Integrated Circuits, MOSFETs, OP-Amps and their Applications
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Lecture – 30
Hartley and Colpitt's Oscillator using Op-amp

Welcome to this module and in the last module what we have seen? We have seen how we can use resistor and capacitors along with operational amplifier to form the oscillators right. And we are seeing two kinds of oscillators one is your phase shift oscillator and another one was your Wein bridge oscillator. Now if I want to operate or if I want to use the circuit in a high frequency range from 200 kilo hertz to few gigahertz can I use the similar RC phase shift oscillator or Wein bridge oscillators I may not; I may not be able to use those oscillators at high frequency.

So, in the application when you are asked that we have to we have to design an oscillator which can be used for or at higher frequency; what you will do? What you will do? You have to design oscillator using LC using inductor and a capacitor. So, how does a inductor and capacitor help us and how does the use of inductor and capacitor along with the Op-amp will help us to form a LC oscillators and then we will see the type of LC oscillators as well ok.

So, let us see what are the LC oscillator?

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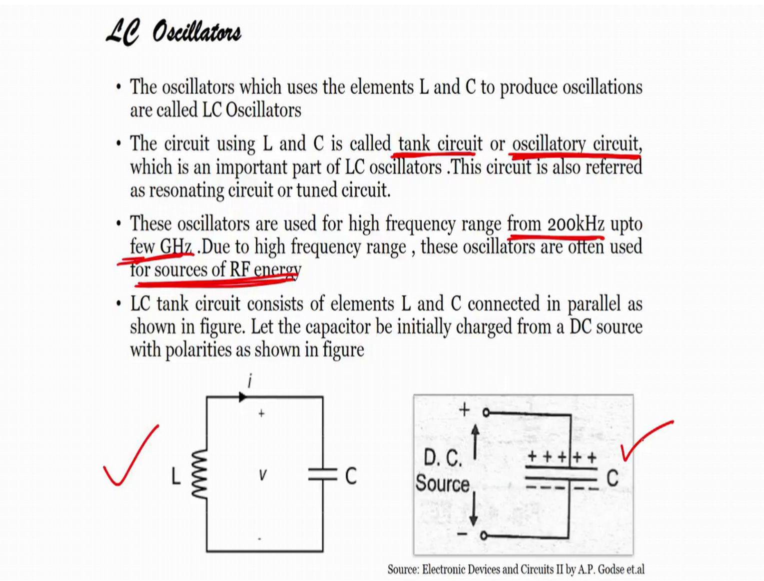

If you see the screen what you will see? That the oscillator which uses the elements L that is inductor; L C that is capacitor to produce oscillations are called LC oscillators very easy definition right. Now the circuit uses or using L and C is also called tank circuit right this also called tank circuit or oscillatory circuit tank circuit or oscillatory circuit.

Which is an important part of LC oscillator this circuit is also referred as resonant circuit or tuned circuit that is why LC oscillators are also called tuned oscillators, tank oscillators; resonant circuits they are if the circuit that is a feedback circuit is a LC circuits. This oscillators are used you see at higher frequency from 200 kilo hertz to up to few giga hertz.

Due to higher frequency range these oscillators are often used for sources of radio frequency energy ok. So, now, you know that what kind of oscillators can be used for RF energy? We can say that the oscillator like LC oscillators can be used to understand or to if I know the LC oscillator, I can use as a source for RF energy ok. I can use LC oscillators as a source for RF energy. So, as we have discussed LC tends circuits of L and C connected in parallel as shown in figure you can see here right.

Now how does this works? Ok how does this work? So, initially let us consider that the when we apply the DC source the capacitor is charged with polarities as shown in figure; as polarities are shown in figure all right.

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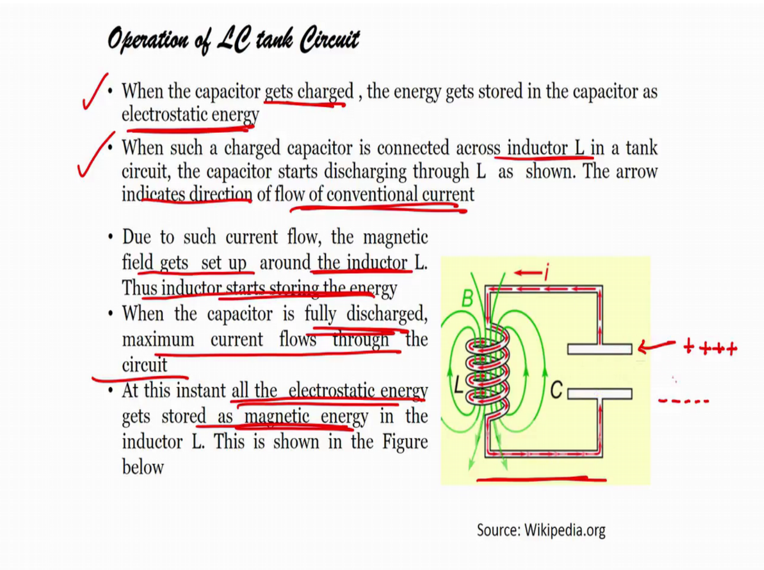

Now you can see here the video right when the capacitor gets charged, the energy gets stored in the capacitor as electro static charge ok. We will see how this; what exactly this is happening in this particular aj video here; we will see later. Right now you focus on the first slide even this video is distracting you from focusing try to focus.

These are another exercise that when we are when we are learning, when we are understanding something; now our focus should be completely on what we are learning and not to other things. So, if I am saying that let us focus on the slide we should not focus on this particular video; let us see how many of you can do that.

So, whatever is where were we? We were that when the capacitor gets charged right the energy gets stored in forms of in the form of electro static energy when such a charge capacitor is connected across the inductor in a tank circuit the capacitor starts discharging. So, what will happen? If there is a capacitor which is charged and if I connect the capacitor to a inductor what will happen it will start discharging it will start discharging.

So, if you see the screen that is what is written when the capacitor is connected across the inductor right; the capacitor starts discharging through inductor as shown the arrow indicates the direction of flow of conventional current; the arrow will indicate the directional of the conventional current. Due to such current flow the magnetic field gets set up around the inductor and thus inductor starts storing the energy. So, what we are saying is; capacitors will starts discharging, inductor will start charging. When the capacitor is fully discharged the maximum current flows through the circuit correct initially the capacitor was charged.

Now, the capacitor is discharging through the inductor and the inductor got charge and the capacitor is discharged. At that instant all the electrostatic energy is stored as the magnetic energy; where why magnetic energy? Because now the energy is converted into the inductor initially there was capacitor, it was charged that charging is called electrostatic energy.

Now if I connect a capacitor or in series or in a fashion with the in the inductor what will happen that the charge in the capacitor this will start discharging and inductor will assume that this pen is a inductor this two fingers that I am showing it to you is; the thumb enough index finger these are capacitor plates.

Now, capacitor plates are fully charged when you connect the inductor with the capacitor this plate will charge the capacitor will starts discharging and inductor will starts storing the charge right; inductor will start storing the charge. So, this electro static energy is converted to magnetic energy, the electro static energy is converted to magnetic energy all right this is easy this is what is shown in the figure.

So, let us come back to the screen and what will see here is you see here if you see initially the capacitor is red where you see; when the plus is here you see here right. So, when there are plus like this you see you can see here 1, 2, 3 and that is it correct. So, when there is plus here that will be minus here; you see this one can you see this? When you see that you will see that maximum electrostatic energy is there. Now when you have connected inductor when you connect an inductor; the capacitor will start discharging and the inductor will start charging that is what is shown here; initially capacitor is charged now inductor is charged, now inductor start discharging and capacitor will charge charging in reverse direction.

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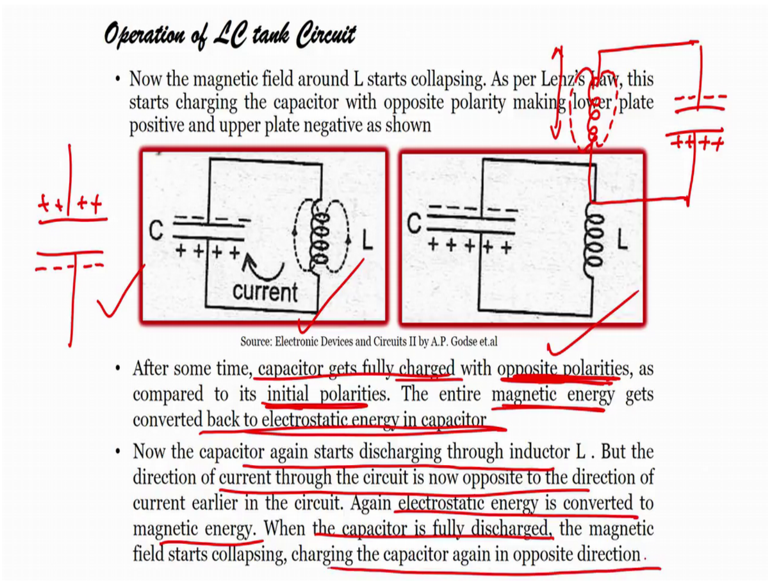

We will see here you see. So, what we have seen? Capacitor is charged initially with plates in this particular fashion right then it is connected to a inductor.

What will happen the capacitor will charge discharging and inductor will start charging. So, magnetic energy is there right this is what is shown here; now once this is there the magnetic field will star collapsing and we should know a law called Lenz's law; Lenz's law. As far the Lenz's law this starts charging the capacitor with the opposite polarity making low longer plate positive and upper plate as negative making; the lower plate as positive and upper plate as negative. So, what does he said this is a first condition right.

Now, the inductor is charged and capacitor is discharged. So, we have to remove the charge from the capacitor because it is now discharge. Now what will happen now this magnetic field that is there in the inductor this one; that will start collapsing and the it will start discharging and capacitor will starts charging, but in the reverse polarity because of the Lenz's law because of the Lenz's law right. So, now, it is charged like this and inductor is completely discharge, which you can see here right or you can see here this circuit where it is when the inductor is discharging capacitor is charging.

But now it is a reverse way right. So, after sometime capacitor fully gets charged with opposite polarities as compared to the initial polarity initial polarity is where that this capacitor, this capacitor cause having positive polarity like this upper plate and lower plate was negative in this case it is reverse. So, at the capacitor gets fully charged with the opposite polarities right.

The entire magnetic energy gets converted back to the electro static energy in the capacitor correct. So, when the inductor starts discharging the entire magnetic energy would be again converted back to the electro static energy; entire magnetic energy will be converted back to the electro static energy.

Now, what will happen? Now capacitor again starts discharging through the inductor see. So, so beautiful first capacitor charge then is discharge, inductor charge that discharge, the capacitor charge and capacitor discharge again inductor charges this goes on this goes on continuously right. So, by the direction of the current again through the circuit is now opposite and again the electro static charge is converted to the magnetic charge. When the capacitor is fully discharge, the magnetic fields are collapsing charging the capacitor is again in the opposite polarity or opposite direction.

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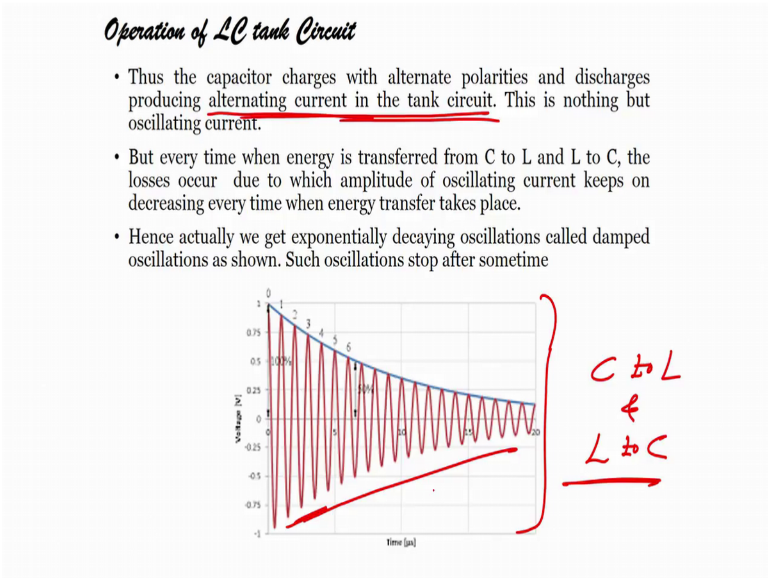

So, what will happen thus the capacitor charges it alternate polarities and discharge is producing alternate current in that circuit right is charges; it discharges it charges sorry, it charges discharges charges, discharges, charges, discharges, charges, discharges like this.

Now, one thing you may have seen one thing you have seen which is shown here that there is oscillation right see, but, but they are dying they are dying right you see here oscillations are dying right? That is why because every time when an energy transfer from capacitor to inductor and back from inductor to capacitor, there is a lose due to which the amplitude of oscillations; amplitude of oscillations of current keeps on decreasing every time an energy transfer takes place; you see here? it keeps on decreasing.

Hence actually we get exponential decay right oscillations called damped oscillator. Since we have seen right there are damped oscillations. So, this is a damped oscillation such oscillations should stop after sometime such oscillations will stop after sometimes. So, now, we know why there is oscillation we know why there is alternating current? Because of charging and discharging of the capacitor and inductor simultaneously and in opposite polarity; so, capacitor is positive then capacitor will charging the negative polarity upper plate and again it will discharge inductor will charge sorry magnetic energy a magnetic energy collapses; electro static energy again comes in to picture because capacitor again charges with opposite polarity.

So, this goes on continuously, but whenever there is a charge transfer there is a loss of energy and subsequently you will see that the oscillations will start decaying. So, if it such decaying you cannot have oscillator because it will stop right. Oscillator something that can have sustained oscillation; sustained oscillation not decaying oscillation, not amplified oscillation sustained oscillation for long time, but in this particular case what we have seen that LC oscillator in this particular case the damping is called damping right it is dyeing.

So, what we can do to save it or we can generate again the similar kind of wave form let us not let us not let the signal die if you do not want the signal to die that we can do? What we can do? Let us see in the figure let us see here in the slide in LC transistor amplifier supplies this loss LC oscillator transistor amplifier.

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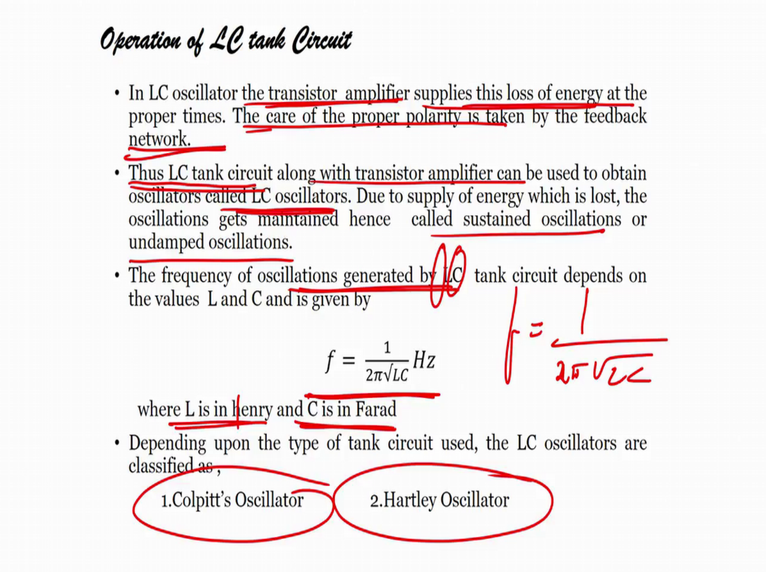

Or a Op-amp supplies this loss of energy at proper times; the care of the proper polarities taken by the feedback network; that means, that whatever the whatever the loss was there that can be that can be taken care of by using the amplifier circuit right by using the amplifier circuit. Thus LC circuit or LC tank circuit along with amplifier can be used to obtained oscillator called oscillations called LC oscillators ok.

So, LC plus amplifier will be called LC oscillator. Due to supply of energy which is lost oscillations gets maintained hence sustained oscillations or un damped oscillations are formed; the frequency of oscillation generated by LC tank circuit is the frequency generator by LC will depend on what? It will depend on inductor and it will depend on capacitor right.

So, here our formula would be instead of 1 by 2 pi R square C square right; we do not write like this right here because there is no RC what we write here? We write 1 by 2 pi under root of LC right where L is in Henry and C is in L is in Henry and C is in farad. Depending on type of tank circuit uses the LC oscillators are classified as Colpitt's or Hartley oscillator.

So, if once I know the function of oscillator; the function of LC oscillator I can use the LC oscillator in two different ways one is called Colpitt's oscillator, one is called Hartley oscillator.

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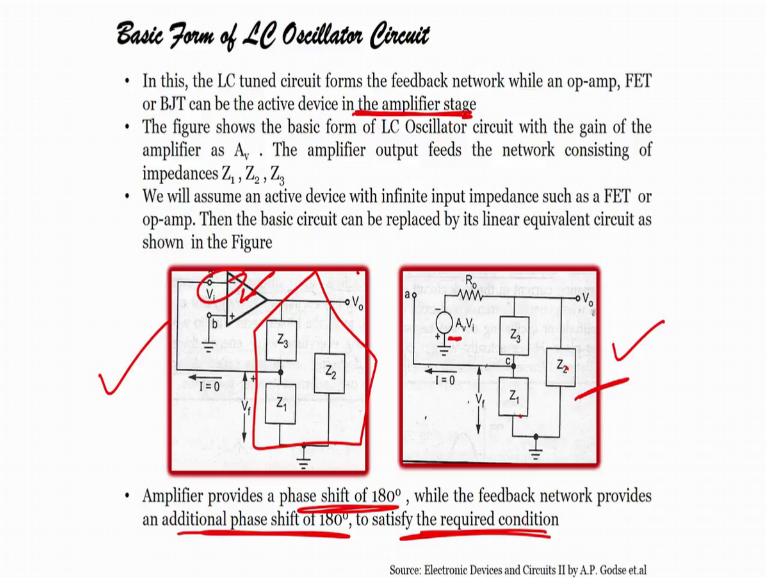

So, we have to see what is Colpitt's oscillator; what is a Hartley oscillator we will see later. First let us see the basic LC oscillator and the feedback network and let us see how it works. So, in this particular circuit what we are looking at the LC tuned circuit forms a feedback network while an Op-amp or FET or BJT can be active devices in the amplifier stage right.

So, the figure shows basic form LC oscillator with the gain of the amplifier as A V ok. So, gain of this particular amplifier right is A V the amplifier output feeds a network consisting of Z 1, Z 2, Z 3 this is your feedback network. We will assume that active device with infinite input impedance such as FET or Op-amp and the basic circuit can be replaced by linear equivalent circuit as shown in the figure; it is a linear equivalent circuit is very simple input impendence extremely high, then you have gain, then you have output impendence low and then you have feedback network Z 1, Z 2 and Z 3 right.

We are talking about this particular circuit. So, amplifier producing a phase shift of 180 degree because is a inviting; while the feedback network provider resurface of 180 degree to satisfy the required condition for the oscillation.

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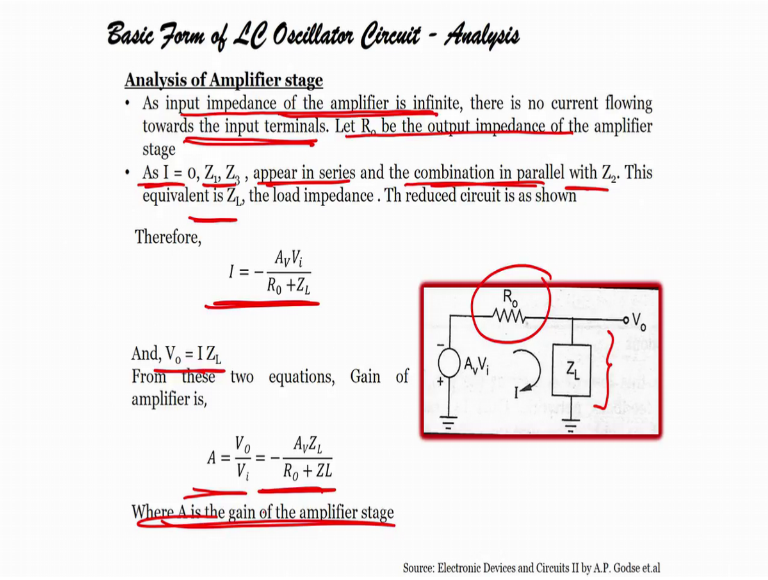

So, let us let us see or let us analyze the amplifier stage let us analyze the amplifier stage ok. So, what we see here? As a input impedance of the amplifier is infinite there is no current flowing towards the input terminals right; as a input impedance of the amplifier is infinite no terminal no current was input terminal we know.

So, let R o be the output impedance which is one here of the amplifier stage as I equals to 0; Z 1 and Z 3 appears in series right clear because I is 0, it looks like Z 1 and Z 3 are in series right while combination in parallel with Z 2. So, Z 1, Z 3 looks as if they are in series as combination of Z 2 in parallel correct? Is where is written here this equivalent circuit is Z L. So, Z 1 Z 3 in series with Z 2 we call as Z L we have Z 1, Z 3 in series with Z 2; this combination we call Z L.

Now, I is what? I is nothing, but minus A V I upon R o by Z L R o plus Z L and V o is nothing, but I into Z L right. So, from this two equations what we gain? Gain is nothing, but V o by V I equals to minus A V Z L divided by R o plus Z L where a is the gain of the amplifier stage right; very easy to determine this.

So, if I want to do analysis of the feedback stage; so, let us consider that now I have feed back stage Z 1, Z 3 and Z 2.

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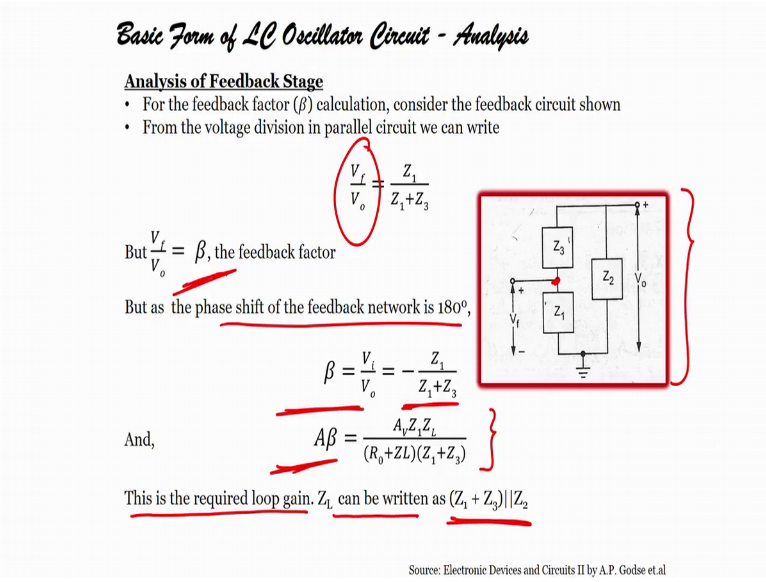

So, far the feedback beta calculation; let us consider the circuit which is shown here from the voltage division in parallel right you see here right what will I have? I it looks like V f by V o is V nothing, but V f by V y nothing, but Z 1 plus Z 1 Z 1 divided by Z 1 plus Z 3, but V f by V o is what? V f by V o is nothing, but your beta. So, beta equals to V I by V o right phase shift is 180 degree. So, beta is V I by V o is minus Z 1 by Z 1 plus Z 3. So, A into beta if I want to write then again I can write the formula is from here right A V into Z L divide by R o plus Z L right which is here into beta.

So, this can be nothing, but this is required loop gain; Z L can be written as Z 1 plus Z 3 parallel to Z 2 right; Z L can be written as Z 1 plus Z 3 parallel to Z 2. This is how the feedback stage analysis can be done; this is how the feedback stage analysis can be done now we did not finished it the we are not finished the feedback let us see further.

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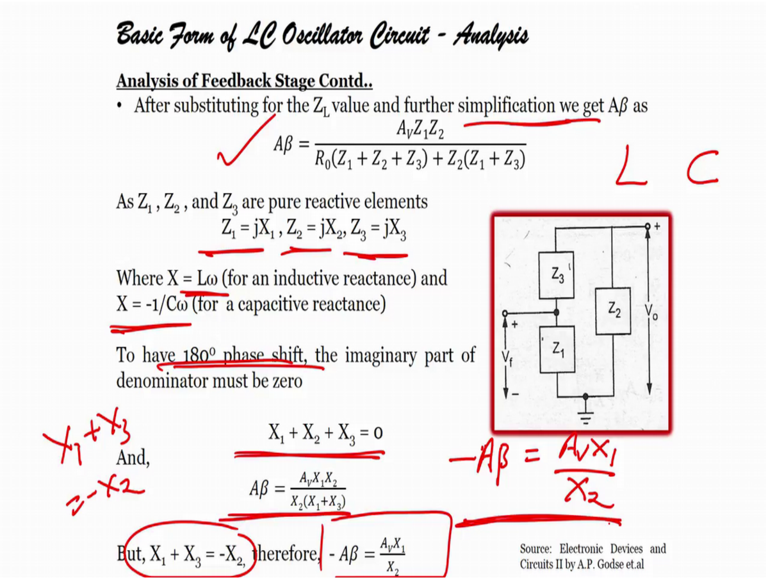

So let us see further; so, after substituting value of Z L, we have to further simplify for further simplification we will get A beta equals to this value.

Now, here Z 1, Z 2 and Z 3 are what? Reactive components because they are either L Z 1 and Z 1, Z 2, Z 3 are either L or they are C; that means, they are reactive components right reactive elements. So, Z 1 is minus j omega X 1, Z 2 is j omega X 2, Z 3 is j omega X 3. So, where X is nothing, but L omega or X can be minus 1 by omega C right for capacitor reactor for inductance we know its omega L.

So, to I have phase shift of 180 degree the imaginary part of the predominated must be 0 right. So, imaginary part of the denominator is 0 then we can have X 1 plus X 2 plus X 3 equals to 0 right and A beta is value which is here. So, what will I have we have you see A V equals this same equation A into beta that is we have replaces Z 1, Z 2, Z 3 by X 1, X 2, X 3; so, but X 1 plus X 3 equal to X 2 right therefore, minus A beta will be equal to minus A V by X 2.

So, minus A beta we will get we will derive A V into X 1 by X 2 correct if X 1 plus X 3 equal to minus X 2 we can have A minus beta equals to A V into X 1 by X 2.

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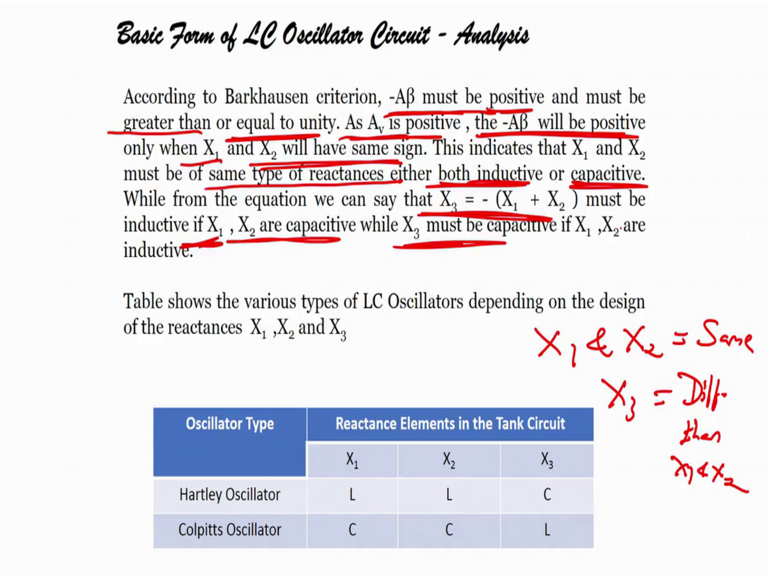

So, in this particular case according to Barkhausen criteria minus A beta must be positive and must be greater than or equal to unity right. As A V is positive minus A V will be also positive because A V is positive here right; only X 1 and X 2 will have same sign; while X 3 will have a different sign right. This indicates that your X 1 and X 2 can be same capacity same the reactive element, but X 3 should be different than the X 1 and than X 1 and X 2 ok.

So, this indicates X 1 and X 2 must be of same type of reactances either both inductive or both capacitive. While the equation the equation what we have seen previously what we have seen X 3 equal to minus X 1 plus X 2 must be inductive if X 1 and X 2 are capacitive while X 3 must be capacitive if X 1 and X 2 are inductive.

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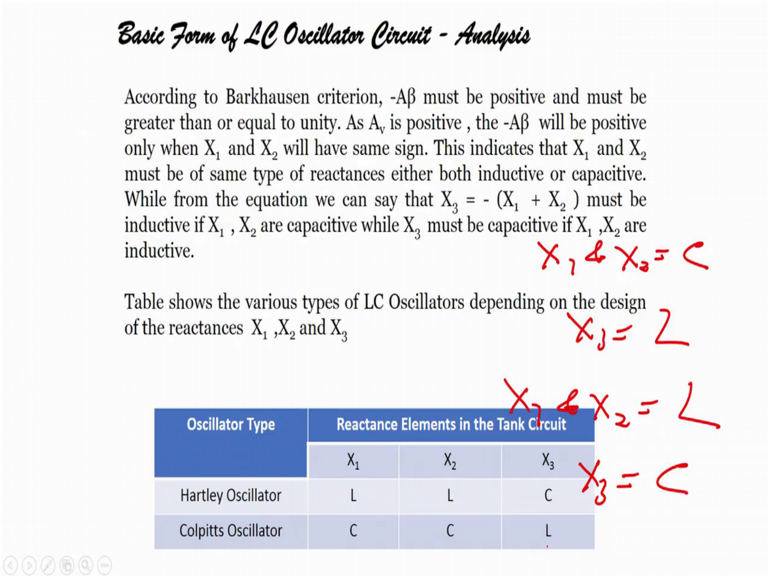

So, what we understood is what we understand here is that if I have a reactances; if I have value of X 1, X 2 and X 3 and if I select X 1 and X 2 to be capacitor then my X 3 can be inductor.

If I have X 1 and X 2 to be inductor my X 3 would be capacitor ok. So, this is what we have to remember in case of the LC oscillator using LC oscillator circuit and what we understand from here is if I have X 1, X 2 equal to L X 1 and X 2 equal to L and X 3 equal to C then it will be my Hartley oscillator; Hartley oscillator. If I have X 1 and X 2 equal to C and X 3 equal L; then I will have Colpitt’s oscillator; then I will have Colpitt’s oscillator alright. So, depending on the reactances element in the tank circuit; we can determine whether it is L Hartley oscillator or Colpitt’s oscillator ok.

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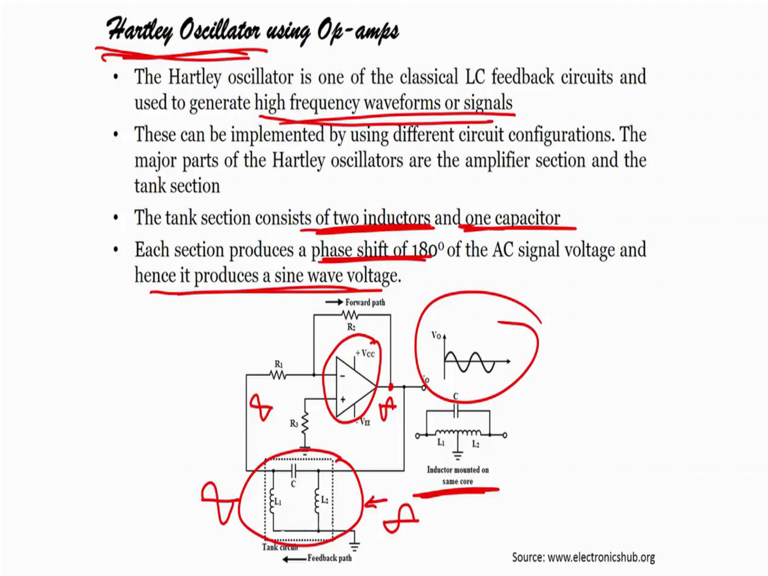

So, let us see now let us see to Hartley oscillator and then we will go to the Colpitt's oscillator alright. So, what exactly Hartley oscillator is? Now we have seen LC oscillator and we understood that how LC oscillator works, but using LC oscillator; if we have two inductors that is X 1 and X 2 are inductor and X 3 is a capacitor; then it becomes an Hartley oscillator.

So, in case of Hartley oscillator what is a circuit and how does it work? If it is a Colpitt's oscillator, you see you have to again be little bit smart; if you do not remember in exam how many capacitor Hartley was using and Hartley oscillator we have used, how many inductors in cap in Colpitt's oscillator we have used.

So, we think like this it is easy way of understating remembering Colpitt's start with what C right Colpitt's starts with C; we have two capacitors we have two capacitors and one inductor opposite is Hartley one inductor two inductors one capacitor right. So, now, I do not forget between Hartley and Colpitt's because I know that these are trick these are trick to remember trick to remember; we will not work every where it will not work every time, but in case if you do not remember is a trick to remember how many capacitors can be used, how many inductors can be used.

If there are two capacitors it will be Colpitt's oscillator right start with C; if there are two inductors it will be Hartley oscillator; it does not start with L, but I am just giving you an example to remember quickly Colpitt’s oscillator. So, anyway let us see Hartley oscillator and how does it work.

So, the Hartley oscillator is one of the classical LC feedback circuits and used to generate high frequency wave form or signals alright. This can be implemented by using different circuit configuration; the major part of Hartley oscillator are the amplifier section and the tank section of course, it is amplifier section and the tank section. The tank section consists of two inductors; you see two inductors and one capacitor that is your Hartley oscillator ok.

Each section produces a phase shift of 180 degree of the AC signal voltage and hence it produces a sine wave. So, this is the tank circuit you can see two inductors one capacitor right is an inverting amplifier inverting amplifier; that means, that; that means, that my output would be output would be 180 degree out of phase with respect to input that is why this LC oscillator will help me to again provide a phase shift of 180 degree.

So, here my output would be 180 degree out of phase with respect to input right with respect to input and that is why this LC oscillator when I feed this 180 degree out of phase, it will make again in phase with the input signal these what a circuit is; inductor mounted on the same core you can see here and the output voltage you will see the oscillations happening.

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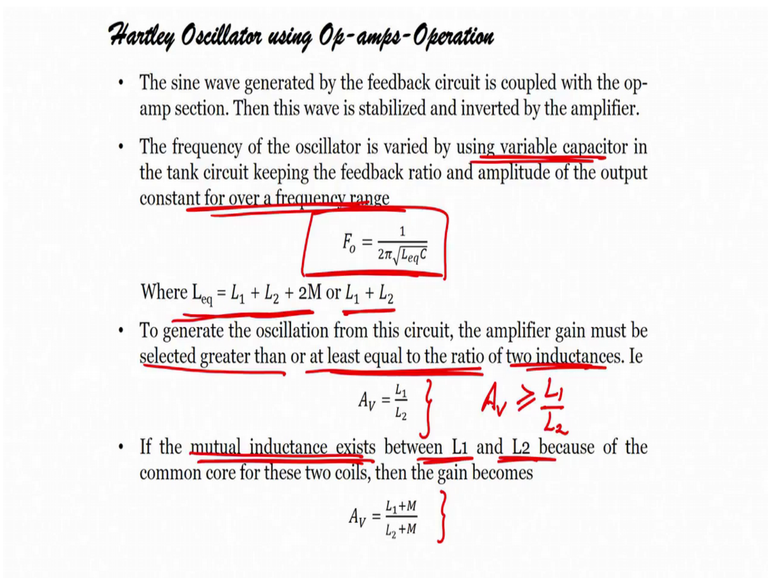

So, sine wave generated by the feedback circuit is coupled with the Op-amp circuit we can we have seen that. Then this wave is stabilized and inverted by the amplifier the frequency oscillator is varied by using the variable capacitor; in the tank circuit keeping the feedback ratio and the amplifier amplitude of the constant; output constant for the frequency over a range of frequencies; so what is that?

The capacitor; the capacitor right can be used for varying the frequency; varying the frequency of the oscillator and the feedback ratio and the amplitude of the output is constant right for a frequency for over a frequency range.

Now, frequency how it is given it is given by F o equals to 1 by 2 pi under root of L equivalent in to C right because there are L 1 and L 2; what is L equivalent? L equivalent can be L 1 plus L 1 plus 2 M or L 1, plus L 2 right. To generate oscillation from this circuit amplifier gain must be selected greater than or equal to the ratio of the two inductors right which A V can be; A V can be greater than or equal to L 1 by L 2 right.

If the mutual inductance exists; if the mutual inductance exists between inductor L 1 and L 2 because of the common core for this two coils then the gain will become L 1 plus M divided by L 2 plus M. Now what is mutual inductance? Guys you have to understand, you have to learn right there were something Lenz's law you have to understand you have to learn right; learn by yourself learn by yourself right. How when you use inductors, how come mutual inductance comes into picture and how the equation comes into picture you have to understand.

So, this is how the gain of the amplifier can be determined in case of the Hartley oscillator. So, let us solve let us solve a problem.

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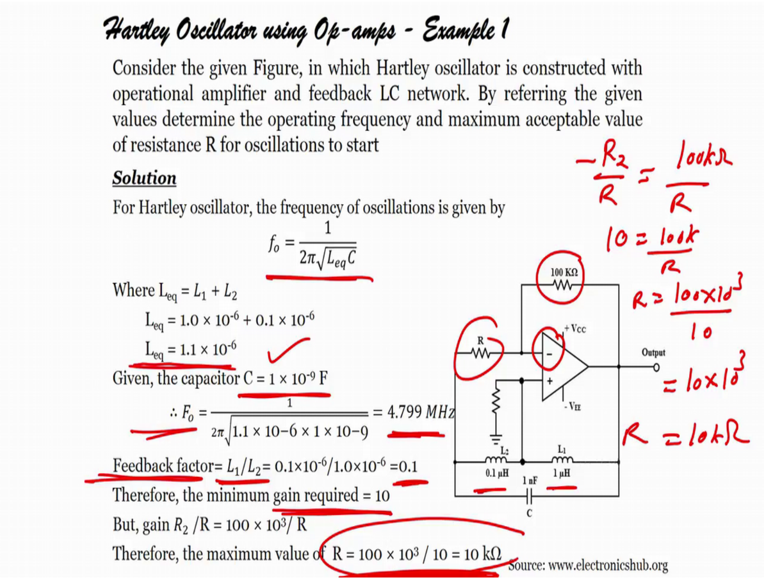

Let us solve the problem and this circuit is taken from electronics hubs dot o R g. So, consider the figure in which Hartley oscillator is constructed with operational amplifier and feedback LC, a feedback LC. By referring the given value determines the operating frequency and maximum expectable value of resistance are for the oscillations to start.

So, what we are asked? We are asked to find the value of R; we are find asked to value find the value of the frequency; operating frequency right. We know operating frequency is given by 1 by 2 pi under root of L equivalent to C; where L equivalent is L 1 plus L 2; L 1 is given 0.1 Henry; L 2 is given sorry L; L 1 is given 1 micro Henry, L 2 is given 0.1 micro Henry. So, we substitute the value of L 1 and L 2 and we get L equivalent equals to 1.1 into 10 raised to minus 0.6 right? Now capacitor is given? Yes.

So, let us substitute the value F o equals to 2 pi under root of L equivalent in to C. So, 4.799 mega hertz; you see. Now feedback there feedback factor; what is feedback factor? Feedback factor is nothing, but L 1 divided by L 2. So, what is L 1? L 1 is 1 into 10 raised to minus 6 is because; it is 1 micro Henry; what is L 2? L 2 is 0.1 micro Henry; 0.1 into 10 raised to minus 6.

So, answer would be 0.1 right therefore, therefore, the minimum gain required would be 10 right; minimum gain require would be 10; now you see this is an inverting amplifier. So, we have R 2 by R what is R 2? This one right. So, my gain would be R 2 by R. So, what is R 2; 100 kilo ohms right; what is my R? I do not know right and gain should be equal to 10. So, 10 would be equal to 100 K by R or R would be nothing, but 100 into 10 to the power 3. So, in terms of ohms divided by 10 or that will give me 10 into 10 to the power 3 or R equal to 10 kilo ohms; R equal to 10 kilo ohms right this is what we have found here R equals to 10 kilo ohm here right.

So, very easy to very easy to solve the problem for the Hartley oscillator; so, what are the advantages of Hartley oscillators using Op-amps ok? Why we have to use Op-amp based Hartley oscillator.

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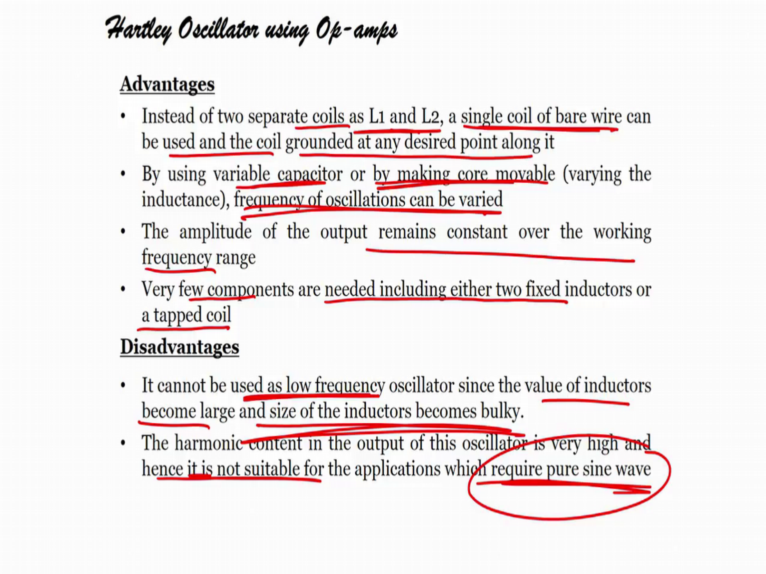

So, instead of two separate coins as L 1 and L 2; a single coil of bare wires can be used in the coil grounded at any desire point along it. So, that is advantage right we are using L 1, L 2 separately we can use a single bare wire by using variable capacitor or by making core movable frequency of oscillators can be varied correct. The amplitude of the output remains constant overworking frequency range that is very big advantage; few very few components are is needed including either two fix inductors or a tapped coil, but there are some drawbacks also.

So, what are drawbacks is? It cannot be used as lower frequency, you can see the frequency that we derived just in the previous case 4.9 mega hertz right we have seen that it is about 200 kilo hertz and above or mega hertz and about to some giga hertz.

So, its high frequency right its high frequency oscillator; so, we cannot be used in low frequencies is value of inductors become larger size of inductor becomes bulky correct. The harmony content in the output of this oscillator is very high hence it is not suitable for the application which requires the pure sign. So, the harmony component output signal would be. So, high that we cannot use when we have application where sine wave where is pure sine wave is required; pure sin wave is required ok. So, that is another disadvantage or a drawback of the Hartley oscillator.

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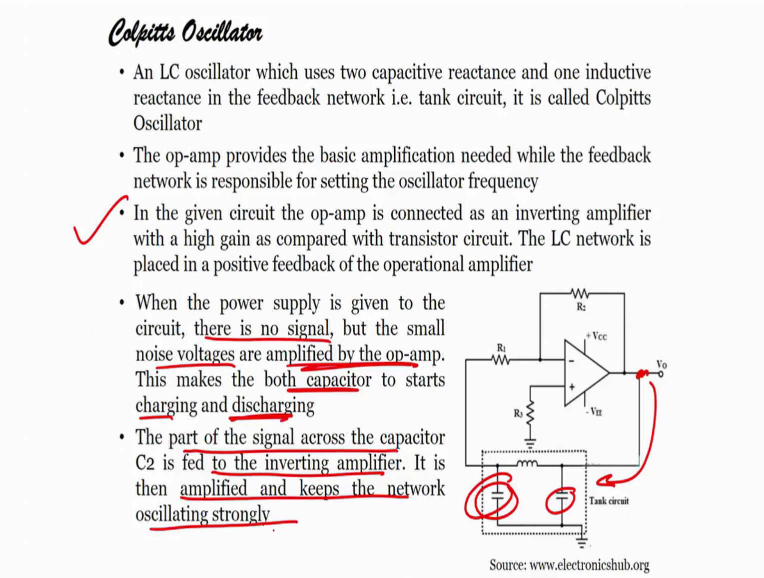

Now if we have seen Hartley oscillator; then we also see Colpitt's oscillator; why? Because in Hartley oscillator we have two inductors; one capacitor Colpitt's oscillator two capacitors one inductor; you see this circuit? Two capacitors one inductor this is called tank circuit what is called tank circuit ok.

So, what is a Colpitt's oscillator? The Colpitt's oscillator is an LC oscillator which uses two capacitive reactances and one inductive reactance in the feedback network ok. So, LC nothing, but oscillator in which two capacitive reactance and one inductive reactance in the feedback network is that is tank circuit is called Colpitt's oscillator.

The Op-amp provides the basic amplification needed while the feedback network is responsible for setting the oscillator frequency correct; feedback network this feedback network is responsible for the oscillator frequency right and the this particular network Op-amp is this is nothing, but a amplifier; so, it will provide the amplification. Now in the given circuit, the Op-amp is connected as an inverting amplifier with the high gain as compared to with the transistor circuit. So, we have not seen transistor circuit.

So, forget about it, but the Op-amp here is a high gain; the LC network is a placed in positive feedback as you can see right and of the operational amplifier. Another point is when the power supply is given to the circuit, there is no single by the small noise voltage or amplifier by the Op-amp. This makes more capacitors to start charging and discharging right.

And power is given the capacitor will start charging and discharging right be with the help of the noise voltage; because this noise voltage are amplified and we are provided back to the feedback network from here right.

And this will cause the capacitor to charge charging and discharging; the part of the signal across the capacitor C 2 right or this one is fed to the inverting amplifier the desired amplifier and keeps the network oscillating stronger easy very easy right.

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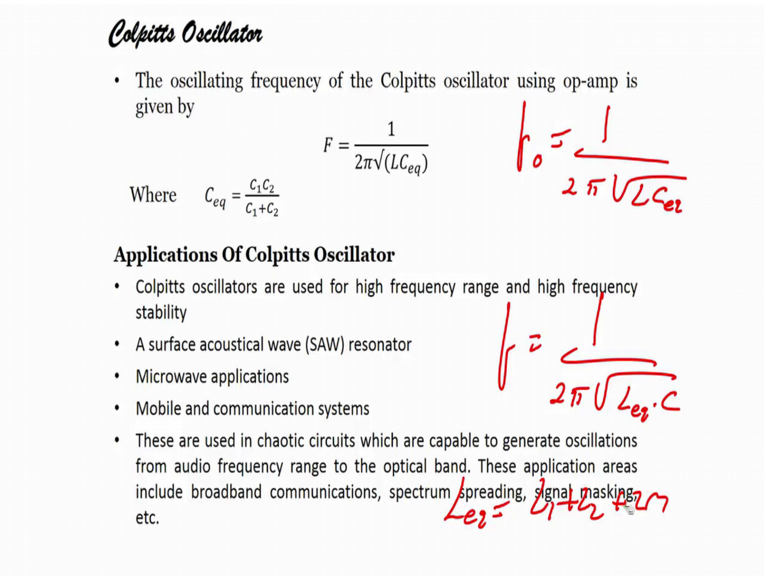

Here the frequency is given by f o. 1 by 2 pi L C equivalent. In case of Hartley; 1 by 2 pi L equivalent into C right. So, in that case L equivalent was L 1 plus L 2 plus 2 M or L 1 plus L 2 right L 1 plus L 2, but in case of Colpitt's oscillator the kept the C equivalent will be nothing, but C 1, C 2 divided by C 1 plus C 2 correct.

So, what are the applications of the Colpitt's oscillator let us see application of Colpitt's oscillator are Colpitt's oscillators are used for high frequency range and high frequency stability. Second a surface acoustical wave or saw resonator saw resonator which when we want to have saw resonator, we can use Colpitt's oscillator.

Microwave applications very high frequency applications, mobile and communication systems right these are used in chaotic circuits which are capable to generate oscillation from audio frequency range to the optical band. The application areas includes broadband combination, spectrum spreading, signal masking etcetera right. So, the application of Colpitt's oscillators are in several area several area from saw to microwave to mobile communication to spectrum spreading and so, on and so, forth.

So this is the this is the this is how we can this is how we can design the Colpitt's oscillator using L C. So, guys what we have seen in this module what we have seen? In this module what we have seen is how we can design an Colpitt's oscillator and how we can design a Hartley oscillator using a tank circuit. So, whether we have to use 2 L or whether we have to use 2 C and 1 L or 2 L and 1 C that depends on the type of circuit that we are designing in case of Hartley oscillator it will be 2 L; 1 C, in type of Colpitt's oscillator it will be 2 C and 1 L alright.

So, this is about this particular module; in the next module in the next module what we will see? We will see how we can design another kind of oscillator that is your crystal oscillator; that is your crystal oscillator very stable oscillator crystal oscillator. So, look at this particular module, understand how the Colpitt's oscillators and the Hartley oscillators can be used; in principle how the LC oscillators can be designed.

And let us see in the next module crystal oscillators and then we will move forward. So, I will see you in the next module and till then you take care; have fun bye.