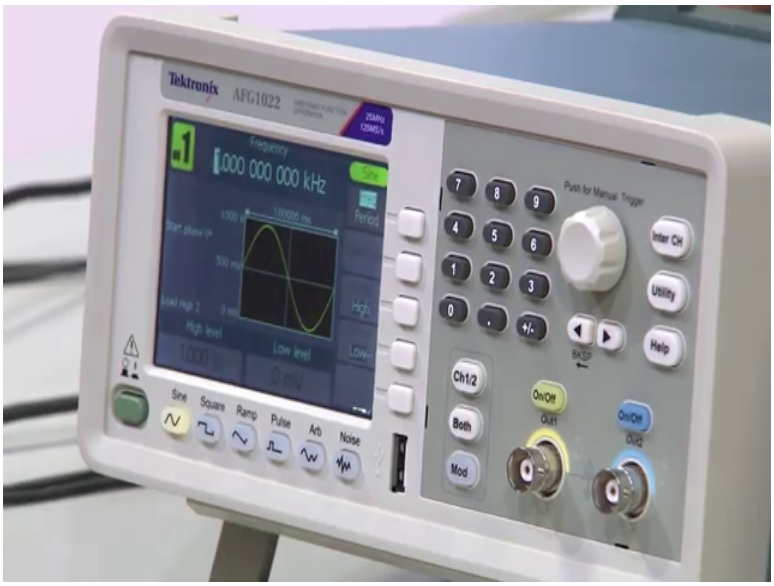
Integrated Circuits, MOSFETs, OP-Amps and their Applications

Prof. Hardik J Pandya
Department of Electronic Systems Engineering
Indian Institute of Science, Bangalore

Lecture - 40
Experiment Working with Laboratory Equipment Function Generator, Oscilloscope

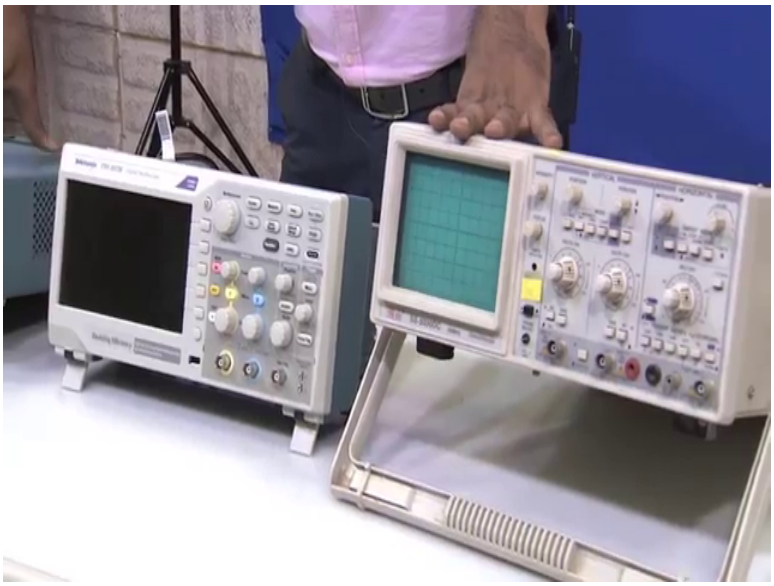
So, welcome for to all of you for this particular module. And here today we will concentrate on two different equipment: one is function generator which is right over here.

(Refer Slide Time: 29:00)



And another are oscilloscopes which are 2 on which I have my hand oscilloscopes, all right.

(Refer Slide Time: 00:34)



But before we move to oscilloscopes, let us first understand what is the function generator, and what is the role of function generator, all right. So, function generator again it is in my hand, now we can zoom in. So, we can see clearly function generator is used to create several different signals, all right.

Signals in the sense that when you talk about AC signal, it is generally sine wave, but what if I want to get square wave, what if I want to get triangular wave, how can I get this square wave triangle waves I can use the function generator. This function generator is from tektronix again, it does not matter does not matter from which company you are buying, right. Right now, because we are not worried about the performance, of course, we should worry about performance. But the module is not to not to make you understand what is the performance what is accuracy what is resolution, the module is to understand that what is function generator and how we can use it, all right.

So, I will again request my teaching assistant sitaram, who is with me for last 2 modules also. So, he will help us to understand when I when I ask him to press power button he will press it. So, it is easy for me to talk, and easy for you to understand the function generator, all right.

So, can we it is already connected to 220 volts. So, can we start the function generator please. So, this is the power button, all right. So, we are connecting the power button,

and you will see the display, it is always a marketing strategy. So, it always starts from the company function generators and that is fine.

Now, what we see? What we see is extremely important, all right. So, focus first thing that we see is sine wave, can you please show where is sine wave? Yes, this is sine wave, all right. Now if I want to convert this sine wave, or if I want to apply a square wave instead of sine wave, then what is there? A square wave see wave converted to square, right where your duty cycle is one term that we will see later, on and off time is different. So, how you can say it is a square wave or not and that is a different topic.

But right now, we can see the wave is squared ok, next one which is the ramp. If I want to see a ramp, then you see this is a ramp signal, right. If I want to see the pulse, then I can see the pulse, right. If I want to see arbitrary signal, I can press arbitrary button. If want to see noise, then I can press noise you see noise excellent. So, this is the you can you can apply different waveforms, right you can apply sine wave or square wave or ramp or pulse or arbitrary signal or noise to a circuit using this function generator, right.

Now, what you see on the screen? So, if you just zoom out little bit, yes. So, I want to show you the channels here channels are there, can you can you see a show channel ? Sitaram, can you please press channel one. So, right now this channel one, now can you press another one more time this is channel 2 right. So, there are 2 channels, if you see channel one channel 2, right? And this is these are both channels together. So, either you can apply signal through channel one, or you can apply signal through channel 2, or you can apply signal through both channels simultaneously, right.

So, here we can see now we again pressing it; that means, we can go back to channel one when we switch off the mode. Now when you switch channel one you will also see on the display channel one. So, it is easy for you to understand, see the display channel one ok, now there are several things that are on the on the function generator. One is on off on off button at the channel one on off button at channel 2. You see on off is there channel one and on off a channel 2 right. So, depending on what channel, you want to use you can use the particular probe.

Now, you can you can change the frequency here. Right now, is one kilohertz frequency, you can change the frequency with this push for manual trigger right. So, these are knob, you can you can change the knob, and you will be able to see the change in the

frequency. The frequency is how much is one kilohertz 2 kilohertz and so on and so forth, you can change it.

So, you can also see that we changing frequency, you will also be able to see the change in time. So, again if you can change the say frequency, you see you have to concentrate on this particular the y axis, where it is showing 33.33 333.33 microseconds. If I increase the frequency, can you increase the frequency, please, see again change increase it, again change increase it. So, it is changing; that means, you at this point, you will not be able to see the change in the sine wave, that it is increasing the frequency.

But if you keep that time constant, then you will be able to see the change in the sine wave. So, we can also change the value using the buttons given. So, we can directly say that I want to use 800, all right, let say 800 kilohertz watts, megahertz millihertz 800 millihertz right. So, 800 millihertz, I can directly press 800 and I can get it. If I want to have one kilohertz, then I will have 1 and then 3 times 0, or we can directly use kilohertz option also. So, we can just press and we can have kilohertz option.

So, there are several options on the on the side of this screen which are white colour buttons, right. So, each of those options are used to change the signal. Let us see the first one which is the frequency and period. So, when we press the first button, first is your frequency, and another one is your period. So, you want to change your period, you can change the value again using the manual trigger knob. And same way if you want to change the frequency again press the white button, and you are back to the frequency mode, again you can change the frequency, excellent.

Now, we go to the second one so, second knob is a start phase. What is so, we will we have seen in inverting amplifier, we have seen in non-inverting amplifier, we have seen in oscillators, that what is the input phase? What is the output phase? What is the start phase is this 0 degree? It is 90 degree? It is 180 degree? You can change the phase of the signal by changing the by giving any value that you want to give.

So, suppose we are changing the phase, you can see that there is a change in the sine wave the phase of the signal, and right now is 15-degree 16 degree. And you can see the change anyway, the next one would be the next white button. Please, can you and if you want to reset it back to 0. Suppose you want to reset it back to 0, then you can just write 0, 0, and you can again press enter, and it goes to 0 degree. It is very easy to operate, that

is what I am I am showing it to you it is very easy, do not do not worry if system looks very complicated. Actually, it just looks complicated the operation is really simple, right?

So, if you have all of you use laptop, all of you use internet. If you really see how laptop operates or how the what are the circuits within the laptop, or how the internet is you know comes into existence, and how the signals are sent, how you can send, an email it is extremely complicated, super complicated, but do you worry no because you can easily use internet. You can easily use laptop, this is how it is it is extremely complicated machine, but what you are using you are just operating it. So, do not worry when you look at something which is complex the operation is really simple, all right.

Now, next button which is a white button, now we have seen this is a frequency here. And you can again change it to high level or low level. You can change it to amplitude, amplitude you can be whatever voltage peak to peak right now it is one-volt peak to peak you can change it to another see 3 volts 4 volts. And when you see when he is changing, you can also see the signal on the y axis if you see minus 2 volt to 3 volts; that means, total is 5 volts. So, this is how you can see the change in the amplitude, if you want to change the amplitude, you can easily change using the manual trigger.

Next 1 please, so, next white button you can see you have, if you want to create a offset, you can create a offset by again changing the manual trigger or by using the display key the other push buttons, all right. So, if you see again the offset, you can you can clearly change the offset.

So now the instead of earlier it was minus 2 volts to 3 volts peak-to-peak voltage. What is here now? 0 to 5 volts, you see this is 5 volts only. but now it is from 0 to 5 volts so, you can change the offset, all right. What is the next 1 please? You can change the to whether it is a high level, or you can change it to low level, again if you want to change it you can see.

Now, the it is from 3 volts to 5 volts so, only 2 volts peak-to-peak ok. Can you please go to the next knob white that is it right? So, so, we have this functions in the function generator, but now the main point is how we know that this is the signal appearing or how we can measure the signal now? Right now, we can see on the screen there is a sine wave. If we change the square wave we can see change in signal to square wave. But if you want to measure it, then you have to use another equipment, all right.

So, first thing is you understand the function generator, very good. Now how to use this function generator, and how to see the display on some other equipment. So, for that we have to connect this function generator to the another equipment called oscilloscope. So, for connecting this function generator to oscilloscope, you need some connectors isn't it? So, for connecting the oscilloscope and function generator, we are using connector called here it is with in my hand here, right? And we can use these connectors, you can use this connector and you can connect it to the oscilloscope, and one side to the frequency generator, right. And we can measure the frequency, we can see the change in voltage, we can see the change in signal by connecting both the things together, all right.

So, this is your BNC connector is called BNC connector, it is also called probe in general, if you don t understand what is BNC connector just say multimeter probe or frequency generator probe, oscilloscope probe, right. But if you know the terms it is better, all right if you know the terms is better if you forget the terms say probe, all right.

So, we have to connect our function generator to the oscilloscope. Now there are 2 oscilloscopes, one is this one which you may have seen in most of the most of the places right lot of places. Lot of universities, lot of institutes, they still use this oscilloscope which is your CRO, all right, or cathode ray oscilloscope. This is your digital oscilloscope, right it is also called DSO, DSO, this is again from tektronix, this is the older version and I use personally like when I was in my undergrad, or when I was doing my post-graduation, or even I when I was doing my PhD I used this oscilloscope. So, so don t worry about the about the kind of oscilloscopes, but, but the advantage here is if I, if you can just zoom that is good. You can you can keep it like this. you see the width, you see the width here, right

And now let me show you the width of this particular oscilloscope, oh man you see so big, right? Why it is so big, why so bulky, right? The reason is because we are using CRT, it is called cathode ray tube within this oscilloscope, within this oscilloscope, this itself makes it bulky there is a creation of vacuum. So, I don t know how many of you have open doors in a scope if you are not open do not open it, but in case if you somebody are someone of you who are already curious may have open the oscilloscope, never open a thing in the laboratory first of all that is not your property that is the property of the institute, if you are in government college they say the property of the not only institute, but also of government right. So, do not ever destroy any component

because you are curious. If you are too curious, and if you know how to operate the component, how to open the component, how to open the equipment, do it at home in a safe place first understand the safety parameters understand what are the things within the oscilloscopes, how you can open it, and then only open it, and I am not recommending at all that you should open the oscilloscope.

What I am trying to put here is, that if you if you open it then you will see a CRT, and as it names CRT is cathode ray tube, you may also seen TV. So, TV bulky or TV's weather right, earlier they all were having CRT, now there is a vacuum. So, if I put a pin inside the vacuum, what will happen? It will, the air will rush into this particular tube and that is why there is a blast, suddenly you see there is a blast, is blasted because the vacuum is gone and air is there within so, that is why it creates the blast. But anyway, we are not interested in blasting anything we are interested in understanding the oscilloscope; so cathode oscilloscope here digital oscilloscopes here.

Right now, let us see that if you want to connect this person function generator to the digital oscilloscope how it will operate, all right, and then we will compare both the oscilloscope. This is the, if you know this many items or this many equipment, it is enough for you to run lot of experiments to test lot of circuits, all right. So, once you know function generator, once you know DC power supply, once you know multimeter, once you know oscilloscope once you know variable actually that is more than enough for you to start working on the experiment part, all right.

So now again, I will ask, sitaram to please connect the function generator to the oscilloscope can you please do that, all right. Can we please zoom in? So, what he is doing? He is connecting the probe right to the channel one, this is channel one, right? And then, he has to connect the oscilloscope, he has to start the oscilloscope.

So, I will explain you the function of oscilloscope, probably in the next module or in the same module let us see, but first let us understand how you can connect the function generator to the oscilloscope. So, again this oscilloscope, digital oscilloscope is from tektronix, there is a provision, if you really see there is a provision for connecting the USB, at the at the at the bottom can you please show it at the bottom you can see there is a provision for connecting it to the USB; that means, that you can save the signal, you can save your data on to your USB drive, all right?

So, like we have all use oscilloscope, right there is a x-axis there is a y-axis, and then there is there are multiple channels, right channel one channel 2 you can change the signal we will see that things, right. Now let us see that what kind of waveform, we can see in the oscilloscope when we connect can you please zoom in into his hand so, we can and we can see.

So, you see the probe has this long things too long things, right too long things. And then he is connecting these 2 probes, and the shorter version shorter one he has connected to this shorter one, right. So, the shorter that goes with shorter one longer who goes with longer one when you make the connection. Now let us see how it looks on your system here. So, you can see the you can see the square wave, right is you can see the square wave.

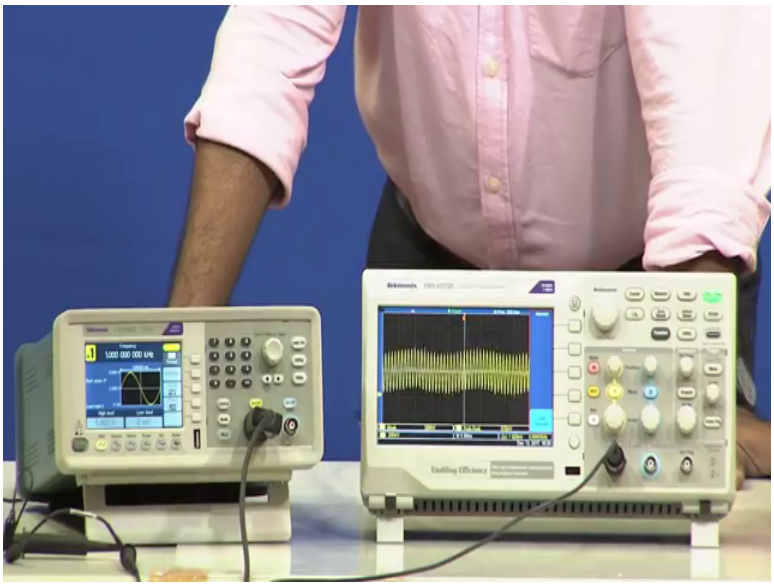
Now, you can you please move it down. So, there is a function for positioning right, one is vertical positioning, one is horizontal positioning. So, a vertical positioning he is moving the vertical position. So, you can see vertical horizontal can please show it, you can always see well see this is horizontal, when you when you move the horizontal it can the waveform will move in horizontal. excess when you move in vertical and some vertical axis.

Now, you see for horizontal, for both the channel it is same, only one horizontal position, right? For the vertical there are 2 different things. One is channel one, one is channel 2 right now we have connected to channel one channel one so far easier thing we have they also colored it yellow and blue. So, if yellow is channel one blue is channel 2 excellent.

Now, if we can if we change the signal in the function generator, let us see the change in signal can you please zoom into function generator, yes. So now, if I have from the square wave 2 sine wave, you can see there is a sine wave, right. And he is changing the frequency is about 66.66 hertz right. So, can you increase the frequency please, all right.

So now it is 1 kilohertz right, so, you can see there is a one kilohertz frequency again you can change the knob.

(Refer Slide Time: 19:09)



So, when you when you change the knob what you are able to see is you are able to see the one kilohertz frequency. Again, you can widen it by increasing the time. So, or by decreasing the so, this is there is the change in the frequency and the same frequency you can see the change in the oscilloscope excellent.

Now, can you change it to square wave please ok, can you change the frequency less, can you make it a ramp right. So, ramp you can change the sine wave you can change the square wave does not matter. So, arbitrary signal you can have if pulses you have. So now, whatever is showing here on the function generator, you can also see similar thing on the oscilloscope.

So, this is how the oscilloscopes are used, now we can also stop the signal by run and stop button is there, and here I think run and stop button is here that is. So, you see you have now captured the signal. This capturing of signal you can save using your USB drive, you are USB port, right?

So now we can we can connect it to the function generator, you can connect your oscilloscope, and then you can save the data in the USB type. Now let us see that what how the what is the difference between the oscilloscope that we see here one is your CRT base or CRO. And another one is your digital oscilloscope, all right. So, both the oscilloscopes let us see what is the difference.

Now, can you first assume in to the digital oscilloscope which is DSO, yes, ok. So, let us go one by one, can you please stop the run and stop, all right I have done it. Now you see there are 2 channels like we have discussed, right? Channel one yellow color, channel 2 blue color, right? Then this channel one and channel 2 are used for changing the vertical position. So, right now it is connected to channel one, right. So, connect can you please change the vertical position, excellent you are look you are looking at the y axis look at the y axis it is changing right excellent, can you change the horizontal position please, horizontal position very good see. So, you can change the horizontal, you can change the vertical positions ok, this nice.

Now, similarly for channel 2, all right, then we have similarly for channel 2, but right now channel 2 has no signal. So, probably we cannot see, but to first start the oscilloscope, first to understand the oscilloscope. You should connect the oscilloscope to the for the compensation probe compensation. When you start using the oscilloscope, first thing that you have to do is you have to compensate the probe; that means, when you have the probe you connect the probe to the oscilloscope, you will connect it to the probe compensation knob it is right here you can see he has connected to the probe compensation knob then other one to the ground. And then he is doing the auto set. So, auto set button is set can you please show again auto set auto set right. So, you press this and the probe compensation is done. After you compensate your probe, then and then only start using your oscilloscope, all right. It is a good practice to always do a probe compensation, all right.

Now, let us go to the function of the oscilloscopes. So now, we have the vertical we have seen the horizontal. Now let us see the math function. Suppose I want to understand the math function, which is see M is the math function right. So, what is this mathematics function? Is it operation? Is it multiplication or addition? Or it is a subtraction? So, I want to do a multiplication for example. See if I want to do a multiplication, then I have to use this operation, and then I can I can see if. So, I have to apply 2 different voltages right, now only one voltage is given right one signal is given, if there are 2 signals, I can use 2 signals to multiply, and I can get that function. Similarly, I can do addition similarly I can the subtraction right. So now, I can do addition I can do the subtraction, all right.

So, let us see the white knobs there are there, the top knob the top knob the not that one. this one so, this one is used for saving the data save right. It is for saving the data, can you please use the next knob, all right? This is the operation, like I said it is a operation, because now is the right now it is in mathematical mode. So, it can be used for operation, next 1 please. Source channel one or channel 2 position, right? What is the position? Can you want to right now is 0 division? So, you can change the position, you see.

Next 1 please, vertical scale, yes, and again you can you can change the vertical scale, using the vertical scale knob, all right, then the knob is just to change the vary the signal ok, vary the signal, all right. can you use FFT? So, if you want to do Fourier transform, you can use FFT signal and you can do Fourier transform. Similarly, if you have a reference voltage, and you want to check that is the signal with respect to some reference signal, then you can use a reference terminal here, there is a reference RF, IEF, yes. So, that is a button for REF, all right.

So, these are several buttons on the on the oscilloscope, all right. Now other than that we have cursor, right? On the top we have cursor right. And then we can write I do you want it on or you want it off is it amplitude or time. So, let us say if you want to connect to amplitude. So, if I were pressing amplitude, I will know see the top signal at the amplitude, all right one line our cursor is at the top of the waveform. Another one should be at the bottom. So, if I want to have another cursor see cursor 2, you can have the bottom, now you know you can measure the voltage, what is the voltage or cursor 2? what is the voltage or cursor one, right?

So, you can see cursor one cursor 2 that is the voltage. You can have the difference, you can measure the difference. This is the use of your cursor, right, you can also do the source, you see channel one or channel 2, you can change the mathematic function FFT reference function reference a reference b. So, so lot of lot of options are there when you when you get a digital oscilloscope. These are 70 megahertz oscilloscope, you can you can see on the top the 70 megahertz, all right.

Now, other than that save and recall is the same function that you can save the signal, and you can recall it later. default setup is whatever the setup is given by the manufacturer default setup we can we can use a default function. Also, when you

compare when you compare this digital oscilloscope with the with the CRO. So, if we if we compare both the things, let us see, both the things let us see.

Now, this is your cr oscilloscope, right? Or CRO, it is a cathode ray oscilloscope. in this you can see the similar functions, but in a in a more crude way, more crude way, all right? So, let us see what are the functions. So, first is the intensity and focus right, because in that we have we are using in digital oscilloscope either LCD or LED. Here we are using the cathode ray tube. So, he have to we have to change the intensity, we have to change the focus.

So, can we please show the change in intensity. You see by changing the intensity you will be able to see the change. You see intensity of the signal focus. If you change the know focusing knob, you can focus the signal. Now it is not focused, you have to focus certain point so, focus is there ok. Then we have a position, you see vertical horizontal. First let you let us use a vertical. So, vertical position you can move the signal horizontal, horizontal next one, horizontal you can move the signal in a horizontal the x axis, right.

So now you have 2 positions vertical, right? First position is for the channel one, second position is for channel 2. So, there is channel 2, there is channel one. Now we can change the volts per division. So, let us connect another probe to this oscilloscope. here also we can do the testing of the probe. So, we are now connecting the probe as you see the probe is connected ok.

Now, we have to test the probe. So, there is a probe adjust yes you can just connect it to there another one would be at a ground, and then, all right. So, so anyway this is how you can connect the probe and test the probe, all right. So, don t worry about this one. it is just to show that this also oscilloscopes also has the also oscilloscope also has the function for testing the probe, all right.

So, the point that I was making is, now this oscilloscope has several functions, with this oscilloscope also has it. But there are a few things in this oscilloscope which this one does not have that is one thing is you can easily see the signal you can see very clear compared to here second. You can you can save the data, here you cannot save the data, right third. this is portable easy lightweight this is not lightweight, right if you want to just compare quickly compare quickly ok.

But the final point is that oscilloscopes are used to measure the signal, and we can change the signal and we can change see the change in the signal by measuring the time or by measuring the amplitude, we can change the peak to peak voltage you can you can apply different filters to aid even to match function, you can we here you cannot do here you cannot do right, but here you can do. Of course, you can perform several functions using both the oscilloscope, and it is not necessary that you should learn both oscilloscopes. If you have this oscilloscopes, fine, if you don t have and you have this one, better right, does not matter, whether you use this one or this one.

The point is if you want to use function generator, and you want to measure the signal you can use oscilloscope as an equipment, all right. So, what we have seen until now let us quickly recall right. In the in the last 3 modules if I if I correctly record including this one is we have started with the discrete components. Then we have seen the breadboard, right? Then we have seen the how to connect the components to the breadboard. Then we have seen multimeter we have connected multimeter to several components.

And then we have measured the properties like resistance, the capacitance, frequency, not by connecting to components, but by frequency from the variable AC or variac we have measured the voltage AC voltage. We have measured the DC voltage, then we have measured we have measured the we understood the DC power supply, right one was old version one was new version in a newer version, there was plus minus 15 volts, you can change the voltage you can change the current I told you that if you do not know always keep the current on maximum probe on maximum, then you have positive voltage you have ground, and then we have seen the function generator which is right over here, and then what is the role of function generator what kind of signals it can generate, how it can be used. and finally, we have also seen the oscilloscopes.

Oscilloscopes are 2 types one is digital oscilloscope. One is the CRO, CRO is based on CRT this is on LCD or led this has multiple functions fewer better version than this one, but still both the both the oscilloscopes are used in the laboratory. and it does not matter what oscilloscopes you have, the idea is you should be able to operate the oscilloscopes, all right?

So, in the following lectures series, we will see experiments, and several parameters that we have already learned in the previous classes, whether it is operational amplifier you

have to use a operational amplifier, as an inverting amplifier or it is a non-inverting amplifier or we talk operation amplifier as a filter or we talk operation amplifier as an oscillator. Or we have to use the instrumentation amplifier, and lot of other experiments lot of other experiments.

But the point was that until and unless you are able to know that what are the equipment's that we have to use with this circuit, it is useless to start you know working on experiments, working on the circuit side, I can tell you a lot of things about analog circuits, what is use how you can apply it, what kind of equipment you require for measuring the signal, what kind of equipment you require to apply the bias voltage, how can you use multimeter, right? What are the functions within the multimeter? These all things may look extremely basic, but I am sure that you know learning every time again and again refreshing the things will help you at some point, right. That is why I am trying to keep a lot of things which are basic the same time we will see lot of things which are really advanced right.

For example, how you can fabricate indicator circuit. like I said it is very difficult to understand what is within the IC, right? I took your first lecture and I told you what is within the IC, but, but you if you if I ask you, how you can fabricate the IC, I am sure now because of the because of the lectures that you have been looking at, you are able to understand how MOSFET is fabricated. but if before if I just ask you that whether you can fabricate a MOSFET do you know what is a process flow, then probably I am sure that in a lot of people would be not able what would not be able to answer it.

But the point is not only to learn theory, but use the practical knowledge whatever we learn in theory applied, applied in some form and let us see in few lectures from after this particular module, how we are going to use the operation amplifiers and MOSFETs for the from the experiment point of view, all right.

So, I hope now you are clear with this components with this equipment. and like I said that, you do not have to you do not have to use equipment from this set of companies does not matter, right? there is a there is a point of accuracy, there is a point of resolution which comes into play, when you get a equipment from different companies. So, that is data sheet that you have to understand, how to operate the equipment is already given in the data sheet.

But, but I hope that with this particular set of modules, you are now able to or you are more comfortable in understanding what are these equipment's all right. So, I will see you in the next class, and let us see what experiments we can perform, there are several experiments that I want you to learn, and we will perform the experiments. And we will we will see how we can measure the parameters.

So, I look forward to see you in the next class, right. Have a nice day. Bye.