Integrated Circuits, MOSFETs, OP-Amps and their Applications
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Lecture – 28
RC Phase Shift Oscillator using Op-amp

Welcome to this module. In the last module, we have seen the criteria requires for oscillations, right and that in summary, we have understood the Barkhausen criteria, right. Now, in this module, let us see how we can classify the oscillators; how we can classify these oscillators.

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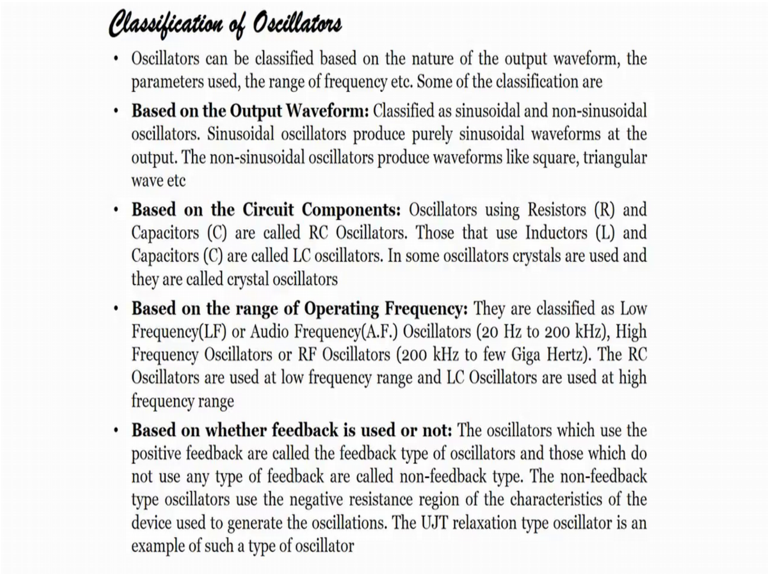

So, if you come back on the screen, what we can see is that the oscillators can be classified based on the nature of output of the waveform nature of the output waveform the parameters used the range of frequency, etcetera, right.

Nature of the output waveform parameters used a range of frequencies etcetera. So, some of the classifications are based on awesome, based on output waveform based on circuit components based on operating frequency based on whether feedback is provided or not, right, you can see very easily how the oscillators are classified. So, based on output waveform what does that mean that the classified a sinusoidal and non sinusoidal oscillators, right.

So, either it will give us the sin wave and the output or it will not give a sin wave; that means, it can give a square wave it can give a triangular wave it can give any other waves which are not sin ways. So, either sinusoidal or non sinusoidal, all right, sinusoidal or non sinusoidal oscillators produced purely sinusoidal waveforms, right, at the output non sinusoidal produce waveforms like square triangular wave etcetera easy very easy, right, then based on circuit components oscillators using resistors capacitors are called RC oscillators right resistors R capacitors is RC oscillators.

Those which requires inductors right and capacitors are called LC oscillators inductor L capacitor C; LC oscillator in some oscillators crystals are used, they are called the crystal oscillators. In some oscillators, crystals are used and these oscillators are called crystal oscillators. So, very easy to remember based on circuit components as well. Now, let us see based on operating frequency how we can classify the oscillators.

So, based on the operating frequency the oscillators are classified as low frequency oscillator or a frequency oscillator L F; A F high frequency oscillators or RF oscillators the RC oscillators are used at low frequency and the LC oscillators are used at high frequency oscillators.

So, based on frequency if the low frequency oscillator generally it will be RC oscillators if the high frequency oscillators it would be LC oscillators. So, based on the component we have seen based on the output waveform we have seen based on the frequency we have seen now let us see based on whether feedback is used or not. So, if I see based on the feedback the oscillators which use the positive feedback are called feedback type oscillators and those which does not use any or do not use any type of feedback are called non feedback type oscillators.

The non feedback oscillators use the negative resistance region of the characteristics used to generate the oscillation, the UJT relaxation oscillator type of oscillator is type of this example of such type of oscillator which is the non feedback type oscillator, all right. So, these are the types of or classification of the oscillators.

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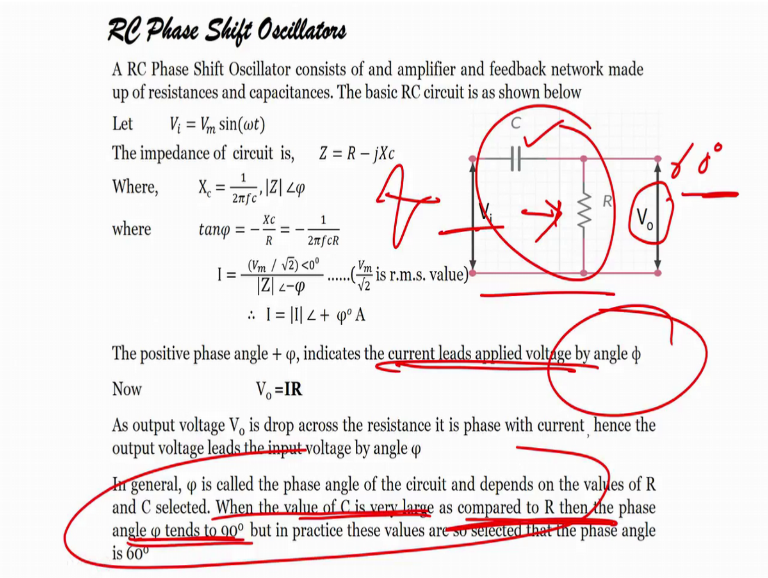

Now, let us see first oscillator that is our RC phase shift oscillator RC phase shift oscillators.

What are RC phase shift oscillators a RC phase shift oscillators consists of an amplifier and feedback network made up of resistors and capacitances the basic RC circuit is shown here right now let us see let us see what is V o equal to V 1 into find V o. So, if I say my input signal is V m sin omega t the impedance of circuit would be R minus j omega c correct where f c equals to 1 by 2 pi f c.

So, tan of phi minus f c by R or minus 1 upon 2 pi f c by R, right f c is what one upon 2 pi f c. So, tan phi plus 1 is f c by R or this value. So, I would be nothing, but this value correct; that means, what we see that when we have equation like this the positive phase angle indicates that the current you see here it is positive so; that means, indicates z the current leads applied voltage the current leads the applied voltage by angle phi ok.

The positive phase angle indicates that the current leads the voltage by phase angle or by angle phi. Now V o equals to I R, right, easy and the output voltage V o is drop across the resistance, it is in phase it is phase with current as the output voltage leads the input voltage by angle phi in general phi is called the phase angle of the circuit and depends on R and c selected.

So, what we understand from this everything, this whole slide is that in this particular phase since the current is leading the applied voltage by an angle phi what we find is that the when the c is very large as compared to R the phase angle tends to be 90 degree; that means, with one R and c.

If c is extremely high then RC is extremely high than your R then my phase shift would be 90 degree phase shift would be 90 degree at the output, but in practice the values are selected such that 1 RC will provide us phase shift of 60 degree.

But the values are provided such that one RC provides a phase shift of 60 degree.

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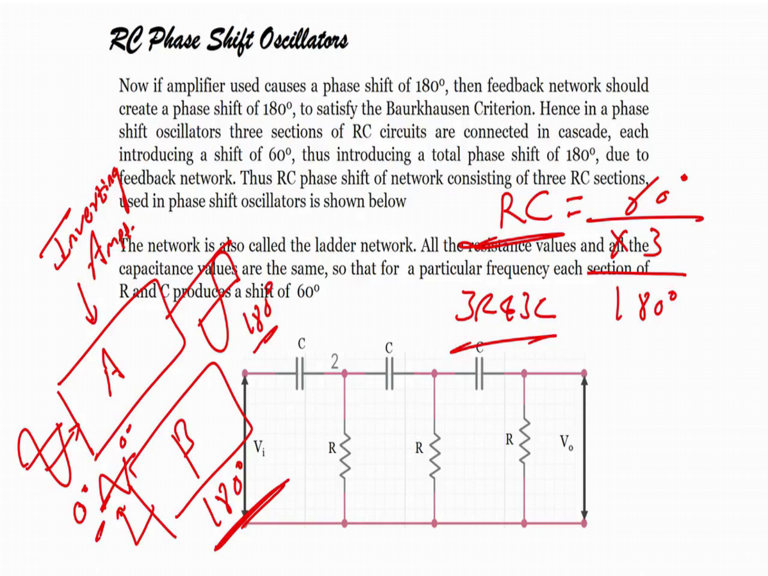

So, if I want one RC is 60 degree. So, if I have a amplifier that is my inverting amplifier inverting amplifier, right if I apply a signal, then my output would be 180 degree out of phase, this is 0, this is 180 degree; that means, my feedback should produce another 180 degree phase shift. So, that my feedback signal will also be 0 degree, correct, this we have seen.

Now, one RC we have seen in last slide will we will we will adjust the value such that it provides 60 degree phase shift. So, how many RC circuits are required to provide 180 degree very easy right 60 into 3 180 degree; that means, we require 3 R and 3 C, we require 3 R and 3 C. This is what is shown in this slide this is what is shown in this particular slide, right.

Let us see what is shown let us see once again, if the amplifier used causes a phase shift of 180 degree the feedback network should provide 180 degree to satisfy the Barkhausen criteria right because Barkhausen criteria is that the input phase should be the output feedback provided back to the input of the oscillator should be 0 degree in phase or 360 degree in phase, right.

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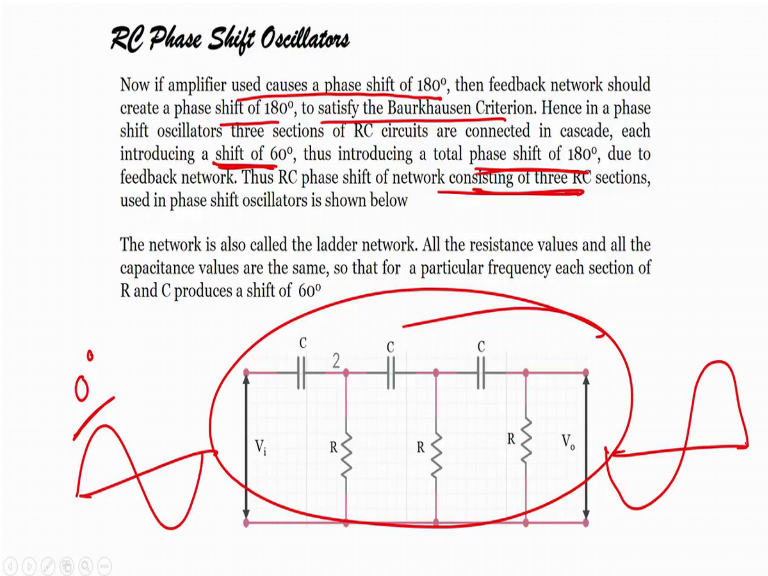

Hence, in a phase shift oscillator 3 R sections of RC circuits are connected in cascade each introducing a phase shift of 60 degree each introducing a phase shift of C 60 degree does introducing a total phase shift of 180 degree this is what we have discussed right thus RC phase network consists of 3 RC sections as shown below which is shown right over here.

So, if I have a signal at the input my output would be 180 degree out of phase and 180 degree out of phase or in another way if I because this circuit, this is a beta there is feedback network this is a case is nothing, but my beta, right.

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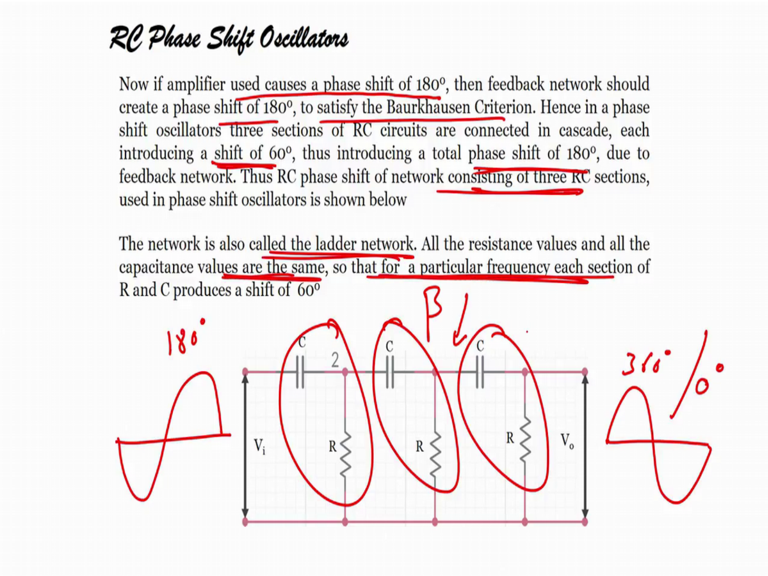

This one is my beta. So, if I apply output voltage which is 180 degree of phase shift or out of phase with input then my feedback to the input will again be a 0 degree because 180 plus 180, this is 60 from here, 60 from here 60 from here.

So, 180 degree phase shift it becomes 0 or 360 degree phase shift right the network is also called a ladder network all the resistance value all the capacitor values are same. So, for a particular frequency each section of RC produces a phase shift of 60 degree, right guys, very easy.

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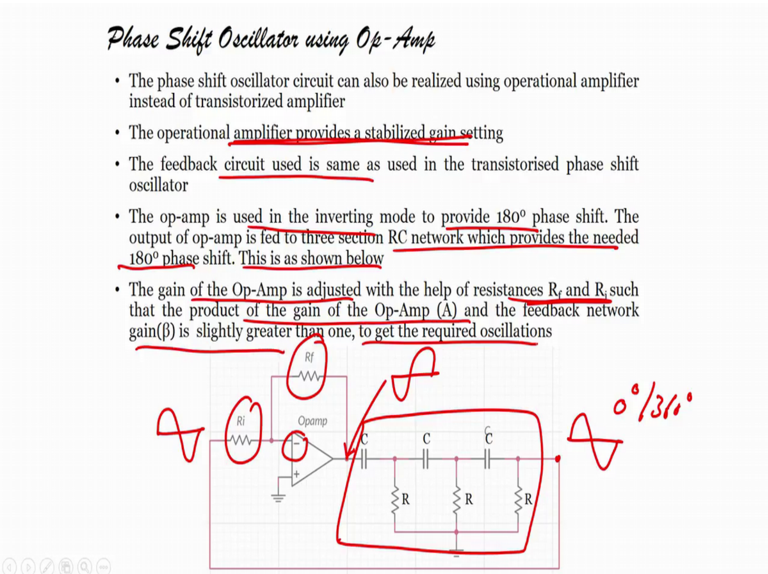

So, if I want to design a phase shift oscillator using an operational amplifier if I want to design a phase shift oscillator using an operational amplifier, how will I design the phase shift oscillator can also be realized using op amp instead of transistorized amplifier op amp provides a stabilized gain setting the feedback circuit used is same right you can see here if I use transistor base amplifier then in also.

But if I have what we are studying is op amp base amplifier. So, this is the op amp now here the advantage is that that I can change the amplification factor by changing the value of RF and R I another point is whatever the I introduced phase my output at the op amp that is here, I will have a 180 degree phase shift because it is a inverting amplifier. So, this 180 degree phase shift is provided to my RC network.

So, here at this point, I will have phase shift of 0 or 360 degree right this is what is written the op amp is using used in inverting mode providing 180 degree the RC network device provides the 180 degree phase shift, this is shown in figure.

The gain of the op amp adjusted with the help of resistors RF and R I such that the product of gain of op amp and the feedback network is slightly greater than one to get the required oscillations; that means, what he said that the same thing again and again we will say in a different fashion that to start the oscillation initially my A into beta is crap greater than one.

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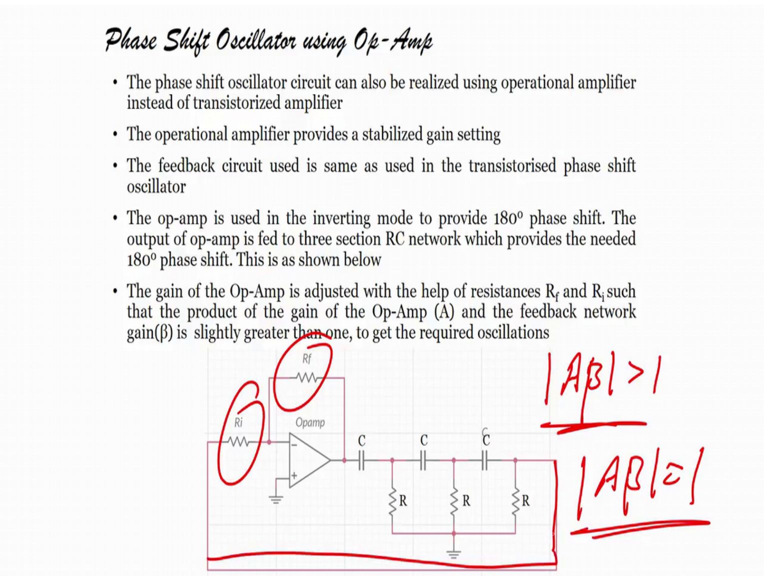

Once the oscillations are is by a beta should be equal to one right. So, this you can change by changing the value of RF and R I, this you can change by changing the value of RF and R I, this feedback here it is connected here its connected here through the from output to the input from output of the beta that is feedback network to the input of the oscillator.

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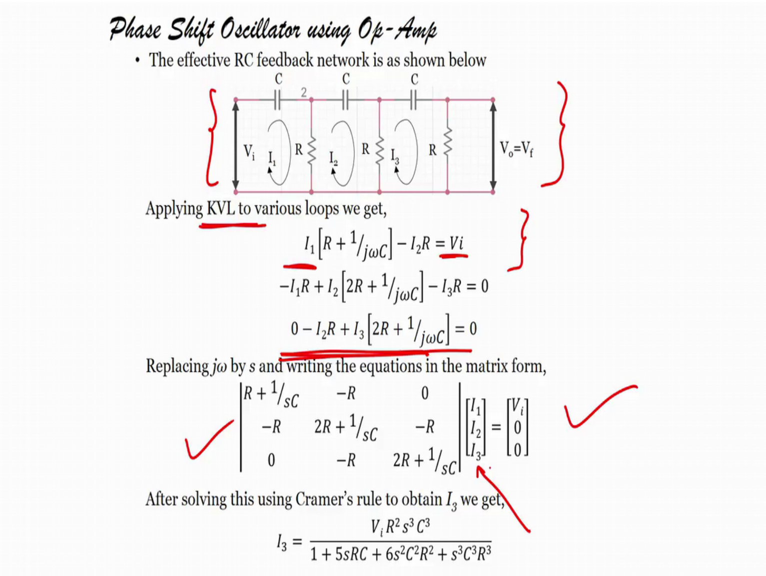

So, the effective RC feedback network is shown in figure here right. So, this is V I, this is V o equals to V f. So, applying k V L to various loop what we have what we will have is I 1 into R plus 1 by j omega c minus I 2 R equals to V i right now if I solve this thing if I solve this equation, what will I have; what will I have this in particular equation.

If I keep on solving this I will have this 3 equation. Now if I replace j omega by s and write the equation in the matrix form, then I can write in this particular format right. Now everybody should know the Cramer's rule. So, using Cramer's rule, I can understand what is I 3, I can understand what is I 3.

So, to obtain the value of I 3 we have to use Cramer's rule and then we can get I 3 equals to this particular value.

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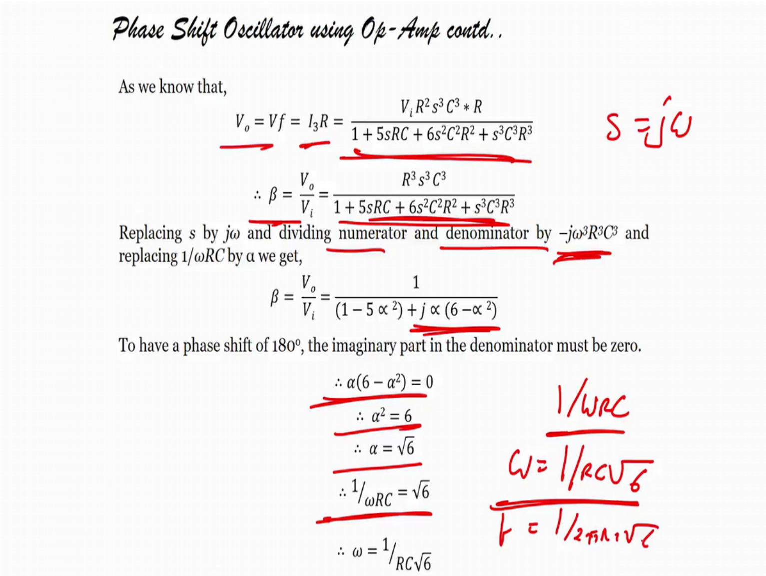

Now, as we know that V o equals to V f is I 3 into R. So, if I substitute the value, then we have beta equals to n beta equals to V o by V i, I will have this value. So, replacing s by j omega because we have considered s equals to j omega right here.

So, we are replaced by j s equal to j omega and dividing numerator and denominator by this particular value we will have beta equals to this equation right now again what we had to understand to have a phase shift of 180 degree the imaginary part of the denominator must be 0.

What is imaginary part imaginary part is imaginary part in the above equation is this part right. So, alpha into 6 minus alpha square equals to 0 alpha square equals to 6 alpha equals to root 6 then what is alpha? Alpha is nothing, but one by omega RC right because we have used alpha instead of one by omega R c. So, we have one by omega is equal to root 6 or omega equals to 1 by RC under root 6 right.

So, what is omega? Omega is right omega n f. So, f equals to 1 by 2 pi R over root 6 right you see omega is 1 by RC, right. So, I can write f equals to 1 by 2 pi RC root 6 correct. So, that we are substitute.

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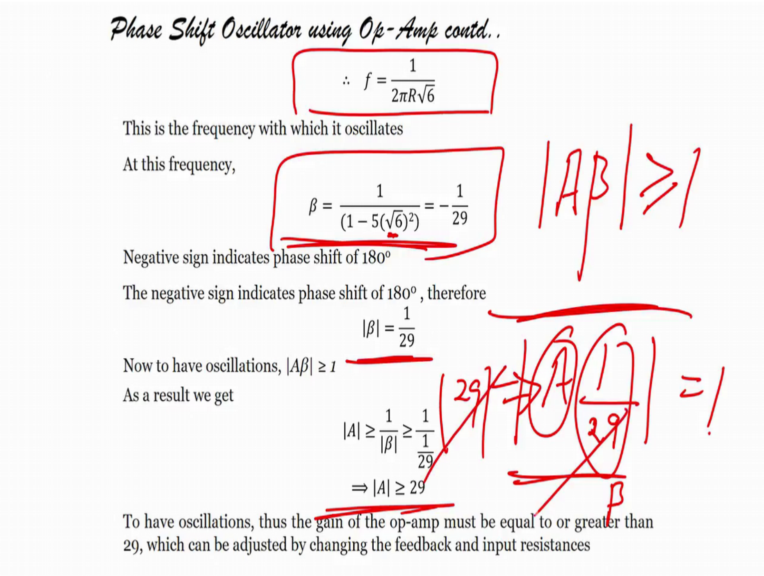

Now, this is the frequency at which the oscillator will oscillate this is the frequency at which the RC phase shift oscillator will oscillate.

Now, at this frequency beta is nothing, but 1 minus what is alpha? Alpha is root 6. So, we have beta equals to minus 1 by 29 beta equals to minus 29, you understand see from here applying k V L, what we get we get this equation. Now if you rewrite the question from a matrix we can get this equation from here using Cramer's rule we can get I 3, once we get I 3 we can get V o from V o, we can get beta from beta we can get the value which is this.

Now, to have phase shift of 180 degree, the imaginary term should be 0 when we do that we can get value of alpha and then we can have also have formula for f from formula of f and substituting the value of alpha in the equation, then what will I have? I will have beta equals to 1 by 1 minus 5 under root of 6 whole square equals to minus 1 by 20, but I know that my Barkhausen criteria will be satisfied only when a beta equals to 1, right.

So, if my beta mode of beta is 1 by 29, should be greater than equal to 29 right because my beta is 1 by 29 right. So, how can be equal to one this value this is nothing, but my beta right. So, how this more can be equal to 1 when my a should be equal to a would be 29, 29, 29, gone equal to 1, right. So, that is what is shown that if my beta is 1 by 29, my gain a would be greater than 29, right.

So, do have oscillations the gain of op amp must be equal to or greater than 29 which can be adjusted by changing the which can be adjusted by changing the feedback and the input resistances. So, what we have seen in this particular module is that for the RC phase of oscillator all right what are we have seen in this module and this is a last side of this particular module we have seen that for the RC phase shift oscillator we can design an oscillator.

If we have an inverting amplifier we have to use 3 R and 3 C to obtain a phase shift of 180 degree because 1 R and 1 C will give us 60 degree phase shift, then we have seen that for the frequency the frequency for the phase shift oscillator using R and C, we have frequency formula 1 by 2 pi RC into under of 1 by 2 pi R under root of 6, then we have also seen that to sustain the oscillations our a into beta should be equal to greater than or equal to 1. So, from the solving the equation; what we find is if we found that beta equals to 1 by 29.

So, if I have the formula a beta is greater than or equal to one my gain should be equal to 29 right thus we know that whenever you have a phase shift oscillator your a or gain should be 29 and your beta should be 1 by 29, you see again that the important point is beta is extremely small compared to your gain value right if 29 beta is 1 by 29 and another 1 is the phase shift of 180 degree.

Why 180 degree because we have used inverting amplifier right we have used inverting amplifier. So, RC phase shift 3 RC will give us one degree inverting amplifier 180 degree 180 plus 180 360 degree that is provided back to the input Barkhausen criteria is satisfied second one is a beta equals to 1 satisfied. So, satisfying both the criteria, we can now understand how we can design an RC phase shift oscillator.

We can understand how we can design an RC phase shift oscillator we will also see few examples of the oscillator in the experimental part. So, you actually see that how we can how we are designing and how we are getting the output at the oscillators when we do not provide any input. So, initially we will have a beta greater than one and then it becomes a beta equals to 1, right.

So, now in the next module what we will see? We will see another class of oscillator that is called a Wein bridge oscillator, all right the next module what we will see another class of oscillators that are called Wein bridge oscillator. So, what are Wein bridge oscillators;

we have we will see in the next module, till then you just see this RC phase shift oscillator and its functioning.

So, then you read this stuff and I will see you in the next class, bye.