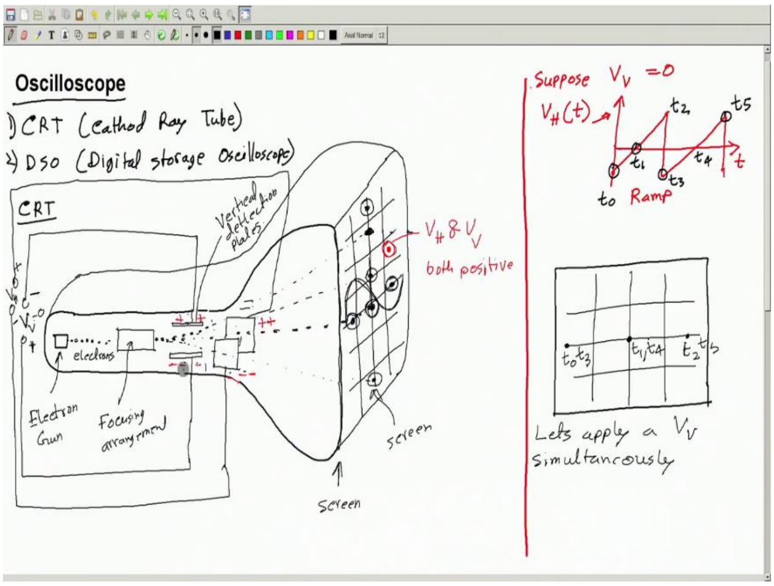
Electrical Measurement And Electronic Instruments
Prof. Avishek Chatterjee
Department of Electronical Engineering
Indian Institute of Technology, Kharagpur

Lecture – 81
Oscilloscope – II

(Refer Slide Time: 00:30)

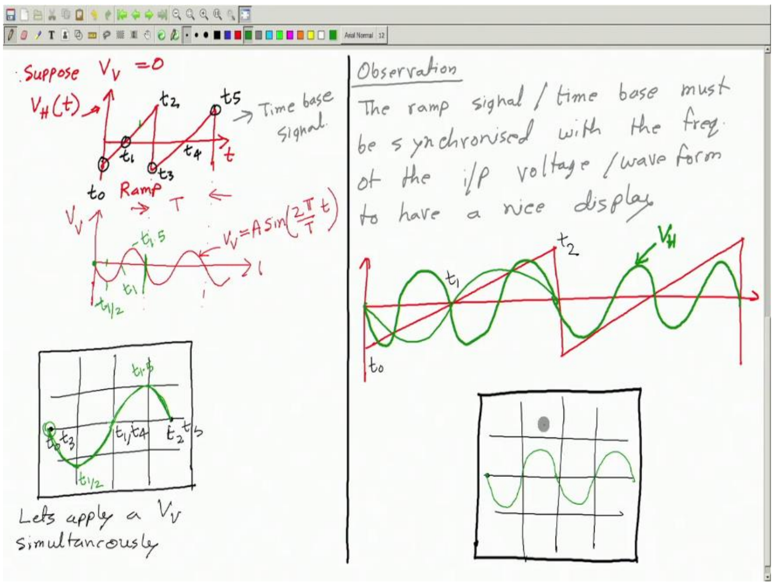


Welcome and we are studying Oscilloscope. So, in our last class I tried to demonstrate how an cathode ray tube oscilloscope work, it is construction and working principle we talked about. So, let me recap very quickly, it is made up of glass tube, evacuated glass tube with an electron gun basically this is a cathode ray tube, this is the cathode which emits, which is heated up I am not going into much detail ok.

So, electrons are emitted then we have some arrangement to focus it make it a narrow beam etcetera and then this essentially passes through 2 sets of plates ok. One we call the vertical deflection plate and another is the horizontal deflecting plate ok. Now, this between these two and these two plates, you can apply some voltage difference.

Therefore, the electron beam will get attracted towards the positive plates and instead of going straight and hitting the centre it will hit some other point, whenever it hits a bright spot appears there. And, if you are changing these 2 voltages here and here, then that spot will move continuously on this screen and that can generate patterns like sine wave etcetera.

(Refer Slide Time: 02:02)



In the previous class we have taken a specific example where we apply this ramp signal, across the horizontal deflecting plate and the sine wave across the vertical deflection plate. And therefore, we saw that the spot moves in the form of a sine wave like this and this sine wave appears in front of us that is how it works. And, so now if you just want to measure or see any other waveform ok.

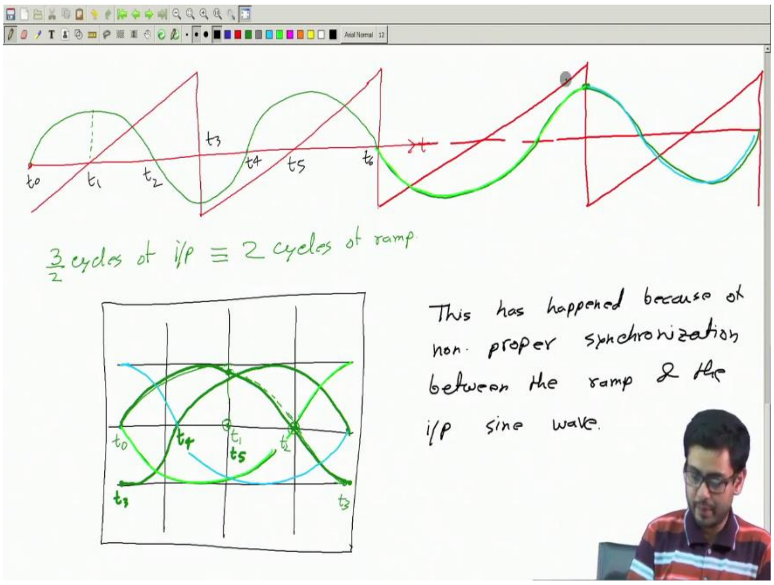
So, basically the waveform that you want to visualize is to be applied across the vertical plate here. So, this is where you apply the waveform, which you want to see ok. And, we can have amplifiers before that, amplifiers or attenuators and we have studied a lot of amplifier circuits. So, by changing the magnitude or the amplification of this voltage, we can change the height or amplitude of this wave we can make it larger or smaller by having an amplifier before applying this voltage at this point.

So that is easy, but one important observation is that this signal, this ramp signal, which is also called the time base signal, this is also important to have this pattern displayed. Because, essentially these moves the spot from left to right back to left, again left to right back to left and so on ok. So, this is therefore, very important ok. So, the ramp signal or the time base must be synchronised with the frequency of the input voltage or waveform to have a nice display.

Say for example, you know for example, I can take the same time base signal, let this be the time-based signal, this is the 0 level and say previously I had the sine wave which was like this. So, it used to complete one cycle within one period of this time base signal, but if say instead of this I have another signal sine wave which completes 2 complete cycles within this period then how will be my display ok.

So, I request you just give a thought to this, if this is my input signal, which is applied to V H horizontal plate, then you know the display will of course, be like this. You know we start from extreme left and then we go to the right from here to here call it t 0 t 1 or call it t 2 and this point t 1 middle point, then as we go from left to right we first go down. So, from extreme left we will first go down here and up and to 0 down up and to 0 this is t 1 and then we will continue to go to right, but 1 more cycle down up and 0 down up and 0. So, we shall see this pattern we shall see 2 cycles on the screen right.

(Refer Slide Time: 07:24)



So, the end, but now suppose let us take another example, say the input time base is like this one period, second period ok, this is the 0-line, 0 voltage line time axis. And, say the input signal is not synchronized with this frequency. See, what is what we have input signals he completes half cycle here, then quarter cycle here, then another quarter cycle and then half cycle here. So, we have 1 2 3 half cycles. So, we have 3 half cycles ok. See, 3 half cycles mean 3 and half cycles of input is equivalent to 2 cycles ok, this is 1 and half and this is 2 2 cycles of ramp. So, how will the display?

Do not watch my answer plus before that think yourself then verify with my answer ok. So, think please let this be the screen with division smart. Now, say we mark some points here t 0 or t 1, t 2, t 3, t 4, t 5, t 6 all the corner points all the 0 crossing points I am just marking. Now, at t 0 you see we are at the extreme left. So, say we are here and height is 0. So, will be here, then as we as time progresses at t 1, we will be at the centre of so, will be here somewhere on this axis and the height you will see is this much ok.

So, we will go that much. So, this part will be here. And, sorry not this much I made a mistake this much ok, maybe that is this much. So, we have gone like this ok. And, then at t 2 we will come back to 0 and here. So, at t 2 t 2 is somewhere will be here xx x position will be somewhere here, not totally right somewhere here ok. So, then this will be the pattern at t 2 and then we will go down further ok. So, this will be the 0.t 3 where when we are at the extreme light, but height is negative.

So, this is point t 0 t 1 somewhere here not 1 is here when we are at the centre from according to the on the x axis. This is t 1 so, that point will be here somewhere and this is t 2, this is t 3, t 2, t 3. So, we will have a trace possibly looking like this ok. And, then what will happen after that at t 3 we will come back immediately to extreme left, but the height will still be negative. So, from here we will come back immediately here this is the same time t 3. So, we are here and then we will start to traverse again to the left to right and then we will go slowly up cross the 0 at t 4 and then half cycle like this ok.

So, this point is t 4, t 5 is the point when x position is at the centre horizontal descent at the centre. So, this is t 5. So, this is the plot that we shall see on this screen ok. And, this has happened, because this 2 are not properly synchronized. So, we will not see the sine wave correctly.

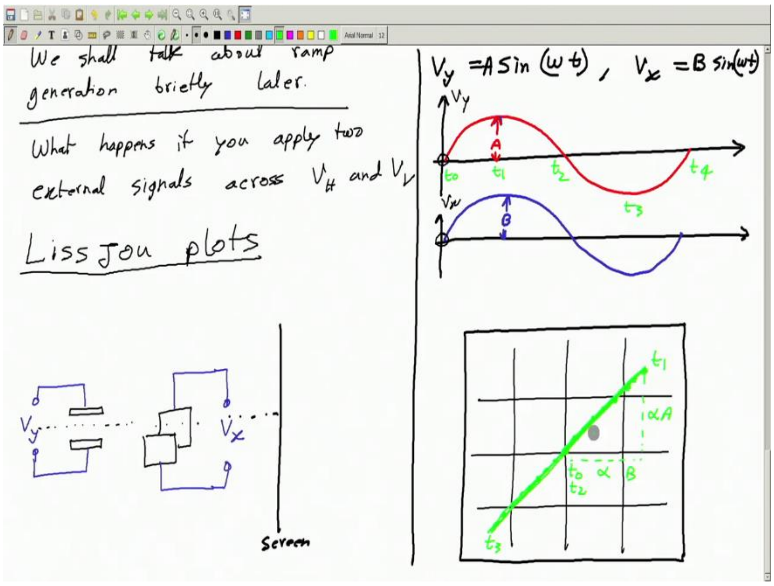
So like one and half cycle here and another 1 and half, 1 sorry this is like half cycle plus quarter cycle plus another quarter cycle and a half cycle is here ok. And, then what will happen let us extend. So, let us see what actually happens after this. See, this is the next these are the next 2 cycles of the ramp signal and the input signal will complete half cycle, quarter cycle, another quarter cycle and another half cycle ok.

After, this point I need not consider anymore because you know after this point the situation will be similar to this ok, but before that let us see what will you see here. So, you start from extreme left go down 1 half cycle and a quarter. So, go down it would possibly look like this my drawing and scale etcetera may not be accurate, but roughly it will look like this. And, then again from x will start from extreme left here go towards the right and simultaneous we have to come down and up. So, we shall start from here no here ok.

So, this is I guess, I made a mistake previously. So, this is half psych no it is correct. So, this was the previous path let me make it a different colour ok. So, this is this portion right, this is this portion and then we will have this portion let me use a different colour, which will come here as starting from high value of high y axis we go down first and then a half cycle ok. So, this is this will be the complete pattern. Although, I have drawn it with different colours, but you will not see with different colours on a in a oscilloscope everything will be of same colour ok.

So, this is this has happened, because of nonproper synchronization between the ramp and the input sine wave. So, this way you possibly can draw different patterns for different frequencies of the input and the different frequencies of this ramp ok. So, two important things. So, synchronization is important and we will not have time to talk about how exactly the synchronization can be achieved automatically, you can study this from the books and if you are interested, he will make possibly additional videos later on.

(Refer Slide Time: 17:50)



But, we will talk briefly about at least how the ramp signal is generated. We shall talk about ramp generation briefly later ok; because this ramp signal you know is very important, we have seen it being used in different cases like those voltmeters digital ramp type volt meters, there we have seen ramp signals right. So, ramp signal is used in the many different instruments that we have studied. So, we will talk briefly about ramp signals soon ok.

But, before that let me just talk about another interesting thing, which is what happens if you apply to external waveforms or signals across V H the horizontal plate, horizontal reflecting plate and vertically deflecting plate, what happens if you apply 2 voltages from outside ok. So far what we have talked about is this here we apply so, here across V H we will apply a voltage from outside, which you want to observe or see onscreen, but sorry across V V vertical one.

Here, we shall apply the external voltage from outside and across the horizontal one we will apply the time base signal or the ramp, this ramp this goes to V H this and V V is from the waveform that we want to see. Now, in oscilloscopes we have provisions to apply 2 waveforms at 2 across these 2 sets of plates. Instead of applying this ramp across this horizontal plate, which is generated internally in the oscilloscope, we can apply a external signal across this plate as well.

And, then we can see a lot of different patterns on the screen, which is called Liss Jou plots or figures ok. So, basically so, what do we do see we have these two sets of plates you know one and this is the horizontal one, electron is flowing through it and we are applying a voltage V V ok, let me call it V y. Because, this voltage deflects the electron beam along the y direction vertical and between this we have a voltage call it V x.

And, the electron beam is flowing through this and hitting this screen ok. So, this is the arrangement right, this is the side view of an oscilloscope. Now,

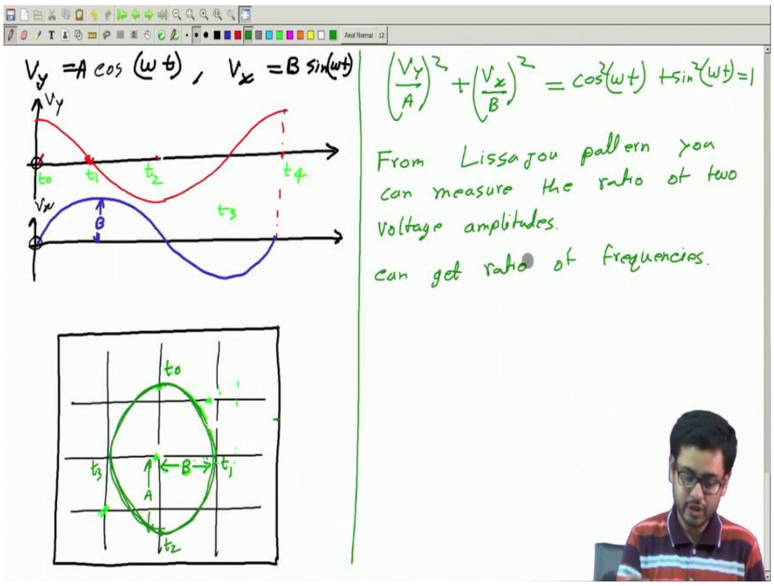
$Vy = A \sin(\omega t)$ $\qquad$ $Vx = B \sin(\omega t)$

So, can you tell me, how will the sport move on this screen? Say, at t = 0 the vertical position or y position should be 0 and the x position should also be 0. At t = 0, so, here you see both x and y 0 so; that means, the spot will be here, at the centre. Then as time increases the y position; y position increases x position also increases and you see y position and x position are proportional to each other ok, at say this time if I call this t 0 this is t 1.

So, at t 1 a y position will be maximum x position will also be maximum. So, we will have y position here, this height will be proportional to A the amplitude of this wave and this will be proportional to B, the amplitude of V x ok. This is V x this is V y. And, from here to here the dot will traverse like this ok. So, this is how the dot will go like and after that so, starting from here you see the height in decreases x position also decreases and comes to 0.

So, the dot will come back like this again here. After, that the y position becomes negative x position also becomes negative. So, we will go like this up to this point. So, let me mark this points t 2 t 3 t 4. So, this was t 0 t 1 t 2 again here t 3 is here and then from t 3 to t 4, we will go back height will decrease x position will decrease so, we will go like this. So, then; that means, we will go like this come back this come back and this will repeat. So, this is the plot that we shall see on screen right ok.

(Refer Slide Time: 26:36)



Now, let us take another example, where say I say that V y is or V x is as it is, but I will make V y cosine omega t. So, then this will change, this will be like this, if you start from value A and this is how the pattern will B?. So, now, let us see how this looks like? Say, at t equal to 0 here up at t 0 x position is 0, but y position is given as A positive. So, the dot will be at t 0 somewhere here x position 0, but height is positive.

Then as time increases x position will increase and y position will decrease. So, from here x position will increase so, will go towards the right, but y position will decrease. So, we will come down and this will look like this ok. So, this point is t 0 at t 1 we have height 0, but x maximum and this is proportional to B. So, this will be equal to be proportional to B. And, then from this point onwards so, this is t 1.

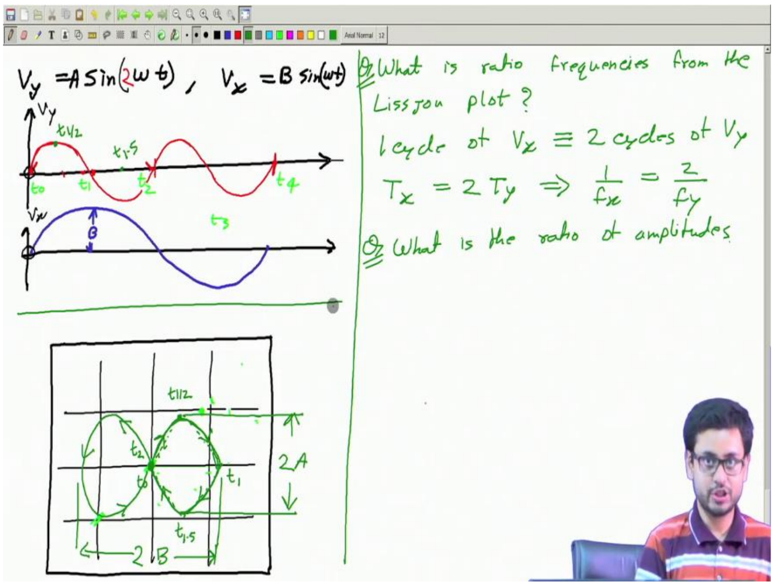
So, after t 1 what will happen let me change the colours. So, after t 1 height goes to minus negative x decreases to 0. So, this will be like this. And, at this moment t 2 height is minus A. So, this height is proportional to A here and x is 0 and after this what will happen y will go back to 0 and x will be more and more negative. So, we will move like this ok.

So, this is the point t 3 and after t 3, x becomes 0 again and y goes to positive like this. My drawing is not very good, but you know this will actually look like an ellipse perfect ellipse. So, this will be an ellipse ok. And, you can also verify this, I mean you can say for example, you can write the equation as V y. So, from this divided by A take a square of that and plus V x/ B take a square of that this you can definitely write as.

So, what is V y by A? V y by A is cos square omega t and V x by B sine square omega t, this is equal to 1 cos square cos sine square is equal to 1. So, this is the equation of an ellipse right ok. So, this way you can generate lots of different patterns and you can also measure for example, the ratio of these two amplitudes ok. So, from the pattern Liss Jon pattern you can measure the ratio of two voltage amplitudes.

For example, in this case this is the amplitude or twice of the amplitude of the signal applied to the x, I mean for to the horizontal plates and this is the amplitude of the voltage applied to the vertical plates. So, from this height and this width you can get the ratio of these two amplitudes, you can also get the ratio of frequencies and let us talk about the ratio frequency ratio of frequencies ok.

(Refer Slide Time: 32:56)



So, let us take an example. Say, we have this varying at double frequency. So, I will make it. So, I will put a 2 here 2 omega t so; that means, it will complete one cycle, another cycle here. So, one cycle, sorry one cycle here and another cycle here ok. So, now, let us ask how will this plot look like please do not watch my answer before trying it yourself ok. So, once again we will start from say t 0, at t 0 x position and y position both are 0. So, we will be here. Then, you see x position increases y position also increases up to this point ok.

So, we will go towards the right and up here. So, maybe like this. I am not claiming that this is going to be a straight line ok, this will not be a straight line, but it will go we know that from here we will go towards the right and upwards and this point call it t half this is the point t half. So, this is t 0, t half will be somewhere here. And, after t half height will decrease, but x position will keep increasing so; that means, will go towards the right and down so, will come somewhere here, ok.

This will be t 1, this is t 1. After, that what happens we go down and x position also decreases. So, x position will decrease and we will go down like this. So, here we will have this point call it t 1.5, t 1.5, this is this point right. After, that what happens y increases goes to 0 and x decrease goes to 0 y increases goes to 0 and x increases goes to 0.

So, this point will be t 2. So, the pattern will actually look like this, I told you those will not be straight lines. So, this will go like this ok. And, after that what will happen after that will go to the left and up. So, this you can continue yourself, you will see this will look like this. So, we will have a pattern like this, like a loop ok. And, from this just from this observed ok.

Now, can we find the ratio of the two frequencies from this pattern, suppose you do not know the prior that these are the forms of V x and V y, can we suppose this is just given we do not see this. So, we start from this and let us ask, what is the ratio of; what is the ratio of frequencies from the plot, from the Liss Jon plot?.

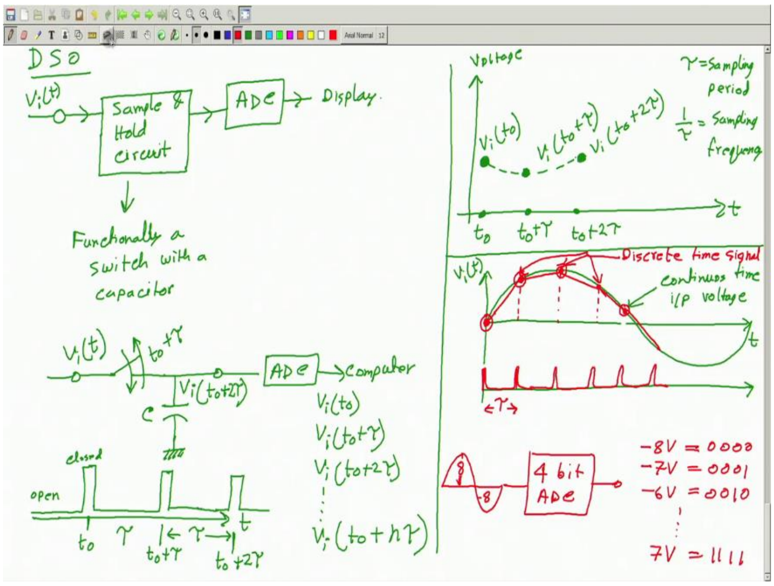
Say, how to let me tell you how to do it? Say, you start from here ok. And, make a complete traversal of this locus. So, I start from here and a complete traversal means this. Start from here and go and this, this is one traversal. And, in this way I have gone you see right 0 left 0 so; that means, 1 cycle of the horizontal signal V x you see right 0 left 0. So, this is 1 cycle of the horizontal signal or V x and what happens to y up 0 down 0 1 cycle, up 0 down 0 2 cycles. Once again in one compute traversal up 0 down 0 up 0 down 0 so, 2 cycles.

So, we see that 1 cycle of V x is same as 2 cycles of V y. So, we can write that T x time period of the V x is same as 2 times the time period of the V y ok, and from this you can write that 1/fx = 2/f y. Now, what is the ratio of the amplitude? You see the amplitude of the x signal is how much? So, in the x direction I am moving this much. So, this is 2 times B ok, this is 2 times B.

And, similarly how is the y signal chain moving or varying? So, this is just observe the y movement, y movement is only this much. So, this is the 2 times A. So, you can read these values this height and this width from the screen of the oscilloscope and from that you can find the ratio of 2 B and B and A or A and B. So, that is about the Liss Jou plots.

Actually, oscilloscope is a very interesting topic and we can go deep and talk about lot of different aspects of it, but due to the time limitation we will not go further deeper into CRT oscilloscopes. We will talk now briefly about and only one important aspect about digital oscilloscope digital storage oscilloscopes and we will conclude this topic on oscilloscope.

(Refer Slide Time: 41:37)



So, let us talk very briefly about DSO. How does a DSO work? A, DSO does not have a cathode ray tube like this. This is not available is not present in a digital storage oscilloscope, what does the DSO have? A, DSO roughly speak very brief I mean broadly speaking works in this way. Say, this is a input wave form call it Vi t, if this is the input wave form, then a DSO will have something called a sample and hold circuit. After, that it can have a digital voltmeter or analogy to digital converter.

And, then we can have the display. What is sample and hold circuit? Functionally speaking it is just like a switch functionally, switch and maybe with a capacity; with a capacity ok. So, it is like this switch with a capacitor. So, this is V i after this we will have a switch and here we will have a capacitor C. So, what happens you know I mean when the switch is open, then V i does not affect this side at all.

Now, what we do we close this switch for a brief 1 ok. So, we close and then immediately open it close and open ok. So, this switch is like it is closed. So, if I write a timing diagram like this. So, the switch is open see here it is open then it gets suddenly closed and then opened this is not a voltage waveform.

So, by this I mean if this is high I mean the switch is closed or on and if this is 0 I mean switches off. So, as a function of time, what I do, I close it for a brief moment. And, then open it then what will happen the moment you close it a brief moment this voltage V i will charge this capacitor to a voltage V i.

V i at the time t naught which is what is t naught? T naught is the time when you close the switch ok. So, the moment so, this is the moment t naught not, if at t naught you are closing the switch then whatever value of so, let me write V i t not t naught, but here I will write V i t naught ok. So, this is a time varying function, this is changing this voltage is changing, but the moment you close it that moment t naught whatever is the value of V i will go from here to here ok.

And, capacitor will be charged to that voltage. Now, you then open it and once you open it the capacitor will remain charged at that voltage, it will not get discharged much. And, therefore, after this you see we can have this ADC etcetera. What is an ADC? This is basically a voltage measuring circuit ok.

So, this is basically a voltage measuring circuit. So, this will then measure the value of V i t naught ok. So, this will measure the value of V i t naught. And, this will then pass this value in the digital form to a computer. Basically, a DSO inside it has some computing mechanism. So, it will pass that value the measured value of V i t naught to the computer. And, the computer will then display that value on the screen in the form of an waveform ok.

Then, what happens you know after the that I keep this switch, open or off and after say time gap tau. So, this point is t naught plus tau here I will open the switch again, sorry close this switch once again and then opens it immediately. So, then what happens no you close this switch again at t naught plus tau, this voltage is changing this voltage is continuously changing and you are closing this switch once again at t naught plus tau, then this voltage will come immediately to this capacitor.

And, the value of this voltage across the capacitor will get changed to the new value V i t naught plus tau at this moment ok. And, this value will then again be measured by this ADC and this ADC will pass the value measured value to a computer and the computer will draw a plot using the values like the voltage at V i t naught, after that we got the voltage V i t naught plus tau and this way we will keep repeating it so, after this say again after a gap of tau.

So, this instant which is t naught plus 2 tau we will close this switch again and loop in it. So, this voltage which is at that moment t naught plus 2 tau V i t naught plus 2 tau will come here to here and that voltage will be measured by this ADC t naught plus 2 tau and we will go to the computer. In this way we will have V i t naught plus in general call it in tau n is 1 2 3 4 etc. And, these voltages are available to the computer.

So, the computer what the computer will do? It will now draw a plot on the screen of the computer like this. So, time axis so, at t 0 the voltage was measured to be V i t naught. So, it will draw a point here let this be the voltage axis. So, it will draw a point whose value is V i t naught. After, that this ADC told the computer that, the value of the voltage is this much at the moment t naught plus tau. So, here at the moment t naught plus tau the value of the voltage whatever is that said this is the value V i t naught plus tau will be displayed here.

Similarly, then at t naught plus 2 tau some other value call it V i t naught plus 2 tau will be plotted as a dot. And, the computer if the computer likes can join these dots to give you a smooth plot, instead of giving you this set of dots ok. So, then you shall see that this is the waveform or how the voltage is varying? And, so, this is how it works? It basically measures the voltage at different instants, discrete instance, at t naught t naught plus tau t naught plus 2 tau t naught plus in tau and plot seat plot those points dot dot dot dot dot like that so on.

And, you can join it to give you a smooth plot if you like ok. So, this is how it works? How a DSO works? So, therefore, now say let me take V i t as this a sine wave say, this is V i t ok. And, we call this tau; tau is called the sampling period sampling period and 1 over tau is called this sampling frequency, why? Because, as if we are taking samples sample measurement of the input voltage at that frequency.

So, we are not measuring the input voltage always you know the switch is not always closed. So, we cannot see this voltage always. We can see this it is only at those moments, when this switch is closed. So, you are taking samples ok. We are not made it measuring it always. So, that is why this is called the sampling frequency the frequency at which we are measuring the voltage and this is inverse of that is the sampling time, stamping period.

Now, say here on the time axis I mark the points where I take the samples. Suppose, I take this sample at this moment at t 0, then I take the sample at here; that means, at this moment this moment I close this switch ok. The switch is closed here and then opened, here closed and then open. So, this is the moments are marking where I am taking these samples. And, this gap is tau sampling period a period 1 over tau is the sampling frequency. So, if so, now; that means, we will measure this voltage only at these moments and my measurement will tell me that this is the voltage at t = 0.

So, the voltage will be measured to be 0, then at t equal to tau the voltage will be this much, this is the measured voltage ok. Here, the measured voltage will be this much; here the measured voltage will be this much ok. This green see green thing is the continuous time input voltage, why continuous time? Because, it exists continuously for all the law of time, but this great set of points this we will call discrete time signal.

This is a discrete time signal, descript time measurement, because these values this method values we know only at discrete values of time. We do not know, we do not measure, what was the voltage at this moment or what is the voltage at this moment? So, we only have the value here, here, here. So, the computer will only draw these dots. It cannot draw this smooth waveform. Even, if it joins these plots it will join possibly like a straight line like this.

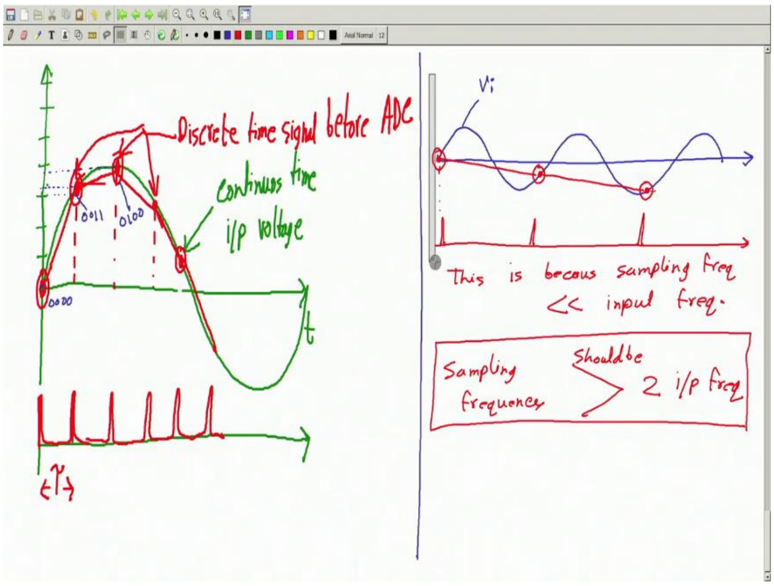
So, it will join the points possibly with state lines. So, we cannot get exact detail or exact voltage between 2 samples ok. So, therefore, you know the measurement that we do is not smooth unlike a cathode ray oscilloscope. Cathode ray oscilloscope also have some limitations or band width limitation which we have not talked about, but leave that aside.

Anyway this is clear that discrete digital oscilloscopes will not give me continuous measurement. There is another fact, another important fact, that fact is that the measured value is not just discrete in time; it will also be discrete in the measured value. I mean you know this is a ADC analogy digital converter which is measuring this voltage. And you know when our ADC measures a voltage it discretizes or make or divides the range of voltage into small quantum right.

So, for example, if I take our say if I take for simplicity let me take a 4 bit ADC and if on this side, if I give a sine wave whose amplitude is say plus minus 8 volt. So, this is plus 8 volt here minus 8 volt this is a 4 bit ADC. So, it can give you only 16 different outputs. And possibly it will map 0 for say like minus 8 volt, maybe this will get mapped to 0 0 0 0 ok, then minus 7 volt will get mapped to 0 0 0 1 minus 6 volt will get mapped to 0 0 1 0 and soon ok.

Similarly, if you add 15 to this so, I think 7 volt will get mapped to this level 1 1 1 1 ok. So, you cannot get smooth output from the ADC. So, what will happen is this? I will just finish this in a few minutes ok.

(Refer Slide Time: 58:14)



So, this is the discrete signal which we have before ADC ok. And, the ADC will again say quantize it to a set of values say the accepted values, let me zoom it ok. Say, this is V i ok, say the ADC can give you only these levels like 1 this is 0 1 2 3 4 5 6 7 so on. So, therefore, this value let me take a different colour, this value will be represented as 0. So, this will be represented as 0 0 0 0 ok. 1 2 3 4 5 6 7 8 etc these are the levels.

And, this value will get approximated by possibly this is the closest integer. So, it will come down somewhat below. So, the value we will have here is possibly 1 2 3 1 2 3. So, 0 0 1 1 this point will be approximated by 4. So, the value we will have here is 0 1 0 0 and so on. So, you see we have more a rod or more approximations introduced. The true value of the voltage at this moment was possibly 3.2, but the ADC will tell me this is only 3.

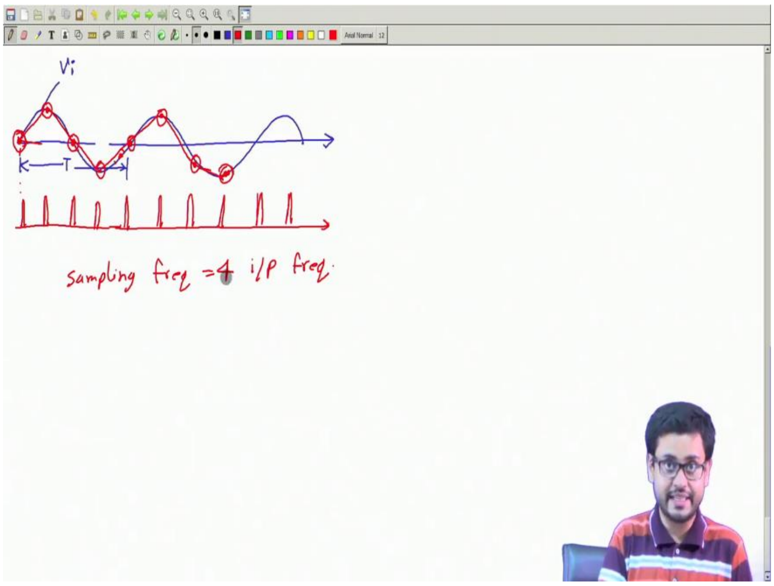
Normally, I mean so; here I am take assuming a 4-bit ADC. Of course, 4 bit is not a good number are good and oscilloscope will have much more number of beats than 4 ok. So, the approximation will be much lower, but this will be the situation no matter how small is the approximation or error there will be some error ok. So, this is something you should know about digital oscilloscope, that the voltage is measured number 1 voltage is measured only at discrete times, discrete intervals and number 2.

Due to the use of the ADC there is some quantization error in the measurement. So, we do not get perfect measurement of course, last 1 statement or 1 fact is this. Suppose, if I have a signal Vi which is like this. And, say if I am sampling it at a very low frequency compared to this input signal. So, I am sampling 1 sample here, then say I am sampling another sample quite far maybe here and then maybe another sample here and so on. So, what will be my measure value?

So, my measured points will be this, after that the next point is here, after that the next point is here and so on right. So, the oscilloscope will display only these points. It cannot display this intermediate pattern. And, if the oscilloscope joins this path these dots with maybe straight lines, you know this does not look at all like the original signal. This has happened, because this is because sampling frequency is much much less is less quite less compared to the input frequency.

And, there is a theorem called sampling theorem Nyquist sampling theorem, which says sampling frequency should be greater than, should be the greater than 2 times the input frequency, this is called Nyquist sampling theorem. And, he says if you sample the signal with a frequency twice or higher than the input frequency, then you will get a proper shape of the input signal. Let me just demonstrate it up very quickly.

(Refer Slide Time: 64:04)



So, this blue curve is the sample is the input signal and now I will sample it at say 4 times of these input frequency ok. So, this is the input time period. So, I will take at least say 4 samples within each time period. So, one then I will take next sample here, next sample here, next sample here 1 2 3 4 within 1 period. And, then in the next period again 4 samples 1 2 3 so, 1 2 3 4 and this is within 1 cycle and then another 1 2 so on.

So, how will the pattern look like? So, this is 1 point, this is another point, this is another point this is another point this is sorry not here, this is another point, another point, you just join this point. Now, if you join these points, you get a quite good approximation of the input signal ok.

So, here sampling frequency is equal to 4 times input frequency, minimum requirement according to Nyquist theorem is 2 we have more than that good oscilloscopes generally have more than twice of the I mean input I mean sampling frequency they take more than the twice much more than twice of the input frequency ok. So, this is required otherwise you will not get correct waveform.

Thank you.