Design for Internet of Things
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Lecture – 06
Power management in IOT device

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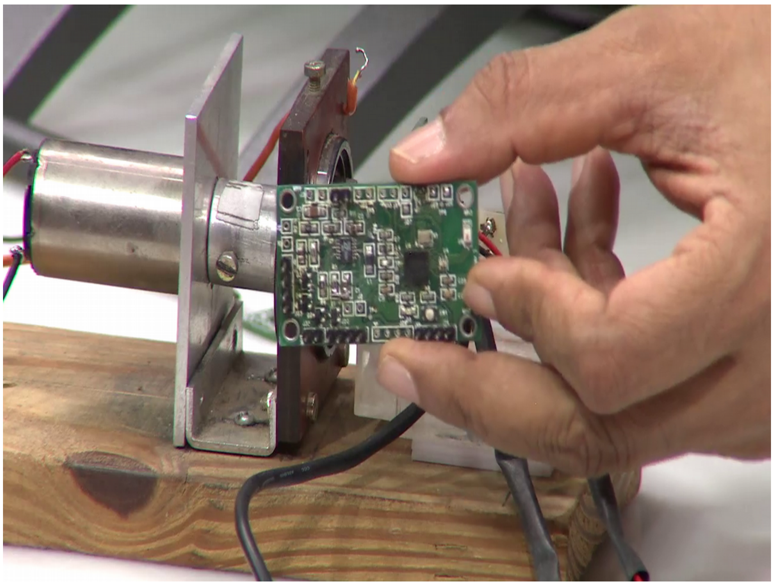

This PCB is what we have to understand, what is its block level schematic, how does it work, how does it store energy, how is it that I am able to read; this bearing temperature this one's temperature without any battery, non invasive, no battery and values by magic appear on the dashboard of the automobile driver. I have just take a automobile as an example, but it could also be any workshop; mechanical workshop machine like laths, milling machines and so on.

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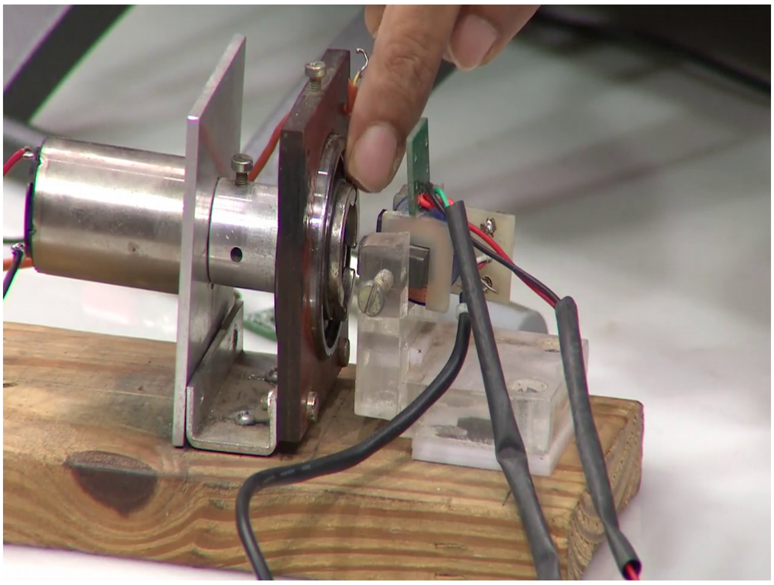

Wherever there are bearings, wherever there are rotating components, rotating machines; you will have to have a bearing and this is the whole focus really about measurement of bearing temperature.

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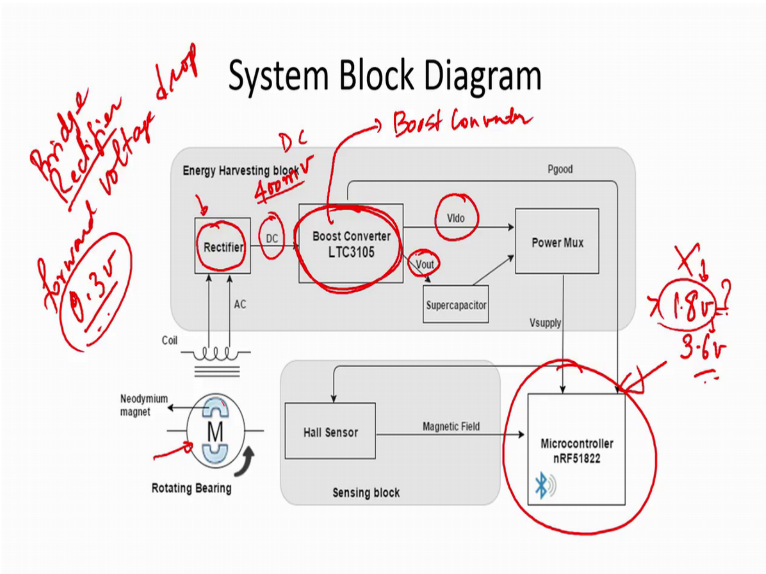

So, let us go back and look at this circuit; the block level circuit diagram. You can see that we have the rotating bearing here, with the neodymium magnet that I mentioned right here. So, this is the neodymium magnet; arc one arc is here, another arc is here; both the arcs are shown here. So, let me rub it off so that we maintain some clarity in the picture and this is a rotating bearing; this is the bearing which is rotating all the time.

Now, what happens when the bearing is rotating; the arc magnets which are attached to it are also in motion, are also rotating and what actually happens is; it induces a small amount of AC voltage across the blue coil that we mentioned and that voltage that is induced is shifted, is given to a rectifier block because there is no centre tap; you may have to put a bridge rectifier. And because you are energy harvesting, you want to ensure that the forward voltage drop of this bridge diodes is as low as possible, as small as possible. So, you would go for short key; which would give you a forward voltage drop of 0.3 volts.

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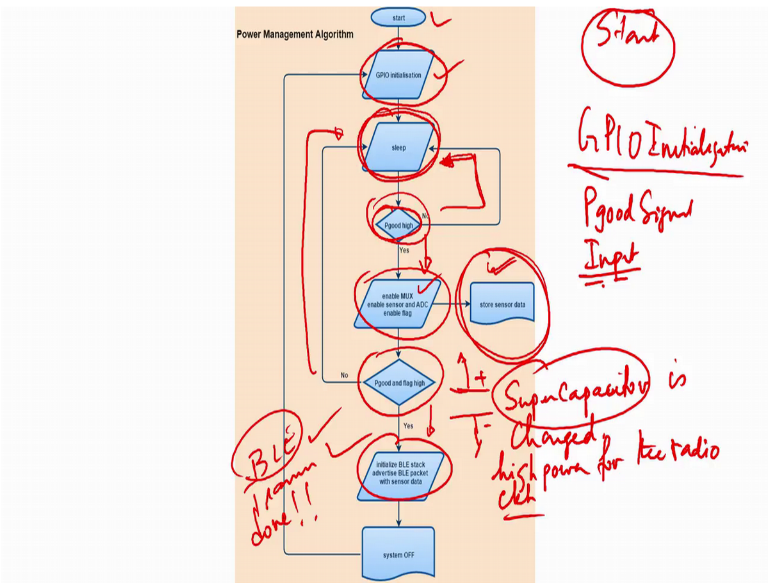

So, choose short key diodes so that you will be able to essentially ensure that; you will be able to maximize the amount of energy that is harvested. Now, we see another block which perhaps we have never come across and this is the boost converter. I have written it here, but I will just write it for the explanation purpose. Its business is this, that this microcontroller typically operates at somewhere from 1.8 volts, greater than 1.8 volts; up to about let us say 3.6 volts.

Now, what you get out of this DC here is not this; here not this voltage at all. Now, the question is, How do you generate this voltage? How to generate this? Or any voltage greater than or equal to 1.8 to about 3.6, How do you generate this? For that, they use this boost converter; which can take anywhere in the range of 250; now I would say that is conservative, that is being; I do not think that will work there, but let me put it, 400 millivolts upwards, takes 400 millivolts DC as an input and is able to generate 1.8 volts to 3.6 directly, so that is the function of this boost converter.

Now, this boost converter gives you two outputs; one is called V ldo and the other is called V out. Just for explanation, let me just rub off everything here and continue the story, I am sure you are making notes about the different components that we have; that we are sketching.

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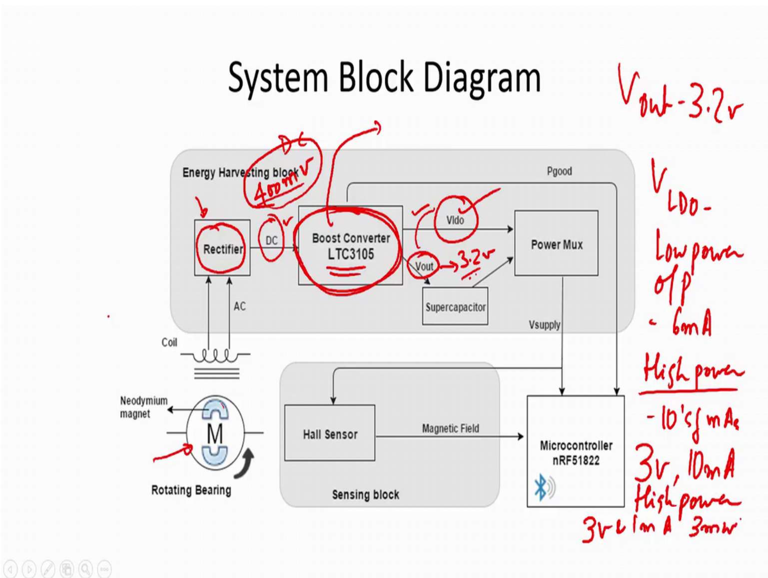

So, here we have two outputs one is called Vldo, this LDO actually stands for Low Dropout Regulator; Vout is; v out, Vout is what you are looking for is Vout. Let us say; so now you have V l d (Refer Time: 05:52) Vout, let us say that you are interested in setting Vout to 2.8 volts or let me make it even lower. I said there is a range over which it operates, I will take an example; let us say you are interested in 2.3 volts, I think we will keep it at 3.2 that is better. You are interested in output voltage of 3.2 volts, so which means this Vout is now set to 3.2 volts.

Now, this boost converter moment it has a stable 400 millivolt at the input here; the first output it generates is the Vldo. Vldo, the speciality of Vldo this is very specific to this chip called LTC3105; the speciality of this chip is, it cannot allow you to draw more power, it is a low power output. I would say low power output, I think there is a suspect that it should not exceed; you cannot draw more than 6 milliamperes of current. So, and typically Vldo can also be set, I think there is a relation between; if you set Vout to a given voltage, Vldo will be of a certain voltage. We will not get into the detail, but still understand at the block level.

But the important point is this Vldo, you cannot use it for high power applications; the whole area of IOT is design of these embedded systems and all that. When you say high power, we are already talking of high power for us is already in 10’s of milliamperes; that is the thing. If you say 10 milliampere that and 10 milliampere and 3 volts is a lot of power for us, so if you say 30 milliwatts; 30 milliwatt is a lot of power for embedded systems whereas if you say. So, I will say oops; not able to write this properly, if you say 3 volts, 10 milliampere is a lot of power; I would say its high power already, tending to become high power. Whereas, if you say 3 volts and 1 milliampere then you are still at 3 milliwatts, which is still fine.

So, the point I am trying to drive at is that this Vldo you cannot draw; high power, the maximum you can draw, you may want to look up the data sheet for better clarity is that is about 6 milliampere. I will not get into the detail of the data sheet at this stage, but I am trying to drive home a very important algorithm that is out here.

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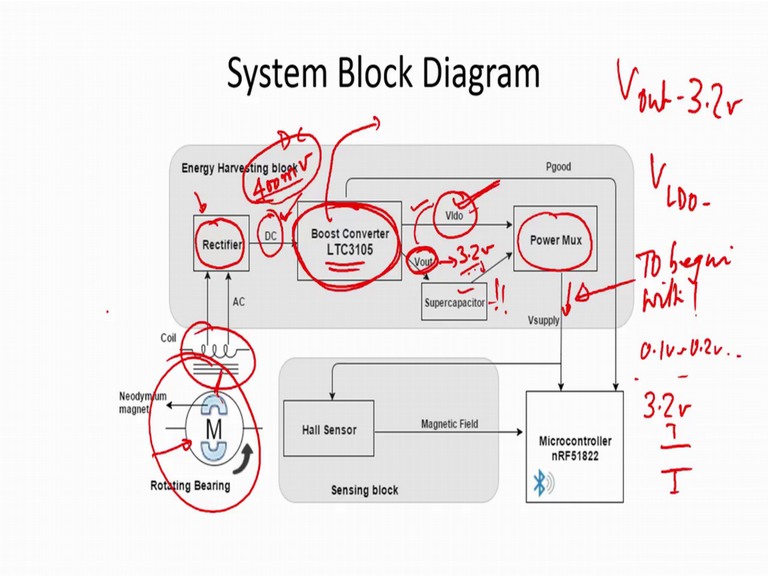

So, what you now do is moment Vldo is available to you, from a stable let us say 400 millivolt at the input here, this Power Mux essentially takes two input; one coming from the super capacitor and the other coming from Vldo. Obviously, if you put a large capacitor here; the energy storage is going to be slow because the plates are very large, the area of the capacitor is large. It has to build up slowly and at one stable point, it will actually come to the set Vout of 3.2 volts. However, it is going to take time to reach that set voltage across the capacitor, which would largely depend or only depend on the value of this capacitor, so that is the key point here.

So, it now turns out that Vldo is the one that will give you resupply to begin with; I hope you will agree because Vldo is still coming up slowly 0.1 volts building to 0.2 volts building, building, building; all the way it has to reach 3.2 volts across this capacitor. So, to reach that point it takes; obviously takes a lot of time and the fact that it has reached3.2 volts from this harvested source, this coil and this magnet source is already good enough to mention that you can actually use it to do something useful, let us move on.

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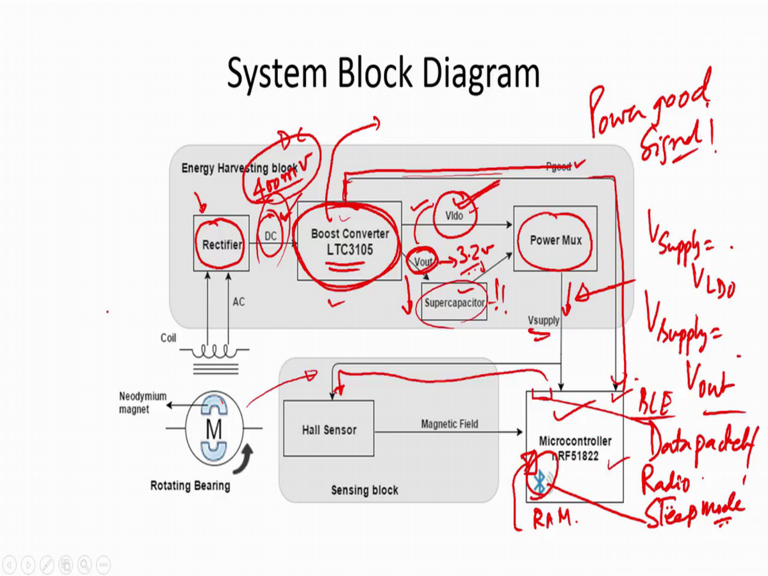

Now, that Vldo is the first one to be the output from this power muxs; we now switch on the microcontroller and what we do is; we energize the hall sensor to obtain the magnetic field value, the ADC value which I showed you in the previous graph. So, this ADC here this is the ADC; so the ADC I showed you some numbers 450, 500 range and all that; so that number is what you will see here.

So, what you do now is; you just sense the value of the hall sensor and store it in perhaps in ram; for example, it could be in ram. Meanwhile, when the output from the boost convertor starts to build up because of a copious energy flow at the input, the boost converter senses that there is sufficiently good input and gives a signal out called the power good signal. Let me write it again, generates the power good; moment the power good signal comes to the microcontroller, the power mux would have actually shifted from Vldo which was originally the V supply was equal to Vldo to begin with; now becomes V supply equal to Vout.

Moment this condition comes, the microcontroller decides that it is time for this high power operations such as computation and communication to go on and decides to send out a Bluetooth data packet, Bluetooth low energy data packet and because the super capacitor provided sufficient power for the Bluetooth low energy packet to be transmitted, the output Vout now falls down. When Vout falls down Pgood signal; obviously, goes reverts to its original status and microcontroller decides to switch off all power consuming blocks; such as radio and itself in fully on state and goes to sleep mode awaiting the next Pgood so that it can do a communication.

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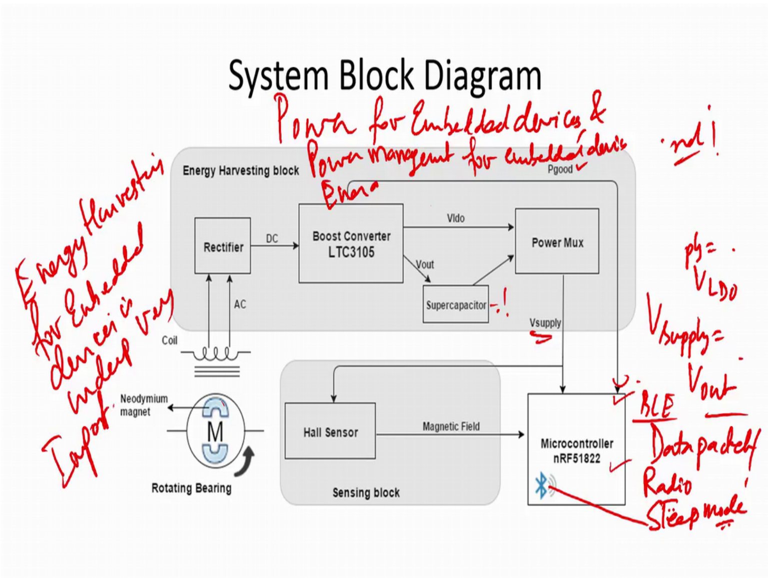

This is the big picture the block diagram of what is actually implemented on the PCB that we have seen and essentially all of this means a very important point and that is that power for embedded devices, power management for embedded devices. Energy harvesting, let me write it here energy harvesting for embedded devices is indeed very important.

So, let us capture this bearing temperature measurement into a flowchart and let us explain this flowchart in clear terms, so that you actually know how an IOT system; IOT device that you want to; an IOT product that or an IOT system that should be doing bearing temperature measuring or temperature monitoring actually works or actually should be done can be captured in this little flowchart.

So, how do you start? What is the whole process? Let us go back to this a flowchart, essentially what I will do; is I will I have this flowchart here, but I will just recap everything so that it is better for you. The first block indeed is the start block which you see here, this is the start block. After that is this block, this block is the GPIO initialisation. What does it mean? It simply means that the power good signal, which is like an input to the microcontroller is configured that particular input GPIO line is configured as input, all that activity is actually done in this block which is the GPIO initialisation block.

Then, what you do; you essentially put the microcontroller and go to sleep. Keep in; remain in sleep condition for as long as Pgood continues to be low. In other words, if the signal Pgood is low means you cannot do anything with respect to communication and although you could do sensing because with the Vldo output, you can actually go and sense the signal. But that is a minor point that you can use Vldo and, but that is not really completely captured in this little flowchart; so at high level, if Pgood is low; you go to sleep and moment Pgood becomes high, you come down; you enable several sensors.

You may also want to read the ADC value again if you wish and you may want to store and check if Pgood continues to be good. If Pgood flips to know because low do nothing, just go back and sleep. Good thing you would have done is; you would have probably got one value, either using Vldo or using the Vout; not actually Vout; actually the Vldo. You would have read the sensor value and stored it into your RAM, moment Pgood continues to be high for a sufficiently long time, you know that the capacitor has charged sufficiently well.

This is the super cap in the previous super capacitor is charged and is now ready for providing a high power for the radio circuit, so that a BLE transmission is now possible along with the sensor data; which was obtained from the hall sensor into the ADC analogue to digital converter pin of the microcontroller. Soon after a BLE transmission is done, this is done, what happens; the system automatically shuts down because the super capacitor would have depleted significantly below its normal offering of stable output voltage, pulling down Pgood again and the system actually goes back to a cold start situation. This is essentially what is done, in this power management flowchart that I mentioned to you.

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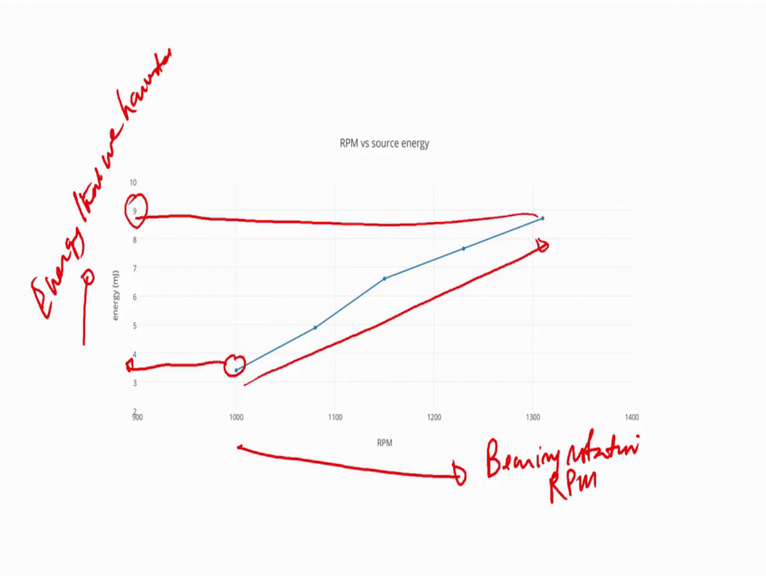

Let me quickly also show you something, some energy something related to the energy harvesting part. This is a picture of the x axis indicating the Bearing rotation RPM and this indicates the energy that we harvested. Clearly, as the bearing speed increases rotation RPM increases, the possibility to harvest energy also increases up to 9 millijoules of energy was harvested from a minimum of about 3.5 millijoules of energy. So a clear indicator that; speed of the bearing also is a important requirement to ensure that the whole system can work, can run with harvested energy.

In summary, let us go back to this nice picture of this ball bearing system; the bearing rotates and bearing heats up due to malfunction, sense by these neodymium magnets there is a change in magnetic field due to change in temperature; caught by this hall sensor given a way to a microcontroller unit, which is essentially measuring the magnetic field. In the process this blue coil here is actually harvesting due to change in magnetic field, due to this arc magnets that is here on this cable here connected to a rectifier circuit, condition through a boost converter, power management circuits and boost converter; energy stored on this super capacitor here; this one, this capacitor here.

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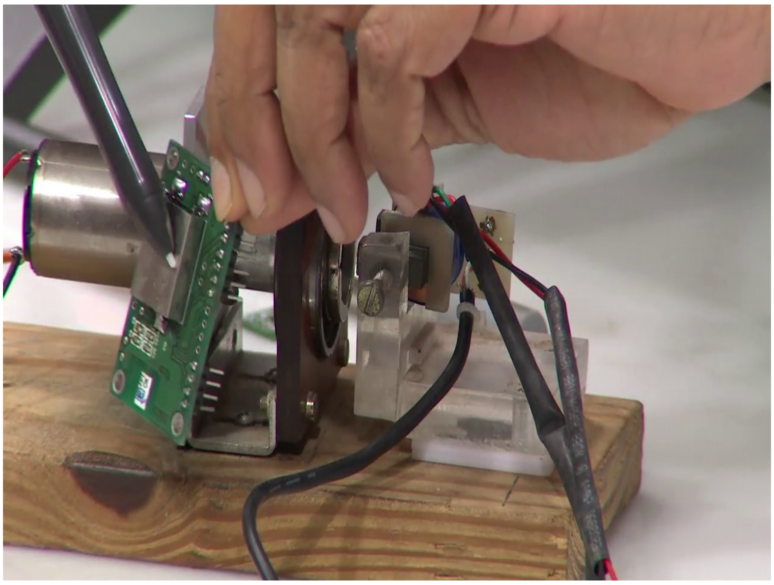

We will put it here, this super capacitor here and the complete circuit here; which essentially contains a microcontroller and of course you can see a chip antenna here, right here which is essentially the Bluetooth low energy antenna here. Which in summary means, that we did several things right; we measured temperature indirectly, we also harvested energy and we actually built a semi IOT system. I would say which essentially makes a measurement does some computation, does communication as well and we did; we call it semi IOT system because we did not get into any actuation part, we did not close the loop, we did not jam the bearing for instance, we did not jam breaks on the vehicle or we did not stop the lath from rotating because we see an abnormal condition for this bearings; we have not done that.

So, all of that means you must get into deep analytics on the data that you obtain in order to see trends with respect to wear and tear up this such a bearing and then conclude indeed that it is time to replace these bearing components. Thank you very much on this of your patience and we will handle power management as a next module because we got into power management and with this example, let us start with the power management in our next class.

Thank you.