Fabrication Techniques for Mems-based Sensors: Clinical Perspective

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Lecture – 39
Introduction to Equipments: Impedance Analyzer

Welcome. So, this is the next module in the lab familiarization section that we are carrying out for the micro Fabrication course and microfabrication lab environment. So, we have seen how what is to be done for proper gowning to enter the lab and how devices or sensors can be brought in and taken out of the lab using desiccators. And now, let us see how sensing is done carried out. There are different types of sensors that are fabricated. There can be impedance sensors or electrical based sensors, they can be mechanical sensors, chemical sensors where they see ph and concentration there is there are varied classes of sensors.

Today we will see one equipment called the impedance analyzer, which is used to characterize and test electrical based sensors or impedance measurement based sensors.

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So, if you see to my left, you can see an equipment called the LCR meter or the impedance analyzer. So, this is a very high tech equipment. So, you would have all of you would have seen multi meters. So, what does a multi meter do, a multi meter can be used to do lot of things like, you can measure resistance, you can measure capacitance inductance.

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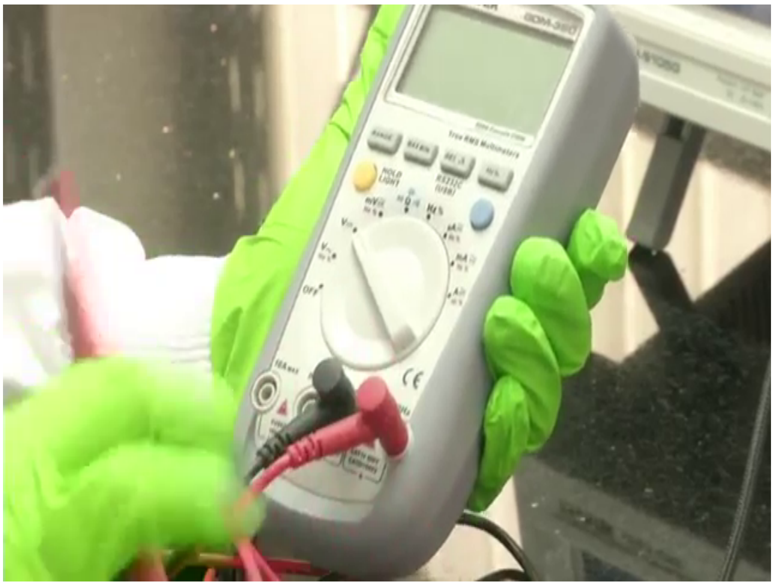

So. I have one handy multi meter with me. So, this is a normal multi meter. So, as most of you would be familiar with using a multi meter, you can measure voltage across these two terminals, these two terminals using a multi meter in the volt range millivolt range you can measure ac voltage here, you can measure dc voltage. And you can measure frequency, what is the frequency and duty cycle, what is the resistance is there a shot between the terminals, what is the current, what is the current flowing through two terminals, some multi meters can measure capacitances inductances several things.

But this has a limitation; this multimeter is made for measurement of a particular frequency only or it will be limited to a few frequencies and the sensitivity. That is a most important thing, the sensitivity of this probes are much lesser for a sensor application. Sensors are very very finely fabricated equipment, that have that needs to be used at very high amounts of sensitivity. For such an application a multi meter is not the correct choice of equipment, for that we go ahead with the impedance analyzer which I just introduced to you.

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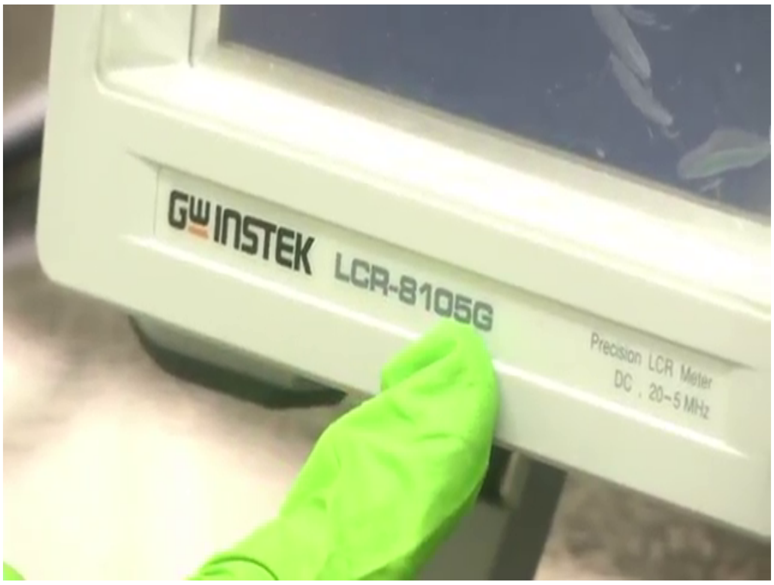

So, if you can see here in the description. So, this is a GW INSTEK LCR 8105G equipment. This is basically an impedance analyzer or we can call it an LCR meter. By LCR yes you guessed it correctly, L is impedance, C is L is inductance, C is capacitor, R is resistance. So, it is basically, measuring different impedance related quantities the capacitor total impedance inductance and all and it can measure at DC, that is DC resistance or DC resistance and also measure the total impedance or inductance and capacitance from 20 hertz up to 5 megahertz that is the specialty of this equipment. And more than that, there are a lot of complex design that has gone into these probes.

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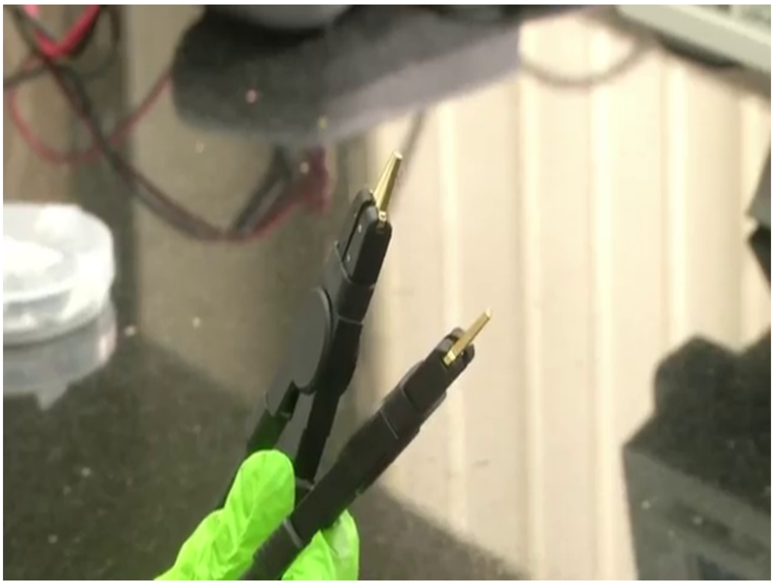

They are they are they have very very high signal to noise ratio and they can pick up even the smallest change or smallest signal, that comes out of your sensor and this is tailor made for the application that, we discussed in the duration of this course.

So, let us see how we use this equipment or let us familiarize with what are the different knobs that are available. First thing we have a power on off switch here, let us power it on. So, we have powered on the equipment. So, before you start any equipment, leave the impedance analyzer. Before we start any equipment the first thing to do is to be calibrated before you use it. So, we have a calibration port here, now we are at the home screen of this equipment, as you can see it is in the measurement mode. So, measurement mode you can see what all things you can measure see, capacitance, inductance, the impedance, the admittance, reactance everything we can measure.

So, capacitance; capacitance value inductance value reactance value admittance value, all make sense only if you do a frequency based measurement. That is why this equipment is useful. It can measure across the range of frequencies. So, now, these probes which we saw, they are both a source and the prob. So, if you see the probes here, so, there is force, sense, sense and force.

So, thing is, these probes will force a voltage across your terminals which we have to measure and the same probes will sends them back. This is a standard design method that is used to make these hi tech equipments. If you see a 4 probe point measurement that you might see in the characterization related topic, there also you use same technique where the same probes act as both the source as well as the sense terminals.

The source or the force here will send a voltage and it will sends back the impedance. In a simpler way what it means is that, these probes will put on the pads, they will send a definite voltage and then that voltage will create a current and with those voltage and current information, these sense probes will measure the impedance for that particular frequency and show it on the screen.

So, that is why this 10 milli volt ac what you see here is the force voltage that will be applied from the sensors, and here you see what is the frequency that it will measure at. And once we probe something that impedance value will come here. Let us not jump to things now, first thing to do before measurement is to do calibration. So, let me press calibration here. So, there are two types of calibration that we have to carry out, called open circuit calibration and short circuit calibration. So, in open circuit calibration we have to keep the probes open, they are not in contact.

So, let us do open circuit calibration, once we click open circuit calibration, the device will ask to what all frequencies he want to do the calibration because, maybe some of your some our application might be limited to a particular frequency only. We might be interested in only maybe less than 10 kilowatts or we might be interested in only one particular frequency or less than 100 kilo volts. Generally let us do the calibration for all frequencies.

So, I will select all frequencies now. Now, the calibration is in progress and I have kept it in open mode because, this is an open circuit calibration. So, I kept the probes in open mode and that calibration has succeeded. Now, let us repeat the calibration,,, but let us touch them together. So, this they are actually shorted correct, when you test the probes together they are shorted. But let us do with them shorted let us do the open circuit calibration, ideally, that calibration should fail. Let us see it happening. So, again I have connected, I go to calibration mode, I clicked open circuit calibration and I am calibrating for all frequencies.

Now, this calibration process will fail see, it has failed.

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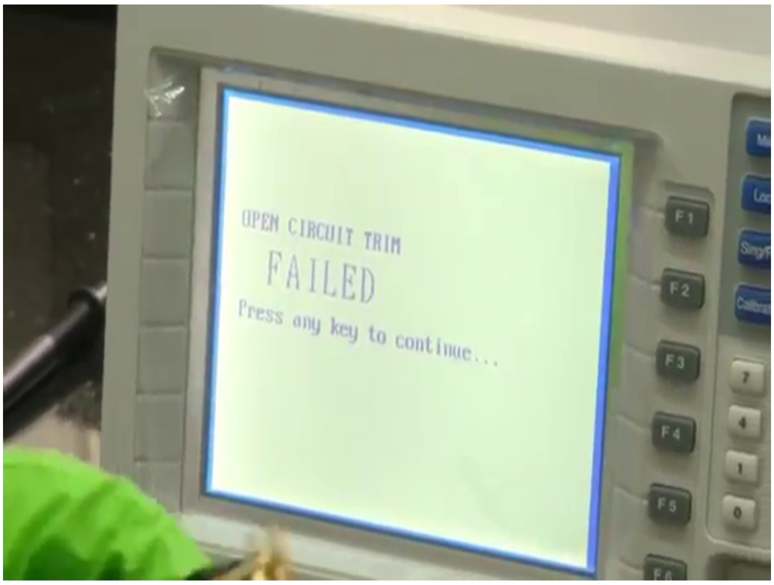

This is because for open circuit calibration you should not connect the probes and keys you should keep them like this. Now, let us repeat it once again, I go to calibration, I click open circuit trim, trimming is same as calibration basically, all frequency now it will calibrate. So, you see the progress bar, because it is in all frequency calibration that is why it is taking time, it is trying to calibrate across the entire spectrum of frequency is that the equipment can handle it has succeeded.

Now, we have to do short circuitry. So, before we do short circuitry, we can I have to actually short the probes. So, we have shorted the probes, click short circuiting, all frequencies again same thing will happen. So, all frequency, short circuit trim it is doing and it is pushing 0.01 volte or 10 millivolt So, I have kept it shorted and you can see the progress. So, that progress bar once it is complete; that means that the calibration is successful. Now, we are good to go ahead with measurement. .So, will now we will click measure and it will go to the measure screen.

Now, let us say, I have shorted the 2 probes and here we are seeing the frequency. So, this knob here, this knob here can be used to select whatever region of the home screen we want to go to. So, if I click right, it will keep going to each of these things. So, now, it is 1 mega hertz. Suppose, I want to go to a lower frequency. So, I can just click the down arrow it will go to lower frequency, it can go up to 20 hertz as is the spec of this equipment. It can measure dc and after dc it can measure from 20 hertz up to 5 megahertz.

So, I have kept in 20 hertz; let us say I can increase it. I can even change the force voltage 20 millivolt 30 millivolt up to one volt it can go. It can even go more than that actually. So, as you can see,,, but usually we use 10 millivolt as the dry voltage why so? Because, we should not destroy or hamper our sensors, while we test it. Our testing as much as possible should be a non destructive testing. So, suppose we do not know, there are lot of there might be lot of transistors, there might be lot of critical layers in our device that cannot take a high voltage So, because of that we have to apply sufficiently low voltage. So, that our device continues to work and we get the results that we expect.

So, let us go back and keep it at 10 millivolt. So, we have seen calibration, and what are the different knobs available. Now, let us just have a look at a sensor.

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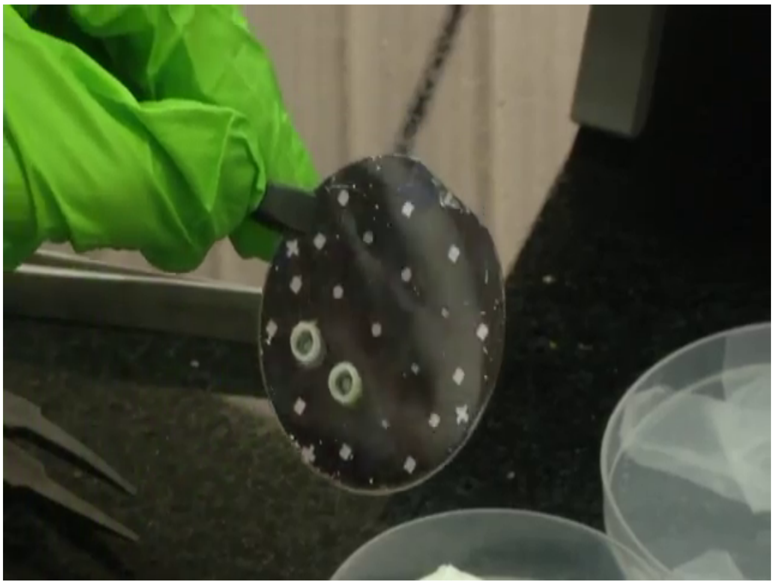

So, this is one sensor that we are having in our lab. As you can see there are contact pads, these 4 squares which you see are contact pads. So, we if we are probing with a probe we have to have a metal probe there will go and touch on this, it is not advised to manually go and take this probe and put it on top of that.

So, for that we have other equipments like micromanipulator and other probe stations, which we can use to make this contact go and touch these contact pads and actually measure the impedances. So, these contact pads. So, if you see here, these are micro wells where there are electrodes call these are called le interdigitated electrodes, they are called interdigitated electrodes.

So, that electrons are placed under these wells. So, there are wells here, these are wells, this is a bigger well that we have created, we have created a well around it using tubings around the well. And the measurement of that well will be carried out across these contact pads to these contact pads only we will put these probes of the impedance analyzer. I just wanted to show you a sensor and measurement we will see in due course of time in this course.

So, we have seen calibration of the equipment and we have seen how a sensor will look like, how the contact pads will look like, how we will what is a way to connect these probes to the contact pads.

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Now, let us see. So, this equipment. So, you will see you will think I have to measure; I have to take measurements I have to take measurements from 20 hertz to 5 mega hertz. Do I go ahead and every time if I want to measure do I go and change the frequency in single steps. Then you will think that will take ages right, it will take. So, much time to go change 100 hertz again measure again 200 hertz measure, 150 hertz measure that is not possible. For that this equipment comes with a software.

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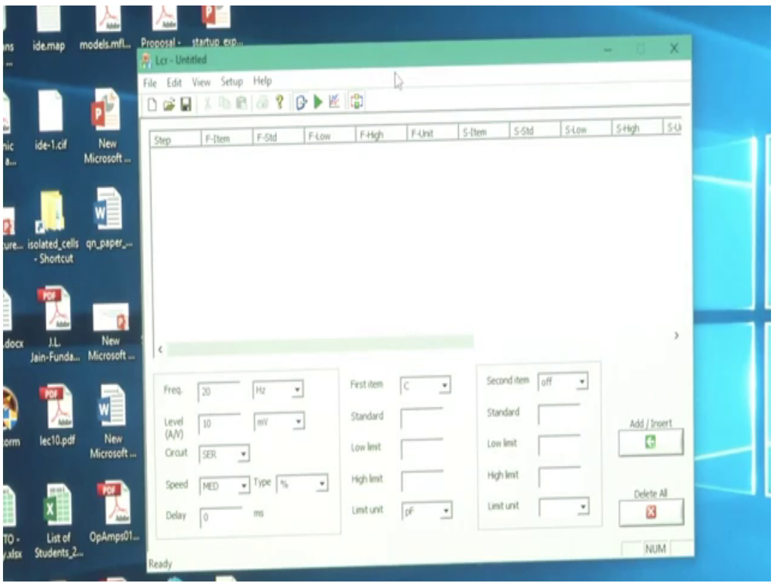

So, if you can see the computer screen here now, we have to go to setup communication; communication setup and this device usually gets connected to the third comport. So, we will give 3 and then connect.

So, it has got connected. Now, see as I told, do you do we actually measure by setting each frequency?

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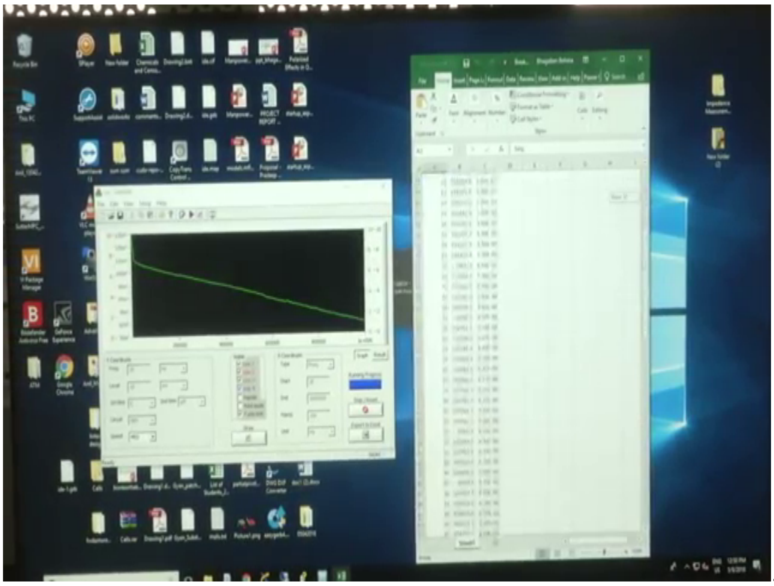

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No this equipment comes to this software where it will sweep through the frequencies that you want to measure. So, I will introduce you to the different knobs that are available before that, let us first do a small measurement with the equipment itself.

So, as you see here now, we have connected a capacitor to the probes. So, you have you see the probes and we have connected a capacitor to the probes. So, this is 0.1 micro farad capacitor.

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So, hope this is clearly visible to you guys. Now, I have connected the probes in here, in the measurement mode in the screen if you see.

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We have kept it in capacitor mode and we have kept the frequency as 300 hertz. It will show the capacitor value and the impedance at that frequency.

So, what is capacitance? Capacitance will just the capacitors value, that will be in farads. So, we have this is a 0.1 micro farad. So, it is showing 130 nano farad, those that is roughly around 0.1 micro farad. Now, what is impedance, impedance is 1 by c omega, impedance for the capacitor. So, that is 1 by c omega, the omega frequency is 300 hertz so, that also it will show. Now, let us change the frequency and see what happens. And every time you change we have to click trigger and it will measure.

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So, now I have increased the frequency to 4 kilo hertz because, it is 1 by c omega and an increasing omega value this ohm as you see which is the impedence it is coming down,,, but the capacitance if the capacitance, as such is not dependent on the frequency that will remain around 0.1 micro farad. So, every time we change the frequency here, let us go to a very low frequency, let us say 20 hertz that means, now when we click trigger, every time you want the equipment to measure this individual values you have to click trigger, this is the trigger button. When you click trigger, you can again see.

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See, now, it is again the capacitance value is almost roughly in that range of 0.1 microfarad,,, but see the impedance it has become 3.6 kilo ohms.

Now, let us go to very high frequency. Let us say in the megahertz range. So, now, we have gone to 5 megahertz ok. Now, again if you click trigger, the capacitance value will still remain in that range,,, but the impedance will go very low because it is one by c omega.

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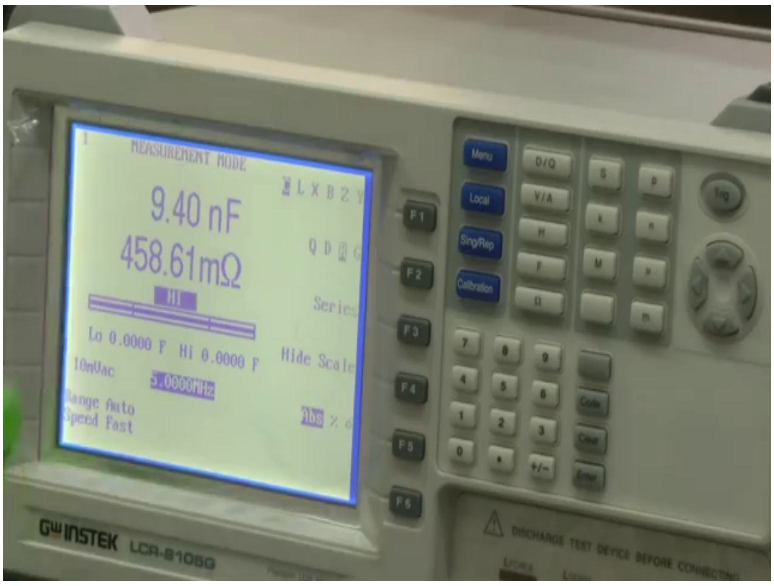

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See it has become in milli ohms, the impedance is milli ohms and because, there is a limit to the operation conditions of the capacitor. So, we have gone to 5 megahertz.

So, this for that is you have seen different types of capacitors, it is showing a very low capacitance value. So, that that measurement has also got affected. So, let us go to somewhere intermediate value like 100 kilo hertz, which would be within the operational conditions of this capacitor So, now, we are in 150 kilo hertz, now let us do trigger.

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See, there will be a correct exact operating conditions for this capacitor. So, it is around 100 kilo hertz, that is why it is almost showing 100 nano farad which is 0.1 micro farad c and the resistance is very low, it is around 1. Not resistance impedance is very low it is around 1.58 mega ohm 1.58ohms. As you can see it is a very laborious task to measure this capacitor across different frequencies that is why this equipment comes with this software.

Now, let us see what are features are available in the software. First this is the screen we have clicked this draw icon and this is the, what you call input voltage that will be applied, that we have seen before. Forcing voltage of 10 millivolt, this 10 millivolt will be only the peak voltage of the ac signal that will be applied because; it is a measurement across frequencies. Now, what are we going to measure, see we have we are going to measure capacitance here. So, you can have different options inductance, reactance.

The field intensity, impedance, admittanc and even dc resistance and you can have even a second item for let us keep that as off. Now, how are you connecting that component to the probes, are you connecting it in series or parallel? So, we are connecting it in series. Then what is the speed with which you want to do the sweep.

So, this software will be doing a sweep across the frequencies. So, if you give a low speed, it will give a much more accurate value. If you give a fast sweep, the sweep will happen very fast,,, but the accuracy will come down. So, anything in life comes with the cost. So, if you want past measurement, your accuracy will go down. Let us keep it medium, it is neither slow nor fast.

Now, what is your x coordinate, x coordinate is your frequency anyway that we are going to sweep across a frequency. You can even have a voltage sweep. Right now, let us do the frequency sweep. What is your starting frequency, our starting frequency is 20 hertz, what is your ending frequency, let us keep it is 1 megahertz. So, it will be 100 hertz, now it is 1 kilohertz, 10 kilohertz 100 kilo hertz and 1 megahertz. How many points do you want to measure between 20 hertz to one megahertz, let us keep 100 points and the unit will be in hertz ok.

Now, now we have set up the whole equipment; we have connected our capacitor here to these probes, as you can see before. And now, once everything is set we will start the measurement. So, I am starting the measurement no that is stop. So, to start the measurement, we have to click draw here. So, I will click draw and it will automatically force whatever voltage we have set and sweep through the frequencies. So, you can see no, how the capacitance value is varying across the frequencies that it is plotting it out also.

So, for most of the of within the operational conditions of this capacitor, most of the values will lie within a tolerance level and it will lie within 100 nano farad to 130 nano farad that is the actual value of the capacitor, which is designed for that is 0.1 micro farad. As it crosses its stated operating condition frequency level, it will start coming down. So, we are going to measure till 1 megahertz, it is taking 100 points. As and when that measurement is made, here in the equipment also we can see what are the different measurements that are being made, it will keep getting updated for each frequency that see that, device equipment itself is sweeping across the frequencies.

Now, it has reached 800 kilo hertz 850, 838, 848, it showing the capacitance and the impedance value that is measured. And once it finishes one megahertz it will stop fine. So, it has stopped. So, this is the last value, now in the software we have got a sweep nice graph we have got. What are the different capacitance values that we are measured for this capacitor across the frequencies.

Now, just seeing the graph is not enough, we need the data right. So, we have to export this data to an excel sheet. We can do it here, click export to excel. So, it will open an excel sheet and dump all the data that it has captured. So, see. So, this is which is this is number of serial number of the reading, what is the x axis, which is the frequency and what is the capacitance that is measured in farads.

So, let us see 100 data point should have been taken. If you check it you will see that there are 100 data points and till around its operating condition it is staying within the 0.1 micro farad range. See this is like around 0.9 micro 0.09 micro farad and that a frequency of 363 kilo hertz.

So, this is how we can have a sweep, this is a very useful software that comes along with the tool. This way we can do the measurements of various components as well as sensors. Capture the plots and save it in excel sheets for us to view it later. So, these are the different norms that are available in the software and this is how an impedance analyzer works. So, in this module, what all we have seen, we have seen how to do calibration, what is the impedance analyzer, why it is.

So, special as compared to a multi normal multimeter and what are the frequency ranges that this particular can operate in, what does the probes actually do it acts as a source as well as a sense terminal, what all different items can be measure, parameters can we measure, how do you do actual calibration and how do you do a frequency voice sweep of your measurements using a software that comes with the tool.

Like this we will introduce you to other very interesting equipment that are available, that are usually available in a lab that does testing with micro fabricated components.

Thank you, see you once again.