Design for Internet of Things
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Lecture - 09
RFID DEMO

Welcome back. What we will do today is we will understand this RFID technology from several applications, which are possible, and we will try and as usual set up a small demonstration to give you a feel of what exactly is possible.

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Now what I am going to do is I am going to take you to one application and this application is based on Continuous Glucose Monitoring. We cannot start, we cannot start building this application from scratch, but there is a fantastic GitHub source code which you can take and start. And I will point you to that source code straightaway.

(Video Starts: 01:18)

Look at this website. This is the application I will start talking to you about LimiTTer. LimiTTer is a freestyle Libre FGM system and Libre sensor is essentially the glucose Continuous Glucose Monitoring sensor. Now if you look for Libre if you just Google for Libre sensor, I have it here you see, you will get this whole lot of information on Libre sensor. Now let us just take an image of the Libre sensor, there you are.

Look at this picture, this picture is telling you two things, one is I will tell you what exactly think about that right side device. The right side is the one extreme right top right that is so

this this picture, this picture is essentially the sensor. The sensor is applied here. Now I will show you how this sensor is applied. Think about this device, this is like a device which can hold the sensor.

Think about that old day's round seals which people used to put around seal packed like that you put that seal you get the seal on the paper. Think about it like that think about it like a stapler where we would just press it like this, the pin gets ejected out and then it staples the paper out there right it does a fastening of multiple sheets. Quite like that what it does is you put this round sensor which I showed you and then press it like this against the arm.

And then take out this container. By that time that sensor would have got stuck here. And that sensor is pack is the whole thing is packaged so beautifully. That moment you press it here, the sensor gets stuck and then it sort of starts going a little below it does subcutaneous, as it is called just below the skin it goes and sits and then starts looking at the starts getting a sample of the fluids which are flowing there.

And that fluid actually if it analyses it knows what is the glucose content. All of that is done by that little this little disc here. Look here this little disc, you can buy them. You can buy them in Amazon actually. What is interesting is? But where is all this taking us to you see pictures are there on the other side how they have applied it and all that. Look at this picture. If you look at this picture, this picture tells you that there is a device which if you take it close by that device will directly tell you the glucose level here.

Alternately, this is a standalone device. You do not like these standalone devices anymore. You are a device in the pocket is the mobile phone always. And it is a device which you use for payments, you use the device for turnstile in Delhi Metro, you buy a ticket, there and then you can you have this one the QR code on it for that and then you store the show this QR code against it the turnstile opens and then you go.

For Metro, for transportation, for buying your items, groceries, petrol fuel for your car, everything is your mobile phone, everything including transfer of funds from one account to the other. Of course, there are some limitations Google pay for instance tells you can do 10 transactions per day. And there is a limit on how much money you can transfer from the banks and all that.

Given those kinds, these are all things which will sort of get stabilized as you go along. So, the things will become a lot more, but mechanisms exist today even to buy a paan beeda let us say, as you know we used to say many years ago, you use your mobile phone, that is what we are doing today. 5 rupees, 10 rupees, small micro payments are actually done using the mobile phone, use Paytm is that.

And so many other related payment gateway mechanisms and apps, which are the Bharath Pay, Phone Pay then Google pay Amazon pay so many are there anyway. So, everything should come to the phone. So, go back to this picture. This picture only tells you that I can read it locally. But I also want this data onto the phone. Therefore, first of all you should build this device.

If you build this device, this device has the ability not only to take it to the phone, but it can also perhaps connect to your home Wi Fi and put it onto the cloud, where a doctor remotely can see it. These are some of the advantages. You not only see it locally; you can also upload this data onto the phone at any instant in time. It is not necessary that you should have the phone each time.

Therefore, the standalone device as its own merits. Now in our demonstration, we should be able to show that we can construct that little device. Can you construct that simple device? Can you configure an RFID device, to in order to read the data? So, what actually happens is something very nice. This device I mentioned to you, I will put it back here this device actually has a battery.

It has a battery and when you take the device put it into this, let us say equal into equipment into which you install inside and then you are going to place it here, when you press it, there is a beautiful YouTube video, look at it yourself do that as a simple exercise, you will see that it is like a stapler. When you press it like this, it gets stuck here you should not do it on cloth, you should do it on the bare arm.

You put it there, and then take the device I showed you, and then switch it on, you switch it on also with the same device. Then this battery will start inside, everything is sealed, there is no configuration that you have to do just press a button on the device. So, I think about the

devices, something like this, there is a button on the device, which I showed you, you press the keep it like this, and you press a button, this device, this round disc will start will start logging data.

It does data every 5 minutes 1 minute, depending on what you want to do. It reads the glucose value stores it in memory reads stores it in memory reads stores it in memory, up to 14 days, it can store the data here, it can store the data here. And then you could essentially, let us say every day you want to read the data every day, let us say 14 times a day 14 times over the period, you want to collect the data on to that specific module that you will have designed.

So, that module will essentially collect the data from the actual sensing device and put it onto its memory. Then after that you want to upload it give it to a phone and so on and so forth can be done. Now we will see what actually happened. So, this is the story of what you can what you can actually do with this RFID systems. Connection comes because this application which I showed you the limiter application, which I showed you, which you can look up here actually uses 15693 technology, it uses 15693 technology.

Now we have to get into the details. The devil is in the details. Let us do let us find out one good chip, which has which can do ISO 14443 as well as 15693 and that chip is the nothing but a very popular one which we have used is that TRF7970. Let us see TRF 7970A. Let us look at this chip datasheet and let me go, I will not use this, but I will use this one. I use this one and let us look at this great 7970A multiprotocol fully integrated 13.56 RFID and Near Field Communication transceiver IC.

So, everything is loaded here. Let us do a little more expansion and let us see how we can explain this. Suppose near field communication. See anything we do, if you look at this course, I will try and take you to data sheets. This is very important. This course is actually hinging on the fact that you should know how to read data sheets, understand on an overview, what are the parameters associated with the specifications associated with respect to a particular technology from a data sheet perspective, very, very important.

People neglect this but I think it is very important. So, let us always learn from data sheets supports near field communication, fantastic. We know this there are NFC IP standards, it is called IEC 18092 and NFC IP 2, which is another standard integrated protocol handling. I

mentioned to you about the protocol handling which are ISO IEC 15693 and one ISO IEC14443 A B, and Felica.

These are all some A B and C type A and type B I mentioned already. Felica is another industry standard like Mifare, which is also another standard. Felica is another standard, so Felica Mifare, Mifare. Then integrated encoders, decoders, data framing for the, NFC initiator. Active and passive target operations for all 3-bit rates 106, 212 and 424 kilobits per second card emulation mode. These are different modes by which NFC can work.

Then RF field detector with programmable wakeup, then RF field detector, I mentioned this RF field detector for NFC, physical collision avoidance. I already mentioned that if you take the five feet case where there are multiple tags in the vicinity. It is possible that when the reader throws power on these tags, the tags wake up and try to communicate back at the same time.

And that might actually create collision among the tags and therefore you need to space them out either in frequency or then in terms of time. So, that is anticollision and so on. Look at the applications a Plethora of applications, mobile devices secure paring public transport or event ticketing, passport or payment point of sale reader systems and so on. Now, what are the typical powers?

When you talk about an RF signal you characterize it in terms of its frequency and also the output power by which it throws. You can see that it can be as high as plus 20 dBm 100 milliwatts, it operates in a certain voltage range 1.8 volts to 5.5 and system clock frequency is adjusted from 13.56 or 27.12 megahertz. These are the crystal or oscillators circuit. Anyway, the operating frequency is indeed 13.56 which is a standard.

You can also operate it in some perhaps proprietary modes by choosing other frequency operations. Integrated voltage regulator very important, it gives you the dual receiver with RSSI for elimination of read holes and adjacent reader system or ambient in band noise detection. Supposing you have a situation where multiple interrogators are present in a field; you should be able to that is essentially the dual receiver architecture.

There are methods and mechanisms available which can avoid this elimination of holes and adjacent reader systems. And of course, power modes are there you can use ultra-low power modes and so on. So, if you read this datasheet of this device, it will tell you what is inside this device, and it will tell you all the features and so on. You have to program this device somehow and that is where the trick is we will show you some code on that.

So, now it is time to look at the actual experiment and a small demonstration of the system. For that, let us look up this exciting the continuous glucose monitoring system. It is s a tabletop version of course, I am not going to put a patient and show you glucose monitoring, continuous glucose but how you can develop that in a lab, that or we will be able to you will be able to appreciate.

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What I want to show you here is this board this is that TRF7970 board, these 7970 boards is packaged nicely, chip is packaged nicely. This is the package under which electromagnetic shield, which is applied here, and inside that is this chip. And this chip essentially is the one that is used to read from the Libre sensor. Remember, I was telling you about the Libre sensor, this is the Libre sensor 1 and this is Libre sensor 2.

These two sensor values will have to be read by this chip, when it is brought in close proximity, taken to this board, which is a development board, and this development board does not have any battery. So, RTC or what time you collected that data and so on, is not there. So, you need an RTC chip as well. So, we interfaced an RTC module.

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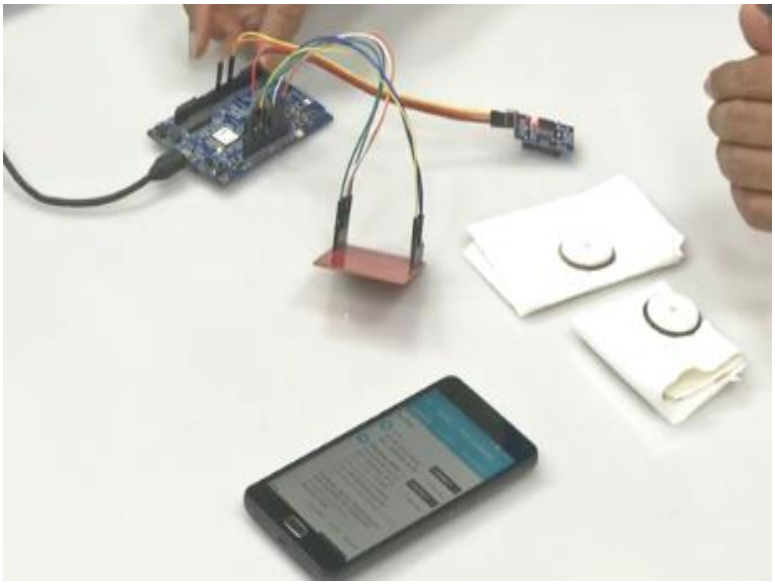

Now you may ask this looks monstrous. So, bigger board, how can you actually package it into a device, which you can use like this.

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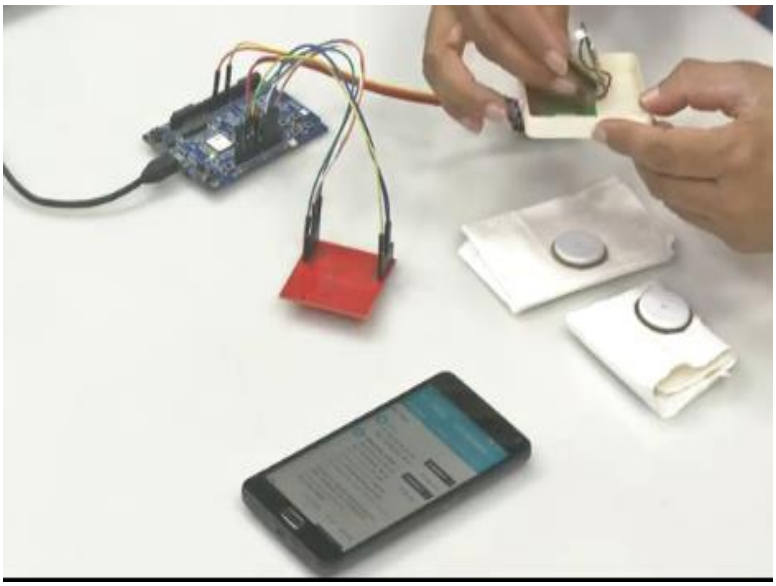

Because I recall, I showed you a device which was quite a small one from which was developed by the company to read off the glucose values. So, if you have a lid on top of this, you get a device like this as small as this device. How do you do that? That simple. We have this board.

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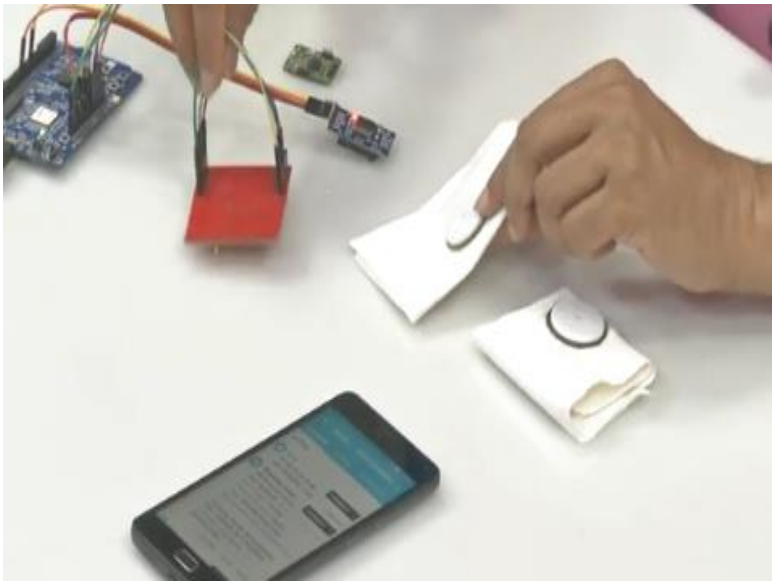

We actually made this board. And this board is a direct replacement. This board is a direct replacement of this board here, this board. So, direct replacement of this big board. So, in a way this gets compacted. Now, what is your final product? Your final product is this board, this chip is board. In fact, you can make your own chip, or you can buy a chip and then make your own antenna and put it on top.

And then this RTC module, these three things put together, go into one package, and then it becomes packaged into a device like this. And this device is the one that the human will use to read off the glucose values. So, this is the Libre sensor. This is the sensor which has a battery inside it has the sensor for reading, taking the blood glucose sample and storing it in memory. It cannot do anything more it cannot communicate; it cannot do anything.

Unless you bring it closer, the values cannot be read off. So, we will see a demonstration of that. Ultimately, the value will have to be shown on some device like the user's phone, is in it. So, that is this phone here, at the moment, what you see is all zeros here.

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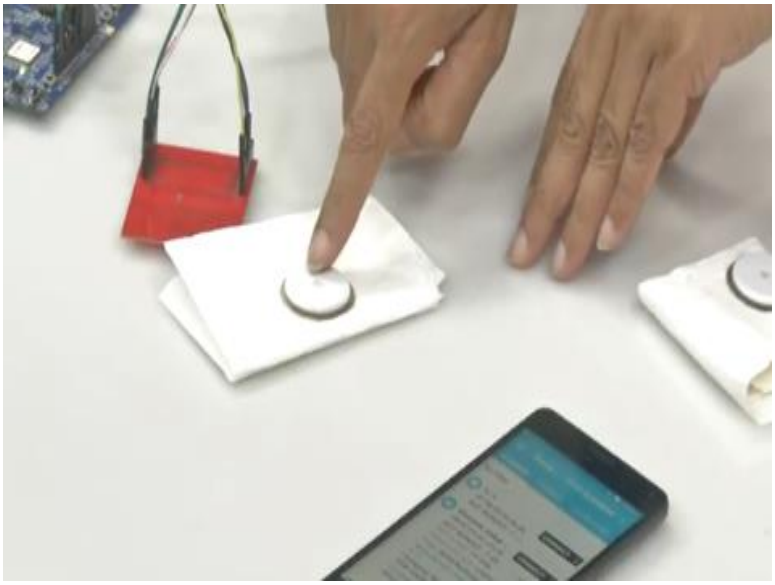

Actually, it is all shown here you will see that it is all zeros here, right here are all zeros here and we will add to see whether the values are changing for the two Libre sensors which are shown here. These are the 2 Libre sensors, which are shown here. This is sensor 1 and sensor 2. So, let us start the demo and let us see how these numbers change from the application of this. So, assume that this sensor is applied on the forearm of a person.

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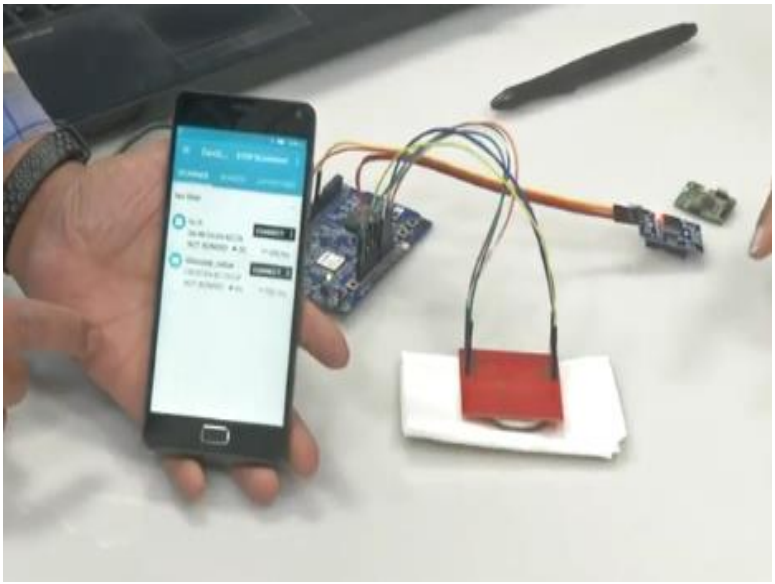

And at one snapshot in time, a certain blood glucose value is read from that human. So, let us do that demo. Now what we do Abhishek is taking the reader. This is the reader which is placed on top I mentioned to you that it is absolutely vicinity-based sensing.

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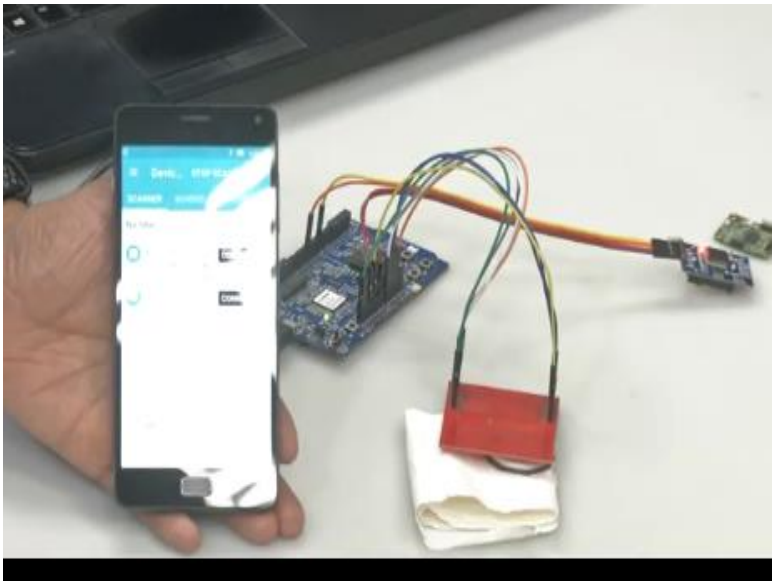

So, once it is vicinity-based sensing, it is going to read a value and then it is not going to show you anything all zeros, but it actually shows you a value. And you can see that this value is B7D, let us see where the B7D, you can see the last three digits here it is B7D, from all zeros it went to B7D. Now, let us replace Let there is a very simple expression which actually corresponds to this B7D, this B7D translates to 309.

So, we did some simple calculation, it shows that it is equal and tough 309 mg per DL this is the actual blood glucose value. There is a simple conversion formula which the company gives you, you can use that. Let us now try replacing this blood glucose, the value of the sensor with another one which has another static number. So, let us place it on top of this, now I will place this on top of this.

And let us see what actually happens? And now what we should get is some other number, which essentially is let us see what the number you get here is 938, you see that 938 here. Now this 938 corresponds to 248 mg per DL, mg per DL. So, this is essentially what is being read. So, you can see that it is so simple to do this blood glucose monitoring system, you can build the systems of your on your own and they are really lifesaving and game changing applications.

In the next video, we will show you the source code and you will be able to appreciate from the source code how this whole system has been configured in a manner that very effectively the 15693 standard based RFID tag system is actually sensing the sensing the blood glucose

value and is able to record the whole system. So, the configuration, the source code behind it is very important.

So, we will try and spend some time to understand source code of this system. Thank you very much. I hope this was exciting enough for you to get into the world of RFID related applications, particularly in the medical domain. Want to leave an important note here that the company which started this activity is when the name called Abbott. Abbott is using this Libre sensor.

And actually, the origins started with Abbott,and they claim that this and they in fact have an approval for medical approval FDA approval in Europe particularly it can be applied to humans for continuous monitoring of 14 days. So, it is already approved. It is not a quack product, it is something it is not in the labs anymore, you can actually build these systems you can if you are interested and you can actually use them in a very effective manner, you can get the sensor patches.

You can buy them in Amazon, I think it costs about 5000 rupees each or so, you can buy them and build your complete system around it and make very interesting applications are covered. Now, let us look at the source code related to this chip TRF7970A, and how it is to be configured? This is a multi-protocol chip. So, you should know how to configure this chip in a manner that you are you are able to exploit the ISO 15693 protocol.

So, the first step that I want to show you in source code which Vasanth will actually point to by highlighting this screen is related to the initialization part. So, this is initialization which will be shown. The I2C slave address of this chip will have to be mentioned. And so that is exactly where he is pointed to. You can see that initializing the simulated e squared rom, and this is the initialization part of I2C.

That should give you when you initialize it will actually tell you the address of the I2C slave, which is 0 hex 68. So, let us go and look up that exactly so he shows the slave address of simulated e squared rom, slave address which is actually 68. Let us begin first by showing you the initialization of the RTC module. In that you will see that let us Vasanth go to that point where he initially the RTC module.

This is because there are two systems which are connected to the controller, one is the RTC and the other is the TRF7970A. So, you can see that it is initialized to zero hex six eight. The reason why we need the RTC module is because you also want to know the timestamp at which you are reading blood glucose values, I mentioned to you that the tag does not have a time does not have an RTC. So, Time Stamping is not there.

So, you do it in this manner. The next is the SPI configuration of the reader TRF will point you to that part of the code you can see that this code that here has highlighted clearly shows how you configure the SPI basically all the pins, the MISO, the MOSI pin, the clock and other related pins and also the chip select is a four-wire interface. So, all the four wires are actually shown there.

Next is after you have configured the SPI is to go into the configuration of TRF7970A. So, let us see how it shows here this is the function which is highlighting the configuration of TRF. Here one of the most important things that you have to look for is that he configures this chip for 15693 and that part of the code is also present here where he shows that, look use configure set to ISO 15693.

In continuation of this particular aspect of the configuration of 15693, all the inventory related commands are also mentioned here. You can see that the inventory command is shown basically for 15693 it will be hex 26 which is shown on top there you can see the top line there exactly. So, that actually shows the hex 26. And then there are the tag ID is present in hex 7f the tag ID is present in 7f and that is also indicated in this particular function.

Moving on you also need to know the system information. So, that system information is available from through, UUID which is essentially pointing out to all these you can mention, you can see that you will get better information once you read the datasheet, I am just pointing you to different configurations which are there. So, please read the datasheet in much more detail.

So, that you will be able to connect to this particular aspect. Next is to see whether you want to do single block or multiple blocks. So, here is the section related to reading of multiple blocks are seeing the block which is also highlighted there. Now, this is essentially the TRF

command as you can see, this TRF command is essentially containing all this information in this court, will share this code to you so that you will be able to appreciate it better.

This is as far as the TRF is concerned you also want to know from the Libre sensors perspective, where exactly the data is being written on the Libre sensor. So, for that, this TRF will do a probe and he does this probe by these highlighted two things that he has mentioned here a memory address of the Libre pro sensor. And then interestingly, once you send this command, I will show you another document, which actually points to where on the Libre sensor, the value actually comes.

See, first time when the value of the blood glucose sample is taken, it is written in some memory location may be value 1 value 2 and so on. But the address of that is actually stored in the pointer current glucose. So, that actually contains the information of where the values are actually being written. So, the address information is held in the pointer, current glucose and the actual values are actually returning value 1, value 2, value 3, and value 4 and so on.

So, therefore, by this configuration from the TRF side to the Libre pro sensor continuously, you should be able to read from the blood glucose sensor. That is all we have from source code perspective. I hope you have had a first cut, look at this system and by looking at the source code and by looking at the datasheet very important. By looking at the datasheet of TRF7970A and looking at the source code I am sure you will be able to figure out several things from this experiment. Thank you very much.

(Video Ends: 29:46)