Design for Internet of Things

Prof. T V Prabhakar
Department of Electronic Systems Engineering
Indian Institute of Science, Bangalore

Lecture - 16
Power Conditioning with Energy Harvesters - III

I showed you a demonstration of the thermoelectric generator, by applying it on my body. And I also In fact, on the hot side I just rub the little bit to create a little more you know a little more heat. And we measured it went to quite a significant higher voltage.

So, what does it mean? It means that the body heat and the ambient if you are able to get some temperature differential, you will get reasonably good power output. How does it compare with photovoltaic systems? Well, in terms of power density, I would say thermoelectric generators are even 30 to 50 times higher. But then lot of paraphernalia circuit, and lot of adjustments have to be done to get the thermoelectric generator to actually work and give you something useful.

Nevertheless if you find a nice application, then this is the best place this is the best kind of energy harvester to actually try out your circuit. Let us think of some kind of a nice application. One thing is let us say you are interested in finding out you have your household geyser right. And for some reason assume that you have access to some you know some part where the water the water that is getting you know, getting heated inside your access to that temperature.

You are able to access the place where the system is you can feel the heat right. Then I mean it is a little bit hypothetical at this stage. Inlet is cool, outlet is you have hot water, you have stored in the geyser. If you are able to harvest, this temperature that is one side of the TEG you, connect it to you as essentially interface it to see the one that we had in our hand. Here you have hot side. So, this is the hot side one side is the hot and the other is the cold.

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So, as you know as thick as this. If you are able to do that then you could use that to measure certain critical parameters of the geyser itself for instance the temperature of the water itself can be measured by a putting a temperature sensor right.

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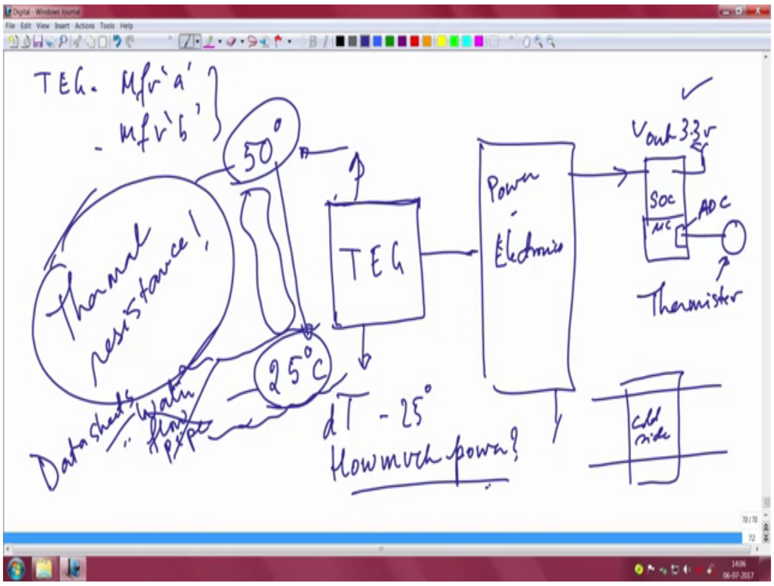

So, you take the TEG, you take the TEG, and then you connect it to some piece of electronics, you piece connected to some electronics. What you should get will be a V out, let us say I like this 3.3 volts, because it seems to be more and more standard and you get ground. So, you connect this to some system which essentially has the thermistor let us say. Let me write it neatly T h thermistor right. S t e r I think, it is.

So, this is essentially thermistor, which is connected to some sort of let us say an SOC and which also has some communication ability and the microcontroller. And of course, this is connecter some ADC port right. And this TEG is like a power supply for this. So, as long as you have temperature differential, which is let us say room temperature you will have let us says 25 degree Celsius, and water is boiling and it is even going up to let us say 50 degrees. And you are able to keep this surface in contact with that, you perhaps have a nice way to harvest, because you now have a temperature differential which is dT essentially, some people even say they use this word dT which is a very important which is then. So, it is a temperature difference, differential difference, some temperature.

So, that if you are able to maintain is something like 25 in this case, you will get sufficiently good amount of power which you can harvest. The question is how much power? Everybody keeps worried is, In fact, this is the question that you will have to keep how much power do we get. What can we do with that? So, this is I think I am sure is prime in your mind, it is all good, but can you what can you do. Surely, you will be able to drive this thermistor directly without any battery or anything. With this electronics this is basically power conditioning electronics, like this is the power electronics I will say power electronics.

And using this power electronics this gives you this table output voltage and then you should be able to do. Continuously you should be able to sense comfortably it should work if you are able to maintain this temperature difference in a sustained manner. The real challenge is, dear friends, how do you maintain this temperature differential continuously? It appears that what I said is a very nice solution, provided you can actually pull it off. The cold side it is insufficient if you keep it at ambient right. When you say ambient you can not get away by keeping it at ambient. Because very soon the hot side heat flow because you have a flow of heat from the hot side to the cold side, you will attend this 50 quickly back here, this is going to create a problem for you.

Therefore dear friends, it is insufficient to maintain it at 25 degrees ambient instead, you may have to keep it in contact with the water flow pipe right. So, you have a water pipe and outside of the water pipe you will have to keep this cold side. The hot side should the other side, the other side which is the thing one that should be in touch with the place where you can tap into the surface over which the water is the hot water is actually in contact with. Then you will be able to harvest and keep this sustain. But if there is no water flowing and you just want to keep it in ambient, I do not think it will work ok.

So, this is the very interesting thing, another this is the very important thing. So, maintaining this temperature difference is the key please note because very soon heat flow is indeed an issue. All of this means in physics terms the right. What does it mean? It simply means everything about thermal resistance, thermal resistance. If you have a low thermal resistance you have this problem. In fact, TEGs really have this problem that the thermal resistance is pretty low, and it is also so, this is one part.

So, you much keep this you must bear this in mind that, because of thermal resistance change in thermal resistance, you will have to ensure that this temperature differential is maintained in a sustained manner. You must look up the data sheets, look up data sheets, which will allow you to which you will give you some specifications on the thermal resistance of this, particular TEG that you have.

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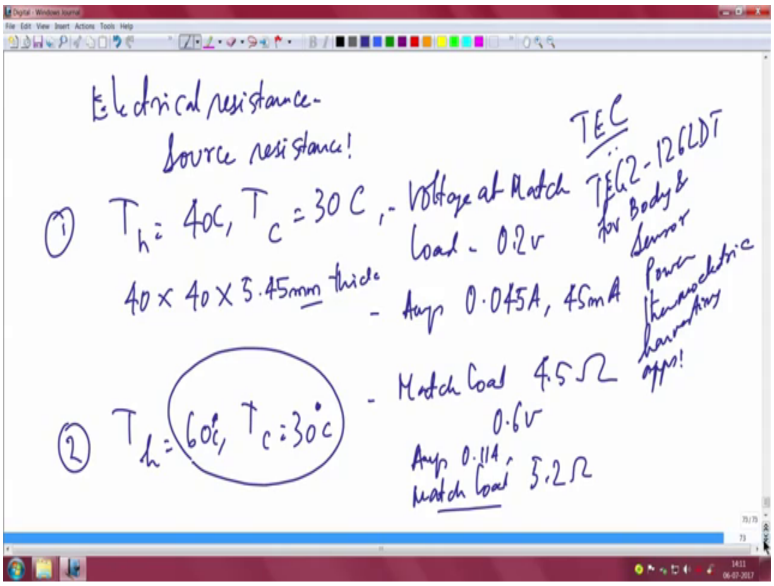

So, but as electrical engineers it is just not about thermal resistance, but it is also about the electrical resistance right. Electrical resistance of the TEG that you are into interested which is nothing but the source resistance, source resistance also called the source resistance. I will put down some numbers; from the TEG that we used the hot side if it is maintained at 40 and the cold side is maintained at 30 Celsius, you will get a voltage at match load which will be about 0.2 volts, that is 200 millivolts. And current you will get 0.045 amps; that means, you will get 45 milliamps. And so, this is the volt spec, this is the current spec, and this is the most important thing will be match load will be match load will be 4.5 ohms. This is a number given by the manufacturer I am not inventing anything here.

Second if T h is 60, T c cold side is at 30 degree Celsius. You will get a voltage the match load voltage at match load will be 0.6 volts. And current will be amps will be 0.11 amps, a 110 milliampers. And the match load I should write it here, because match load just to be consistent match load is 55.2 ohms. So, you can see as the temperature differential, difference in temperature, here it is 10 and here it is 30. You get higher voltage and higher current also, the match load resistance we will continuously keep increasing.

So, the TEG that we this particular specification of the TEG you may be interested in knowing is from a company called TEC, I bought this from TEC. And this particular TEG is indeed TEG2-126LDT for body and sensor power thermo electric harvesting applications. So, in this design for IoT course, you may have an idea of designing a variable right. And you may be wondering if I design a variable I will have put a battery. Definitely you will have to put one option is it put a battery, because if it is measuring a critical parameter. You can not be a hunting for temperature differences when you are actually measuring that parameter you will put a battery. This TEG can be used for charging the battery continuously. Wherever a temperature difference whenever temperature differentials are available you should be able to harvest from that. And then from that you should be able to keep charging the battery.

So, it is a nice solution indeed which you can seriously consider, to if you are trying to build at the end of you know going through this you know with these inputs that we are discussing at this stage. So, the take that we have is a 40 cross 40 mm cross 5.45 mm, all the is actually you can see it is just a little over half a centimeter thick. And it has a 40 cross 40 4 centimeter cross 4 centimeter into a thickness of about 5 5 about half a centimeter 5.45 mm.

And it is a good TEG indeed and you as you can see it seems to be giving reasonably good output voltage, from directly from the you know from the ambient maintaining the ambient. If you are in an AC room, surely temperature will be at 36 and ambient will be at around 20 or even 22 depending on comfort level. So, you should get a clear safe 10 degree differential, delta t will be about 10, 10 and with that you should be able to get reasonable amount of power.

From what we have seen this from this specification. So, this is the story of the TEG. And So, how did we go about a power conditioning this TEG and what is the story behind this TEG with respect to you know understanding the kind of numbers that people talk about in terms of power output and this particular power condition and power electronics that is associated. Let us revisit that picture and then let us see to put everything back into place.

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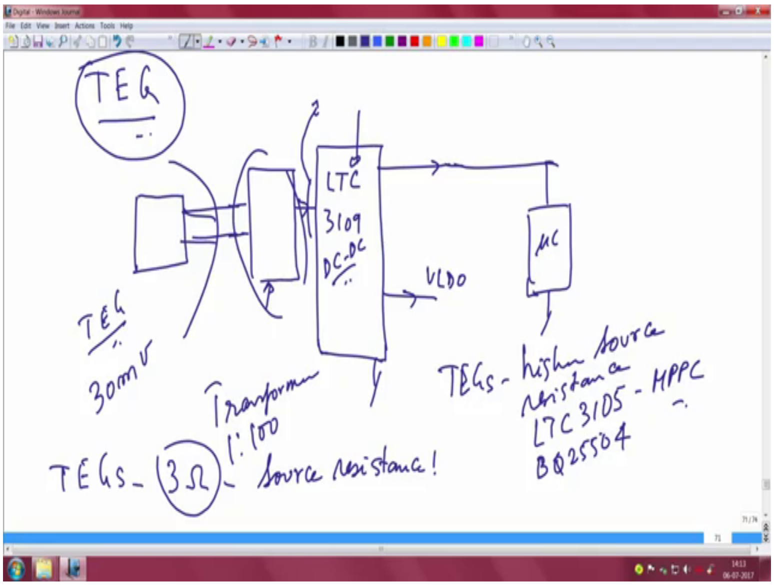

So, for that what I will do? I will go back to this picture right. We started with this ITC3109 as you can see the TEG of interest has been discussed. The one that we purchased and we were trying this power electronic part is this ITC3109. This is a 1 is to 100 transformer we will discuss that in a moment. And we also mentioned about source resistance which is which has to be as low as possible. And then we talk about a microcontroller read you and all that. And of course, what is important is, you see now we got a body sensor right, body heat harvesting sensor which I wrote here. The here I had written about the fact that this has a application for body sensor right.

So, this if a body is a body and sensor power applications. This one essentially what we were doing is so, this is a very nice you know energy harvester alright. What is the correct power electronics that you should choose? Because this company TEC has not indicated any specific company that we should use any vendor particular vendor chip energy harvesting chip for harvesting to use to be chosen. So, we were investigating this in the process we found that this ITC3109 seems to be an appropriate one.

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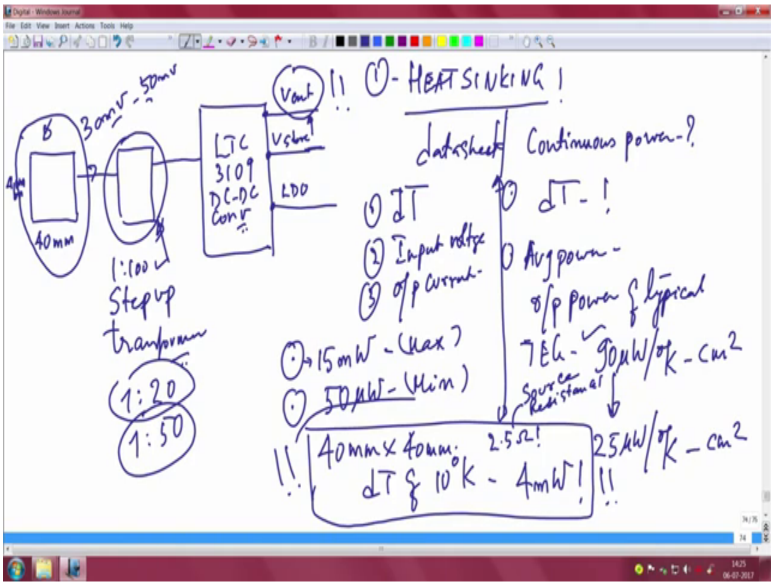

So, let us put down that. We have an ITC3109 this is ITC3109 DC-DC. Of course, everything around what we discussed in till now has already been that we are talking about boost converters. And nicely this boost converts often give you an LDO output as well apart from the actual V out. And they also give you a something called a V store right. And V store is meant for applications where some amount of energy stored in the V store is pumped into vs V out. During the time and the input harvest it is not there. For some reason if the harvester is absent, the energy for a very short duration from V store goes to V out.

Here with respect to this particular TEG of interest that we are we are we are talking about, as I mention to you this is 40 mm, and this is 40 mm as well. I can not show you thickness on this thing, but imagine that it is thick enough which is 5.45 mm. And that has to be connected to something we have mentioned is the 1 is to 100 step up transformer. Here there are some design considerations. And we will discuss that in a as we go along. When to choose one is 100, when to choose 1 is to 20, for instance and one to choose when to choose one is 50 for instance, it is quite obvious right.

So, you would if your input is typically of the order of 30 millivolt; that means, just coming from body sensors. Then you have to choose 1 is to 100 if your input is more than this let us say it is 50 millivolt and so on. 50 or 60 millivolt then you do not need this kind of one is 200 step up. So, you could choose 1 is to 20. And accordingly if the voltage goes up you can choose 1 is to 1 is to so, sorry 1 is to 50 and then 1 is to twenties also are possibilities, as this input voltage goes up. Now when will the input voltages go up depends on your application right. The geyser application I mentioned is giving you a good amount of temperature differential, in which case you ill perhaps not need a 1 is to 100 you will be able to get away, even sometimes you may even be able to get away without any transformer. Directly interface it to ITC3105, which is good for us; in some situations if the volt.

So, you have to actually find out, what is your harvesting opportunity in terms of the temperature differential. Find out that then choose this particular transformer that is the key to what I am trying to get it. Now the problem with this TEG, is this particular TEG, is that you must I must put this downright, I will put it down in capitals, heat sinking, you must do heat sinking there is no other way. The cold side should be able to with I mean draw the heat, which is emanating from the hot side. It should be able to pull out that heat otherwise, temperature differentials will go down and then nothing will come. So, you have to look at how to design a good heat sinking ability for this, for this system ok.

So, there will be some sort of data sheets. There will be a data sheet, which will tell you So, you must go back to your data sheet and carefully look at what are those data what is it that the curves in the data sheet are actually telling you, about the current ability for different input voltages and different turns ratios. So, this transformer again is the issue. So, you must look at so, that is the most important thing. So, you must look at temperature differential. So, I will say d capital T 1. Then input output everything input voltage input showing output current capability for different input voltages right. So, input voltage output current all of that should be essentially coming up to you from the data sheet ok.

So, that is the most important thing. In general you can say you will get 15 milli from watt the manufacturer is claiming; you will get about 15 milliwatt at the output. In terms of power output you will get about 15 milliwatt of output maximum and the minimum you will get, this is maximum, and then this also we will be about the minimum will be roughly about 50 micro watt. This will be the minimum power. So, that is another important thing. Now question is, whether you will get continuous power? Is the question, continuous power? O u continues o u s continuous power. Well, I do not think you will get continuous power. If you if you are able to keep the temperature differential for long time, for in a sustain manner why not surely you will get, but in practice that will be a little bit difficult.

Now, you will have to also battle several things on, why did you choose this TEG in the first place? I mention to you that the data sheet did talk about the fact that it is meant for body heat harvesting and for body sensor and all that, but I could have chosen other some other vendor also right. And from that so they may be a similar product from other vendors. Well so, the question really is like this right. It will the basically depend on the average power for the given application.

So, the question really is about the dT. So, the question is about dT is the is the key and the application average power is So, dT and average power. These are the 2 important things you will have to worry about. Again the manufacturer gives a lot of nice numbers. I would like to stick to what the manufacturer is saying rather than speculating anything from my experience on working with TEG. Because that I have looked at several TEGs, and I think you should just go by looking at the data sheets, studying it carefully around the data sheet you should be able to plan your design.

What the manufacturer is actually claiming is that he talks in terms of the manufacturer is actually talking about, if you take a you get an output power, the output power of a typical TEG, of a typical TEG is roughly ninety microwatt per degree Kelvin for every one square centimeter of TEG area. This what it simply means is this means that you are maintaining good heat sink, that is very important I am not when taking that taking that into any account.

But what is usable? It turns out that this is what you will get output power of the TEG is this what you will get. But if you do all this ITC3109 conditioning 1 is to 100 and ultimately what is important is this V out right. What is it that you will get it V out and the I out the current and voltage, out at the output if you see they claim the manufacturer make some nice observation he says, you would not get this.

So, I will strike this off. This is input if this is the input what you will get will be 25 microwatt per degree Kelvin, for every square centimeter area of a typical TEG. That is what you will get. So, if you take 40 mm cross 40 mm that is your area hat you have. With the dT of let us say 10 degrees 10 degree Kelvin right. 10 degree with the 10 degree Kelvin across we will give you roughly 4 milliwatt, will give you about 4 milliwatt. So, that is a good enough power in my opinion with all the low power electronics that we have. So, this is reasonable right. You should be able to use this 4 milliwatt power in a very effective manner with some good power management algorithm this is a good number, I would say. This is the very good number to work on.

So, do look at the manufacturer's data sheets carefully and go ahead with the design. So, here the point is that we have assumed source resistance to be 2.5 ohms of source resistance. That is the key point, the source resistance assumed will be 3 point to sorry 2 5 ohms. So, which is also another important consideration?

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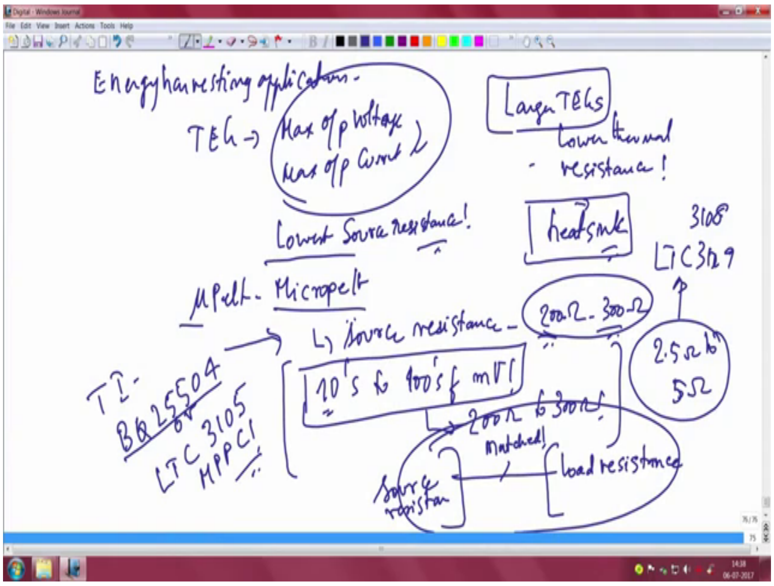

The energy harvesting applications, energy harvesting applications using TEGs you will obviously, choose a TEG this is the very trivial answer right. Maximum output voltage and maximum output current, you will want to go and buy that TEG which gives you the maximum power maximum power output right. So, this also means; obviously, with lowest source resistance. This is always the nice thing please note maximum output voltage maximum output current and lowest source resistance, the smallest the smaller it is the very good thing it good for the system to give a good amount of power output.

They also mention that larger TEGs larger size TEGs like what we are discussing about 40 mm cross 40 mm, this is the pretty large size TEG the 4 centimeter cross 4 centimeter we will also have lower thermal resistance, we will also have a lower thermal resistance, indeed a pain right. This is a problem. So, you are heat sinking should be very good because very soon the hot side and the cold side we will come into an equilibrium, because of this lower thermal resistance problem.

So, heat sink you have to that is why I said the geyser example looks a little shaky at the moment. But automobile maybe good, you have the radiating radiator some coolant and some circulation of or even if the vehicle is moving the engine surface can be hot, wherever you have placed the TEG, but because of circulating air the cold side may continue to remain at some reasonable point. And that can be definitely in an automobile you know in the engine compartment part of the automobile, that it is very possible that you should be able to harvest significant amount of high power from that system.

Also this is TEGs a meant for this kind of very high temperature applications, hot side can really go to high temperatures. So, again you will have to choose based on your application you may have to choose what kind of temperatures this TEGs can which stand. Also note that you should not reverse the hot and cold side. Cold side cannot which stand high temperatures.

So, if you touch the cold side on to the engine side which is emanating lot of heat then you may actually the TEG may actually go bad and may not be able to you may not be use it. So, take care of these simple precautions before you start you know using it in a particular application. Let me complete the story. So, this low thermal resistance has an issue and therefore, which means you will have to put good amount of heat sink sorry, heat sink, sink becomes definitely a critical requirement for this.

But if you are using large TEG which means area is of no constraint to you, putting a heat sink is also not an issue right. If you have if you have sufficiently large area I would not recommend way TEGs for body based systems. But at the moment they seem to be the only ones which can give you sufficiently good power that is the issue. So, you may even want to examine small tiny nano pelts or micro pelts, micro pelts. In fact, there is a company called micro pelt, just Google it you will find a company called micro pelt. Here the source imp source resistance of these systems is roughly I think my from a memory 200 ohms or something like 2 to 300 ohms.

See what it all of this is leading to something very interesting right. If you have higher source resistance to begin with, the output voltage that you will get from the TEG will be high that is clear. Whereas, if you take the lower heat this lower source resistance TEGs like to ohms 2.5 ohms 5 ohms and all that, the output voltage will be in the order of a few 100s of millivolts 10s and 100s of millivolts, I would say 10s 100s of millivolt. So, you do not even have to worry So much about if you first thing that you can look up in a data sheet is, what is the output voltage let us says he says 30 millivolt, 50 millivolt I can give you 50 millivolt I have a circuit for 50 millivolt to give you 3.3 using power electronics and all that, or if you says I will give you a 200 millivolt or 100 millivoltand so on.

First thing to infer straight away is it is source resistance must be in the order of a few 100s of ohms, 200 to 300 ohms. This is very clear. First I would say rough first cut understanding. Why? Why I am stressing this? Why I am stressing this? I am stressing this because, your choice of power electronic chip become very critical here. You take the wrong power electronic vendor chip for a thermoelectric application and connect it you get nothing, in other words this source resistance should match the input resistance of the chip right. For instance if you take this TEG that we are discussing from this company called TEC, TEC and connect it to the same vendor some other chip, which is also energy harvesting chip is an incorrect decision.

I will give you what the vendor himself says. He says if you take my TEG my chip my chip 3109, ITC3109 or 3108, I assume the source resistance inputs or the source resistance kind of TEGs that are going to be connected or the order of 2.5 ohms to 5 ohms. Because he is on load resistance is around this. And unless the load resistance, the load resistance and the source resistance, these are not matched, if they are not matched you have serious you know extracting you have serious problems of extracting any useful power from that system.

Keep this picture in mind that is why your design is has to your choice of component become very critical. So, micro pelt is another company I mentioned to you whose source resistance which is in the order of 200 to 300 ohms, do not choose this ITC3109 or 3108 choose some other one, what he recommends on the micro pelt website is from this vendor from the chip from this vendor TI which is BQ25504. Or he even suggests the LTC you can also use LTC3105 with MPPCI, we already discussed this. So, with MPPCI you can use LTC3105 or you can interface it to BQ25504. Remember, whatever you do you have a beautiful tool in your hand, and do not forget to use the tool, and what is the tool, simulation tool right.

Every vendor will have a simulation tool you just have to look out for it. If you choose a component from vendor a look for a tool from vendor a it will be there. In fact, BQ has a simulation tool for this BQ chip. The once that we spent a little time trying to show you this vendor linear technologies has his tool typically LTC spice. You go to some other company they will have a tool. Them even have an online tool simulation tool which is you feed in values and then you will get some you know system design related part numbers and components of your of that would be required for taking up your circuit. So, lot of system design challenges building the IoT system is in become start becoming very comfortable, if you know where to find things and how to do things, that is all I am trying to say. For instance if you say this is my input voltage and this all I can harvest from the environment and the differential that I am able to maintain.

Feed in those values, it will actually tell you what kind of components would be required. Do you have to put a 1 is to 100? Should you put a 1 is to 50? Should you put a 1 is to 20 step up transformer? What are the other components? What should be the inductor value for instance? Output inductor value, because do not forget this is a buck con this is a boost converter right. So, either boost or buck the output inductor is an critical thing here. So, that will definitely be there.

So, let me draw your attention to the simulation tool for ITC3109, we can discuss that I can show you the simulation and then please download and try it yourself. If you do not have a TEG it does not matter right. You have a PC or a laptop; you have any internet connection download the tools which are available. Do not be sold to any specific vendor all vendors do not exam. In different vendors and then try and mix match, change make changes to the simulation parameters based on the models given by the vendor or closest to what the vendor provides. Run your simulation once you are satisfied, and then go about investing to by these kits or components to design your circuit.

So, that part is something you will have to look up just now. So, let me turn my attention to this nice simulation, which I have done on for piece spice.

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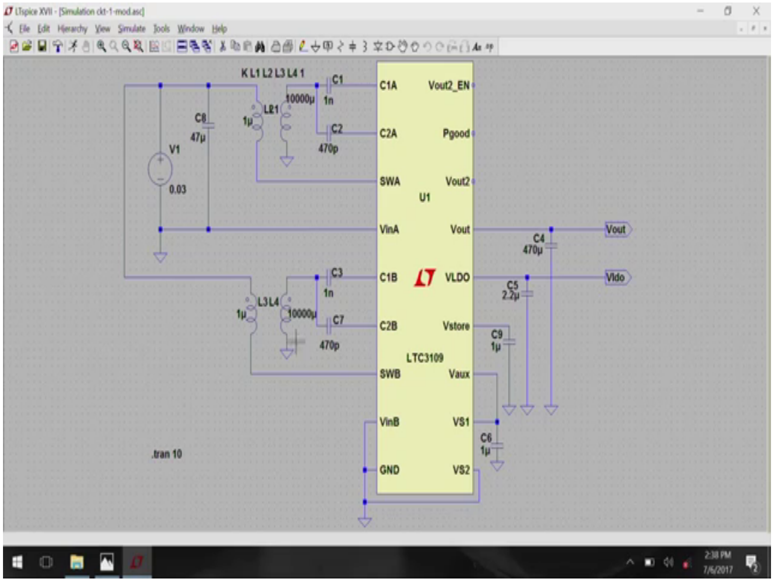

So, this is the LTEspice, LTE3.09. You can see that this top side wherever I have pointed my cursor this top side essentially is the transformer which has been used. I did not make changes to this circuit which I also found on the web. So, let us not waste much time. I will expect you that I expect that you will be able to modify whatever is available here. And then start and actually try out do a hands on by this yourself.

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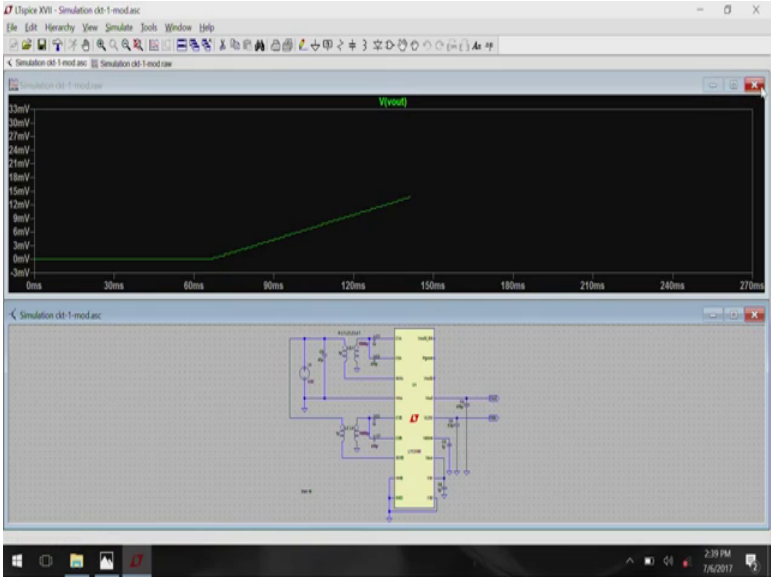

So, you see now from 0 volts the output is slowly picking up and this simulation will run for a while, and you can essentially try everything that you want you can modify parameters I will just stop it here, so that we can spend a little moment or two here.

So, you essentially can change parameters, you can change the output capacitance you can change the transformer, you can change the kind of source that you are looking at and then re simulate the circuit and before you actually prototype anything. So, what is important is to really run this thoroughly before you finally use it. So, this is in summary a big summary of all that was required with respect to a use of thermal energy with when you talk about energy harvesting for the power section of the embedded system, or the IoT system that we plan to we actually will plan to build.

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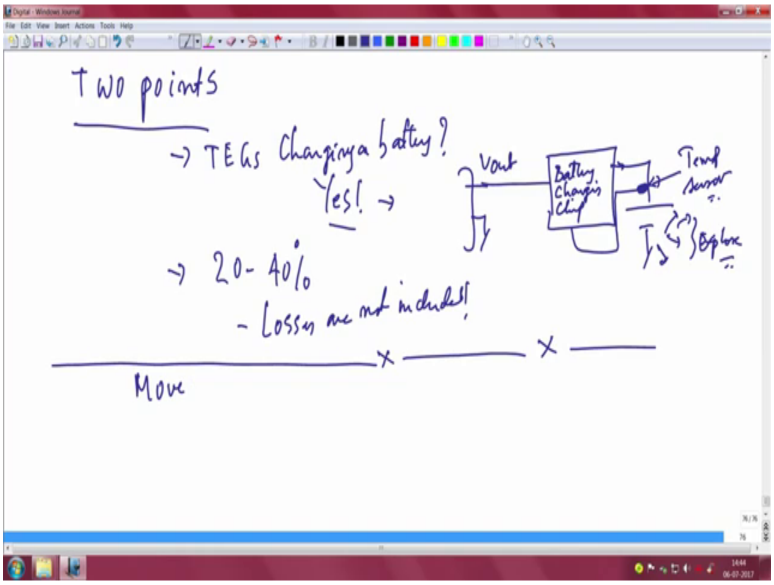

Two points, two points come up to summarize or you know to further you know to further, let us say you know sort of consolidate our learning on use of TEGs is. One thing that come up is can I use TEGs for charging a battery? The answer is yes, but you should be careful that you should actually pass the output of the TEG, into the power management or battery charging IC of the battery

So, in other words you have the V out coming from the from the boost converter of the let us say ITC3109 or boost converter chip. And this one should actually go through the battery charging chip, and then it should connect to the battery. This will take care of all the over voltage and under voltage protection, which will ensure it, because particularly if you are if you are charging a lithium ion battery then you obviously, we will have to connect a temperature sensor right. So, it will be connected to the temperature sensor, because you do not want to charge in the battery during charging with the battery gets very, very hot there is a chance that this might even explode.

So, lithium is an explosive. So, you have to take care and use all possible precautions to ensure that the charging is safe. So, you should not directly you know charge that. That is another important thing. Second thing that occurs is what is the, efficiency of this system? Typically I would say it is anywhere between in TEGs if you are using, the efficiency can be anywhere between 20 and 40 pa 40 percentage. Unlike solar which is you know people say even solar theoretical efficiency about with efficiency on paper is

20 6 percent. Most panels do not give you that kind of efficiencies and the discussion I did with respect to solar after all the conversion and all the losses and taking care of all the climate a weather changes I have just taken 10 percent. And I give you those numbers with respect to 10 percentage. Quite like that in the TEG world people do claim that it is in the order of 20 to 40 percent, but there are there is not include all the losses, losses are not included.

So, I let you judge for yourself based on several of these things before you decide the actual efficiency of the system. Let us now move on to another type of, let us now make a clean slate right. So, I will rub this, and I will make a clean slate.

 let us know talk about another type of energy harvester right. Harvester and as usual Let us begin with the demonstration of this energy harvester.

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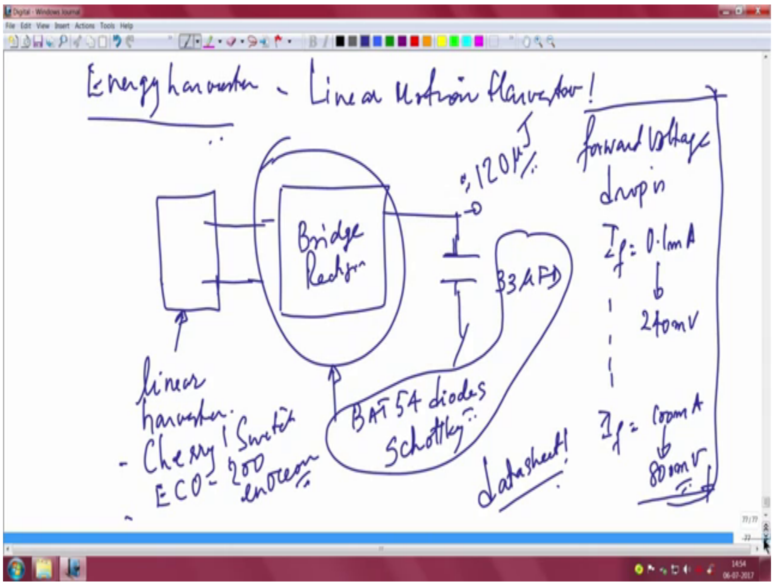

Then we will see; how this, what kind of applications this particular energy harvester actually has.

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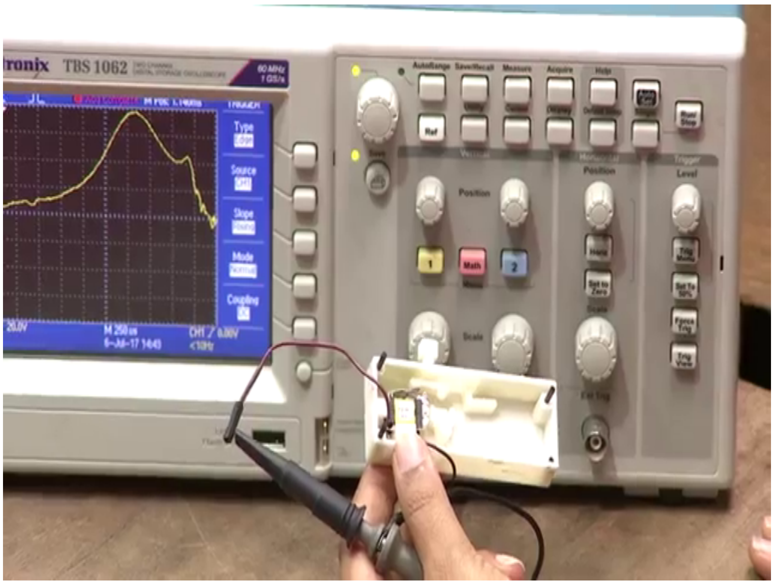

Madhuri, my colleague here we will actually demonstrate another type of harvester, and what she is actually going to do is you will see that there is a nice enclosure. This enclosure is made out of 3D, it is a 3D printed enclosure. And it is a 3D printed enclosure here, and you will see carefully that there is a plunger here. There is something though like a press which she can actuate. And she will press that in a moment, and what you will see is if she process that plunger essentially it is like a switch right.

You will see this mechanism inside, getting also depressed and a certain amount of voltage being generated. So, let her adjust the time base, such that you will be able to capture a nice system. What she actually has in here hand is nothing but electromagnetic switch. Basically linear motion harvester you can call it. So, a linear motion of this plunger there is a coil and there is a magnet inside of course. And every time she presses there is a small amount of voltage that is induced across this coil. And it is just essentially a source of energy for the system. As you can see this can be used in many applications where one can you please that again, yes. So, you can see that the systems can be used for essentially you know pressing, for harvesting energy for using them as push button switches.

So this is essentially a electromagnetic switch which is harvesting energy from kinetic. A kinetic energy harvester which essentially is a source of power to power in applications where push buttons push buttons are required where should we so, what is this, what is this, is this the actual So, what you do with that kind of way form that you get that is an AC waveform, right? Obviously, you have to build a small circuit around this push button switch. So, let us develop that circuit also and see what actually happens at the output of this kind of a harvester.

What you will have to do is, so this is a linear motion harvester. This harvester is a essentially I will represented like a block, and I will have to connect it to a bridge rectifier. Bridge rectifier and output can be stored in a small capacitor here. What I have used is a 33 microfarad capacitor to store our energy. And what I have used here are BAT54 diodes, these are schottky, diodes schottky barrier diodes. And very effective for this kind of energy harvesting applications, essentially these are schottky, schottky diodes, meant for energy harvesting applications. This diodes these diodes is schottky diodes have you had to note several things about these diodes.

Basically there volt forward voltage drop, forward voltage drop is dependent on the forward current essentially. If the forward current is something like 0.1 milliamperes, the forward voltage drop is 200 and 40 millivolts. And if the forward current the current drawn through the diode goes up to 100 milliamperes then you will have a forward voltage drop of about 8 millivolts.

Again I draw your attention to the data sheet please look up the data sheet, design everything around the data sheet this is the key point. So, and. In fact, the data sheet we will tell you nicely all these data in fact, all these numbers that I am putting out here or actually from data sheets right. So, the whole design can if you have the idea right. Rest of the thing can actually come out from the data sheet itself.

So, here is the linear harvester, linear harvester which is basically an electromagnetic switch. This is from a company called cherry you can use it from cherry is called the cherry switch. We can also use ECHO-200 from enoceon, enoceon this is another company which were by which you can buy this kind of a linear harvesters. Use them, put them through a bridge rectifier circuit and essentially store that energy and use this energy. How much we will you get again the same question right. We think from our calculations we get about 120 micro joules of energy. You are getting about maximum of about 120 micro joules of energy.

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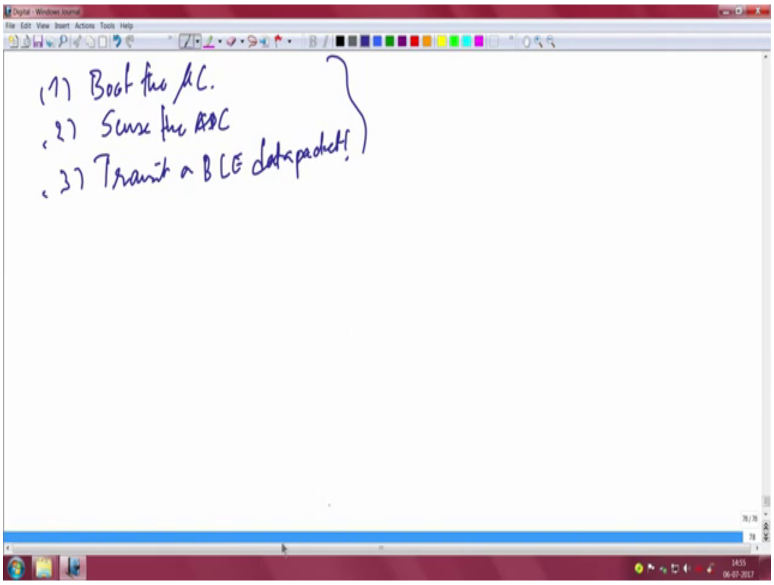

And what can you do with this kind of micro joules of energy? Well, you will be surprised that you can do several nice things. First thing you can do is you can boot the microcontroller, you can boot the microcontroller. You can sense on the ADC, ADC port. And you can also transmit a BLE Bluetooth low energy data packet.

That is all that you can do right, and this is already good enough. Suppose you want to send an on or an off you want to sense a position of a switch you can do all of this with this little small harvester. How does the DC output look? That is the next question right. Because AC you have to do all that power conditioning and all that. Let me know draw your attention to the DC output. So, for that let us look at the DC output coming from I have taken a snapshot of the DC output. So, let me show you how that looks.

This is how the output actually looks. You can see that this is one volt per division.

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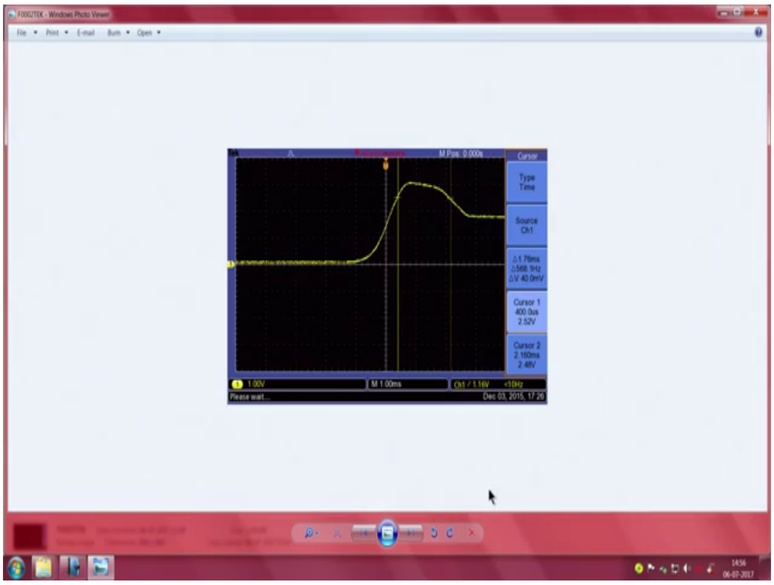

So, it is going up to a quite a high extent of about 3.3 volts or So. It is able to go to roughly 3 volts plus and remains there for this 1.7, 1.8 milliseconds of time, and after which it is so, this time from this point here, to this point here is already good enough for you to boot the microcontroller to sense the ADC and also to do a transmission of a data packet.

So, now you see the trick. You must have your crystal or crystal oscillator should come up very fast it should give you a stable clock out in microseconds, macro controller should run at a clock frequency should be quiet fast. ADC conversion time should be very fast, and you should be able to do quick communication to the BLE link, BLE over whatever SPII2C communication puts and also do a transmission of a data packet. Very tight time budget you just harvest on the fly, do a transmission on the fly and be done right.

This is the challenge and you should be able to write software, embedded software which can essentially run all this in the given limited time of about 1.7 to 1.8 milliseconds or even 2 milliseconds after which there is no more energy right. So, this is what software code will have to do the magic for you to ensure that you manage the power effectively.