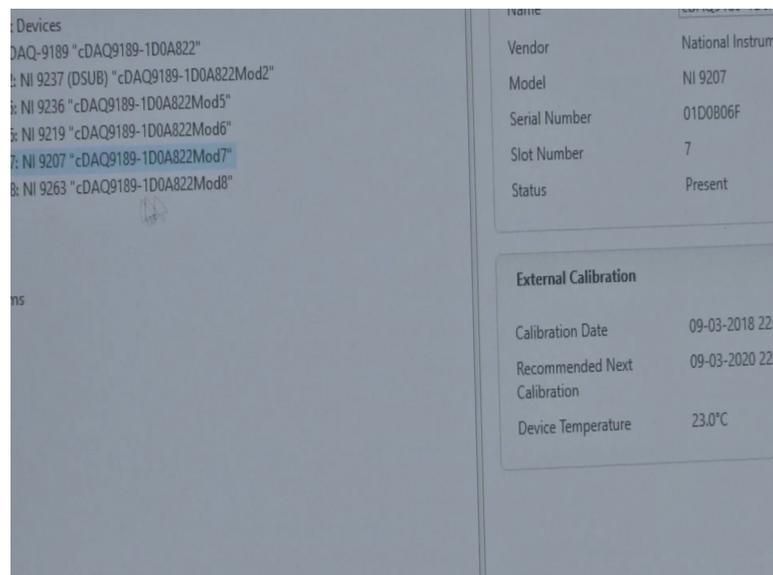
And if you see the first terminal AI 0 plus and AI 0 minus are side by side right.

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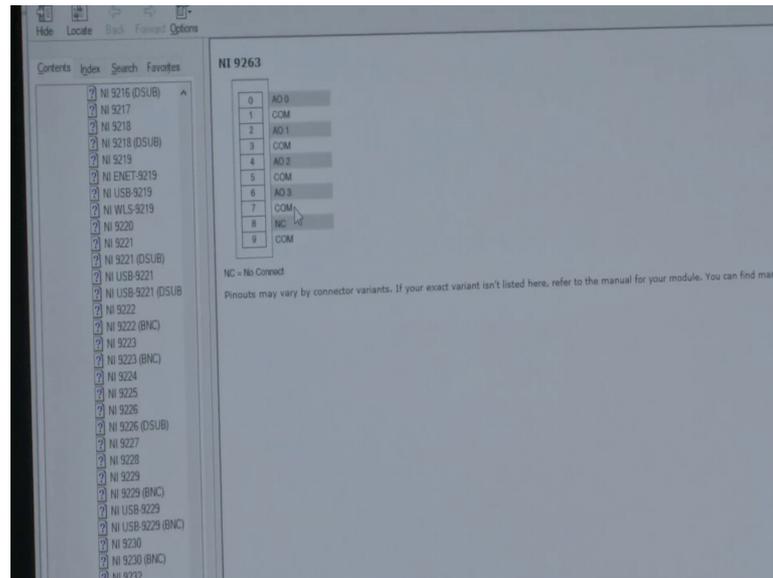
The output from the temperature sensor will be connected at this point and at this point this is ground and this is the output voltage. So, that since it is connected to the acquisition pin and AI represents analog input channel 0, acquisition it records the data and display in a software right.

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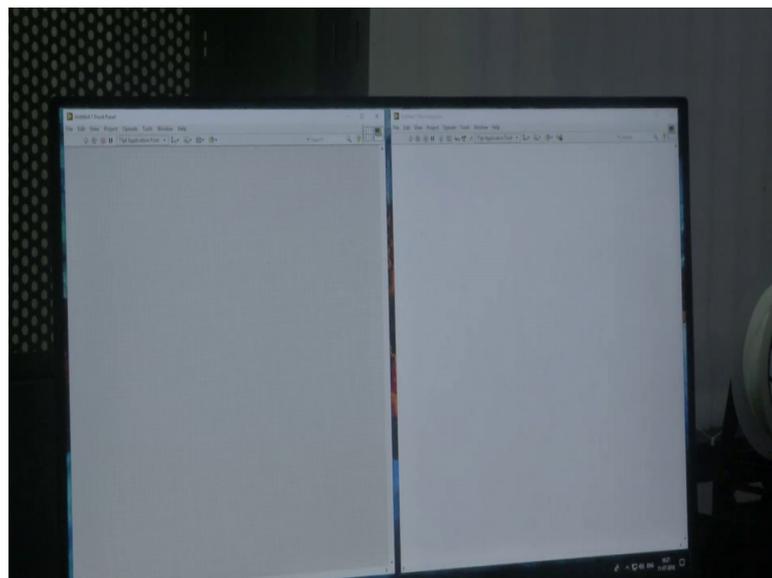
And whereas, for generation of a signal we will be using: module 8 which is 9263.

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When I look into the device pin out so, it has a total of 4 channels right. So, AI 0 common AI 01, AI 02 and AI 03, I will be using 6th and 7 th pins are 0 and 6th and 7 th pins so, I will be using the third channel right. So, these are I am going to use it. Now, how do I generate how do I construct a logic? So, for that we require to go with we have to develop a logic using a software.

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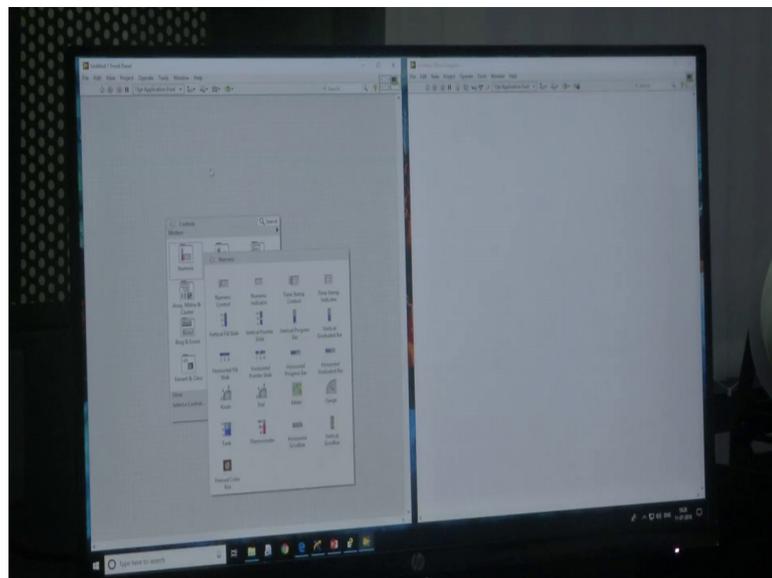


So, I am going to use Lab VIEW, I will be opening a new VI, I am pressing control t so, that both the VI's will be accommodated side by side. Now, this is called the front panel.

So, which is nothing, but user understandable palette sorry user understand and understandable space and this is the block diagram which is nothing, but your actual logic will sit.

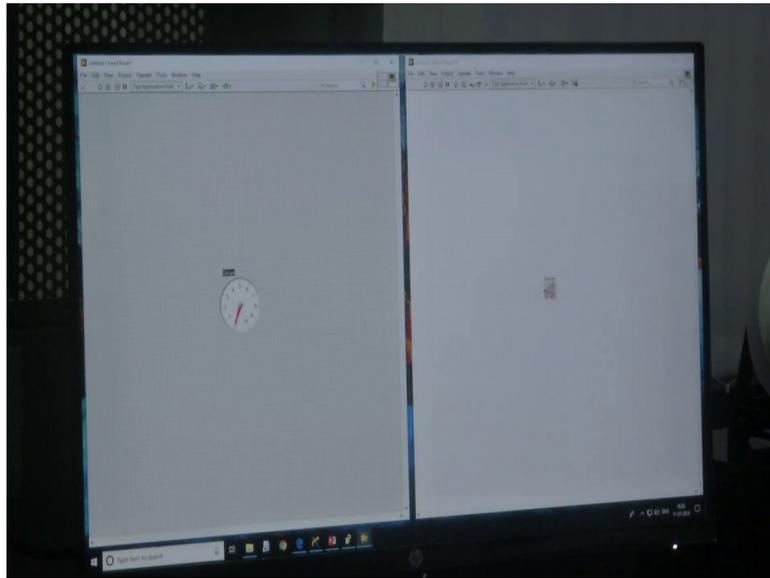
So, when you are running the program you do not have any access to your block diagram. So, once the program is running you cannot change any anything which is available in the block diagram, but user has a space to change completely in the front panel.

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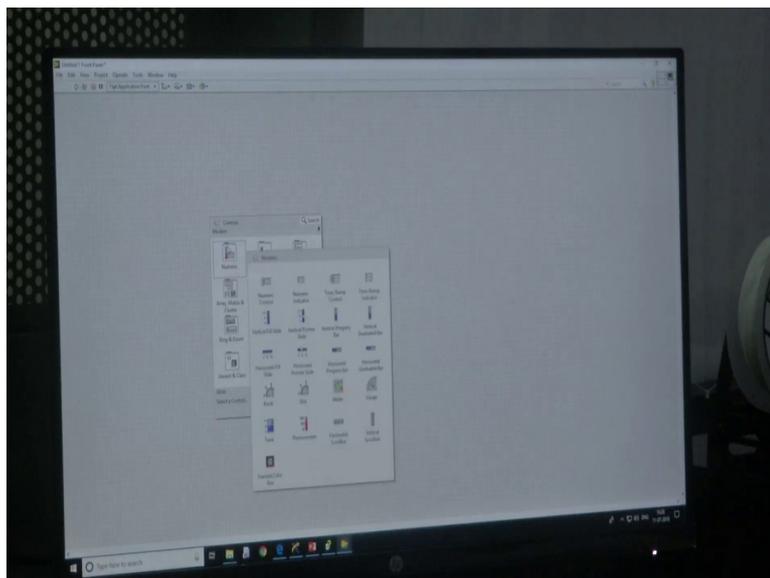
Now, whenever I create some signals here whenever I create some you know indicators or controls in a front panel.

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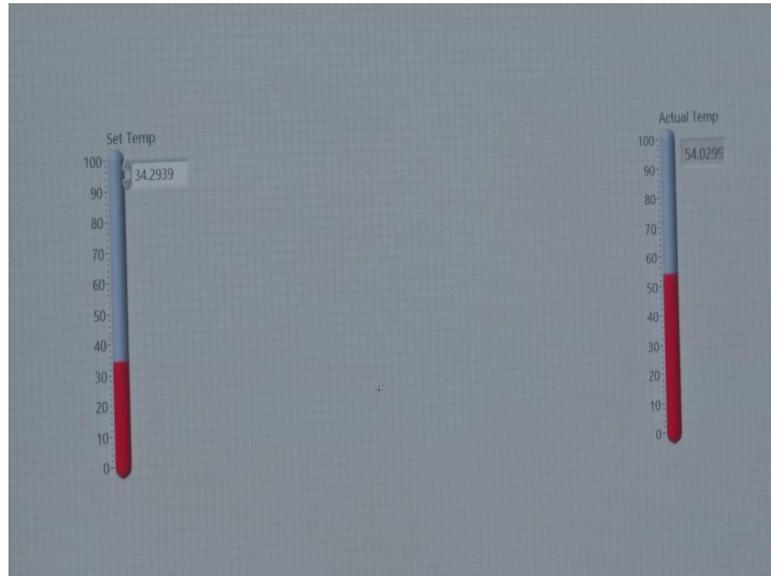
And automatically that corresponding you know you can see here a corresponding block will be created even in a block diagram. So, that whenever we change or whenever we displays here automatically it will update even in the front panel as well as a block diagram so, now in the case our idea was to develop a temperature control to make it more unique what I will do is that.

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I will take the inputs and outputs in the same fashion.

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So, what I will do is first as an input I will take it is in thermometer. So, thermometer represents you what like a temperature increasing and decreasing. So, to make it realistic ok so, I am changing it to control. So, right now this is a control and I will make it as digital display. So, whatever we are setting it here either you can set even by using the digital display or even you can set using you know the hand tool.

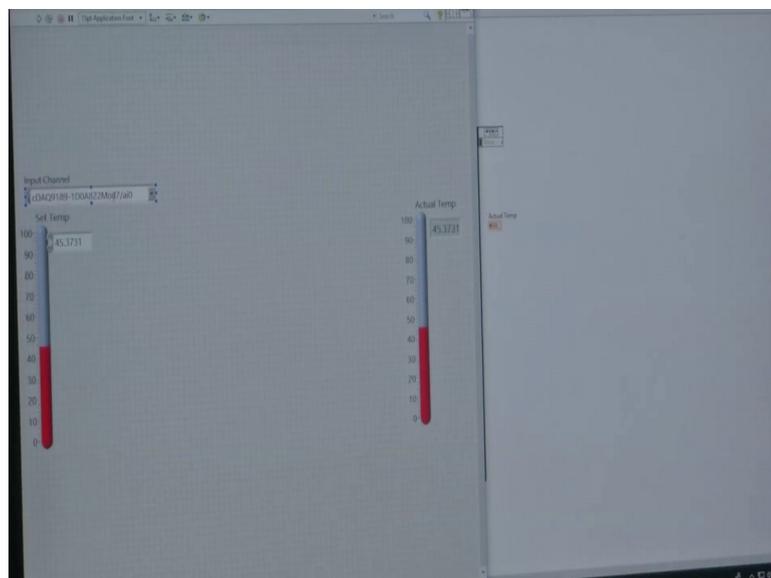
So, naming it as set point set temperature ok. So, what are the required temperature that we require we will be setting at this point, we will be setting using this. Now, other one is we also require output temperature so, but this should be indicator right. So, this is an indicator so, it tells you it gives you the information of what is the actual temperature um; that means, it displays the temperature of the plant; that means, the output of the temperature sensor is connected to this particular icon. So, when I look into the block diagram.

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Here we can see that whichever we have created on the front panel the appropriate icon has been even created in the block diagram. So, whenever I update here.

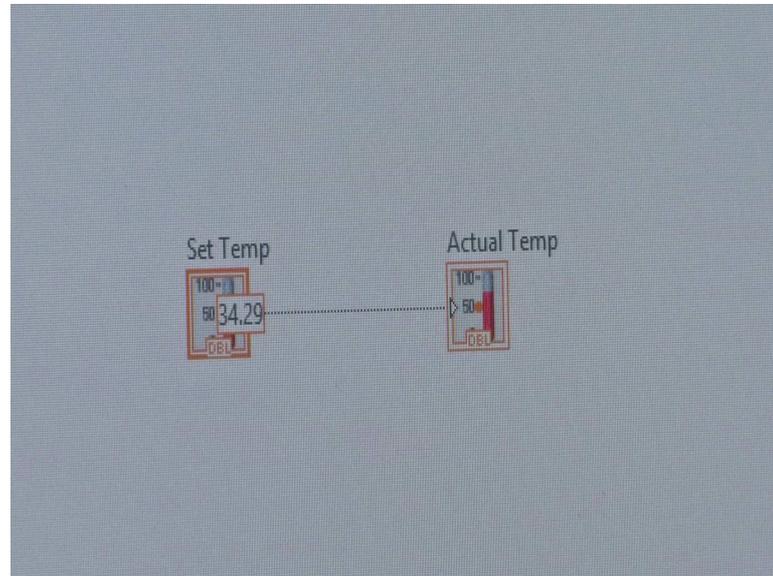
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So, whenever I update here automatically the value will be sent at this point. If you want to understand this what I will do is that I will connect output of the set point to the actual temperature. Now, let me put highlight execution so, that the execution speed will slow down to human understandable values and we can also see what is the data passing

through the wire. Now, let me run I am making it as a continuous run, see the set value is 34, 34.29.

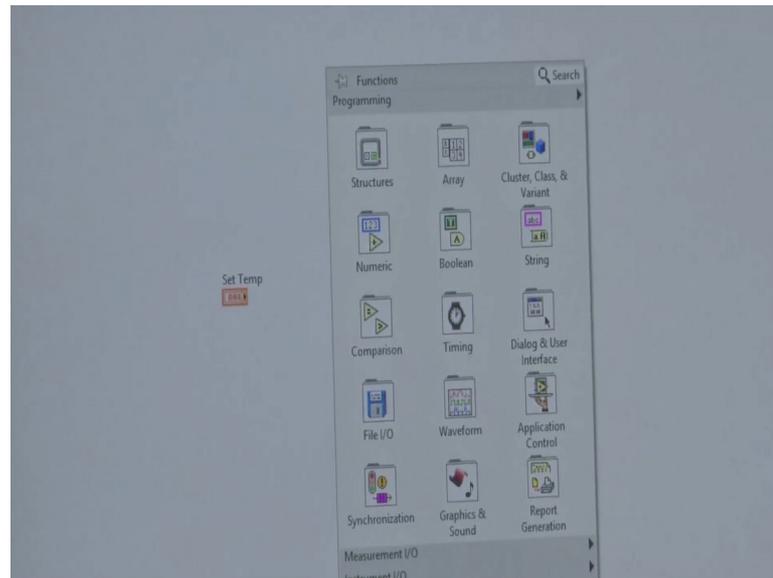
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Let me extend this, here we can see the set value is 34.29. Since, the output is directly connected to the set temperature output is connected to the actual temperature input. Here we can see whatever I do in the set point the same thing will be updated even here, it is a one to one connection that is the reason.

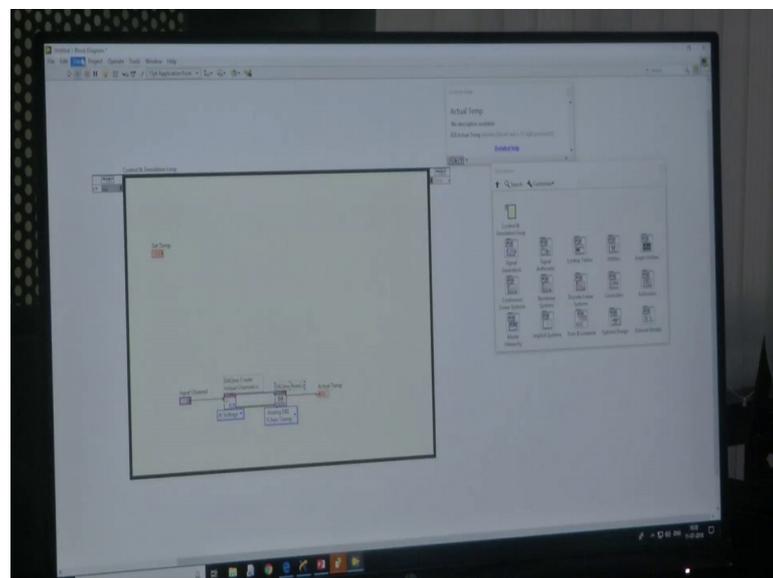
Right so, but we require the actual temperature value from the temperature sensor ok. So, let me show you how to do that, how to do the connections. So, if you look into the block diagram now what I am doing is I am changing it to the icon level. So, this is the set temperature and this is the actual temperature. So, set temperature is nothing, but what? Set temperature is from is nothing, but user input how much temperature that the plant should have. So, that will be completely set by using this. So, by using a software I am using in this case.

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Now, since it is a controller we have a toolbox, we have a separate toolbox in our Lab VIEW that is called control and simulation toolbox.

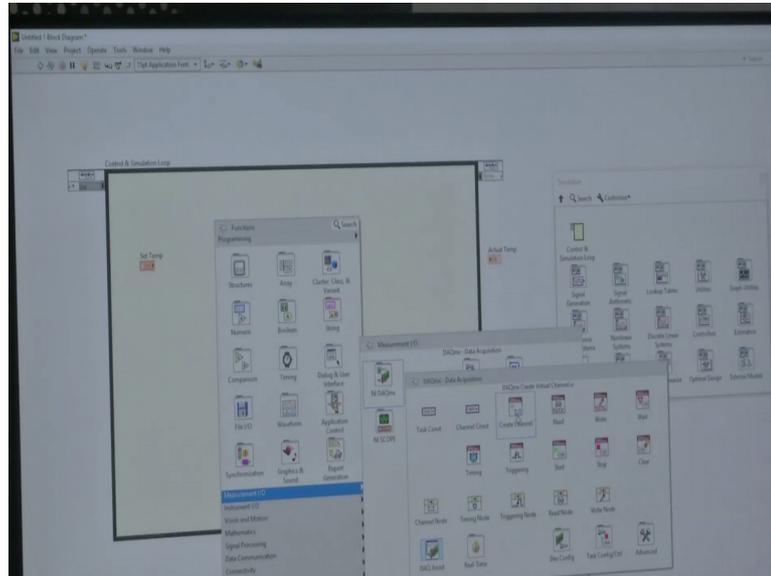
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Let me keep control and simulation toolbox and since I am doing the simulation I will be developing I will be using a control and simulation loop right now. So, the input that should be passed through your controller should be an error input. So, how do we get an error input? One thing is whichever the temperature that we said minus actual temperature. So, how do we understand actual temperature? In order to understand about

an actual temperature we should acquire the data by using data acquisition unit right. So, if you want to create a block for acquiring the data from the external world we have to use measurement I O.

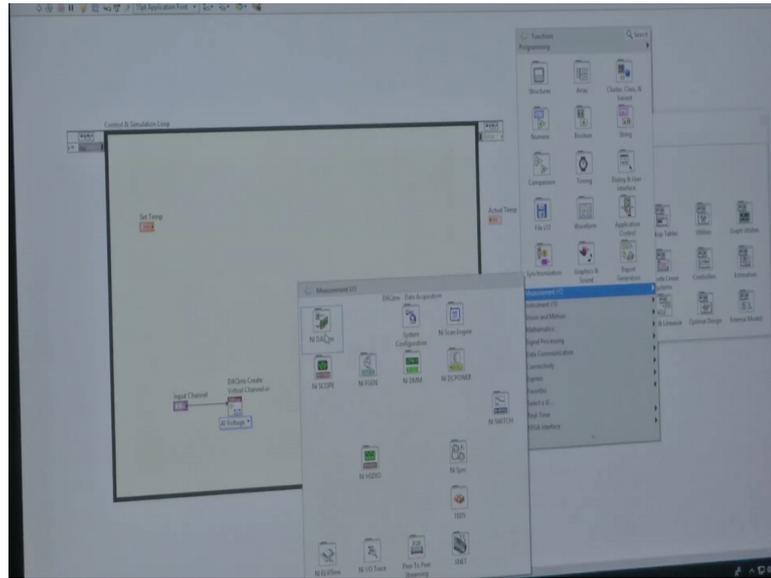
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So, this case what I will be using is that I will be using low level VI's and I will be creating a channel and it should be analog input because I have to acquire the voltage that is why analog input voltage where as from which channel? So, I have to select from which channel that have to do. So, let me make it as a control, input channel temperature this is nothing, but temperature input channel and I will be placing it here; so, we require input channel from DAQ NI 9207 which is nothing, but if you remember here.

Or acquisition we are using module 7 and if I look into the device pin outs AI 0 plus and AI 0 minus right. So, the module pin is module pin is module 7. So, I will be selecting cDAQ 9189 module 7 sorry, I have to go for module 7 yes module 7 AI 0 right. This particular pin out has a total of 8 input channels of analog input and sorry total of 15, 16 right 16 channels. So, in that I am selecting only AI 0 channel. So, here we can see cDAQ 9189 module 7 AI 0. So, since we have specified from which channel that I have to acquire the data it passes through this particular block this is nothing, but virtual channel DAQ MX create channel.

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Then after that I have to read the data that. So, by using this block whatever the data that it is there in this channel will be read and convert into digital because of on board signal conditioning unit which is available. On board data acquisition unit which is nothing, but your PGA or amplifier as well as an ADC. It has on board everything on that module. So, once it is converted into digital data you will store in a buffer and from the buffer I have to read the data. So, for reading it I will be using a read block here DAQ MX read label. So, DAQ MX read right.

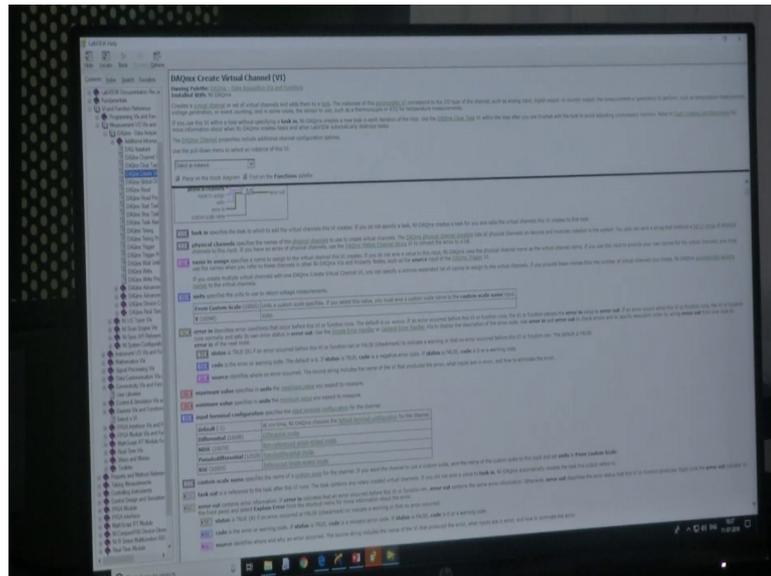
So, since I have to read the data whichever get from this DAQ MX create virtual channel I have to connect output of task to the input of the task of DAQ MX read. And it is always a good practice to connect error block from the output input. Now, if you want to understand what different you know in configuration sorry terminals that it has for this channel press control h so, that we can see the content content context help.

And this is DAQ MX create channel, if you look into this channel few things there are different input terminals as well as an output terminals. And few things are displayed in terms of a bold whereas, few things are normal text. The bold indicates it is compulsory, it is mandatory until unless you connect this block cannot work otherwise it throw us an error if you do not connect it.

Whereas, the normal text indicates it is a recommended it is required whereas, others are recommended right. So, if you connect it, it will consider those value if you do not

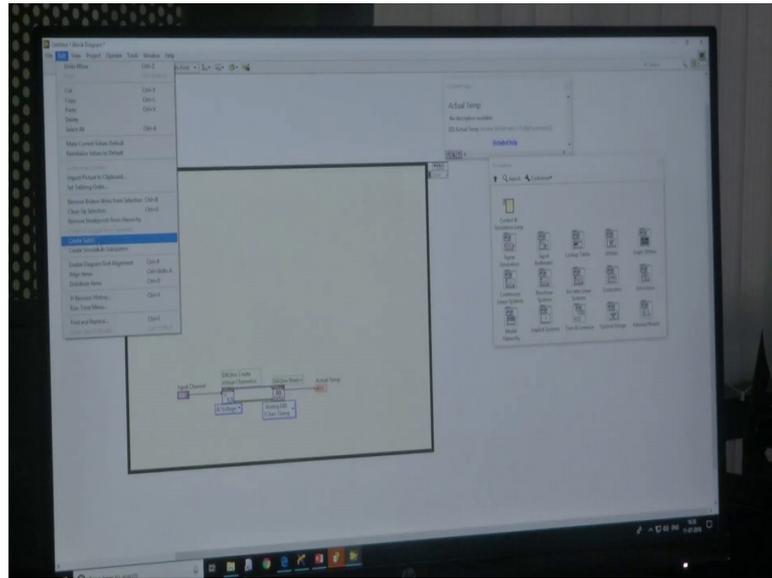
connect it will consider the default values. If you want to have much more information of this, if you go to the detailed help press on the detailed help the complete understanding of all the input terminals and the default values that itself can be completely seen here right.

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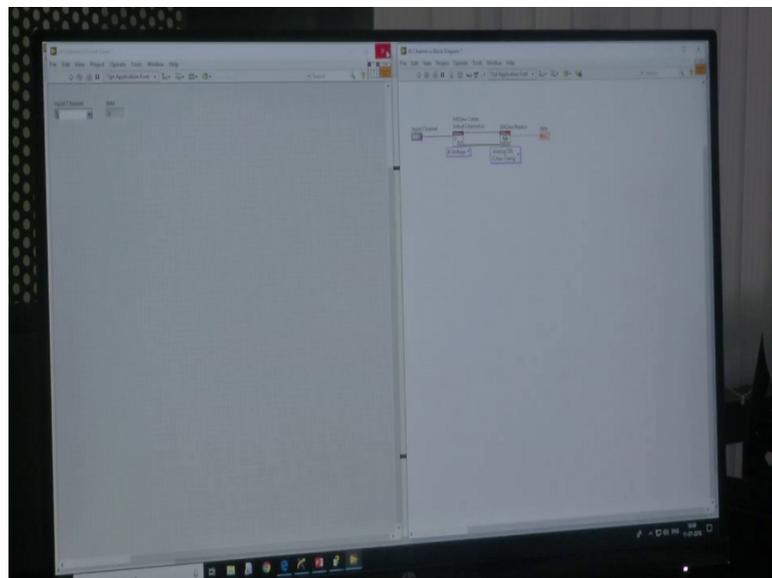
Completely can be seen in the help right. Now, even for in case of DAQ MX it is also a same. So, tasks or channels in has to be connected here, error in has to be connected and this is optional or recommended. Now, whatever the data which is there in the buffer will be displayed at this point right. So, this data is nothing, but your actual temperature data. This is our actual temperature right. So, the output from the LM 35 if I connect it to a module 7 which is nothing, but NI 9207 at analog AI 0 plus and minus terminals that value will be displayed here ok. So, to make it more short what I will do is that I will create a sub VI.

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So, if I want to create go to select those components go to edit and create sub VI. Now, this is the sub VI which we have created so.

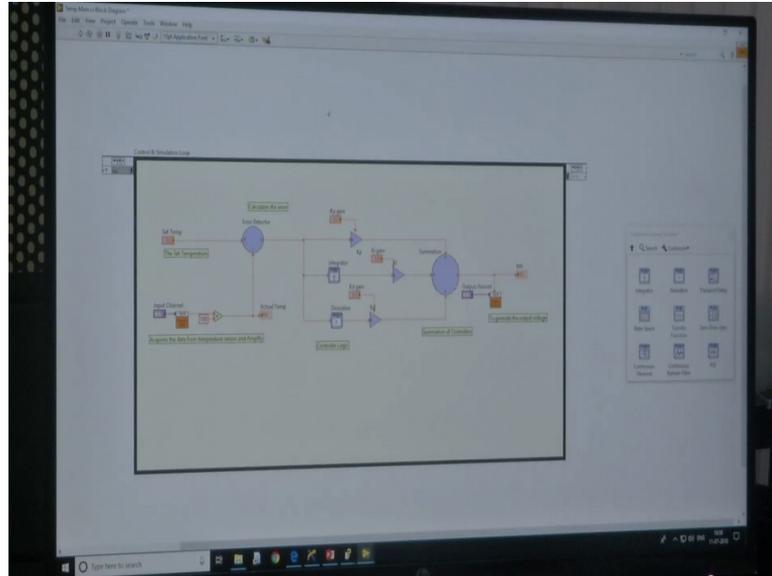
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So, I will be editing it for our understanding. I am not going to write anything, but I am I will be say I am not going to write do any documentation in this case, but it is always a good practice to do a documentation. So, I have to save the data so, what I will do is that I will I will create a new folder in documents. So, by saying temp temperature controller underscore SIL software in loop right here I will be naming it is analog input AI channel

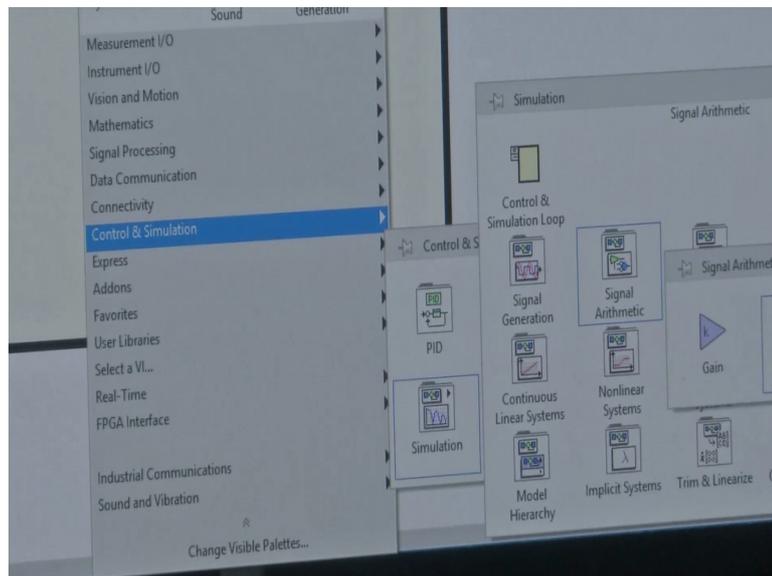
info AI channel ok. So, this I will make it as icon this also I make it as icon ok, let me save.

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So, now the input channel I have done. So, whatever the data that is available will be displayed on this actual temperature. So, till here it is clear, but ok. So, till now this is clear, but it displays, but what has to be done? So, once we get actual data into the software it has to be compared with your actual value and we have to understand the difference between your actual value to the set point. How do we do that?

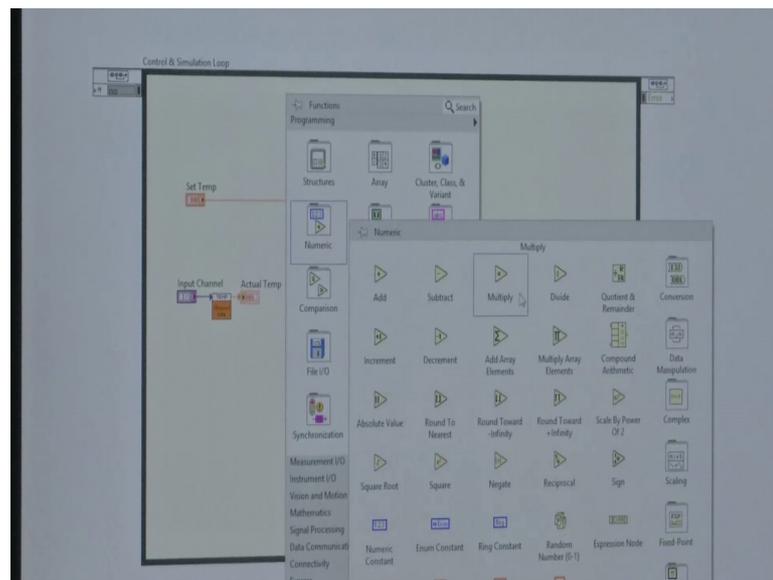
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In order to do that we have to use an error detector. So, for that I will be going to control and simulation and simulation here. Here we can see different other palettes and the blocks, here you can go with an summation tool signal arithmetic in a signal arithmetic. Here you have summation and gain block as multiplication, right now I am going to use summation block ok.

So, now I am naming it as an error detector. When I do an error detector the first step is that the output of the set point has to be connected to the positive terminal. Now, if I directly connect it the sensitivity factor of the set point scaling factor what I mean as well as the output of the LM 35 scaling factor is not same. The reason is that the LM 35 has a sensitivity factor of 10 millivolt per degree centigrade, but it has 0.1 volt per degree centigrade. So, you have to convert amplify the output of the signal to the required temperature value by using an amplification factor of 100.

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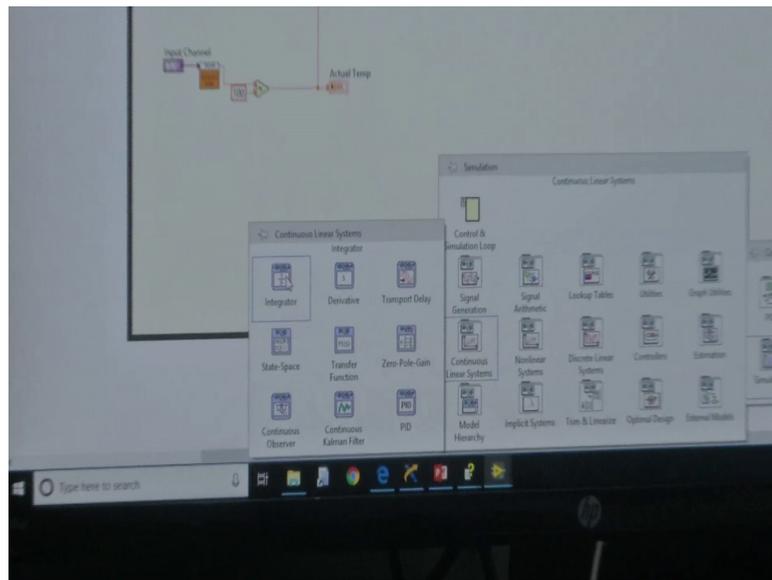
So, what I will be doing is I am going to numerate here I will be taking a multiply the actual temperature value will be multiplied with a factor of 100. So, that both right now after multiplying it both will have the same units so, 10 millivolt into 100 which is nothing, but 0.1 volt per degree centigrade even this 0.1 degree centigrade right.

So, since it is easy to understand the signal which has the same unit what I will be doing is the actual temperature I will be connecting it here. So, both are having in the same unit so, easy to realise. Now, after doing this we get the error signal. So, this has to be passed

through your controller. So, depends upon what type of controller that you are using that that particular you know block has to be logic has to be implemented.

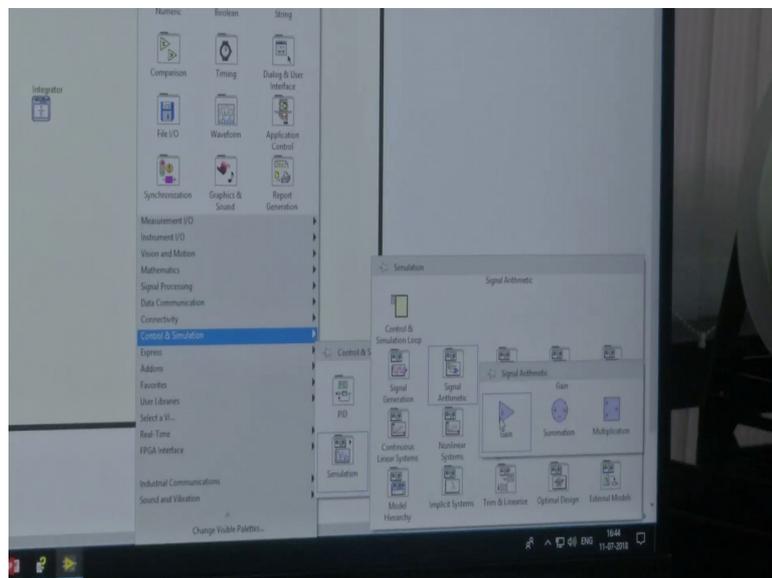
Either you can create the logical of p controller or logic of integrator as well as differentiator. And, I can do that or Lab VIEW already had, this particular software has onboard VI's where you can see it in control and simulation and in the simulation.

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Here if you go if you go to continuous linear systems here we can see integrator derivator too. So, I can say I can take integrator I can take an integrator.

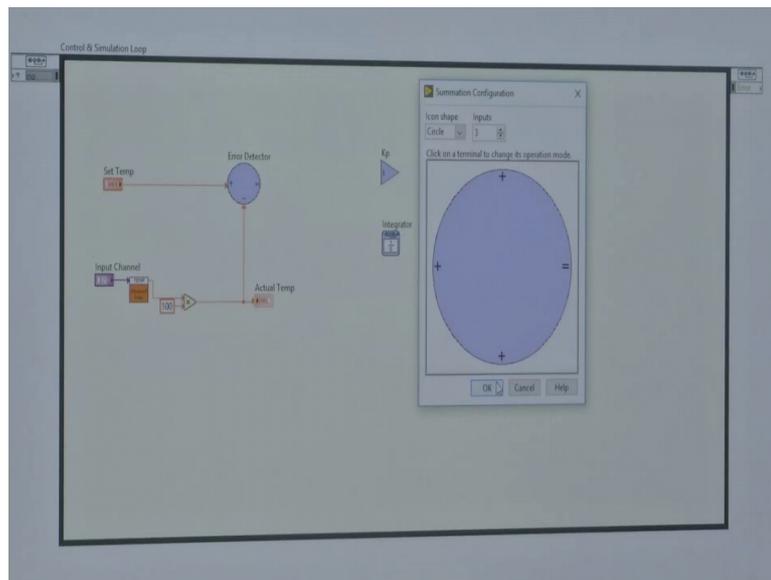
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And I also require the gain blocks. So, here I will be going to control and simulation and this is the simulation. So, let me keep this on so, signal arithmetic here you have gain. So, I am taking it is proportional or K_p proportional gain and I also require integral gain. So, let us take it as K_i , I also require derivative gain. So, let me take it as K_d right.

The summation of all these 3 p plus I plus d is nothing, but your PID if you make K_d as 0 it is nothing, but p plus I, if I make K_i as well as K_d as 0 it is nothing, but p.

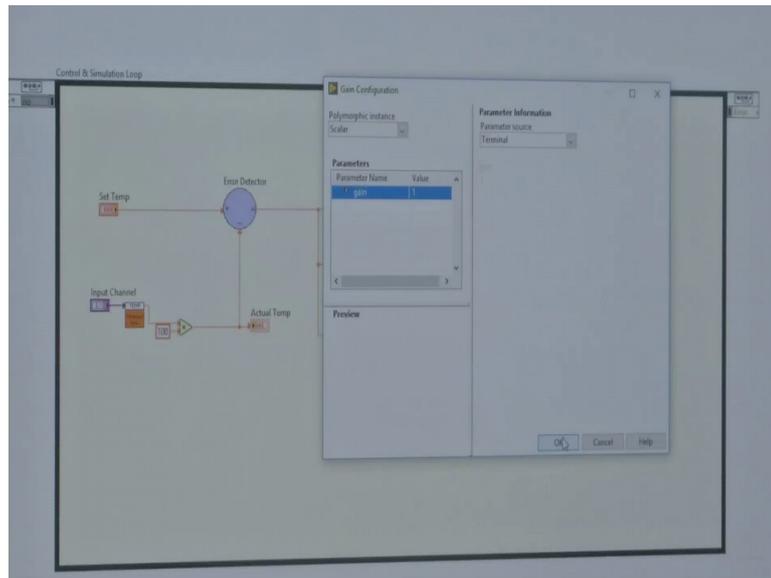
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So, since we require 3, I will be using this and this has also positive. Now, I have all 3, I will be adding it up; this one, this one, as well as this one too right. So, the output of this has to be connected here 1 and another one is integration with gain K again and another one is differential gain.

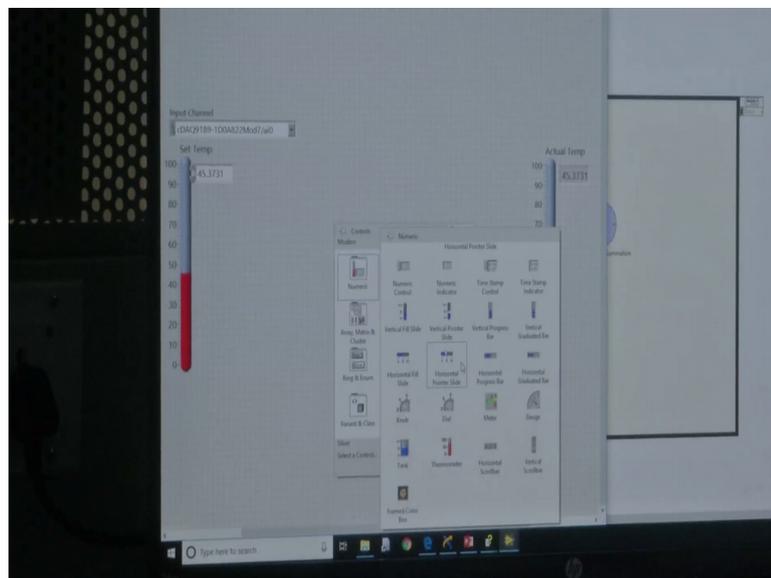
So, I have to go with continuous and here we have a derivative that is represents derivative connecting it here and the connecting it here clean up wire now. So, the complete K_p , K_i , K_d , K and sub them.

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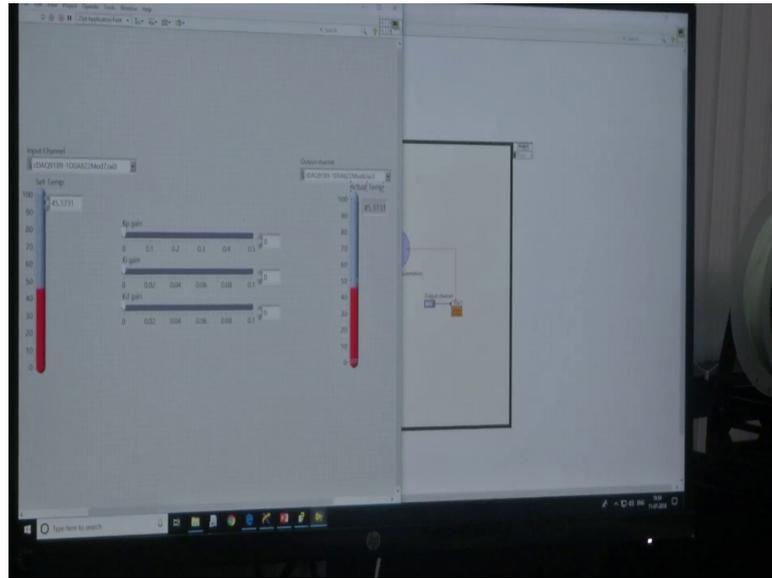
But, since we have to change the gain settings, what I will do is that rather than making at a configuration dialog box I will create a terminal right. So, by using this terminal here I can create a control.

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So, I will be selecting the control. So, what I will do is I will go to front panel go to the numeric I will create a slide horizontal pointer slide.

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I will also create a visible items digital display this is for K_p , this is for K_i , this is for K_d . So, this I naming it has K_p gain this K_i gain and this I am naming it as K_d gain. I may not be required this much of value. So, because when you observe the complete you know the voltage manipulated variable should be within the range of 0 to you know 1 volt. So, what I will do is that I will change the gains to be somewhere around max of 0.5 this also 0.1, this is also 0.1 something later may I will change.

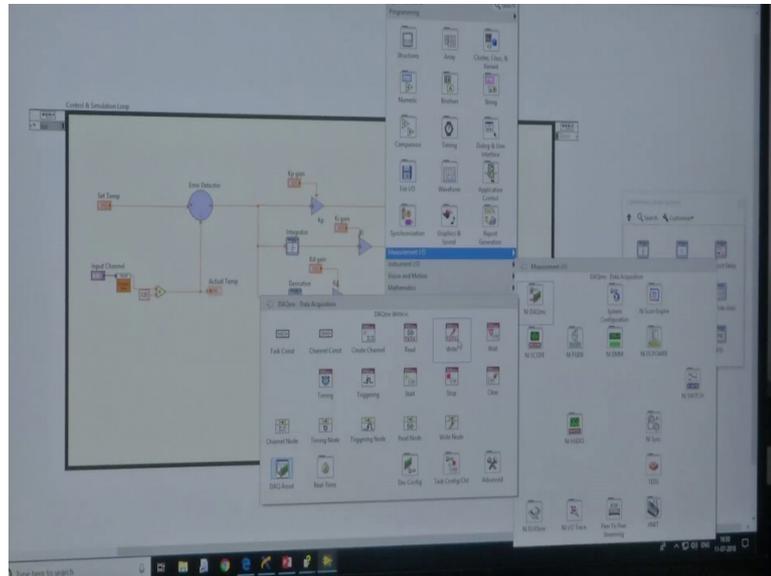
Now, I have created those, here you can see K_p , K_i the block appropriate block for that for whatever we have create in the front panel that I will be connecting it here. And similarly, for K_d again from here I will be connecting it to. So, now, I have to change it to terminal changed from here to here, even the same in case of here to I have to change it to terminal press ok, then K_d gain make it as icon connect the output here to here.

So, both K_i , K_p , K_d , PID controller is constructed in software. Now, what to do? Now, using the software we have done a controller. What is the next step? Whatever the whatever the data that is you know based upon the logic is going to generate that is nothing, but your manipulated variable right that has to be given as an input to a plant.

If you want to give it is an input to the plant what I have to do? I have to send it to the real world or send it to the external world, but whatever we have design the PC everything will be the digital how do we do that? Again, we have to make use of data

acquisition. So, in a data acquisition unit we have to generate we have to use a generate signals.

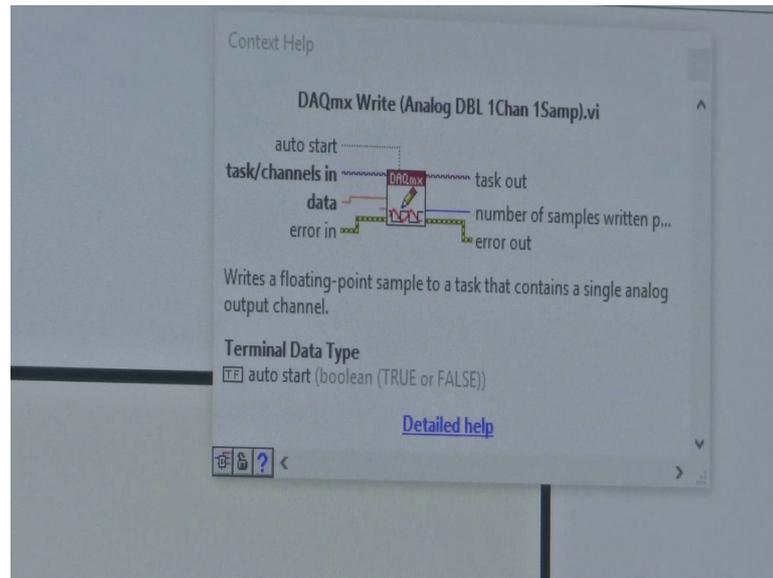
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So, how do we do that? For that what I will be doing is I am going to measurement an instrument. So, here I will be using create channel 1, but previously we have used analogue input read now, we will be using write that is it.

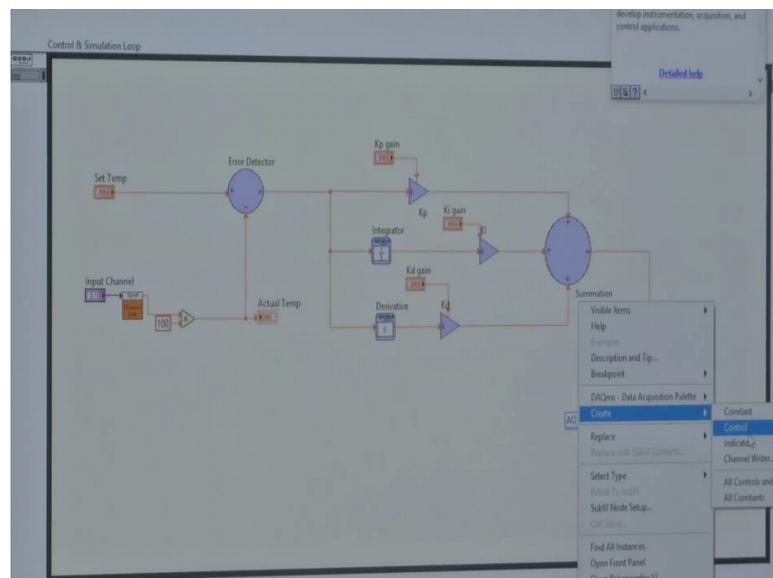
So, but now it it should be analogue output not the input should be the voltage and single channel single sample and dbl form. So, this should be connected here, this should be connected here to make it understand let me press control h here you can see the complete physical channels information.

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And here we can see auto start, if you require auto start yes create constant through the data this data is nothing, but this value.

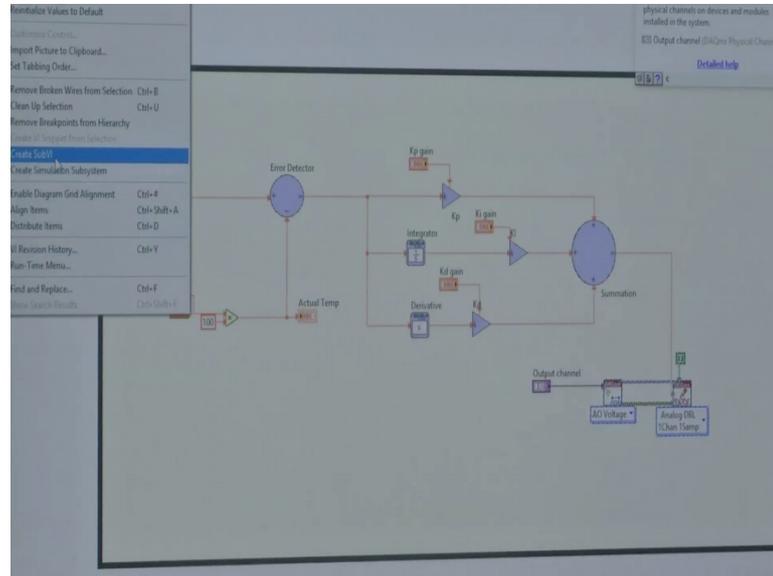
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But, to which channel? So, in order to generate the channel I will be going to I will be creating a control renaming it as output channel, output channel. Now, which channel? So, if you recall, if you look into the device pin out we will be using NI 9263 which is modulate in this case and will be using AO 39189 module 8. Only one in the in this complete chassis I have only one analogue output module say AO 0 right. So, I have

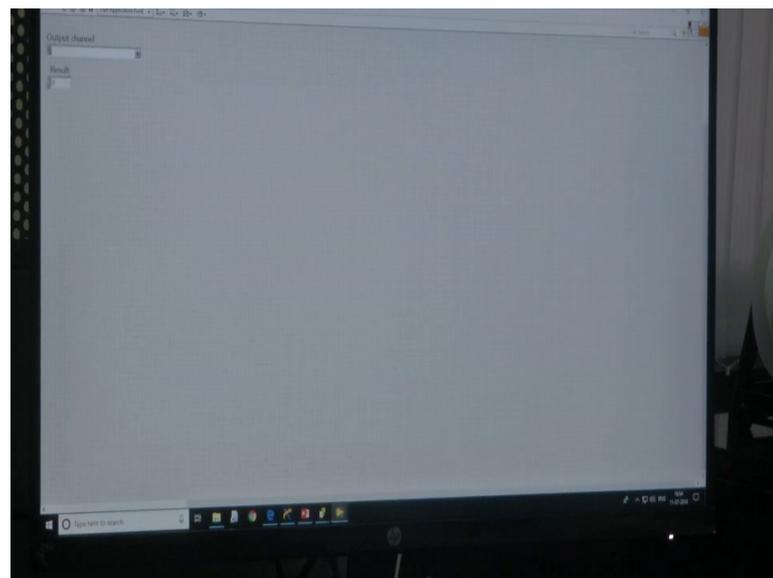
selected it, done now, since it does not look like this what I will do is that I will select everything right and visible ok.

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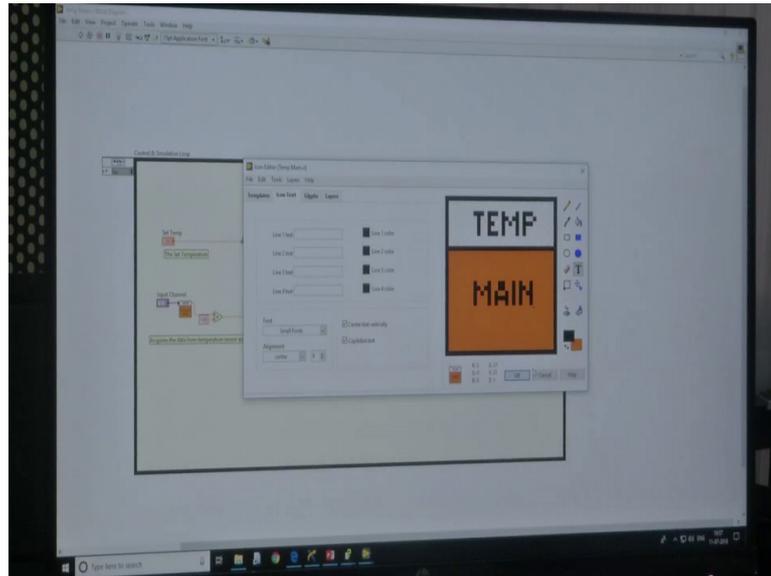
Edit go to edit and make it as create VI so, sub VI is 10. So, let me change everything now the complete channel information everything is provided what are the signal that I am getting here? Ok.

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Let me change the connection. So, output channel this one so, this particular terminal I am connecting it here. So, whatever the result I am getting, I just simply connected here.

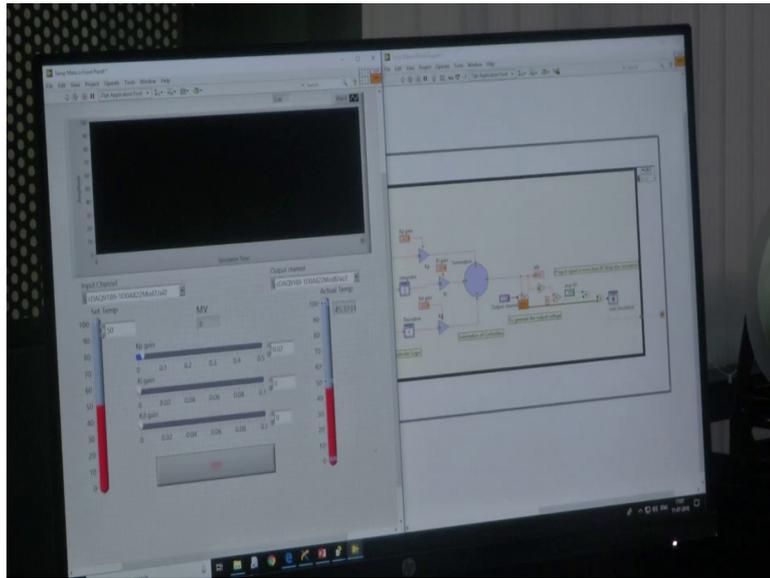
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So, I will be taking it out completely and this is my block, this is temp and this one is main this is done. So, but the analogue input channels as well as analogue output channels can I know it has a particular range above which and below which you cannot work. So, the range of analogue input is maximum is of plus or minus 10 volts, even for analogue output is plus or minus 10 volts. So, in order to not to have any complications by general since it is a simulation.

So, by a by observing in to you know the logic that we have created the output channel can also provided with a higher values to. So, in order to not to damage a signal conditioning units what I will be doing is I will be creating, I will be a creating a stop execution thing right. So, I will be creating the stop execution and I will show you.

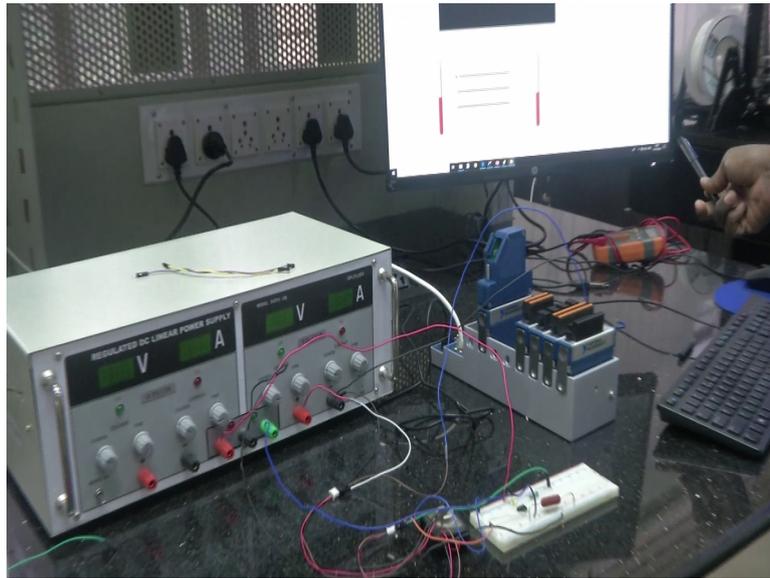
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Now, if you see that this is our final circuit. So, I have created even for if the input voltage is greater than 9 it will automatically stop the simulation everything and this is how the front panel looks like ok, my current value default ok.

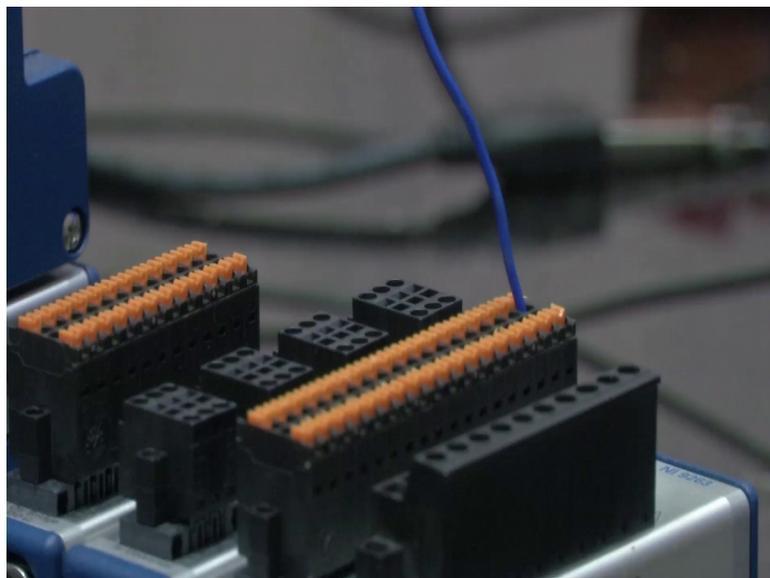
So, let me make it as set point as 50 right now and again is have also tuned proper previously and those values I am using it here right. Right now I am realising only p a p gain and K gain. So, to make you understand about a proportional gain as well as integral gain what I will do is that first I will make even K i gain as 0, only p gain is there which is 0.02 I will be slowly increasing the value 2 ok. So, this is our complete circuit now, before running the circuit let me do the connections.

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The output from the system should be connected to the input of data acquisition analogue module. And sorry output from the data acquisition has to be given as an input to the system, output from the temperature sensor has to be connected as an input to a module 7. So, what I will be doing is that the temperature sensor output.

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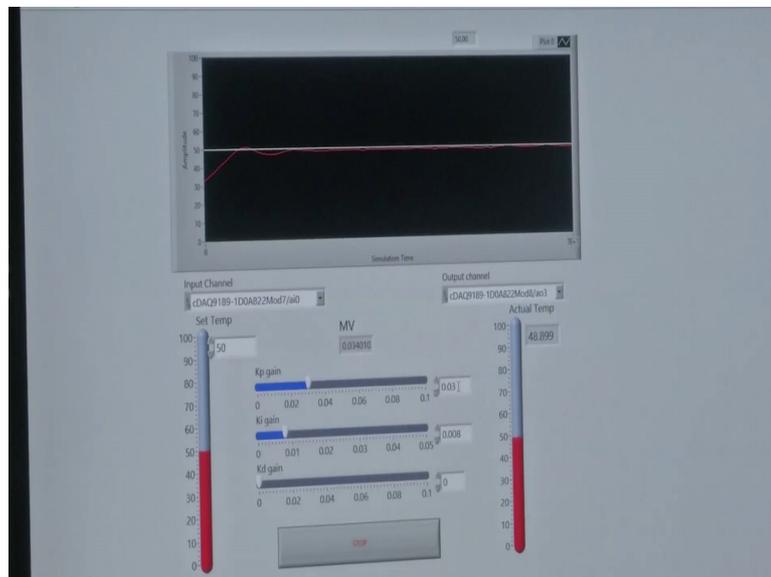


This I will be connecting it to the first channel. So, since it is a spring connection press connect. So, the output of this is connected and the grounds also has to be connected here I will be connecting it. So, both the channels I have shortened right, negative terminal to

negative and to the power supply the output of the LM 35 is connected as an input to this. So, whatever the output whatever the temperature sensor the temperature will be displayed on at this point actual temperature with amplification factor of 100.

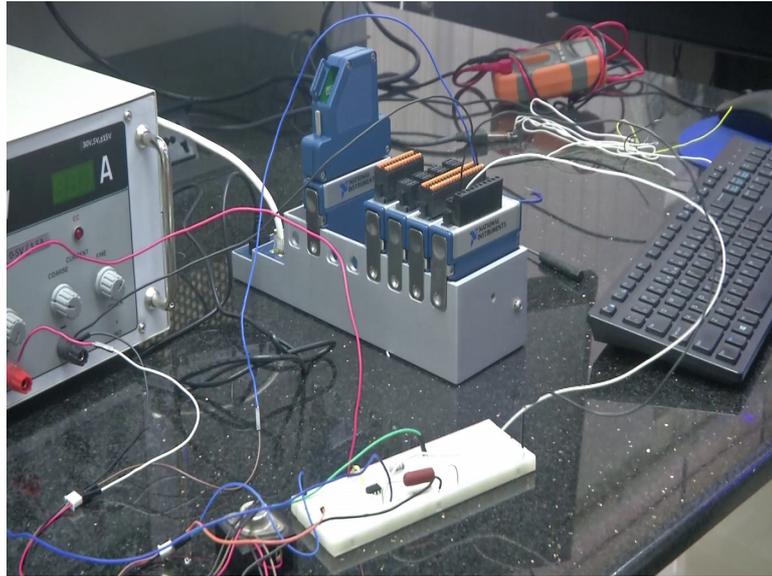
So, since we are looking into in degree centigrade if I multiply with 100 it gives me the actual temperature value right, sorry in this case we are using a sensitivity factor as 1 per degree centigrade. So, since it is a digital representation I cannot even say whether it is a voltage or something. 1 per 1 degree see if it is a 1 degree, it is shows 1 degree, if it is 10 degree it shows 10 degree, if it is 100 degree, it shows 100 degree. So, that is why we are multiplying within factor of 100 in this case ok.

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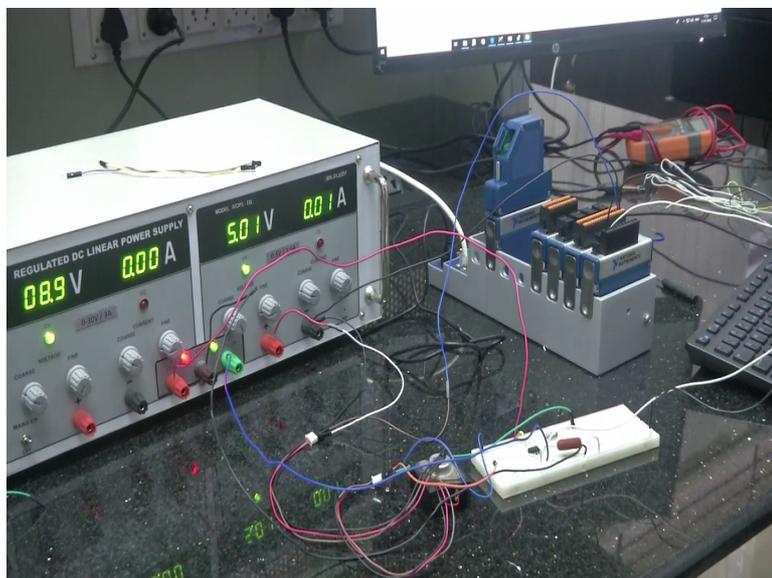
Now, the temperature sensor sorry the transistor is connected to this, but output from module 8 which generates an output based upon the manipulated signal from the software has to be connected as an input to this point at input 3, terminal 3. So, for that what I will be doing is I will be taking 2 wires.

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I am connecting it to the sixth pin, this is the input to the positive terminal right and I need a ground terminal. So, what I will be doing is I will take one more black wire. So, to the 7 th pin I am connecting this ground right to here right.

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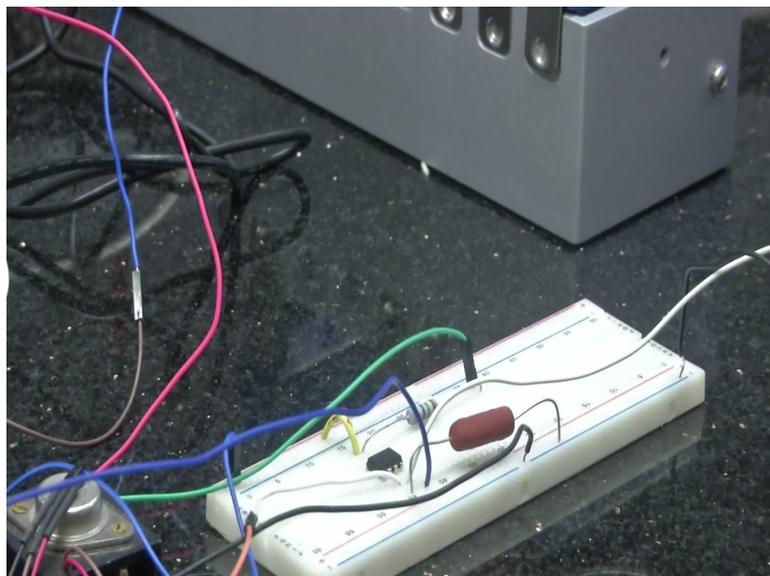
So, let me switch on the circuit, sensor requires 5 volts right. Right now it is at room temperature so, let me run. When I run the circuit right, right now the temperature is at 25 degree, the set temperature is 50 degree, here we can see that the white one represents

our set point which is 50 whereas, red one represents your actual temperature meaning the temperature on top of a transistor.

So, here we can see so, since there is a difference right now it is at 70, 47.9. So, even though I am will be keep on waiting, waiting, waiting, even if I increase the value to some 1 volt right we cannot see much change in this. So, that is the problem with proportional controller when you are going with an higher order systems right, when you go with higher order systems the proportional gain even though if we keep on increasing it will always have some offsets. It depends, it depends upon what kind of a system that we are using.

So, in this case since we have applied a gain of 1 ok so, the temperature has increased as a result the manipulated variable is negative. Since, it is a negative the transistor will be in switch off condition. So, by natural convention it starts cooling. So, let me cool down to 0 degree and we will show the response with 0.5. Generally since we have you know increase in the middle of the state it has emergence way so, let it cool it down. So, rather than stopping it what I will do is that let me run it, but where as I will be you know remove the power here.

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We will remove the power, since there is no power at not heat anymore, started cooling right now the temperature is at 49.4. So, as long as since it is a simple proportional

controller as the (Refer Time: 51:25) is keep on increasing the manipulated variable since a gain is 0.5 the manipulated variable will also increase proportionally.

Right so, let it cool down and again let it cool down to room temperature again we will start heating with a gain of 0.5, we can understand that. Now, the major problem with the gain of higher gains because if you see the manipulated variable whatever it is going to generate is 5.6 volts.

So, now, I when you realise 6 volts applied as an input as of the plant it results in higher current 6 amps of current, but you also have to see pumping a 6 amps of current whether your plant can with stand or not. If that is a case if that is a case you cannot go with the higher K_p gains to that is another thing that you have to always remember right. So, even in this case my power supply cannot provide more than 3 amps of current. So, I cannot one thing is I cannot go with 0.5 value.

So, let me change it to 0.2. So, since because of the n is point 2 it is gone to 3 3 volts, 3 volts as an input to the plant. So, maximum of 3 amps of current will be passing through that. So, now, it has reached to somewhere around the 34.3 degree centigrade. So, let it cool down to some more temperature, some less value even 3 amps. So, I will yeah let me take it to 0.3 ok. It may be initially difficult to cool it down initially difficult, but let me stop once again and run it.

So, it starts from 0 if I stop and done it. So, before running it let me run it and I am connecting the power here. Since, of connected a power to the breadboard the temperature started increasing 34, see how fast it is started increasing. So, the time it takes to reach to the set point to the set point entirely depends upon what is the gain that we have set.

And because of higher gains there are also chances of generating overshoot. Here we can see because of the higher gain it is pumping higher amount of current, there is an little bit of overshoot. If that overshoot is that is fine, if not if not we have to go with a smaller gains or we have to go with a different differentiator right also settling time.

Now, if you see 48.9 this is a 50. So, we have to wait for some more time to settle it down. So, almost it is taking somewhere around right now it is at 3 seconds. So, right now it is 50.3 so, almost settled. So, by using a p controller also when it cools down

again it is pump with a little higher current again started heating it. So, it is still not settled, it is keep on fluctuating right that is the problem with your p controller 2.

So, one way to realise is by using a K controller K gain to. So, let me stop at this point and I will decrease the K p gain and slightly increase the K a gain. So, that we can understand by using i gain, adding an i gain how fast it can reach to the set point as well as it reaches to the settling point to.

Right so, let it cool down so, just to cool down I am removing unplugging the power supply unit so, it will cool down. So, right now the temperature as reach to 30 degree. So, I have set a gains K p gain as 0.02 and K gain as 0.062. Now, we can see: what is the time it takes to reach to the set point, let me run and I am applying the power.

So, you can observe started heating, heating and with no time almost with 3 seconds, 4 check 43 and is this to the set point 47 somewhere and is to 49, 40.8. Now, it will try to maintain. So, that is an advantage when compared with p controller the p a controller it can have fast response as well as it can reach to the steady state error very fast.

So, that entirely depends upon the what is the gains that we have set for K i as well as K p. Still it is in fluctuations not yet reached to setting point, yeah settling point can be calculated 1 or 2 percentage 5 percentage of your set point. So, now, it is almost at 49.4 degree almost settle.

So, that is the difference between a normal on off controller and the your proportional and integral controllers. So, in case of on off controller it will be on off, on off something like that, but whereas in case of a p r p a controller it will control right it will try to control to the set point 48.6. If this plus or minus 1.5 degree is ok, we can go with this gains, if not we can we have to slightly increase a gains of i controller or p controller. So, let me change it to somewhere around 0.08. So, it is completely a manual tuning. So, this is out to do the manual tuning.

We can see at this particular point it is started almost you know close to that of our set point right. So, this a why we can understand how can we make use of a data acquisition unit as well as software in loop system and. So, I you know and working with you know real world signals as well as the software interfacing both together. So, hardware system

come most system or data acquisition using a data acquisition to the real world hardware system and controlling the temperature of a plant.

So, this is how this is simple case study to make you understand about the working of a data acquisition as well as working of controller using Lab VIEW as well as a closed loop control system as a software in loop system.

Thank you.