Analog Circuits
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Week 07
Module 03
Multi vibrators

Hello welcome to another module of this course analog circuits, in this module we are going to start a new topic new type of nonlinear circuits these are known as multi vibrators, now multi vibrators are a special class of circuits for analog circuits as well as they have their counterparts digital circuits as well in digital circuits they are also know as flip flops.

But in the analog world multi vibrators are not just flip flops they have some other applications as well, so basically the multi vibrator circuit is a circuit that has 2 states so one state, state number 1 state number 2 and depending on how these states transition from one to the another we can classify the multi vibrators into 3 different types, so let us see what are multi vibrators.
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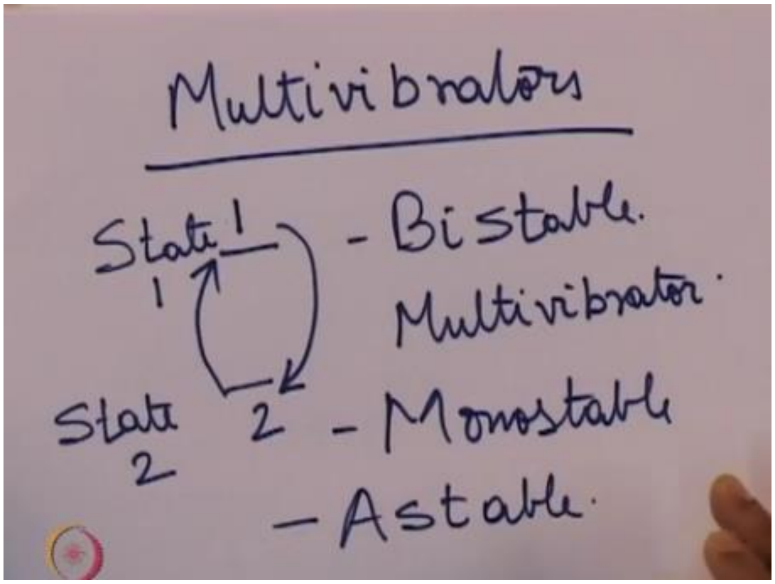

So suppose you have 2 states these are just symbolic representations these are not actual voltages or currents, so I just represent this line by state 1 a state 1 and this is state 2, so now this state one has to transition to state 2 and this state to has to transition to state 1 now in a circuit this states would correspond to some output voltage which would be either high or low.

If the output voltage is high then I will say it is state 1 and if the output voltage is low I will say to say that the circuit is in state 2 or vice verse, the important thing is suppose each of these states are stable in their own right that means if the circuit is in state 1 then it continues to be in state 1 until I actually change something physically manually in the circuit, so then it will transition or I force the transition from state 1 to state 2.

So such a circuit where both states are stable and I have to actually apply some stimulus to change from one state to another and the change from one state to another is same for both states that is for changing from state 1 to state 2 also I have to apply a stimulus and from state 2 to state 1, also I have to apply a stimulus such a type of circuit is known as a bi-stable multi vibrator.

If on the other I need some manual input to change the state from state 1 to state 2 but once in state 2 automatically after some time the circuit will transition back to state 1 that is only if say state 1 is stable the other is not stable if I go to the other state then the circuit will after sometime go back to state 1 such circuit is known as a mono stable multi vibrator is called mono stable.

Because only one of the 2 states that the circuit is in instable that is not stable other will go back to the stable state and then third case is the case when no state is stable that is if I am in one state then after some time I will transition to the other state and once I am in the other stage again after some time I will transition to the first state so such a circuit is known as an Astable multi vibrator.

Now you might think that this Astable is somewhat similar to this oscillator isn’t it because after all we are going back to the first state yes it is a kind of oscillator but the difference between an oscillator and an Astable multi vibrator is that in an oscillator there is no concept of states of the system of the system that is we cannot identify any clearly clear state in which the oscillator is all at every time the output is changing but no at no point of time in the oscillator output can be clearly defined 2 distinct states but in the case of an Astable multi vibrator we can distinguish to clear states.

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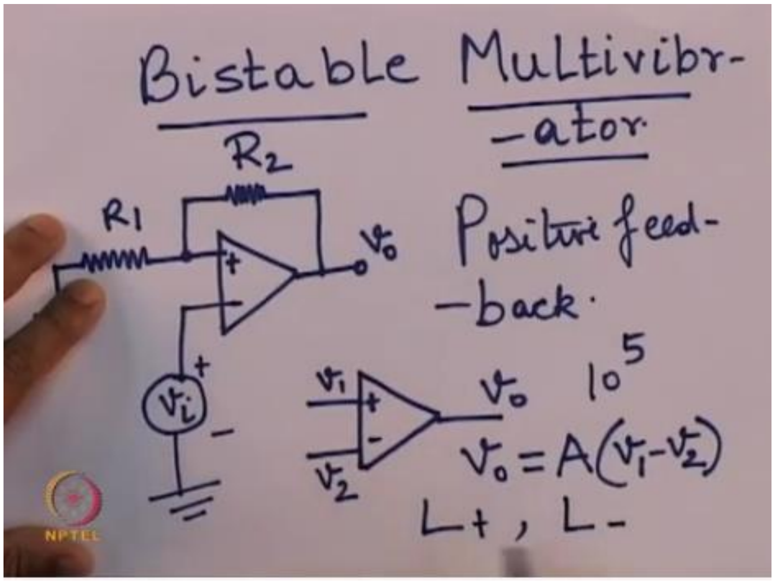

So let us start from the bi-stable multi vibrator and slowly we will move on to the astable multi vibrator, so first thing is in a bi-stable multi vibrator we need to have 2 states, so let us consider this circuit this is an opamp and this circuit might look very similar to the non inverting opamp topology but it is not it is not because look at the point where we are applying feedback it is to the positive terminal in a non inverting opamp the feedback is applied to the to the inverting terminal whereas in this case we are applying the feedback to the non inverting terminal so this is the case of positive feedback.

So in positive feedback we call from the discussions we had when discussing feedback we purposely want to make the system unstable we do not want to make the system stable now going back to the circuit of the opamp this is the circuit of an opamp this is the equation for the output voltage and as we know the gain A this capital A the gain of this opamp is quite high is ideally it is supposed to be infinite but for real opamp also it is quite high in fact it is as could be as high as 10 raise to power 5, now on top of this we are applying positive feedback so what that means is we want the output voltage to get saturated.

So though the gain of this opamp is quite high the output voltage will never exceed the saturation voltage so let us call the upper saturation voltage as L+ and the lower saturation voltage as L- so L+ is the upper saturation voltage and L- is the lower saturation.

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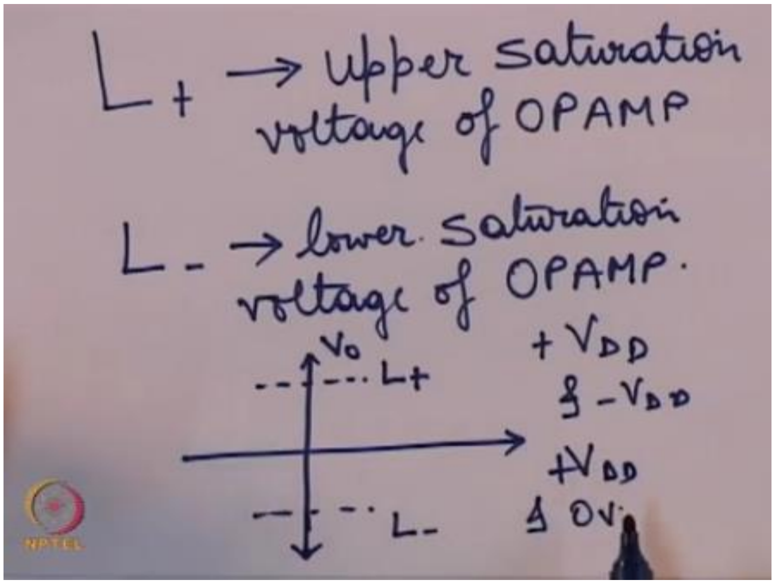

So what it means is that if we draw the output voltage then L + is the maximum say this X is some independent variable which we shall see later on is the input voltage Vi but if the Y-axis represents the output voltage then L+ is the maximum positive voltage that can happen that can be present at Vo and L- is the maximum negative voltage.

Now usually as I had said earlier this out L+ and L- correspond to the upper and lower supply voltage that is suppose my supply voltages are + VDD and - VDD then L+ will correspond to + VDD and L- will correspond to - VDD this is the rule but not always true if there is for example some drop from the supply voltage to upper maximum permissible voltage then L+ may not be = VDD but usually it is L+ is = the + positive supply voltage and L- is = the negative supply voltage.

If my supply voltages were + VDD and 0volt that is ground then L- would correspond to 0 voltage and L+ would correspond to + VDD, so now our circuit from the circuit where are applying positive feedback our output voltage will vary from L+ to L-, now how do we make this variation?

So let us go back to the circuit once again, as I said for a bi-stable multi vibrator (Refer Slide Time: 11:39) you need some external stimuli to change the output voltage so this L+ corresponds to one state L- voltage at the output corresponds to another state if I change my Vi then as I will as we shall see I can change suppose my output voltage is L+ by changing this Vi suitably we can bring about a change in Vo how, so look at it this way Vo is saturated is at the say Vo is at the upper saturation voltage L+, so then this voltage Vx this voltage Vx will be given by the voltage division of this feedback circuit.

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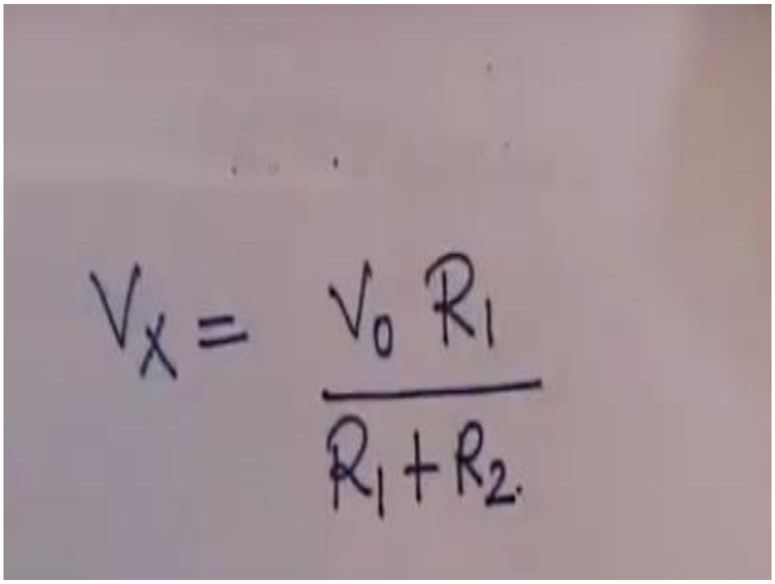

So Vx I can write it as, so till the time my Vi let us go back to this circuit this is my circuit and this is the value of Vx till the time Vi is less than Vx Vo will continue to be saturated and = the upper saturation voltage L+, now suppose I keep on increasing Vi if I keep on increasing Vi there will be a point where Vi will exceed Vx voltage when that happens V1 - V2 from this equation this is V1 this is V2 becomes negative and so the output will becomes saturated but to the lower saturation voltage L- okay.

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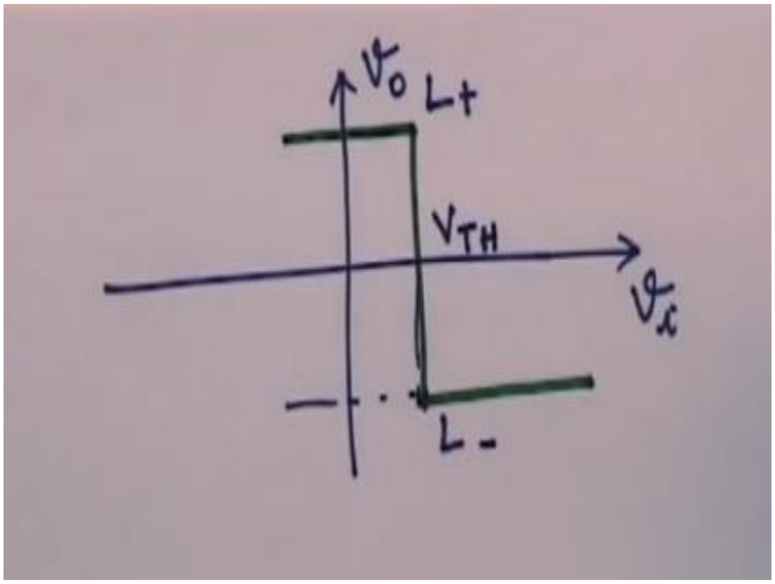

If we draw the graph for this one so we have our output voltage this is my Vi this is Vo this is L+ this L- say initially the voltage output voltage is at L+, now I keep on increasing Vi such that at certain point there is a transition and say the volt a value of Vi where this transition occurs I call that VTH so at VTH if I now use my green pen, so the curve will look like this okay on the return path however so let us go back to the circuit once again, so Vx when Vi exceeded VTH so VTH I can I have already written that let me go back to that equation where I have written it.

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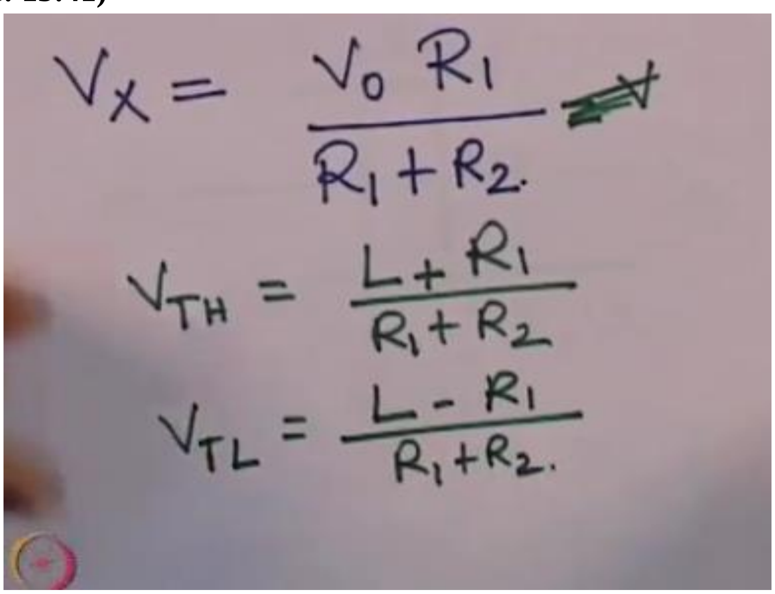

So when Vx is = VoR1 upon R1 + R2 this is the value of Vx so VTH will be given by L + R1 upon R1 + R2 similarly on the return path when there will be another voltage which I call VTL when Vi becomes lesser than this value VTL a similar transition will occur so let us go back to the curve once again see when Vi is increasing my Vo goes from L+ to L- when Vi exceeds VTH on the return path when Vi goes below this VTL.

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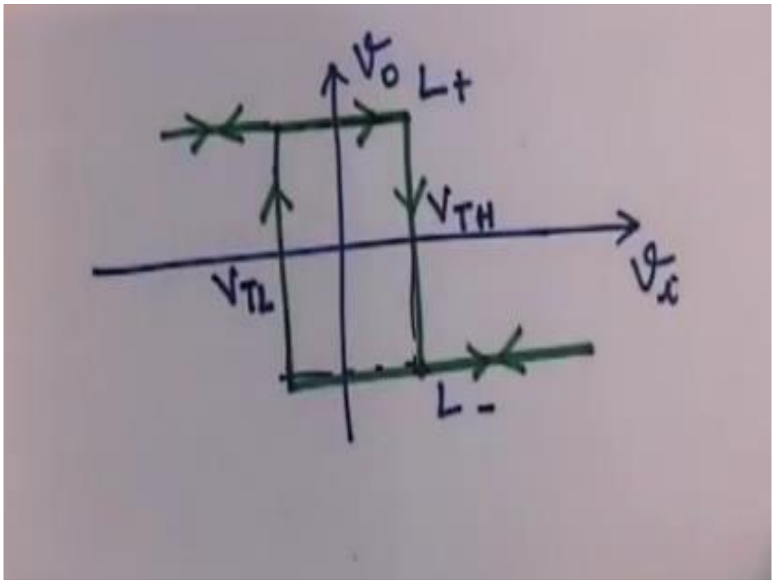

So on the return path your V0 is at L- VTL is the voltage or the threshold voltage if Vi goes below VTL then there will again be a transition because let us see here let us go to the circuit so Vo Vx is at the lower threshold voltage VTL usually that is negative voltage now till the time Vi is more positive than VTL V1 - V2 will continue to be negative and V0 will continue to be at its lower threshold at its at L- V0 will continue to be at L- and Vx will also continue to be at VTL.

But when V0 becomes more negative than VTL then V1 - V2 becomes positive and once V1 - V2 becomes positive V0 will go to the upper saturation voltage L+ and so there will be a transition from L- to L+ for V0 so graphically that means when Vi is more negative than VTL there will be another threshold another transition and the transition will look like this, so when Vi increases the path followed for transition will be this when Vi decreases the path followed will be like this so this is how you know this bi-stable multi vibrator works.

Now we can make the in this case in this circuit that we have been studying so far we have applied the Vi to the inverting terminal and the feedback is given to the non inverting terminal we can do the reverse also that is we can apply the input to the non inverting terminal as well so then the circuit will be somewhat similar to the inverting opamp circuit that we have seen earlier.

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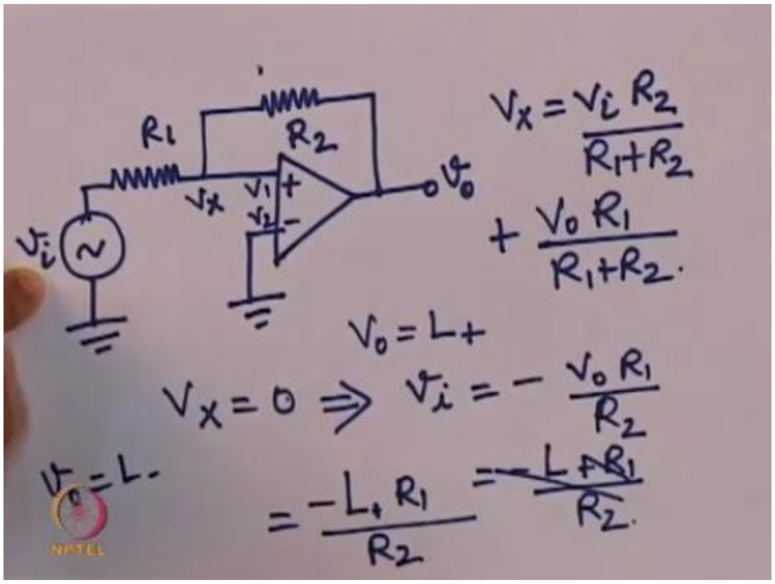

So the circuit is when the input is applied to the to the non inverting terminal in the previous case we had given the input to the inverting terminal in this case we are giving to the non inverting terminal now in this case it will be slightly different the Vx value here is a combination of Vi and V0 so Vx here will be given Vi times R2 upon R1 + R2 + the contribution of Vo is obtained by shoring Vi okay.

So in this case the contribution of Vi is obtained by shorting Vo and then seeing what is the value of Vx to find out the contribution of Vo2 Vx we short Vi and then find out the contribution of Vo so this will be VoR1 upon so this we know from the principle of superposition now initially say V0 is at the upper saturation voltage L+ so when and say L+ is positive so then Vx will also be positive okay.

Now if we keep on decreasing Vi then from this equation we see that Vx will go on decreasing and at one point Vx will go below the if I call this V1 and this as V2 at one point Vx will go below V2 that is the ground voltage and the transition Vo will transition from L+ to L- so what is that value of Vi for which Vx becomes lesser than the inverting input.

So that value is obtained by equating Vx is = 0 and the value we get is from for Vi that we get is Vi is = - V0 R1 upon R2 and since Vo is = L+ so this becomes - L+ R1 upon R2 this is not L+ R1 this is let me write it in a different way so that it is L with a small subscript + + R1 upon R2 okay so when this Va Vi becomes lesser than this value there will be a transition similarly when say V0 is = the lower saturation voltage L- and then Vx will is say negative.

So because Vx is negative so Vo will continue and Vx is negative and V2 is ground so V1 - V2 is negative and therefore Vo will continue to be in the lower saturation voltage L-, so for that to obtain the transition of V0 from L- to L+ we have to keep on increasing Vi till the value of Vi becomes = - of L- R1 upon R2.

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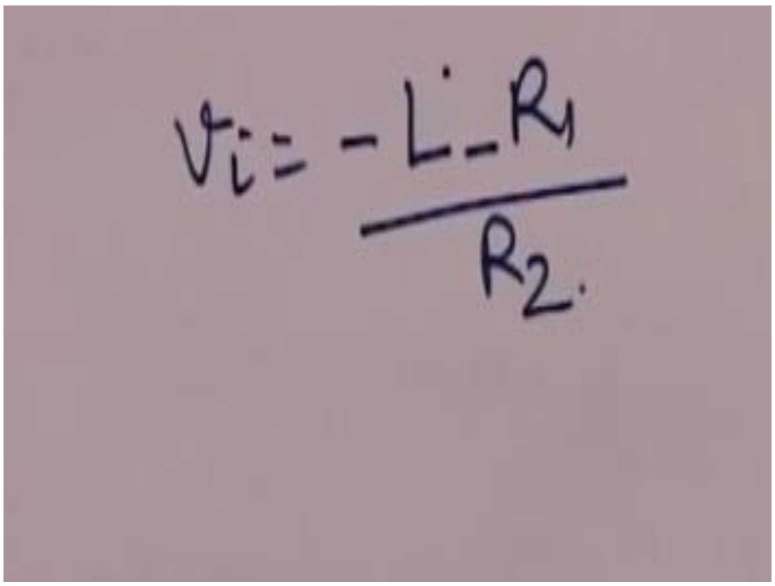

So for Vi greater than this value when Vi becomes greater than this value V1 will become more positive as compared to V2, V2 is at ground and therefore V0 will transition from L- to L+, so then graphically how does it look so we will follow the same procedure that we followed for the previous case that is when the input was given to the inverting port in this case the curve looks similar.

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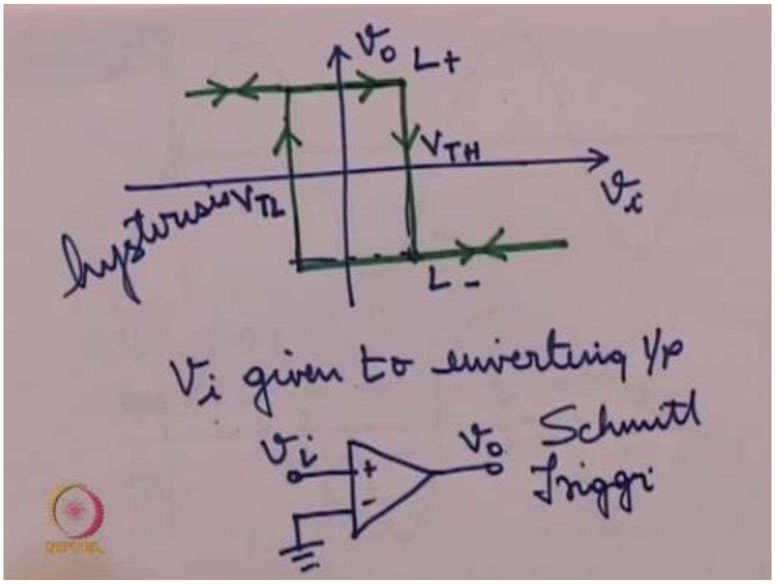

So the difference between the previous graph and this one is the way the transition is happening this is Vi given to inverting input, so in this case when Vi goes high the transition of V0 is from L+ to L- and vice versa in this case when Vi goes high the transition of Vo is from L- to L+ and vice versa now one thing I want to you know what is interesting here is that why do we have such a system after all you know if we wanted a transition between L+ and L- we could just obtained it with a like this isn't it.

This circuit will also cross a transition from L+ to L- when Vi is greater than 0 Vo will be L+ when Vi is lesser than 0 V0 will be L- why not choose such as such a simple circuit over these more complicated circuits that we are discussing to understand this let us let us see how a normal analog signal is.

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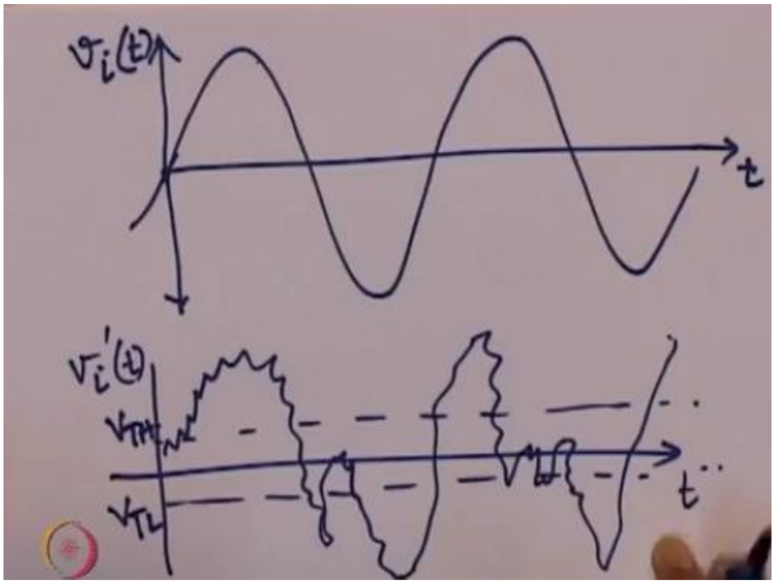

Now ideally we want a signal which is like this a very clean signal if this is the input signal okay this sinusoidal looking signal then we really do not have a problem with this circuit with this circuit that I just came here whenever my input is greater than 0 (trans) V0 will become go to the upper saturation voltage and when Vi is lesser than 0 V0 will go to the lower saturation voltage.

But in reality this kind of signals that you get are like this suppose you have your input signal like this in this case you see any time even though the general trend of this signal is downwards because of noise the signal first of all is distorted and there are occasions there are time instance when the signal actually becomes positive even though its average value remains negative.

Now in this kind of circuit if even for a moment the input becomes higher than 0 and V0 will undergo a transition which what we do not want when we have signal like this in this case whenever the average value of the signal or the mean value of this signal is lesser is negative we want the output to go to the lower saturation would so that is why in the proposed circuits that we had discussed both for the when the input is given to the inverting as well as when the input is given to the non inverting inputs of the opamp a certain gap is there between VTH and VTL.

So for this signal this would translate to something like this what we enable why this circuits is that is that even if for some noise present if suppose the out input voltage momentarily crosses the 0 mark both positive and negative but still remains within this gap VTH to VTL there will not be an abrupt transition which is anyway undesirable, so just to prevent these spurious transitions which we do not want is undesired transitions that is when for some noise suppose the signal goes momentarily high above 0 voltage even though we want even though the average value of the mean value of the signal is negative.

So for to avoid this we need such a circuit this kind of characteristics is also known as hysteresis (Refer Slide Time: 29:15) instead of calling this gap we call also call it as hysteresis that is when we are increasing the input voltage the path followed by the output voltage is different from the path followed by the output voltage when we are decreasing now this kind of circuit that we discussed just now also is referred to as a Schmitt trigger this bi-stable multi vibrator is also known by the term Schmitt trigger.

So in this module we covered the topic of bi-stable multi vibrator or the Schmitt trigger and we saw that we need to actually give a manual or physical stimuli to cause the change from one state to another, in the next module we shall cover the other types of multi vibrators, thank you.