Analog Electronic Circuits
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Module No 01
Lecture 35: More on Oscillators

On the last occasion we had concluded with the circuit of the Wein-Bridge oscillator. Did we analyse the oscillator circuit?

Student: No Sir.

Professor: We did not.

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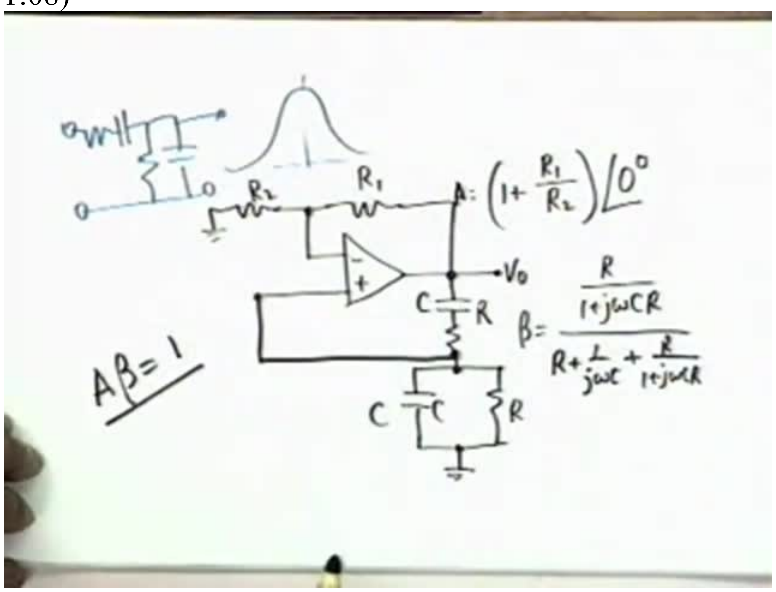

The circuit is this. In all these circuits, we represent the amplifier, the basic amplifier by means of a block. And usually, it is realised in the form of an op amp, by a modification of an op amp but there is no reason why a single transistor or 2 transistors cannot be used okay? And if instead of op amps, transistors are used, then obviously there would be imperfections in the input and output impedances which you will have to take care. So we analyse ideal circuits and we leave non ideal circuit analysis to you.

We havean amplifier, a 0 phase amplifier which is realised by means of an op amp with two resistances, let us say R1 and R2 and the output is this. You know that between this point and this point, the gain is 1 + R1 divided by R2. This is the gain which means that the gain has a phase shift of 0 degrees. And therefore for oscillations, a feedback network or the beta network has to produce 0 phase shift and an attenuation which is 1 by 1 + R1 by R2 and this is done by means of a simple CR circuit, RC circuit, a series RC and a shunt C and then R. This is the beta network and the it is a voltage feedback, a part of the voltage is connected here.

One of the basic philosophies of oscillator analysis is here of course you can very easily identify the A circuit and the beta circuit. The beta is equal to this voltage divided by this voltage. Okay which is simply R by 1 + J Omega CR, this is the shunt circuit. Shunt impedance divided by R + 1 over J omega C + R divided by 1 + J omega CR. Agreed? This is the beta circuit. This is very easy to identify. It may not be so if the input impedance here was not infinity. Then you might have to include the input impedance here okay. So you will have to take care in oscillator analysis but nevertheless, one of the basic philosophies in oscillator analysis is that you open the loop. Yes please, I am not turning it here. Yes yes.

Student: (())(3:56) RLC?

Professor: Why I put this RLC? This is to produce oscillations at a specified frequency. That is, the beta network, beta now is a function of omega and the Barkhausen criterion which is A beta equal to 1 has to be satisfied at a single frequency. Then only we get sinusoidal oscillations. That selection of frequency is done by this. As I had indicated last time, circuit, RC, RC is a band pass filter which has maximum response at omega 0 equal to 1 by RC. The maximum response occurs at Omega 0 equal to 1 by RC and at the maximum response, the phase shift is 0. And therefore this isan appropriate network for selecting the frequency by this oscillator all right?

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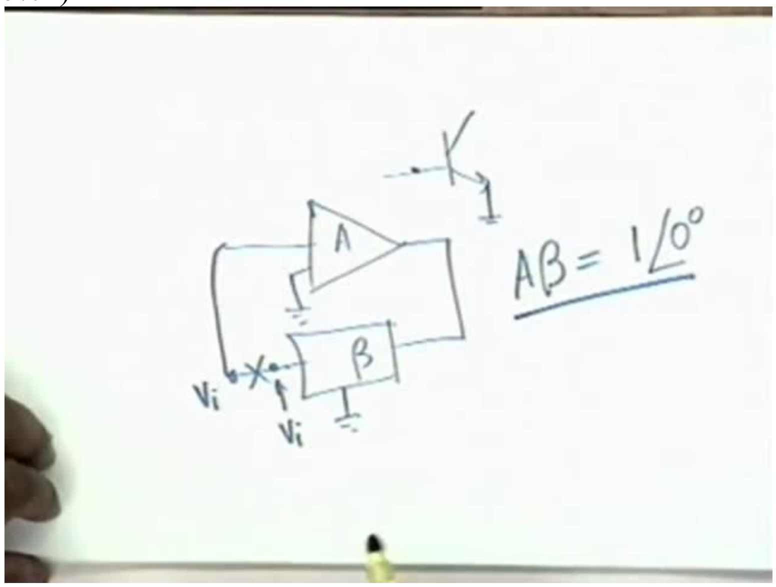

But what I was mentioning is the following. That in any oscillator circuit, the philosophy is, the philosophy of analysis, you do not have to identify A and beta. If the circuit is complicated, you do not have to apply feedback. There is simpler way. What you do is simply open the loop, do not close the loop. Oscillator is a closed loop circuit positive feedback. What you do is do not close the loop or if the loop is closed, well you open it somewhere but take care that in this opening, the beta network faces what it was facing in the closed look, that is if theamplifier has a finite input impedance, after opening the loop, put this input impedance here. Is the point clear? That is all that you have to do. Then you analyse the circuit. You analyse the circuit and apply a VI here and find out the condition under which this is also VI. Is the point clear?

Student: Sir is it not like spitting that short-circuit current into 2 currents?

Professor: No short-circuit. I have shown it bya block diagram.

Student: No Sir, that wire joining A and beta circuit, that wire splitting into 2 ports, that goes across A and beta giving it…

Professor: You see you see there is another point which is grounded. The beta network is also grounded. Whatever the connection is,from output to input okay, you break the connection at the amplifier input. You break (())(6:43). Apply a voltage VI at the amplifier input, obviously if oscillations have to occur, then the output of the beta network must also be VI because the total transfer function which is A beta should be equal to 1, 0 degree and therefore you argue that if this voltage is VI, this voltage has also to be VI.

This is a simple philosophy of analysis of oscillator circuit. Any oscillator can be analysed by this, provided you take this care that whatever loading the beta network had in the closed book, must be kept intact. That is all. For example if this is the transistorinput, let us say this is grounded, then this R pi has to go into the beta network. Is the point clear? That is only care. After that, you can do itroutinely. There isno problem. You do not have to identify A separately, you do not have to identify beta separately. In an op amp based circuit, it is very easy because op amp gives near ideal conditions.

Infinite input impedance, 0 output impedance, only a gain, either a + sign or a - sign but this is not true if you have instead of an op amp, an FET stage for example. An FET stage would have had a high output impedance. High input impedance is okay. On the other hand if it is a bjt stage, then the output impedance will be high, input impedance will be low and therefore both have to be taken into consideration. Okay.

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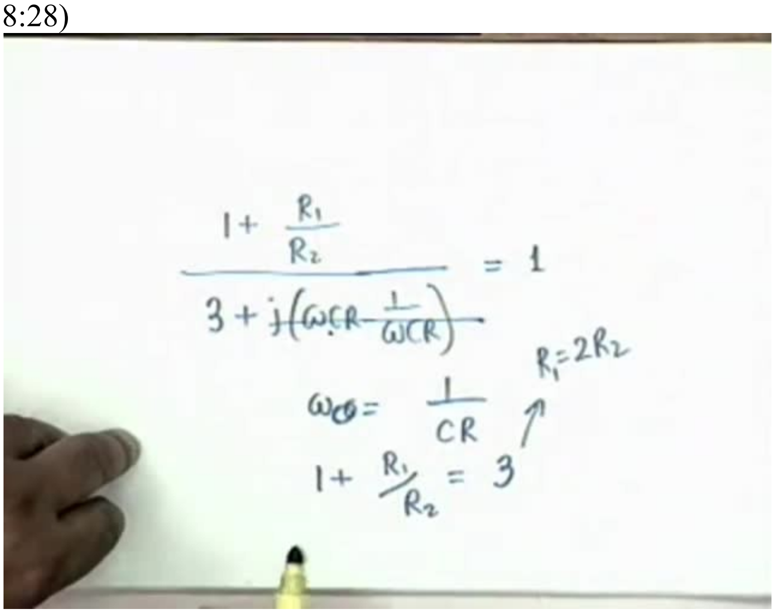

Now going back to the Wein-Bridge circuit,the Abeta is 1 + R1 divided by R2 and the beta can be simplified to the following.3 + J omega - 1 by omega CR the expression for beta theif you clear this, if you clear out 1 + J Omega CR and J omega C goes up, it becomes J omega CR divided by a polynomial then you divide both the numerator and denominator by J omega CR, this simple algebra you can show that this is the final story. Beta I is 1 by 3 + this and this has to be equal to 1. The angle of the right-hand side is 0, the angle of the left-hand side can be 0 only under the condition that omega CR is equal to 1 by Omega CR and therefore omega 0 is 1 by CR.

And under this condition, yes?

Student: (())(9:33)

Professor:No (())(9:34). Omega squared C squared R squared is 1. Therefore omega is 1 by CR. And 1 + R1 by R2 should be equal to 3. If this is 0, then this should be equal to 3 which means that R1 should be equal to twice R2. The feedback resistance has to be twice the input resistance okay. These are the simple conditions. Of course you know that the gain, exact gain of 1 + R1 by R2 may not start the oscillation. You might have to put a little bit extra. We will come backto this in a moment. But 1st, why is it called a Wein-Bridge oscillator? Why is it called a Wein-Bridge oscillator?

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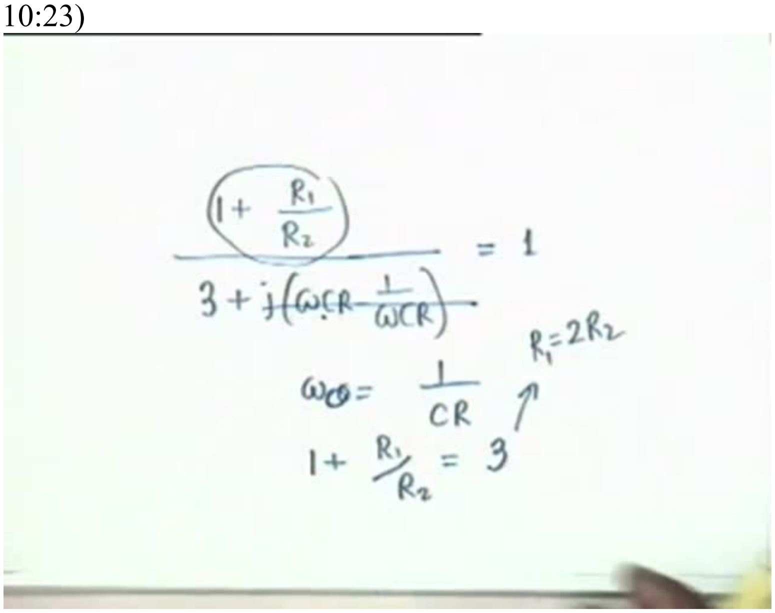

If you look at this circuitand call this point as A and this point as B, then you can redraw the circuit in the following manner.

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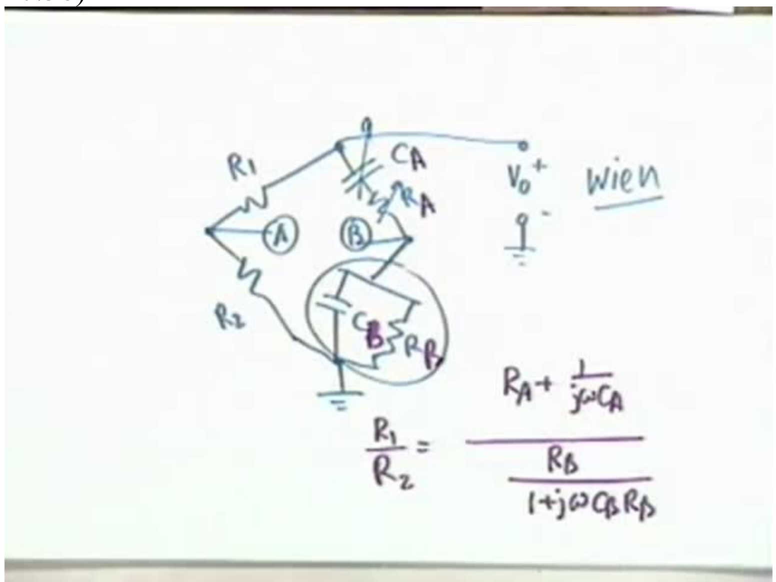

You can redraw it in the form of a bridge. R1 and R2. R2 is grounded and this point is A . Then from the end of R1, that is from the output of op amp goes a series combination of C and R and this combination goes to ground through the parallel combination of C and R and this point is B let us say. This is my output voltage V0 okay? In between, between A and B, you have the inverting and the non-inverting terminal of the op amp. And you see that this exactly looks like a bridge. It was 1st introduced by the German gentle manWein and therefore it is called a Wein-Bridge.

It is used for measuring the unknown capacitance and its leakage. This bridge is used for measuring a capacitance and its leakage. Usually, the unknown capacitor is put here and these 2 are made variable. Obviously, you cannot make them equal. So let us say, this is C2 and all right, CB and RB and let us say this is CA and RA. You can find out the conditions under which the bridge would be balanced okay. The condition would be R1 by R2 should be equal to RA + 1 over J omega CA divided by RB divided by 1 + J omega CB RB.

And if you clear the fractions, you can find out the relationship that is needed for balance of bridge. 2 conditionswould be there, one for imaginary parts and both sides being equal and one for real parts being equal. Okay? Two conditions are needed which will give the 2 unknowns. That means namely CB, the unknown capacitance and its leakage which is represented by a shunt resistance R sub B.

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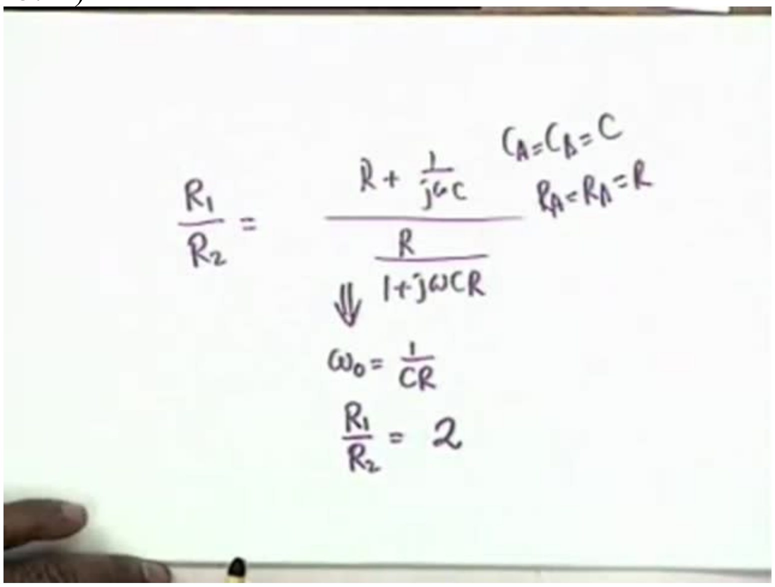

In the present case, if you find the condition for balance of the bridge, you will see that R1 by R2 is equal to R + 1 over J omega C divided by R by 1 + J omega CR and if you clear this, you will see exactly what we got for the condition of oscillation. Namely, you get a balance at the frequency omega 0 equal to 1 by CR and R1 by R2 has to be exactly equal to 2.

Student: Sir, where is the CA and RA?

Professor: Oh, in the present circumstances, CA equal to CB equal to C and RA equal to RB equal to R. I was going back to the oscillator condition. But in general in general, CA, RA, CB, RB okay. Now that is the story with regard to aWein-Bridge oscillator. Now with regard to this oscillator, it is very easy to see how one stabilises the amplitude. As I mentioned to you earlier, the gain if it is exactly 3, then oscillation may or may notstart. It may be a squaged oscillator. I do not know if you have got this term in the dictionary,squaging.

That means it oscillates for a short time, then goes off. Then again comes for a time, goes off and these are uncertain. This is called squaging. That means, an oscillator is willing to oscillate but unfortunately as soon as it starts oscillating, something goes wrong, it stops. This is called squaging.

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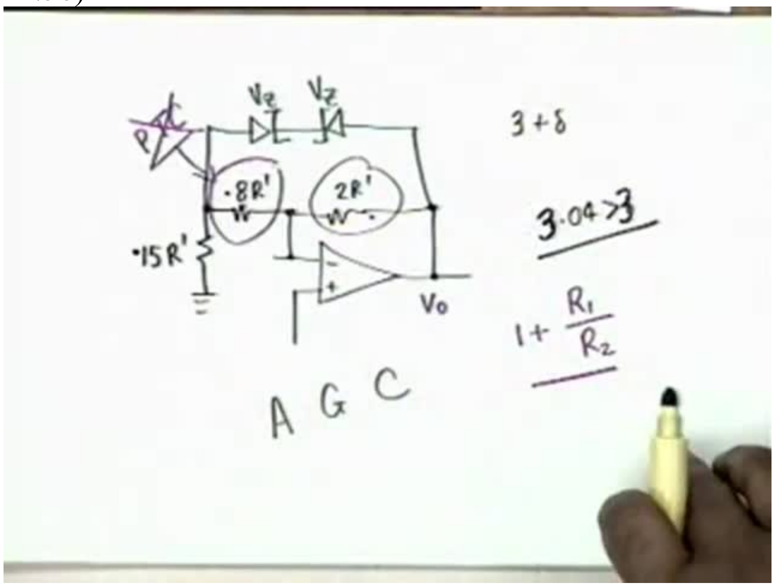

Now in order to stop this, what one does the gain is made slightly greater than 3. 3 + Delta. And a practical arrangement would look like this. Let me show you the arrangement, then I will explain. A practical arrangement , ok let usgo back to this.-,+, I will not draw the RC circuit. I will drawonly the amplifier. What modifications are required in the amplifier? What is done is, let us saythis is twice R prime which goes here, this is R1. R2 should be equal to R prime right but it is made0.8 and then it goes to ground through another resistance which is 0.15 R prime.

It is broken up into 2 parts. This is a practical circuit. A rule of thumb. I mean, there is nothing strict about it but this circuit works. If you find the gain, the gain is 1 + 1 by, no 1 + 2 by 0.95. So it is slightly greater than 1 and the gain happens to be 1.04, slightly greater than 1 okay. So the oscillation starts.Ya, the gain is 3.04, that is right. The gain is 3.04, greater than 3 and the oscillation starts. Now how does it stabilise? Normally, if you do not take any precaution for stabilising the amplitude, what happens is the amplitude goes on increasing and obviously, it will give a distorted waveform.

It will not be a pure sine wave but one can do something, one can use thisinstead of a fixed resistance, one can use a resistance with a positive temperature coefficient, positive temperature, that means if the temperature increases, the resistance increases okay. Now you know the gain is 1 + R1 divided by R2. Suppose due to some reason, please follow this, suppose due to some reason, the output voltage increases. Suppose it increases. Then what happens?

Output voltage is voltage between this point and this point and therefore the voltage across 0.8 R prime also increases. If the voltage increases, current increases. So this resistance gets heated and this heat causes the resistance to increase and therefore the gain shall decrease. So this is the stabilising effect. On the other hand if you do not want to use a PTC, a PTC is not available, an NTC available, then put that NTC here. Same effect.

If V0 wants to increase, this will cause V0 to decrease. Okay? So temperature sensitive resistor is required for stabilising amplitude. In the olden days when NTCs and PTCs were not readily available, people used to use an ordinary bulb,lightbulb in place of one of these resistors. Of course, op amps were not available. They used to make with valves and therefore valves, V A L V E S. And therefore B U L B S were the natural choices. And obviously, electric bulbs are temperature sensitive. Positive or negative? They are positive temperature coefficient. Okay.

One of the commercial Wein-Bridge oscillators does not rely on this only. It uses in addition 2 zener diodes, 2 zener diodes, in parallel with these 2. That is one of them is like this. A very very interesting concept. Should I draw like this now? It should be like this. These are 2 zener diodes, identical with a voltage, with a zener breakdown at VZ okay with a Zener breakdown at VZ. Now normally, because the gain is 3.04 which is greater than 3,oscillations start and since the gain is greater than 3, oscillations build up.And when the oscillations build up of both the Zeners are nonconducting.

They do not conduct till the amplitude of oscillations rises to VZ. Not exactly VZ. VZ + 0.7. Agreed. VZ + 0.7. Because if this is positive let us say, if this is positive and this is negative, then this conducts in the Zener region and this diode conducts in the normal region. Okay? And therefore as soon as the amplitude of oscillations exceeds VZ by a small amount, VBE on, well the Zenerstabilises the amplitude. It does not allow to go beyond that right? Similarly in the negative direction. And therefore the amplitude of oscillations gets cut off at the VZ, approximately VZ okay.

If this VZ is 6 volts, then the amplitude of oscillation stabilizes at 6 volts. Is the point clear? If the amplitude wishes to go down, then this becomes nonconducting, again this takes over and this builds up the amplitude to VZ. Okay? The voltage across these 2 points, the amplitude cannot exceed VZ + VBE on because the diode cannot support more than this. So it isa case of a so-called AGC, automaticgain control of the device. Okay, as I mentioned earlier, these RC oscillators are useful only up to 100 kilohertz or so.

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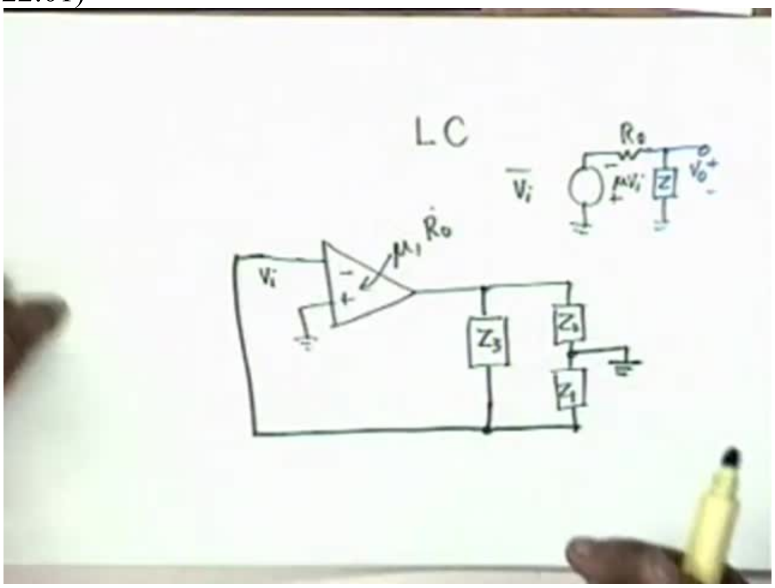

If you go beyond that, then it is more convenient to use LC oscillators, LC. And the general configuration is the following, general configuration for an LC oscillator is the following. What you require is a noninverting, aninverting amplifier which is ideal in all respects except that it is allowed to have a non-zero output resistance R0 okay? This is the non-ideality that we can permit. Of course we will permit later, a finite input resistance also but to see how things work, we have a inverting amplifier of gain mew andoutput resistance R0 so that if this voltage is VI, then the output shall bemodelled as mew VI with opposite polarity in series with R0. Okay?

This is the model that we will permit of this device. It could be an op amp . If it is op amp, then R0 obviously would be approximately 0. If it is not,it could be aFET be an FET and the output resistance is approximately capital R subscript capital D but the input is approximately infinity okay? Then this goes to a passive network like this. 3 impedances, Z3 then Z2 and Z1. It goes to 3 impedances and this point is connected together. The middle point is grounded okay. And this is fed back to the input.

This is the general configuration of a simple LC oscillator okay where Z1,Z2,Z3 are either inductances or capacitances. And in the analysis we will assume all the 3 to be ideal reactances.That meansZ1 is JX1 where X1 positive meansZ1 is an inductance.Z2 is JX2. If X2 is negative, it means it is a capacitance. SimilarlyZ3 is also JX3. Although you know that you cannot make an inductance or a capacitance without a resistance, we will 1st ignore the resistance, a non-ideality.

Now obviously, the A and beta are not very difficult to find out. What would be A for example? For A, you have - VI R0 and here, there would be an impedance Z. This is V0, okay, the A circuit. And this impedance would beZ2 in parallel withZ1 +Z3. Is that okay? Now let me draw it again. Is it okay?

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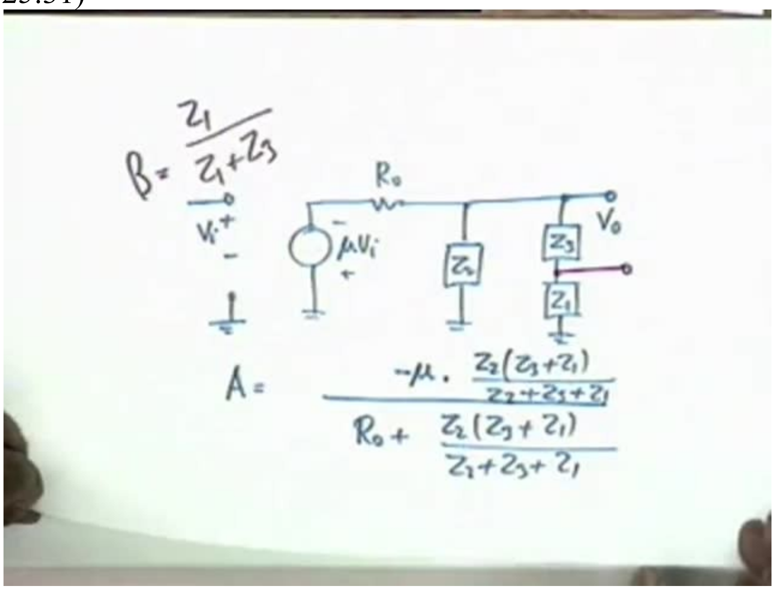

Alright. The equivalent circuit is mew VI -+ R0, then we have to ground isZ2 okay? to ground is Z2 and then we haveZ3 andZ1. The other end of Z1 is also grounded. And this is my V0 okay? So this is the A network and therefore, the gain A would be equal to - mew, the gain I amfinding with respect to VI, okay V0 by VI is the basic amplifier. I have opened the loop, okay. So - mewmultiplied by the load which isZ2Z3 +Z1 divided byZ2 +Z3 +Z1. Agreed? Divided by R0 + the parallel combination ofZ2 andZ1 +Z3.Z3 +Z1 divided byZ2 +Z3 + Z1. This is my A. I can also identify beta very simply. From the output voltage, a fraction from here is taken and fed back to VI to the input and therefore beta is simply equal toZ1 divided byZ1 +Z3. Agreed? I have identified A, I have identified beta. All that is required now is to multiply the 2 and put equal to 1. Agreed? Let us do that.

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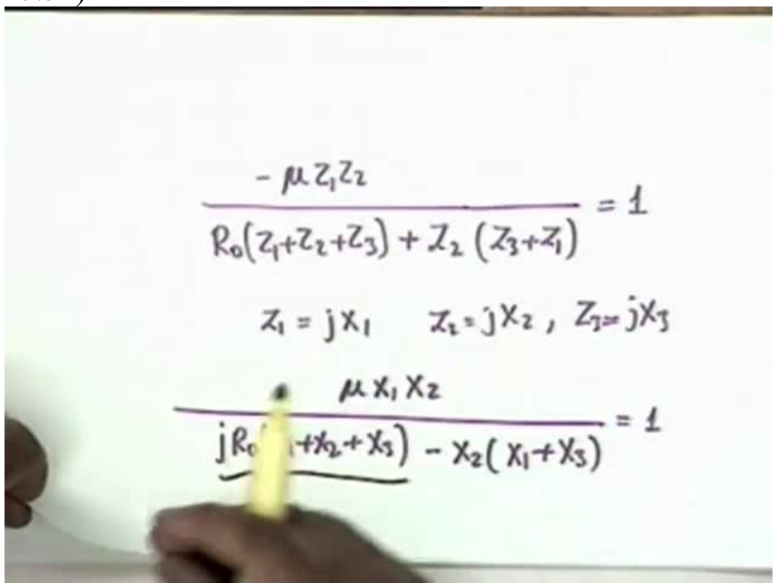

If I do that, then I get after a little algebra, I get - mew Z1 Z2 divided by R not Z1 +Z2 +Z3 +Z2 Z3 +Z1. You can see this very easily, how this simplification is done. This has to be equal to 1. This is the condition for oscillation at theBarkhausen criteria,A beta equal to 1. Now wesubstitute the condition that all these elements,Z1,Z2 andZ3 are reactive. SoZ1 is JX1,Z2 is JX2 andZ3 is equal to JX3. If I substitute this, then I get in the numerator, I get mew X1X2, is that clear why the negative sign disappears? Because theZ1 is JX1,Z2 is JX2, J multiplied by J is - 1. Divided by JR0X1 + X2 + X3. What do I get here?

Student:-.

Professor:- X2 X1 + X3 all right? This has to be equal to 1. The right-hand side in the right-hand side, the angle is 0 degree. So the left-hand side angle must also be 0. And one of the essential conditions is that the imaginary part should vanish which can vanish due to 2 reasons. Either R0 is 0 which we have not assumed or the other reason is X1 + X2 + X3 should be equal to 0.

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$$X_1 + X_2 + X_3 = 0 \qquad (1)$$

$$X_1 + X_3 = -X_2$$

$$\frac{\mu X_1 X_2}{-X_2(-X_2)} = 1$$

$$\mu = \frac{X_2}{X_1} + \delta \qquad (2)$$

So my essential condition is thatX1 + X2 + X3 equal to 0 which can happen ifat least one of the elements is of a different sign. Is not that right? At least one of the elements. Okay. What do you mean by at least? Only one can be of opposite sign because there are only 3 elements. So 2 inductances, 1 capacitance or 2 capacitances, 1 inductance all right? If this is true, then obviously X1 + X3 should be equal to - X2. If this is true.

Now if I substitute that,mew X1X2 divided by the reactive term is 0. The imaginary term is 0. So - X2 multiplied by X1 + X3 which is also - X2. Therefore this should be equal to 1 which means that mew should be equal to X2 by X1 all right? So these are the conditions of oscillation. One is that this should be satisfied. This is the 1st condition and this is the 2nd condition. That is the reactive elements should be so chosen that their sum is equal to 0 and the gain of the amplifier should be X2 by X1. It does not depend on X3.

X3 therefore determines the frequency of oscillation and X1 and X2 determine the condition for oscillation. And you of course know that mew has to be slightly greater than this okay? The condition of oscillation therefore now can X1 and X2 be of opposite signs? No because by definition, mew has been assumed to be positive. We took - mew VI okay.

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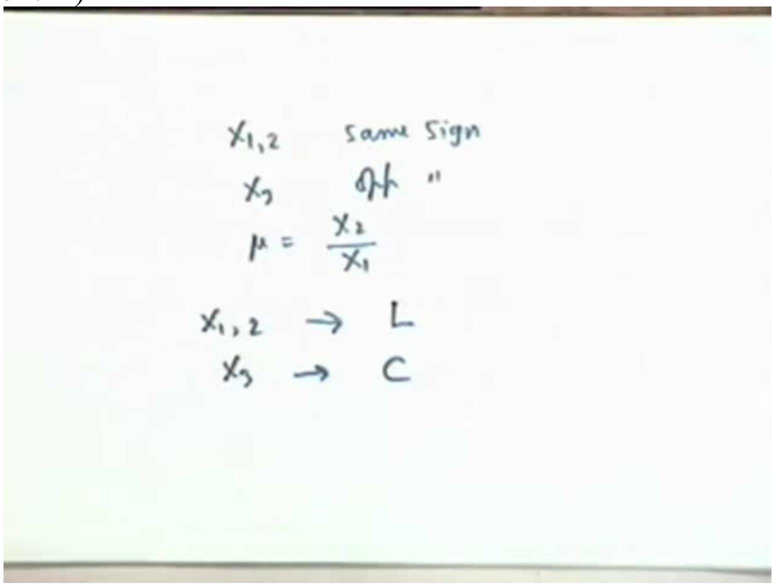

So the condition of oscillation is that X12, same sign, that is both are either inductors or both are capacitances. X3 of opposite sign and mew should be equal to X2 by X1. These are the conditions of oscillation. Accordinglywe can have 2 different types of oscillations. For example, X1 and X2, suppose both are inductances, L, then X3 should be a capacitance. Agreed? Let us look at the circuit.

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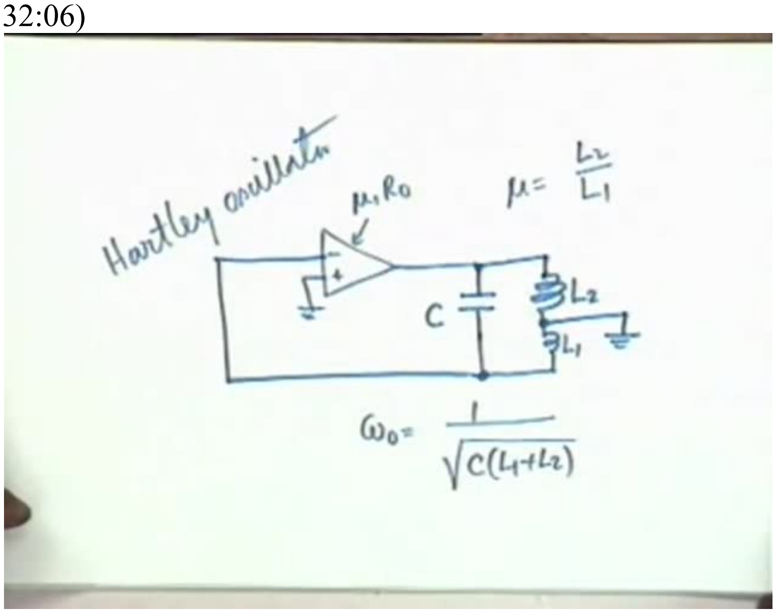

-,+, this is grounded, this is the input, this is mew R0. Now X3 is a capacitor, so I have a capacitor here, C. Then I have two inductors. Was this X2 or X1? This was 2 okay, so this is L2 and this is L1 and then you have this point is grounded and this goes to the input. Okay? Mew now has to be L2 by L1. And what is the frequency of oscillation? The sum of the 3 reactances should be equal to 0 which means that the 3 reactances should resonate in series, series resonance.

Now what is omega 0 then? 1 over Square root C L1 + L2. Very good. No further analysis is needed absolutely byinspection. This goes by the name of Hartley oscillator. Hartley. Hartley is the name of a British man. I do not remember his initial. Hartley oscillator. Hartley oscillator is the one in which 2 inductors are used and one capacitor. As we shall see a little later, this isa little unfavoured as compared to the other possibility. That means 2 capacitors and 1 inductor.

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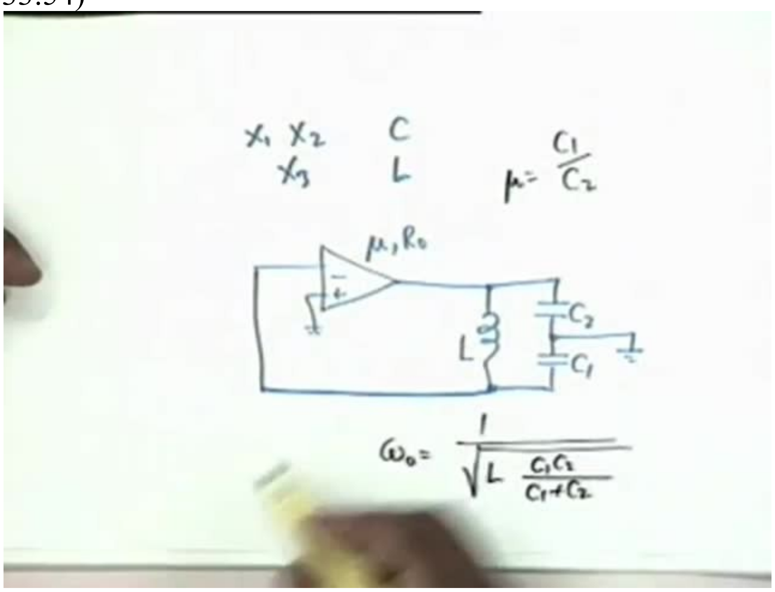

35:53If X1 and X2 are both capacitors and X3 is an inductor then the circuit becomes like this. Mew R0, we have an inductor here. Then two capacitors, this is C2 and this is C1. The middle point is grounded, these are connected. That is how it goes. Okay, now what would be the required mew?

Student: C2 by C1.

Professor: No.

Student: (())(34:27)

Professor: C1 by C2 because the reactance is 1 by omega C okay? And what would be omega 0? Obviously 1 by Square root of L, not C1 + C2 but…

Student: Parallel.

Student: Parallel.

Professor: C1C2 divided by C1 +C2, that is right. Okay. Everything by inspection. Nowthis will work perfectly all right provided you get a device like this. Suppose mew R0, the worst thing that can happen is that we use a single bjt, a bjt, bipolar junction transistor,then youhave a finite input impedance also a nonzero output impedance, okay. Let us see what can happen.

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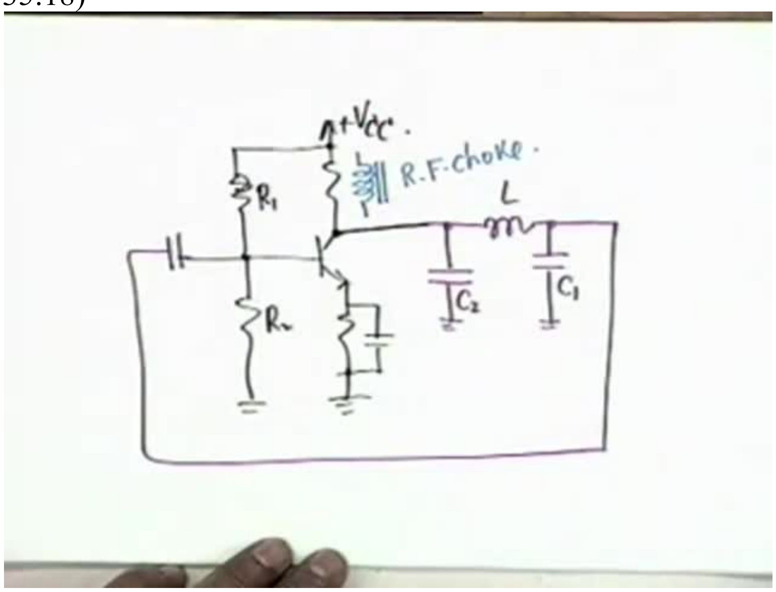

Let us have a single bjt. The usual methods of biasing,+ VCC, then you have the two resistors here, R1 and R2. This is your input point and supposeit is a oh, II beg your pardon, did not mention this. This is called a Colpitt's oscillator.Colpitt(())(35:46) also the name of a person.Colpitt's oscillator.2 inductors is Hartley and 2 capacitor thisColpitt. I must go back and tell you why Hartley is slightly unfavoured as compared toColpitt's. Cananyone gives the reason? Hartley is not preferable as compared toColpitt. If you have a choice,you go for Colpitt's. Why?

Student: Inductors are difficult…

Professor: Inductors are difficult to make. SupposeAs I said at 1 megahertz, inductors are not difficult to make. You give me a short length of wire and this pen, I will make you a good inductor but there are other problems. If you have two inductors, they couple with each other as a mutual inductance. Not only that. Anything, any other circuit element nearby will also get coupled and therefore the whole circuit becomes an electromagnetic interference, an island of electromagnetic interference.

Okay. Nevertheless, these are done. One of the inductors or both the inductors have to be shielded. And very simple shields work. Just raise an aluminium partition between the 2. You just need to break the magnetic lines, that is all. Okay, simple shields do. Of course the market, sophisticated shielded inductors are also available. You may ask if it is shielded and sealed, how do you change the inductance? Well there are there is a screw at the top which varies the length of insertion of a ferrite rod, a core inside.

If it goes further inside, inductance increases, if it comes out, inductance decreases. So variable inductors, very high-quality inductors are available in the market provided that the frequency is high of the order of megahertz or so. Okay. So on the other hand in theColpitt's oscillator, capacitances can be made without much of an electrostatic coupling between them. Okay. Without much of electrostatic coupling between them. Now suppose you want to make a Colpitt's oscillatorwith a single bjt then obviously the beta circuit would be like this.

You will have a capacitor here. Which capacitor is this? C2 or C1?

Student: C2.

Student: C2.

Professor: C2. Then you have the inductor and then you have a C1 which goes to ground and this has to come the input. Obviously, you cannot bring it like this. You must bring it through through another capacitor, a blocking capacitor which has to be very high compared to C1 or C2. Agreed? Number 2, can this be coupled directly? Oh, there are problems. Even though there is a blocking capacitor here, see there is an inductor here. No,you answer my question. Can this be coupled directly from here to here? Will DC go?

Student: Yes sir.

Student: No.

Professor: Yes or no? There is a capacitor here. How can DC go? Through the inductor It it cannot flow through the capacitors to ground.

Student: (())(39:12)

Professor: If it is… That is okay but there is a DC here. There is a DC voltage VCE here okay which will appear across this capacitance. No problem. The inductor cannot pass DC because of this capacitor. So this is a good circuit. In a practical circuit, we do not want to unnecessarily waste power and this is not an absolute need, this resistance. Why was this resistance needed? To bias the transistor and also to provide the required…

Student: Gain.

Student: Gain.

Professor: At what frequency? At the frequency of oscillation? Is not that right? So what one does is instead of using a resistance, one uses an AC load which means you replace this by means of an inductance, a high valued inductance because you require a gain of ideally it should, the gain required would have been 3. But what one does is, one uses a high valued inductance so that there is no DC dissipation in this. And high value can be obtained only by putting a core. So this is called an RF choke. RF choke.

What does an RF choke do? It chokes RF. As simple as that. In other words, it does not allow RF to pass through this. Where should RF go then? It must go through the feedback circuit. Is the point clear? Okay. Instead of this resistance, one uses an RF choke, a high valued inductance. Okay. Now if I draw the equivalentcircuit, this can of course betaken as short but R1parallel R2 parallel R pi, that is what will come.

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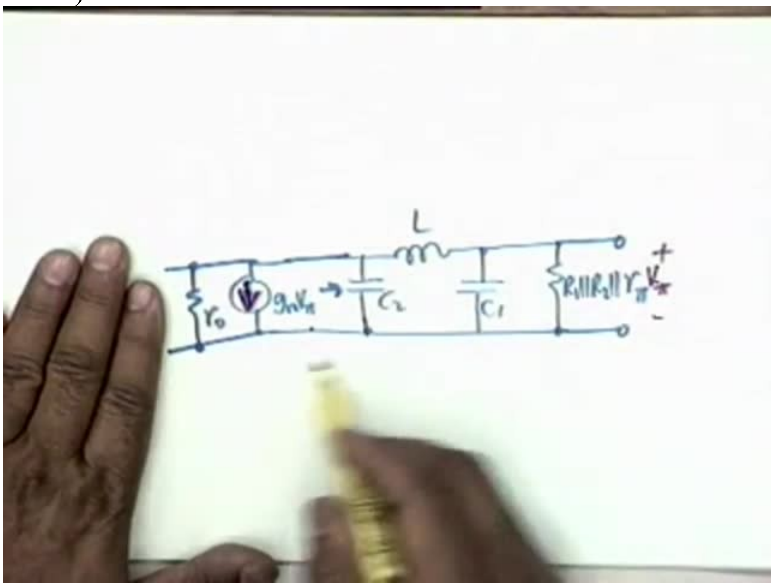

And therefore if you openthe loop, you have C2, L, C1, then it should be terminated in R1 parallel R2 parallel R pi. Okay? Now whatcomes here? Here comes the RF choke. For all practical purposes can be taken as of infinite impedance as compared to the impedanceoffered here okay and therefore that we can ignore. We have a current generator, GMV pi in parallel with R not. This is what gives the output impedance. And you see, the output impedance is far from being negligible.

Agreed? But as you know, the output impedance does not affect the condition for oscillation. Neither does it affect the gain requirement. The gain requirement is simply C1 by C2. It is not affected by R0. All right. Then you have GM V prime andthis is VI. This is R pi, this is V pi okay? This is the total circuit after opening the loop and in order to find out the condition for oscillation now, obviously the oscillation frequency as well as the required GM shall now be affected by R0 as well as R1 parallel R2 parallel R pi and you will have to find this out.

Student: Sir, is the position of L okay?

Professor: Is the position of L okay? Yes, it is okay. Itlies between the 2 capacitors.

Student: Sir, but the direction of the current is from the ground.

Professor: Oh. I have made a mistake. Otherwise, it would not work because you wanted an inverting amplifier. This is the equivalent circuit of the transistor. Okay? Sowhat I am mentioning is that if it is a BJT, then you shall have to be careful, you have to analyse this circuit. Now what is the condition for oscillation now? That this voltage should also be equal to

Student: (())(43:57)

Professor: Soyou forget about this part. You start from here, find out this voltage and equate that to V pi. That would give you the condition for oscillation. And this is the general philosophy of analysis of such circuits. If you had instead of the RF choke, RF choke is the one is the thing that is used in, you open any radio-frequency circuit any radio-frequency circuit, even in amplifier, they use RF choke instead of a resistance. And the purpose is thatyou reduce the requirement of power supply because there is no DC drop in the RF choke and you reduce the dissipation.

So in high-power circuits, for example, the modulator amplifier in a transmitting station, 50 kilowatt transmitting station and you can understand the amount of dissipation that one has to do. Evena few kilowatts dissipation saving makes a lot of saving in transmission. So one uses usually an RF choke.

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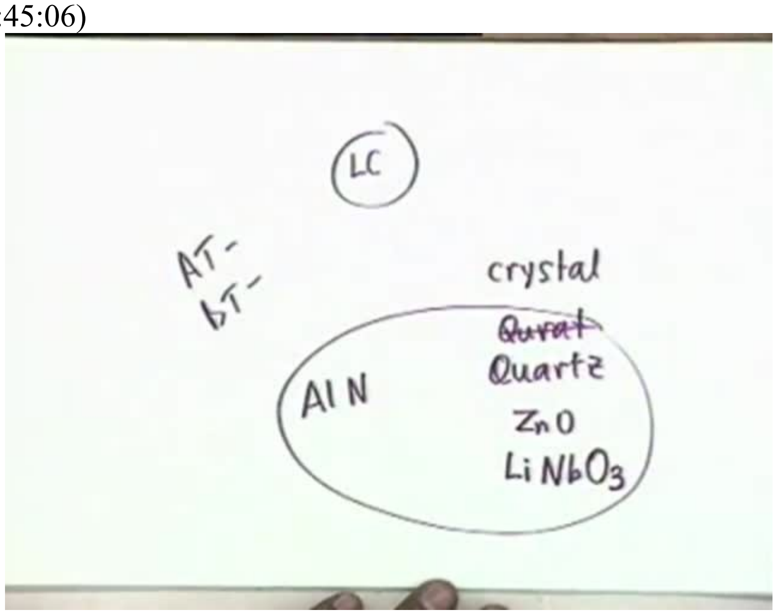

These LC oscillators unfortunately are not very stable oscillators. They are not very stable because of various reasons. They use inductors. If the inductor picks up a certain magnetic field froma nearby circuit, the frequency strays, frequency goes sray, frequency deviates from what the value should be. If the temperature changes, the inductor, the capacitors, the resistors, all of them will change and therefore the frequency deviates. There is a particular circuit which is obtained with a solid-state material like Crystal which is equivalent to either an inductance or a capacitance whose value remains very stable irrespective of changes in the external circuit.

And the material that is used for the Crystal is either quartz,Q U A R T Z or zinc oxide is one of the materials or lithium niobate, NbO3. I am not too good in chemistry.lithiumniobate among these are the materials. Also,aluminium nitrite,AlN,aluminium nitrite or nitrate, I do not know.

Student: Nitrite

Student: Nitrite

Professor: I D E?

Student: Yes.

Professor: Okay,aluminium nitrite. These are the materials from which a Crystal is made and if you know what a Crystal is, a Crystal can be cut in various symmetries and the usual symmetries that are useful for oscillators are either AT or BT cut, AT or BT. Just remember the names. We do not want to go into the physics of this cut of the crystals but the phenomenon that is utilised this called the Piezo Electric effect.

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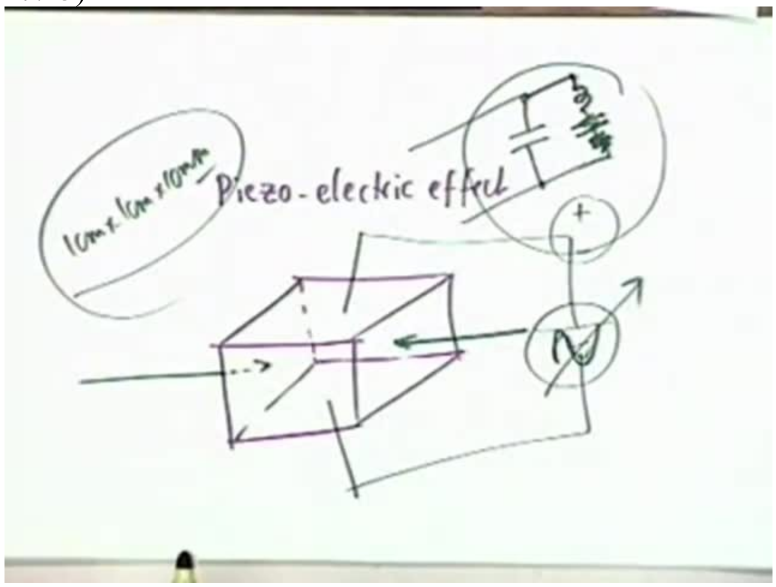

P I E Z O electric effect. And this effect is as simple as this. If you have a block, let us say rectangular block of the Crystal which is properly cut and suppose you apply mechanical pressure to 2 of these faces, okay, suppose you apply mechanical pressure.

You take a box, apply mechanical pressure, then it turns out that the opposite, the other 2 faces, the other perpendicular faces develop a voltage, an electric voltage. The material itself is non-conducting. It is an insulator, it is a dielectric material and you can understand why it happens. The physics is that there is a polarisation of charge. That is positive charges go on one side, the negative charges go on the other side. All the charges are not mobile, how come they move? What happens is, take a dielectric molecule, it contains positive as well as negative charges.

So these molecules orient themselves is that the positive face is let us say up and the negative face is down. So there appears a charge on this surface and a charge on this surface. This charge is not mobile. It is an electrostatic charge.

Student: Sir?

Professor: Yes.

Student: Sir, how can these piezo electric crystals provide current?

Professor: Oh, I am coming to that. I am coming to that. Now on the other handif you provide an electric field, that is if you connect a potential difference between the 2, the effect is reversible. That is, there is a mechanical deformation. All right? So if this instead of a DC, is it is AC, then the mechanical deformation, there is a compression and expansion, compression and expansion if this is AC okay. So if the direction of the field changes, compression changes to expansion all right? And if yes?

Student: Sir, this happens to 4 faces?

Professor: This happens to…

Student: All 4 faces (())(49:37)

Professor: I have taken all the 4 faces. Oh, the remaining ones?

Student: Yes sir.

Professor: No, these are the white happens on the other faces also but you have to cut the Crystal in such a fashion that the effect is dominant on 2 of the faces only. This is why AT and BT cut crystals. Okay? Now the basic phenomenon is this that if this is an AC, then the mechanical deformation, it expands and contracts. Expands and contracts alternately in consonance with the AC okay? Now if the frequency of this AC changes, if it is kept varying then obviously the mechanical vibrations will resonate at a particular frequency. Okay?

And this is what is utilised in a Crystal in an oscillator. That is you apply a field which is by the oscillations, which produces mechanical resonance. If it produces mechanical resonance and ifBarkhausen criterion is satisfied, then the oscillations are self-sustaining. Okay? Oscillations are self-sustaining. However,you cannot observe this mechanical resonancewith naked eyes. The Crystal itself is very small, typically 1 centimetre 1 centimetre 10 millimetre, this is a typical dimension.

And obviously, in order to apply a field, because this is a dielectric, you have to have 2 faces coated with metal from which you take the terminals. And if you do that, obviously you create a capacitance. A dielectric material between 2 metal plates is a parallel plate capacitor. And therefore, the equivalent circuit would be that you have a capacitance between the 2 metal plates and the bulk itself has mechanical resonance at a particular frequency. So in parallel, theequivalentelectric circuit, would be a series resonant circuit, L and C. But unfortunately, there is some dissipation also and therefore you have a resistance. This describes the equivalent circuit of a Crystal. A capacitance shunted by a series resonant RLC circuit. This R is a very small quantity and in the analysis, as you will see next time, we shall ignore this out and carry out the analysis. We will continue this tomorrow.