Electronic Systems for Cancer Diagnosis
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Lecture – 70
Closed loop control of temperature sensor

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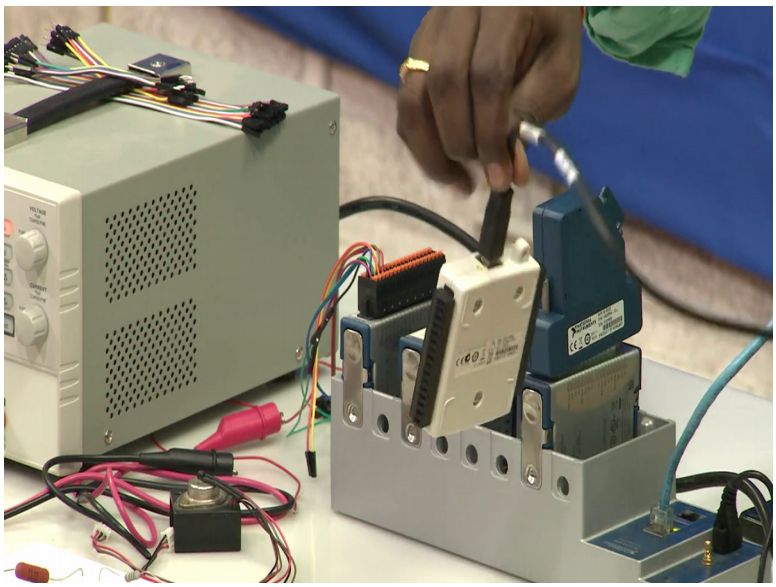

Welcome to the module. So, now, we will see the case study on using a temperature sensor as well as a heater circuit in order to control and monitor the temperature on a plant. So, now, we will see how exactly you know you use a temperature sensors in order to measure a temperature of an object and as a result we also require to have a plant in order to understand the exact behavior of a temperature sensor.

So, for that to you know, to explain you about the case study of making use of temperature sensor as well as a plant and as we already seen about a data acquisition, by combining all these systems I would like to show you today about you know controlling the temperature of a plant using transistor as well as data acquisition system as well as a controller which is building in a lab view.

So, in the last module we have also seen about the data acquisition device, different types of data acquisition devices one is our normal USB based data acquisition device and cDAQ, compact DAQ so which has multiple channels and multiple slots so which is

attached to the chassis. So, the whole idea of this experiment is that we have a temperature sensor.

So, here if you observe we have a temperature sensor which is of LM 35 which is interface or mounted on a transistor. So, this is a power transistor so 2N3055. So, we will be building an electronic circuit in order to heat this transistor to particular temperature. So, what temperature it entirely depends upon the user requirement. So, since we are developing a controlling unit. So, user has a ability or user has you know flexibility in order to maintain the temperature on top of this transistor. So, but for that we require to have you know driver circuit or in a excitation circuit in order to make the transistor to heat.

So, in order to monitor and in order to control the temperature on the transistor we have mounted this temperature sensor which is LM35. So, this temperature sensor measures what is the amount of heat available and what is a required you know at the set point as decided by the user and based upon the control will understand how much amount of input to be given to the plant such that it can maintain or it can able to you know reach to the particular temperature.

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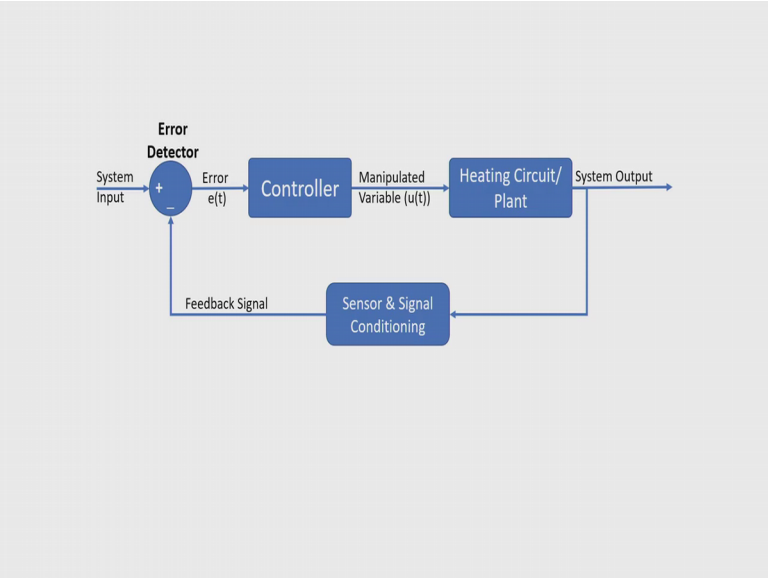

So, if you recall the complete you know closed loop control system as the user intended to understand about you know system output. So, where as the output in this case is nothing but your temperature. And the temperature is not some kind of electronic unit,

we require to have a sensor which converts from temperature to an electronic output, but moreover sometimes it is necessary to have a signal conditioning circuit. The reason is that, in order to match the input units to that of the input, system input units to that of the output of a signal conditioning; output of a sensor.

So, in this case if you clearly observe we have an error detector which the input is connected to this positive terminal of an error detector and the negative is connected from the output of sensor as well as signal conditioning circuit if required. Such that this particular block will measure the difference between the input as well as a output signal, but both should be the same units. In this case both are of electronic units, as we are developing the complete system using electronic unit both should be understandable by the electronic system.

So, that is a reason we have realized the temperature as well as input in terms of a voltages. So, the system input voltage is nothing but what is the amount of voltage required, you know what is the amount of temperature it is necessary in order to maintain the temperature on the heating plant.

For example, let us say if I consider the mapping factor are the scaling factor as 1 volt per 100 degree centigrade, sorry 1 volt per 10 degree centigrade which means that if I provide a system input as 1 volt the system will understand that the plant should heated to 10 degree centigrade. So, depends upon what is the requirement and which what is the amount of heat to be generated on the heater circuit, the user has to be specified at the input side.

So, based upon that the based upon the current temperature available on the heater the sensor will understand and gives a electronic output voltage and which is fed back to the input of the system. As a result depends upon how much amount of input signal is available and what is the output temperature, it will measure the error this error will be given as an input to the controller. So, generally you can use controller on off controller, P controller, PI controller or neural network based or fuzzy logic based any kind of a controller which will understand the error component and will generate a manipulated variable such that it maintain or it controls the temperature on the plant. The temperature on the plant is equivalent to the set temperature by the user.

But unfortunately sometimes whatever the manipulated variable given by the controller may drive the plant or sometimes it may not. So, in order to make compatibility with respect to the output of the controller to the heating plant we require to develop a driver circuit. So, in this case as I have already told we are generating a temperature on a transistor. So, we require and where as the controller which is nothing but lab view plus data acquisition device in this case.

The data acquisition device cannot provide you enough current in order to heat the transistor to the required temperature. As a result we require to build a triggering circuit or driver circuit which can act as an input from the controller and you know takes power directly from the power supply and allows the plan to heated to certain temperature.

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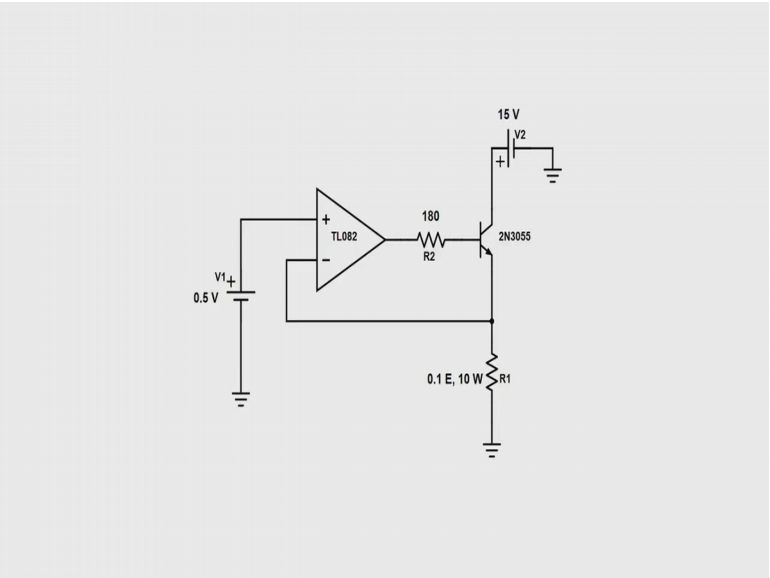

So, for that we will be using this particular circuit where it uses an operational amplifier, it need not to be TL082 we can go with 741 general purpose operational amplifier 2 and this is a 2N3055 which we have seen just previously which contains temperature sensor which is mounted on it. And it is powered by the plus 15 volts. The base of the transistor is connected to the output of operational amplifier using a current limiting resistor so that it will not damage the transistor. And to the negative feedback, to the negative feedback we have connected the emitter of the transistor. As a result if you recall the complete working of the circuit it maintain the output voltage across this R 1 resistor to be same as the voltage connected at positive terminal, this is because of virtual concept.

So, has the operational amplifier virtual concept is that, the difference between the both the terminal should be is equal to 0, since the input is positive terminal is connected to 0.5 it tries to maintain the native thermal also be at 0.5. As a result the drop across R 1 will be 0.5. So, since the R 1 is known to us which is a 0.1 ohm 10 watt resistor and then the voltage connected is of 0.5 volts. So, the current flowing through the emitter of this transistor would be somewhere around 0.5 divided by 0.15 amps.

So, as a result out of 15 volts so, since the emitter is connected with R 1 resistor the emitter current will be 5 amps and based upon you know the principles of transistor we know that the collector current and the middle current is approximately the same which type which is proportional with the proportionality constant as alpha. As a result the emitter the collector current will also be approximately of 5 amps. But when we see the input is connected with 15 volts, but the drop across a resistor is of 0.5, but what about the rest of 14.5 volts?

So, that 14.5 volts as well as the current flowing through this transistor will mean I will generate heat on top of the transistor. And this will be the heat which is generated on top of a transistor will be measured using the sensor and fed back as an input to error detector. So, as a result it generates an error and it continues the you know understanding based upon the intelligence that we create on a controller it will try to understand how much amount of input voltage to be provided at the input side of the driver circuit.

Now, if you look into; carefully look into the working of the circuit the current flowing through this through this R 1 register entirely depends upon the voltage drop which is been generated across this R 1 resistor. And moreover the voltage drop across this R 1 resistor is due to the voltage connected at the positive terminal of an operational amplifier. Higher the voltage higher the drop across the R 1 resistor as a result higher the current flow through this.

But lower the voltages lower current so, lower heat dissipation across the transistor. So, the complete working as we have already seen now we will see how to build the controller logic using lab view and how could interface the driver circuit the plant as well as sensor to the data acquisition device and how can we understand the working of different controllers is the today's task.

So, in lab view you will be developing error detector and the system input is also be controlled by using the lab view user inputs, whereas the controller will can also be realized inside the lab view environment. Whereas the plant as well as the sensor will be externally connected to the data acquisition system where acquires the data and displays on the lab view device.

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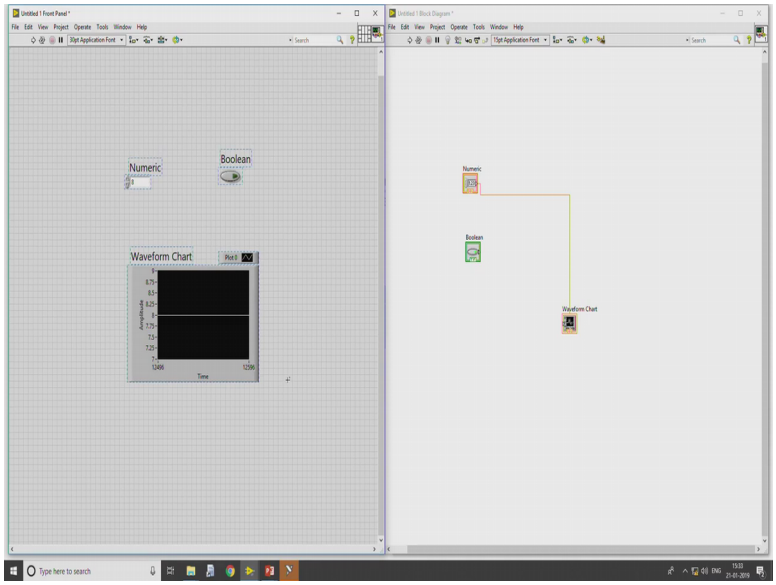

Now, when we look into the lab view so, it contains front panel as well as a block diagram. So, it is similar to that of our day to day life systems what we see in our laboratories too. So, the front panel realize similar to that of our you know function generator or power supplies where user will have you know, user can have access only to either the knobs or can visualize what exactly happening, the buttons, chart if it is a oscilloscope, it is like having a graph or chart on the front panel, but the complete logic will be sit inside the block diagram.

So, during operation the user will not have any access on the block diagram, but user can manipulate things in you know front panel. So, it is similar the structure of lab view is also similar to that of that of our real time environment. So, even in case of our normal systems if you observe the electronic modules will be sit inside the system, when the system is under running condition or operation we do not have any access to manipulate or modify any items. But user can change the knobs to understand or in order to create a curses inside a graph. So, everything can be controlled by the user end. So, the same way

even the lab view platform looks in the similar way. So, now, what we require we have to connect our control unit, one is error detector as well as other one is controller in a lab environment then we have two interface to the real world.

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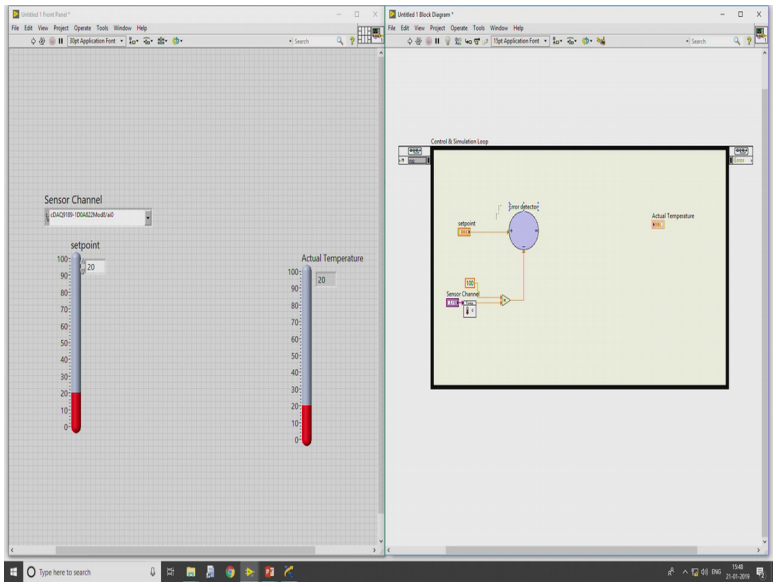

Now, if you see so as our application is similar to temperature monitoring application. I will take one input the set point. So, this I will rename it as set point. So, let me use in, so I am changing it to control. So, I will also provide in a display as well as digital display so that whatever the required temperature that user require can be set at this point. Now, we also require to have the output system. So now, I am generating the temperature output, actual temperature. So, this is set point what is the exact temperature that the system has to be.

Whereas this actual temperature what is a temperature right now in the system has and this should be in indicator so I will change it to indicator. Now, if we observe if I directly connect from here to here and when I run the process we can see that say for example, 100 automatically the temperature on the indicator will also change.

So, this is the difference between and control and indicators with at the user we can only have an access in order to change any parameter, but whereas indicator can only display. But the intention was not to directly connect it here, our intention was to develop an logic algorithm which can monitor and control the temperature on the plant. So, for that so what I will do is that, I will go with a control system toolbox so which is nothing but

control and simulation tool box so where I will create a control loop. So, this is the control and simulation loop and in this I have to build an error. So, first step in our circuit is we have to build an error detector.

So, I will build an error detector now. So, for that I will take summation block which is already available in signal arithmetic of control and simulation tool box. So, I just rename this to error amplifier because this operation of the summer in this case is similar to that of actually it is a difference amplifier it is similar to that of our error amplifier. So, not to confuse I will change it to error amplifier or error detector.

So, one input to this error detector is connected with a set point and another input the negative terminal should be from the sensor, but in this case the sensor is externally connected. So, we require to create a data acquisition modules in order to acquire the data from the real world. So, for that what I will do is that, I will create a measurement I O, I will create the data acquisition modules in order to acquire the data. So, for that I will create new vi. So, in this case I will go to ni I will create a channel and then I have to read the channel then I should display it. But which channel?

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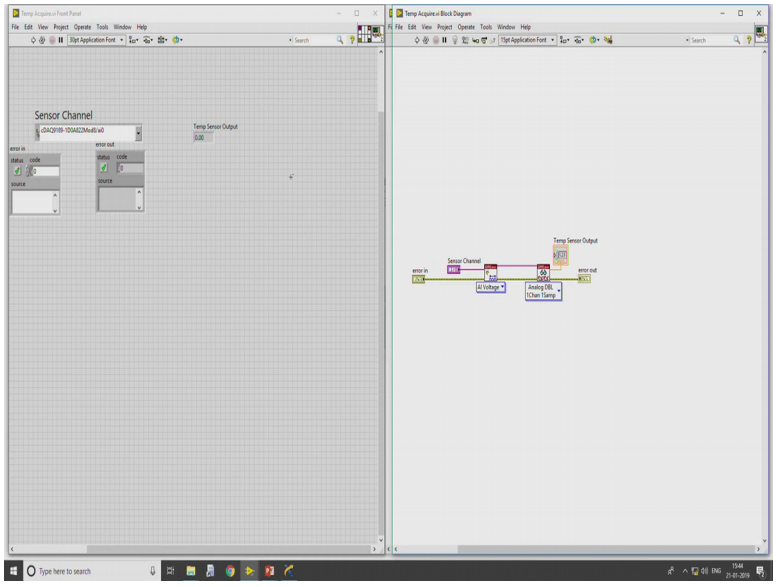

So, for that I will create physical channel create change to control. So, I will rename this as sensor channel. So, if you observe the system has been connected with two different modules; one is my DAQ one is our cDAQ other one is USB DAQ. So, in order to understand about the configuration of USB DAQ as well as cDAQ, what we can do is

that as we have already seen in the last time we can go to NI MAX, which is a measurement and automation explorer.

So, where we can have the complete access of the particular data acquisition models connected to the pc. So, in this case if I go to devices and interfaces here we can see one is USB DAQ which is called which has named as Dev1 and other one when I look into the network devices we have cDAQ 9189 which is also named as cDAQ 9189-1D0A82. So, we will be using these two, so in this case, so I will be using since it is for the acquisition I will be going with cDAQ module 2. So, we can see what are all the modules has been connected into this one. So, we will be accessing NI 9207 in order to acquire the data from sensor. So, in NI which is a modulate 9207.

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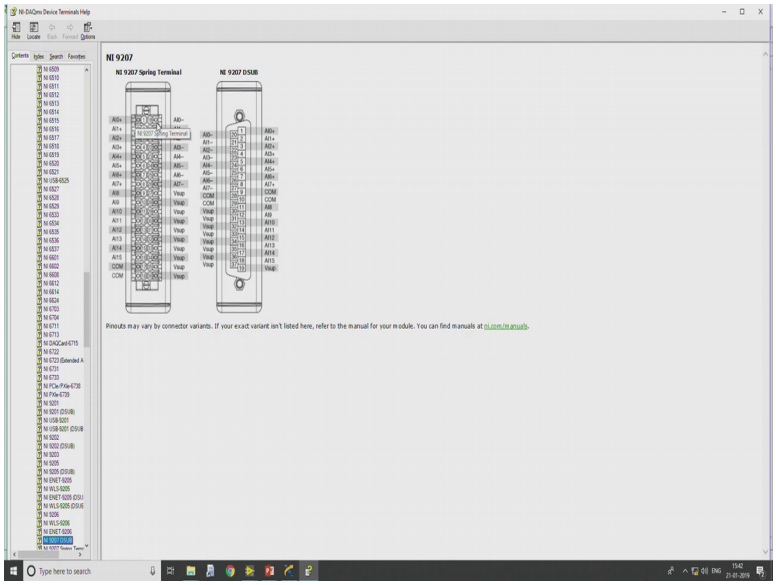

If you look into the pin nodes of this particular device so this is the particular system what we have. The first set if you see here we have AI0 to AI7 which can make differential output and it can also work for both acquisition of analogue signal as well as generating acquisition of current as well as it can also be used as a power supply. But it cannot provide enough current or enough voltage in order to you know drive any circuit, but since our in intention was to acquire the data from the sensor we will be connecting the sensor to AI0 plus and AI0 minus which will be in voltage format. So, what I will do is that I will create a sensor channel with cDAQ module 8; so cDAQ 9189 yeah mod 8 but AI0.

So, this one just data operations may current value default and our intention was to acquire analogue data so analog voltage. So, as this particular block and we also used for acquiring analogue input as well as analogue current as well as voltage I will be selecting it as a voltage. Then so, the next step is creating an error. Create control so, that it queues an indication if in case if any particular block throws an error without any problem during the execution.

So, custom scale task in and task out will be connected here; so, error out are required changed to indicator and replacing with this one and this particular block is my data so create indicator. So, I will be creating a pin out for this. So, this is an sensor channel in, this is error in whereas, one is error out and this particular pin out will be connected to the data. So, which data is this? Sensor data temperature sensor output.

Now, let me save this file save as. So, I am going with I will be replacing everything in a desktop I will create a folder temperature acquire. So, I saved this file, then I will be calling this file. Since it is I will be using the same file as sub vi. So, just for a sake of interest we can also change the edit the icons as well. So, I will replace this with this one. Let me delete this part. I replace so, this particular block I will replace with temperature sensing, where as this one is AI. So, since it is a temperature sensing value we can using some graphics we can also indicate the functionality of this particular block so say temperature.

So, here we can see different types of blocks available. So, which will not fit in this case, I will take this so already text showing as C ok. Now let me see. So, here we can see, but whatever the output that we get. So, we have to provide this channel, so create control I am creating that control. So, since default is this particular channel it will automatically set. Now what is a mapping fact that we can save for the set point if we recall the mapping factor that we use of 1 volt per 10 degree centigrade.

Meaning if I provide input as 1 volt which means that the system will understand the system has to operate at a temperature of 10 degree centigrade are control light control the system should have a temperature of 10 degree, but when you look into the sensor lm 35 the century of centuries 10 milli volt per degree centigrade. So, in order to map the scaling factor; in order to match the units of the output from the sensor to the set point we have to provide a gain of 100 such that both will have same mapping factor which is

1 volt per 10 degree centigrade; so, for that what I will do is that I will take a multiplier, I will multiply the output of the sensor, the output of a sensor data with 100.

So, let me read a constant, dbl constant so which is of 100, then this I will be connecting it here. So, that whatever the data output that we are getting you will have the same units as input. Now, what we have to do? The output of this error detector has to be interface to a controller right.

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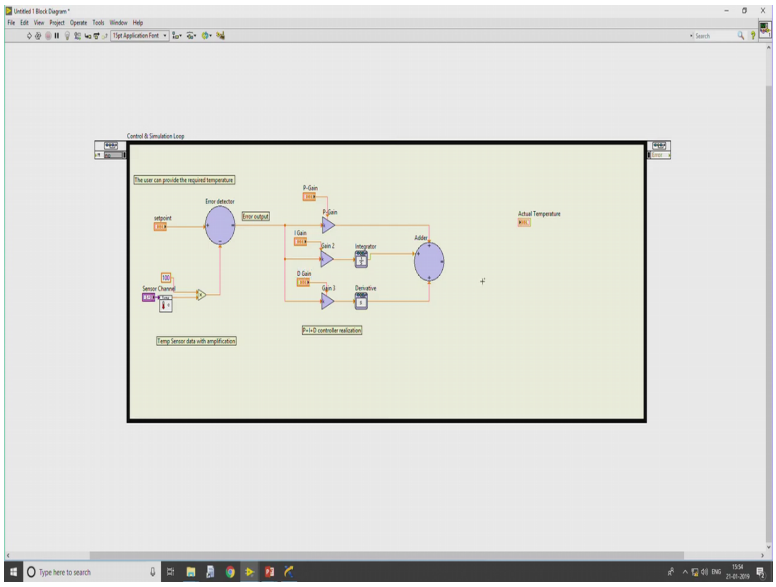

Now, so as we discuss where can we can design on off control, we can design P controller, we can design PI controller as well as PID controller in this case I will go with either P, PI controller but I will also show you how can build PID controller using this. So, just we will go to control and simulation tool box once again and then we will go to simulation, here if you see we have a different types of signal arithmetics where we can create a gain and since we require P plus I plus D in order to construct a PID controller as well as we also require a differentiator as well as integrator.

So, we can go to control linear systems and I we can take integrator as well as a derivative component here and output of error detector which is nothing but output which measures the difference between the set point and the feedback signal output signal so by connecting the output of error to the input of all the gains and by adding an adder circuit we can realize the either p or pi or PID controller. So, provided depends upon what kind of a controller that we are you know realizing other particular gain

should be make it as 0. So, we also require another arithmetic I will copy and paste this particular error detector. But in this case we require 3, 4 inputs and this should also be positive or I will make in this way this is positive this is ok. So, such that this I say add a.

So, P connected here and this should be connected here. But the problem comes here is how do we manipulate the gain from the front panel? So, for that we can do is that we can double click on the gain, instead of taking parameters source from dialogue box we can make it is a terminal so that so P underscore gain so that we can create a control at this point silver. I will go with numeric horizontal points slider. I will also create digital display so that easy to understand what is a value of P gain, but this should be P gain. So, this particular block I can connect it to the input terminal.

Similarly, even for I gain and even for D gain so if we make P gain as greater than 0 and I gain and D gain as 0 0 that means, the particular controller that we are realizing is of PID controller P controller. But if we make only P gain as high and I gain as some value, but D gain as 0; that means, that particular controller is PI controller. So, with this we can understand how can we easily we can create P as well as PI as well as simple I or combination of P and I or combination of P and I and D.

But we cannot use a simple D controller because when error is a constant the derivative gain will become 0 so which the controller will confuses what like the output given by the controller will be always 0 right. So, what we have done? We have created a complete system with error detector, set point connecting as well as the sensor data with a signal conditioning system. So, this is set point, the user can provide this is like commence the required temperature so the plan to operate.

And whereas sensor data with amplification, temperature sensor data with amplification and whatever we get is error. Output P plus I plus D controller realization and output will be manipulated but this manipulated variable should be given as an input to driver circuit. So, that right now whatever the system it is been generated will be the data acquisition device will not understand how much amount of voltage to be given. So, this has to be interfaced data acquisition by using by using analogue output modules from measurement I O so which is similar to that of what we have created for acquiring the signal from the sensor.

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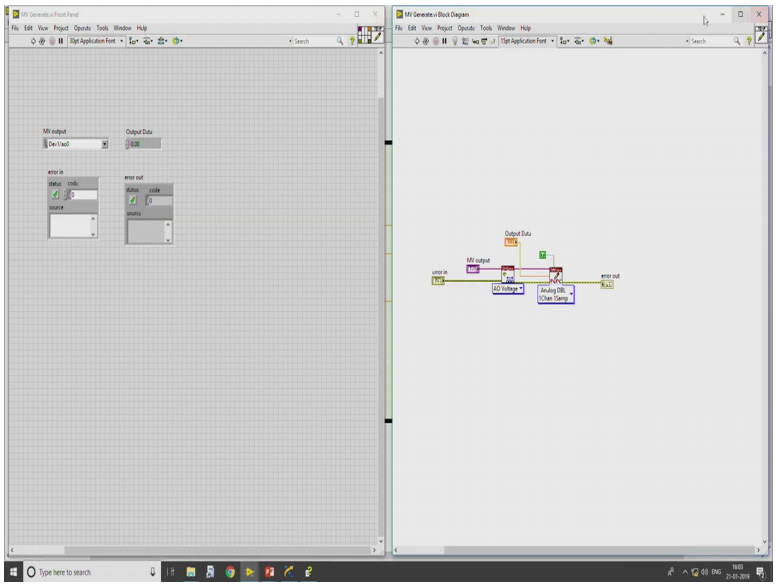

So, in order to do that what I will do is that I will create another lab view file, I will open another lab view file with containing the data about from which particular channel the manipulated variable has to be given to the real world. So, since we require analog output voltage so which is nothing, but a generation. So, I just created a channel I will be creating a channel control. So, this particular channel will provide the manipulated variable as output to the real world.

So, from which channel we have to provide? So, we can use Dev1. So, from the NI MAX if you observe, we have seen different types of devices which is connected which is NI USB 6008 as well as a cDAQ 9189. So, for acquiring the data from the sensor we are using cDAQ, whereas per generating the signal to the real world will be using 6008. It is not meaning that the same device cannot be used, but if we have connected with the same analogue output module to the same data acquisition device, even the same mod the same chances can able to generate as well as acquire the analog voltage signals.

But since right now I am not connected with analogue output and we also have USB data acquisition device I plan to show you the acquiring using cDAQ as well as generating using another data acquisition device which is USB device. Even similarly even with USB device it is able to acquire as well as generate the same signals. So, when we look into the pin out we have a different types of connections here.

So, when we look into that one side yeah it has a total of 16 analogue pins on one side, whereas another 16 pins on the other side. So, one side there written with the name of analogue, other one as written with the name of digital which means that whatever the analog that we require can be connected at this side and distance blocks can be connected at this side. And this is connected to you know to the PC using USB cable.

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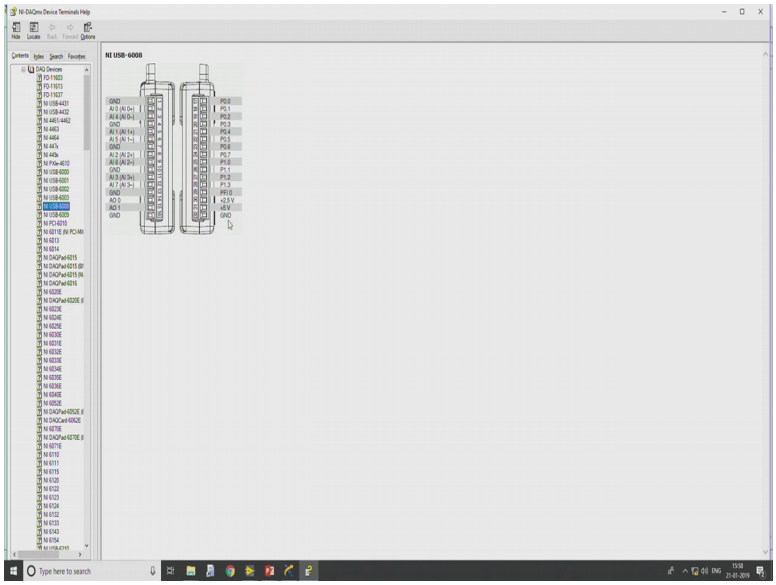

Now, when we look into the pin nodes of this particular device we can here we can see the pin out configuration of complete device. So, it contains the first terminal is ground, it contains the total loss 7, 8 total of 8 analogue channels out of 8, 4 can be used, 4 channels can be used as differential input whereas remaining 8 can be used either a differential used as single ended input. So, in this case I will be using AI0 plus as well as AI0 minus such that the AI0 pin, the output sorry since we require to generate an output signal we have to go AI0 O.

So, AI indicate analogue input, AO indicates analog output so; that means, that it has it not only having analogue input it can also generate an signal by using two channels which are which are at 14 pin and 15 pin. And on the other side if you see which is from 17 to 32 pin it has a total of 8 digital channels along with that it also has power supply to the sensor which is 5 volts as well as it has also voltage which can generate voltage of 2.5 volts and ground.

That means, the sensor the voltage require for the sensor can be easily powered by using this 5 volts too. Now so, what I will do be doing is that since we understood the Dev1 can support for analog output generation I am using the USB DAQ which is named as A1 in the PC will be used to generate it. But so, in order to generate it the output from the manipulated variable has to be right. So, I will I have created a task with which contains is physical channel then I will error control and output of this will be connected here, then create indicator.

So, the detailed explanation of this particular block can be easily seen here, by pressing control H or going to the help window. The detail help this is just summary and if you require the complete detail help of this particular block you can click on the detail help here we can gives The information about the module what we have selected in lab view.

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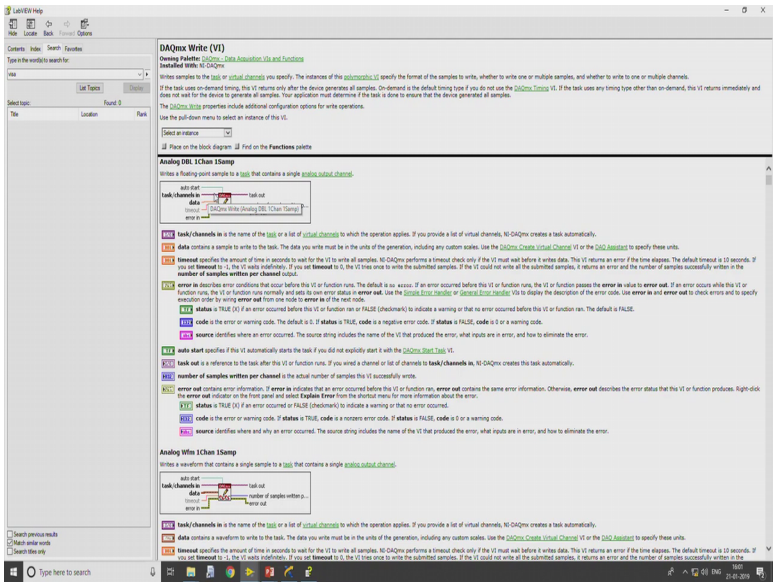

So, in this case if you see the bolt indicate the compulsory terminals to be connected. Whereas the bolt is it is required until unless this particular terminals are connected the device cannot operate The device cannot work. Whereas the hidden text if you see it indicates it is recommended or optional; whereas other states which does not have which is not even bolded as well as which is not even hidden these are nothing but recommended.

So, it will work even if you do not connect it will work, but when you see that it does not mean that it will not pass any data, but default it contains some particular value. So, for

example, say when we consider auto start, auto starts specifies this VI automatically charge task if you did not expressly started with DAQ MX start VI. So, in case even if you connect it will work, even if you do not connect it will it will work, but if you do not connect it I will consider some default settings which is always available it will work like that.

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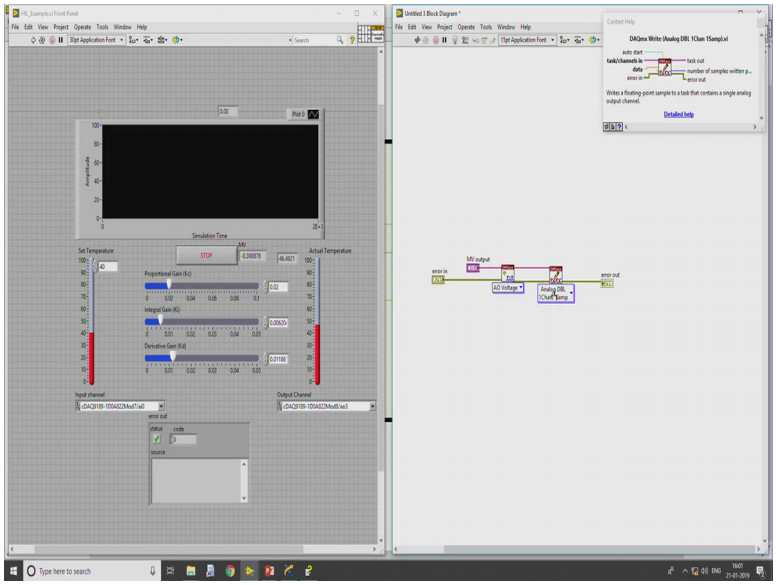

So, since we require to generate analogue output single sample DBL way. So, create constant true then data. So, I have to write the data. So, what I will do is that I will create control so whatever the data that I pass at this particular block the same will be generated at the AO terminal which we have specified here, in the USB DAQ. So, let me rearrange so this is output data.

Now this data operation may current value default. So, similar to the previous one I will also give a pin connections so the same VI can be used as a sub VI in another P another program. And let me go to layers delete it, create a template with since it is sub VI and this is for manipulated variable so which is indication of writing a data so have generated it. So, this is manipulated variable generate.

Now so, this is also done, but this has to be interfaced to; this has to be called in main VI. Now, I will go to I will create a sub VI, I will select a VI. So, which is MV generate I connected it here. So, the output whatever it is been generated has to be sent to. So, this is output data. So, this is an input. So, which should be connected at this point here

control s. So, this I am connected here. But we cannot directly connect, the reason is that since it is a simulation the system we can even provide infinite amount of data as an output but in reality the data acquisition device cannot provide know very higher magnitudes.

So, each device has limitations with respect to the operating voltage as well as current. So, similarly even with a USB devices and output voltage it can generate is of 0 to 5. So, since simulation can go up to more than 5 volts even with a positive as well as negative in order to not to have any conflict between the values we can create some kind of threshold, such that if the input voltage is greater than particular value send the output as a maximum right.

And moreover if we recall that that driver circuit the maximum voltage in order to not to know acquire more amount of current not to damage in the circuit. So, we can restrict the input voltage connected to the driver should be not more than 1 volt. So, that by creating some you know logical icons here. Logic saying that if the input voltage is greater than 1 volt pass the maximum voltage here such that the generated output voltage will not be greater than greater than 1 volt, which both the driver circuit as well as a plant circuit the data acquisition device will be in a safe zone. So, let me add all the required components.

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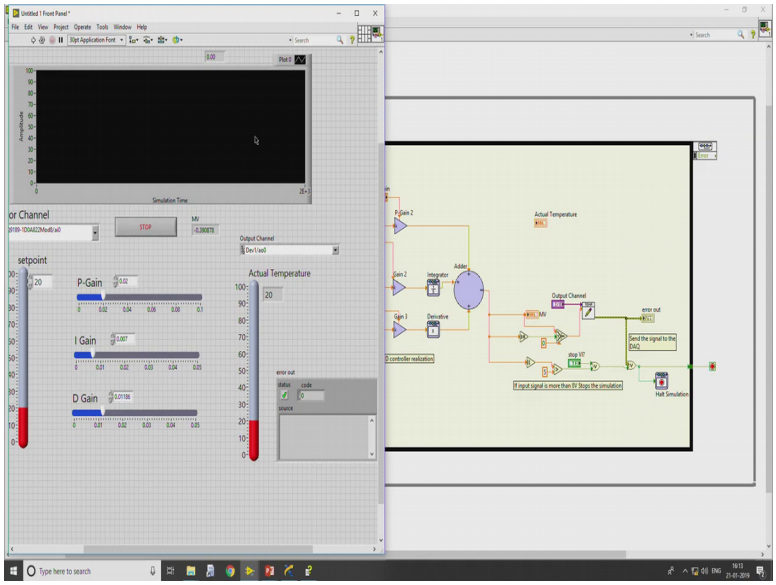

So, now, if you see the complete the system; the complete system is connected. So, I have added with the logic whichever I told you. So, that when the input voltage is greater

than 5 volts since the data acquisition module USB data acquisition module cannot generate an voltage more than 5 volts as well as a less than 0 volt. Say any voltage which shows more than 5 volts will be shown with 5 volts, similarly any voltage lower than 0 volts will be shown as 0 volts that particular logic has been design. And moreover if the simulation generates more than 5 volts the system will automatically make; will automatically switches off.

Moreover any stop button press from the output side of from the front panel even the system will switches off. Similarly I have also added display unit in order to visualize both the input as well as a output signals in the same graph so that it is understand how much time it is taking the system to respond with respect to; the controller could able to reach the temperature on the plant to the required set point right. With this the softer side we have done now, we have to make the connections in the circuit board.