Microprocessors and Interfacing
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Lecture – 24
D/A Converter

In last class, we have discussed about the interfacing of A to D converter to 8086. So, one of the important parameter of this A to D converter is resolution.

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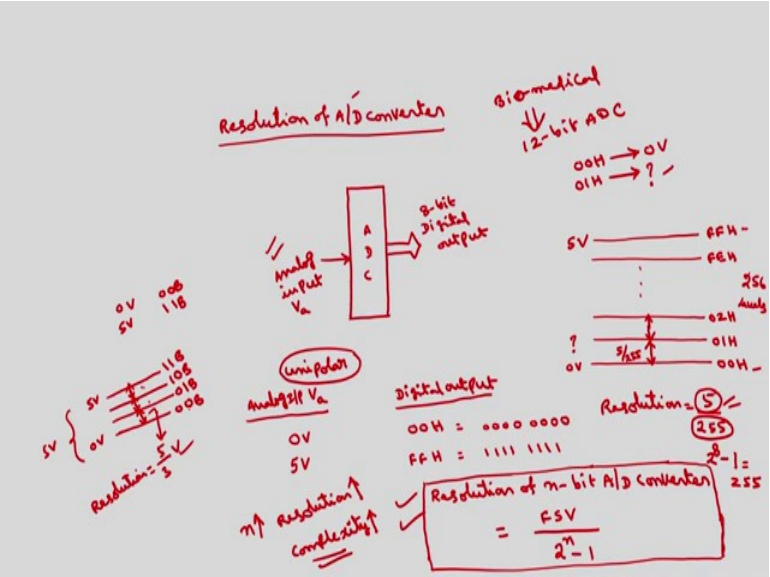

How to define the resolution of A to D converter? So, if you take the A to D converter analog input voltage output is digital. If, you take unipolar A to D converter, in case of unipolar, this analog value Va if I assume that Va and digital output; if I assume that 8 bit digital output, digital output, analog input. So, as the name implies unipolar, we have only one single polarity means all positive voltages only.

So, we will take 0 volts is correspond to 0 0 H, because 8 bits 0 0 H is equivalent to 0 0 0 0 0 0 0 0. And, 5 volts is taken as FFH, this is equal to 1 1 1 1 1 1 1 1. Now, to get 0 0 H, we require 0 volts. To get 0 1 H what is the voltage required? 0 0 H will be obtained for 0 volts. So, what is the voltage required to get 0 1 H? The minimum change in the voltage required to change the position of the digital output. This is what is called resolution.

So, how to compute this? So, here we have totally 256 levels, this side I will write in analog voltage, this side I will write digital value, this is 0 volts is correspond to 1 level which is 0 0 H. Now, what should be this voltage such that this will be 0 1 H, this will be 0 2 H. What will be the distance between these 2, how much voltage will be there between two consecutive levels? And, this will be FEH and this will be FFH this is 5 volts. So, before going for this 8 bit representation to have the clarity I will just discuss about the 4 levels basically.

Suppose, if I represent 0 volts by just only 2 bits 0 0 binary 5 volts by 1 1 binary. So, this 0 volts will be 0 0 binary 0 volts 0 0, this is 0 1, this is 1 0, this is 1 1, these are all binary values B not H. So, this is 5 volts. Now, what is the distance between two consecutive levels, what will be this, what will be this, what will be this? This is obviously, that this is total voltage is 5 volts from here to here and we have 3 divisions. So, each voltage this one will be equal to 5 by 3 volts.

So, if I use 5 by 3 volts at the input change; if I change this input voltage by 5 by 3 volts then you will get a change of position from this will be 0 0 to 0 1 or 1 0 to 1 0 or 1 0 to 1 1, this is what is called resolution. Now, coming over here so, what will be this resolution is total is how many levels are there here only we you have 4 levels. Whereas, here we will be having 256 levels, this is 256 levels correspond to 0 0 to FFH. So, the resolution of this one is given by this is 5 volts divided by we have 3 gaps here whereas, here we will be having 255 gaps.

This is the voltage which is required this voltage is equal to this is 5 by 255 volts. So, in general the resolution of A to D converter in bit A to D converter can be represented mathematically as the full scale voltage divided by 2 raised to the power of n minus 1. So, if I take here this case full scale voltage is 5 volts and this 255 is nothing, but 2 raised to the power of because number of bits are 8; 2 raised to the power of 8 minus 1 which is equal to 255, 2 raised to the power of 8 is 256 minus 1 is 255.

So, the general formula for resolution of A to D converter is this, full scale voltage divided by the full scale voltage need not be 5 volts, we can have 10 volts, 12 volts. So, at full scale voltage divided by 2 raised to the power of number of bit A to D converter minus 1. This is one of the important parameter of A to D converter. So, more the resolution is better is the device, accuracy will be more. So, in order to increase the

resolution of the A to D converter, in simple way is you have to increase the number of bits as n increases, resolution also will increases. At the same time the complexity will also increases.

So, because of this there will be some compromise between the complexity and accuracy resolution decides accuracy. Depends upon the applications, the applications where accuracy is more important will go for more bits of A to D converters like in case of biomedical applications MRI, if I want to I mean convert the MRI information into digital. So, in MRI every I mean sample value is very important. Even if I miss a small information so, it is going to create a problem in such biomedical applications we will use 12 bits ADCs.

And, if we take in general image processing applications so, the most of the information will be a related to the background of a image which is not important. So, 8 bit ADCs is also enough. So, this is about this resolution of A to D converter and we have plenty of applications of A to D converters. So, on the other side, as I have told in the last lecture so, most of the real world signals are analog in nature. So, we will convert into digital by using A to D converter and then we will process. After processing again we have to control the analog devices. So, for that we need a digital to analog converter.

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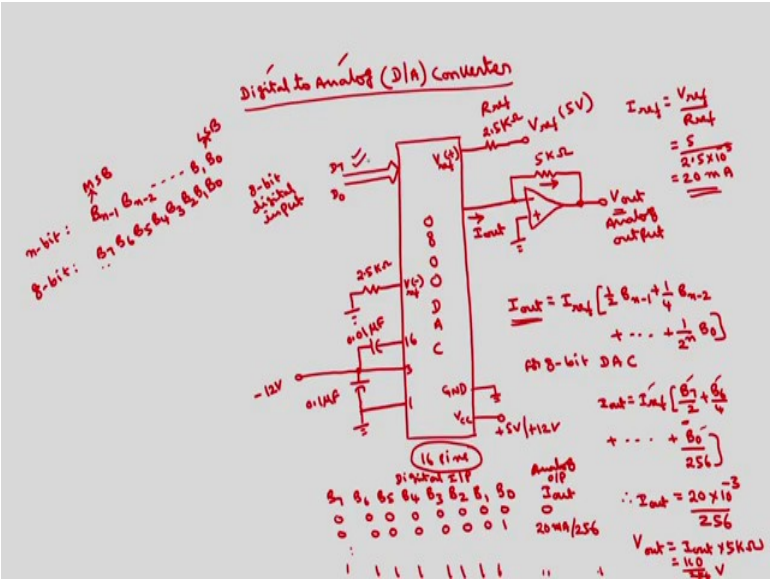

So, next topic is digital to analog converter also called D to A converter. This is simply refers to the A to D converter. So, the input will be digital output will be analog. So, if I

take this interfacing of D to A converter to the microprocessor 8086, D to A converter is a 16 pin IC, A to D converter is 20 pin IC, 0800 is one of the important D to A converter this ADC D to A converter. So, these 16 pins of this D to A converter are so, we will be having 8 bit this is 8 bit DAC.

So, 8 bit digital input D7 to D0. The output will be current rather than the voltage this is current Iout, here Iout will be there. This Iout is proportional to the digital value this has to be converted into voltage by using external current to voltage converter which can be implemented by using operational amplifier. This is Vout, this is analog output and there are some several pins like there will be two reference voltages. If I want to use only 1 single polarity reference voltage, this other polarity has to be grounded you have to connect through some resistance; depends upon this resistance, the Ireference current will be a changes.

So, this is this pin is Vreference minus here grounding, Vreference plus we are going to connect through same 2.5 K to some Vreference voltage. Normally 5 volts to 12 volts, then the Ireference will be given by this is Vreference divided by Rreference. So, in this case this is Rreference. So, this current comes to 5 by 2.5 kilo ohms which is 20 milliamps. Then we have some threshold control signals this is pin number 1, 3, 16, this is 0.1 microfarads, this is 0.01 microfarads. These are basically used for removing of the noise and here this will be given to minus 12 volts and we require VCC and ground.

So, VCC will be this is VCC pin, this is ground pin, VCC can be placed 5 volts or plus 12 volts, this is totally 16 pin IC there are total 16 pins. So, this is I mean pin diagram of the D to A converter. So, there are two types of D to A converter one is called successive approximation type D to A converter, another is R to R ladder type. So, here the expression for this Iout, Iout is so, this is digital input if I call this one as Bn minus 1 is the MSB bit Bn minus 2 so on up to B1, B0 this is LSB. If it is 8 bit this will be B7, B6, this is for n bit, for 7 bit, 8 bit, B5, B4, B3, B 2, B1, B0.

So, this output current Iout is proportional to these bits. If all bits are 1s, we will get highest current; if all bits are 0s, we will get lowest current, in between for different combinations we will get different values of the currents totally we will be having 256 different currents Iout. The expression for this Iout is Ireference into 1 by 2 Bn minus 1 plus 1 by 4 Bn minus 2 plus so on up to plus 1 over 2 raised to the power of n B0. If it is

for 8 bit so, this Iout will be when becomes 8 so, this is equal to I reference into B7 by 2 plus B6 by 4 plus so on up to B0 by 2 raised to the power of 8 which is equal to 256.

So, I reference is 20 milliamps; if all the bits are 0 0 0 0, B7, B6, B5, B4, B3, B2, B1, B0. So, what is Iout? This is current output, this is digital input; this is analog output which is current here. So, if this is 0 0 0 0 0 0 0 0; if I substitute these values here if all are zeros regardless of Ireference we will get current as a 0. If this is 0 0 0 0 0 0 0 1 what will be the value? So, this comes to B7 is 0 all zeros except for B0 Ireference is 20 milliamps. Therefore, Iout is equal to Iout is equal to 20 milliamps into 10 to the power of minus 3 divided by 256, this is Iout.

And if I want a Vout from this Vout is equal to Iout into 5 kilo Ohms, Iout into 5 kilo Ohms because this has to pass to this. So, this kilo and milli will get cancel 100 by 256, this will be 100 by 256 this many volts will be the output voltage correspond to 0 0 0 1. This Iout is 20 milliamps by 256. Like that if this is all 1s then this value will be all 1s you have to substitute here and Ireference is 20 milliamps. If I substitute, we will get the corresponding current as well as corresponding voltage. This is how we can convert the digital values into analog corresponding analog.

Now if I want to connect this to this 8086. So, simply you have to connect this to so one of the ports of 8255.

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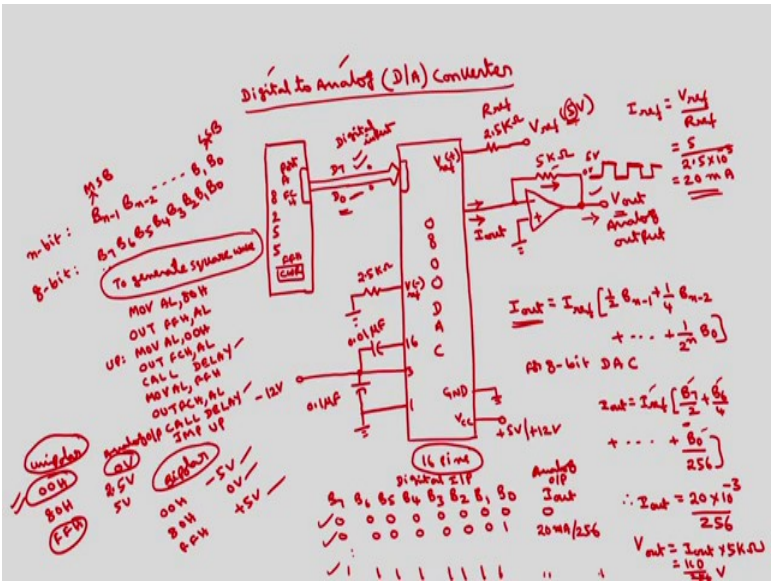

So, if I take here 8255, I will connect to port A of 8255. So, using this 8255 I can give these values accordingly we will get the proportional current proportional voltage here. Now suppose if I want to I mean generate square wave if I connect this Vout to this CRO. So, I want to generate here square wave with the voltage of 0 volts and 5 volts.

Now, 0 volts or 10 volts is up to you. Similar to this I mean A to D converter here also, we have unipolar means 0 volts is correspond to for unipolar 0 0 H is correspond to 0 volt, 0 0 H is correspond to analog output after this voltage conversion and all 0 volts 8 0 H will be the center point. This will be equal to 5 volts and FFH is 10 volts if I use this reference voltage as 10 volts.

If I use the reference is a voltage as 5 volts, this will be 2.5 volts and this is 5 volts FFH will be 5 volts. In case of bipolar 0 0 H is correspond to minus 5 volts and center value 8 0 H is correspond to 0 volts and FFH is correspond to plus 5 volts. So, 0 0 H is minus 5 volts, 8 0 H is 0 volts and FFH is plus 5 volts, this is the difference between the unipolar and bipolar. Here if I want to may generate 5 volts, 0 volts, 5 volts I will take reference voltage as 5 volts. So, if I send here all zeros over this databus we will get 0 volts this line you call some delay then again you send FFH we will get 5 volts.

So, I have to program this port A whose address is FCH and controlled register address is FFH. So, to generate square wave, what you have to do is first you have to program port A as output MOV AL , 8 0 H, 80 H will program all the ports as output ports in mode 0 which you have discussed in earlier lectures also. Then you have to OUT onto controlled register whose address is FFH, then you take AL with 0 0 H this is correspond to this then OUT onto port A. So, port A is connected to the digital input of D to A converter, OUT FCH which is the address of the port A , AL.

So, 0 volts will be outputted on the CRO if I connect this to CRO then CALL DELAY this depends upon the frequency of this square wave that is required, then you make MOV AL , FFH, OUT FCH , AL then again CALL DELAY. So, that these two delays are same so that you will get symmetrical square wave, then you can write unconditional JUMP to UP. So, this UP should be here again we will take AL with 0 0 FF, we will take only these two values only alternatively we will take 00FF 00FF. So, we will not use any other intermediate values. So, because of that we will get only either 0 volts or 5 volts, 0 volts or 5 volts.

So, this is the delay time which is going to decide the frequency of this square wave. So, this is how we can generate a square wave using D to A converter. We can also generate triangular wave as well as sawtooth wave also.

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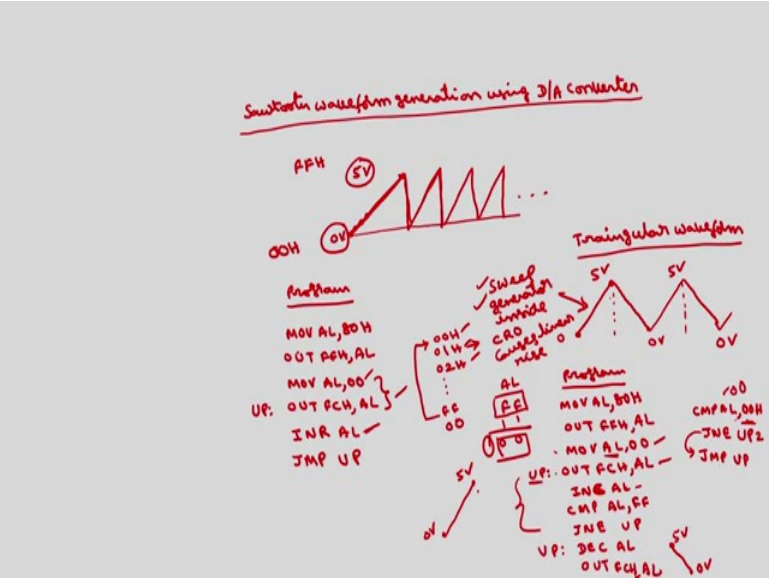

So, how to generate a sawtooth wave form? Sawtooth waveform generation using D to A converter, sawtooth wave form is nothing but how to I mean change from one level to if I start with 0 volts and if I take the peak value as 5 volts. So, it has to I mean rise in a linear fashion from 0 volts to 5 volts and then it has to suddenly drop to this is the x axis suddenly drop to 0 volts, again it has to rise from 0 to 5. So, only drop to 0, 0 to 5, 0, 0 to 5, 0 and so on.

So, the interfacing connection details are same as the previous square wave generation there is no change only the program will be different. So, what is the program for this? In case of square wave, we will just output only 0 volts and 5 volts, 0 volts is correspond to 0 0 H, 5 volts is correspond to FFH whereas, here now we have to change from 0 volt to 5 volts in a linear fashion. So, if I connect the output of D to A converter to CRO, you have to I mean program Port A has output port for that MOV AL ,8 0 H, OUT FFH , AL this will program all the ports as output ports.

Now I will take MOV AL , 0 0 then I will output onto port A whose address is FCH. So, with these two points this 0 volts this starting point will be generated here. Now what I will do is, I will just increment the AL and I will write the unconditional JUMP to UP,

there is no delay here UP is here itself. So, first a 0 volts will be outputted then 1 volt. So, 0 0 1 H, 0 0 H then 0 1 H this is correspond to some voltage which will be decided by the I mean external resistance and all.

This 0 2 H like that this is 0 volts, this is the value correspond to 0 1 H this is the value correspond to 0 2 H, 0 3 H and so on, this is the value correspond to FFH, but you are not giving any delay here. How does this linear change will occur on the screen of the CRO, because inside the CRO there is a linear wave form generator which will be applied to the x blades of CRO.

So, because of that wave from here also the signal that whatever the digital value we are giving the corresponding analog voltage will be moved in a linear fashion, it will go to 5 volts. Then here what happens is this 0 0 it will go up to FF. If I increment FF further what happens is it become 0 0, means this will go to the starting value again this will continue in a loop, FF if I add 1 carry flag will be set, but the result in AL will be 0 0.

This is 1 0 1 0 so, in AL we have FFH if I add 1 after that AL will contain 0 0 H that is why here there is no loop there is no comparison just simply I am incrementing AL. I have taken 0 0 H so, it will go up to FF after that FF this increment AL operation will make that FF to 0 0 again that 0 0 will be transmitted. So, like that we will get a sawtooth wave form. Suppose if I want to may generate a triangular waveform.

So, difference in this sawtooth and a triangular is in case of triangular will be having 0 to 5 volts linear increase as well as 5 volts to 0 volts linear decrease, this is the triangular waveform. This is 0 volts, again 5 volts, again from 5 volts to 0 volts, again 0 volts to 5 volts, 5 volts to 0 volts and so on. For this how to write the program, connections are same for all the 3 waveforms the output of this op amp will be given to the CRO. So, only 3 programs are different, first two instructions are same MOV AL , 8 0 H, OUT FFH , AL then MOV AL , 0 0.

So, we will get this point 0 0 point and you have to increase. So, you have to output this first of all OUT port A FCH , AL here also no need of delay that I mean inside the CRO there will be a linear sweep generator. So, it sweep generator will take place sweep generator will take care about this linear rise, sweep generator inside the CRO we will call this as linear rise as well as a linear fall. So, no need of delay here just simply I will

output this 0 0 volts using this instruction, then I have to increment INR AL compare AL with FF, because till FF I have to use UP counting JUMP not equal go to UP.

So, where should this UP, you have to output that value. So, this program we will generate a linear change from 0 to 5 volt this 0 to 5 volts. Once if it is coming out of the loop means this is FF after that we have to do decrement operation. Here you have to write DEC here DEC AL so, F F becomes FE then you have to output onto same FCH. Then you have to compare with compare AL with 0 0, till 0 0 you have to decrement from here you are decrementing. So, till 0 0 you have to decrement.

So, this 0 0 H JUMP not equal means it is not equal to 0 you have to go to UP 2. So, this UP 2 will be you have to output that value you have to decrement output value. Once if this is equal then you have to again load with 0 0 and you have to repeat the process. So, for that unconditional JUMP to UP 3 this UP 3 will be again we will load AL with 0 0 anyhow 0 0 will be there. So, this UP will be enough, because once this is coming out of the loop means AL will be having always 0 0 because you are comparing with 0 0. When AL is equal to 0 0 then only this will come out of the loop. So, AL is already 0 0 is there no need to JUMP here. So, we can JUMP to this UP, this UP 3 is not required only UP is enough.

So, we will go to here again from 0 onwards we are going to 0 will be displayed, then 1 like that it will display up to 5 volts again. So, this loop will be changes from 5 volts to 0 volts. So, like that you will get triangular wave form. So, the frequency of the saw tooth or triangular wave form will be decided by the sweep generator of the CRO. It is not there in your hand, like in case of a square wave we can control the frequency of the square wave by changing the delay whereas, here the frequency of the saw tooth waveform and triangular waveform will be decided by the sweep generator present in the CRO.

So, that they mean one of the simple application of a D to A converter we can generate different waveforms. Now using this A to D, D to A converters we can design various measurement systems.

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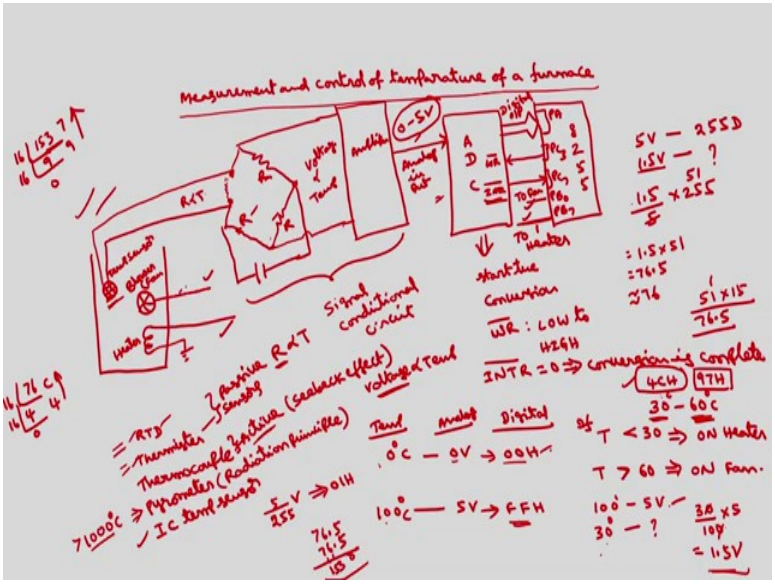

Suppose if I want to measure and control the temperature of a furnace, measurement and control of temperature of a furnace. Suppose I have furnace here, here you have to insert a sensor temperature sensor, this is temperature sensor and here we can control this temperature maintain the temperature by using a fan and blower and heater.

This is heater, this is blower or fan, this is temperature sensor, there are various temperature sensors depends upon the range of the temperature that is to be measured, RTD is one of the sensors normally used for the lower temperatures. We have thermister, thermocouple, then we have optical pyrometers and we have IC sensors also nowadays IC temperature sensor this is available in IC form.

So, this is I mean range depends upon the range normally for lower range we will use RTD, thermister, then for higher ranges the temperatures of the order of greater than thousand degree centigrade. We will use pyrometers this based on the radiation principle, because the temperature is greater than 1000 degrees. If I mean place this any of the sensors there is a possibility that this sensors may burn because of that we will use the radiation sensors where depends upon the radiation we will measure the temperature.

Now again between this three sensors this RTD and thermistor, they are all called passive sensors and this is active. So, the difference between this active and passive sensor is so, in case of active sensor so, directly the temperature produces the voltages.

So, this is how occurring to the seaback effect this operates on a principle of seaback effect.

So, here directly the voltage is produced PMF which is proportional to temperature whereas, in these two cases the resistance varies with the temperature ok. So, now, to convert the change in resistance we need some bridge circuits to convert this resistance into voltage ok. So, this is they are not called active whereas, here this is called active because this directly generate the voltage which is proportional to the temperature ok. Suppose if I use this RTD or thermister here if this sensor is RTD or thermister sensor so, what happens is. So, we will be having 2 leads. So, now, to convert this change in resistance to the voltage, we will connect this to one of the arms of the bridge we will take a bridge.

So, we will apply the voltage this point some voltage. So, this are R R R we will assume that the resistance here because of this temperature this resistance is proportional temperature, at room temperature we will assume that this resistance is equivalent to the other resistances. So, that the bridge will be balanced and if I take the output here, output voltage here will be 0.

So, if the temperature is other than room temperature, we will get a voltage here which is proportional to the temperature. So, this voltage can be converted into 0 to 5 volts range by using amplifier or stages of amplifiers we can use op amp amplifiers now here we are going to have 0 to 5 volts range. So, this is all called signal conditioning circuitry. So, what is required here, whatever the physical quantities is, we need to convert the value into 0 to 5 volts.

So, that I can apply this to the analog to digital converter and I can do the remaining processing. So, I assume that 0 to 5 volts this depends upon the calibration if say for example, 0 degree C is corresponds to hot room temperature or it can be 0 degrees is correspond to 0 volts. Suppose if I want to measure up to 100 degree centigrade 100 degree is correspondent to 5 volts and correspond in digital values will be 0 0 H, FFH, this is how the mapping will be takes place. This is temperature, this is analog value and this is corresponding digital if it is unipolar.

Now, in the digital so, this values can be obtain from this using A to D convertor. So, we have to connect this to A to D convertor ADC this analogue input we will get digital

output. This digital output can be read from 8255 the remaining connections of A to D convertor I am not showing, because that we have discussed in the earlier lecture. So, we have the other connections of this I am not showing only I am showing the important signals analog signal, digital output, then it require the start of conversion which is called INTR bar, end of conversion WR bar.

This we are connecting to port A, this we have connected to PC3 in your earlier example, this we have connected to PC7; hence we have discussed in the last lecture that. So, now to start the conversion this WR bar should be low to high transition we have to apply a low to high transition at WR bar. Then if INTR bar is this INTR bar is 0 implies conversion is complete, otherwise conversion is not yet complete the microprocessor simply waits. Now if we want to control also I am using another pin of another port of this one to control this fan and heater.

So, I will say PB0, PB7 this I will connect to connect to fan so I not showing that connection I am just writing. So, this point and this point has to be connected, these I am going to connect to heater. So, this point and this point has to be connected. Now I will discuss about to how to control this. So, I want to maintain the temperature say between some 30 degrees to 60 degrees centigrade. So, if the temperature is less than 30 degrees if the temperature is less than 30 degrees I have to ON heater, if the temperature is greater than 60 degrees I have to ON fan.

So, this 0 degree is corresponds 0 0 H, 100 degree is corresponds to FFH, what would be the digital equivalent of 30 degrees and 60 degrees, depends upon the resolution of A to D convertor right. So, here 1 volt is equivalent to 0 degrees is correspond to 0 volts, 100 degree is correspond to 5 volts. So, we can compute correspond to 30 degrees. So, 30 degrees is how much voltage? 100 degrees is 5 volts 30 degrees is how much, 30 by 100 into 5 volts this will be 1.5 volts.

So, 1.5 volts is corresponds to what digital value? So, each I mean value will be so, 0 volts if I want to get from 0 0 to 0 1 H hence you are discussed 5 volts by 255 5 by 255 volts is corresponds to 0 1 H. So, 1.5 volts is correspond to or another way if 5 volt is correspond to FFH 255 if I take the decimal value or later I will convert into the hexadecimal. So, this 5 volts is corresponding to 255 decimal value, this is 1.5 is correspond to what decimal value, 1.5 divided by 5 into 255. So, this will be 5x5 are 5x1

are 51 into 1.5, 51 into 1.5 similar approximately equal to 51 into 15, 1576 76.5 this is correspond to 76.5.

Either you can take decimal value either you can take 76 or 77 is up to you, let us take this is equal to 76 because to convert this a decimal number to hexadecimal we need a integer. So, 76 if I converted into hexadecimal 16x4 are 64. 12 C is the remainder, 16 0 is a 0 4 is the remainder 4 C. So, this 30 degrees is correspondent to 4 C H, because you have to compare these values in the program. Similarly what is hexadecimal equivalent correspond to 60 degrees?

So, 100 degrees is 5 volts 30 degree see is this 60 degrees will be twice this 3 volts. So, this will be 3 volts, this will be 3 volts. So, 3 volts means here 3 will be there twice that of 76.5 into 77 this will becomes 76.5 plus 76.5, 153. So, 153 hexadecimal equivalent will be 69s are means 144, 144 67 16 zeros 9 9 7 H. So, this two values are important this is 9 7 H. So, 4 C H is correspond to 30 degrees, 9 7 H is correspond to 60 degrees.

So, whenever this temperature is less than 30 degrees means a digital equivalent is 4 C then you have to ON the heater. So, you have to accurate this is the heater which is connected is PB7 you have to send a 1 on this one so that the heater will be ON. Otherwise if this temperature is greater than 60 greater than 60 then you have to ON the fan. So, that it will cooled down it will reduce the temperature.

So, the corresponding the program how to control this temperature using this fan and heater we will discuss in the next class.

Thank you.