Design for Internet of Things
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Lecture – 05
IOT applications – II

So, what is important when we really look at the thermal sensors that we are talking of temperature measurement particularly, non contact based measurement of temperature, several types of sensors are available for different applications, and we actually focused on one important thing that was with respect to measurement of temperature indirectly using the neodymium magnets, and you know by employing hall sensors, we were able to measure the change in magnetic field; we will come to that. But before we actually look at temperature measurement indirectly let us just finish of the story on the things related to IR thermometers which are basically used for non contact applications.

The point really is if you first thing is you have to understand the IR thermometer and you have to spend sufficient amount of time trying to understand the physics behind it as well. If you really want to look at what a IR thermometer is; let us spend a little time trying to understand you must have all heard seen thermocouples, right? Essentially a IR thermometer what is its business, if you understand from a 40,000 feet view, you will understand that you need a device which will absorb IR heat and it has to give you some has to give me some voltage at the output. So, you need to get some V out ultimately, and how do you get this V out; how do you get to this V out?

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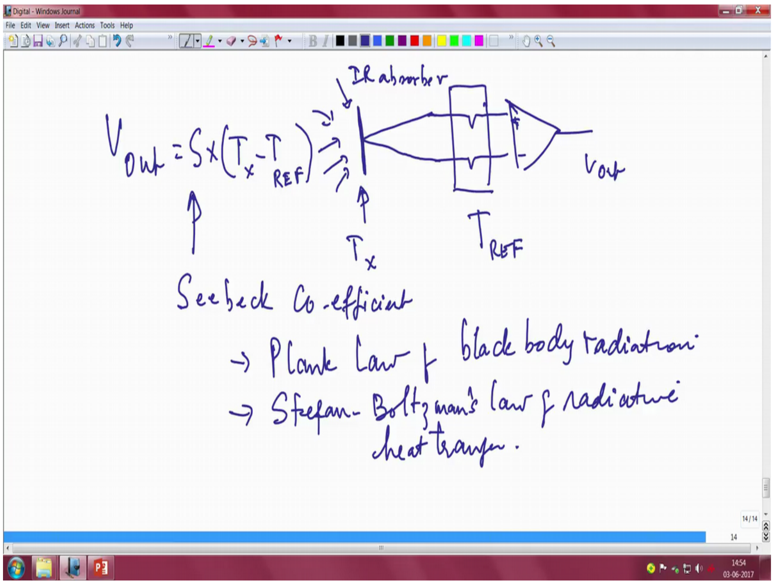

Let us draw the picture of a simple thermopile which is essentially a set of series connected IR thermocouples; so for that let me draw first the picture of a thermocouple. Thermocouple essentially you can denote it like this, and essentially you take it to a amplifier and you generate V out here you know. So, this is the crux of the issue, this is essentially the IR absorber, this is a IR absorber which is essentially absorbing all the IR heat and what is critical is this part this is T REF temperature reference, and this is the actual temperature that you are measuring. A simple expression is going back to this thing is a simple expression here is just look at these systems here and you can write a very simple equation, which simply says V out is equal to S times T x minus T REF. So, let me write it a little better so that we will be able to read it REF. So, this is T REF, S is nothing but the seebeck coefficient.

Now, you could take it to any level, if you actually ask me you must know the physics behind the process this process of absorption, and all of that are governed by Planck's law of blackbody radiation and Stephen; Stephen-Boltzmann law of radiative heat transfer.

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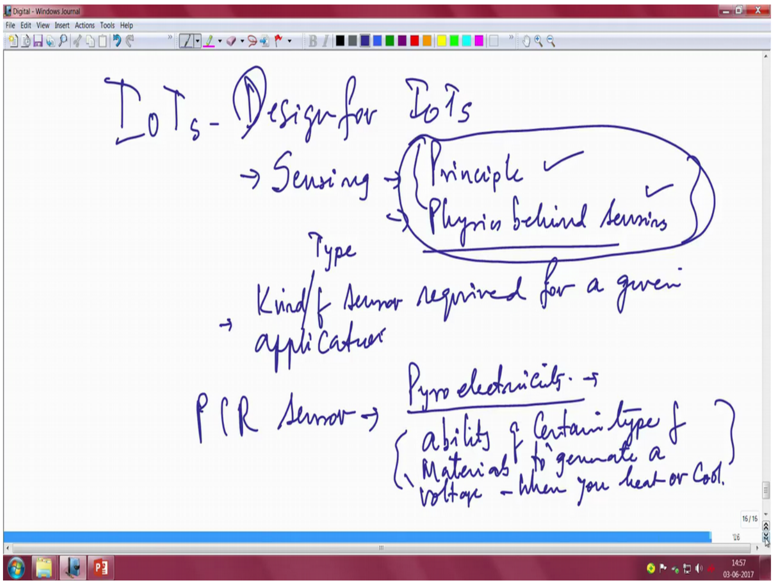

So, again I want to stress a very important point, why am I doing all this? To give you a feel that when you talk about IOT and design for IOTs, and you are looking at sensing you must know the principle behind sensing the physics behind the sensing, and use this together to determine the kind of sensor required for a given application. You must know this there is no other way except going into the details of both of them in order to arrive at the kind of sensor, kind or type of sensor call it type of sensor required for a given application. So, this is a very important thing. So, when you say design you must have many choices many design choices and you pick the best choice, and the choice the way you pick will depend on the kind of application that you have in mind and based on that is what you would ultimately decide.

For example I must show you another type of you know non contact way of measurement or perhaps you can look it up yourself in the next class I will show you, there is another kind of sensor called the PIR sensor. This is essentially a electronic sensor, which is based on the principle the physics behind this is Pyroelectricity right this is what does this mean this principle here is Pyroelectricity, physics indeed is the physics we will get to a little later, but at least is based on the principle of Pyroelectricity and it is essentially the ability you can look up this definitions anywhere in fact, even Wikipedia will have these definitions.

So, I am just trying to tell you from what from very simple terms; ability of certain type of materials certain type of materials to generate a voltage. So, you can see it is a voltage generator when you heat or cool that is also important. So, you could essentially this is pyroelectric; Pyroelectricity essentially, what I have shown is this is what it is, but a PIR sensor uses this principal.

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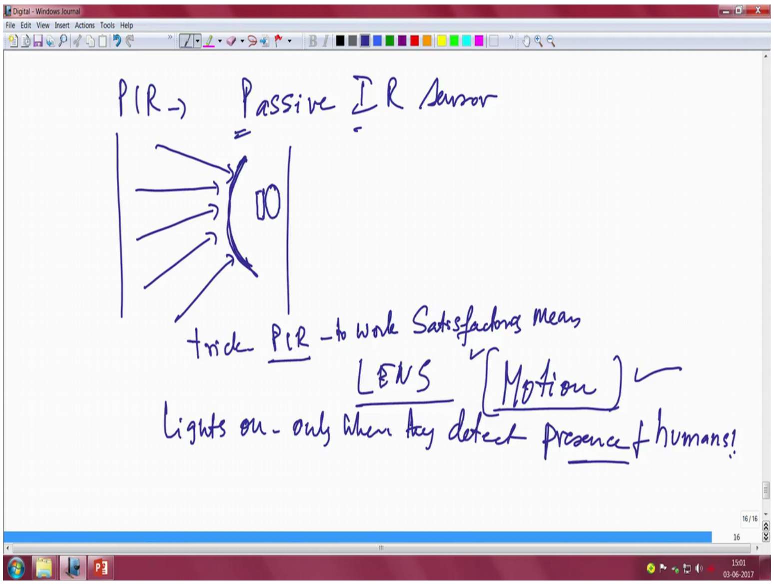

And today you get this PIR and for some reason it is very commonly called Passive infrared sensor. Although the principle is based on Pyroelectricity it is called Passive infrared sensor. This PIR sensor essentially is an electronic sensor and it means that IR light essentially it is also trying to capture the IR heat from objects when it comes in its range.

So, the PIR sensor will have will be something like this, which are lens in the front and there is a possibility that it up and there is a lens, and the lens essentially will ensure that the PIR sensor has a range good range for a PIR sensor means you must have a good lens and there are different types of lenses we will not get into the detail at the moment, but the real trick for a PIR sensor to work satisfactorily means lens. So, you must very carefully choose your lens if you are choosing a PIR sensor for heat detection, for detection of humans and for example, detection of humans is just one simple trivial way of saying what a PIR can do, what it can actually detect is motion right; it can detect motion you might have seen many many applications where motion is actually detector to do a few operations.

For instance if you walk into the corridor of a hotel or you walk into a public place where there are public let us say rooms or common facilities where normally you do not want power you do not want the systems to have the lights on all the time, lights on only when they detect presence of humans; you want to switch on the lights keep the lights in the room as long as humans are present right only when they detect presence of humans.

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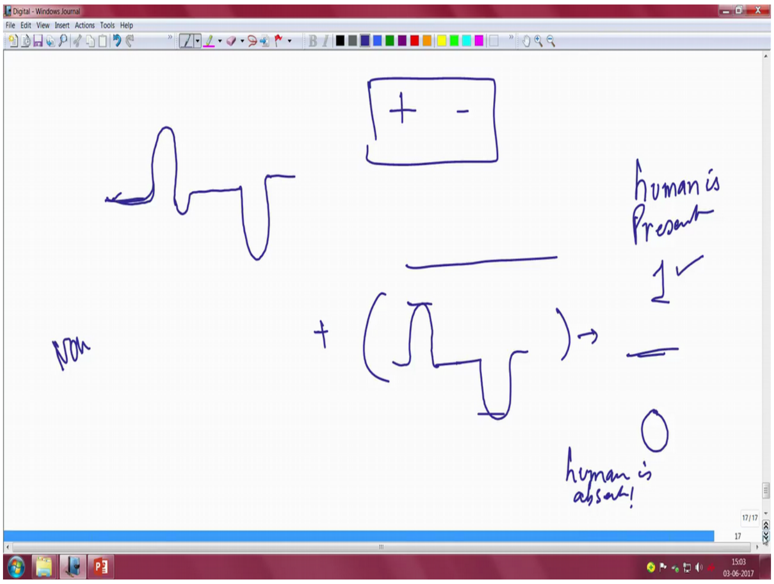

So, first these applications you essentially tie a PIR, you essentially interface at you interface the electron the electrical part like turning on, turning off lamps and all that to a PIR sensor and you will see that a PIR sensor generates sorry this is incorrect; a PIR sensor actually generates a signal like this and a signal like this.

Essentially you will basically have 2 elements in the PIR sensor and the elements when both the elements we will call them plus and minus essentially when these elements essentially see the same amount of IR heat no signal is generated, but if plus sees a higher IR energy, it will generate a it will generate a positive going pulse and the reverse will happen when the negative sees a certain amount of energy higher than the positive and you will essentially end up with the negative going voltage peak. So, essentially you will get signals like this these signals are taken processed and essentially you will generate a digital one or a logic 1 or a logic 0; 0 means human is present and 0 1 sorry; one means human is present, and 0 means human is absent.

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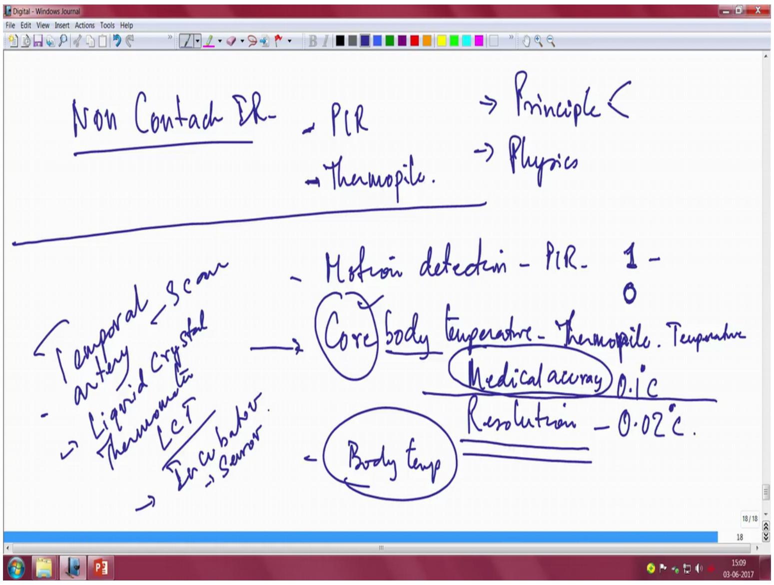

So, this is in a sense what a PIR sensor can do to us. So, you can use non contact. So, the big summary is you can use non contact, oops, let me draw it again non let me write it again non contact non contact IR in different different ways if a different applications; you can use PIR, you can use thermocouple or thermopile and you can measure and so on and so forth you can you different types of sensors for different applications.

So, in other words big summary indeed is that you may have to before you decide the kind of sensor that you want for an application, you may have to you have to first understand the principle of the sensor, because you will know whether such a principal is what the application actually requires based application actually based on that principle or and also the physics behind it right. I give you a very simple example the principal if the application indeed is about motion detection, is about motion detection which we just said PIR can do, then I would use a PIR sensor and I just simply detect a motion 1 no motion 0; presence 1 and no presence of human 0. If I am really and I would use the principle of Pyroelectric effect and if I am using Pyroelectricity effect, and if I want to use measurement of body temperature I would say core body temperature, I will then use thermopile; you see now thermopile and actually measure the temperature.

Here you are not measuring any temperature you are only using it for motion detection, but here your actually using it for temperature detection for measurement of temperature and if you say core body temperature, it has to be 0.1 degrees accuracy you should be you should maintain a 0.1 degree accuracy for all these so the you really is about medical accuracy right. So, let me rewrite it. So, if you are talking about medical accuracy it has to be in the range of yeah. So, high accuracy has to be there, it has to have 0.1 degrees Celsius and it has to have very good resolution as well resolution. So, this I sometimes it is in the order of 0.02 degrees Celsius. These are 2 separate I would say specifications for sensors for particularly thermopile based sensors, if you are looking at for the measurement of core body temperature you will have to look for medical accuracy, accuracy medical accuracy is important. In general if you are talking about thermopile based sensors you may also want to look at resolution which is an very important things so that is the key here.

So, what I wrote here is interesting I wrote core body temperature; if you are interested in body temperature right which is not really core body temperature you recall that if you talk about this core body temperature non contact based, we said arterial temporal artery is what you are going to use; temporal artery you are going to scan the temporal artery scan I will say scan, scan the temporal artery and perform a very simple analytics on the data that you are acquire through the medical grade sensor, and then you decide for actually figure out you actually pull out figure out pull out the core body temperature. If you are interested in just body temperature, many many ways of doing it we also spoke about the liquid crystal thermometer, this is called LCT thermometers which are also quite cheap, but they do not give you medical accuracy. Let us say you are interested in measurement of the incubator; measurement of a small enclosed place of a baby incubator.

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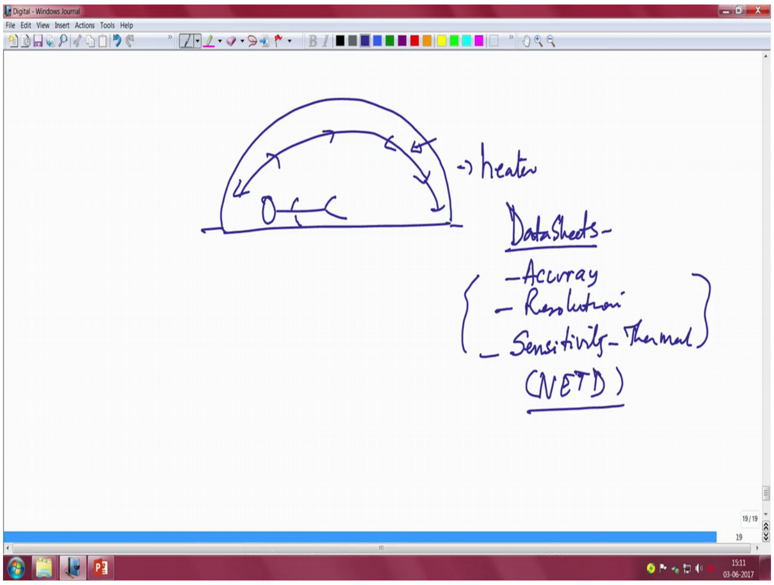

Then the sensor here has to take care of mapping the whole space within the incubator right I will just denote here. So, it has to profile the whole system and a complete profile of the incubator has to be obtained and you are measuring ambient, you are not measuring the core body temperature because you are using the measurement of this temperature here for you know either switching on the heater, the heater in order to keep the baby warm or you know in order to control the temperature. So, you need a different type of sensor here. So, it is interesting that you can do depending on your application your sensors have to be chosen different type of sensors are available, and also very importantly you are to look for the data sheets very carefully, data sheets have to be looked up carefully, you will have to look at accuracy, you will have to look at resolution, you will also have to looked at the sensitivity, thermal sensitivity basically right. Normally the thermal sensitivity is denoted by noise equivalent temperature difference or differential.

So, this is a parameter which you may want to look out. So, these are I think the most in my opinion are the most critical things specifications that you will have to look out when you are trying to use, when you are trying to make when trying to use a temperature sensor for different applications.

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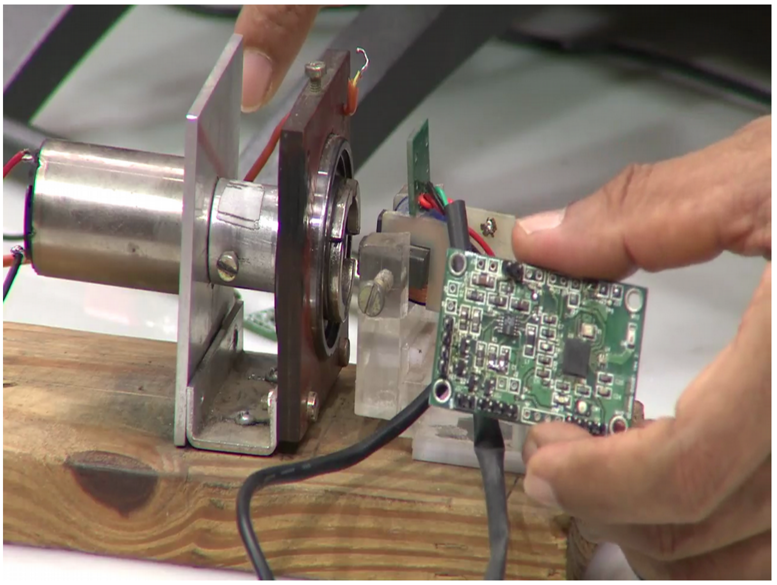

Let us now move on and take an example of we started this lecture by giving you an example of this bearing and when you start rotating the bearing, you have neodymium magnets here and you heat the bearing or rather you when the bearing gets heated up it changes the magnetic field and this magnetic field change in magnetic field essentially is captured by this hall sensor which is sitting here, and is called captured by this hall sensor board which is sitting here. Maybe I should just put in this way so that you see actually see a chip which is here and that chip is essentially interfaced to this little PCB, this little PCB which essentially has very interesting components along with it, and we will describe this nice little components which are there on this PCB to give you an idea to give you a feel of what essentially it means to design and IOT system.

What is also interesting and we mentioned this last time is this coil here let me align it back, this coil here which essentially is used for harvesting purpose. You have a rotating magnetic field caused by this bearing here bearing is rotating, and then you have these arc neodymium magnets the magnetic fields of line lines of force have been cut captured by this coil and essentially a small voltage is developed here which can be used after suitable power conditioning to actually power this board. And all the energy is actually stored on this capacitor you see here this is a super capacitor which essentially holds the power, holds the charge holds the energy, to drive this electronics and make available the temperature of the ball bearing suitably to a driver perhaps on the dashboard of his system. Let us run through the nice thing about this board and what exactly goes behind so that we will be able to connect it to the next set of lecturers which we may have to begin specifically on the power supply section.

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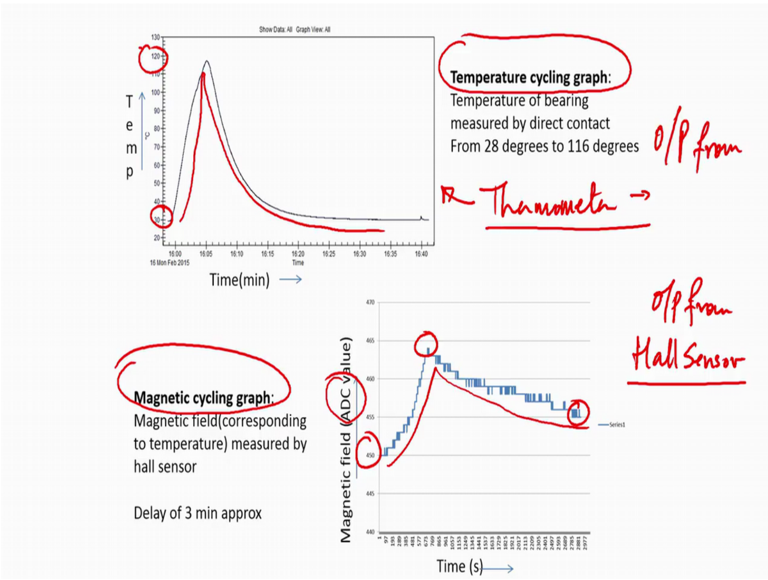

So, let us take this example of the system here that we see is you will see that I will show you the measurement results that we did for that experimental jig which had the bearing, I show you 2 pictures here. First thing is the temperature cycling graph, this is essentially the temperature cycling graph which is on top and what you see bottom here on the left side here is the magnetic cycling graph. Unless there is correlation between the 2 there is no way by which you can actually measure the temperature of the ball bearing in directly using magnetic field. So, you can see that we made this measurement over let us say about 40minutes or so, and we measure and we started heating the bearing race, race of the bearing.

And the temperature was made to rise from 30 degree Celsius to about 120 degree Celsius as you can see this indeed is 120 degrees at this point. So, this is 120 degrees here, and this is 30 degrees here. As I mentioned this is with respect to temperature cycling graph and this is with respect to the magnetic cycling graph. You can see that the

I will not even get into the detail of the units, but I will just tell you about the analogue to digital converter values which actually changed from 450 to roughly 464 and went back to 455, these are the 3 points. More or less the profile followed by the change in magnetic field also sort of mimics the change in actual temperature of the bearing. It was not easy to do this because you need to use a thermometer, thermometer to make this measurement. So, we use a thermometer an industrial thermometer contact based please note we did not use IR, we used a contact based thermometer and this of course, is just the hall sensor values, this is directly coming from the hall sensor, directly output from hall sensor, this is output from sorry let me write it properly output from thermometer very good.

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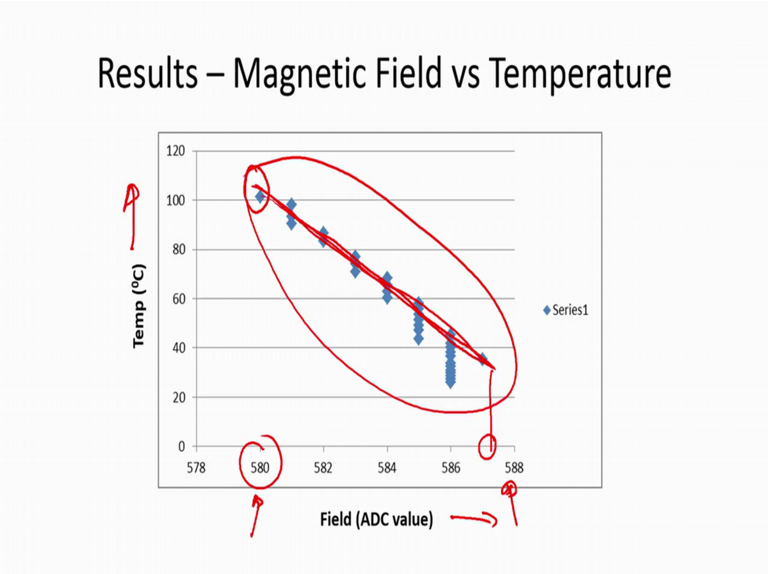

So, if you now see this is an interesting result again, it is just the same result you know shown in a slightly in a different manner, you can see that the temperature the y axis is actually the temperature and the x axis is the ADC value, this is physical temperature that we measured using the contact based thermometer. And these are the ADC values that we got through the indirect method of measurement of the magnetic field; you will see that there is a nice range of change in the ADC values from some initial value of 580 to another point down here which is roughly 587. So, 580 to 587 was a nice range over which we were able to see the change in ADC values with respect to the change in temperature.

You may be a little confused why did I change why is it that changed here I said 450 and it went to 400 and roughly 464 and went back to 455, and in this result we are getting different values.

Well the reason is there were done at 2 different times, and they were essentially the ADC values will largely depend on how the magnet magnets are oriented on the bearing race and so this small variation slight change in values is not surprising, what is important is if you start making a measurement from my initial value, it should essentially show that you are able to see a change in the ADC value. This is important, there must be a change in the magnetic as the temperature increases as the temperature decreases this value this ADC value should go up, and that is what is very very important and so that is. So, just to give you a possibility that if you make such a measurement do not be surprised to see that in one measurement you get a different values and compared to one measurement and another time you get a different range of values.

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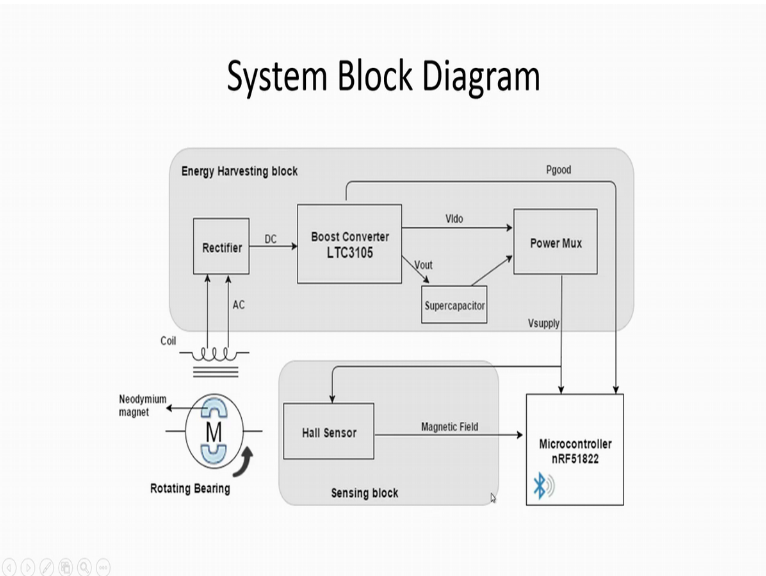

How did we make it work? This is a very critical slide how did we ensure that the whole system really was able to so, this PCB that I showed you this PCB for instance that I mentioned to you, what does it have on it let us see in detail the different blocks. So, let me put back this PCB.