Integrated Circuits, MOSFETs, OP-Amps and their Applications
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Lecture – 29
Wein Bridge Oscillator using Op-amp

Welcome to this particular module and the lecture is on oscillators. So, what we are seen in oscillators? We have seen the criteria that Op-amp can be used in such a way that instead of amplifying, it will start oscillating. So, what are those criteria? This criteria were called Barkhausen criteria right that was we have seen in the last module.

So, to quickly recall what is Barkhausen criteria Barkhausen criteria is that we have a open loop gain equal to 1 or gain equal to 1 and feedback factor. So, gain into feedback should be equal to 1 right that was the criteria gain into feedback should be equal to 1.

So, mode of a into beta equal to 1 that is what we have seen; second thing what we have seen is the phase shift, the phase shift that is the voltage from the output which is fed through the feedback network back to the input that should be in phase. The output voltage with this fed to the input of the oscillator should be in phase with the input signal right.

So, the phase should be 0 degree two things we are seen incorrect; then we have seen that if I have an amplifier which is an inverting amplifier, in that case if I apply a input signal the output signal will be out of phase with respect to input signal that is 180 degree out of phase. So, what can I do? I have to again change a phase so, that 180 degree phase shift one more we have to add that comes through the feedback network.

So, output is 180 degree feedback is 180 degree. So, the total is 180 plus 180 that will be 360 degree or 0 degree; that means, your output part of the output voltage which we have fed back to the input is 0 degree correct. So, we have seen that kind of oscillator and that was our that was our phase shift oscillator right and we have seen that in the phase shift oscillator we had three R and three C because we have adjusted the value of R and C such that each R and C will give us 60 degree phase shift.

So, if we use inverting amplifier in phase shift oscillator we had 180 degree output this three R C will give us further 180 degree. So, when we feed back through this R c; we will get 0 degree or 360 degree we have seen that right and we have also seen an example.

Now, today let us see let us see another kind of oscillator another kind of oscillator and that is called Wein bridge oscillator Wein bridge oscillator. In this oscillator there the output is in phase with the input; the output voltage output signal is in phase with the input; that means, there is a feedback network should not give any kind of a phase shift right because same phase is at output, we have to feedback let us say this is a feedback network we have a output right this is a feedback network.

Now, you have this amplifier it goes it comes back it feeds the feedback network comes back right. So, this what we have seen if you if you come to the screen I can explain you in better way.

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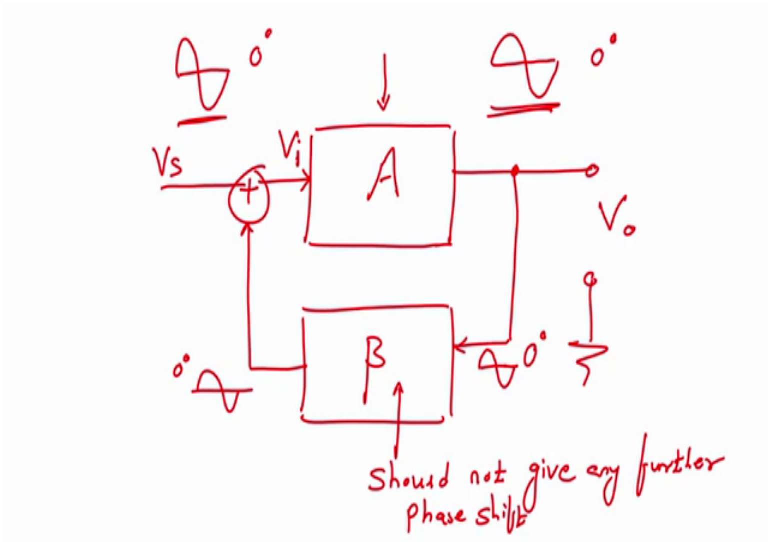

So, what I am showing you here is that you have a amplifier you have an amplifier you have a feedback network correct and you have this signal that is your V S this is your V i this is coming from the feedback network beta, this is your amplifier and this is your output voltage; part of the output voltage is feedback to the feedback network we have seen that right we have seen this.

So, what I am saying is if your amplifier right. The amplifier has no phase shift the output is in phase with respect to input; then this beta should not give should not give any further phase shift. Because the signal the part of the signal that we have providing back to the input right that is also 0 degree. So, the signal that is coming over here should also be 0 degree.

So, this kind of amplifier where there is a phase at the output the output signal is in phase with respect to input we will see this kind of oscillator in which the amplifier will not have any kind of phase shift ok. So, let us see that kind of oscillator that is called Wein bridge oscillator.

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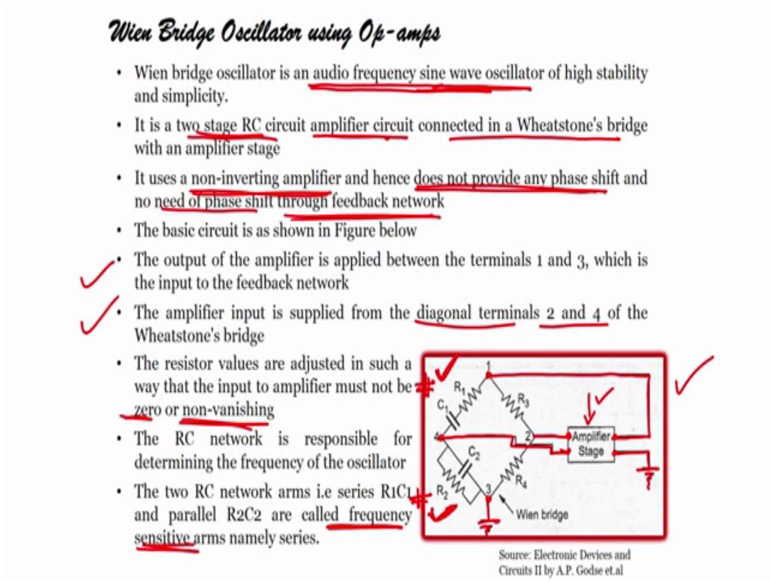

What is called Wein bridge oscillator these are circuit we have used electronic devices and circuits for taking the particular schematic. Now Wein bridge oscillator is an audio frequency sine wave oscillator of high stability and simplicity ok.

So, it is an audio frequency sine wave oscillator audio frequency sine wave oscillator it has two RC stage right two stage RC amplifier circuit connected in a Wheatstone bridge connected in a Wheatstone bridge with an amplifier stage right. So, we see there is one RC here there is one RC over here and there is a amplifier stage correct.

So, you have two RC circuit connected to the amplifier stage ok; next one we have to remember is it uses a non inverting amplifier. So, one it is non inverting amplifier the output will be in phase with respect to the input correct. So, it uses a non inverting amplifier hence does not provide any phase shift you see right. So, no need of phase shift through the feedback network

Since it has no phase shift; the feedback network should not also provide any kind of phase shift this circuit is shown here. The output of the amplifier is applied between terminals 1 and terminal 3. So, you see terminal 1 terminal 3 right this is the you see where is connected this connected to the output of the amplifier right output of the amplifier because this is grounded right. So, this is grounded you see amplifier is also grounded right output amplifier.

How we this is how we take the voltage. So, the output of the amplifier is connected to one between terminal 1 and 3 that is what it is written here. Second is the amplifier input is supplied from the diagonal terminals you see the input of the amplifier the input of the amplifier is supplied from where from 4 and from 2; from 4 and 2 right

So, amplifier input is supplied from diagonal terminals two and four of the Wheatstone bridge right. The resistor values are adjusted in a way that input amplifier must not be 0 or non vanishing right the RC network is responsible for determining the frequency of the oscillator. So, RC network there is two RC network; first one is here second one is here this RC network are responsible for determining the frequency of the oscillator right. So, the two RC network arm that is R 1 C 1 in series this is the one right and second arm that is R 2 and R 2 and C 2 in parallel you can see this one are called frequency selective arms what is called frequency sensitive arms because that two arms are responsible for selecting the frequency of the oscillator ok.

So, what will learnt about the Wein bridge oscillator? That this Wein bridge oscillator is a is used as a audio frequency sine wave oscillator, second thing is that the two RC amplifier circuit is connected in Wheatstone connection, third thing is the amplifier is a non inverting amplifier, fourth thing is the output is feedback output is feed to between the terminals 1 and 3, fifth thing is the input of the amplifier is applied between 2 and 4 right.

Then next one is resistor values are adjusted in a way that input to amplifier must not be 0 or non inverting must not be 0 or non inverting ok. So, that are the few points that we have to remember and finally, what we have to remember that the R and C network is responsible for determining the frequency of the oscillator. So, if you understand this.

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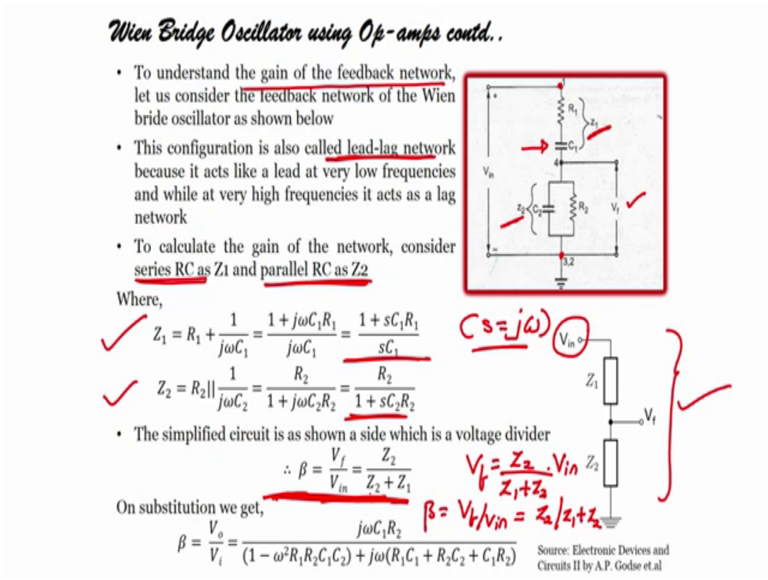

Then let us first look at the let us first look at the feedback network. So, what was the feedback network one R and C in parallel second R and C in series right. So, one you see R 1. C 1 this is our Z 1 R 2; C 2 this is our Z 2 right input voltage is fed between terminal 1 here and here output was a voltage between 4 and 2 you can see here this is your feedback voltage correct these are feedback voltage to the amplifier. So, to understand the gain of the feedback network; to understand the gain of the feedback network let us consider this particular feedback network as shown in figure, this conversation is also called lead lag network lead lag network.

So, you can you can be ask you know oscillators in which the feedback is lead lag then you can say yes we have seen an oscillator which is called Wein bridge oscillator; in which the feedback is a lead lag network because it acts like a like a lead at very low frequencies while at higher frequency it has a lag network. So, it is very obvious right from the circuit at low frequency it will have a lead and at higher frequency it has it will have a lag.

Now let us consider the gain of the network. So, what is the gain of the network? For understanding the gain of the network we have to understand that this RC series RC acts as Z 1 and parallel RC acts as Z 2 what we have to understand series RC would act as Z 1 and parallel RC would act as Z 2 ok.

So, where Z 1 is what will be Z 1? If I write Z 1 would be R 1 plus C right capacitor is 1 by j omega C 1. So, if I solve this what will I have? I will have 1 plus s C 1; R 1 divide by s C 2 right where s is nothing, but j omega s is nothing, but j omega here we are consider s equal to j omega. Same way for Z 2 Z 2 is parallel R 2 is parallel to C 2. So, Z 2 is R 2 parallel to C 2; when you solve this you can again restore this equation where Z 2 is nothing, but R 2 divide by 1 plus s C 2 R 2 where s is nothing, but j omega ok.

So, it looks like this one right it looks like Z Z 1; Z 2 and then V f and then V m. So, the simplified circuit is shown which is shown right over here this is what? This is nothing, but your voltage divider right if you have two resistors you are dividing it C voltage divider potential divider circuit.

So, if I want to measure the voltage right. So, b beta is nothing, but V f by V in is nothing, but Z 2 plus Z 1 Z 2 divide by Z 2 plus Z 1 right how? So, because you see V f equals to Z 2 by Z 1 plus Z 2 into V in right into V in.

So, what is my beta? beta is nothing, but V f divide by V in which is nothing, but Z 2 divide by Z 1 plus Z 2 this is what is written here correct this is what is written here. Now let us substitute the values of Z 1 and Z 2 right let us substitute values of Z 1 and Z 2; what is Z 1 Z 1 is 1 plus s C 1 R 1 divide by s C 1; Z 2 is R 2 divide by 1 plus s C 2 R 2 right. So, if I substitute this values of Z 1; Z 2 into beta what will I have beta equal to beta equal to V o by V i equals to.

So, I substitute this values and then I substitute j omega instead of s right this s is replaced by j omega wherever it is there it is here it is here right. So, I am replacing it; so, what will I have ? I will have this particular equation which is shown here right this one correct.

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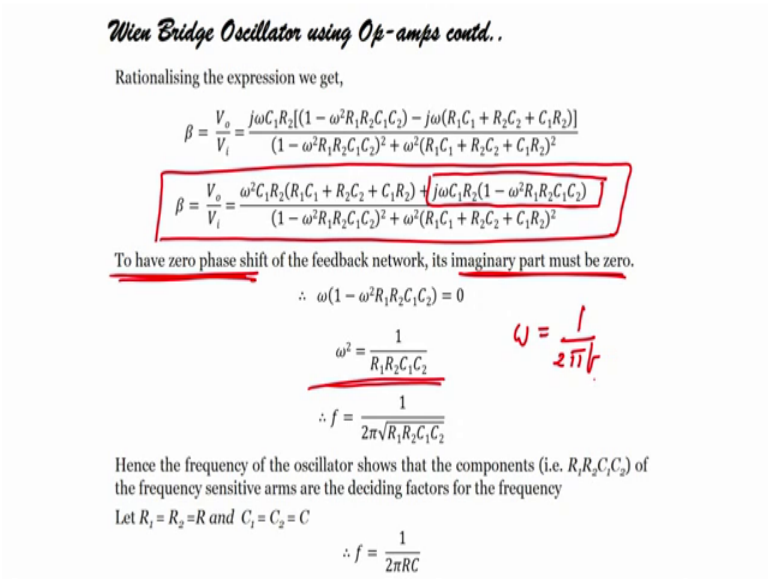

And then if I rationalize this equation; If I reutilize this equation then we can get we can get this particular equation right. You solve it you will get this equation now what is a what are the Barkhausen criterias? The Barkhausen criteria is to have 0 phase shift right 0 phase shift what we what we have learn earlier also in phase shift oscillators? That when we want to when we want to have a 0 phase shift or we want to have one 360 degree phase shift the imaginary part must be 0, the imaginary part must be 0 we have learn this earlier right.

So, here where is imaginary part imaginary part is imaginary part is j 1; this one right here you see where there is j it is a imaginary part. So, I will write omega 1 minus R square R 1 plus in to R 2; C 1 it is equals to 0. So, omega square equals to R 1, R 2, C 1, C 2. Now what is omega? Omega is nothing, but 1 by 2 pi f right. So, for f equals to 1 by 2 pi omega correct 1 by 2 pi omega. So, f would be nothing, but f here would be.

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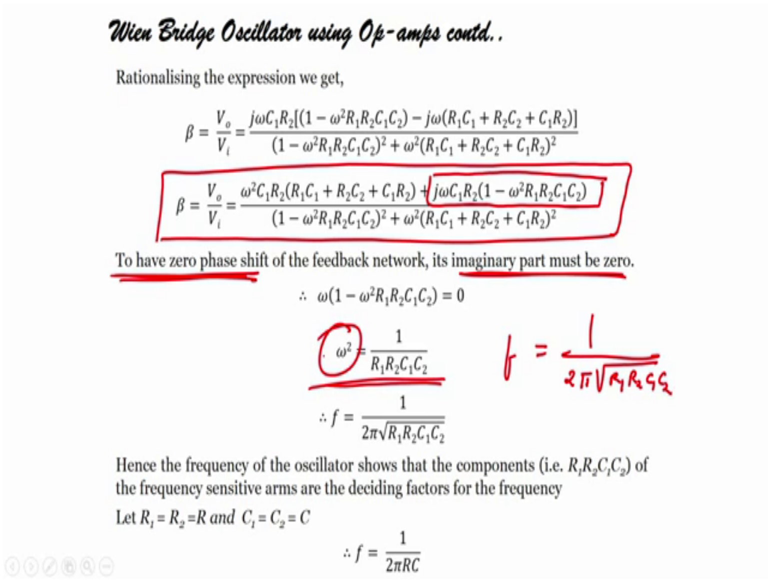

1 by 2 pi right under root of R 1, R 2, C 1, C 2 why under root because omega square is there right.

So, under root of R 1, R 2, C 1, C 2 this is the formula this is the formula what we have to remember when this is the case of a Wein bridge oscillator this is a frequency formula. Hence the frequency oscillator shows that the component R 1 R 2 C 1 C 2 of the frequency sensitive arms are the deciding factor for the frequency; what we understand from this equation? That you changing the value of R 1 and R 2 and C 1 and C 2 we can change the frequency or we can decide the frequency.

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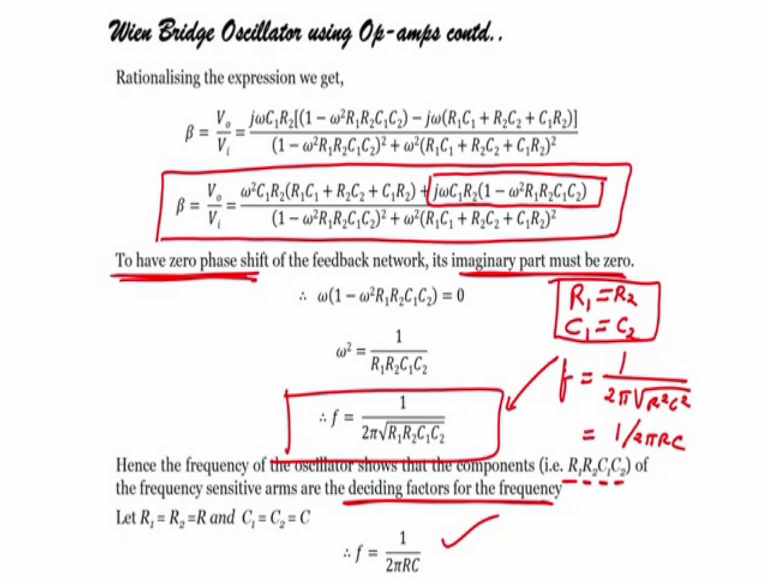

So, in case when your R 1 equals to R 2 and your capacitor C 1 equals to capacitor 2 my formula f would become 1 divide by 2 pi under root of R square C square this is nothing, but 1 divided by 2 pi RC right when? When my R 1 equal to R 2 and C 1 equals to C 2 that is formula that is given here f equals to 1 by 2 pi RC.

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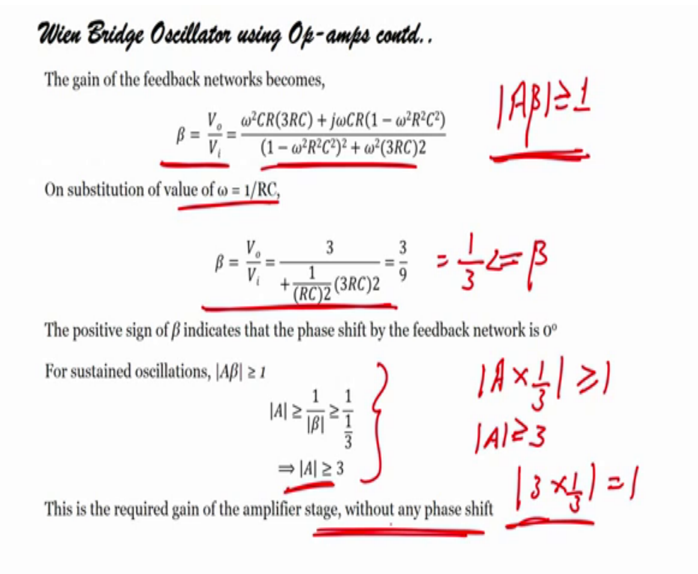

. So, the gain of the feedback network becomes. So, beta is V o by V i that is substitute the value rights or substitute value of omega equal to 1 by RC; I will have beta equals to 3 by 9 I will have beta equals to 3 by 9; this is nothing, but 1 by 3 1 by 3 right.

So, what is the second criteria? Magnitude of a into beta should be equal to 1 right or we can see greater than equal to 1 because initially we are keeping it greater than 1 then it adjust itself to equal to 1. So, that the oscillations are sustained correct this is what we have learned. So, in this case if that is the thing that we have to get and this is our beta this is our beta then; obviously, my gain right into beta is 1 by 3 should be greater than equal to 1 so; that means, A can be; A can be 3 right or greater than or equal to 3; we can right so; that means, I will have A into beta. So, 3 into 1 by 3 is equal to 1 right this is what is written here right.

Once I know what is beta; I could find A and that should be greater than equal to 3; this is the required gain of the amplifier stage without any phase shift this is the required gain of amplifier stage without any phase shift. So, this is how we will solve this is how we will solve for the Wein bridge oscillator.

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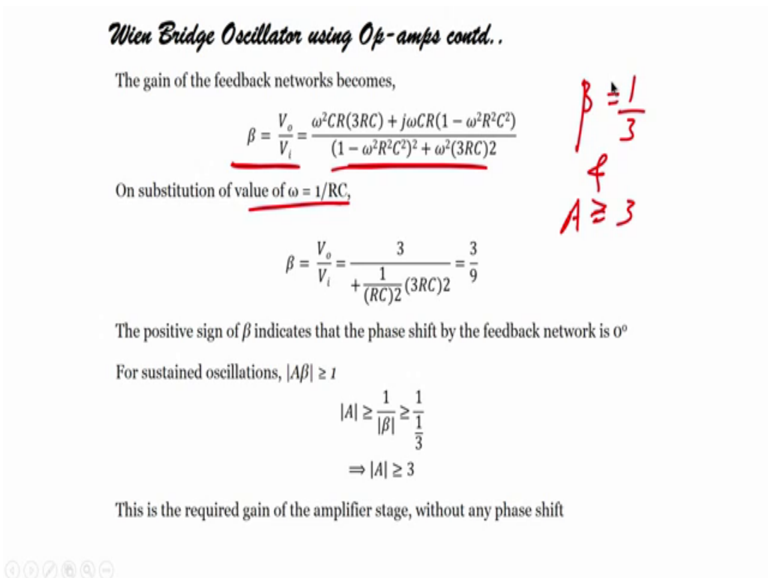

What we have seen? The beta; beta equals to 1 by 3 in case of Wein bridge oscillator and my gain is 3 or if I write greater than equal to 3, then beta equals to 3 by 9; my gain would be greater than equal to 9.

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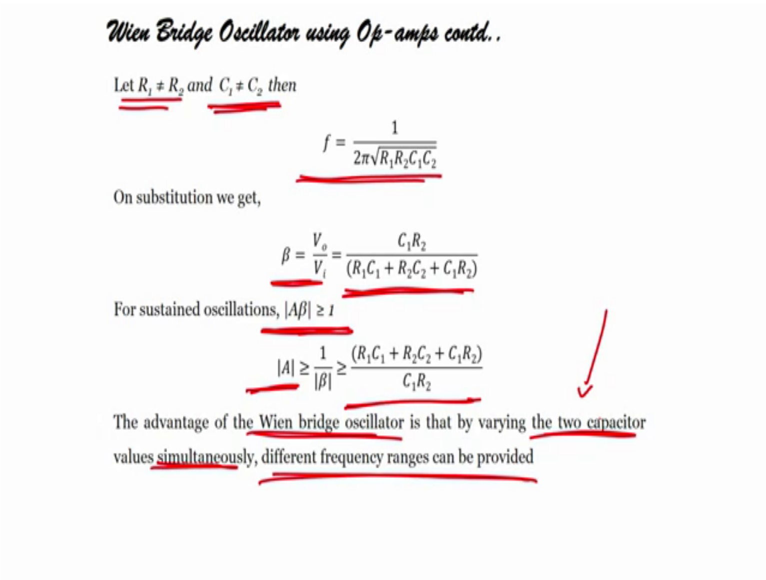

Now, that was the condition when my R 1 was equal to R 2 and C 1 was equal to C 2; what if my R 1 is not equal to R 2 and C 1 is not equal to C 2?

In that case how my equations would change ok? So, let us see that let us see that R 1 is equals to not equal to R 2 and C 1 is not equal to C 2 then my f equals to 1 by 2 pi under root of R 1 R 2 C 1 C 2 on substitution we get beta equals to V o by V i right and we have this equation.

Now from sustained oscillations A beta should be greater than 1. So, A would be nothing, but 1 by beta greater than this particular value or inverse of this right. So, what is advantage of this? Advantage of Wein bridge oscillator is that by varying two capacitors; we if we varying two capacitors simultaneously right different frequency ranges can be provided. We can have different frequency range; if we can change the value of the two capacitors advantage of the Wein bridge oscillator easy super easy right ?

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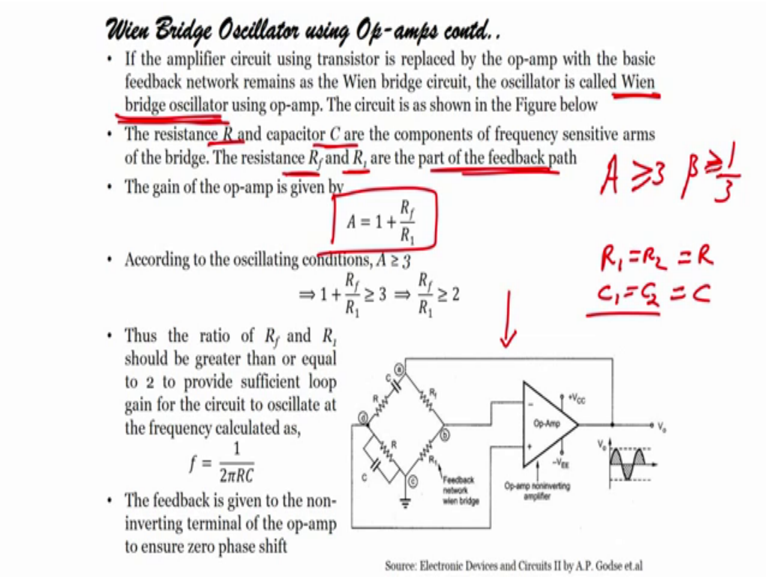

Now, let us see let us see further if the amplifier circuit is in transistor is replaced. So, we are not talking about transistorized circuit here in this particular course, we are only talking about the operation amplifier base circuit. So, if the amplifier circuit is in transistor is replaced by a Op-amp with the basic feedback networks remains as the Wein bridge circuit right; the basic feedback network this is our feedback network which is our Wein bridge circuit correct, this is the operation amplifier that we are using right. So, of course, with this R f and R I R f and R I this is our feedback network right these are feedback network R 1 R 1 C 1 series R 2 C 2 parallel is our feedback network right.

So, what is here what is written here ? If the amplifier circuit is replaced by Op-amp with basic feedback network remaining as remains as Wein bridge oscillator Wein bridge circuit the oscillator is called Wein bridge oscillator what is called Wein bridge oscillator ok. This circuit is shown in figure below the resistance R and C are components of the frequency sensitive arms this R and C R and C.

Here we consider R 1 equal to R 2 and C 1 equal to C 2 that is why we have written just R C instead of R 1 R 2 C 1 C 2 because R 1 equal to R 2 equal to R C 1 equal to C 2 equal to C this is the circuit for where I was talking about ok. Now the resistance R and capacitor C as a component of frequency sensitive arms is R f in R 1 are the part of the feedback part right are the part of the feedback back the gain of Op-amp.

So, where is a where is a input ? Input is coming to the non inverting amplifier. So, non inverting amplifier gain we know gain is nothing, but A equal to 1 by R f by R I right? We have seen that earlier in the case of non inverting amplifier our gain is 1 plus R f by R 1. Now according to the oscillation conditions what should be my gain ? My gain should be you remember right the gain should be greater than equal to 3 and my beta that is feedback network should be 1 by 3 right feedback network should be greater than equal to 1 by 3; we can write like that right.

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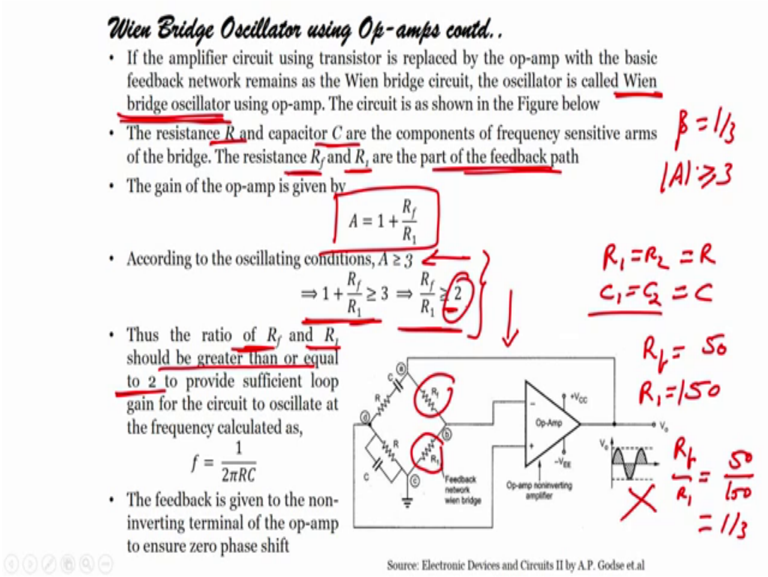

Or in fact, beta was 1 by 3 and gain equal to 3 right; we have just seen. So, according to oscillation conditions gain should be greater than equal to three now what is gain? Gain is 1 plus R f by R 1.

So, 1 plus R f by R 1 is greater than equal to 3 or R f by R 1 is greater than equal to 2 right R f by R 1 should be greater than equal to 2. Now what does that mean thus the ratio of R f and R 1 should be greater than or equal to 2; you see here right what does it mean? The feedback resistor R f input register R 1 ratio should be greater than or equal to 2; that means, my R f if I select R f equal to hundred my R 1 can be can be fifty then R f by R 1 with be nothing, but 100 by 50 will be nothing, but 2. So, it can be greater than equal to 2. So, this condition would be satisfied right; this can also be R f can also be 150 then I will have I will have R f by R 1 equal to 3. So, it is greater than 2.

So, still the condition is satisfied you got it? but it should not reverse should not be reverse it should not be like R f equals to 50 and R 1 equal to 150 and then I will have the value as 50 by 150 by this is nothing, but 1 by 3; this is not correct condition these are correct condition because 1 by 3 is 1 by 3 is less than 2 right 1 by 3 is less than you got it. So, super easy right what we have to understand that R f by R 1 should be greater than equal to 2 frequency is f equals to 1 by 2 pi R C right why?.

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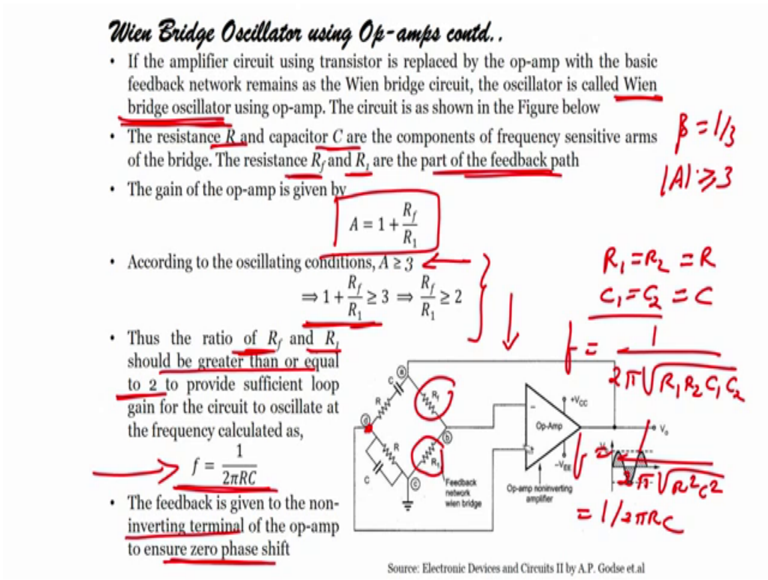

Because actually frequency formula what we found is f equal to 2 pi under root of R 1 R 2; C 1 C 2, but what is the condition that we have selected here? R 1 equal to R 2 equal to R C 1 equal to C 2 equal to C.

So, f equal to 1 divide by 2 pi under root of R square C square. So, R square C square under root will become 1 divide by 2 pi R C; this is what we have seen here correct? The feedback is given to the non inverting terminal of the Op-amp to ensure the phase shifting is 0 right. The feedback is provided to the non inverting terminal of the Op-amp ensure the feedback of the you see feedback here, it provided to the non inverting terminal is provided to the non inverting terminal ok.

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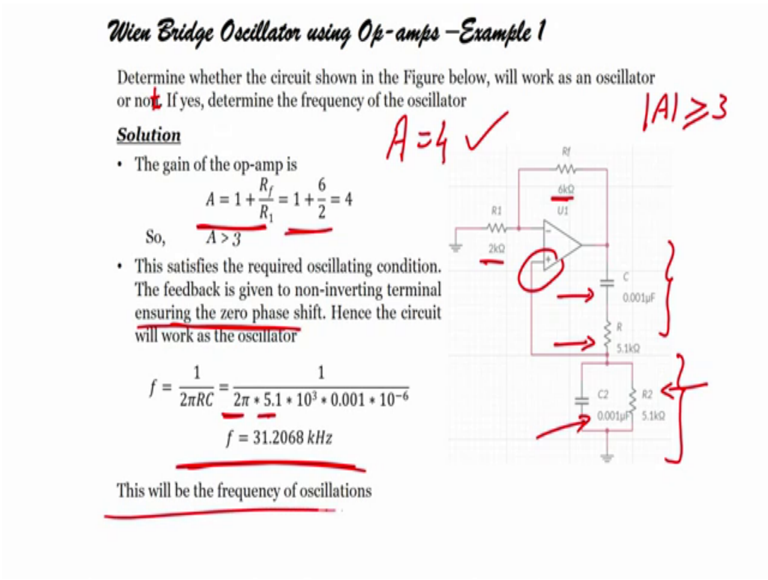

So, if that is the case if we learn how the Wein bridge is oscillator operates then let us solve some problems right let us solve some problems. So, what is the problem 1? Example 1 is determine whether the circuit shown in figure below will work as an oscillator or not. If yes determine the frequency of the oscillator right if it works as a oscillator or not if yes determine the frequency of oscillator.

Let us see; so, we have we have R f R 1 non inverting amplifier we have R and C in series we have R and C in parallel; that means, this looks like Wein bridge oscillator it looks like Wein bridge oscillator. So, if that is the case first let us see what is the gain? Right; We are given R f value is given R 1 value is given.

So, let us substitute the value now this is non inverting amplifier non inverting amplifier we already know the gain is given by A equal to R 1 plus R f by R 1. So, let us substitute the value 1 plus what is the R f? 6 kilo ohm what is R 1? 2 kilo ohm; 1 plus 6 by 2 equal to 4 ok. So, if A equal to 4; what we found A is equal to 4 now what is the condition? A should be greater than equal to 3.

So, this condition is satisfied correct this condition is satisfied. So, this satisfy the requirement oscillation criteria the feedback is given to non inverting terminal ensuring the phase shift of A 0. So, if feedback is given by non inverting terminal ensuring phase shift is 0 hence the circuit will work as an oscillator f equals to 1 by 2 by RC. So, let us substitute value of two pi and R C 2 pi R what is R 5.1 why? Because here R is same what is C 0.01 microfarad here C is same.

So, f will be 31.2068 kilo hertz this will be the frequency of oscillation. Now what we here what we have seen until now? Let us complete this module here and we will see in the next module the another kind of oscillator. So, what we have seen until now? Until now we have seen that how you can design how you can design a Wein bridge oscillator using operational amplifier right.

What we have seen how we can design a Wein bride oscillator using operational amplifier. And then we have seen that in case of Wein bride oscillators their feedback is there is the output is the phase with the input therefore, the feedback should not provide any phase shift the feedback should not provide any phase shift ok. Then we have seen then in the case of Wein bridge oscillator the gain into beta right that the condition should be greater than equal to 1.

So, gain would be greater than equal to 3, beta would be equal to 1 by 3 1 by 3 right. Then we have seen an example how we can solve or how we can determine whether a given circuit will work as an oscillator or not that to particularly Wein bridge oscillator right. Same way we can determine if it is a phase shift oscillator, whether the given circuit will work as a phase shift oscillator or not ok. So, this is how you can determine or you can understand the functionality are there for or the working of the Wein bridge oscillator working of Wein bridge oscillator.

So, in the next module let us see how the another kind of oscillator works that is your LC oscillator; what is that? L and C. Here what we have seen until here? R and C whether it was phase shift oscillator RC; 3 RC s right if it is Wein bridge 1 RC in series, 1 RC in parallel; now you will see LC oscillators. So, just go through this particular module, understand it thoroughly right and I will see you in the next module with a new kind of oscillators or new class of oscillators to learn.

So, let us learn in the next module what are the LC oscillators till then you take care bye.