Op-Amp Practical Applications: Design, Simulation and Implementation

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Lecture – 03
Introduction/ Summary on Op-amps Contd

Welcome to this module. And, this is in continuation with our last module. So, the idea here is that we are looking at the summary of integrated circuits, MOSFETs, op-amps and their applications. The reason of revising this particular slide is that we can use the knowledge that we acquire either in the last course or in the present modules for practical applications of op-amp.

So, to understand the op-amps, we need to understand the theory for op-amp, right. And that is why we are looking at the characteristics in the parameters of the op-amp. So, the in the last module what we have discussed, we are discuss oscillators right. And in oscillators we have seen that there are several kind of oscillators depending on the waveforms, depending on the frequency, depending on the components used, depending on the feedback. And then we have also seen the Barkhausen criteria, right where we required the mode of a into beta it is again into feedback factor should be greater than equal to 1. And actually not or its and the phase shift that is the output signal that is feedback to the input the phase of that output signal that is feedback to the input should match the input signal phase right. That means, that feedback phase should be 0 or 360 degree.

Then after that we have seen RC oscillators, right. So, and in RC oscillators we have seen RC phase shift oscillator, how we can phase shift 180 degree signal from the output of the inviting amplifier using RC network. And then we have also seen Wien bridge oscillator where there is no need of a phase shift and that RLC which as the frequency sensitive arms by changing the value of RLC; we can change the frequency right.

So, we have also discussed that I if I go and use LLC instead of RLC. That means, inductor and capacitor than the oscillators can be used for high frequency applications, right. So, what are high frequency applications and how we can design LC oscillator?

So, let us see today how we can design LC oscillators.

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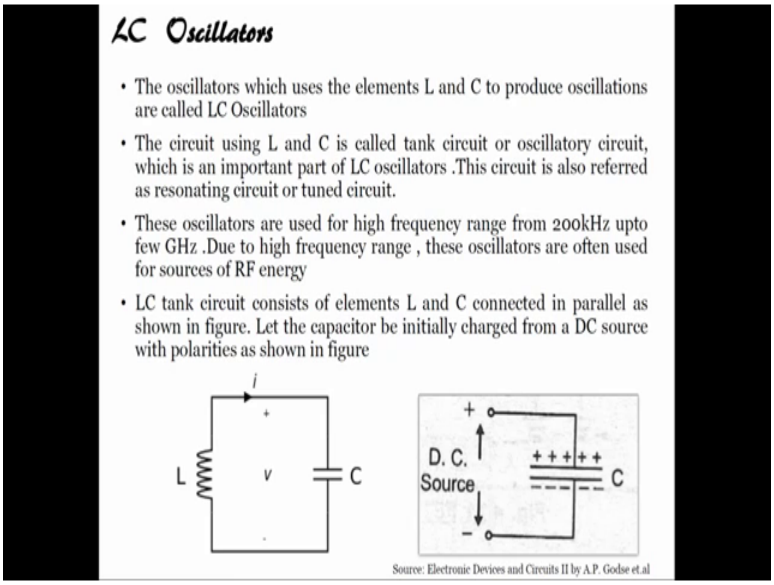

So, if you see on this screen what you see; that the oscillators which uses the elements L and C to produce oscillations are called LC oscillators. The circuit using L and C in is called tank circuit or oscillatory circuit which is an important part of LC oscillator circuit, this circuit is also referred to as resonating or tuned circuit, right. So, you can see on the left side L inductor and capacitor, this is the circuit used for oscillation in the LC oscillators. These oscillators are used for high frequency range like we discussed from 200 kilo hertz up to few gigahertz.

Now, since the frequency range is high this oscillators are also referred as RF or sources for RF energy; resources of RF energy. LC tank oscillators circuit consists of LLC connected in parallel as shown in the figure. Let the capacitor initially charged from a dc source with polarity as shown in the figure. So, suppose the DC source is there. And we are charging the capacitor in the polarity shown in figure what will happen, right.

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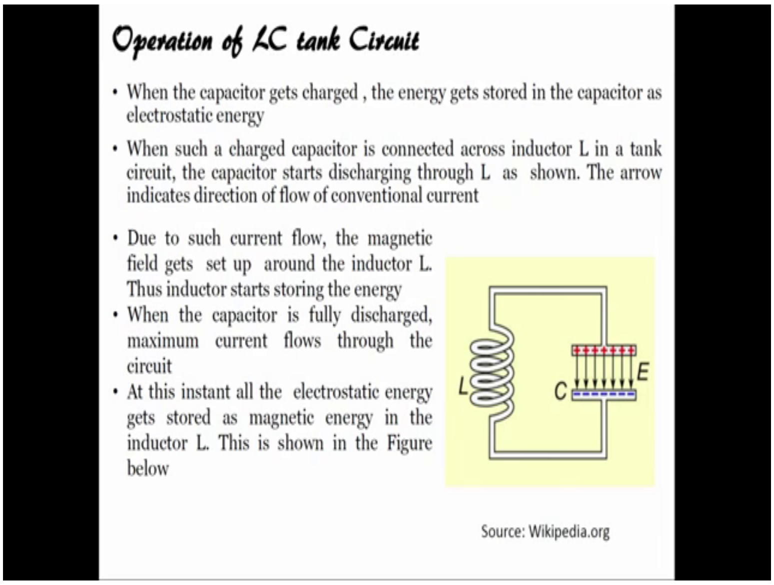

When the capacitor discharges; when the capacitor discharges; the energy that is stored in this capacitor right. When the capacitor charges, let us say first when it charges what happens. When it charges energy stored in the capacitor is electrostatic energy right. And when such a charged capacitor is connected across the inductor then what will happen the capacitor will start discharging. So, when it starts discharging through L right the magnetic field said gets set up around the inductor and thus inductance starts during the energy, right.

So, when capacitor is fully discharge maximum current flows through the circuit at this instant all electrostatic energy is converted to magnetic energy or is stored as a magnetic energy in the inductor.

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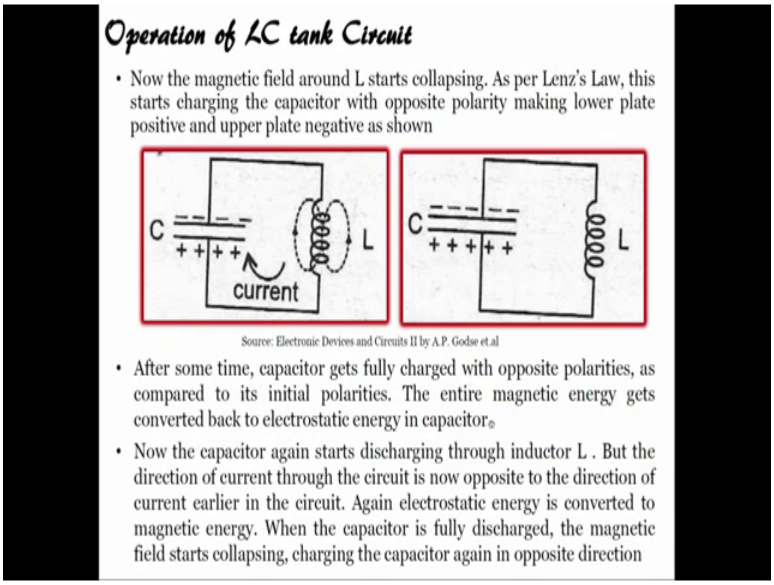

Now, when the magnetic field around L starts collapsing what will happen as per Lenz's law this starts charging the capacitor with the opposite polarity right. So, now, when discharge this starts collapsing the capacitor will start charging in the opposite polarity right making lower plate more positive and upper plate negative right. Now again after sometime when capacitor fully gets charged, it will start discharging and with the opposite polarities as compared to its initial polarities, right. Initially it was plus on the top plate minus on the bottom plate. Now it is plus on the bottom plate minus on the top plate.

So, now it is discharging with the opposite polarity compared to its initial polarity and the entire magnetic energy gets converted to electrostatic energy in capacitor wow that is earlier, we have seen. And now the electrostatic energy when it starts discharging is converted to magnetic energy once again, right. So, it is from when inductor discharge it is electrostatic energy that is stored in a capacitor when the capacitor discharges in the magnetic energy that is stored in the inductor, right. And this keeps on it is keeps on continuation until end and because of this; what will happen?

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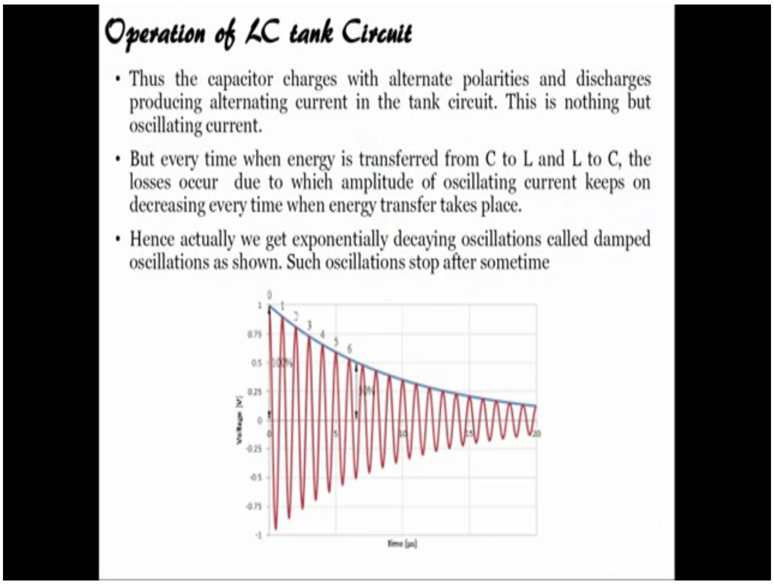

What will happen that every time when this transfer of energy occurs, right, there is a loss and this loss causes the amplitude of the oscillating current decreasing?

See this loss because of the inductor charging and capacitor charging and capacitor charging and capacitor charging and inductor discharging. And again this goes on continuation what happens every time this discharge and charging happened there is a loss in the circuit; And this results in the lower oscillation; oscillations gets down as you can see here and current keeps on decreasing, right. So, actually we get an exponential decay as you can see from the figure oscillations. And these are called damped oscillations this are called the damped oscillations, right. So, such oscillations stop after sometime of course, right.

So, initially you can see and then it is after sometime you can see that these oscillations are on the on the edge of die right; on the edge of die.

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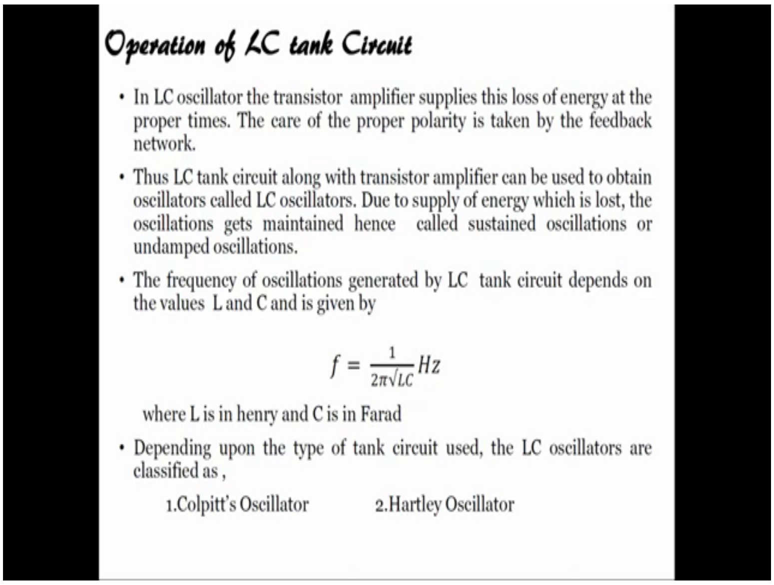

So, what will be what we can do right what we can do. So, in LC oscillators the transistor amplifier supplies this loss of energy at proper time. So, if I have a transistor amplifier then that will be energy that is loss during the charging and discharging of the inductor and capacitor right can be compensated using the transistor amplifier right. The LC circuit along with the transistor amplifier can be used to obtain oscillators called LC oscillators due to supply of energy which is lost the oscillation gets maintain; and hence called sustained oscillation or undamped oscillation.

Here the frequency of oscillation generated by LC is given by f equals to 1 by 2 pi root LC right. Where, L is in Henry and C is in Farad depending on the type of tank circuit the LC oscillators are classified into two categories: one is called Colpitt's oscillators, another one is called Hartley oscillator.

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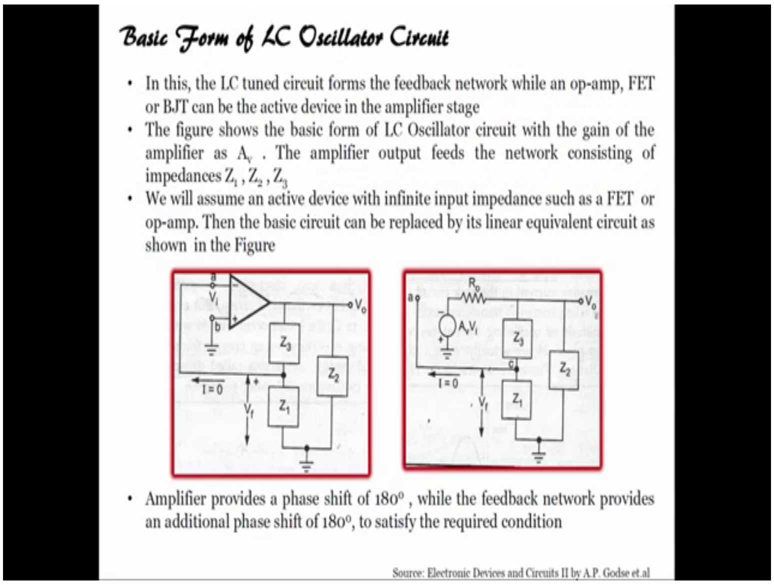

Now, LC or circuit forms the feedback network while an op-amp or FET or BJT can be active device the figure shows here. You can see the left side of the figure shows form of LC oscillator with gain of amplifier A, right amplifier output feeds the network consisting of impedances Z 1, Z 2, Z 3.

We will assume that active device with infinite input impedance such as a FET right or op-amp then the basic circuit can be replaced by linear equivalent circuits. So, if I want to replace this by linear equivalent circuit, I can draw like this right see its input impedance is infinite right and amplifier provides a phase shift of 180 degree, because it is the inverting terminal. We are applying the signal while the feedback network provides the phase shift of 180 degree. So, here the feedback network that we are we are designing or will be using it will provide another phase shift od 180 degree to satisfy the required oscillation, there is a that total phase shift should be 360 degree.

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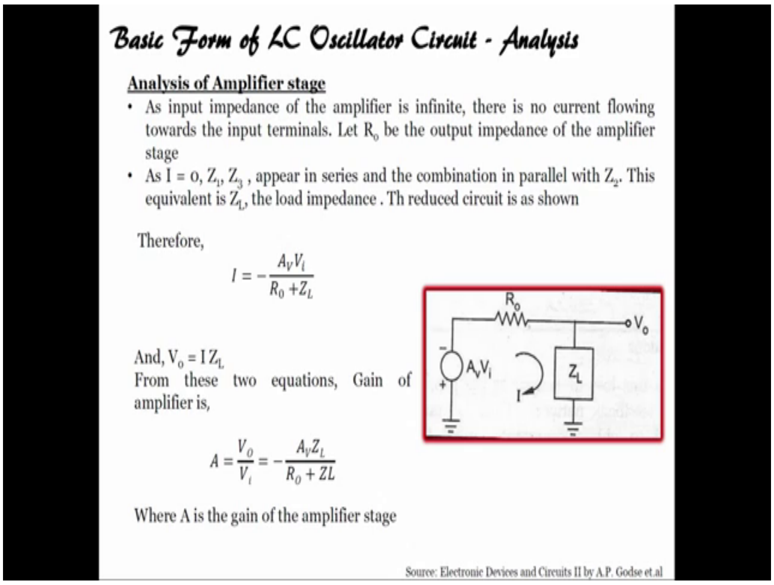

So, if you analyze this amplifier stage if analyze this amplifier stage what we get what we get is that I equals to minus A v V i upon R o Z L R o plus Z l, you can see from here right. And using the equation right what we can get gain of the amplifier V o by V i equal S to A v Z L upon R o plus Z L where a is the gain of the amplifier stage right.

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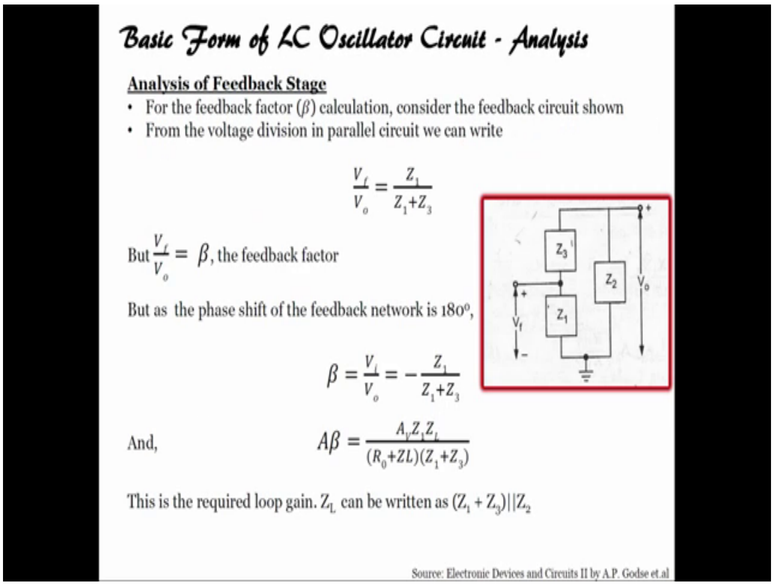

So, further when we analyze what we get we get beta equals to V i by V o and that will be nothing, but the Z 1 upon Z 1 plus Z 3 in terms of minus that is 180 degree phase shift. So, a beta would be this one.

So, this is the required loop gain this is the required loop gain Z L can be written as Z one plus Z 3 parallel to Z 2, you can see here, right.

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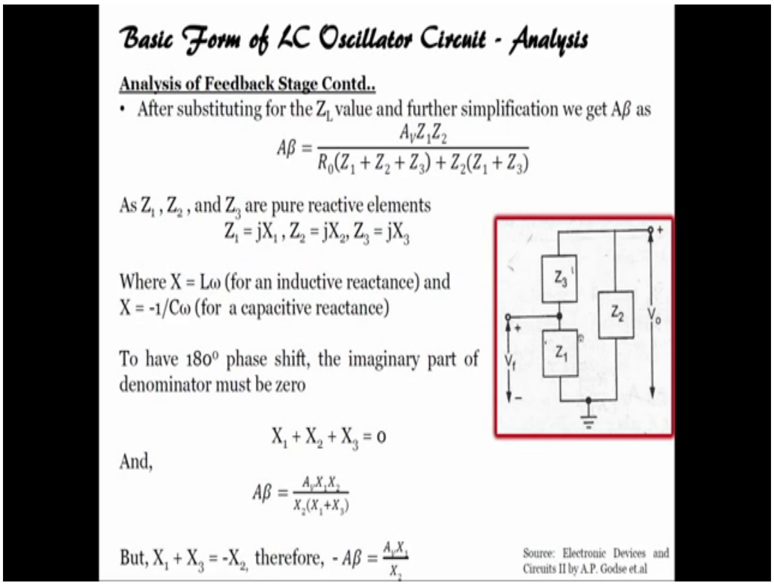

So, if you substitute what we get you substitute. Then finally, when we when you solve this equation when you solve this equation what you get you get is that you are a beta right will be A v X 1 by X 2; A v X 1 by X 2.

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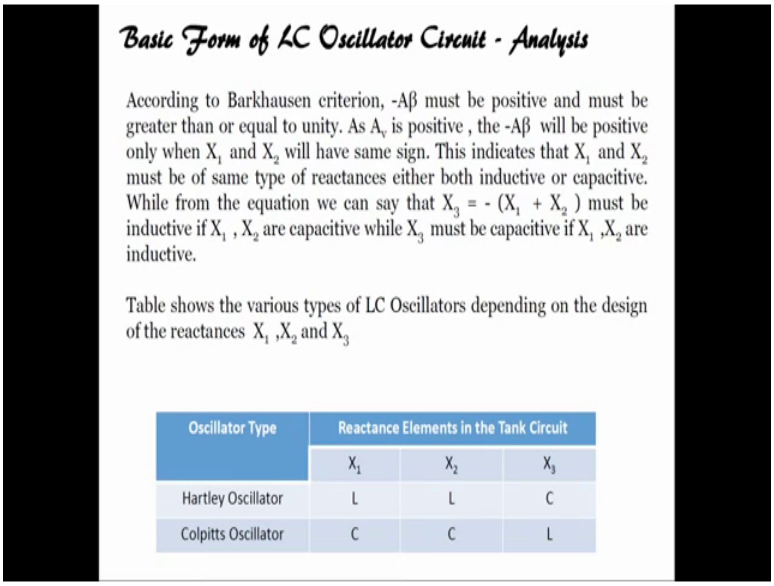

And A v must be positive right here what we see is minus a into beta minus a into beta in the last line, we see that when we derive this when we solve this we get minus A beta equals to A v X 1 by X 2, but it cannot be minus right it should be X minus A v should be positive and it must be greater than or equal to unity right we have seen that it is Barkhausen criterion.

So, as a v is positive minus a beta will be positive only when only when X 1 and X 2 will have same sign right when if X 1 and X 2 have same sign. Then only minus a beta can be positive right this indicates that X 1 and X 2 should be of same type of reactances you see here again minus a beta equals to a v into X 1 by X 2, but minus a beta should always be greater than equal to 1. That means, X 1 and X 2 should be same reactances right should be have same type of reactance. So, either we can use X 1 and X 2 as inductive or we can use X 2 and X 2, X 1 and X 2 as capacitive, right either X 1 and X 2 as inductive or capacitive while we can also say that X 3 equals to minus X 1. That means, that if X 1 and X 2 are capacitive X 3 should be inductive and if X 1 and X 2 are inductive X 2 should be X 3 should be capacitive, right. So either X 1, and X 2 are inductive, then X 3 its capacitive X 3 if X 1 X 2 are capacitive, then X 3 should be inductive like vice versa.

So, if X 1 and X 2 are inductive and X 3 is capacitive, it is Hartley oscillator and if X 1 and X 2 are capacitive and X 3 is inductive and it is Colpitt’s oscillator right, we have seen this.

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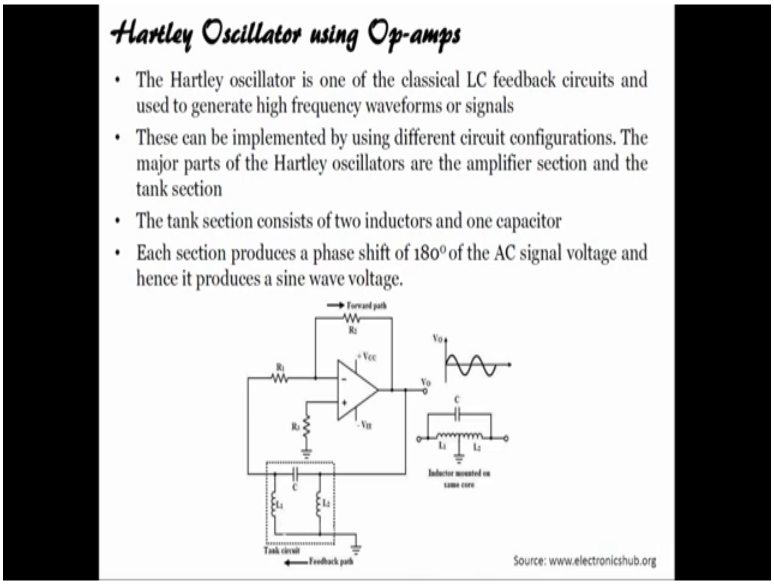

Now, if I want to design Hartley oscillator, if I want to design Hartley oscillator, then this is the way to design Hartley oscillator. This is the tank circuit as we know right and this can be implemented by using two inductors and one capacitor each section produces a phase shift of 180 degree, right each section produces 180 degree. And hence, it produces a sin voltage right produces a sin wave voltage.

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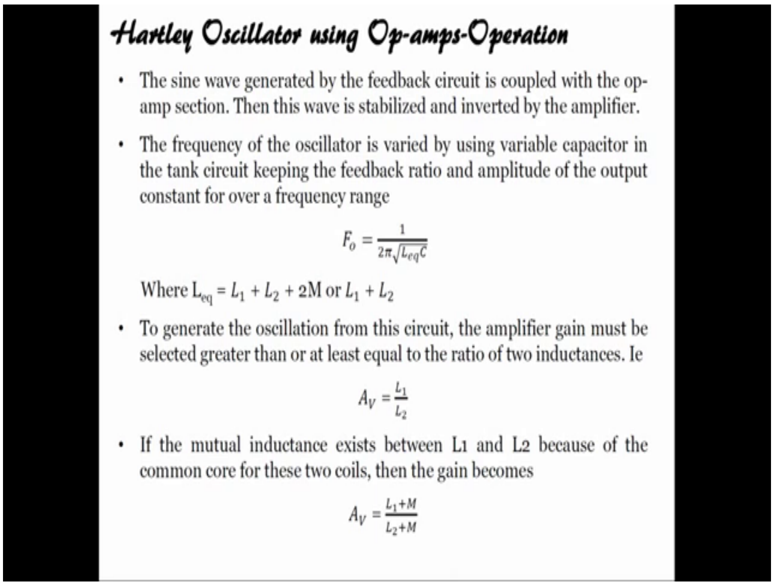

Here we know that the F o equals to one upon two pi under root of L equivalent into c right, because there are inductors L 1 and L 2. So, where is L equivalent L equivalent is nothing, but L 1 plus L 2 plus 2 M or L 1 plus L 2 to generation oscillation from this circuit the amplifier must have be selected greater than or at least equal to the ratio of 2 inductances, right. That means the amplifier gain should be at least equal to L 1 by L 2. So, it should be greater than or equal to it should be greater than or equal to the ratio of L 1 and L 2 if there is a mutual inductance if there is a mutual inductance that exist between L 1 and L 2, right.

Because of the common core, then the gain becomes L 1 plus M by L 2 plus M.

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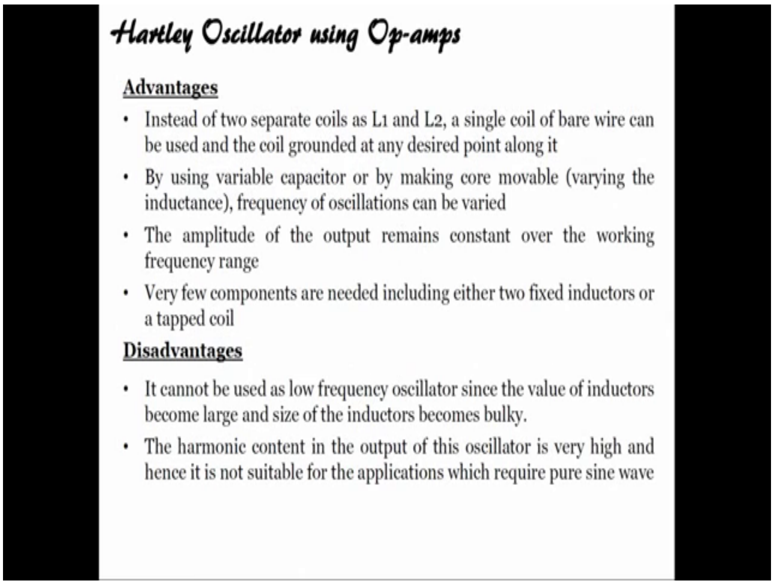

So, what is the advantage of this oscillator the advantage is that instead of two separate coils as L 1 and L 2 a single coil of a bare wire can be used. And the coil can be grounded at any desired point second is by using variable capacitor or by making core movable frequency of oscillations can be varied right. This, another advantage, amplitude of the output remains constant over the frequency range. and finally, very few components are required right for including either to fix inductors or tapped coil, but there are few limitations what are limitations it cannot be used for low frequency oscillation, right.

Since the value of inductors becomes large and size of the inductor becomes bulky right it is obvious correct the harmonic content in the output of this oscillator is very high. And hence it is not suitable for the application which requires pure sine wave, there is harmonic oscillations that limits its use for pure sine wave Colpitt’s oscillator.

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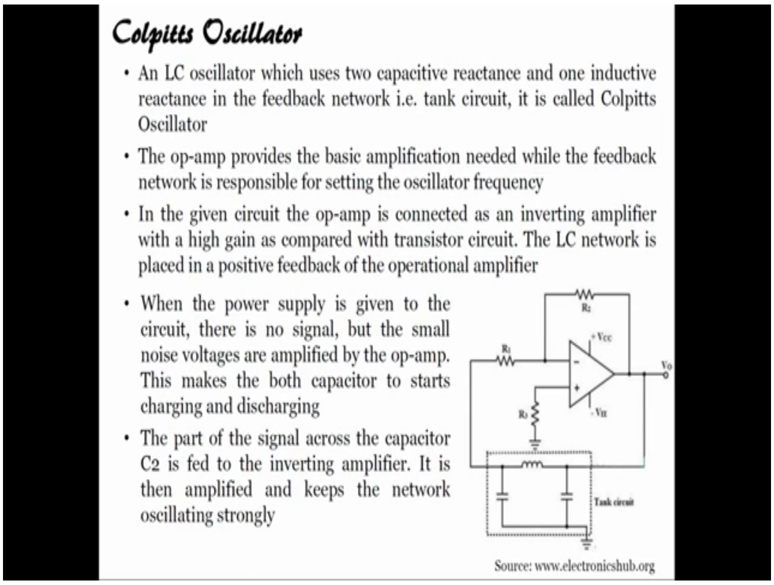

Next is a Colpitt's oscillator, here we are using two capacitor and one inductor in this oscillator like we see here in the tank circuit there are two capacitors right and one inductor. So, here the op-amp provides the basic amplification needed with the feedback network in the given circuit op-amp is connected as inverting amplifier the high gain as compared with transistor circuit in the power supply given to the circuit, there is no signal, right. Initially there is no signal, but the small noise voltage are amplified with the help of amplifier op-amp amplifier.

This makes the both capacitors to charge and discharge write the part of signal across the capacitor C 2 is fed to the inverting amplifier right. Here, it is fed back to the inverting amplifier and then amplified and keeps the network oscillating strongly right. Initially through the noise voltage where amplifying the noise voltage with the help of amplifier with a feedback to the tank circuit and the part of signal is feedback to the amplifier and there is a strong oscillations which causes strong oscillations.

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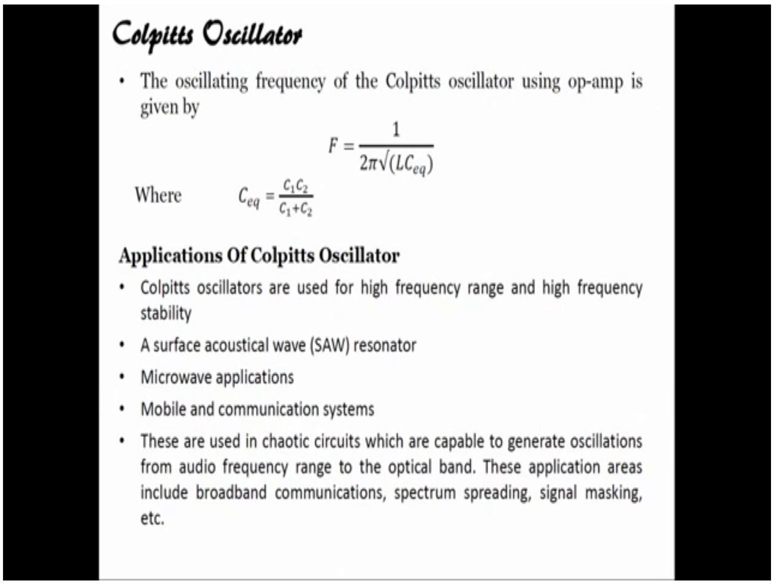

Here we have same formula, but instead of L equivalent here we have c equivalent and we know that c equivalent is nothing but C 1, C 2 by C 1 plus C 2; what are the applications of Colpitt's oscillator; Colpitt's oscillators are used for high frequency range and high frequency stability right, can also be used as a saw resonator a surface acoustical wave resonator used in microwave applications mobile and communication right. And these are used in chaotic circuits which are capable to generate oscillations from audio frequency to the optical band the application area include broadband communications spectrum spreading signal masking etcetera.

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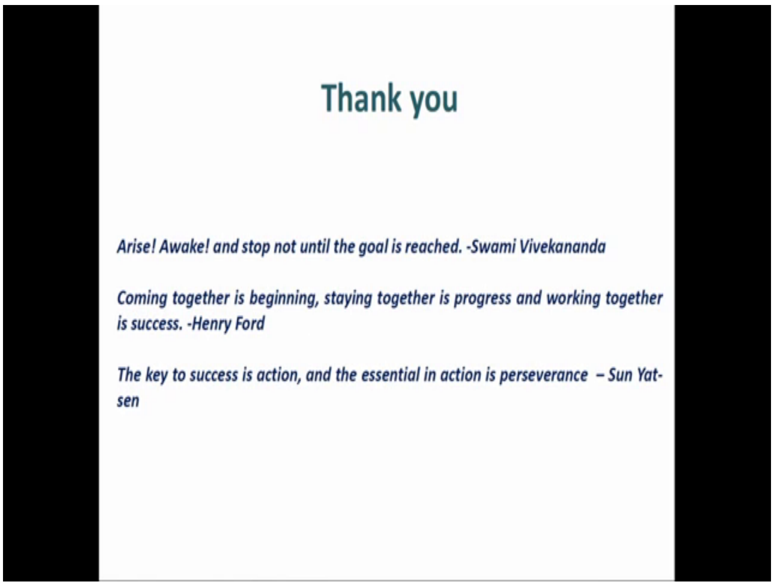

So, this was the end of this particular summary of the oscillators, right. So, if you recall we have just understood right from the indicator circuit quickly right, then we went to op-amp its characteristics. Then we saw few amplifiers then we saw oscillators right and we also saw filters we also filters. Now in the in the next module, or in the next module or other in the next lecture we will see how we can implement design and implement circuits using operational amplifier. Like I said, slowly and gradually you will understand when you when you read from my earlier course till now, we are slowly and gradually increasing the tempo right we are increasing the tempo.

The reason is that we should start from basic right understand the concept grab it and then move on to applying it. So, you will see in this particular applications of op-amp it is little bit complicated than the earlier particles that we have seen in the last course right. And finally, we are actually designing signal conditioning device for measuring ECG as well as heart rate right and that is really complicated project.

So, let us see how we go further in the next lectures. I will see you in the next lecture, till then you just go through all the models right, keep your basic strong right refresh it, even you know it it is always good to refresh, right. I will see you in next class. Till then you take care. Bye.