Analog Circuits
Prof Jayanta Mukherjee
Department of Electrical Engineering
Indian Institute of Technology, Bombay
Week 07
Module 02
Oscillator Amplitude Control, Quadrature Oscillator

Hello, welcome to another module of this course analog circuits, so in the past module we had talked about you know the oscillatory circuit design using opamps and one of the oscillator topologies that we had discussed was the Wien bridge oscillator, but we did not discuss about amplitude control we had obtained certain conditions that satisfy the Barkhausen criteria but then those conditions are just the conditions that need to be satisfied for successful oscillation they do not specify what the final amplitude will be.

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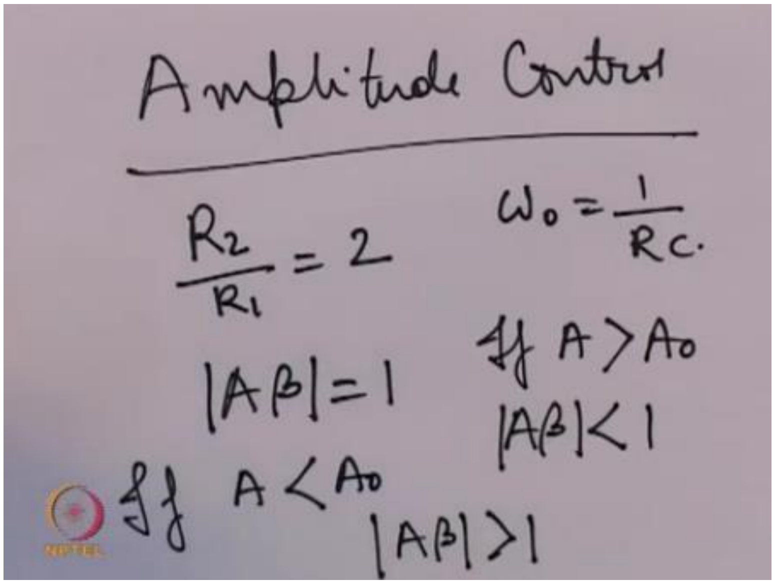

So in this module we will be discussing techniques to control the amplitude of that same oscillator, so in the last module amplitude control so for the Wien bridge oscillator we had seen that R2 upon R1 should be = 2 and the frequency of oscillation was given by RC if this condition in these 2 conditions are satisfied then the frequency of oscillation is determined but not the amplitude so for amplitude control we call that we needed to have 2 conditions that is at the point of oscillation A beta should be = 1.

However if A is greater than A0 the steady state amplitude then A beta should be lesser than 1 similarly if A is lesser than the steady state amplitude then A beta has to be greater than 1 so these how to achieve this so let us go back to our Wien bridge oscillator once again.

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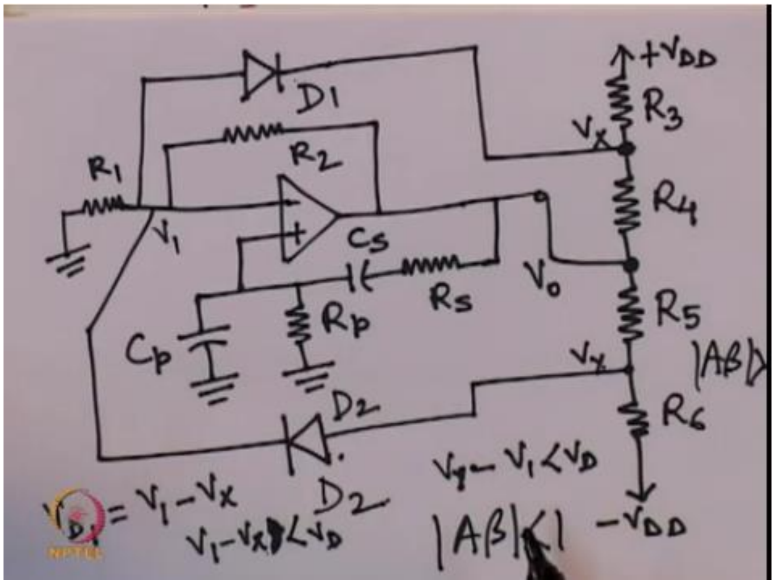

This was our Wien bridge oscillator, now to this we if we add the limiter circuit which we had discussed a few module back then the circuit that we get is something like this so that limiter had 4 resistances on this end the supply voltage was - VDD on this end the supply voltage was + VDD so this is my V0 output amplitude comes stabbed from here this is diode D2 this is diode D1.

Now for you know for amplitude control we have already discussed the following conditions right that if A is greater than A0 the steady state amplitude then A beta should be lesser than 1 if A is lesser than A0 then A beta should be greater than 1 that is if the amplitude is lesser than the steady state amplitude or the desired amplitude then the feedback should be positive in or should be such that the amplitude is that a little instability is created and the output kind of goes a little higher similarly here also when the amplitude exceeds the desired value a similar instability is needed to be created.

So that amplitude comes back to its steady state value now how does this work (Refer Slide Time: 05:42), so in this circuit as we have seen that this voltage see that diode the voltage across diode D1 if I label this voltage as say V1 then VD1 is = V1 - say I call is Vx and this I call Vy, Vx as long as Vx is greater than V1 or V1 - Vx is greater or I should say is lesser than VD as long as V1 - Vx is lesser than VD this diode will be cut off similarly as long as V1 - or Vy - V1 is lesser than VD this diode D2 will also be cut off.

Now suppose the voltage at V0 exceeds the steady state value then these R3, R4, R5, R6 are so adjusted that when Vo exceeds that value Vy will also exceed Vy - V1 will now be greater than VD and that will cause this D2 to conduct once D2 starts conducting let me write it nicely this is D2 once D2 starts conducting R5 will come in shunt with R2 and so the net opamp gain will reduce because of this shunt combination because in the feedback path we now have a shunt combination of R5 and R2 similarly when say V0 becomes lesser than certain value ok.

So this happens when V0 exceeds in the positive sense that is when V0 amplitude is more positive than the desired amplitude well on the other hand say V0 amplitude is more negative than the desired value that is on the negative half cycle it becomes its magnitude is much higher then what happens Vx goes down when Vx goes down there is a particular point when VD1 given by V1 - Vx.

Now becomes greater than VD and therefore D1 starts conducting once D1 starts conducting an effect similar to that D2 started conducting happens that is R4 will be now in shunt with R2 and because of the shunt combination of R2 and R4 that total gain of this opamp will reduce so that is how it happens okay so once when the amplitude exceeds the desired value 1 of R4 or R6 will come in shunt with R2 and cause decrease in the gain that way we ensure that the condition of A beta lesser than 1 is satisfied.

What happens when V0 for some reason becomes very low when V0 becomes very low R2 and R1 are so adjusted that actually A beta is always greater than 1 for when D1 and D2 both are not conducting then this combination R1 and R2 provides again such that A beta is greater than 1, so A beta greater than 1 means that when D1 or D2 are not conducting the tendency of this circuit will always be to keep the amplitude going higher.

However the moment the amplitude crosses the desired limit one of VA either Vx will become more negative or Vy will become more positive cause 1 of D1 or D2 to conduct and thereby bringing down the amplitude early so as a result of which the amplitude at this point remains at the desired value A0 so this is at a dynamic balance we can have an alternate implementation of this circuit as well.

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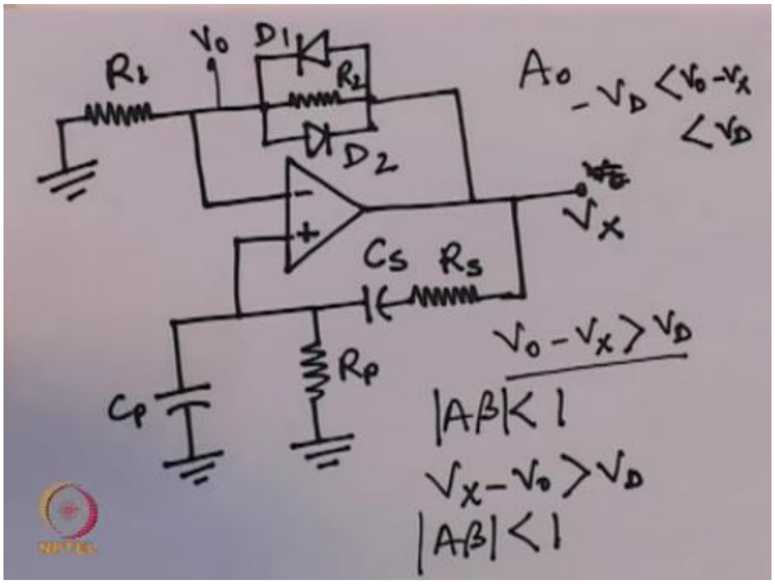

Consider this circuit, this is Vx and this circuit see this if we ignore this D1 and D2 then the circuit is exactly like the Wien bridge oscillator that we have discussed earlier the purpose of keeping these 2 diodes D1 and D2 is to provide a control on this output voltage V0 now how this output voltage works is like this so when say D1 and D2 both are not conducting then of course it will be a normal oscillator with a and suppose R1 and R2 are so adjusted that when D1 and D2 are not conducting the output is A0.

Now say for some reason V0 goes high it goes high such that V0 - Vx is greater than VD the threshold voltage of diode D2 when this happens D2 starts conducting once D2 starts conducting so this resistance R2 will be shorted by this diode D2 so once this resistance R2 is shorten the gain in the feedback loop provided by the feedback loop will be 0 and therefore A beta will become lesser than 0 and so V0 will again fall back.

If on the other hand V0 falls very low such that Vx - V0 is greater than VD then diode D1 will start conducting and again a similar event will happen or I should say you know if suppose V0 becomes more negative than such that Vx - V0 is greater than VD then also we will have A beta lesser than 1 when V0 is between these 2.

So when - VD when V0 - Vx is within this range then however our circuit will oscillate our diodes D1 and D2 will not conduct and out amplitude will be maintained at the desired value so this is also another method to control the amplitude okay so now we have obtained you know the solutions for oscillator for 2 different ways to control the amplitude of the oscillator let us now move to another type of oscillator which know as the Quadrature oscillator.

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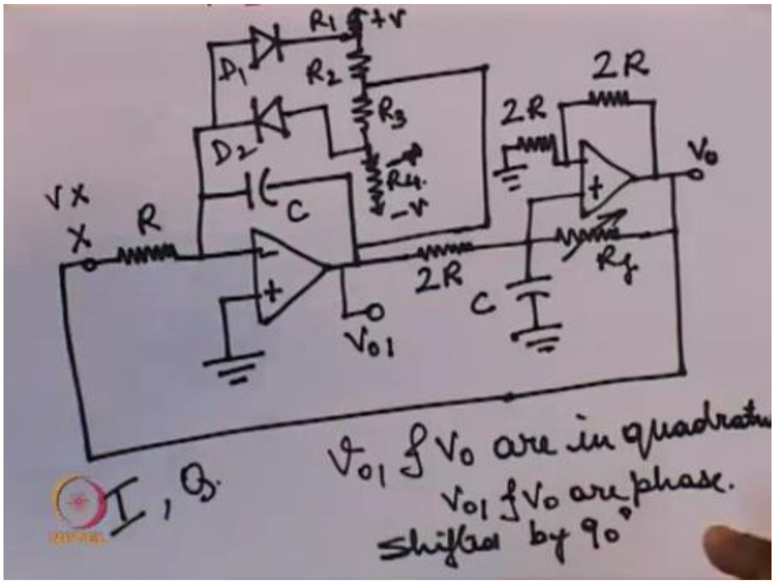

The circuit for this Quadrature oscillator is like this, let me use a fresh page so you know the reason it is called a Quadrature oscillator is because V01 there are 2 outputs here one is this Vo1 and the other is V0 so in Quadrature means V01 and V0 are phase shifted by 90 degrees in many applications such oscillator come in handy for example in communication you need to generate a I & Q signal which have to be phase shifted by 90 degree so this is an example of that there are of course many other topologies using MOSFET's, BJT's but using opamps this is one of the topologies for this Quadrature oscillator.

Now here note that this combination that you see here is just an amplitude control mechanism like the one circuit that we discussed previously so overall actually if you see then your V01 if suppose our output amplitude is kept within control then my V01 will simply be = - upon RCS times Vx.

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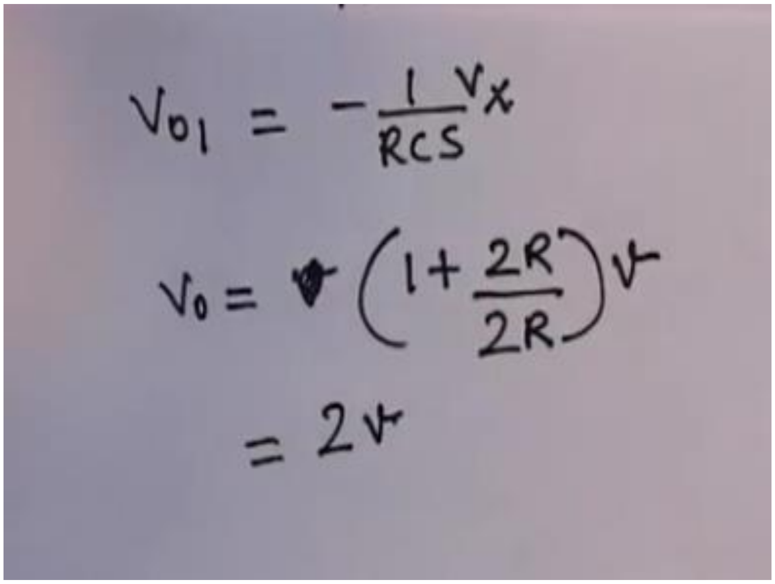

So on that and also so this is the relationship between V01 and Vx and what is the relationship between V0 and V V0 and V01 so to understand the relationship between V0 and V01 or say in order to understand the relationship between V0 and V01 let us label the voltage at this point as V so then your V0 will be = V times 1 + 2R upon 2R times V and this is written V twice and this is simply = 2V.

So V0 is = 2 times V always so then the current that is flowing through this RF see the voltage here is V and the voltage here is 2V this voltage is at a higher value provided of course V is positive so we can say that current is flowing through RF in this direction and the value of the current that is flowing is 2V - V upon RF which is = V upon RF.

So what is happening actually is that even though voltage from V01 is appearing at V but current through RF is flowing in this direction, so we can say that this RF act as a negative resistance isn't it, you usually current from V if I increase V by increasing V01 then current should flow in this direction but instead what I find is a current the current through RF is - of V upon RF if I consider current flowing in this direction so then my equivalent circuit for just this part can be written something like this.

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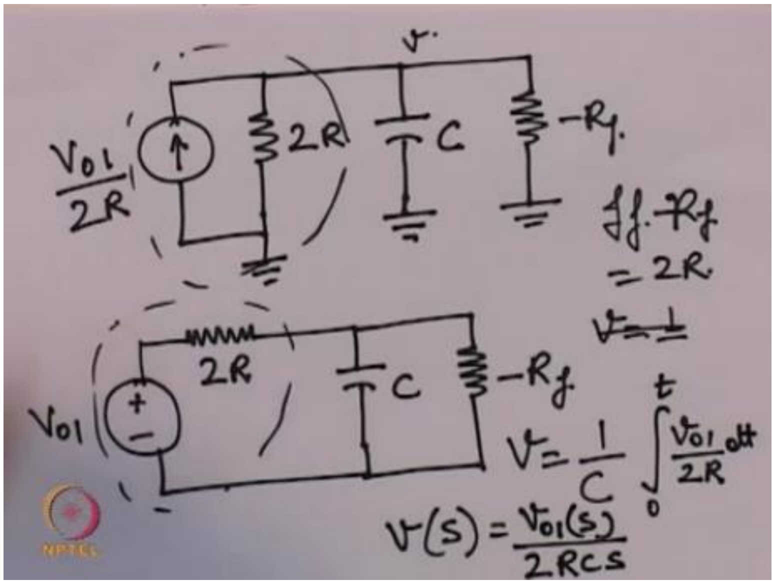

I have a current source V01 upon 2R with a resistance 2R like this followed by a capacitance C and a negative resistance Rf just to clarify how we are getting this circuit see this is a voltage source okay V01 with a 2R resistance in series, so I might as well have written this circuit like this structure that we this circuit that we obtained is the Norton equivalent of this structure that is it otherwise the rest of the thing just follow.

There is a C following this V0 and 2R combination and this Rf which actually acts as a negative resistance having value - Rf with the other end grounded okay now if this Rf is = 2R so see we have obtained this as the equivalent circuit if - Rf is = 2R then what will happen so then this resistance that appears across this capacitance vanishes and so that is the condition of oscillation.

So this Rf if we can make it oscillatory that is the resistance the shunt resistance across the capacitance becomes vanishes then the system will oscillate isn’t it then there are no losses happening and any signal that is present across any sinusoidal signal that is present across the capacitance will continue oscillate the rest of the thing that we need to provide is the Quadrature nature of the oscillator.

So for that we find that this V the voltage across this capacitance is given by V and this V is nothing but the voltage drop across this capacitance due to this current source we do not take into account this 2R or - RF because they have already been neutralized so or what is the voltage drop across the capacitor that is given by let me write it here V is = 1 by C 0 to T the current V01 on

2R dt so in Laplace domain V of S will be given by V01 of S upon 2RCS so we have now obtained a relationship between V and V01.

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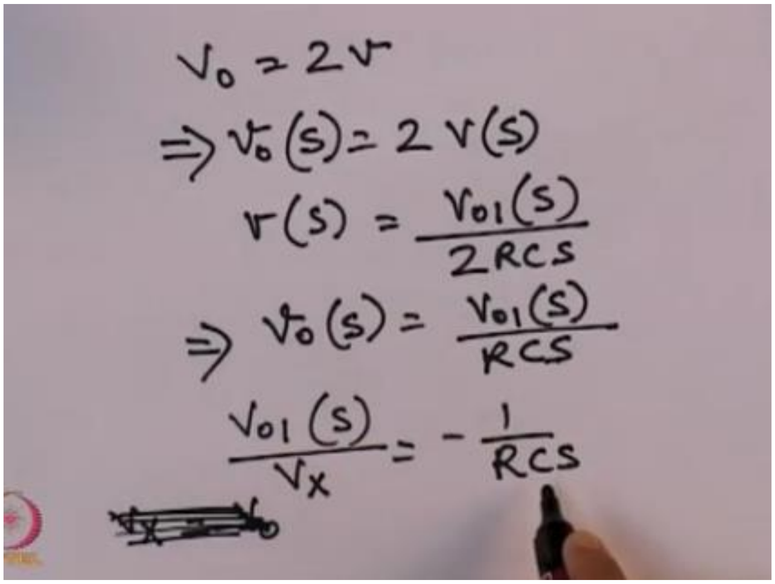

We know what is the relationship between V and Vo, we saw that Vo is = twice of V so this implies in the Laplace domain V0s is = twice of VS and since VS we just saw is = V01 of S upon 2RCS therefore this implies V0S is = V01 of S upon RCS, now what is remaining is the relationship between V01 and Vx that is so we have found a relationship between this voltage and this voltage what was the relationship between this voltage and this voltage that I had mentioned that this is just a voltage control mechanism so V01S upon Vx is nothing but 1 upon RCS and note that Vx is we have V01 upon Vx given like this okay.

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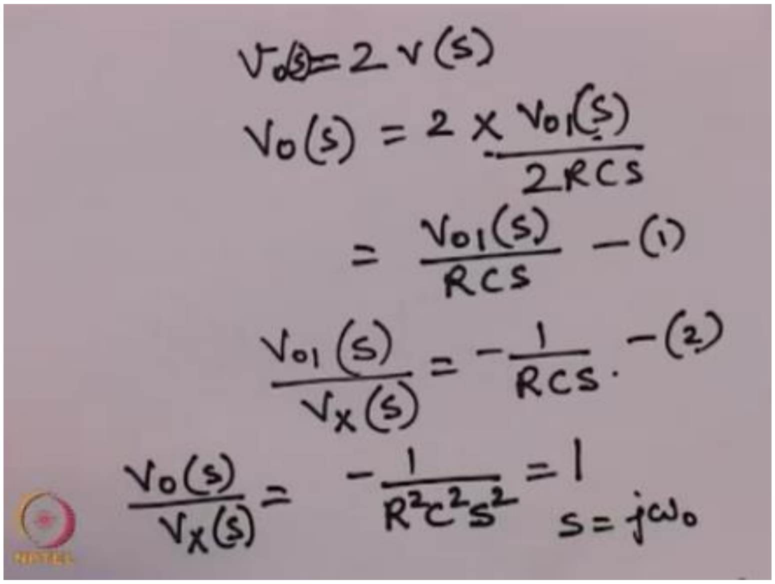

Vs is given in terms of V01 of S like this therefore so the relationship between Vo and V we already know is given like this from which we can say that that V of o S is = twice into V01 of S upon 2RCS which is = V01 of S upon RCS so this is one relationship which we got between V01 and V02 now coming to the other relationship that is between V01 and Vx so we see that the relationship between V01 and Vx is nothing but that of an integrator because this diode circuit base circuit is just for voltage control.

So V01 of S upon V of x S is = - 1 upon RCS so then from these 2 equations from equation 1 and equation 2 we can write V0 of S upon Vx of S is = - 1 upon R square C square S square of now for oscillation as you see for satisfying the Barkhouse criteria V0 should be = Vx so this should be = 1 so then from there we can see that if this relationship has to be satisfied then by substituting S = J omega 0 where omega is the frequency of oscillation we get.

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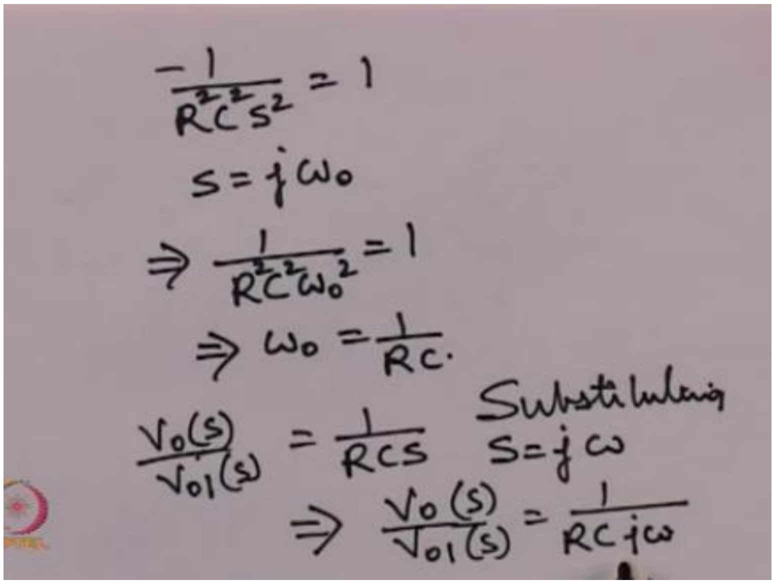

So starting from - 1 upon RCS square = 1 substituting S = J omega 0 this implies 1 upon RC omega 0 square is = 1 which implies sorry this is R square C square R square C from which we get omega 0 is = 1 upon RC so the frequency of oscillation of this oscillator is given by omega 0 = 1 upon RC.

Now did we establish the condition of Quadrature that V01 and V0 are indeed in quadrature? Yes, how did we do that because V01 we call this relationship that we just rewrite V0 upon V0V0s upon V01 of S is given by 1 upon RCS substituting S = J omega this implies V0 upon V01 of S is = 1 upon RCj omega.

So this relation clearly shows that the phase difference between V0 and V01 is indeed 90 degree as seen by this J the imaginary quantity J which is = the square root of - 1 because of the presence of this J in the denominator the phase shift will indeed be 90 degree and we have already established the way the amplitude control takes place by this diode circuit.

If say for some reason the voltage V01 exceeds the stable value then the diode D2 will start conducting and this capacitor will be shortened if on the other hand V01 is much lower or becomes more negative than the desired value then this diode D1 will start conducting and so the feedback part will be short circuited and once the feedback circuit is short circuited the this amplifies with lose its gain.

So I hope it was clear, so in this module you know we discussed a 2 different oscillator topologies the first one we had already started in the previous module in this module will be discussed about the amplitude control mechanism and then we saw for the same Wien bridge oscillator another way of controlling the amplitude and finally we saw a Quadrature oscillator were not just 1 output was produced but 2 outputs were produced and these 2 outputs were phase shifted by 90 degree or in Quadrature, thank you very much.