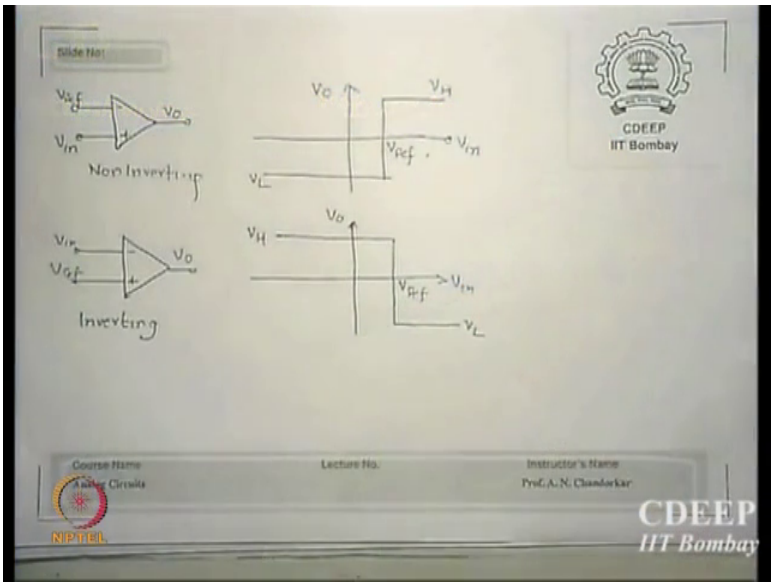
Analog Circuits
Prof. A. N. Chandorkar
Department of Electrical Engineering
Indian Institute of Technology-Bombay

Lecture-24
Oscillators

(Refer Slide Time: 00:23)

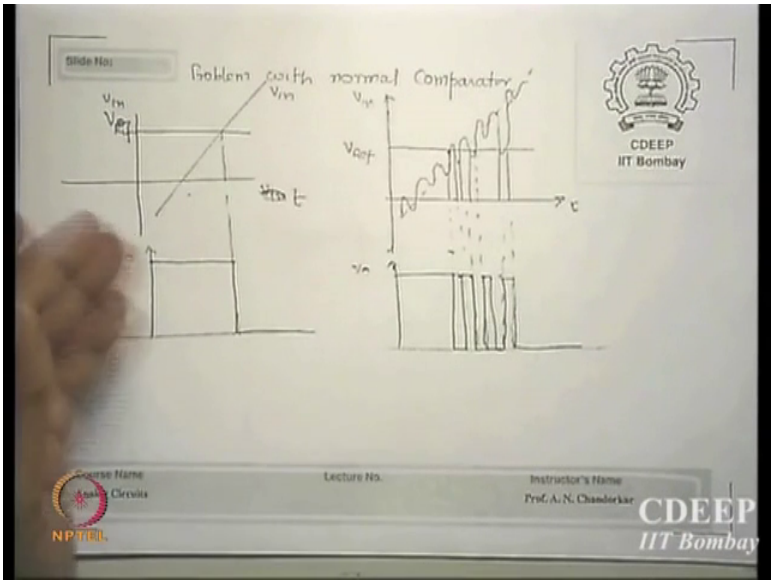


We will last discussing about comparators and we did say that if V in is larger than the reference are smaller than the reference output will be correspondingly + or - and two circuits which may be used one is inverting kind the other is non-inverting kind may have a characteristic shown here. If it is a non-inverting for being less than 0 are smaller than V reference you have V low. At V reference when it crosses it will jump to high value which is VH.

And if you do the inverting kind that is you substitute input at the V- and put reference at the V + the opposite will occur aspect. So, this idea that input when exceeds or decreases below beyond reference can change the state of the output from high to low this is the basic feature of a comparator. And I already said that this will be very sharp in what case when the gain of the comparator is very high, ideally infinite but very hard in the power 4 or 5 or even higher surely right.

Now I did comparators in real life there will be a slope and some adjustment has to be done but for our simplicity right now you believe the comparators are ideal. Why I said we do not have to do more accurately because at the end of the day it only decides the time going from low to high if the gain is not infinite it will take some finite time to these the other level okay. Otherwise it is as much as saying instantaneously which normally will never occur in any system okay.

(Refer Slide Time: 02:35)



All said and done here is the first of the kind of comparator which we are going to use okay. The problem with which I do not know whether shown here if I have a normal comparator like this which has a anything below V reference or about reference state changes. This is I plotted V Ref V in versus time and this is my V reference value if this is your V reference voltage and this is my V in, T which is following some straight line in some sense. But in real life this will not be state line it will have some kind of noise over reading them.

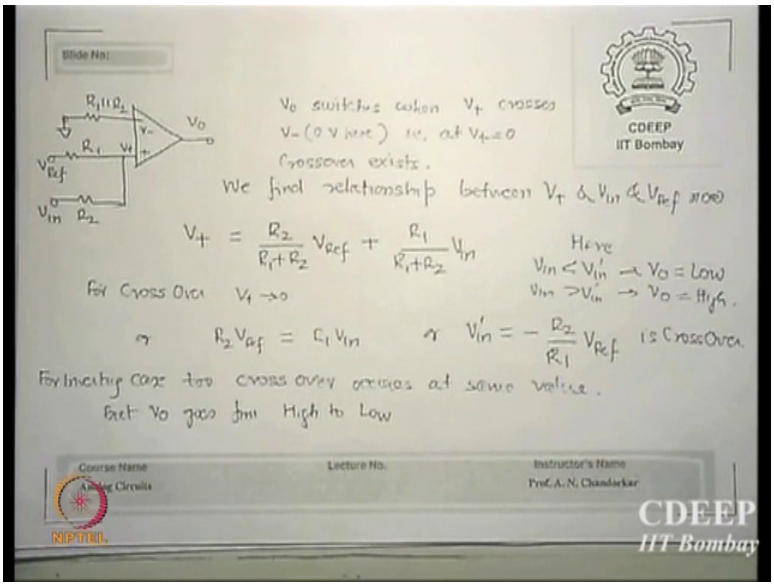
Now the way it will occur anytime V in crosses V reference it will switch the state is that clear. If it goes above or below either case that means when it crosses here at the end when I come back again it will change the speed is that one clear. Any time gain crosses the V reference from lower to higher or higher to lower it will switch the state that. The output if you see any time it is crossing the output V0 which what would happen actually I expected it a good straight line curve.

Let us say at this point I would have expected something like this one. But now I find the noise if the amplitude of noise is not very small and whenever it crosses the reference either going from low to high or coming from high to low it will switch the state. This means the noise essentially is now actually being transferred at the output okay. We do not want this to happen but it is happening.

So, one of the suggestion it was done that if we do little carefully this circuit in which we would like to see that there is not one value of V reference we quickly there is one higher reference value and one lower reference value. So, one can cross once there is admitting but unless it costs the lower side the value it will not change the state of that correct. I repeat I will show you the figure so if I can make two reference value created from one single reference value.

w are switching can from going from higher to lower to higher it may switch at one point and when come from higher to lower it will switch on some other points then the noise in between cannot change the speed okay that is essentially the feature of Schmitt trigger. The word which we use is Schmitt trigger.

(Refer Slide Time: 05:14)



Here is that basic circuit which you can create for example I have a V reference and I have a and given at the V + and there is a ground at the V- okay I will leave it to you find out in a book or from somewhere. Even if you are going to ground something you should ground through some

kind of a resistor what does it do even in inverting or non-inverting case the ground potential is essentially created via some resistor?

I can state directly come but I do not okay think of it, it is a very simple circuit issue and therefore in real life circuit even if potentially they are same no current passes in the OPAMP, so there is no question of me saying that anything happens but their presence is some kind of essential is that clear. So, if you are doing some circuits in the lab which you all must have already completed your lab now but you must have found that most cases we say put some resistor at V+ to the ground before we use non inverting circuits okay.

So, that is basically nothing to do with our analysis but just to show you. The kind of resistor I am using is identical now look at this is average resistance in the V + is R1 parallel R2 so the same register I have put to be - s okay this has nothing to do with how much as much as possible make it symmetric okay is that clear. Whatever is here substituted upstairs I mean upwards. So, V0 switches when V+ crosses V- see whenever comparator change the state when we difference potential is + or -.

If we V - V is larger than V + output will go low if V- is lower than V + output will go high. This part that means these comparison of V - and V + essentially decide when the switch will occur. So, now this V + value we can say can be now represented as R2 upon R1 + R2 times V reference this is the summer is that correct this is their summer circuit which kind non-inverting kind summer okay.

So, I will go upon R1 + R2 V in a fronts just superposition at this point because this shirts like this shows all - upon R1 + R2 times V reference + R1 upon R1 R2 Vin is essentially V + for cross over at let us say crossing at 0 because V - is grounded to 0. So, whenever crossover occurs V + must cross 0 so, R2 V reference is R1 V in, so we say now the new crossover point can be I repeat what did I say now normally compare I want to have two separate values off switch over.

So, how do I change those future points is that point clear what I am doing otherwise what was the future point V reference from there it was switching. Now I said okay I do not know I want a

value which I can create separately so I said okay I have another method of changing that point which is my V - or V + which essentially gives - R2 by R1 times V reference is the new crossover point okay. So, I have moved my crossover points is that one clear to you.

I am I am moving in the ratio of R's with reference to your actual reference value my cross over cross. Cross occur where when the V+ crosses V - is that clear but I can change V + now earlier was just me definitely because we are subject now I say okay with reference to this we will compare. This fact that crossover point can be changed when the input process V - is what the trick we shall use in the case of Schmitt trigger is that point clear.

The reference point is now modified by this ratio if they are equal then there is no question that here it remains same. Otherwise it can always be shifted to any other value now I will show you why I am actually trying to show you this because what is the idea I showed you what is that I was looking for that the input going from low to high should cross over at the whatever difference point I want at one crossroad point.

But when I return it should not switch at that point it should cross over at other point okay. So, that whatever noise at that higher level was should not be now crossing over that point but should cross even have a point which may not offer because if I separate the two cross over the noise here cannot actually cross this point so I say okay I can eliminate the noise if I remove the cross or I may separate the cross reference.

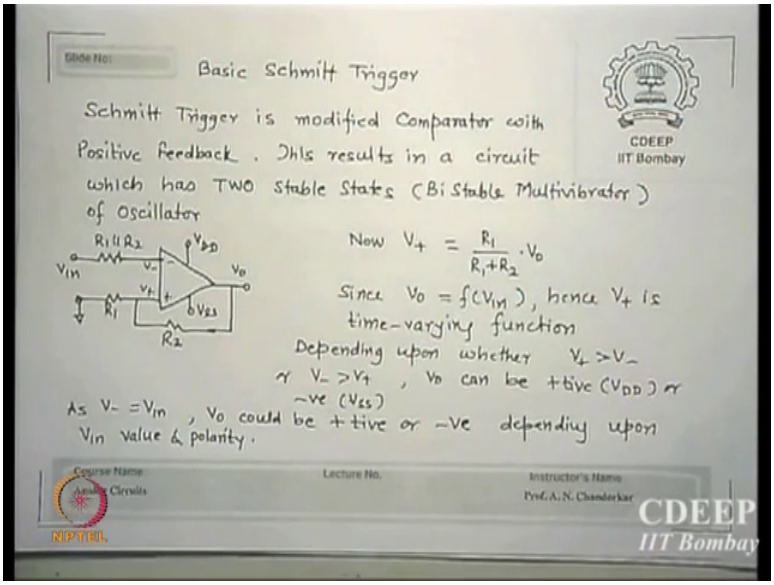
Which two cross over point I am talking one going from low to high crossing the reference the other coming from high to low input going from high to low crossing there. Those two crossover points I want to remove away from each other this is essentially the feature which Schmitt trigger, is why it is called trigger? Actually a comparator itself is a trigger is that were clear, comparator is essentially on-off, it is a switch.

So, any circuit where you want to have one input that is high input they do something and if it goes 0, it will do something else so you say I am changing the output of next circuit by putting a Schmitt trigger. So, it is essentially called trigger it turns on and off that were clear why trigger.

So, what I am not suggesting that in real life we do you Schmidt trigger number of times. In this particular area I am actually looking for Schmitt trigger oscillator.

We are in the oscillator area we are trying to say how can we use me to therefore a square wave oscillator. But in turn I am also showing it can be used in variety of ways where on-off is essentially required okay.

(Refer Slide Time: 11:52)



So, here is the basic Schmitt trigger essentially a Schmitt trigger is a comparator which is modified with a positive feedback. This results in a circuit which has two stable state and therefore it is at times called by stable element. On bi-stable element and bi-stable multi vibrator, I repeat my ultimate aim is proceed Schmitt trigger which has separate crossovers and does that create at then some oscillator which is of what kind square wave generator.

We are already what kind of a let us we already seen then aside all earlier or say letter sinusoidal says in effect the first square were generator what I showed you earlier simple inverters in odd numbers if you feedback then you get a square wave okay. Now I want to see can I use after all its inverter is where how many states it gives? Two stage. So, I am still while using the same words switch in some sense to states bi-stable okay.

So, now I say better bi-stable element can be created than the normal switch is the Schmitt trigger. Now if I have a R2, R1 and the feedback for V + which is granted an input is given to the upper inverting kind of input then when the switch over will occur when this value will cross V + value crosses or sorry V - value crosses V+. But there is a problem what is the problem here the V0, please remember V0 is feeding back through R2 R1 ratio to V +.

But V0 is a function of V in that point clear, if I change V in I am going to change V0 if I am going to change V0 I am going to change V+ is that correct so this is some kind of a feedback going on is that current. This is all so therefore sometimes called positive feedback the other term what is the name given to positive feedback, regenerative, positive increases. Now this fact since V + is a time varying function please remember this is not constant in normal case what would have been the value whatever fixed value I get at feedback.

Now V0 itself will change as being changes Vin as V0 changes V+ changes. If V is a function of T so if V + is a function T therefore the difference potential between V - and V + is also varying is that point clear this is what my trigger is trying ok that this value is also a function of time and compared with the function of time inputs. And then we find at that instant of time whether cross over can occur or cannot occur, let us see how it occurs.

Depending upon whether V + is greater than V - or V - is greater this output can go to VDD to VSS is that clear. If it is higher if this is higher than this what will be the output - VSS lower value if this value is smaller than this, this will go to be opposite phase. So, it will switch to the opposite side if V difference is positive output is low. If V difference is negative output is high. Now this; another thing which we will do later probably this VDD may be a 5 volt 10 volt any amount.

But in real life in digital what can be their typical values of this level you want it is four square inputs maybe 1.5 volt these days it is even less than 1.5, 1.2 volts at least we need at least 3.3 or 5 volt maximum these may not the comparator maybe or better if it is higher voltages as the power supply because then the noise on that will be very small. However the output I do not want to rise to VDD or way set so how can I do that numbers different. You have done that

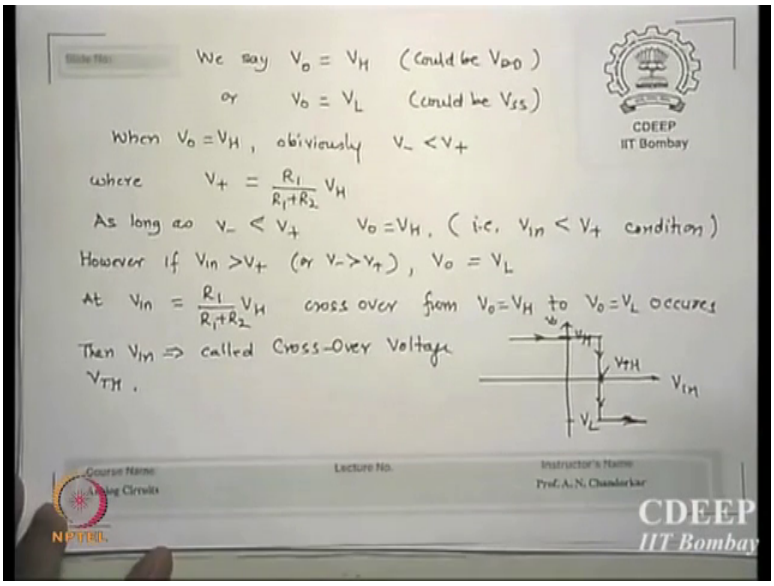
circuit already I have a voltage is going to 10 volt but I do not want the rise to 10 who I wanted 3 what stopped what should I do.

Clamp, use clamp's okay diodes so you can clamp the input outputs by diodes and then you actually it is going towards VDD but it will plan to some value is going to be as it will clamp to someone. If I do not because these are given it will climb to + - an equal value is that clear this is the circuit will show what we do. So, that is called limiting the outputs okay. So, in real life I will show you the actual limit symmetrical.

I may actually put some diodes here so that the output can be clamped to a smaller values okay. However right now as a theory whatever VDD, VSS down here. Now if V - is since V - is V in, V0 could be positive or negative depending on of course V in value and the polarity that is real difference is + or - will decide whether output is high or low. Yes I told you I am not going to tell you, think of it. (FL)

Actually it is not very compulsive that it should be parallel combination of same resistant but symmetry demands and it should be same to that inverting non-inverting (FL) I am not saying that you I should not tell you all these but I thought you should start thinking in circuits why people do some things and they do not explain okay. Why also fun how we learned you should learn if you came out then well I will tell you what exactly will happen. (FL) There is a book by Electronics Made Easy by Harlem Horowitz okay.

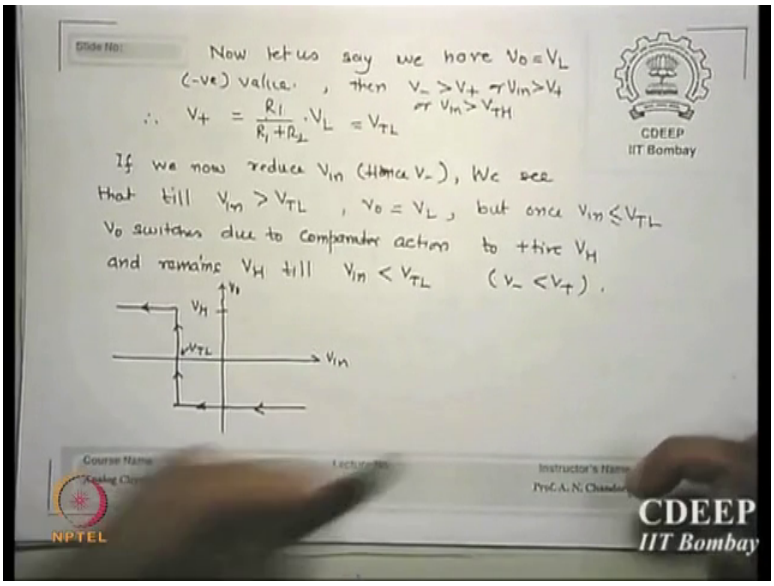
(Refer Slide Time: 18:59)



So, having told you this so it could be V0 = VH or V0 = VL could VDD your vehicle if not run let us V0 = VH, V - must be less than V + (FL) so, you calculate V + now is the R1 upon R1 times VH as long as we - remains less than this V0 remains VH that is V in is less than VH (FL) what is crossover point it is that input voltage where outputs things the state from high to low or low to high that is called turnover or threshold value.

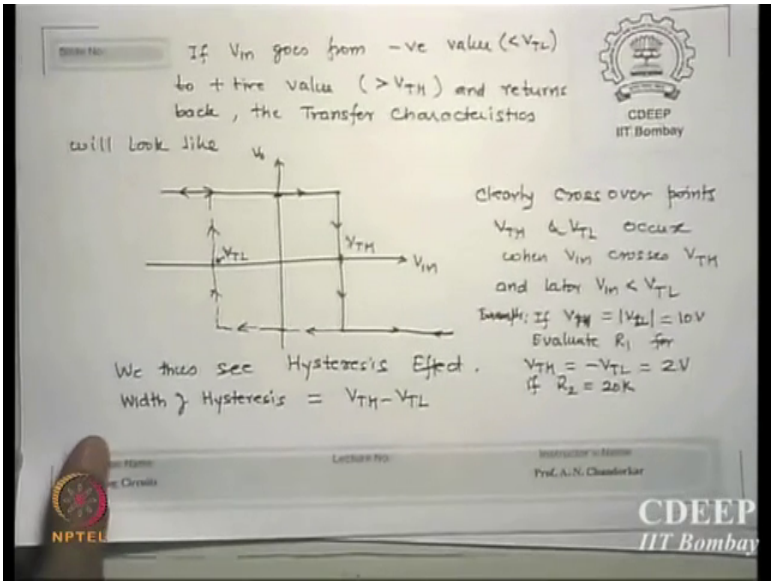
They are crossover voltage but that is not output this is the input value at which switch occurs is that correct. (FL) Since it was at VH this value was a function of VH is that clear this threshold was a function of because till this value output was high. So, this value was decided by output what is the V + value we are getting they ratio of R2 upon R1 times V0. If V0 is VH the first threshold offers at proportion to VH.

(Refer Slide Time: 21:16)



However if we were at VOL initially (FL) please remember VOL is – and VH is + so if I now calculate when I am reducing V in, I find the VOL is R1 upon R1 + R2 into VL and not VH. Please remember really the opposite sign is that VL is – and VH is +, so first (FL) VH was positive the switched here since VL is negative it switched at the negative bandwidth. (FL) If I am going from + to – (FL)

(Refer Slide Time: 22:07)



If I am going from – VL to - V in + when the output was high then what will happen it will switch over at this value VTH. However if I am at VL and I am reducing V in it did not switch on here why because now the value of switches at VTL – of that time is that clear. When I went

from - V2 + V in as we became crossing that V + value the step change is high to low it went through okay. (FL)

VN is less than V + or output remain high as being exceeded V + that is the switcher point. At this point output went low this output went low and you are in the VL position now. Now you reduce your being back where you are at much higher V, you start reducing being back towards – V where were you initially had for that case at VL. So, the new switchover point will be proportional to what value in feedback it is proportional always R2 upon R1 + R2 times V0.

But V0 is now VL which is negative so it switches here. so, if I am going from like this I switch at this point if I am going from this side it did not switch here but it switched back from this point and been (FL) what is that one day I will get out of his way very soon seen that why I am looking for instance is that point clear do what is that Mr. Schmitt trigger did is, because the difference of VTL and VTH is + or – okay. (FL)

The one switcher that VTH the opposite when you come it switches from - VTL okay and the gap between VTH and VTL essentially the hysteresis voltage (FL) so it is a matter of decision which way you want to swing okay either use inverting comparators or use non in what does that mean (FL) okay. So, if we now reduce V in that is V - you are already at the state V0 = VL and you are reducing it now.

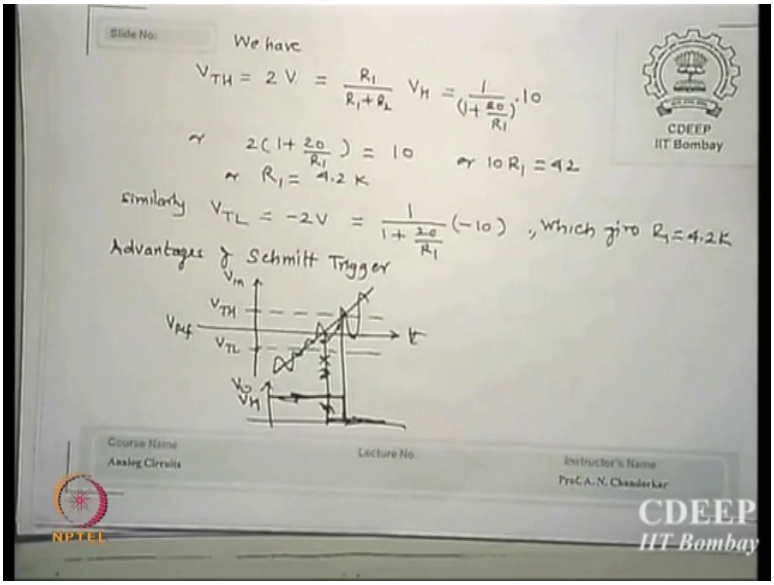
So, it switches over when V + become crosses the Vin, V - value (FL) but that value is now function of VL which is - value so it has a value of VTL which is away from VTH is that correct. So, (FL) so, you create an hysteresis is that you clear, you create a hysteresis. (FL) What do you mean by swing? (FL) AC cycle, if you are going through an AC cycle it will actually switch at two points now is that point clear.

So, what does that trying to give you hint? (FL) Using a Schmitt trigger I will be able to create a nice looking; (FL) how we do that is what Schmitt trigger isolated that. Now what is the different between (FL) what is a oscillator is there any input for oscillator? No, so that means whatever

input point is must switch (FL) is that point clear. So, idea up a Schmitt trigger is that I can create two separate states okay. (FL) is that what clear.

So, these are very much (FL) okay let us say a problem is there if VH is and VL is 10 volt + 1 - 10 volt (FL) I am asked to find this value, given this value and assume that equivalent value is there and let us say R2 is T value. And we also assume that VTH = - VTL why it is same because we are saying VH and VL are + - same man they can also be separated okay. (FL) How do I calculate R1?

(Refer Slide Time: 28:39)



Either use VH or use a VT h or use VTL either of them VTH is R1 upon R1 + R2 times VH that is given to you 2 volt. (FL) So, R1 upon R1 times VH is 1 upon 20 by R1 into 10 this gives me a value of 4.2k, if I use – 2 volt (FL) either use VTL or will use VT as longer they are saying it does not matter, it does not. What is the design we say okay (FL) so, it should be 4.2k is that clear that is how you actually will hook up the circuit.

Given those values you say ok put this value I should and then verify (FL) because my assumption that the comparator is ideal is not correct so, there will be change but then what do we do you actually put a pot on R1 and keep adjusting that and some point will come very close to it exactly (FL) but very close to it you can bring it. That is how the design actually tuned finally okay. (FL)

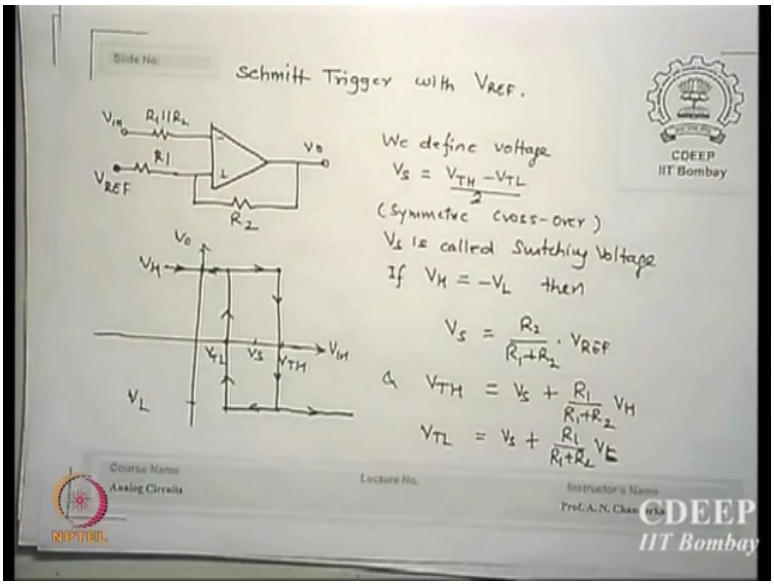
So, what is the advantage here (FL) so when I am actually crossing over VTL now sorry VTH only then I will because I am going from input low to input high. So, crossover will only occur at this point is that clear. (FL) Please remember what I am saying, I repeat I am going this is my VN increase with a nice low reading on that (FL) no switch till this point there is no switch because at this point only first time in put crosses VTH.

V in we are increasing till VTH it cannot change the speed (FL) since it is not reaching VTH it is not crossing over. At this point will crossed is that clear. (FL) now as long as this noise does not cross VTL even if it is a larger noise going on it cannot cross over. Because now we are going from higher side towards lower side, so now at do whatever you do till it crosses VTL it cannot re-change the state. (FL) is that correct.

So, Schmitt trigger (FL) is that there that is the fun of it (FL) inverting the non-inverting or non inverting it should be possible but it is little risky because comparators voltages if you change which can do we can then the problem is comparator OPAMP (FL) so that cannot be done because this internal chip you have no control on that. If you can hook up something otherwise (FL) if you have a OPAMP with PN circuit I mean N channel as a load or N channel of the current mirrors and P as the driver is given okay.

But that is means you are having another chip with the same chip giving VDD whatever is given you have no choice for external you cannot do but you can use another chip which has a P DPAMP with N nodes okay that can do the opposite that is possible is that okay. So, is that advantage of the Schmitt Trigger is clear that it triggers at one point now okay and it eliminates noise over reading on it is that correct, is that point clear.

(Refer Slide Time: 33:53)



So, that is advantage of Schmitt circuits (FL) I will just show you I instead of you know this putting to be there for me this is a inverting kind (FL) if I do the same analysis once again the transfer characteristics will now move away from that point okay by so much as V reference point by ratio of; there is a potential called VS which is the half way switching voltage as we call VTL + VTH- VTL by 2 which is again R2 upon R1 times R2 (FL)

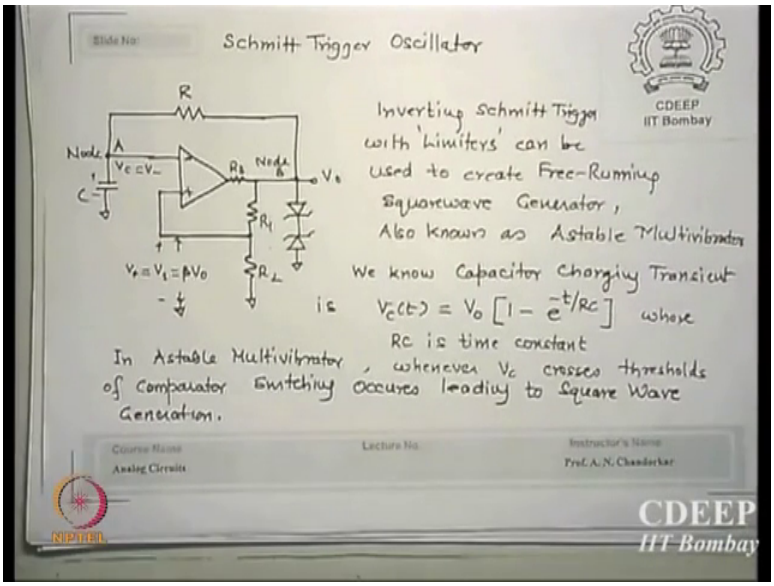
R1 upon R1 + R2 times V0 V + is also created from so also remember (FL) so if I do that analysis I can for as I say you do yourself VTH and VTL would be now both positive but shifted by as much voltage is that clear (FL) by putting some positive value here is that correct. (FL) So, these current itself can be moved left and right by choice are V reference, do analysis ,please remember this is the superposition requirement (FL) is that clear.

Only thing is both can be positive or both 1 can be both can be negative or if you do not know anything you put V reference 0 it is symmetric to 0 is that clear. What is VS essentially is (FL) is that ok, so this is something you need at times that this cross or point need not be negative it can be positive itself, is that correct. So, by making a slight modification in Schmitt circuit I can also decide where my switchovers can be.

This is the, another thing which may trigger always uses. Please this is given in our Sedra Smith book you can read and I think they are also solved it I only written the final answers okay. Now

we go to the final part on the Schmitt what is the all that we were doing so far as if we are only honour that was not my; this is useful less why show too many other places. But the circuit which I am going to use is really okay.

(Refer Slide Time: 36:57)



The circuit which I am interested in is those oscillators why am I did all that because to understand the operation of this. I thought you should first learn the Schmitt itself is that point clear. Otherwise for this circuit I could have started here and say this is how it happens but I thought it is not fair let us say what is Schmidt and then use Schmitt trigger to create an oscillator. Please take a circuit okay. (FL)

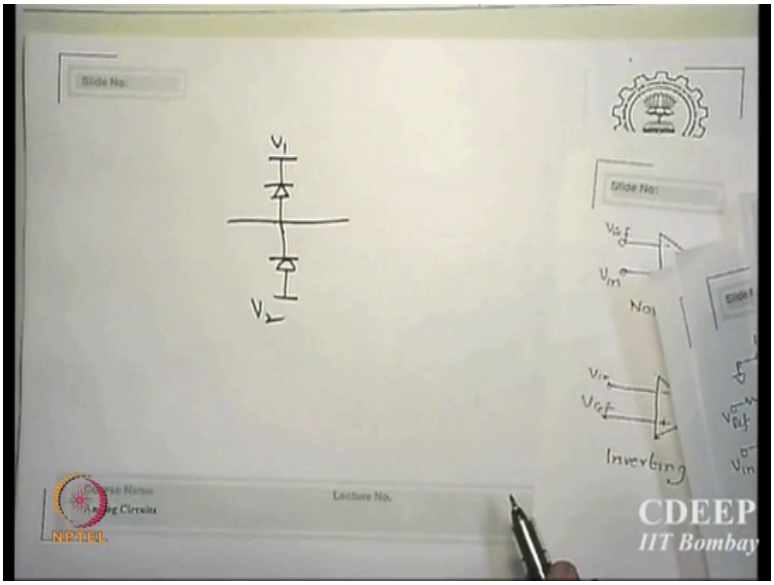
Before you draw you start drawing and then I ask you one other query regenerative (FL) few points we shall note this is your standard Schmitt trigger input (FL) this is your V - which is your input this is your feedback regenerative feedback and I have added two new elements R and C. R and C, I also added two devices here both are general diodes.(FL) If it is negative bias larger than VZ if the inner the inner voltage is VZ negative value of any voltage closer to VZ.

Current will be higher or lower increase very sharply but voltage you will now be getting fixed to VZ, we will get too positive then what will happen like a normal diode equivalent length do not say exponential but as if it is rises again; we do what is VD as I put VD means cut in voltage VZ means Zener voltage. So, V0 (FL) depending on what V0 sign you are getting but the value

at V0 will be always (FL) total potential will be always VZ + VD science accordingly is that correct.

So, what is that do you know what did you see what I have done it output (FL) I repeat two separate plans can be given to diodes need not be zenners then okay (FL) I mean just tell you what I am saying I am necessarily making these statements (FL)

(Refer Slide Time: 40:18)



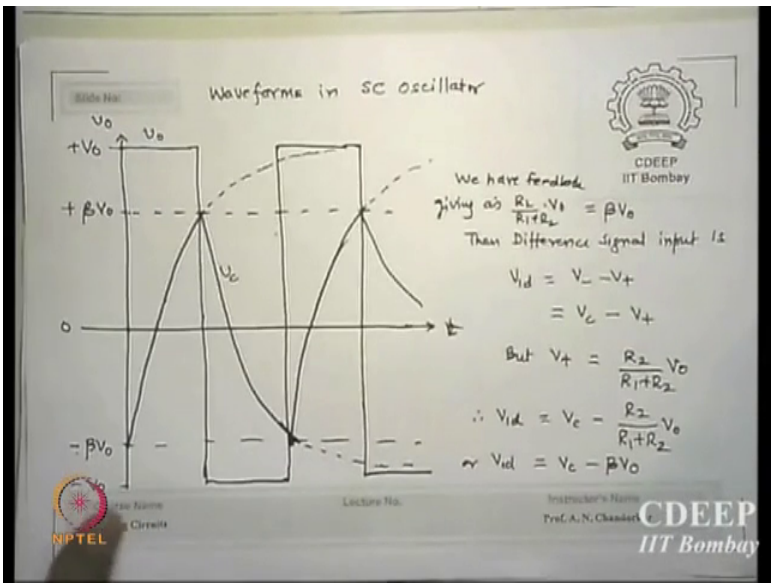
So, I can always clamp separately at a line by two opposite direction diodes there is that clear. So, that is not that I cannot climb separately but I why I am not doing that Schmitt (FL) otherwise do not think that it can I can always be done the way you like okay. So, how many things I change I have put a diode here I have also put a resistor R3 (FL) if let say this somehow grounds somewhere because of some failure somewhere that is a diode failure. (FL)

R3 is a limiter is that (FL) is that clear to you. So, this is called limiter, current limiter (FL) is that clear to you. So, these are some issues the basic idea is to create potential at A this node where RC is their capacitor (FL) The basic idea is to create V - with charges and discharges (FL) which is V - which is getting compared in V + any time it crosses those VTH, VTL value the output will swing okay.

So, square wave (FL) whenever there is nothing in the circuit put a limit to the ground is that correct. If already paths exist through some resistor you do not have to want additional you do nothing you do not gain is that clear. So, in this you know and please remember this is only a case when a terminal is directly connected to the ground that issue should be a avoided it should always go through a reached to the ground.

If current does not flow the potential does not change for you and in the case of OPAMP inputs. So, any R you put it the current event change there but let us check see current shot at A to your current view by our car they also shortcut listen that is why I think there (FL) very good let us say some reason this put it this V0 gets to ground. The OPAMP (FL) in case there is something happens a short circuit at V0 point then we are worried about is that correct. (FL) That is what, is that okay these are protections okay, let us finish this. (FL)

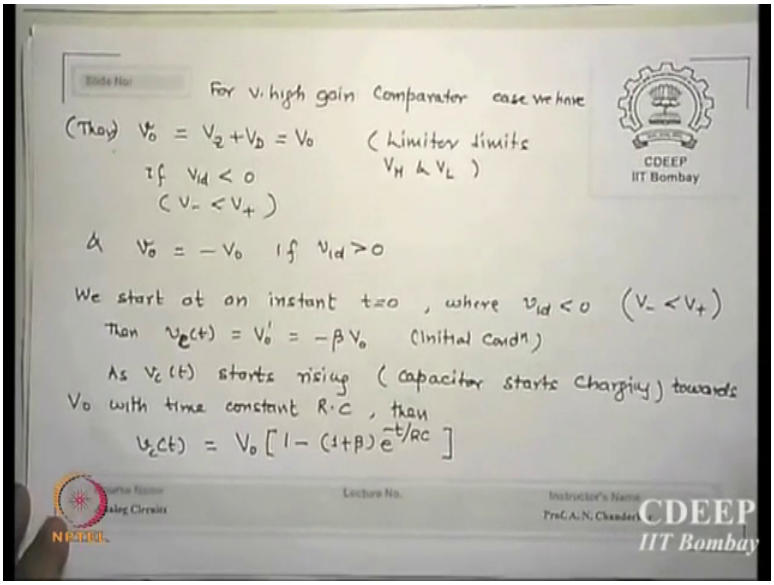
(Refer Slide Time: 45:54)



Before they come here okay (FL) before we say if in this circuit what is being fed back (FL) which is nothing but I2 upon R1 + R2 times V0 (FL) is that okay (FL) is that okay beta is sink feedback factor voltage received from the voltage V0 (FL) so, this is the voltage which is V + across RC0 V + is that okay (FL) - beta V0, is that correct two values of V + I can attain either + beta V0, V0 is positive. If V0 is negative - beta V is that okay.

If this whole tension is positive this is also positive if this potential is negative this potential is also negative is that clear. So, this is two values of V+ I can create V+ which is + V + which is - and what which I will compare with P-, P- is nothing but the potential across capacitor voltage across capacitor is that correct. The capacitor whatever voltage is nothing but your - okay. At this node, so you are two nodes node A and node B this is my input node this is my output node okay is that correct.

(Refer Slide Time: 47:57)



Now I say let us say comparator is a very large gain very, very in then that means what does that mean it can go to VDD and VSS full swing it can take. And if that happens, the voltage at V0 now you can see we reach to VZ + VD just now we have seen (FL) is that clear to you output potential (FL) if this is positive which one is diode drop VZ1 or Z1 and Z2 is reverse biased. If this is negative then this is diode drop and this is inner drop.

If they are identical zenners which only on the chip you can create independently (FL) V0 will be VZ + VD which is limiting VH and VL is that correct otherwise (FL) it would have gone to VDD and VSS I do not want to go to a higher voltage I want to swing it for the known amplitudes square (FL) is that correct. If you want a different value of swings then you should have a different Zener diodes there is that clear to you okay.

So, if VID is 0 or V - is less than V0 if V ID is greater as a standard (FL) of now comparator car situation if it is difference voltage is positive then output is negative will different voltage is negative output voltage is positive is that clear. So, let us start in our circuit (FL) okay. Let us say initially the capacitor is some beta V0 okay (FL) initial condition and VCC please remember I am saying.

If this potential is higher than this potential which way the current will flow I am saying node A, node B potential is higher than node A potential how the current will flow it will start charging the capacitor. So, initially (FL) if it is that - beta value beta 0 value this will be V0 value so essentially what does it mean capacitor will start charging and voltage start rising. As voltage start rising and corresponding to this V0 value whatever V+ I was receiving VA + V;(FL)

Whenever it will cross that value (FL) is that correct okay (FL) I repeat initially it was – value, so this was V+ value, so start charging okay. It is charged to a higher value which crosses something like this. So, as soon as this become - V0 this potential is higher than this potential. So, the capacitor starts discharging (FL) so, whenever again switch that V- changes lower than that we tell it will again switch over. (FL)

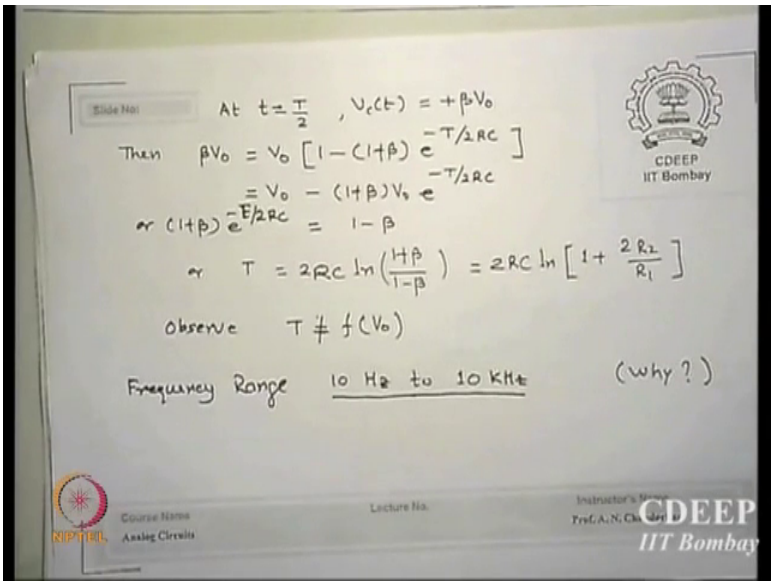
So, point A will charge and discharge as the output voltage or beta V0 value VC value which is Vin essentially crosses beta V0 is that correct (FL) Actually there a another part so that is why I said but it will draw much lower current compared to this because VZ is sinking heavy currents that is why this fixed to a visible it is a drawing a recurrence okay. (FL) Initially Vin was at - beta V0, so node A voltage was lower than node B because V0 is positive.

V0 was + V0 capital value as soon as this capacitor starts charging and reaches a threshold of beta V0 okay (FL) which ever will occur output will go from high to low initially output was high we see a value of - beta V0, so it starts charging because current will flow from B to A as VC start charging and reaches a value of B crossing the V + value which is beta V0. Switch of the output will switch each other.

But as soon as you reach -V0 it will remain -V0 is that correct. The capacitor start now discharging how long this will remain VZ - V0 till VC crosses -V next threshold which is –beta Vo (FL) why this dotted line are showing if you do not discharge. If you do not have a comparator it will actually charge to V0 (FL) the capacitor charges discharge between what values - beta V0 + beta V0 and V + crosses V- switch over occurs (FL) is that correct square pulse.

You can read book I only wrote on the cup this value etc is given their (FL) Please remember initial condition this may include - beta V0 is the capacitor pre charge okay V = 0 capacitor is bleach R2 - V tau V 0 is that clear. (FL)

(Refer Slide Time: 55:59)



So, t = T by 2 VC T is beta V0 so beta V0 (FL) 2RC Ln 1 + beta upon 1 - beta which is 2RCLby R1 + 2 R 2 by R1 (FL) is that oscillation clear to you because V0 changes the state beta V0 goes from - beta V0 + V2 which is about threshold values. So, capacitor charges to 1 discharges to other so the output spring from high to 1 node 1 or V0 (FL) VZ + VD this is - VZ + VD is that clear. (FL) The period of this Smith oscillator is to RC Ln 1 + 2 R2 by R1, R2 by R1 can a feedback ratio.

But it is not a function of those diode volt potentials amplitude (FL) these triggers oscillators are generally used at low frequencies 10 Hertz to 10 to 10 kilohertz (FL) There is a problem in

OPAMP or comparators its slew rate. If you want to charge it faster you will require a larger current is that correct. Slew rate (FL) so you cannot enhance too high a frequency how from this typically Schmitt oscillators are used only for; (FL)

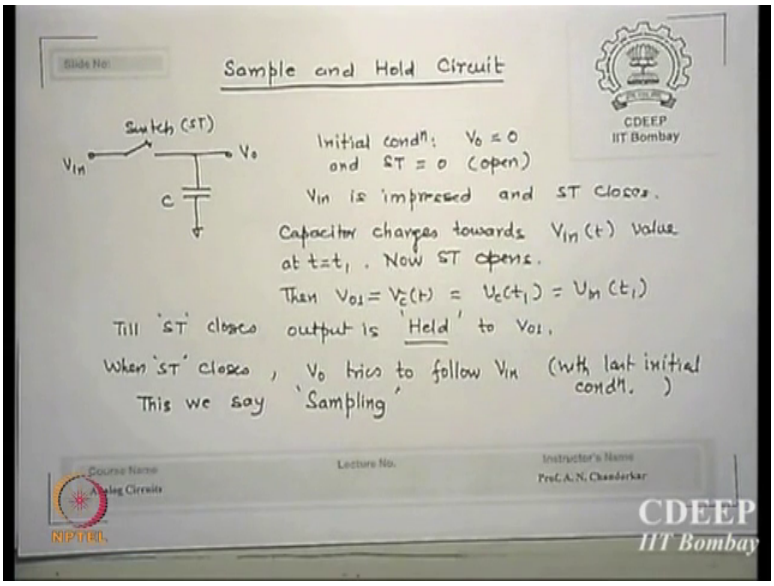
Let us say I have five inverters it is higher as you can see are three in order higher if I 3 inverters the period will be decided by delay in three larger the delay smaller is the time 1 upon T (FL) so 121 inverter (FL) why we do not mind that because inverter is the smallest size W belgae inverter with them okay so you put as many small area you can create very high frequency oscillators is that square wave (FL)

Clock generation is done through series of inverters in a ring form yes the opposite you are right. (FL) It is what it is, I did not say it correctly okay so is that all kinds of oscillators are clear to you what kinds we have studied so far, we are looked into RC oscillators we are looked into LC oscillators, we are looked into look ring oscillators and we finally said Schmitt Trigger (FL) is that correct (FL) is that okay.

Please remember buffers are always used when you are taking from outside something and feeding to your ex circuits (FL) is that clear, OPAMP can always drive an OPAMP is that clear because (FL) all OPAMP in series okay all of them sensitive okay so Schmitt triggers are very useful (FL) comparator say with two comparators and some small counter we can create a chip which is called timer circuit which number is that 555 timer (FL) okay.

Before we quit will introduce a new topic we are now interested in doing last part of our course these conversions our converters what are we talking about converters means digital to analog and analog to digital, digital to analog circuit (FL) we need one circuit which is very popular which is called sample and hold. if you are dual degree students some of you and continue to remain in micro electronics.

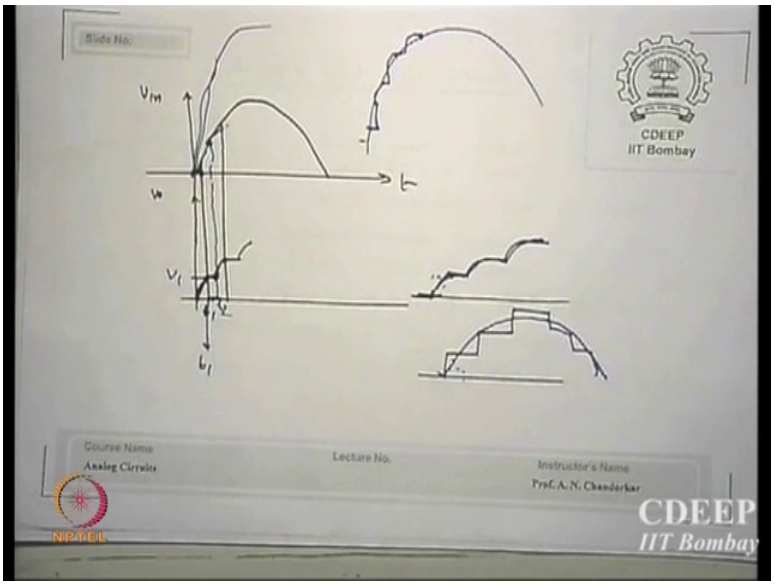
(Refer Slide Time: 01:02:56)



And also you take analog VLSI design course and let us say I am teaching that time that course too many on and conditions then I will show you there are other circuit which is called hold and sample (FL) sample and hold there I will show hold and sample of it okay. (FL) Okay that is how to make check all that we say test our pudding is in eating but how puddings are made will only decide what test okay.

It is a very simple circuit (FL) capacitor let us say this is the input and this is the output across a capacitor and switch is open. So, what will be V0 as shown 0 but can be the charge state of the capacitor as initially be seven this is open output is 0 and now I start V and at the same time I close the switch (FL) so it will start charging the capacitor (FL) At second time when I switch it on (FL) over and above the pre state value is that clear.

(Refer Slide Time: 01:04:51)



This is what essentially I am now seeing example (FL) time varying these are the instances when I am actually going to turn on the switch (FL) Vin pass as it is please remember ideal switch (FL) which in reality there is an issue there but right now so if Vin is here it will start charging to that value it will output will follow V in charging the capacitor (FL) is that okay so it charges to some value which is so V1 which after them. (FL)

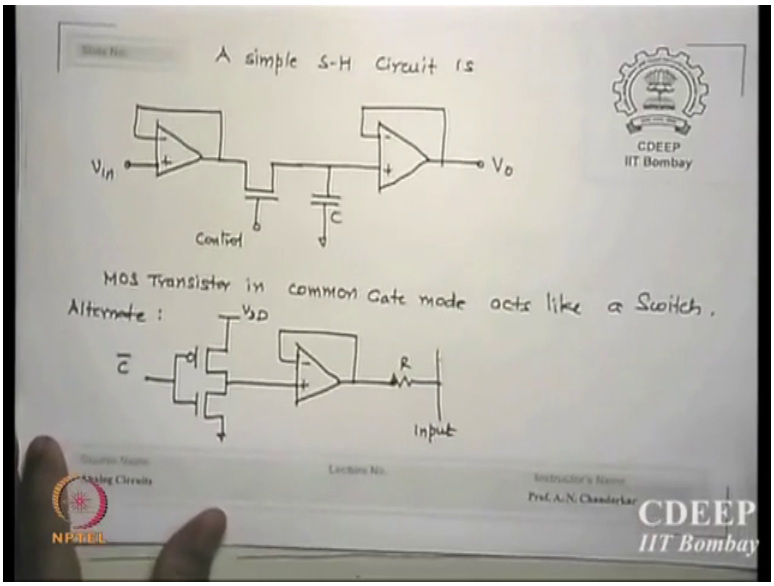
So, as soon have it remain constant at some instant again I switched on the this but at this instant of time we cannot have input higher value (FL) can you tell me in an insular side when these two conditions are similar when the amplitude of the signal is too high then this is linear. (FL) This is your AC cycle (FL) we say we are converted an analog signal into digital signal is that principle of A to D converter is clear.

Using my sample and hold which is described essentially (FL) as close you will actually cut it it will be replicating closer to this innocent (FL) sample and hold should do that job faster across switch or (FL) is that clear (FL) different circuits that will use essentially differentiate on what K otherwise I will convert analog to digital. But what will be the deeper from how fast you convert how quickly you discretize so that it replicate close to AC's.

Essentially I repeat I have an AC signal I am only doing and they all be buzzing so I am trying to almost come closer to AC signal by jumping over it okay. So, I say equivalent (FL) so I can say I

am actually using discretization I am somewhere coding digital that is called A to D converters okay. A sample and hold (FL) is that correct wire sample-and-hold ok okay.

(Refer Slide Time: 01:09:48)



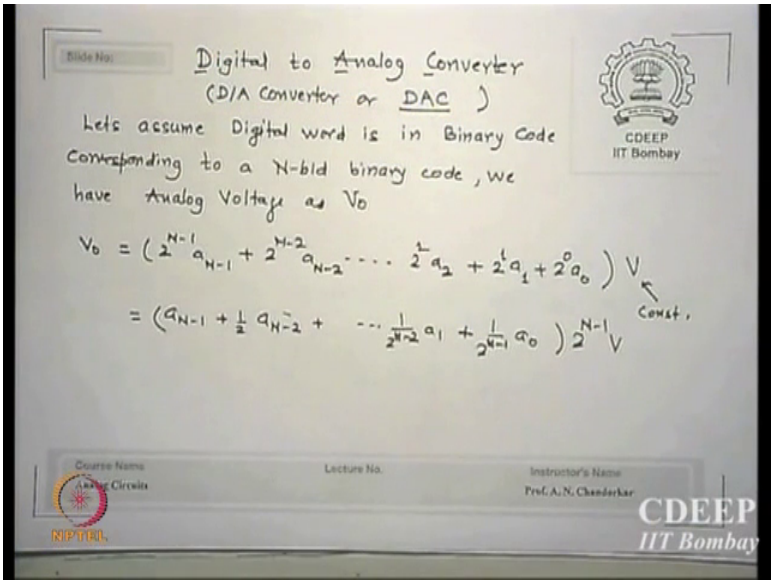
Second Circuit has is a discrete value or some other circuit whose input impedance is not very high which like at this transistor does not have I must always feed input to this through what a buffer okay follower. (FL) Transistor is turned on if Vin is higher than VT less than it is off. So, I had a control signal which goes from 0 and 1 higher or lower value and allows input to charge the capacitor and hold it. (FL)

Will hold during this time through another buffer I will output it is that correct the typical sample hold circuit will have two buffers in between (FL) it is a CMOS which or transmission gate this is called transmission gate is that okay. So, if it is only N channel it will only pass nearly - VT it will be the P channel and it will only profound VTV to VDD parallel current get the 0 to VDD full (FL) okay that is the purpose.

So, this is what the sample and hold circuit does and what is the purpose of sample and hold is that point clear. (FL) is that correct so I am using and sample own circuit to actually discretize the digitize the analog signal is that correct. This is the property which I am going to use in converting an analog signal into digital signal. Different circuit like successive approximation, flash comparators your slope single slope there are many multi modes.

Finally Sigma deltas all these are the different speed and different purpose is to be used otherwise basically they all descriptors is that correct. All they discretized (FL) given a data in digital form 101101 want to know equivalently what is its voltage okay. So, the next block code will learn next time

(Refer Slide Time: 01:13:15)



But just the name for this is digital to analog converter in short it is called D slash A converter or more popularly called DAC. (FL) So, we will like to see how ADC's and will not actually as I said there are large number of ADC than DAC's will only do basic ADC few of two of them and one A to A which is also very busy larger length which is and then we will close you.