Analog Electronic Circuits
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Module No 01
Lecture 37: Problem Session – 9 on Oscillators

The 37th lecture and this will be a problem session on oscillators. Basically, our aim in this session would be to see the limitations of the assumptions that we made during the analysis of the oscillators. You recall that our active devices were all very ideal devices. Infinite input impedance, no capacitance inside, zero output resistance for some of them. For LC oscillators, we could permit alittle R0 there. So our problems would be directed towards practical oscillators in which the effects of the transistor capacitances and transistor imperfectionscan be taken into account. Before we take up a problem, there is a smallcircuit that is left tobe discussed, that was a crystal oscillator.

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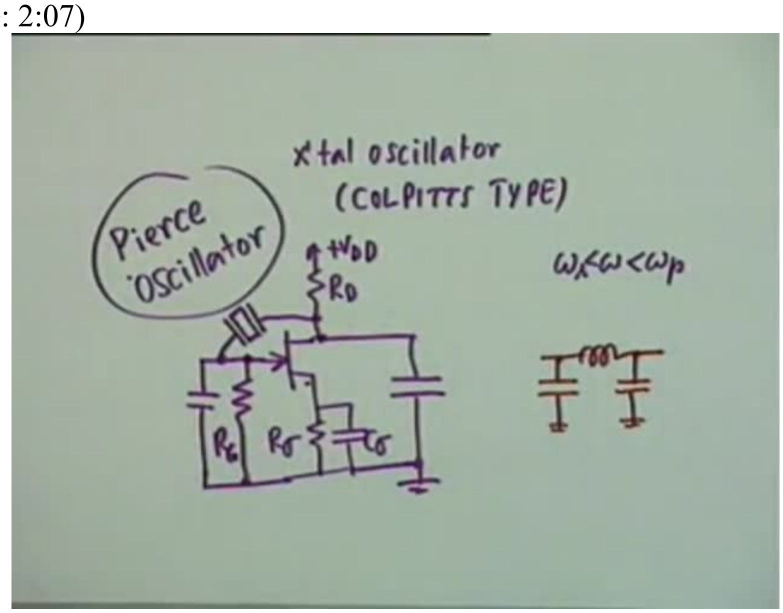

Let us quickly do that. Then we will go to problem. Crystal oscillator of theColpitt's type.Colpitt's type. You know that the crystal oscillator, a crystal is used in when its reactance is inductive okay between omega S and omega P . SoColpitt's type oscillator uses 2 capacitors and one inductance. And to bring variety into experience, let us say we aim at aFET oscillator, then in an FET, you have the R Sigma, C Sigma. The input impedance is no problem, the output impedance, you have an R sub D + VDD.

Then what we require is, from here to here what you require inColpitt's is a capacitor in shunt, then an inductor and then another capacitor. This is the Colpitt's circuit. This should go here and this should come here. Now since the crystal is to be used and the crystal is used as an inductor, it is this inductor which will be replaced by the crystal. Now where does this inductor appear? Between the drain and the gate. And therefore you connect the crystal between these pointsokay?

Then obviously you have to use a capacitor, the 1^{st} capacitor. Well, you use it to ground, the 1^{st} capacitor. The 2^{nd} capacitor is to be betweenthis point and ground. Okay? Between this point and ground. So use another capacitor and to be able to terminate the gate, you use a resistance here. Is this resistance essential? Would someone tell me why this resistance is used? Is itnecessary for biasing? No.

Student: No.

Professor: It is not necessary for biasing., it is yes or no? It is necessary because for DC, you have to establish this point as zero potential. Now if you leave it open, it is anybody's guess what potential it would go to. It might pick up stray charges and go to certain potential. Even if it wants to go, if you provide a resistive path, the charge will pass to the ground and therefore this RG is essential. In theory, no but in practice, yes okay? So the VGS VGS is 0 - VS.

This is the circuit of a crystal oscillator using theColpitt's type, Colpitt's type architecture and this circuit was independently discovered by a gentleman named Pierce and therefore this is also known as the Pierce oscillator. Pierce, Pierce oscillator. Okay. Pardon me? We can instead of RD, instead of RD, we can use a choke but you know in LC oscillators, my source can have an output resistance. It does not matter. It does not affect the operation of the oscillator and therefore a resistance can be used.

But if you do not want a dissipation, you can replace this by means of a choke. Fine.You can replace the dimensional RF choke. Now these were all very simple circuits thatwe have discussed in theory. Now let us complicate our life and you will see life is indeed complicated. Even with a single transistor, the imperfections cause many problems in the analysis and design.

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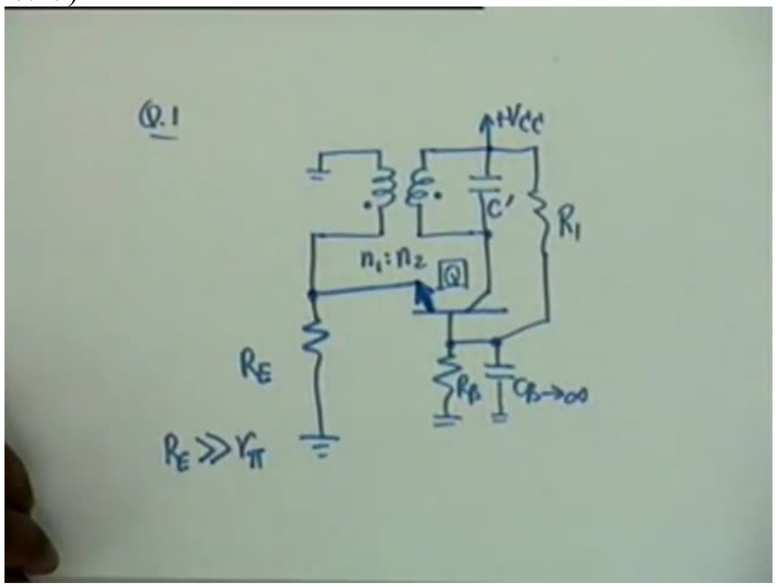

The 1st problem that we take question 1, draw the circuit with me. I have not done this circuit in the class because there are hundreds of varieties of circuits. I thought some of them are used toillustrate how practical oscillator is analysed and designed and this is the 1st problem that I take. Draw with me. There is a transformer, 2 coupled coils and the turns ratio is N1 is to N2. This is N1 and this is N2. This, the primary of the transformer is used to form a tuned circuit with a capacitance let us say C Prime. There is a reason why I am using C prime. You will see it later.

This acts as the load of a transistor and therefore this is + VCC and this terminal goes to the collector. The transistor is a commonbase circuit instead of a common emitter. You see the variety of oscillator circuits thatexists. The emitter is connected to the secondary and in addition for biasing, you have an R sub B and C sub B which goes to infinity, it is very large, it is a bypass capacitor. And in addition, what else do you require to bias the transistor, Q. So, I have shown a PNP. This is not necessary. You can use it an NPN.

Okay. What else is necessary for biasing? Pardon me? I must have a resistance between the base and the power supply. Let us call this resistance as R1, some R1. Is that all? That is all but usually a resistance is connected between the emitter and ground also. RE which is usually chosen to be much high compared to R pi. You see R pi will come in parallel with RE. Is not that right?R pi from base to emitter will come in parallel with RE and therefore in order that it does not load unnecessarily, weusually make RE much greater than R pi.

This circuit does oscillate. It is not very easy to see how this circuit oscillates but obviously, feedback is applied through a transformer through magnetic coupling through a transformer and the transformer winding, you know the meaning of the dots that the potentials of these 2 points rise and fall simultaneously. You know if this goes up, then this also goes up. So there is positive feedback. There is positive feedback in the circuit and it does oscillate. Let us see how it oscillate. The question is to analyse this circuit for the frequency of oscillation and the condition for oscillation.

Now obviously, the 1st thing we do, I have told you that in oscillator analysis, you do not have to identify the A circuit and the beta circuit. You can simply draw the equivalent circuit and see what condition is satisfied in order that the input voltage is V pi when the output voltage is GM V pi multiplied by the load. So you just draw the equivalent circuit and oscillator analysis is eased out. Let us see what the equivalent circuit is.

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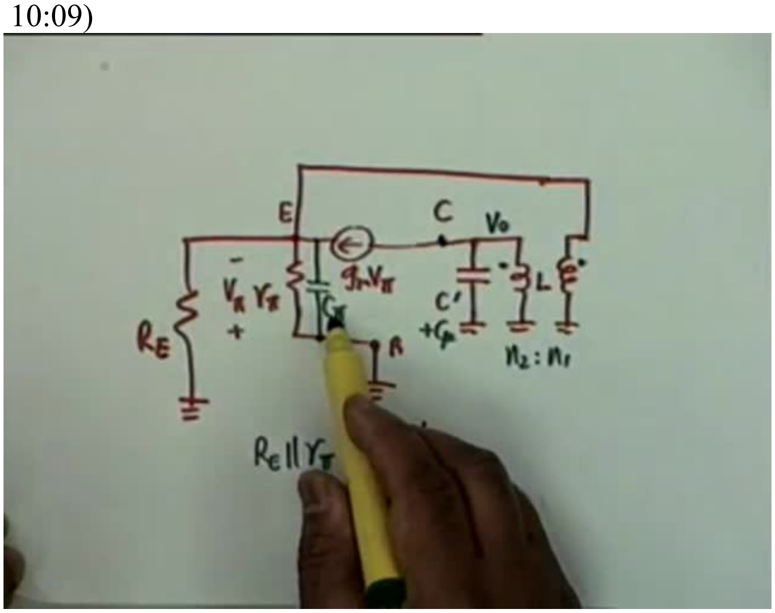

Now you see, let us take the point E, C and B. B is grounded for the transistor. Between E and B, there is a resistance, R pi and this voltage is V pi. Do not make a mistake about the polarity. This is V pi. Polarity is B side is positive and emitter side is negative okay. Between C and D, we have GM V pi. This is a common base circuit. So the GM V pi is drawn horizontally. There is no reason why you could not provide otherwise. Then you have at the collector between collector and ground, you have the capacitance C prime.

Then the inductance L with this polarity and you have another, a secondary whose dot is here and this couples to the emitter. In addition you have a resistance RE to ground. Now we have ignored several things in this equivalent circuit. RB-CB combination is short, so we ignore that completely. We have ignored the transistor capacitances. Since this is a high-frequency oscillator, transistor capacitances usually cannot be ignored. In other words, I must include a C mew 1^{st}, C mew from collector to base and therefore C mew can add to C prime.

Is that clear? C mew is from collector to base. Therefore it comes in parallel to C prime. So C prime is C mew all right? C mew is taking care of. Then R pi mug R pi appears between this point and ground. I am sorry, not R pi. C pi . This also should have been taken into account all right? Nowthen is the question of analysis. You see, whatever the connection here whatever the connection at the emitter terminal, the voltage output V0 appears across this parallel combination of C prime and L into a current GM V pi passing through this.

And therefore I do not care where GM V pi goes. I do not care. My V0 would be simplythis current multiplied by this impedance which is not not quite correct. Becauseof the transformer, there is a reflected impedance and that is how this termination comes into effect, all right? So let us sayRE parallel R pi let us not neglect completely, let us call this as R pi prime. We will neglect it later wherever necessary. Since we can take care of it, it comes in parallel with R pi, whyignore the poor fellow right at the beginning okay?

Let us call this R pi prime. Then you see, as far as the collector concerned, this ratio was N2 is to N1, all right? N2 is to N1. It wasN1 is to N2 from the other side. SoN2 is to N1. Now what does this primary sees? What does the primary see by looking into the secondary? There is a reflected impedance and the reflected impedance would be the multiplied byN2 by N1 squared and the capacitance would be divided by N2 by N1 squared.

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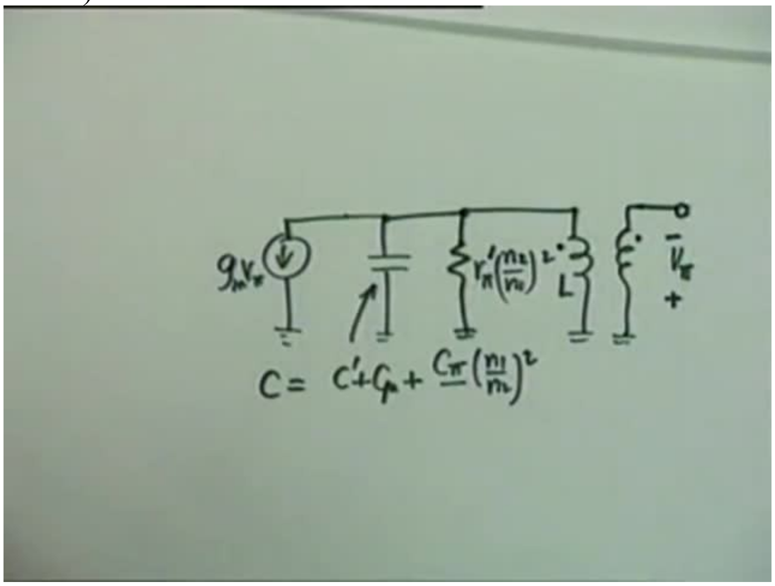

And therefore as far as the collector is concerned, my equivalent circuit is GM V pi, let it go to ground, I do not care wherever it goes. Then a capacitance. Now what will be the total capacitance? C prime + C mew + the reflected capacitance. What is the reflected capacitance?

Student: C pi by N.

Student: C pi by N.

Professor: C pi byN2 by N1 whole squared okay? So C pi N1 by N2 whole squared. Is that clear? Let us call this capacitance as C. Then we have the resistance, what is the resistance? R pi into N2 by N1 whole squared. Is that clear?

Student:R pi prime.

Professor: R pi prime, that is right.N2 by N1 whole squared and you have finally the inductance L which is coupled to another inductance with this polarity. Now what should be the condition of this terminal? Once you have taken the reflected impedance, this should be open. And this voltage would be V pi with what polarity? +,-. Is that clear?

Student: No Sir.

Professor: Okay what I did was, I wanted to calculate V0. So I look atthis transformer. This transformer reflects a certain impedance into the primary. I have reflected that. Okay? Sothe amplifier circuit consists of GM V pi passing through C prime + C mew L and the reflected impedance. So I have been able to calculate V0. Then V pi appears across the secondaryand the secondary should now be such that there is no reflected impedance. Obviously, the secondary to be open because I have taken care of the reflected impedance. All right? And it is with this polarity. Pardon me?

Student: Why not it can be shorted?

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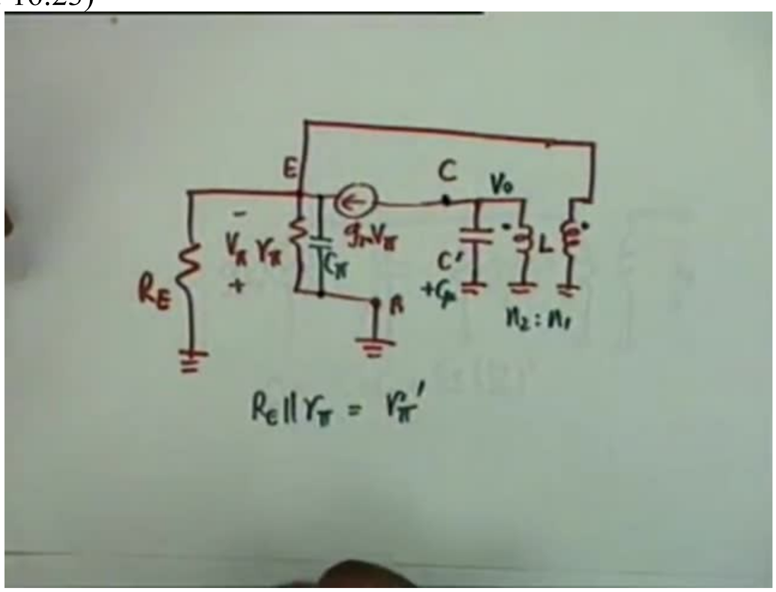

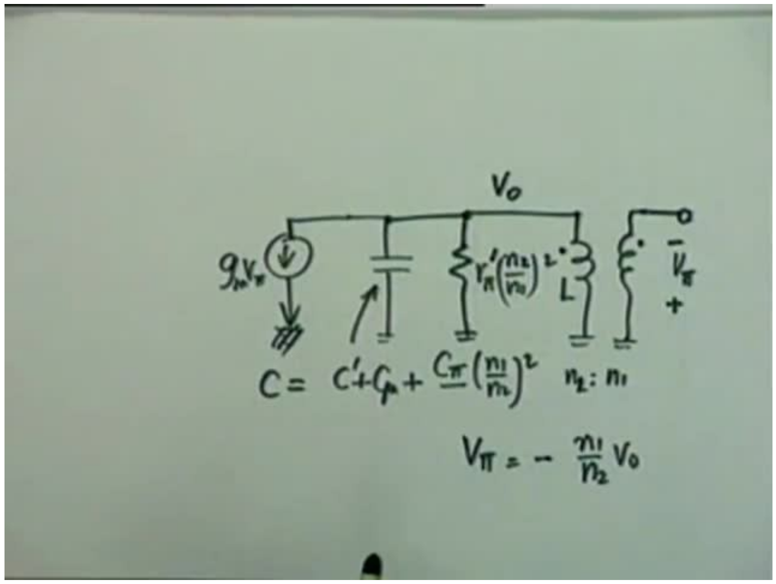

Professor: Which one can be short? If it is short, then there will be short reflected here which means that V0will also be short. Agreed? It is only infinite impedance reflected as an infinite impedance.

Student: Sir?

Professor: Yes.

Student: How is GM V pi going to ground?

Professor: How is it going to ground? As I said I do not care where it is going. It has to come through this impedance. I am calculating, as far as I am, my calculation of V0 is concerned, this circuit is good enough. I do not care where it goes. Ican leave it empty if you so desire. It has to go somewhere but it has to come through this combination okay? Now I also know because of the transform ratio,N2 is to N1 I also know that V pi should be equal to, this is V0, V pi should be equal to - because the polarities do not agreeN1 by N2 times V not. Agreed?

Student: Sir what about (())(17:18) coupling?

Professor: What about the coupling? I have taken care of that. Oh, we assume that it is ideal, 100 percent coupling.

Student: (())(17:27) considering multiplied by turns ratio square.

Professor: That is why.

Student: Sir, but that is valid only when the current through this load, ZL in the 2nd…

Professor: Hmm, once I reflect the impedance, the current can be put equal to 0 in the secondary.

Student: Sir, but that is valid only when the current is only because of the secondary coil. Here, the current is not going only because of…

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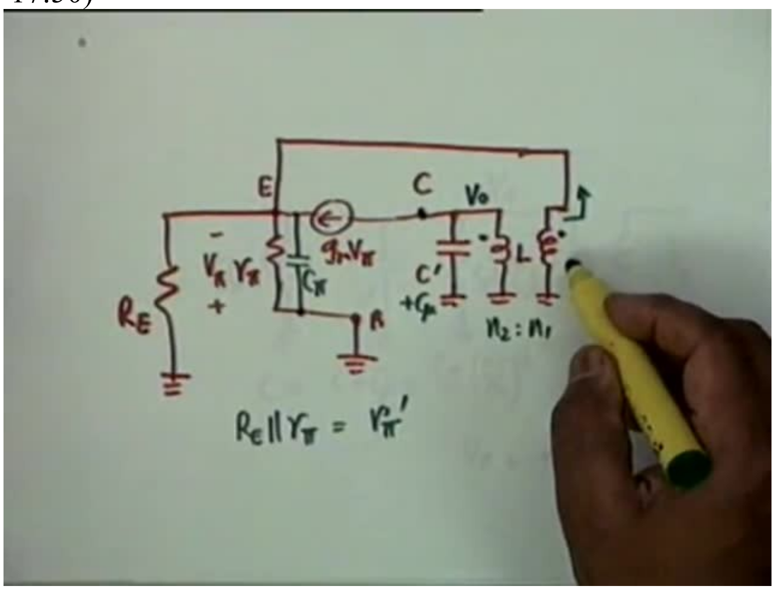

Professor: Does not matter. There is a current here.

Student: There is that, through the load…

Professor: Does not matter. This current goes through the load. Now the load, I have reflected into the primary. Therefore, the secondary can be left open. No no current in the secondary because the effect of the secondary current has been reflected already.

Student: I am not saying that. I am saying that when we reflect this impedance, I am multiplying by the turns ratio square.

Professor: Right.

Student: That we do it because the current through this load is only because of the secondary.

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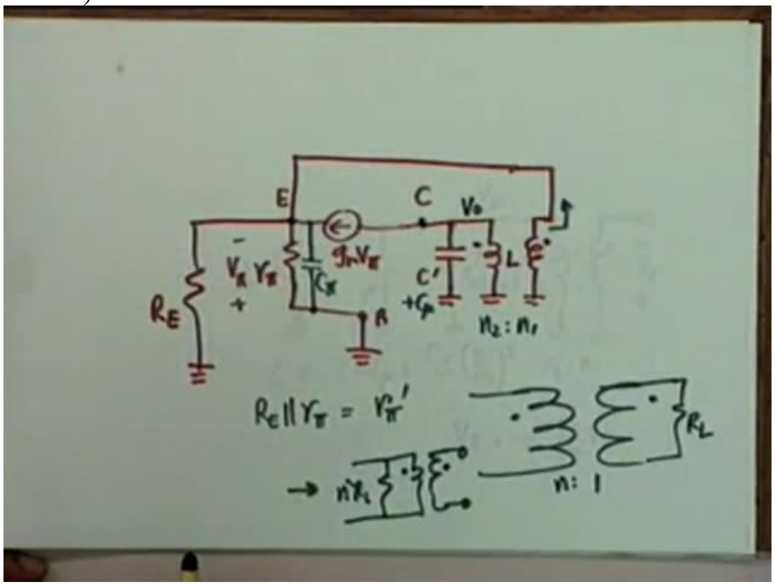

Professor: No, no only. You see, so far as there is a load R here, RL and the turns ratio is N is to 1 then this is equivalent to a simple resistance, N squared RL in parallel with an with a transformer whose output is open. As far as this side is concerned, this is a perfectly valid circuit.

Student: Sir, what if there is another DC or say AC connected to RL secondary?

Professor: Oh, that is a different story.

Student: So here, that is what is happening because…

Professor: There is nothing connected.

Student: The current GM V pi is also I think going to the load.

Professor: Oh, that does not matter. How does it matter? Between this point and this point, whether the current is coming or not, the impedance is that of RB, R pi, C pi. Impedance does not change. Whatever the current, I do not care. Okay? Think about it, it should be clear.

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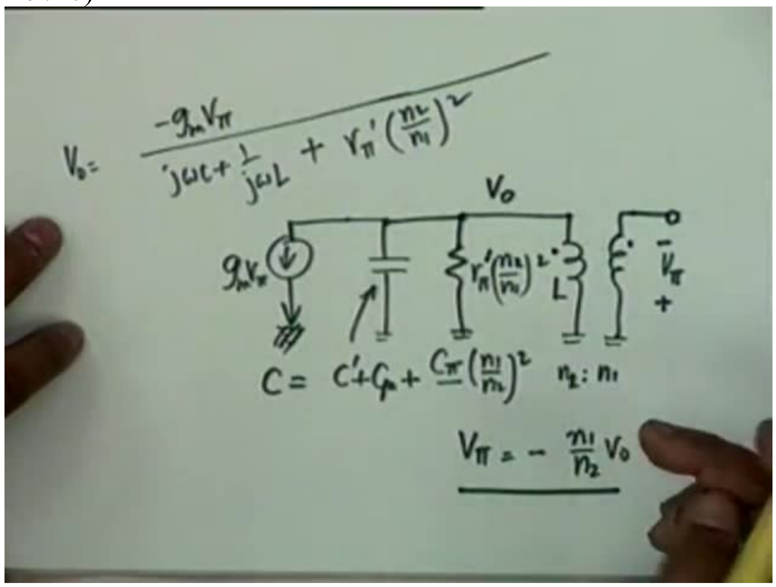

Now therefore my equationfor oscillation should be, this is V pi and my V0, V0 should be equal to - GM V pi divided by the admittance of the total combination, that is J Omega C + 1 over J Omega L + R pi primeN2 by N1 whole squared. Agreed? That is my V0. GM V pi passes through this. That is my V0. AndV pi is - N1 N2 by V0. So substituteV pi, then cancel out V0, you get a certain relationship between the coefficients okay?

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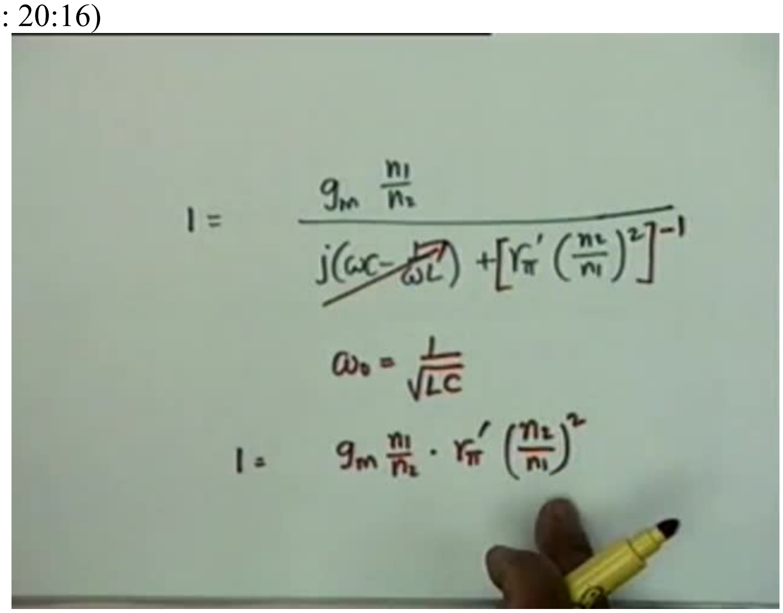

And obviously, that can be let me write this relationship, 1 would be equal to GMN1 by N2 divided by J Omega C - 1 by omega L + R pi primeN2 by N1 whole squared.Student: Sir, 1 over R pi prime.

Professor: Okay, I have made a mistake. All right? Now obviously this can be satisfied. The right-hand side should not have an imaginary part because the left-hand side does not have one and therefore the frequency of oscillation is 1 by square root LC. This C you must remember is not simply the external capacitance. It will be supplemented by C new and C pi N1 by N2 squared okay? L is the external inductor that is used in theprimary of the circuit. Now if this is so, then obviously what we require is that GMN1 by N2 multiplied byR pi prime N2 by N1 whole squared. This would be the condition, this goes to 0 and this comes after and therefore this is the condition that I need.

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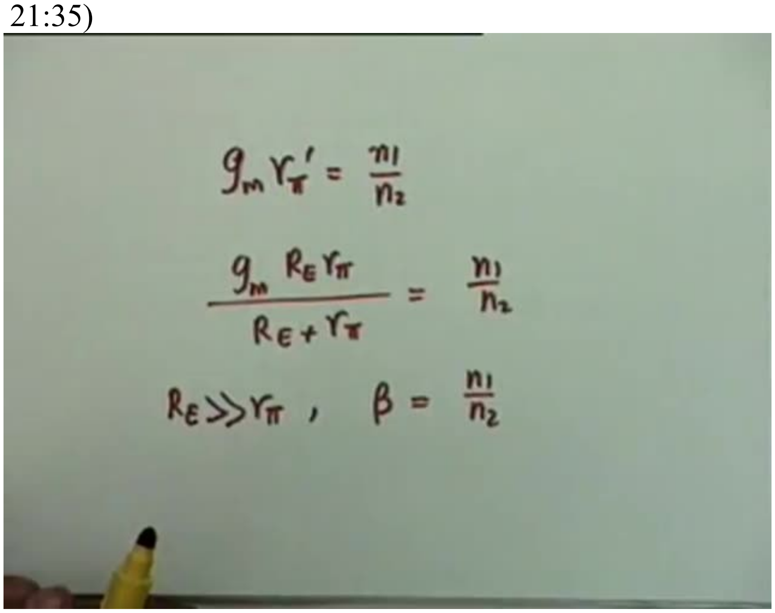

Which means thatGM R pi prime should be equal to how much?N1 by N2. Now GMR pi prime is RE R pi divided by RE + R pi, this should be equal toN1 by N2 and if RE is much greater than R pi by design, then obviously beta should be equal toN1 by N2. In other words, the turns ratio of the transform should be equal to the beta of the transistor. Yes?

Student: (())(22:12)

Professor: Oh, analyse the circuit to find the conditions of oscillation. Then I can give some numbers in terms of the circuit parameters required to calculate the frequency of oscillation. Okay? Now thisproblem was not too difficult. Let us next come to a difficult problem, more difficult problem although it looks simple. Simply says, analyse the Colpitt's oscillator circuit shown below taking account of transistor imperfections.

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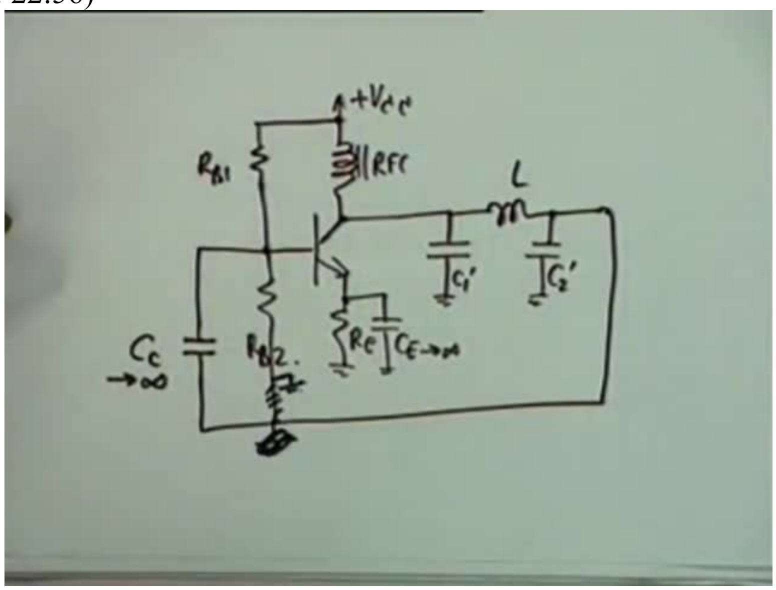

The circuit, this is also revealing what kind of circuit one makes in practice. Instead of a resistive load, one uses an RF choke, RFC so that there is no DC dissipation. Then you have the transistor, RE, CE. CE goes to infinity. It is aColpitt's circuit, so you have let us say a C1 prime, then an L and a C2 prime. You will understand why I am using primes. Because they are supplemented bythings. And then this goes to the base. Do you require a capacitor? Yes, you do. You require a Cc which is very large. You require otherwise, this DC will pass to the base. The circuit is not complete.

You require the base biasing and the base biasing is done by 2 resistors, RB1 and if you are if you want to conserveno, if you want RB1 and RB2 not to load the transistor, then you use an RF choke. Otherwise you do not. Usually RB1 and RB2 parallel combination is much greater than R pi and therefore, that can be neglected RB1 and RB2. The question is to take care of all possible imperfections of the transistor and analyse this circuit. In the usual analysis in the class we had ignored all those perfections. So the 1st thing we do is to draw the equivalent circuit and now the real problem starts.

Student: Sir, RB2 should be grounded or…?

Professor: RB2 should be grounded. I beg your pardon. This should go up. I beg your pardon. Please do correct this circuit. RB 2 should be grounded. It is not connected to Cc okay. Now let us draw the equivalent circuit.

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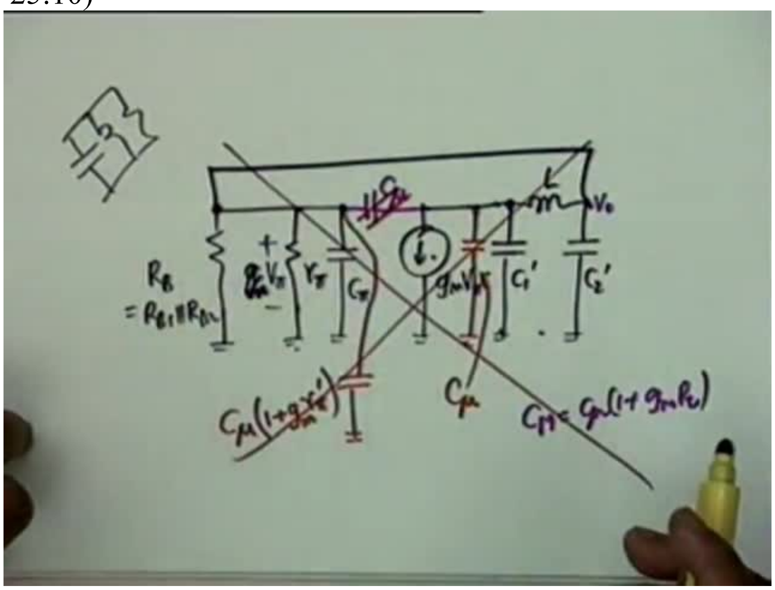

The equivalent circuit starts with RB which is RB 1 parallel RB 2. Then an R pi in parallel withC pi, then you have this voltage isV pi. This voltage V pi +-, a GM V pi, goes to ground. The RFC poses no problem. It is infinite impedance, so ignore that. Then we have the C1 prime, L and C2 prime, this goes to this point. And one thing that we have not drawn in the circuit is this menace of C mew even though it is a small value. Now C mew complicates the problem of analysis because this is a coupling between if we call this as V0, between V0 and V pi.

We cannot isolate the 2 circuits. There is a connection from here, there is also a connection from here. Now can we use Miller effect? Please do consider, please do listen to me very carefully. Can we use Miller effect? You see, the load here is not resistive. So that C mew 1 + GM RL, that will not work. Agreed? The load here, the load that it sees is not resistive. In the Miller effect, wealways had a C mew, the Miller capacitance reflected was C mew 1 + GM RL okay? It is not RL, it is no longer RL here.

But there is a saving grace. The saving grace is at the resonant frequency, at the frequency of oscillation, you see, this is not a wideband circuit. It has to work only at one frequency and at the oscillation frequency, at the oscillation frequency, these will resonate and what will be left is a parallel combination of RB and R pi. Is that clear? If the circuit oscillates, then between this point and ground, the GMV pi source shall see a resistance because the condition for oscillation is that the inductor should resonate all the capacitances that are present in the circuit. Otherwise it cannot oscillates. Okay?

So approximatelyyou can replace C mew, this is approximate. It will not give you an exact solution. I will come the exact solution later. But you canignore the effect of C mew by including a capacitance here which is equal to C mew, then 1 + GM R pi prime. Agree? And in addition, C mew shall also come in parallel with this. So there is a C mew here.

Student: Sir?

Professor: Yes?

Student: Sir, can you please repeat what happens at the oscillation frequency?

Professor: At the oscillation frequency, what this source sees is an anti-resonance circuit. Anti-resonance circuit, C1, this capacitor in parallel with an inductive reactance which cancel each other okay? And therefore,what will be left is this resistance, R pi parallel RB. This is what it will see. You agree? No, this is not correct because GM V pi does not see the resistance across this. It is not a pure CLR. If it was so, it could have. Is the point clear?

Student: No Sir.

Professor: No Sir. I have been arguing probably and I am waiting and pausing after every sentence. Nobody objects. Okay. From here to here, what this current source sees is not a pure resistance because the resistance is here. It is not a parallel LCR circuit. If the resistance was put between this point and ground, yes I will do agree but it is not so. It is after the inductance. You see what I amseeing is the following.

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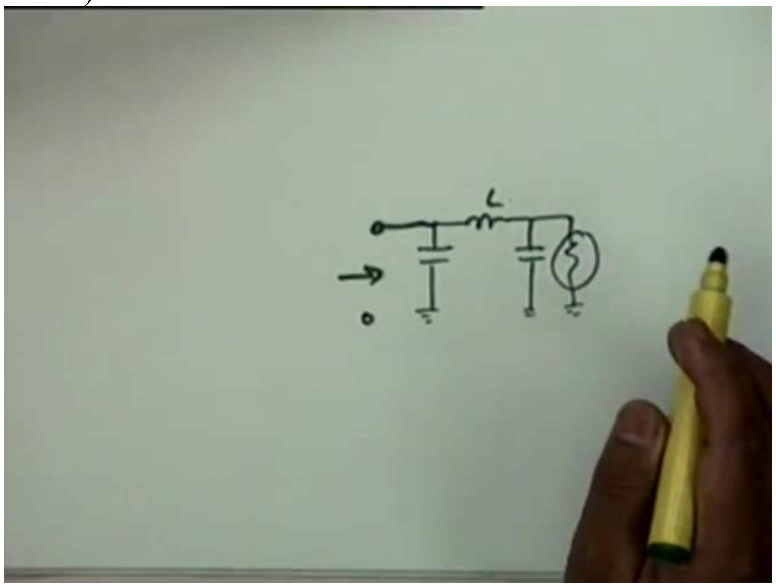

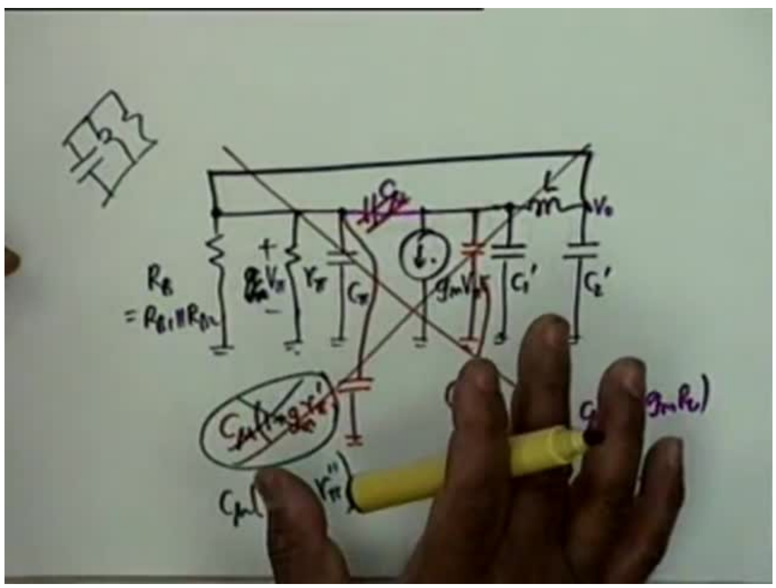

What the current source sees, a capacitance, then an inductance, then a capacitance and a resistance okay? So what it sees here at resonance is not simply this resistance. Agreed? It is notthis resistance only. It sees C in parallel with L + this RC combination. That has to resonate. It does not mean that this input impedance will be this resistance. Nevertheless the input impedance would be resistive and that resistance has to be calculated. It is not simply this resistance. Okay? So while in theory, the procedure would be correct, the reflected Miller capacitance is not this. It would be something different. C mew 1 + GM, let us sayR pi double prime. Effective impedance seen byGMV pi. Do you see the problem of analysis? And then C mew has to come here. If I do this,mind you, this is approximate. If I do this, then my equivalent circuit becomes simple. What I get is the following.

Student: Sir, calculatingR pi double prime, you have to include C mew also in that.

Professor: We have to include C mew, C1 prime, C2 prime, and C pi, all of them. Then myequivalent circuit becomes the following.

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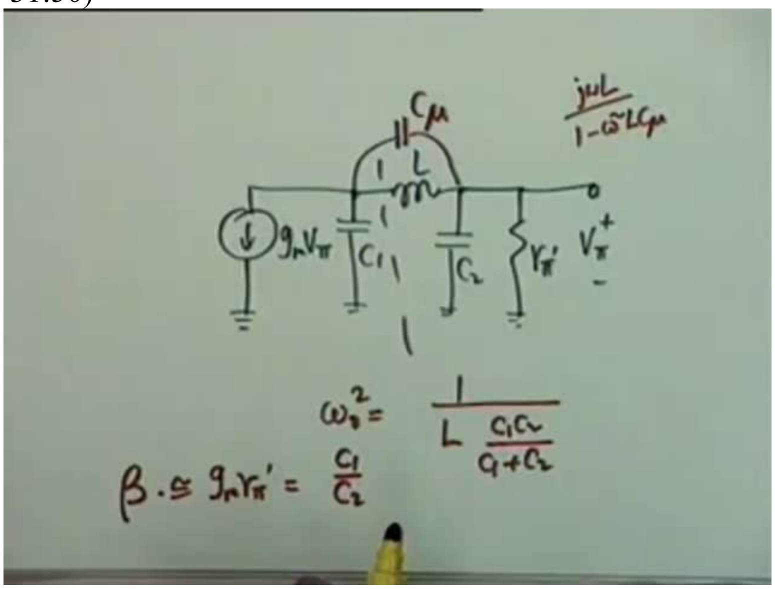

I get GM V pi. You understand the simplification. Even with the simplification, it isan approximate analysis. I will come to the exact analysis a little later. What I get is GM V pi, C1, then an L, C2. Now I have removed the primes. C1 now is C1 prime + C mew. C2 is now C2 prime + C pi + CM, the Miller capacitance okay? And that comes across R pi prime and this is my V pi with this polarity,+,-. Now you analyse the circuit. You analyse the circuit and obviously, you do not write loop equations or node equations.

You make a Thevenin source here, you make the equivalent of a Thevenin source here and then it is a one potential division which gives you a single equation given the frequency of oscillation and the condition of oscillation. I would skip this algebra.it turns out that omega not square, can you tell me what omega not square would be?

Student: 1 by (())(33:15)

Professor: 1 by L

Student: C1C2 divided by C1 + C2.

Professor:C1C2 divided by C1 + C2. It is the series resonance of these 3 okay? And the condition for oscillation is that GM R pi prime is equal to C1 by C2. GM R pi prime equal to C1 by C2 and if R pi prime is approximately R pi then you see that beta has to be C1 by C2. Okay? This is approximately equal to beta. I have skipped the algebra. If it is not so, if Miller effect is not acceptable, you see these results obviously willbequite away from what the exact results are because it is based on the assumption that the shunting effect or the bridging effect C mew could be removed by using 2 capacitances, one at the input and one at the output which is not quite true because the gain is not purely resistive.

We consider the gain only at omega 0 at that frequency. How does the exact circuit different from this? Is not it only in the inclusion of a capacitor here, cell which is C mew right? So all this approximation was not really necessary. It does notgive you more complication than what you did in analysing this circuit. Instead of L, it would be J omega L1 - Omega squared L C mew. Is that clear?

Student: Excuse me Sir.

Professor: Yes?

Student: Can you please sir elaborate why should C mew be parallel?

Professor: Oh. Let us go back to the circuit.

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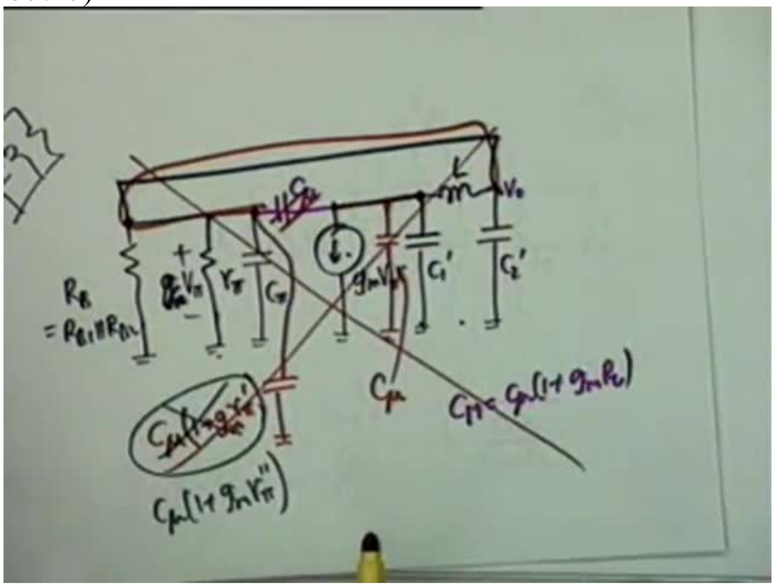

Where was C mew? C mew is between this point and this point. Now this point is the same as this end of L and this point is the same as the other end of L. And therefore, all this fuss about C mew and all this care about C mew was not really necessary. But it creates complications.

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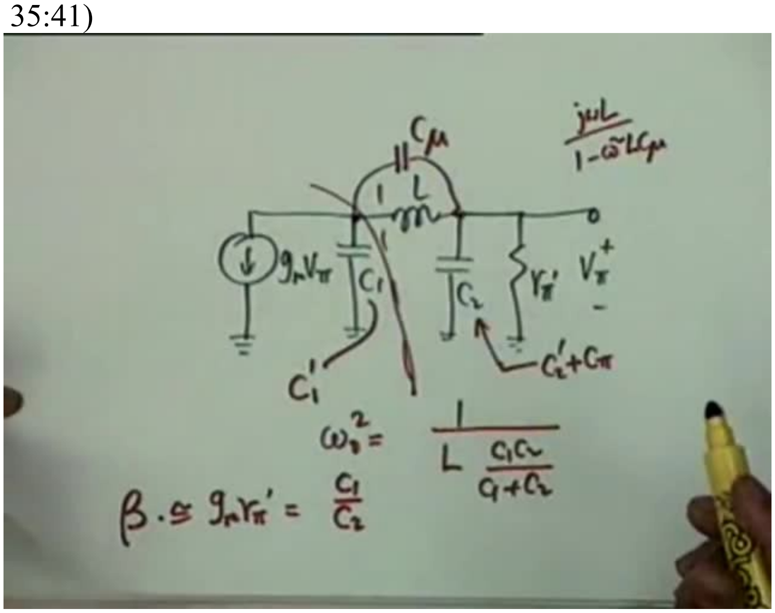

Having aC mew here, obviously my C2 will now be can you tell me what is C2? C prime +.

Student: C pi.

Professor: C pi. That is all. Nothing else. Okay? And what is C1?

Student: C1 prime.

Professor: C1 is simply C1 prime. I am not including C mew. All right? If I include C mew here, then obviously these are the values. And in the analysis, all that you have to do is 1st you applyThevenin's theorem here, then you write a single potential division equation. Whereyou wrote J omega L, now should be replaced by J omega L divided by 1 - omega squared LC mew. So it is not too difficult. What is difficult is that the condition of oscillation will now be of what order? What would be the condition of oscillation? What order?

In the previous case, there were 3 reactances, L, C1 and C2. So the degree of the denominator would have been 3. Now the degree would be 4. So you have a 4th degree okay, the denominator

Student: Sir,Thevenin's equivalent when you make it, what will be the equivalent voltage source because there is a reactance there.

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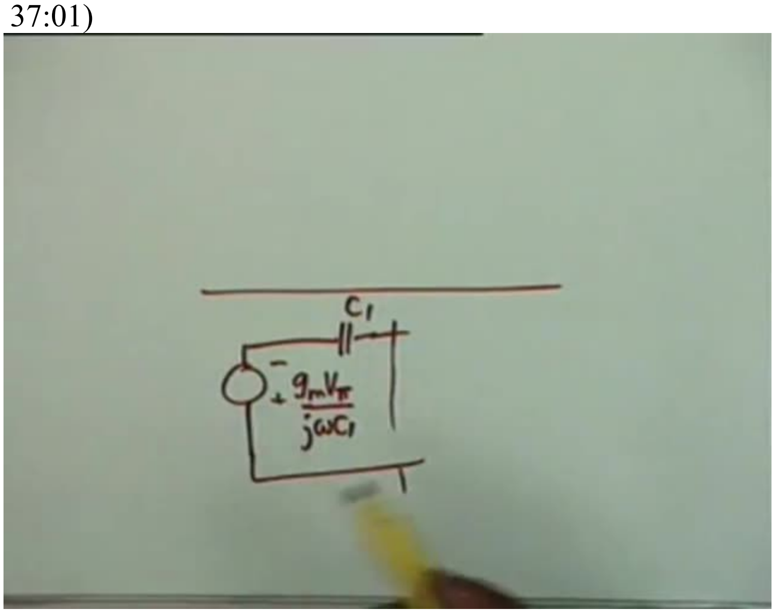

Professor: Oh, let me draw the Thevenin equivalent.-,+ GM V pi times J omega C1 and in series with C1. This is the Thevenin equivalent. It does not matter whether it is resistance, capacitance or inductance. Thevenin equivalent, multiply the current by the impedance and put that impedance in series. Okay?

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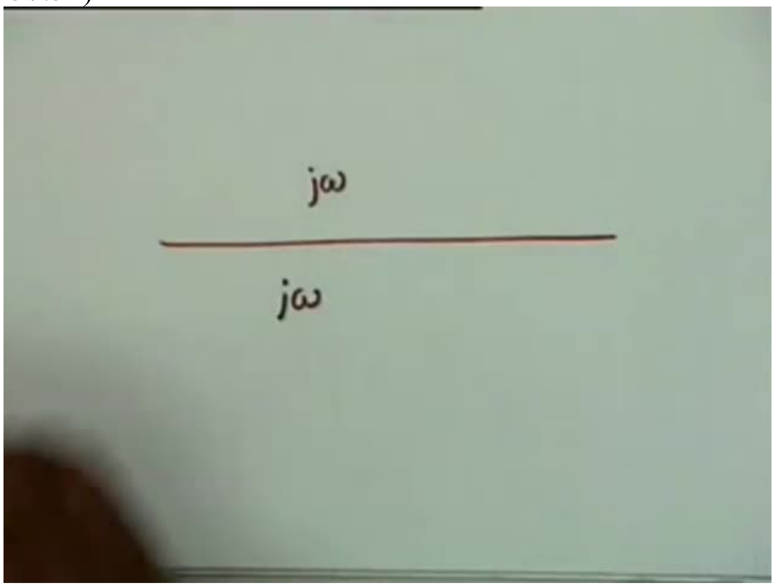

So the condition of oscillation nowshall contain in the denominator a polynomial in omega. To be precise, polynomial in J omega and in the numerator, a polynomial in J omega. And what you have to do to find the condition of oscillation is to make the phase of the numerator equal to the phase of the denominator. Okay? And then find out the magnitude, after you cross out the phase, what remains, that would be equal to 1. And this is a little bit of algebra. It might prove a slightly difficult but if numerical values are given, you should be able to solve it okay? I would not go into thatdiscussion.

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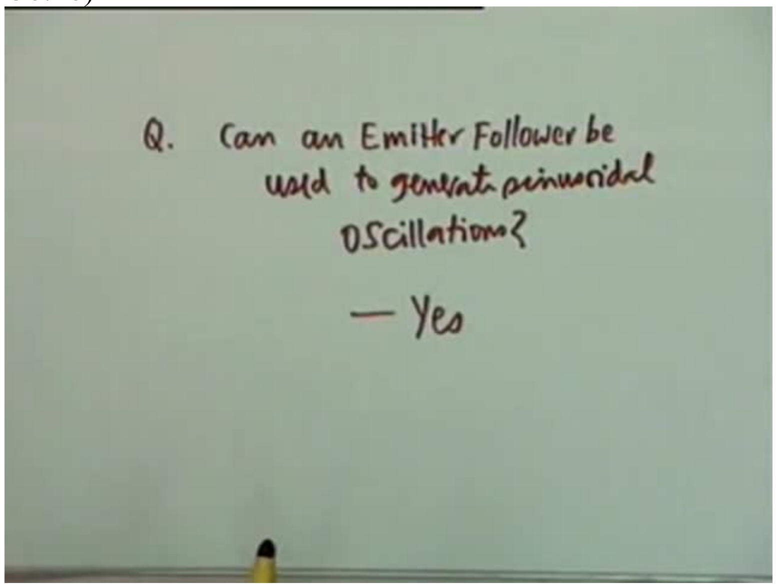

The final circuit final problem that we discuss in this session is the following. The question is can, I do not know if youknow the answer to this question. Can an emitter follower be used, a single emitter follower be used to generate sinusoidal oscillations. You know the answer to this?

Student: Yes yes.

Student: Yes.

Professor: Is the answer yes or no?

Student: Yes.

Student: Yes.

Professor: The answer is yes. Okay. Now? Emitter follower has a gain slightly less than unity. ok? Emitter follower has a gain slightly less than unity.

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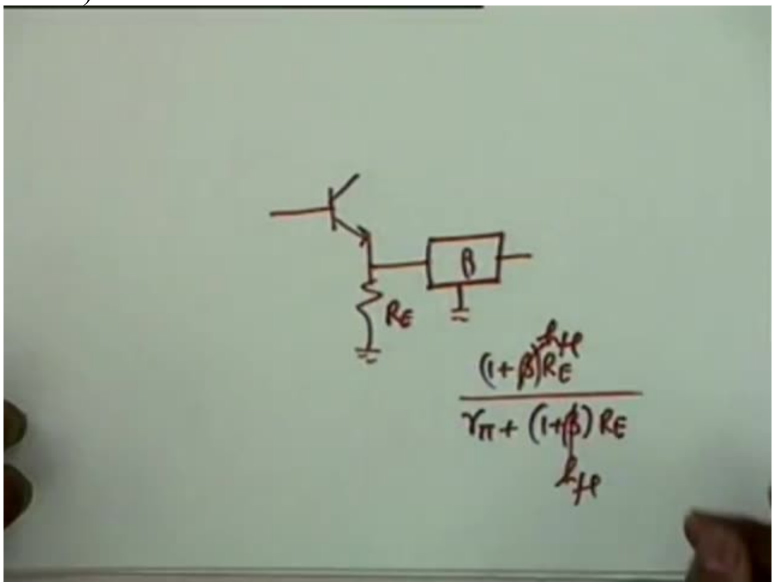

Emitter follower has a gain slightly less than unity. It is1 + beta RE divided by R pi + 1 + beta RE. And since 1 + beta RE is much greater than R pi, it is approximately unity but is always less than unity. And therefore the beta network, I should not use beta. hfe. The beta network that you should use should give a gain slightly greater than unity but a phase shift of?

Student: 0 degree.

Professor: 0 degree okay. And that network can be derived very simply.

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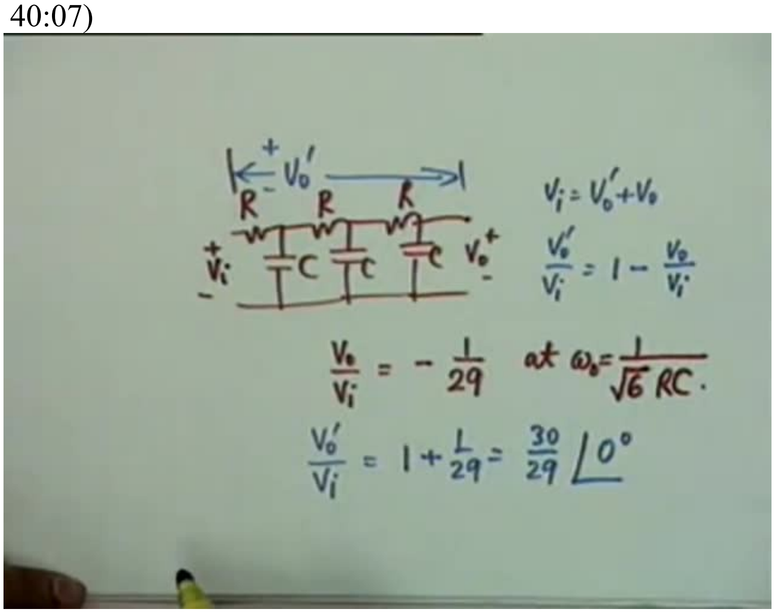

You recall this network. Okay? R, R, R, C, C, C. You know that if this is VI and if this is V0, thenV0 by VI is equal to - 1 over 29 at Omega 0 equal to 1 over yes, what? You do not remember. Root 6 RC. This is the phase shifting network. Instead of CR, I have drawn RC. Okay? If that is so then you consider this voltage, V0 prime. What is V0 prime by VI at this frequency? You see, VI is equal to V0 prime + V0. ThereforeV0 prime byVI is equal to 1 -V0 byVI which means 1 + 1 over 29 which is 30 by 29, greater than 1 and the angle is 0 degree. Agreed?

Student: Sirsir what is the…?

Professor: Is it okay?

Student: Yes.

Professor: So all that you need now is to use an emitter follower.

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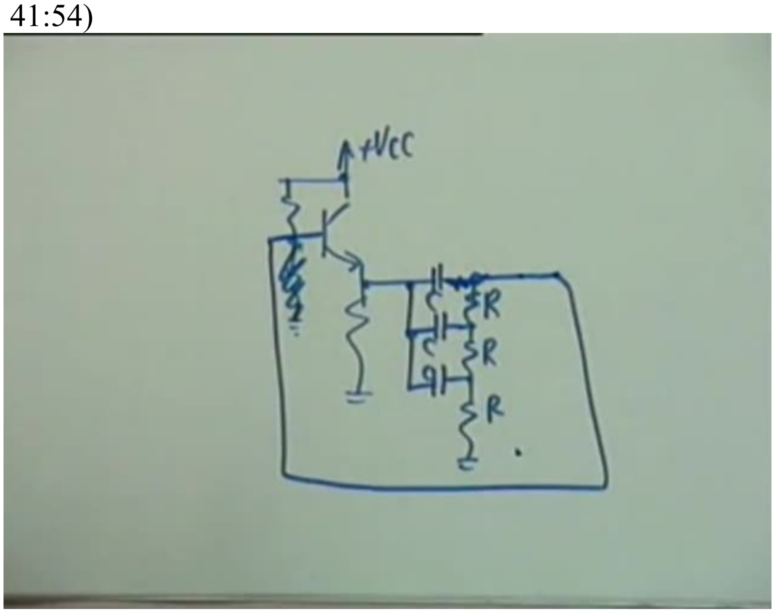

Now let me draw the circuit without any more ado. VCC, youhave to have a blocking capacitor. No, I beg your pardon. Do you require a blocking capacitor? No, you do not. That is what it is. The voltage is from, output is from here to here and this output is 30 by 29 times this output. The gain of the emitter follower is less than 1 and therefore the product can be equal to 1, slightly less.

Student: Sir, you did not put a blocking capacitor.

Professor: Do I require a blocking capacitor? I do not because there is a capacitor here. But I dorequire a biasing arrangement. Do I require this resistance?

Student: Yes.

Professor: No.

Student: No Sir.

Professor: 3 Rs should take care of it.

Student: Sir please show the previous sheet.

Professor: Yes, I know you are going to ask that question.

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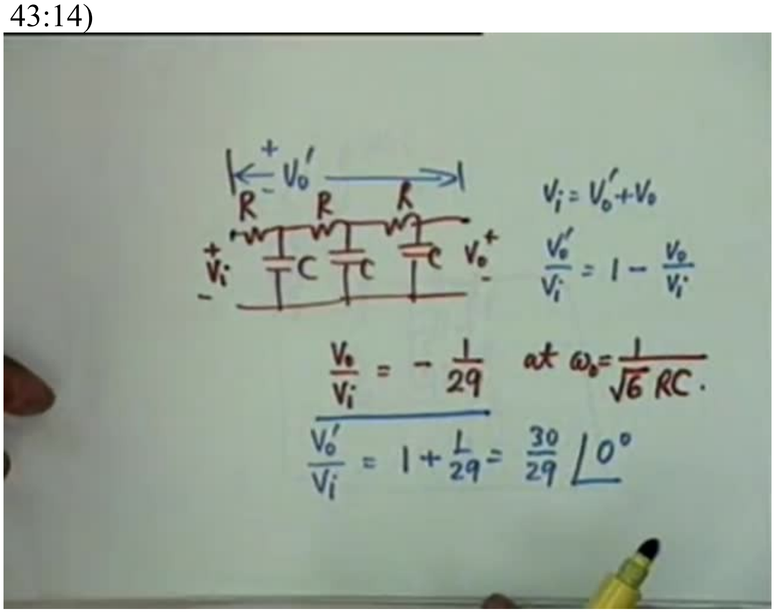

Student: Sir what is the (inaudible 43:13) of - sign?

Professor: Which - sign?

Student: (())(43:17)

Professor: Yes.

Student:(())(43:19)

Professor: What is your question?

Student: Sir, we have a phase shift of 0 degree.

Professor: No, this is 180. V0 by VI is 180 but I am taking the output here which gives me 0 resistance. Okay? This is a very novel way of designing a and you see in an emitter follower, many things, many imperfections are taken care of okay. R pi, C pi and many other things. You can improve the R pi, C pi and see that it does not change substantially. You can always choose your capacitors and resistors in such a manner. Even base resistance is not required because 3 Rs take care of it. Okay.

It is a very simple oscillator. You can quickly wind it up in the laboratory and see. Byputting the power supply on, you see beautiful oscillations. We will meet in another 10 minutes. We will take a break now. Meet in another 10 minutes.