Experimental Physics - III
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Lecture - 11
Lock in Amplifier (Contd.)

I will show you the Lock in Amplifiers and demonstrate whatever I have described theoretically. I will demonstrate those concepts.

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this is lock in amplifier; it is this instrument generally is costly. this is it is power stand for research system, this company name, it has model, this lock in amplifier have different model depending on the frequency range, depending on the function, but forget, but it is called DSP lock in amplifier, DSP means Digital Signal Processor. It has digital signal processor, but forget everything. It is a lock in amplifier,

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it has lot of knobs in panels. I will tell you what are the functions of this lock in amplifier. you see, what is the; what is the aim we have that is basically. We want to single out from the noise a signal of known frequency,

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here you see in oscilloscope, I am showing you a signal, in oscilloscope I am showing you a signal you see this is very noisy signal. but in this signal this I have signal of an interest,

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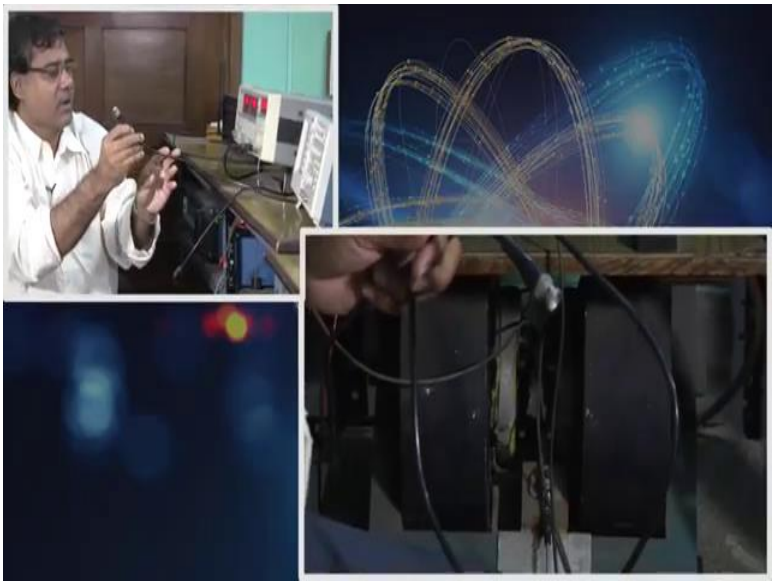

this is the input I have given to the oscilloscope, which is this is the input.

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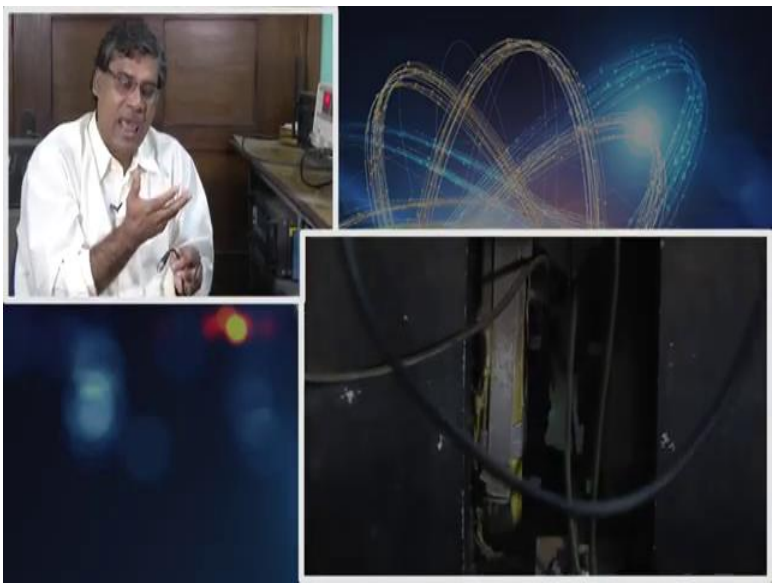

From where I have given input? I have given input from another instrument; this experiment I will describe you, I will demonstrate hopefully, but that I am not discussing that, but we are taking one signal from the system, and that signal is very weak it is in nanovolt, this signal is in nanovolt order,

Now, this signal naturally will have this lot of, any signal will always have the noise, now if signal is strong then signal and noise ratio is very high or noise signal ratio is very

low, we can just we can measure ignoring the signal continuation, sorry ignoring the noise continuation. But when this signal is very weak, my signal as I told it is in nanovolt order, then noise itself is in millivolt order, ok.

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Whatever I has I was showing here it is in 50 millivolt range, 50 millivolt range, it was 50 to 100 millivolt in that range there is a noise, it is impossible to measure the signal correctly to take out to get the signal correctly without lock in amplifier. how it is done? that is the aim we will show. this is my input signal this is the; this is the signal, it is coming from that instrument I want to measure that signal, I want to measure the amplitude of that signal.

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here you see here this lock in amplifier have here A B, A or I and this is B, what is A and what is B? these two input channel, signal input. these are signal input, if you put two signal, if it is voltage volt signal in volt, you can use A or B or both, and or I if it is signal is in current then only you can use this one A, A or I that is why it is written, ok.

this part is for signal input and from these two signal one can get A minus B, difference of the signal, summation of the signal also one may get, ok, you can get I, it is in 10 to the power 6 I it is. there are a lot of things AC, DC. you are single is AC, ground floating. you have to choose ground, generally we choose floating ground, this is the input, I am giving input to the; input to the, these are BNC connectors one has to connect properly, ok.

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Now, I have given input to this system I have given input to this system. I have given the input to the lock in, now, what lock in will do? lock in need now as I described the lock in, now lock in need reference signal, this is my signal. I have given now lock in need reference signal; reference signal of same frequency,

now, this signal of what frequency that I have to know, the signal of what frequency that I have to know, I know say, and this signal of same frequency as a reference signal I have to give to this system lock in amplifier.

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in lock in amplifier there are two options, here you see it is a retail reference, here it is it reference. it has internal oscillator. It can generate signal of different frequency, and there that here it is written phase frequency amplitude, here harmonics it is written but forget that part, here this plus 90, minus 90, here sine, it is a, here since I have here this is a glowing sine, ok.

sine where you can produce you can produce. here frequencies, here you see I placed frequency the frequency is 80 Hertz. I am taking 80 Hertz frequency of some amplitude, amplitude is 0.01 volt, means 110 millivolt, and its phase also some phase is there whatever now I will not bother, this type of signal, ok, I am taking out this is sign out you can take out this from internal oscillator you can take out the signal, that signal I am using I am using to; I am using to produce I may I am using to my experiment,

This signal I am using to my experiment which will give me the signal of say of this same frequency, ok, and that signal of the same frequency what is the amplitude that I want to know and that I am putting as an input of this lock in amplifier, what does it mean? And this lock in amplifier when I am using this internal oscillator as if internal oscillator whatever the frequency we have chosen that we are taking the frequency of our signal, now that signal we have put here, I am interested to measure the amplitude of the signal, ok.

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this is let me tell you, this we have put to the here this is the amplifier, of loud speaker. whatever the signal I am giving this it will amplify and it is given to the loud speaker, you know in below loud speaker is there, loud speaker.

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it is a vibrating with that same frequency, whatever the signal I have given with their same frequency. Now, due to this vibration, there is a some the here there is a magnet and we have a sample magnetic sample, and near sample there is a coil. this now there will be induced emf in this coil. that induced emf in this coil that is that I am taking my signal, induced emf due to this vibration,

I will get the induced emf of the same frequency, and, that induced emf of the same frequency I want to measure what is the induced emf, that I have put here, two major. Now, this instrument has the input signal of my interest and these instruments have the information of the have the internal reference signal,

now, it will process inside it has prohibition, electronic part, it has prohibition to multiply these two signal, it has it is an it has simultaneously it is doing this parallel calculation, one reference cos term and another reference sine term. these two reference separately multiplied with this coil. one output will be one, one signal amplitude proportional to the signal amplitude cos theta and other will be sine theta,b signal cos theta b signal sine theta, ok.

here I showed you. now, what is the input signal we have taken as a reference signal that I showed you? one has to change; one has to change, here amplitude you can change, you can change the frequency phase. all function is here. And you can use your own, your instrument you have instrument there you are using it is producing signal of some frequency, and that frequency you know that is given from the another instrument,

now that same frequency you have to; you have to that signal you have to frequency signal as a reference signal you have to put to this lock in amplifier. that here you can see it is written reference in, if you are not taking from these oscillators these taking from these oscillators of this lock in internal oscillator of this lock in, externally if you have own frequency generator which is you are using for your experiment and that signal of the same frequency you can put in, you can put in and your reference the that will be reference signal and your signal of interest will be put here,

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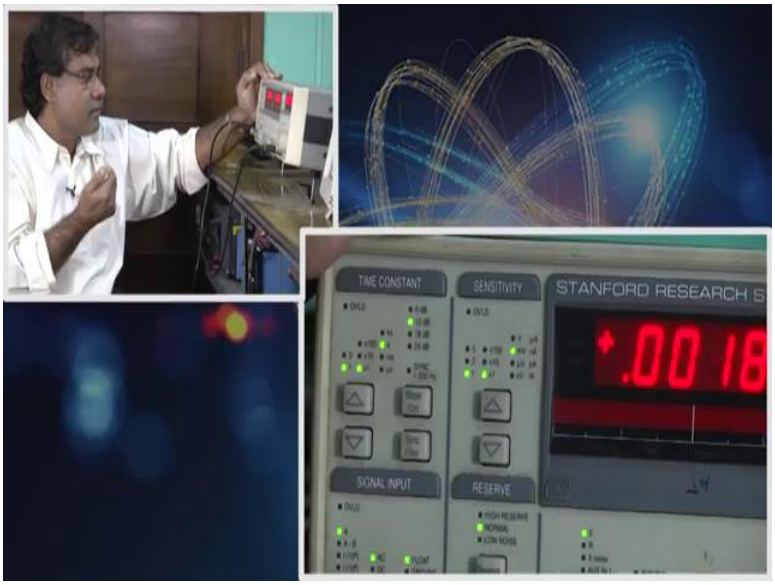

now you see here you see, now here you see when you are putting signal, you can it is a time constant of a signal, it is 80 Hertz. my signal 80, this is 80 Hertz, its time period is millisecond, Time period is I think 1 by 80 frequency will be frequency 80 Hertz,1 by 80,1 by 100. it will be 0.01 of second. 0.01 second means that is time period and that is 10 millisecond, ok.

your time constant, accordingly you have to choose your time constant and here these options are there. we have to choose in millisecond or second range, it is in 0.01 second.

you have to choose here, depending on the frequency you are using you have to choose here time constant, sensitivity means a scale, you can choose the sensitivity depending on your signal you can choose in nanovolt, millivolt, volt, microvolt, in different sensitivity you can choose depending on the signal strength,

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here sensitivity can choose and here input signal input as I told you. some other things are there, it is called reverse dynamics. this I think there are some other purpose also as I told this one can use this one. I will not discuss all of them because I am interested tell you the basic use of this lock in amplifier otherwise things will be complicated. first you should be familiar with this important part, simple, that is simple. now, you see now what I will show you, this is my signal and internally reference is there.

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now here what about these displays there, it is displaying here you see. This is one, this is one channel, this is one displays as I told this parallel two calculations are there, one is one is x and another is y, X display and y display, but there are options here also you can use this x display and this is y display. You can use see you have r value, there are many here. now here what I have to do first let me give some signal.

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You see it is the, whatever without any signal whatever it has showing now also it is showing same thing. Now, you can imagine that signal is really very weak, it does not

affect the this previous one without signal. with signal, without signal to see are it is no difference you know. but now I have to find out I am putting here, I am putting here, here it is showing some value you know.

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here it is in it is a 0.073, It is a millivolt. Whatever this it is millivolt volt I do not bother because this is proportional you know. We are interested about the magnitude even it does not matter, but it should be all radio should be in same unit that is condition, ok.

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here I am seeing some value, here I am seeing some value 0.15 millivolt. this is here display is x and here display is y, what is the display x and y if I tell? As I mentioned this is cos theta, x equal to this signal amplitude into cos theta or cos phi and this is sine phi,

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now if we put r, it will show the r square root of x square plus y square. You can calculate and find out. Here if you want to see the angle in degree, ok, phase angle it is the angle different with respect to reference, this theta phi, this here other there are some other things also you can see, but we are not interested. that is used for other purpose. Now, what I want to do I will keep it at x, sorry I will keep it at is x and I will keep that one is y,

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Now, you see here this by reference signal, reference signal now frequency I want to change phase, you see phase. Now, I am changing introducing phase in the reference 1 that is means phi s minus phi that will change. when this difference when these two phi s and phi r will be same, then what I will get? X term should be 1, x means cos phi term should 1 and sine pi term should be 0. x should be maximum and y should be 0, ok.

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let me do that; change it and let me x should be maximum y should be 0. which one changing? It is phase yes, it is becoming other way, x let me make it x equal to 0, y equal

to y will be maximum; x will be 0, y will be maximum that is happening that is happening, here more or less it is x is 0, y is maximum, Just, if know it is value it is around 1800, Not 1800, 0.17, 0.18, 0.18 millivolt, and if some more or less is 0, I think this punctuation will be there, ok.

And now if I put this r value just check it should be around the same value, right, it should be same value. But in x it was not this it is exactly this because this difference because of this I could not make this x perfectly 0. that is why square root of x square plus y square it is not equal to y, slightly difference is there, ok.

now let me go back to the x y. Now, we see if I add now if I add additional 90-degree phase. then what will happen? It is now; it is now the phase of this one and phase of this one, there is a 90-degree difference is there, 90-degree difference is there. now, if I add additional 90 degree then what will happen? This is cos term is becoming, this is 90 degree, cos 90 degree and this is sine 90 degree,

Now, if we add or subtract 90 degree, then it will be 180 and in this will be, this one also this is the 180. cos 180 or 0 that will be, sorry this is 9 cos 9. this is cos and this is sine, cos will be 180 means 180 or 0 means means plus 1 or minus 1 or this one sine 90 degree plus 90,that will be 0 or 180. sine 0 or 180 that is 0, it should be 0 and this should be maximum.

here you see plus 90, minus 90 this happen if I press it, ok,it will be additional 90 degree will be added or subtracted here. Here you note down this is phase is this.

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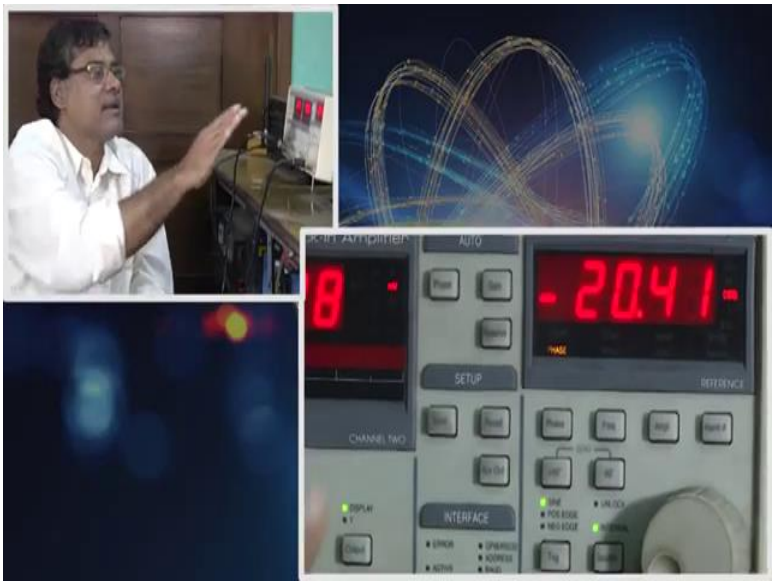

Now, plus of this 90 degree I put from 110 where it is going? From 110 it is coming to the 90, 20. 90 subtracted from there, or 90 it was minus,90 added, it becomes minus 20 for minus 110 it become minus 20, Now, you see check the value here just. now, this is this x and this y, this way what happens? You have to check, you have to check your arrangement that, whatever you have whatever you have kept the norm etcetera, everything is perfect. You are getting testing this way that you are setting of this instrument is perfect, ok.

Again if I put 90 degree, just I will subtract this 90 degree come back to the original position see additional 90 is minus 110, it is it has to be 0 and this has to be. one has to say. But now you see, but it does not matter whether it is; whether it is these arrangements do not need because you have option to get this r, If I put this r, here whatever the value that is the; it will remain this value it will remain this value, it is a square root of x square plus y square,

But if you make one 0 and another if you are keeping, ok,that will be your signal, x value or y value, in that case and you can calculate the square root of x square plus y square all the time it will be less than, all the time it will be less than x, when y is 0 or y, when x is 0, Like example see 5. Now, 5 if you have two components 1 and 4, you are taking 1 square plus 4 square,1 square plus 4 square, square root of 1 square plus 4 square, that means, 1 square 1, or 4 square 16 1 plus 16, the 17; square root of 17.

Now, what is the value of square root of 17? See, it is close to the 4, 4 point something, amplitude r you will get 4 point something. But when you are doing experiment keeping the, I want to see the change of the amplitude of the signal with some variable in my experiment. whatever you will consider that you have to keep unchanged during the experiment,

instead of taking that 5 taking component 1 and 4, if I take two components one is 5 and another is 0 or one is 0 another is 5, then it is your reading is 5. your amplitude is now whatever reading instrument is giving you the reading this 5. that is the advantage you will get, if you make one 0 and other one you are taking as a reading, that you can maximize this, error will be less.

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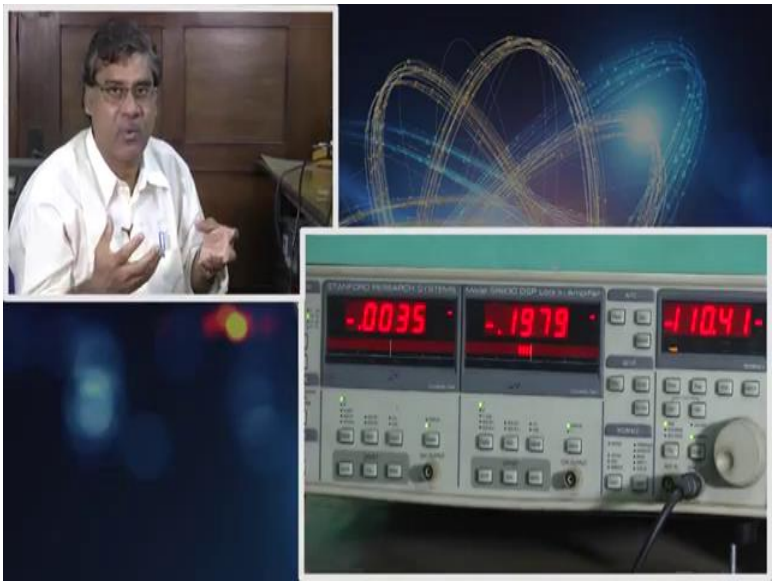

here obviously, if you cannot make it perfectly 1, perfectly 0 and another maximum then there will be error. in that case better to use the r, in that case better to use the r, you in this case I have made x 0, your reading will be this one y, reading can be y or reading can be x, making one 0 or it reading can be r when both are having the value although magnitude will be reduced, but it does not matter. It does not matter much.

I think this is the basic fundamental things because students generally feel difficulties to use these lock in amplifier. It has some concept you need some concept. that I try to tell you, because this it is not only for this experiment there are in higher class or in research

there are many experiment people in many experiment this lock in amplifier is very useful. Like in optics experiments, this using chopper,

this light is passing now using chopper. making it ac signal is like making ac with some frequency. it is a signal of known frequency, this slide is falling on some material as a like ac pattern, from there electrical signal whatever will get that is that will be ac of this same frequency, ok.

Now, that signal if it is really weak then people use this lock in amplifier. In the experiment, in cantilever beam magneto meter there also I use in my laboratory, BSM, this experiment BSM I will demonstrate in other class. in BSM also this lock in technique is used for because the signal is very weak,

and other tools and instrument, basic tools and instrument is how to measure temperature and how to produce electric field and measure electric field, I think these two are these how to measure temperature there are thermo, people use thermocouple, people use register platinum resistance, I think this one I will do the experiment demonstrate the experiment there I will try to explain slightly more.

And electric field, like electric field electric field also very important. electric to produce the electric field it is very simple and there is no instrument for electric measuring electric field, if you can measure voltage then you will know electric field. just two metal plate, two metal plate they are separated with the thickness d, now, you apply voltage and these non-voltage, electric field produced between these two metal plate that is that b divided by this non-d,

to find out the electric field if you know the difference distance between these two electrode, then you can just calculate the electric field that way we measure voltage and calculate the electric field, this is b by d. unities volt per centimeter or millimeter or killovolt per centimeter or millimetre that is the unit we use for electric field,

there is some experiment also there I will apply electric field; I will show you. Since it is very simple nothing to tell you, but you should know how to produce electric field. Just two metal plate you have to use and in between sample will be there for applying electric field on a. what will be the electric field, what is the voltage we have applied and this distance you have to know,

I think I will stop here. And I will next I will demonstrate some experiment in solid state physics laboratory.

Thank for your attention.