Op-Amp Practical Applications: Design, Simulation and Implementation

Prof. Hardik Jeetendra Pandya
Department of Electronic Systems Engineering
Indian Institute of Science, Bangalore

Lecture – 14
Op-amps as Phase Shift Oscillator

(Refer Slide Time: 00:16)

So, welcome to this particular module and here we are looking at the oscillators. So, what are oscillators and how we can design those oscillators, right? So, if I clap my hand you can feel the sound right. Why the sound is there? Because I am pressing a air between my hand right pressing air between my hand. So, if I clap it in particular fashion my sound is different; that means there is oscillation that I can create by pumping something by pumping something is not it.

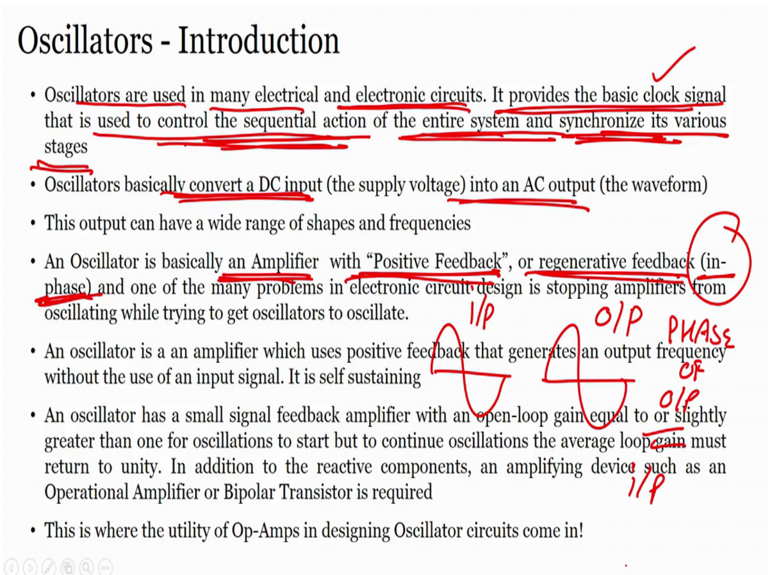
Same way what are the oscillators within your body? Do you have any oscillators, within your body have you ever thought of that, there are oscillators within a body? If you remember we have talked this thing in your theory class right, that the our body also has lot of oscillators or organs which works similar to an oscillator right.

So, in the electronic circuit when you talk about electronic circuits, how the oscillators are designed and what kind of oscillators are available and if I know a theory of an oscillator can I design this oscillators in the experimental form and can I use it and see the output signal as an oscillation right? Input would be noise, we have seen this right, we have seen Barkhausen criteria, if you remember right the gain into beta which is a feedback, it is a mode of a into beta should be equals to 1 and the phase the phase shift should be equals to 360 degree or 0 degree.

So, this theoretical knowledge we already have, now let us quickly once again see if you have if you do not remember what are oscillators and then we will move to the experiment part. Here, in this particular module we will see several oscillators several oscillators. And we will also see how to design a circuit in a Multisim. So, we will see the oscillators designed in the Multisim and see how the oscillations are formed, we also design the oscillators using the breadboard. And the equipment that we have and we love and we will see what kind of oscillations, we get at the output of an oscillator.

So, when I talk about electronic oscillator I had to again think about my operational amplifier right. Operational amplifier is our theme and we keep it at the center of these particular course and then when we talk about operation amplifier we also talk about some MOSFETs. We also talk about some integrated circuits and we or we combine this thing, you see their applications that is what we are learning in this particular course right. So, let us see how the oscillators are or the theory of oscillator and then we will see quick examples and we go to the experiment part.

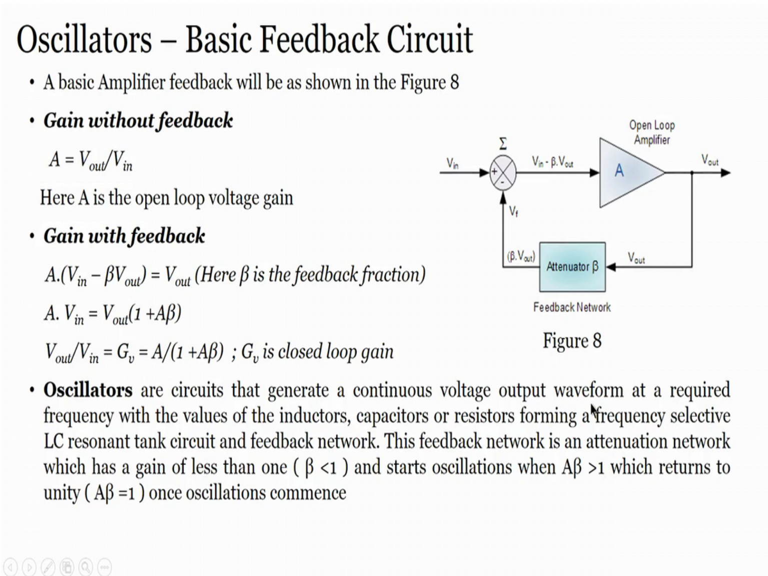
(Refer Slide Time: 03:20)



So, if you can see on the screen oscillators right oscillators are used in many electrical, are used in many electrical and electronic circuits correct oscillators are used in many electrical and electronic circuits ok. Next it provides a basic block it provides the basic block sorry basic clock, clock signal that is used to control the sequential action of the entire system. And synchronize its various stages; that means, the oscillators provides the clock; that means, if I want to give a clock to my electronic module I can use oscillator right.

And the waveform generated at the output of the oscillator can be used is a clock signal to the further electronic module right, that is what am writing here, that is it provides a basic clock signal that is used to control the sequential action sequential action of the entire system.

(Refer Slide Time: 04:26)



And synchronize its various stages. So, if you want to synchronize its various stages and use for the controlling sequential action, than you can use the oscillator alright. Oscillator basically convert it converts the DC input a DC input into an AC waveform into an AC output.

So, AC outputs are always some with some frequency DC at the frequency of 0 hertz we all know DC has a frequency of 0 hertz right. So, this output can have a wide range of shape and frequencies; that means, you can design oscillators with various shapes and frequencies, you can have a square wave oscillator you can have a sine wave oscillator. And then you will see what kind of shapes and frequencies. we can generate using the oscillators.

Oscillator is nothing but a basically an amplifier, amplifier with positive feedback with positive feedback or regenerative feedback in phase in phase you see in phase. So, let us see what is in phase and what is out of phase, what is in phase and what is out of phase you see if I apply input signal.

If I have the output signal this is input, this is output the phase of output phase of output is similar to input signal, but if I say that my output like this my output is out of phase my output is out of phase.

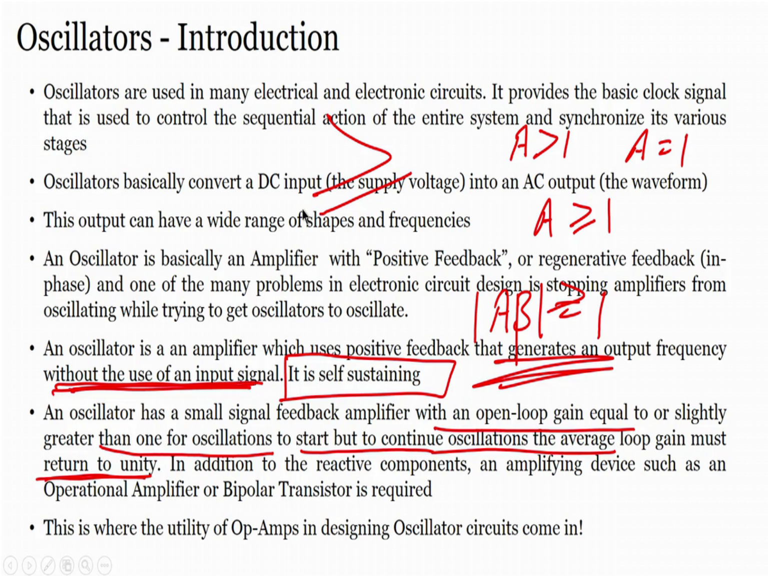
So, what is saying that an oscillator you can generate or we can design a oscillator by using an amplifier and a positive feedback, by using an amplifier and a positive feedback, or regenerative feedback which is in phase which is in phase and one of the many problem in electronic circuit design, is stopping amplifier from oscillating while trying to get the oscillators to oscillate alright.

So, the point is that if you want to create a amplification factor, amplification factor then like we discussed in the theory class we had to apply a negative feedback. If you want to create a oscillation or oscillatory action, then we have to give a positive feedback or regenerative feedback. And in case of positive feedback or regenerative feedback, the phase is in phase and the and it becomes an oscillator.

Now, we will see that if oscillation is an amplifier, you can see that oscillator is an amplifier, which uses positive feedback that generates an output frequency with without the use of an input signal right, that we have already seen in theory class that the oscillator is a circuit which can generate the output which can generate the oscillatory output, without use of input signal without the use of an input signal; that means, the oscillator is self sustaining oscillator is self sustaining ok.

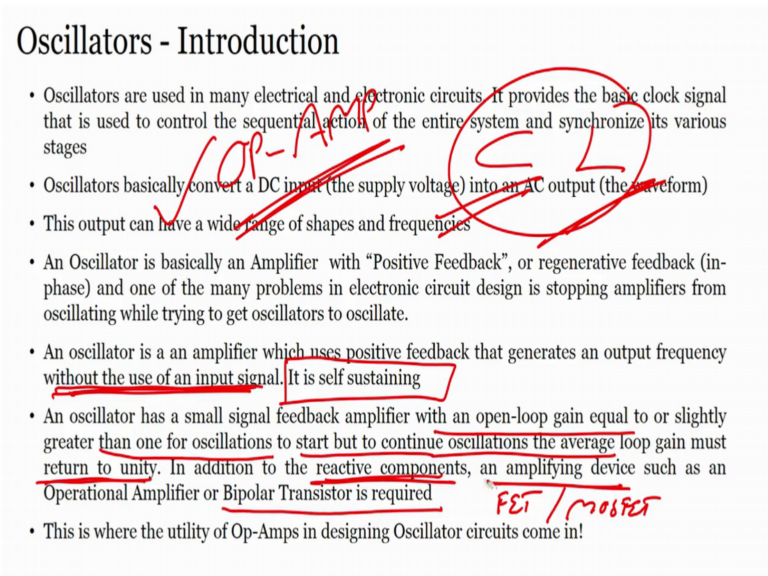
Now, when we talk about oscillator what it requires an oscillator has a small feedback amplifier, small signal feedback amplifier with an open loop gain equal to or slightly greater than 1 for oscillations to start, but to continue the oscillations the average loop gain must return to unity right.

(Refer Slide Time: 08:13)



That means initially your gain can be greater than equal to 1 and it can be greater than 1 and then once you sustain the oscillation it should be equal to 1, that is why when we write gain of a oscillator its gain is greater than equal to 1, but if you write the feedback formula, then we write a into beta should be equal to 1. We also write a beta greater than or equal to 1, but initially greater than equal to 1 later on it should be equal to 1 that is why we write both the symbol greater than equal to so, this about your oscillator this about your oscillator.

(Refer Slide Time: 08:56)

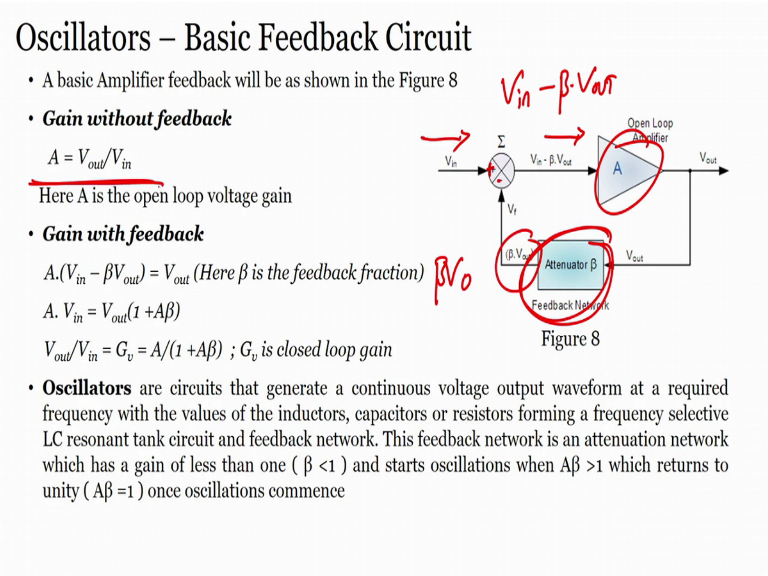


So, in addition to reactive components reactive components are capacitor inductor right, reactive components. An amplifying device what is amplifying device our favorite device Op-Amp right, in addition to capacitor addition to inductor that is our reactive devices, we also have an amplification device or amplifying device which is an Op-Amp or a transistor or a transistor. It can be BJT it can be FET it can be MOSFET, it can be BJT it can be MOSFET, it can be any type transistor right that is not required to be only to be BJT right that is not required to be only BJT.

Now, the we will see what are the kind of oscillators, now we already know right we this kind of refresher that what we have done in theory, that we know about oscillator, we know that there is a self sustaining mechanism, we know it is a positive feedback we know that you have initially a beta greater than one and then suddenly you may a beta equal to 1. So, that you have the oscillations sustaining oscillations, then we have to see that we also know that is nothing, but you have the Op-Amp into the configuration. Now, let us see oscillators with basic feedbacks circuit.

So, amplifier feedback will be shown as shown in figure 8 or is shown in figure 8, what we see here there is the open loop amplifier. So, there is a no feedback right open loop amplifier no feedback and then there is a attenuator, the feedback is here in am talking about the amplification ok. So, now, you have you see this particular, this you see this particular schematic what you see that if I apply a input voltage if I apply the input voltage, I have this input that goes to the Op-Amp.

(Refer Slide Time: 11:05)

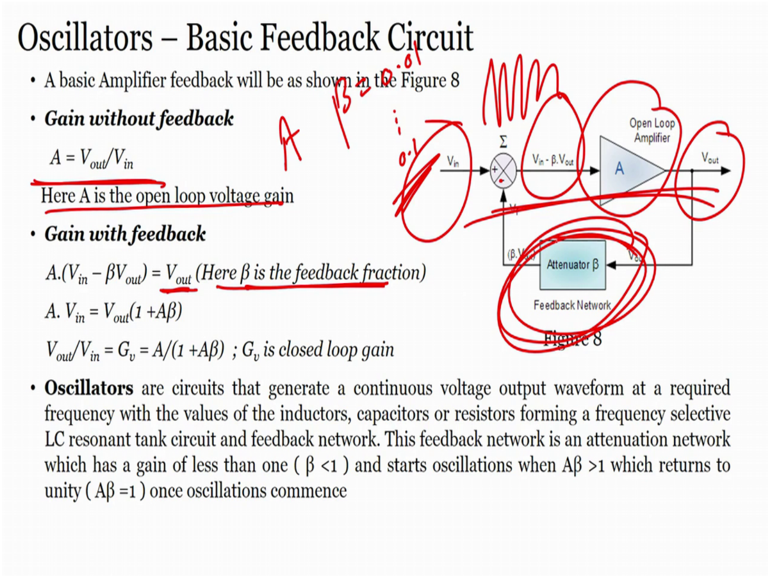


But there is a output voltage which comes an attenuous through beta, so, I have a output voltage beta into V out right which is minus here and this is plus here; that means, V in is plus minus I have beta into V out that goes to my amplifier, that goes to my amplifier. So, now, gain without feedback if I have a gain without feedback you know gain without feedback is very easy to understand V out by V in.

Gain with feedback we have seen inverting amplifiers we have seen non inverting amplifier right. So, this is a gain without feedback, because there is no feedback. So, we have gain equals to V out V out by V in V out by V in right here a is the open loop gain voltage gain with feedback, if I say with feedback; that means, this feedback, if I consider if I just consider this one it is without feedback, if I consider this one with beta, then I have a into V in minus beta V out we have to consider this one right.

So, my gain would be a into V in minus beta V out, or if I have V out where here beta is the feedback which is in fraction.

(Refer Slide Time: 12:14)



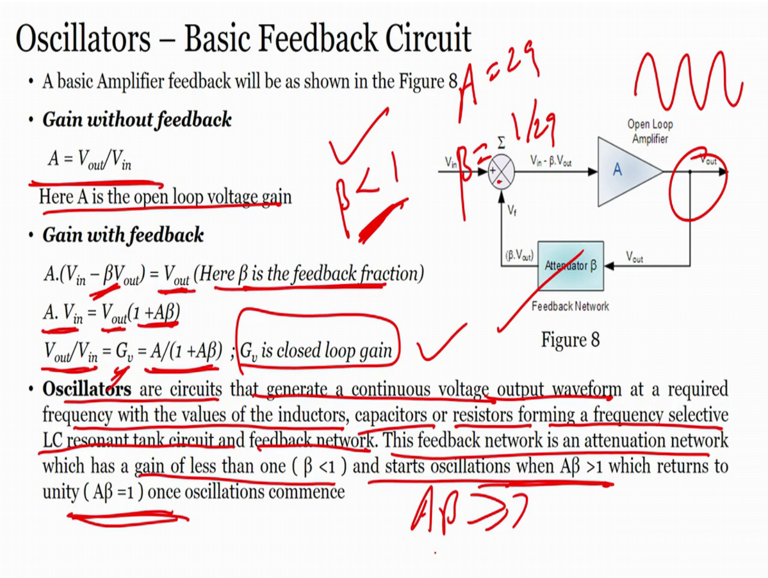
Now, generally we will see we have already seen that we for different value of a my beta will be only 0.01, or maximum it was 0.1, when it was 0.1 my output was oscillating beyond my control right that means, that what we have seen that the beta value is only fraction beta value is only fraction of fractions, when you consider the feedback or attenuation.

So, if I consider beta as very low extremely low, then I have nothing, but A into V in or this would be V out. So, A into V in is V out in to 1 plus A beta or V out by V in is A by 1 plus A beta, where G is where G v is nothing, but your closed loop gain, because here we will consider the feedback here we have consider this feedback given by the feedback network beta feedback network beta.

So, now once we know gain without feedback we know gain with feedback, then what is this? So, oscillators are circuits that generate a continuous voltage output waveform at a required frequency the values of the inductors capacitors, resistors forming a frequency selective LC resonant circuit, and feedback network what this says that. The oscillators are nothing but a circuit that can generate a constant a constant or continuous output voltage alright in a particular oscillation right, or required waveform, or required frequency with the help of inductors with the help of capacitors with the help of resistors which can form the frequency selective LC resonant circuit.

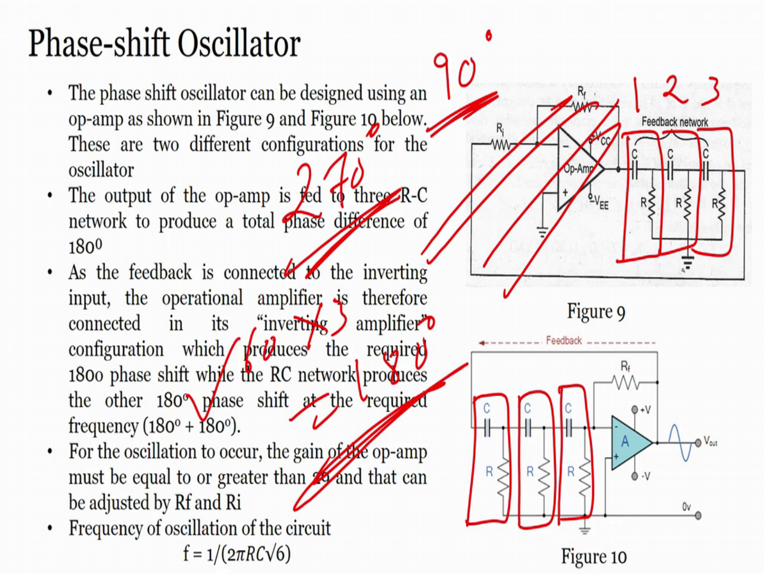
It also uses the feedback network this feedback network is nothing, but an attenuation network which is a gain less than 1.

(Refer Slide Time: 14:05)



We have seen that beta is always beta is always less than 1 and we will see so, we have seen in theory classes right, that when you talk about RC phase oscillator or we talk about Wien bridge oscillators your gain if your gain was 29, then your beta was 1 by 29. So, if 1 by 29 is B less than 1 B less than 1 beta is always a fraction of the output voltage. So, anyway the feedback network is an attenuation network that we know with a gain of less than 1 and starts oscillations when A B is greater than 1, which returns to unity when A B is equal to 1. So, we that is why we write A beta greater than equal to 1 cool alright. So, initially it is greater than 1 later on we make it equal to 1. So, that ours oscillations are sustained right. So, that our oscillations are sustained.

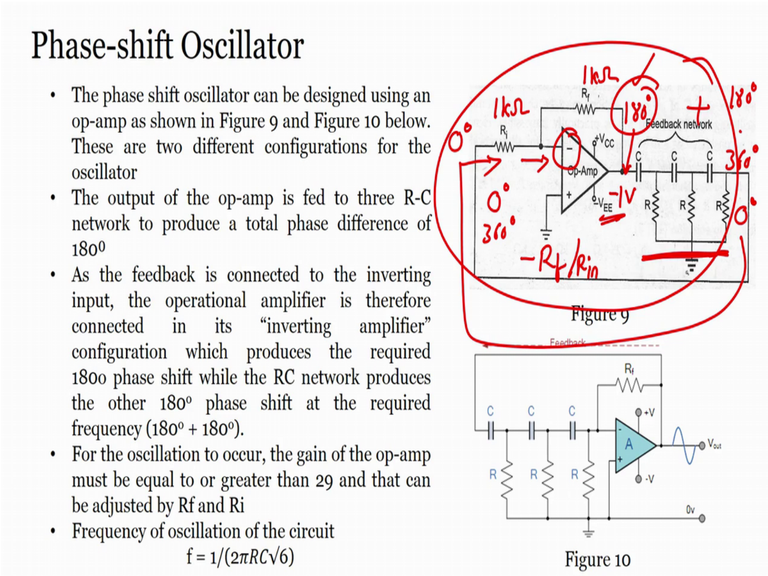
(Refer Slide Time: 15:11)



Now, let us see further about the oscillator and further is we will see, we will see a phase shift oscillator we have already seen in theory, what is a phase shift oscillator right, what we have seen that if I use 1 RC network right, this is RC this is second RC this is third RC that means, I have first second third 3 RC network 1 2 3 right. Just if I do not use op-amp, if I do not use op-amp I can have a phase shift of 180 degree, why because 1 RC generally 1 R and C gives us 90 degree phase shift 1 R and C will give us 90 degree phase shift; that means, 3 R and C should give us 270 degree phase shift right.

But when we talk about phase shift oscillator, we always say no RC 1 RC will give 60 and 3 RC will give 180 degree phase shift right. So, we have seen in theory that this is true only because this is true, because we tune the R and C in a way to get of a phase shift of 60 degree alright, we tune the value of R and C to get a phase shift 60 degree, otherwise R 1 R in 1 C generally is we get a phase shift of 90 degree; that means, 3 will give us to 270 so, anyway now we know that we can adjust the R and C to get the phase shift of 180 degree ok. So, we have 180 degree phase shift why we need 180 degree phase shift, because let us say this particular circuit, if you see figure number 9 this figure what we see what we see here is that the input the input is given to the non inverting terminal of an operational amplifier this a non inverting amplifier.

(Refer Slide Time: 17:12)



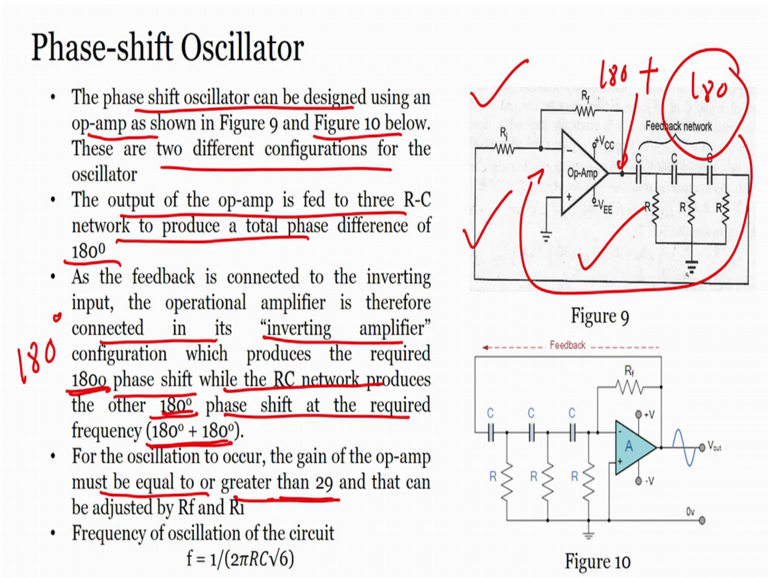
So, my gain is what my gain is minus R f by R in right my gain is minus R f r in; that means, if I if I have voltage of 1 right and my R f is 1 kilo my R in is 1 kilo ohm, then my output voltage would be minus 1 my output voltage will be minus 1.

So, what is minus is my phase shift this is 0 degree here minus means I have 180 degree phase shift at the output here, I have one eighty degree phase shift, but to sustain the oscillation right or to start the oscillation or to maintain the oscillation we know right we have seen the Barkhausen criteria, which says that which says that the feedback the feedback voltage back to the signal back to the input should also have phase shift of 0 or 360 degree, but if I directly apply 180 degree right without the feedback network, then that criteria would not satisfy and; that means, that instead of 0 degree I will apply 180 degree at the input and the oscillations would not happen oscillations would not happen.

So, to get the or to satisfy the Barkhausen criteria, we have to apply we have to apply a phase shift of 180 degree and this further phase shift of 180 degree will give us so, 180 degree this phase shift given by R and C 180 degree is already there. So, 180 plus 180 will be 360 degree phase shift or 0 degree phase shift this 0 degree phase shift we are applying in the input of the inverting terminal; that means, now I have satisfied one criteria of Barkhausen which is my phase shift is 0 degree or phase shift is 360 degree right.

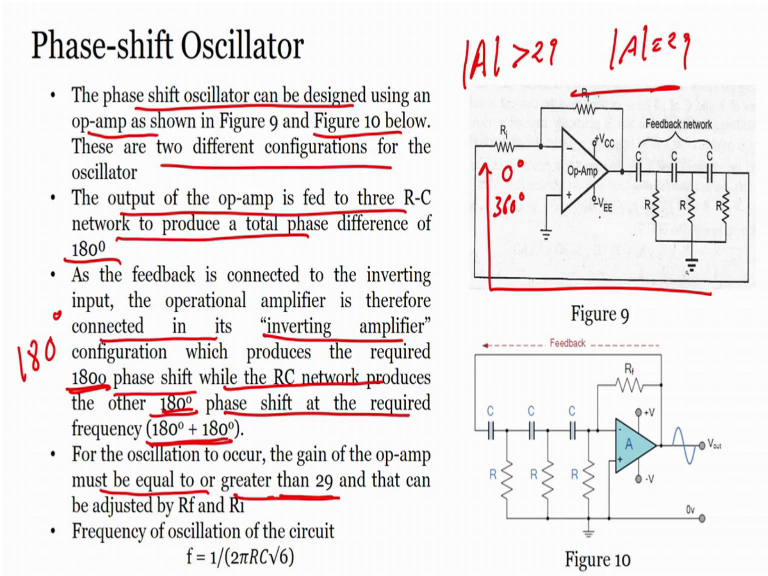
So, now you can use the operation amplifier you can design R and C or a phase shift oscillator right, or you can say RC oscillator and see on the breadboard how it works, but before we move to the breadboard let us understand what I said it is similar thing what I said which is written here, the phase shift oscillator can be designed using an op-amp as shown in figure nine and figure 10 figure 10. So, let us see here right same thing, there are two different configurations for the oscillator the output of the op-amp is fed to 3 RC network to produce a total phase difference of 180 degree which is here right as the feedback is connected to inverting input the operation amplifier is therefore, connected in series inverting amplifier configuration which produce 180 degree this is not 1800, this degree should be subscript superscript ok.

(Refer Slide Time: 20:14)



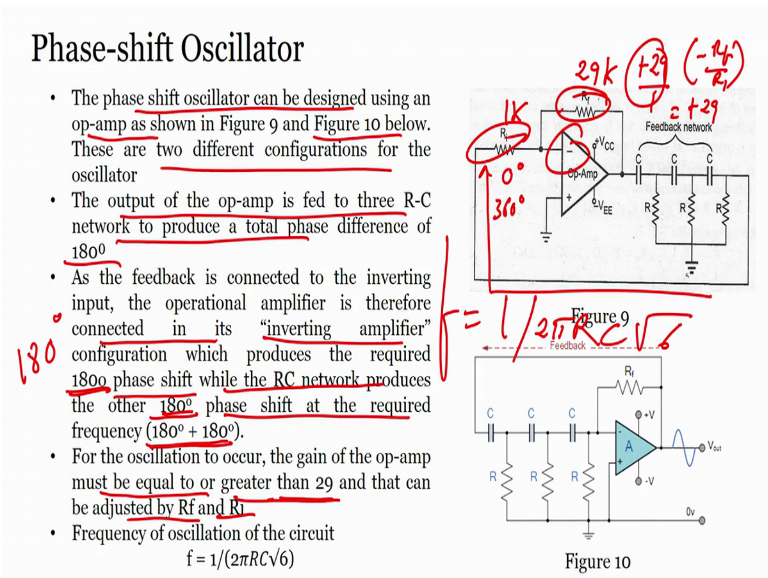
So, 180 degree phase shift while the RC network produces other 180 degree phase shift. And total is 180 plus 180 we have seen already in this 180 we have here 180 so, 180 plus 180 is what we are feeding back to the input for the oscillation, because the gain of the amp op-amp must be greater than equal to 29. This we have seen how this 29 number came in the theory class right. So, the gain should be e greater than equal to 29. So, now, once your criteria is satisfied for RC phase shift oscillator is that.

(Refer Slide Time: 20:59)



The input by the input to the inverting terminal or input with the oscillator is 0 degree or 360 degree; even it goes to the feedback network. Second is that our gain should be greater than 29 initially and then it should be equal to 29 to maintain the oscillation alright.

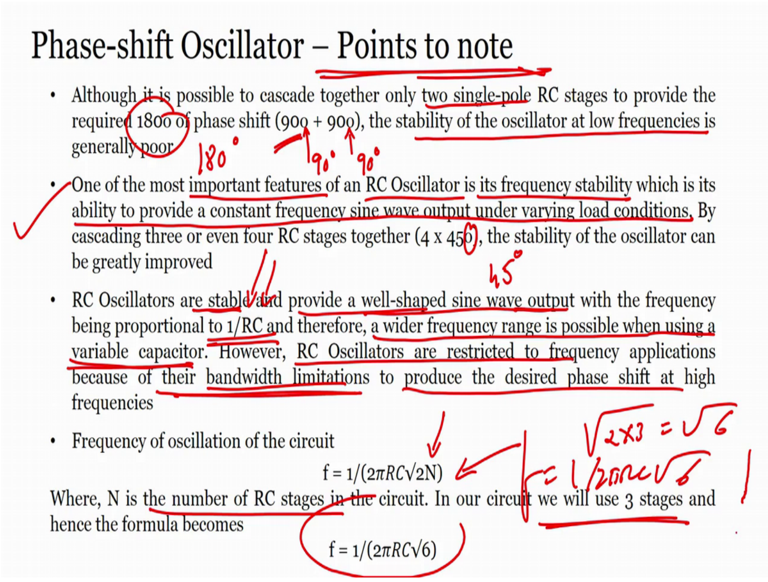
(Refer Slide Time: 21:25)



So, greater than 29 and then the that can be adjusted by so, how can we adjust this gain of 29, we can adjust this gain of 29 adjust the gain of 29 by having R f and R 1 of 29 N 1 29 k 1 k gain of 29 right, because inverting terminal. So, inverting terminal means this is minus 29 gain right, because R f my gain is minus R f by R 1 right 29 by 1 equals to minus 29 right. So, but this minus 29 I do not worry about this minus 29 gain can now be minus so, that is why I said gain can be 29 and at least the gain is 29 we can adjust it by using R f, we can use it by R f and R 1 or R in.

Frequency of oscillator we have seen how can we derive frequency, frequency of oscillator is 1 by 2 pi RC under root of 6 right 1 by 2 pi RC under root of 6. So, this is about your phase shift oscillator this is about your phase shift oscillator.

(Refer Slide Time: 22:27)



So, what points we have to note when we talk about phase shift oscillator alright, the point that we have to note is that although it is possible to cascade only 2 RC stages to provide the required, 180 degree not 1800 180 degree ok.

So, this is my mistake this degree eh should be in superscript right, this is not 900 if you closely see it is the symbol of degree this will be superscript so, 90 degree this is ninety degree alright. So, although it is possible to cascade together only to two single pole RC stages to provide required 180 degree of phase shift of 90 plus 90, the stability of the oscillator at low frequency is generally poor. So, when the frequency is low you will see the stability is poor, one of the most important features one of the most important features of an RC oscillator, is its frequency stability which is ability to provide a constant frequency sine wave output under varying load conditions.

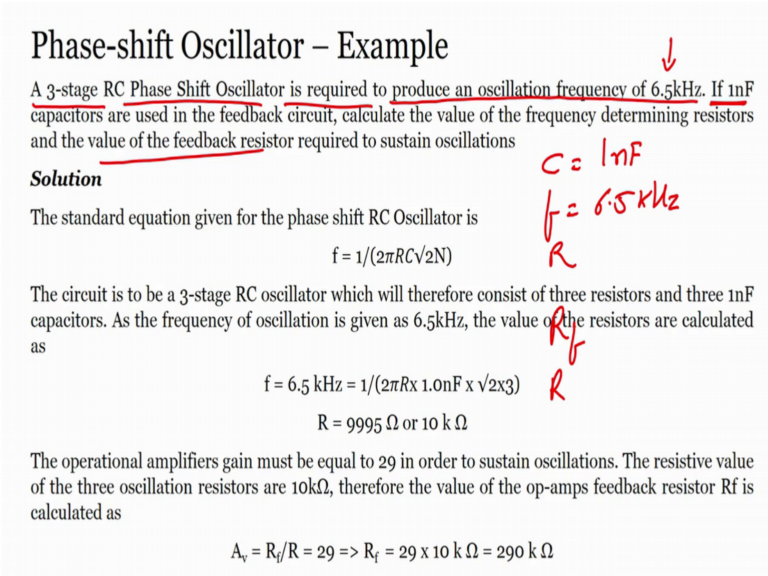
So, this is very important that the frequency would be stable even you keep changing your load, even if you keep changing your load, you will find that the frequency at the output of the RC phase shift oscillator remains constant and that is extremely important right. Now, if I cascade 3 or even more force stage is to whether with 45 degree 4 into 45 degree. So, this is 45 degree stability of oscillator can be greatly improved right, this you have to remember next one is RC of oscillators are stable provide a well shaped sine wave output with the frequency being proposed to 1 by RC.

Therefore, a wider range is possible when using a variable capacitor right, because it is now just depending on R and C and frequency is proposed by inversely proportional to RC and that is why we can see that by just changing the value of R and value of C in general, if that is by changing the value of c if you have a variable capacitor, then you can use a wide range of frequency wide range of frequency.

However, RC oscillators are restricted to frequency applications, because of their band width limitations ok, it is a limited to provide to produce the higher frequency at higher frequency, we have to produce the desired phase shift in the RC phase oscillator, but it is difficult to do that in the that is why they are restricted to only frequency applications of because of their bandwidth application. So, frequency of the oscillation of the circuit is given by this particular formula, when N is nothing, but your N is nothing, but number of RC stages in the circuit hm.

So, in this circuit what are so, how many stages we have used we have used three stages. So, that is why we have under root of 2 into 3 which is under root of 6, that is why we say f equals to 1 upon 2 pi RC under root of 6 this alright and this formula comes into picture, which is 1 upon 2 pi RC under root of 6 alright. This points we need to note so, that we understand that when we actually implement the circuit, what is the output that we are expecting, what is the output that we are expecting.

(Refer Slide Time: 26:00)

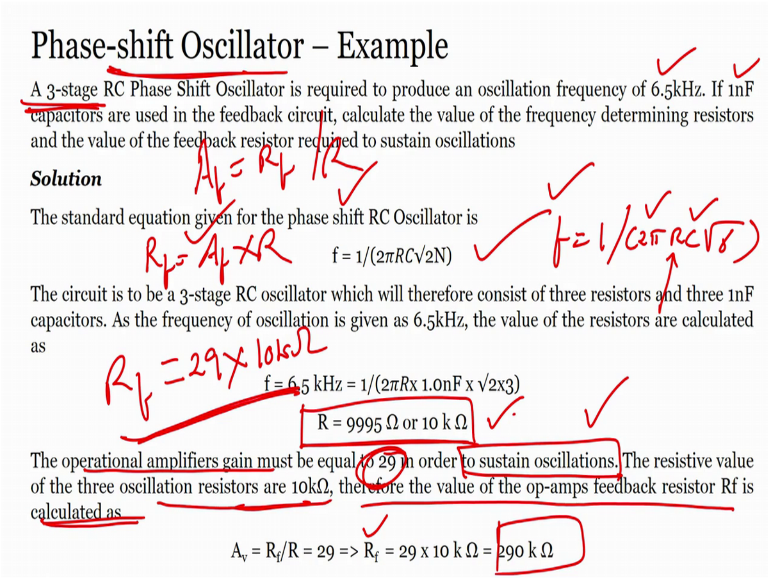


So, now let us see an example, let us quickly see an example it is very important to solve few examples. So, we get the idea of the how the oscillations can work how the oscillators can be designed. So, we say that here the problem is problem statement you read a 3 stage RC phase shift oscillator is required to produce an oscillation frequency of 6.5 kilo hertz 6.5 kilo hertz.

If 1 nano farad capacitors are used if C equals to 1 nano farad calculate the value of the frequency determining resistors, you have to calculate the frequency right here frequency determines the resistors that is frequency is already given 6.5 kilo hertz, we have to be determine resistors we have to determine resistor values. And the value of feedback resistor; that means, feedback value R in and feedback value R f feedback value R in or sorry feedback value R and feedback resistors. So, R f and R value of R f and R ok.

So, in this particular case how we will find the how we will find the values, how you will find this values. So, for that we have formula that was extremely easy and that is the formula which is 1 upon 2 pi RC under root of 2 times N and N is number of stages right.

(Refer Slide Time: 27:36)



Now, how many stage oscillator is there 3 stage that means, here formula will become f equals to 1 upon or 1 divided by 2 pi RC under root of 6, under root of 6 right. Now, we know f we know C we know 2 pi, we can get R right this is what we are getting right.

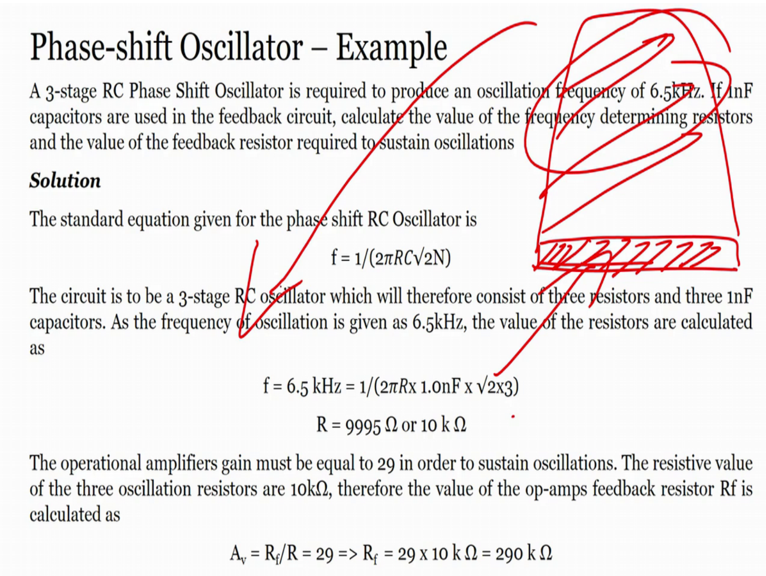
So, here your r would be 9995 ohms or 10 kilo ohms right, and the operational gain operational amplifier gain, why because the phase shift oscillator your gain should be 29 right, if I do clearly gain should be 29. So, the gain must be equal to 29 in order to obtain a sustained oscillation sustained oscillation, we have seen what is the damp oscillation, we have seen what is the over ampli over oscillations or unsustain oscillations and we have seen the sustained oscillations right.

So, for we want always the sustained oscillations to have sustained oscillations in RC phase shift oscillator, we require 29 should be the gain right must be equal to 29 the resistive value of three oscillations resistors are 10 kilo ohm, that we already got 10 kilo ohm right. Therefore, the value of op-amp feedback resistor R f can be calculated by R f right. So, what is A f A f is nothing, but R f by R we know R f we know A f we know we know R, we know A f then from that we can find R f equals to A f into R, what is A f A f is A f is A f is what is a gain 29 A f is 29.

So, we write R f equals to 29 into what is R is 10 kilo ohm 10 kilo ohm, when you when you do this calculation you will find 290 kilo ohm as a value of your R f you get value of R f, you have value of R you have value of C, you have frequency your oscillator is ready right. So, super easy example and super easy solution so, it is impossible for you to make a mistake impossible for you to make a mistake. So, do not make a mistake is such as easy questions are there right, we generally make mistakes when the questions are easy and that is why very amazing generally most of the complex questions we are able to answer, but when you ask when you are asked very simple questions is very difficult for us to answer right.

So, and the beauty is always in simplicity, if you find the simple questions first try to solve the simple questions, then move to complex questions. If your basics are strong, if your basic are basics are strong your all the other things would strong right other things would be strong, we always know this right.

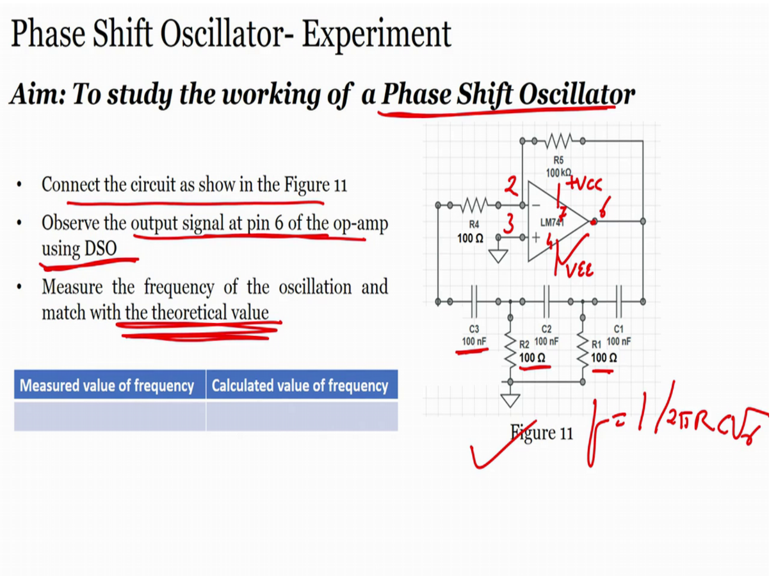
(Refer Slide Time: 30:49)



The foundation of the building it takes the maximum time, you see apartment construction we will see the maximum time comes in the foundation of the building and a whole big apartment comes very fast, this whole big structure becomes very fast, but the foundation comes it at a long time. Because if the foundation is not strong the whole apartment would collapse full collapse down right, that is why whenever we are getting education or when we are learning any subject we should try to make our foundation strong; that means, our basics strong right complex questions is easy to solve, but if you know the basics then it will it will be very easy for you to understand complex electronics as well.

Now, you forget about just this subject any subject, any subject that you are learning first understand what are the basic concepts alright so, that is why even you guys sometime may have feel that this we have learnt, this we have learnt in theory why we are repeating here the reason of repeating is that, now you have a different example compared to theory and you will immediately see how the experiments are done. So, it is the fresh in your mind that what kind of oscillators, we can design what kind of oscillators we can design and how it will behave.

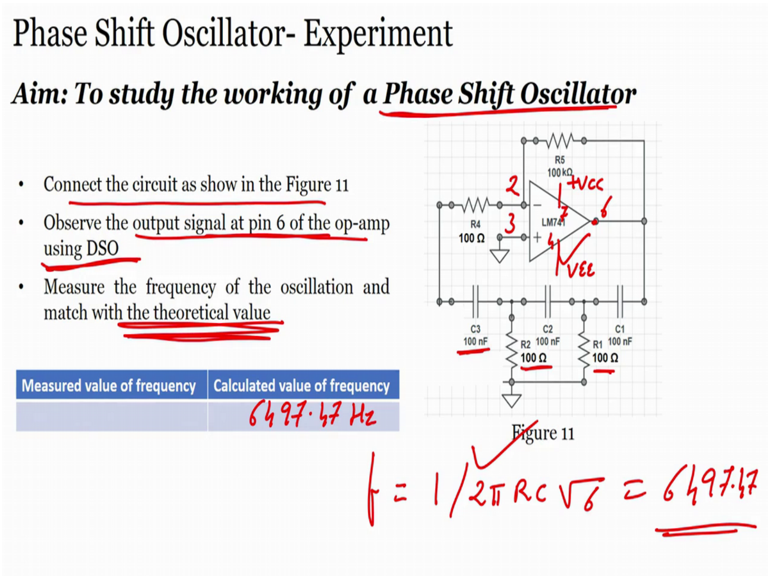
(Refer Slide Time: 32:12)



So, coming to the experiment part coming to the experiment part, what we will see today we will see a RC phase shift oscillator or a phase shift oscillator, using a operational amplifier using an operational amplifier right with some values with some values. So, what are the values are 100 kilo ohms values are hundred ohms. And there is R and C you can see this is C is 100 nano farad and R 2 and R 1 is 100 ohms right. So, we have these values once we design this, once we design this then what kind of output we will obtain.

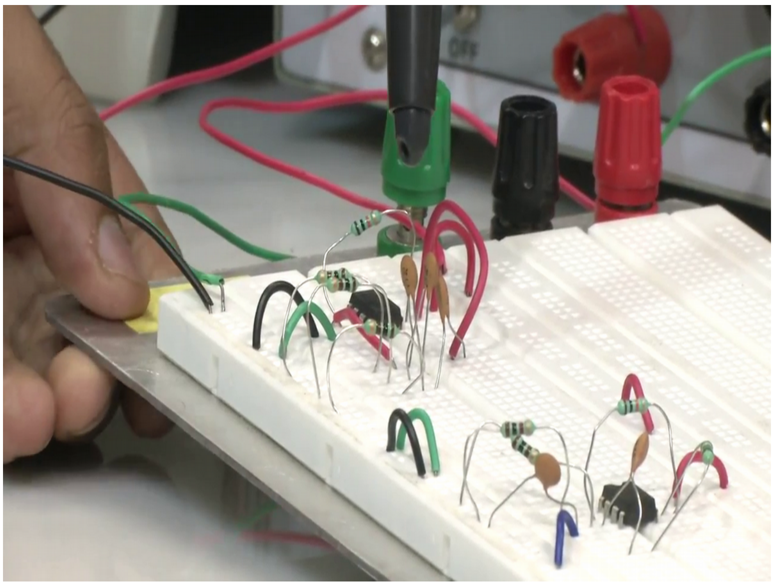
So, we had to do first thing is we have to connect the circuit as shown in figure 11. So, connect the circuit as shown here observe the output signal at pin 6 pin 6. So, where is pin 6 you see 2 3 6 4 7 right pin 6 output here ok. So, observe the output a pin 6 using the oscilloscope using the oscilloscope. Measure the frequency of oscillation and match with the theoretical value, match with the theoretical value ok. So, what is a formula for frequency here f equals to 1 by 2 pi RC under root of 6 under root of 6. So, if I put this value if I put this value I will write down the calculation calculated value of frequency, where and then I will measure the value of frequency obtained from the oscilloscope alright.

(Refer Slide Time: 34:05)



So, right now by the time we call we call Anil to help us to design the circuit, what we can do we can calculate the formula of frequency that is theoretical value and then we will see the measured value alright.

(Refer Slide Time: 34:27)



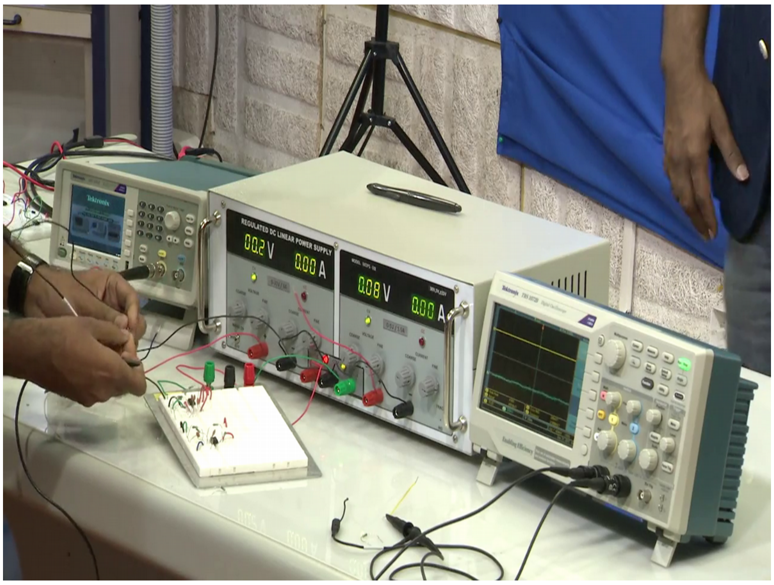
And see very clearly extremely clearly here right that, we have three capacitors we have three resistors three capacitors three resistors right, we have a operational amplifier we have a feedback resistor right and this is the inverting op-amp, inverting amplifier inverting amplifier; that means, that the output will be 180 degree phase shift compared to the input.

So, when it is out of phase compared to input signal with help of RC, you can bring it back to the in phase. So, we can we can have 180 degree plus 180 degree 360 degree coming back to here A and then our A is calculated as 29, then when we apply input we have to just measure the output we do not have to apply input, we are just measuring the output and the we have to apply the bias value we have to apply the bias value ok.

So, if you go back what will be the answer this would be close to 6 4, if you come back to the screen this will be 6497.47 is the calculated value if you come back on the screen, you will see that value of frequency is nothing, but calculated value theoretical value is 6497.47 hertz right and, we will see what is the measured value of frequency ok.

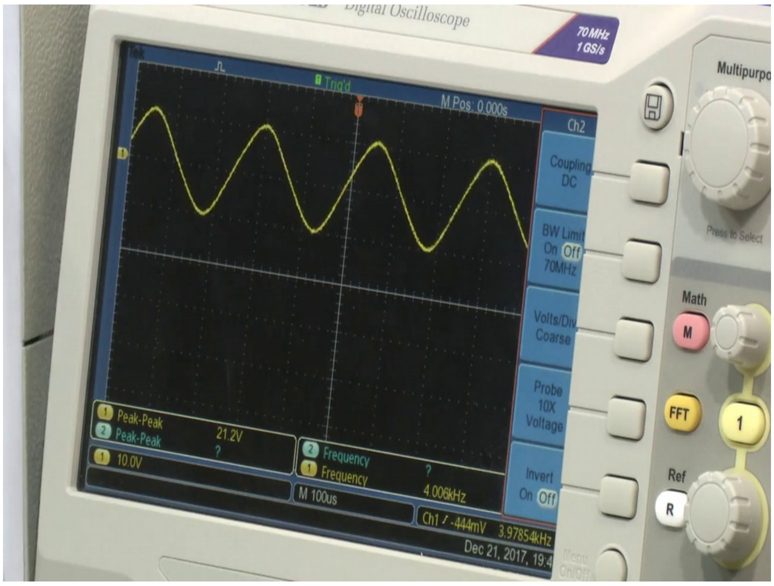
So, now let us come back to the breadboard come back to the breadboard. So, we were looking at the we were looking at the RC phase shift oscillator. And now we have to measure the output in the oscilloscope.

(Refer Slide Time: 36:16)



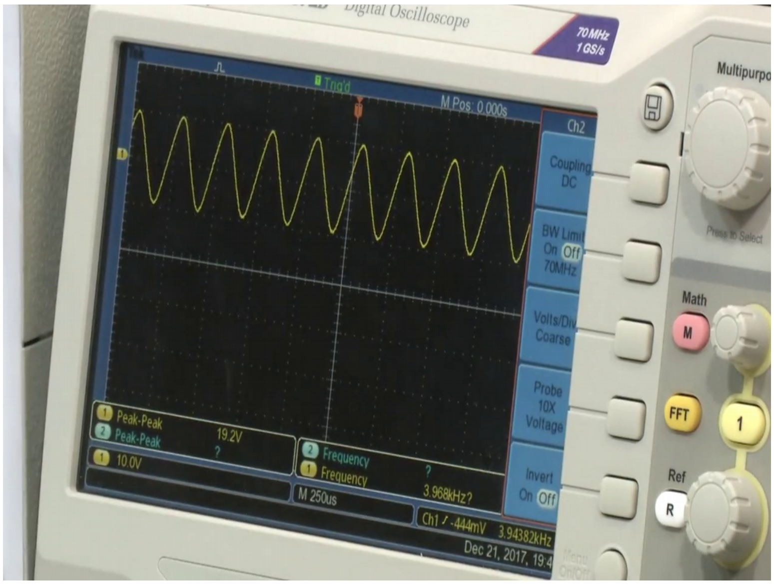
So, he has to connect he has to connect the he has already connected the bias voltage he has connected the bias voltage. And now he is connecting he is connecting, the oscillator the output of the oscillator to the oscilloscope output of the oscillator to the oscilloscope.

(Refer Slide Time: 36:39)



So, what we see we see that at the output of the oscillator the frequency is 3.981 kilo hertz 3.981 kilo hertz, which is half of our three-fourth of we can say theoretical value. And that is again because theoretical value we have assumed the resistors would be exactly 100 kilo ohm. The capacitors would be exactly 100 nano farad, but in actual experiments the capacitors values would not be exactly the one that we have considered in the circuit and that is why we can see the change.

(Refer Slide Time: 37:21)



However one thing that we can see clearly is the oscillation occurring. Now, this oscillation occurs at frequency peak to peak voltage is 19.6 kilo volts around 19 volts, because we have applied the we have gain we have a gain which is very high and, that is why we have 19.2 volts at the output of the oscillator alright. So, this oscillation we will 1 thing you should understand is we have not applied, we have not applied any input signal we have not applied any input signal.

Now, if I change the frequency if I change the frequency, what will happen? Because, you can change the frequency or you can change the signal, by changing the resistors right by changing the resistors or by changing the capacitors. You can see that in the in the slide we are shown that, if you have a variable capacitor, then you can change the frequency of the RC phase shift oscillators right. So, here we were able to see how the RC phase shift oscillator can be implemented, can be implemented using the operational amplifier.

See now he is showing that if you change the feedback right, if you change the feedback what are the, what is the change in the oscillation you see? Now, if he is changing the feedback, that is feedback resistor and thus the if the feedback is changed you will see the oscillations at the output you see it is not there it is died, it is dead right if you see the oscillator output in the oscilloscope you can see that now you cannot see any oscillations right, because a feedback resistor has been changed right.

Now, if you again put it back if you again put it back, you can just hold you can just show the oscilloscope. Now, he is again replacing the feedback resistor with the original resistors and, you can immediately see that you have the oscillations you have the oscillations right. So, from here what we understand is that if we want to implement a RC phase shift oscillator, using operation amplifier, then we can implement it very easily using a breadboard using oscilloscope and using DC power supply.

We do not require any input signal as you see right, because input DC it comes from the noise. And then we have here we can adjust the gain and we can adjust the feedback such that you can have a sustained oscillation., but if you change the feedback we can also see that you will see the signal is dying right.

So, we have seen we have seen that we can have oscillations we can have oscillations sustained oscillations by changing the R and C of in particular feedback of this particular oscillator and, we were able to see what is the change in the output signal? At the same time what we also are able to see is that if I if I change the feedback, then immediately my signal in the oscilloscope comes to 0 comes to 0 alright.

So, what I understand on what I feel is now you are at least able to understand what are RC oscillators what are RC phase shift oscillators, why R and C are used how many number of R and C we used three number; that means, we are getting 180 degree right we are using inverting amplifier, but in case of there are certain oscillators where it does not require any feedback, feedback in the terms of RC feedback or any kind of feedback, because the output is in phase in phase with the input, because the same output we can get feedback right. So, in some of the oscillators we will see that there is no feedbacks required. And in that kind of oscillators what are those oscillators or how can we design this kind of oscillators we will see in the next module.

So, for this module you look at the video once again and understand quickly, what are the RC phase shift oscillator alright till then you take care and I will see you in the next module, bye.