Analog Circuits
Prof Jayanta Mukherjee
Department of Electrical Engineering
Indian Institute of Technology, Bombay
Week 07
Module 04
Multi vibrators (Contd..)

Hello, welcome to another module of this course analog circuits, so in the previous module we had talked about bi-stable multi vibrator in this module we shall be discussing about the other type of multi vibrator that I mention which is the Astable multi vibrator.

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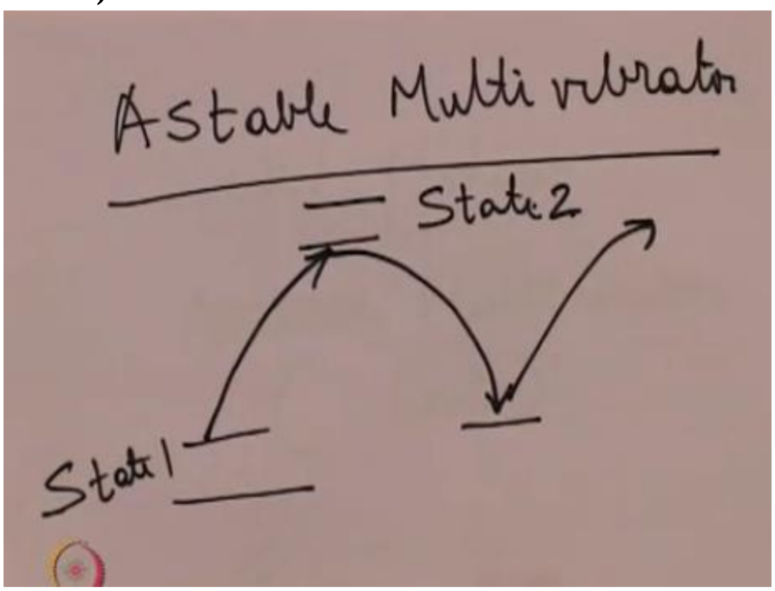

So as I had discussed in the previous modules that multi vibrators are special classes of analog circuits they are non linear analog circuits, because they do not their output is not always proportional to the input or there might be some abrupt changes in the output they might be acting linear in some regions but not in all regions of the input signal, so Astable multi vibrator and which I mention is that if this is state 1 and this state 2 then as time passes the system will transition from state 1 to state 2 and then come back to state 1 and then again go to state 2.

So it is never in any stable state in the bi-stable for the bi-stable multi vibrator, I had mentioned that there are 2 stable states that is if the system is in state 1 then it will continue to be in state 1, if the system is in state 2 if you continue to be in state 2 but for Astable multi vibrator that is not the case if the system is in state 1 it will inevitably transition to state 2 after some time it may stay stable in state 1 for some time but not for all this again benefit is if the system is in state 2 it will stay in that state for some time and then inevitably come back to state 1 so this is the theory behind the Astable multi vibrator.

Let us see how to implement such a circuit so we are discussing about circuits Astable multi vibrator using opamps there are also other ways to implement Astable multi vibrator is using MOSFET's but here for this course we will be restricting our discussions to those circuits which are based on opamps only.

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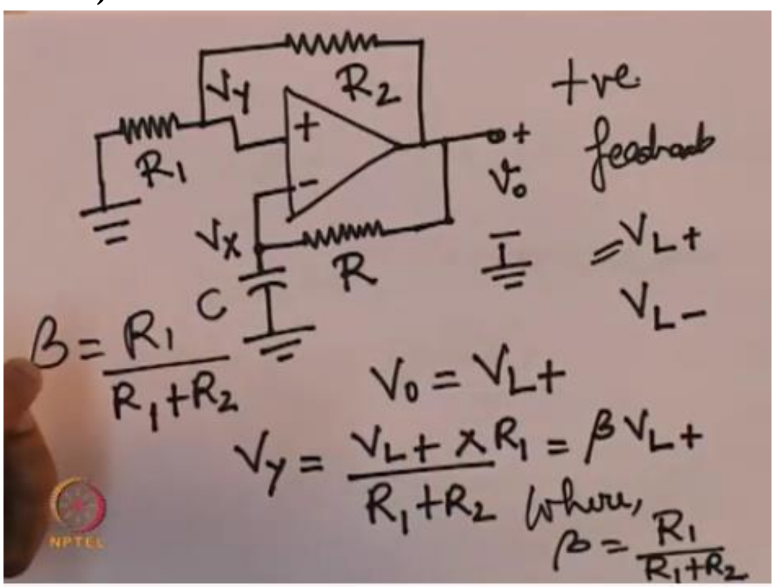

So the circuit for an Astable multi vibrator is like this, this is the circuit again we see the feedback from the output is fed to the non inverting input not to the inverting input so the feedback is positive that is the first thing to know and now in addition to the resistances we also have a capacitance C as you know capacitance is a charge storage element.

So the voltage across this capacitance is not constant it will charge or discharge depending on the voltage difference across its terminals and the voltage that it is connected to and essential this capacitance is the element that provides the necessary timing that is the timing for transition from one state to another.

So let us analyze this circuit, so the output of the opamp as we had discussed earlier it can be in one of the 2 saturation states suppose one saturation state is VL+ and the other saturation state is

VL- and say initially the output of the opamp is at VL+ then the voltage at Vy, so initially V0 is = VL+ for this value of Vo Vy will be = VL+ upon R1 + R2 multiplied by R1 and let us call this value beta this R1 upon R1 + R2 as beta so I can write Vy like this where beta is = okay and let me write it more clearly here ok what about this voltage Vx.

Now see when Vo is at the upper saturation voltage and say the voltage across C does not is a 0 or much less than that upper saturation voltage then due to this voltage difference this C will start charging and what is the equation for the voltage across this capacitance when it is charging so can I write the voltage value across the capacitance or this Vx value if we can go here.

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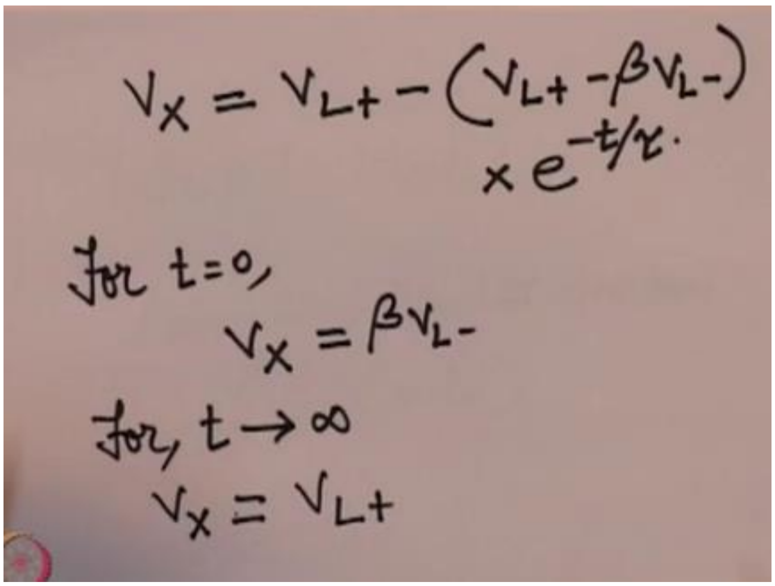

So this Vx value I can write it like this Vx is = VL+ - of VL+ - beta VL- e raise to - t upon tau, so according to this equation when time is 0, Vx will simply be = beta VL- so initially the voltage across the capacitance is beta VL- the lower where VL- is the lower saturation voltage at the output but when T tends to 0 for a beg your pardon when T tends to infinity Vx will be = it will be = VL+.

So had we allowed this capacitor to charge forever then the voltage across the capacitance would eventually be = VL + the upper saturation voltage at the output but that will not happen that will not happen because this capacitor will keep on charging this till the time Vx is lesser than Vy once Vx exceeds Vy then however because of the property of this opamp that whenever the inverting input voltage exceeds the voltage at the non inverting input the output will get reversed so the moment Vx crosses Vy the output will go from VL+ to VL- so what is the time that it will take for Vx to reach Vy value.

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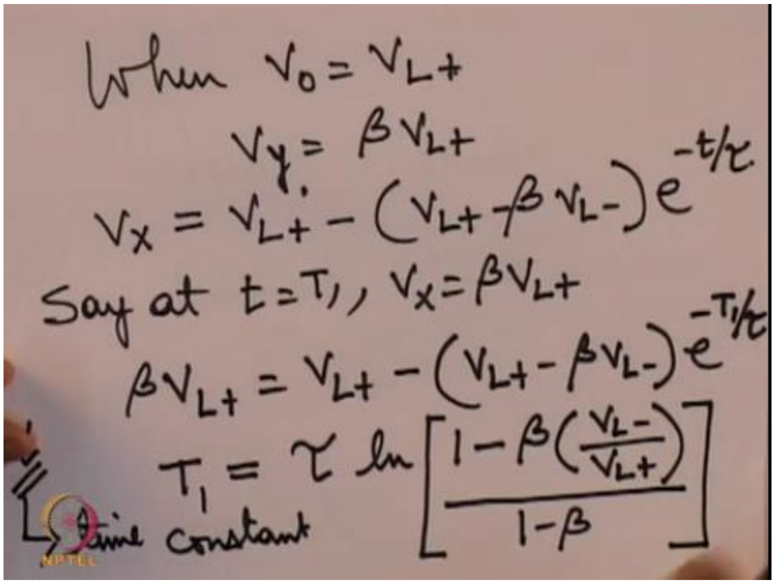

So our if we write it on a fresh sheet Vy is given by Vx is given by ok say at time T1 T = T1 Vx becomes = beta VL+ so then let me substitute that beta L+ is = VL+ - VL+ - beta VL- e raise to - T1 upon tau and the value of T1 if we solve this equation that we should get is like this like this, now here I did not mention what this Tau, Tau is called the time constant for an RC based circuit.

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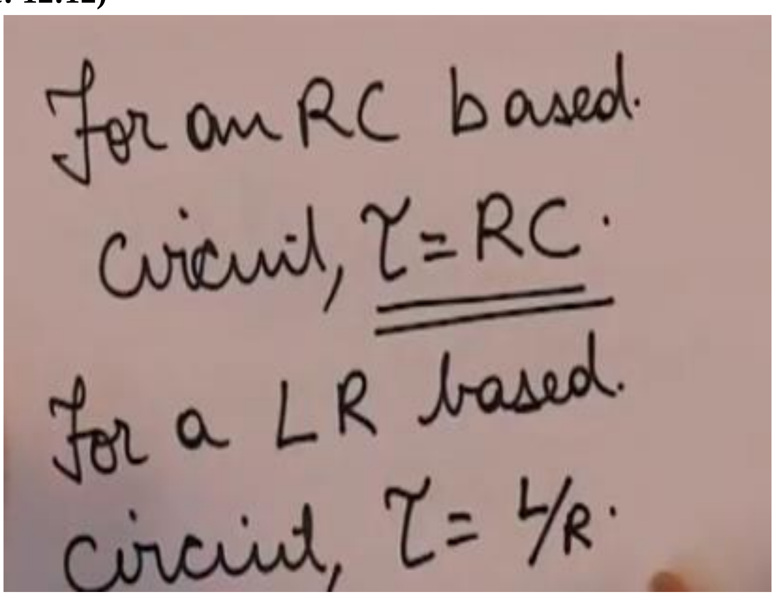

As we have in our case, tau is given by RC for LR or an inductor resistive resistance circuit tau is = L upon R so now that we have this our time constant which is = RC so let us go back to our circuit (Refer Slide Time: 12:59).

So let us come back to our circuit once again this is the circuit which we were discussing and we say that when V0 is = the upper saturation voltage VL+ Vx will keep on increasing or in other words this capacitor will keep on charging till the point where Vx exceeds Vy and then once that happens the output V0 will change from VL+ to VL- and that transition or the time taken for the capacitance to charge to Vy is given by T time capital T1 so if we plot this on a graph how will it look like.

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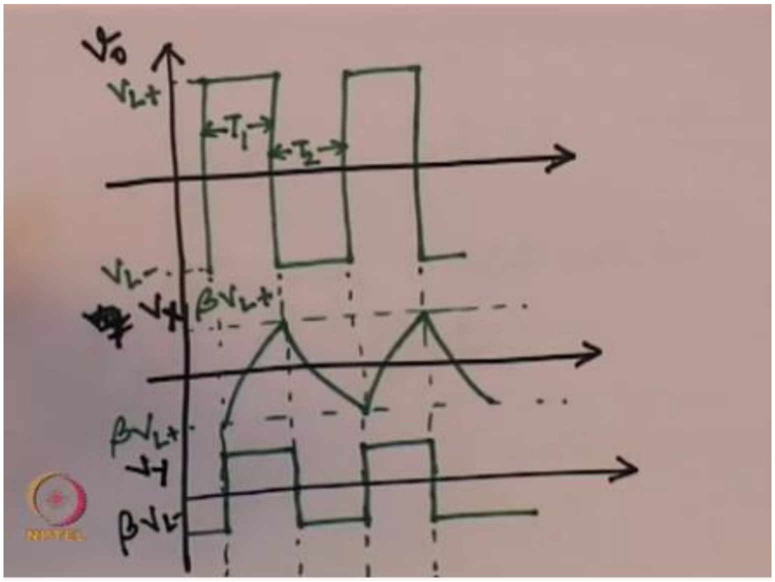

So I have my V0 I use the green pen so initially when VL is at state 1 at the upper saturation voltage or sorry I should say the V0 is at the upper saturation voltage VL+ it will remain in that state for time T1 after which it will transition to the lower saturation voltage and the corresponding Vy response will be something like this sorry this will be Vx please note this correction this will be Vx and this is Vy please note this correction this voltage that I showed here is Vx and this is Vy okay, we will come to the description of time T2 later on but for now let us see that is this Vx how Vx Vy and Vo are changing with time.

So we were discussing about the properties of this Astable multi vibrator, we saw that by this voltage when the Vo is at the upper saturation voltage the Vx or the voltage across the capacitor keeps on increasing till the point where Vx exceeds Vy and then once Vx exceeds Vy the voltage V0 goes from the upper saturation voltage to the lower saturation voltage and the time take for the Vx to reach that Vy value where the transition takes place is given by capital T1 and let us see graphically how this looks like.

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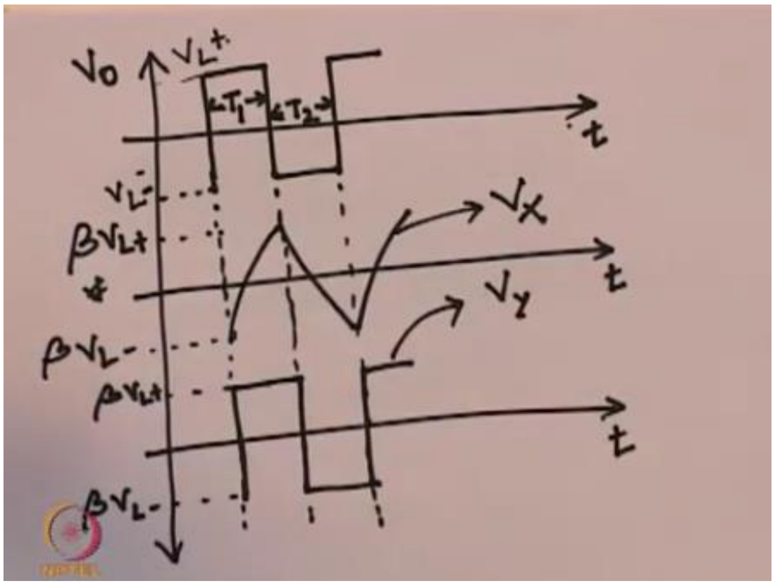

So the top graph is Vo the middle graph is for Vx and the bottom most graph is for Vy so this graph kind of shows you know the what we were discussing mathematically say initially the voltage Vx or the voltage across the capacitor is V beta VL- and you must be asking me a question why did I consider the initial voltage as beta VL- isn't it?

I mean initial voltage would have been 0 but then what happens is yet it is true that initially at the very beginning of operation the voltage across the capacitor will indeed V0 but then once it is operating it will be bounded between Vx will be bounded between beta VL + + beta VL- because in the same way that we saw that there is transition occurring when Vx reaches beta VL+ we shall also be seen that there will be another transition occurring when Vx reaches beta VL -.

So Vx can never go below beta VL- or it can never exceed beta VL+ because whenever say it goes below beta VL- the transition will happen in V0 here and it will from the state of charging or discharging it might go to a state of discharging and charging respective.

So V0 stays at this value VL+ for a total time of T1 once Vx reaches beta VL+ V0 undergoes a transition from the upper saturation voltage to the lower saturation voltage Vy also simultaneously with V0 undergoes a transition from beta VL+ to beta VL-, once Vo reaches VL - the supplied voltage to the capacitor is actually lesser than the voltage across the capacitor which is beta VL+, so once this transition happens the capacitor is subjected to an input voltage of VL- whereas its whereas the voltage across the capacitor is beta VL+.

So the capacitor actually starts discharging so what is the equation when the capacitor starts discharging, so in this phase for time T1 charges and then once the transition happens it discharges and that discharging as we shall see happens also for a certain time which we shall call T2 okay, so what is the equation for the of the capacitor during the discharging phase?

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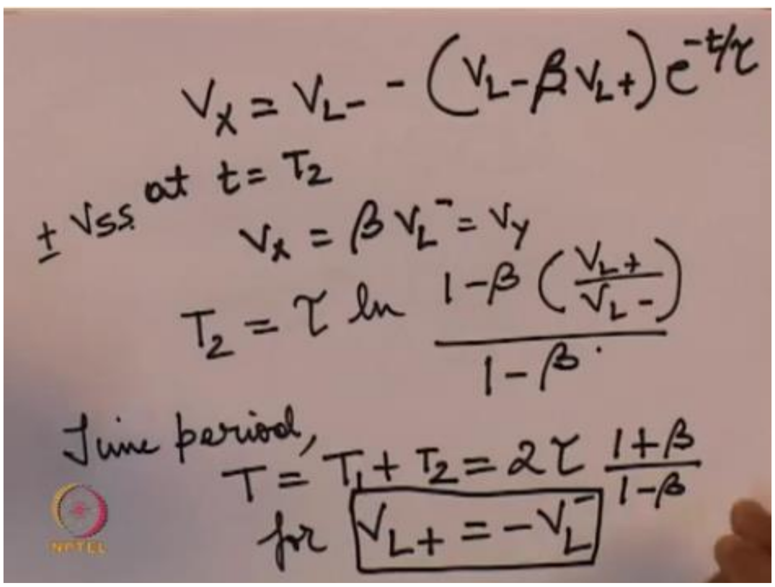

The equation across the capacitor or Vx is given by ok say at T = T2 Vx becomes = beta VL- if you go back to the circuit once again, so now Vy is = beta VL - ok the where VL- is the lower lower threshold voltage or I beg your pardon where VL- the lower saturation voltage Vx this capacitor is discharging so Vx is going down it will go down till the point again when Vx becomes lesser than Vy when there will again be a transition ok.

So we this capacitor will keep on discharging till Vx reaches Vy given by beta VL-, once that happens V0 will undergo a transition from the lower saturation voltage to the upper saturation voltage, so say at time T = Capital T2 Vx is = beta VL- which is = Vy then that T2 if you substitute T = capital T2 in this equation and then solve for capital T2 will get the value of capital T2 as.

So then what is the time period or in other words what is the total time taken for this multi vibrator to start from a certain state and come back to the certain state the time period is this time for this for the charging phase capital T1 and for the discharging phase capital T2 so the time period T capital T is given by which is given by so when VL+ is = - of VL- and the upper and lower saturation voltages and the output are the negative of each other for this condition the total time period is given by 2tau 1 + beta upon 1 - beta.

Now usually this condition is satisfied sometimes for example if the saturation voltage is same as the supply voltages and say the supply voltages are + and - Vss then usually this condition will be satisfied that is the upper saturation voltage will indeed be the negative of the lower saturation voltage.

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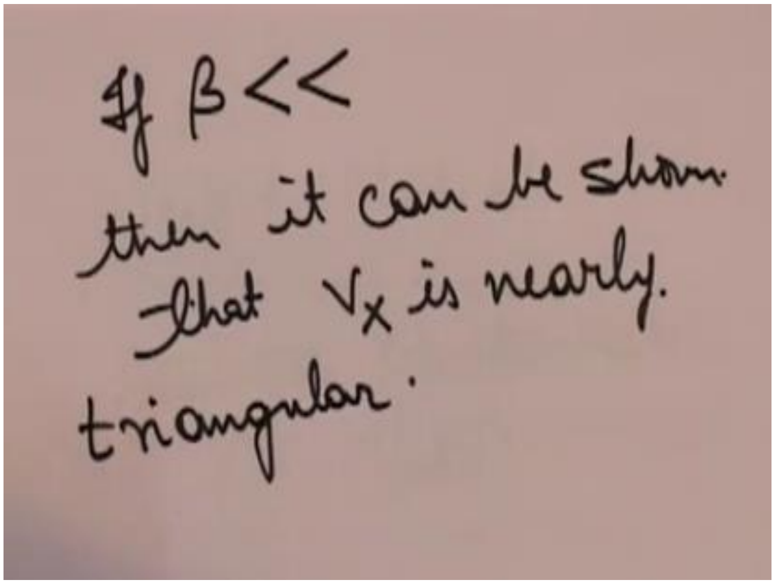

Now there is a particular condition when beta is very less, say if beta is very small then it can be shown that that Vx is nearly triangular of course it may not be perfect triangle for getting a perfect triangular waveform we need some special techniques we shall we shall discuss in a subsequent module but if beta is quite small then you know we can indeed achieve a nearly triangular output at Vx, so in that case Vx itself can also be treated as an output.

So in this module we covered the topic of Astable multi vibrator and saw that this Astable multi vibrator just the bi-stable multi vibrator has two states but unlike the bi-stable multi vibrator the 2 states are not stable that is one state if the circuit is in one state or as in our case if V0 is at the upper saturation voltage after time T1 it will go to the lower saturation voltage and thereby enforcing the sate change and then once it is Vo is at VL- or the lower saturation voltage again after time T2 it will move on to the upper saturation voltage VL+ does V0 keeps shifting from VL+ to VL- and this is periodic.

So after time T1 VL V0 will go from VL+ to VL- and after time T2 it will go from VL- to VL+ and the total time period will be the sum of these 2 time periods, in the next module we shall me covering the mono stable multi vibrator which is different from both bi-stable multi vibrator and the Astable multi vibrator in that it has only a mono stable multi vibrator has one only one stables.

So say state 1 is the stable state then if it is in the state 1 it will continue to be in that state until it is unless it is disturbed if it is disturbed it will go to the other state, state 2 but that state 2 is not a stable state that is if it is in state 2 it will come back to state 1, so that is what we will discuss in the next module, thank you.