**Introduction to Electronic Circuit**
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**Lecture 37**
**Small Signal Amplifiers (Contd.)**
**And Feedback**

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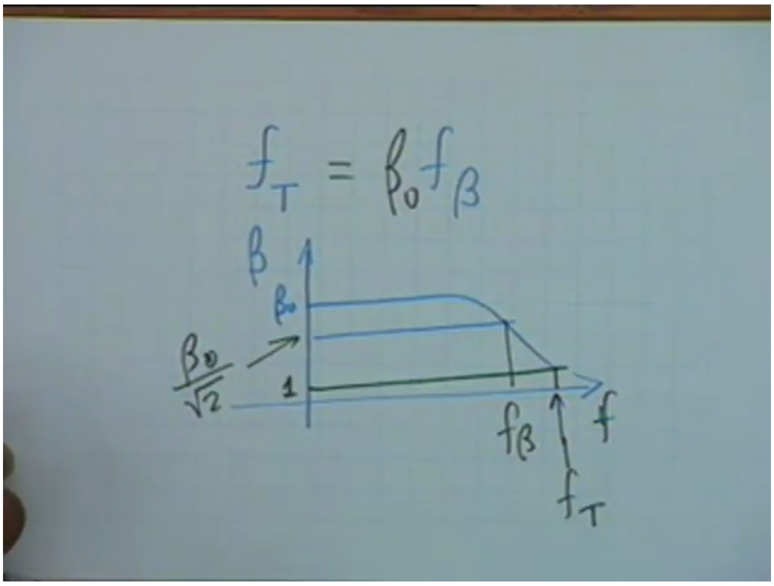


Once again, okay. This is the 37th lecture on small signal amplifiers and feedback. In the last lecture I had introduced the terms fT and f beta for the figure of merit of the transistor and I explained that if you measure beta that is the short-circuit current amplification of a transistor when beta varies its frequency and the variation is like this that is at low frequencies and at mid band beta is a constant.

Beta is a constant at beta 0 and then at some frequency f beta the value becomes beta 0 by root 2 and this is called the beta cut-off frequency and the frequency at which the value of beta becomes equal to1 is the so-called transition frequency or f sub T the variation of beta determines f beta and fT and the relationship between fT and fbeta is that fT is equal to beta 0 times fbeta and that is why fT is also sometimes called the gain bandwidth product.

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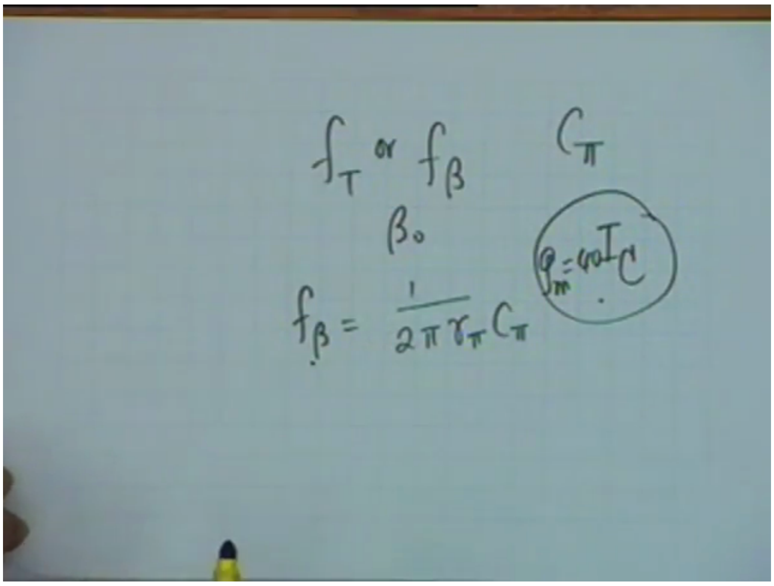


As an example of this suppose the manufacturer specifies this in a clever way he does not give the value of Cpi, what he does is, he gives either the value of fT are value of fbeta one of them, alright. And also beta 0 then you know that, is that enough for specifying a transistor fbeta and fT? f beta as you know is 1 over 2pi rpiCpi, so it is not enough to specify f beta and beta rpi must also be specified or you must find out rpi, how do you do that?

If the capital I sub C the DC collector current is known when you find gm as 40 IC and from this and beta 0 you find rpi and if you know rpi and beta fbeta then you know Cpi.

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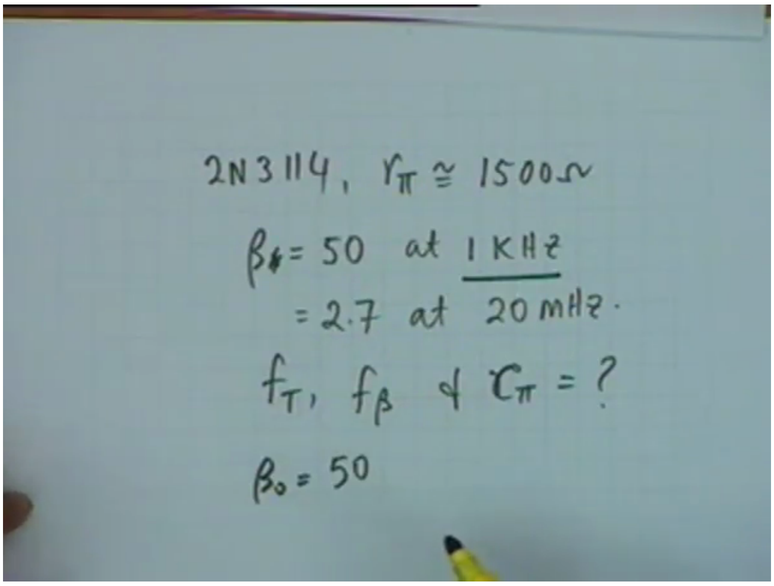


As an example for 2N3114 transistor, a manufacturer shall specify that a typical operating point rpi is 1500ohms, beta is at 50 at 1kilo hertz and is 2.7 at 20 megahertz this is all that is specified, rpi is given the values of beta at 2 frequencies are given and you are required to find out fT, f beta and Cpi, this is what is to be found? Common sense says that 1kilohertz is sufficiently low frequency and therefore you can take beta0 as equal to 50, alright.

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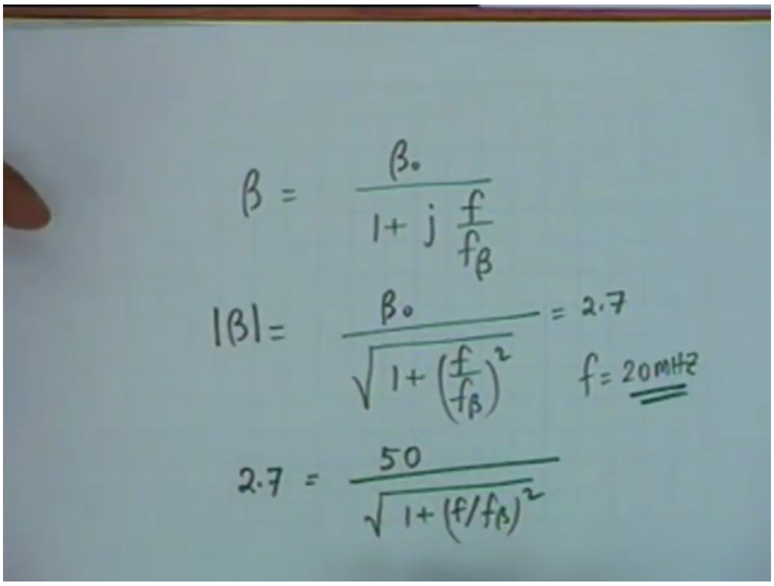


And you know that the variation of beta is given by beta 0 1 plus j f by fbeta this is the evaluation and we have been given that the magnitude beta which is beta0 divided by square root of 1 plus f by fbeta whole square this is given as 2.7 when frequency is 20 megahertz, f is 20 megahertz, alright. And therefore 2.7 is equal to 50 beta 0 divided by square root of 1 plus f by fbeta whole square. Now at such a high frequency 20 megahertz one can be ignored compared to f by fbeta, alright.

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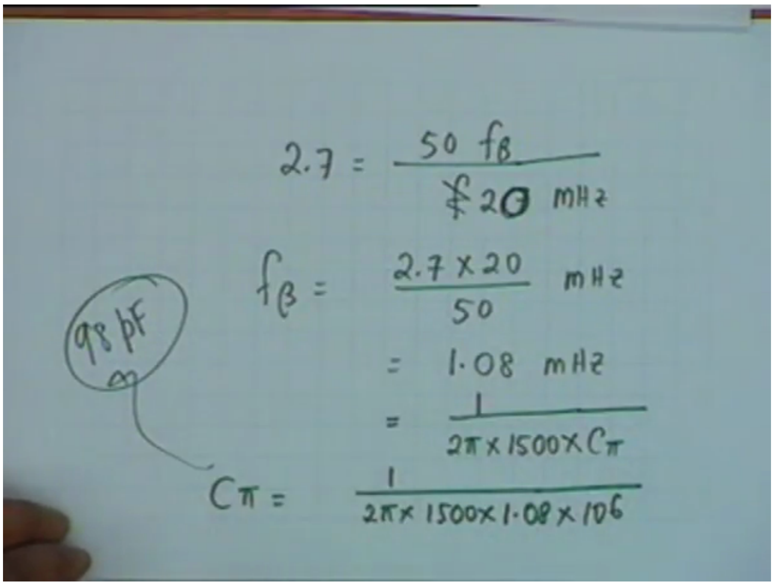


From 50 beta has come down to 2.7 it is beyond fbeta and therefore f by f beta whole square term dominates the denominator expression and therefore you can write 2.7 as equal to 50 divided by well f by fbeta and f is 2.7 megahertz and therefore fbeta is equal to 2point, no I beg your pardon, 20. Therefore it is 2.7 multiplied by 20 divided by 50 megahertz and this is equal to 1.08 megahertz this is your fbeta.

And if you know fbeta then you can find out Cpi, fbeta after all is 2pi times rpi is 1500 and Cpi therefore Cpi is equal to 1over 2pi 1500 multiplied by 1.08times 10 to the 6 and this calculates out to approximately 98 puffs, 98 picofarad that i is our Cpi. Cpi is never specified by the manufacturers, alright.

“Professor -Student conversation starts”

Student: Cpi plus Cmui.

Professor: Actually it is Cpi plus Cmui but Cmui is of the order of a few part, 2 or three-parts, so we will take everything as Cpi, we ignored that quantity, alright.

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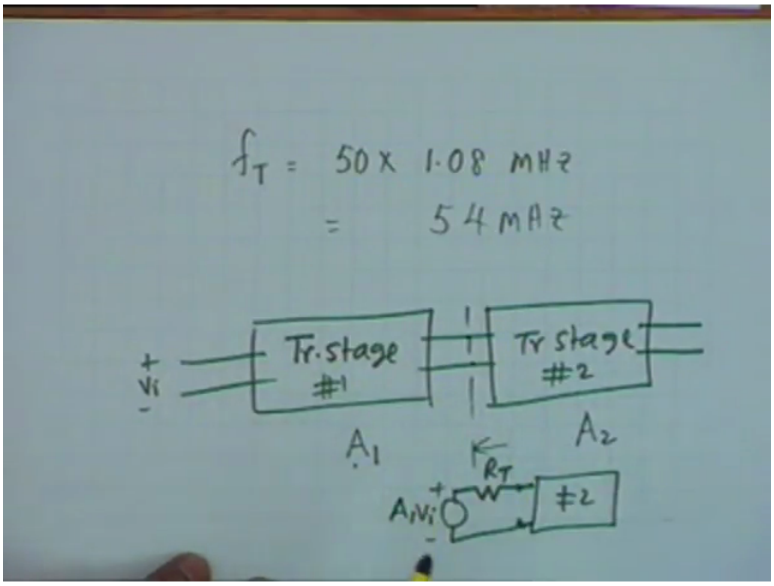


And if you know fbeta then of course we know fT also, fT is 50 times fbeta that is 1.08 megahertz which is equal to 54 megahertz, alright. So you should be able to calculate the quantity of interest given all other quantities. We next consider, what happens when one amplifier stage is cascaded to another, if the amplification, transistor stage I, transistor stage 2, if the amplification provided by 1 stage is not enough then you cascade 2 stages.

Normally it looks like if A1 is the gain of the first stage and A2 is the gain of the second stage that the overall gain should be A1A2, except for the fact that the 2 stages usually in BJT amplifier are interactive. In other words the load of the stage, if you consider the load of the first stage as the input of the second stage then you shall be right in calculating A1 and A2 but if you calculate a 1 by open circuit in this, alright.

Open circuit voltage divided by this that A1 A2 formula shall not be valid because if you look back here transistor stage 2 is being driven by A1, let us see this is vi, A1vi the thevenin source in series with whatever you look back that the thevenin output resistance let us say RT and therefore what is applied here is not A1vi but it is reduced there potential division between RT and perhaps rpi if it is a common emitter transistor and therefore in calculating the gain of cascaded stages one has to be particularly careful and usual take a fairly elaborate example to illustrate this.

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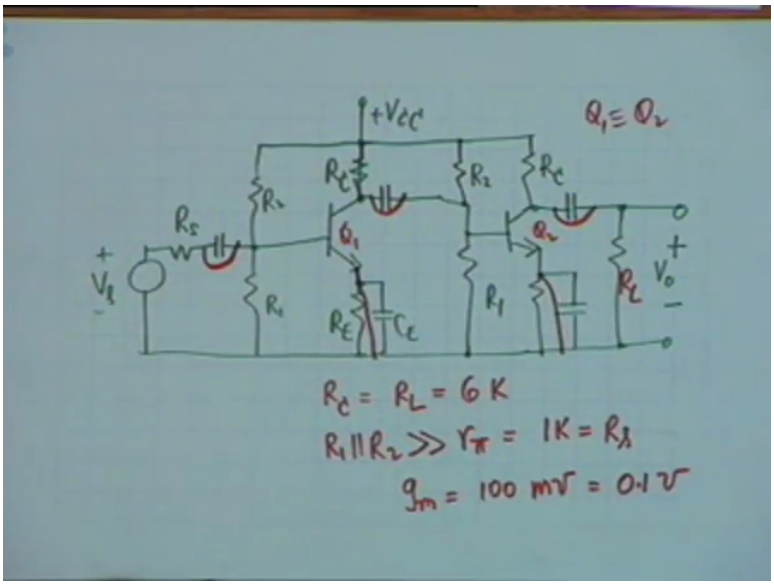


Let us consider a 2stage amplifier, please try to draw with me, 2stage amplifier I will draw the complete circuit Rs then you have a coupling capacitor biasing resistances R1 and R2 plus VCC and the transistor there is an Re and C sub e is connected to the base, there is a first stage is coupled to the next stage, oh! There is a resistance here R sub c the collector resistance to the first stage then it is coupled to the second stage by a capacitor R2.

Let us say they are identical stages R2 and R1 then you have the base we do not use an extra load here because the second transistor acts as a load to the first transistor, alright. And then there is a resistance here truncate by a capacitance and there is another resistance here R sub c, finally you have a coupling capacitor and the load RL this is a typical two-stage Rc coupled amplifier.

Let us say the root mean square value of the voltage here is V0, alright. Now we have to calculate the gain of this stage wherever no specification (()) (12:30) with regard to frequency it is implied that it is the mid band gain and at mid band by definition this is short, this capacitor is a short, this is a short, this capacitor is a short, this capacitor is a short and this is short at mid band, alright.

Also the transistors Q1 and Q2 their internal capacitances are open Cpi and Cmui, let us say that the 2 transistors are identical, Q1 is identical to Q2 and suppose R sub c is equal to R sub L, R sub C, R sub C, R sub L and they are each 6k, right. R1 parallel R2 that is RB, it is so chosen that is much greater than rpi and rpisi 1k which is also equal to Rs, alright. This resistance and rpi they are identical for simplicity.

And we are also given that gm at the operating point of either transistor is 100 millimoh, 100millimoh means 0.1, is not that right? 100 times 10 to the minus, so this is the data that is given, beta is not given we do not need it, how much is beta for this transistor? Pardon me, 1k multiplied by 0.1, so 100, is not that right? Beta is 100, let us draw the equivalent circuit and see if we can calculate, you will see that if you take care and join the equivalent circuit then analysis is almost by inspection there is nothing, no equations have to be written.

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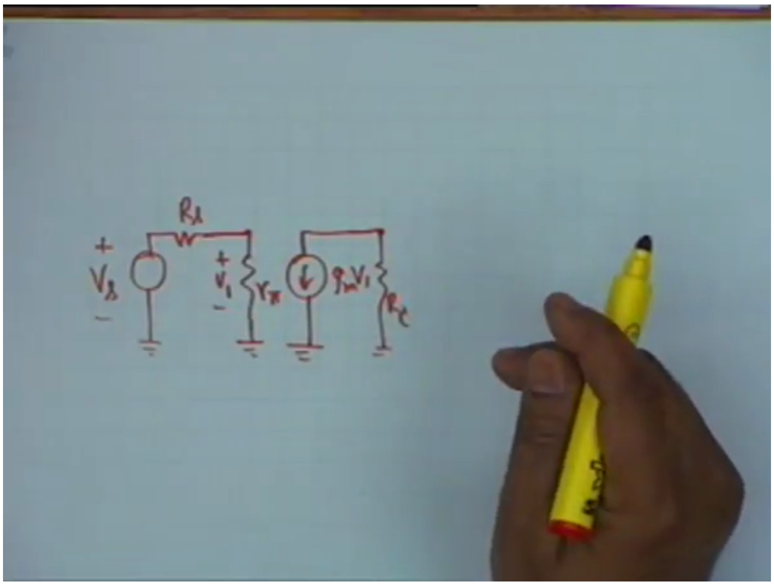

Now let me go ahead with the equivalent circuit Vs then you have Rs, we have ignored R1 parallel R2 and therefore it is simply rpi and if we call this voltage as V1 then the next the output of the collector is gmV1 and its load is, there are 2 loads, one is R sub C and the other is rpi of the next phase, alright.

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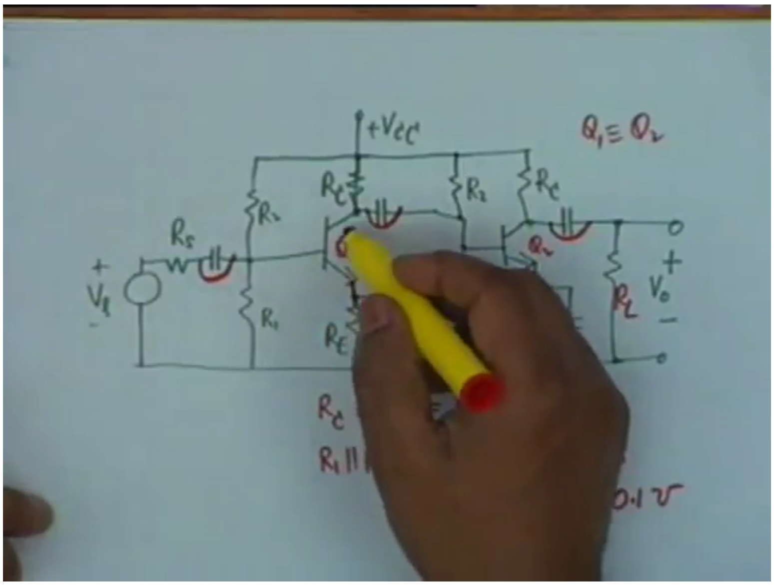


The load of this transistor is R sub C and then whatever it sees, it sees R1 parallel R2 which you ignored and from here to ground that shall be an rpi.

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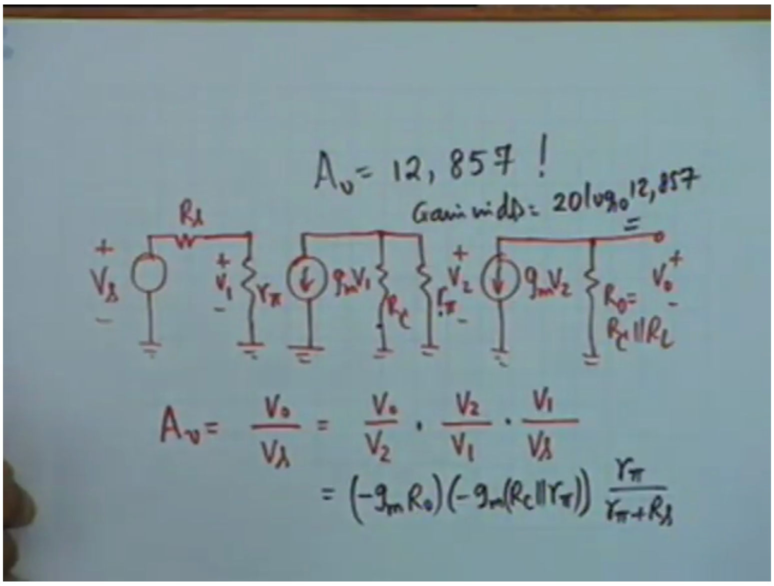


And therefore there is an rpi and let us say this is V2 then at the output of the second transistor we shall have gmV2 and what about the load? What shall be Rc parallel RL, is not it right? It shall be Rc parallel RL, so let us call this R0, RC parallel RL and this is V0 and the calculation of voltage gain is very easy now V0 by Vs is the voltage gain and you calculate this in 3 steps V0 by V2 then V2 by V1 and then finally V1 divided by Vs, alright.

You calculate this in 3 steps and it is quite clear that V0 by V2 is simply minus gm times Rnot, this is minus gm times Rnot. V2 by V1 shall be minus gm times the parallel combination of Rc and rpi, alright. And V1by Vs will be simply rpi divided by rpi plus Rs and if you substitute the values and carry out the algebra, my calculator gain A sub v, you just need to substitute the values now everything is known, alright.

And if you calculate this out you notice that the gain is positive because it is a 2stage amplifier. First stage gives it an out of phase output voltage, second stage gives outer phase with outer phase 2 negatives make and therefore the output voltage shall be in phase with the input voltage and the value that calculates out is 12857, usually fairly large number this is the mid band gain of these 2 transistors.

We have not asked for very sophisticated transistors they are commonly available beta equal to 100 that is not a very large beta transistor, alright. Now such a large number usually as you know is expressed in decibels gain in decibels. If you want to express in decibels then you should get 20 log 10 of this number and I leave it to you to calculate, how many decibels shall this be?

How many decibels, what is your guess? This is more than 10 to the power 4 and therefore it is more than 80db, okay. That is how usually electrical engineers express the gain, the exercise for determining the low frequency cut-off and high frequency cut-off for Cascaded amplifiers can be quite tough but I am sure if you help of (()) (18:56) and the ticks that some of them which we disclosed in the earlier classes in some of the tutorial class we should be able to do that.

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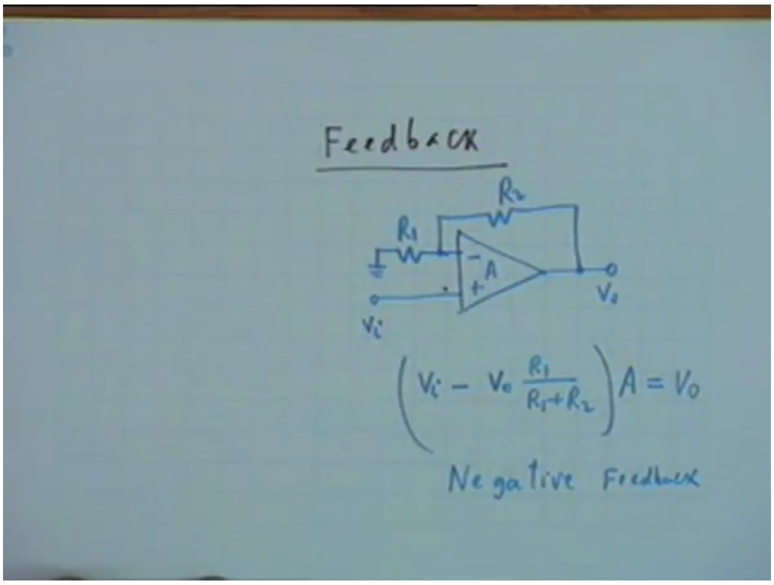


So we leave other problems for the tutorial class and we consider the question of feedback in amplifiers. The definition of the term feedback is, that it is a phenomenon in which the output influences the input, if a part of the output is utilized to influence the actual input to the amplifier then we say feedback exists for example, common example is the op Amp. As you know in the op Amp the gain, the open loop again is very large tends to infinity and if you wanted to make a non-inverting amplifier then what you do is, use a resistance here and resistance here.

So what is being actually done is that the input Vi, the actual input to the amplifier is Vi minus, if this is R2 and this is R1, the actual input to the amplifier between these 2 points is Vi minus V0 R1 divided by R1 plus R2, is that clear? This is the actual input and therefore the input that is applied to the amplifier is being modified by the output, a part of the output is being fed back to the input and this multiplied by A is equal to V0 and the kind of feedback that exist here is negative feedback.

Because the actual voltage applied to the input of the op Amp is less than what is actually applied, alright. If the input had increased then we would have said positive feedback, so this is negative feedback, okay. Evaluation of w110N to the teacher can either be positive or negative depending on how the teacher was.

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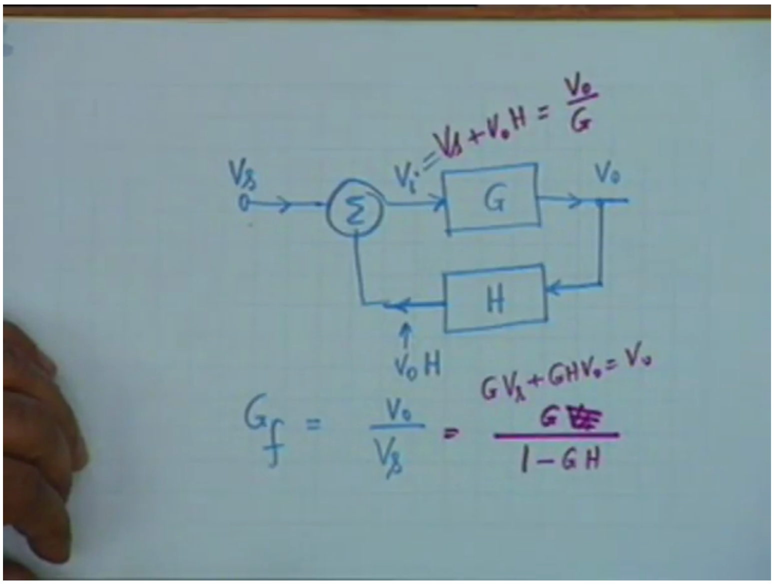


If I take a general philosophical attitude, well, I say that I can represent feedback schematically like this, I have an input let say Vs a source and an amplifier of gain G whose output is V0, a part of the output this is called a block diagram I am not showing the actual circuit I showing the relevant signal quantities and the amplifier in terms of the gain in terms of the block, just a rectangular block.

A part of the output or the output is fed to another circuit which we call the H circuit or the feedback circuit and this output which is obviously V0 times H, alright. Is used to influence the input, that is, what we do is, we simply add the 2 inputs, we simply add them in a block called a summer, alright. We add Vs and v0H and this is the actual input to be amplifier before Vs comes to the amplifier we do something we mix it with a part of the output and this is called a feedback circuit, this loop is called a feedback loop.

And it is very easy to calculate what the gain is under the condition of the feedback. Under the condition of the feedback we represent the gain by Gf and you see Gf would be simply V0 divided by Vs, alright. But as you can see from this Vi is equal to Vs plus V0H, alright. Vi is equal to Vs plus V0H, alright. Vi is equal to Vs plus V0H and Vi times G is V0 therefore this is V by G, is this clear?

This voltage, the signal is Vs plus V0H and this signal when multiplies G shall give you 0 therefore this signal must be V0 by G, okay. Now if I manipulate this then you see Vs times GVs plus GHV0 is equal to be 0 and therefore V0 by Vs shall be simply GVs divided by 1 minus G times H, now Vs shall be there, okay. It is simply G by 1 minus GH. If H is 0 that is there is no feedback and then gain is simply equal to G, okay.

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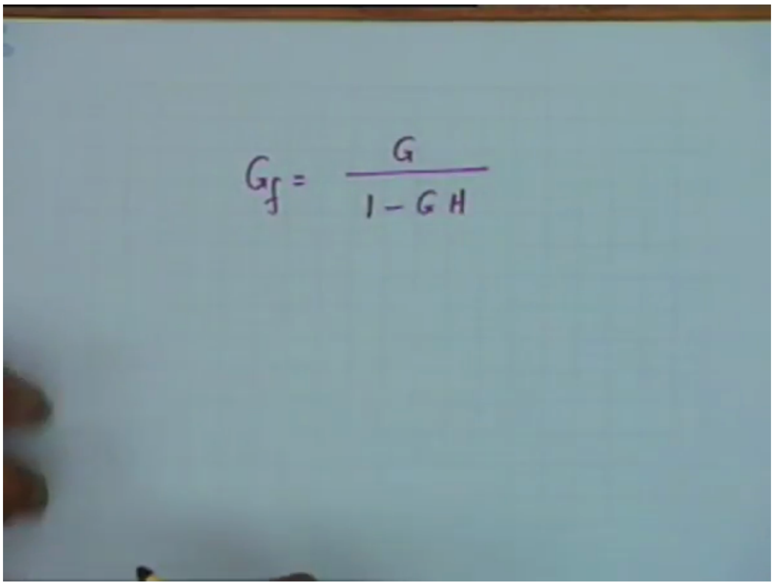


So for a feedback amplifier or any feedback system the gain is in general given by 1 minus GH where G is called the forward path.

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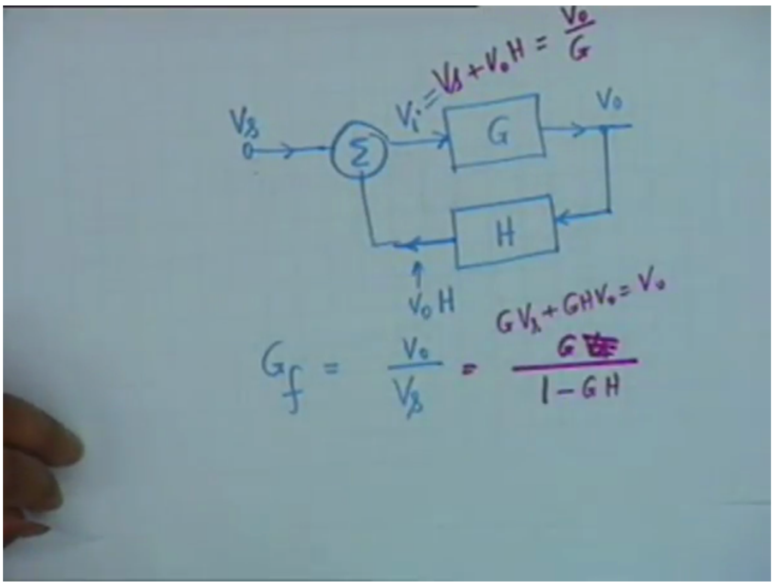

G is called the forward path, the signal travels in the forward direction, H is called the reverse path or the feedback path, it is this path through which feedback is applied, alright. G H and the total loop is called a feedback loop and you can see that G times H, this quantity figures here, G times H is the gain from here to here, if you start from this point and you come here the gain is G times H, alright.

It is also called the loop again, G times H is called the loop gain, it is the gain of the feedback loop that is if you start from your point on the feedback loop and try to come back to the same point through the summa then the overall gain from here to here is GH loop gain.

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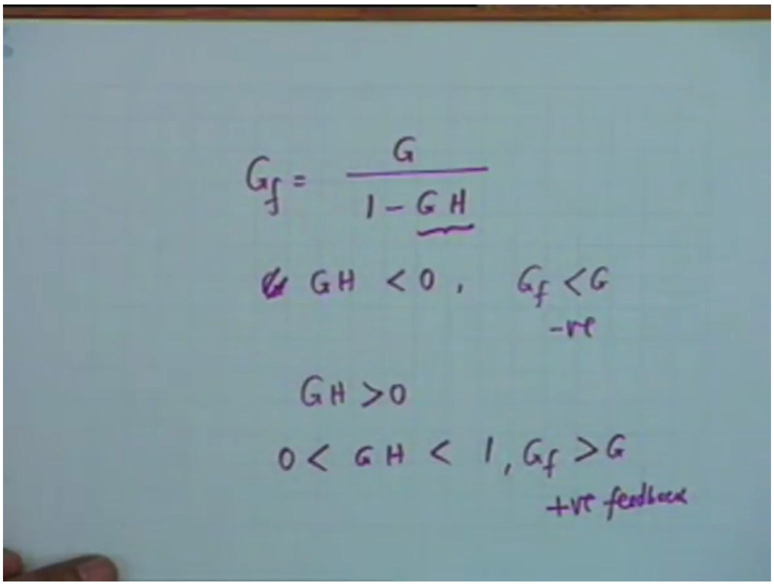


Now the quantity GH affects the overall gain vary drastically, very substantially for example suppose G and H are real quantities and suppose H is negative, let say H is less than 0, alright. Suppose GH is less than 0, the product GH is less than 0 then obviously if G and H are real then obviously Gf shall be less than G and the feedback shall be negative feedback because the gain is reduced, alright.

On the other hand if GH is greater than 0 and let us say less than one, alright. Then Gf obviously is greater than G and the feedback is positive feedback, alright. So feedback can be positive or negative, do we use positive feedback? Yes we do use, we use negative feedback also.

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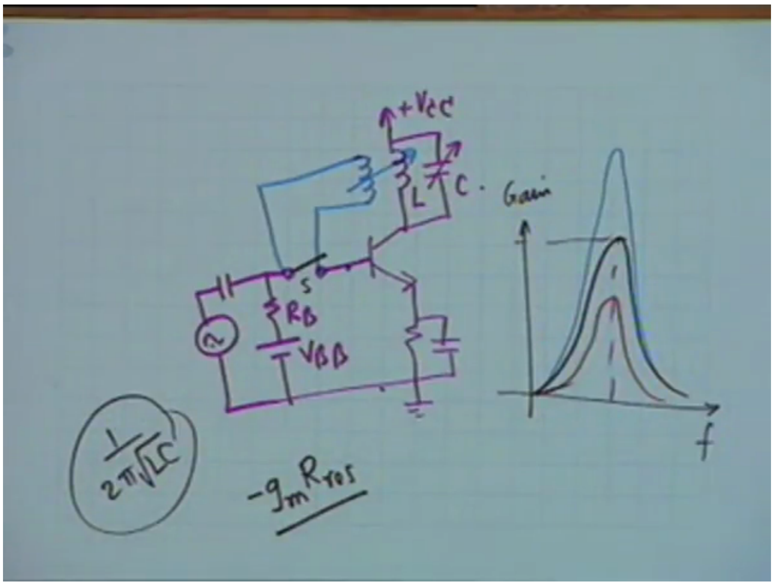


Now as an example of positive feedback let us look at a typical circuit. Let us look at a transistor amplifier in which the load you get tuned circuit, the load is a parallel LC circuit, this is plus VCC L and C and for simplicity let us represent the biasing by this thevenin equivalent circuit that is RB and VBB, alright. Now normally what we shall do is, we will connect this point to this point.

Suppose S is closed, suppose the switch S is close then can you tell me what the gain of the circuit versus frequency shall look like. The parallel resonant circuit has been highest impedance at the resonant frequency, what is the resonant frequency? 1 by 2pi square root LC and this frequency the load it has the highest value ideal it should be infinity but because of resistance of the inductance and because of the parallel resistance of the capacitance this effective load of resonance is less than infinity.

But whatever the load is you know the gain is minus gm times the effective load, so if you see our resonant resistance is Rres then the gain shall be minus gmR resonant at the frequency 1 by 2pi square root LC. If we go away from resonance either on the right side or on the left side the gain shall decrease and therefore the gain shall follow the resonance curve like this where the maximum gain shall be minus gm times the resonance impedance, alright.

Is this point clear? Instant of a resistance I have an LC circuit here and if I have an LC circuit then the gain shall be maximum at the frequency of resonance and you know that if we vary the capacitance than the resonance frequency can be changed and this is what we do in the input stage of a radio receiver, ordinary radio receiver we actually vary a capacitor, so estuary the frequency at which the gain is maximum and it is this frequency which shall be picked up by your radio, alright.

Okay, now suppose we use a coil here, suppose we use a coil here, okay. A small coil maybe 1 or 2 turns and I connect this coil to these 2 points keep the switch as open, alright. We can so orient the winding direction such that a part of the output is fed back to the input, you see the actual signal at the input between the transistor base and ground shall give input signal plus this signal that is fed back from the output because of the magnetic coupling between these 2 inductors, alright.

And this is a very practical circuit, your feedback part of the output and if the feedback signal helps the input signal, that is if these 2 are in phase Vi and the fed back signal if they are in phase if they help each other the same direction then what you will get is, you will get an enhanced gain, alright. The gain shall increase, on the other hand if the direction of winding is opposite that is if the fed back signal opposes the input signal then the gain shall be decreased then it shall be something like this let say.

So you can use this, a very simple circuit can be wired up in the laboratory to demonstrate the effect of feedback, positive feedback increases the gain, negative feedback decreases the gain, I must mention that in order that the frequency of resonance remains the same the coupling between the 2 must be lose. If they are brought very close to each other than the effected inductance that changes because of the mutual inductance. So it must be kept lose

But it can be very easily demonstrated that if you wind the coil in the reverse direction then you get negative feedback. The lower amount of gain as compared to if you wind the coil in the right direction.

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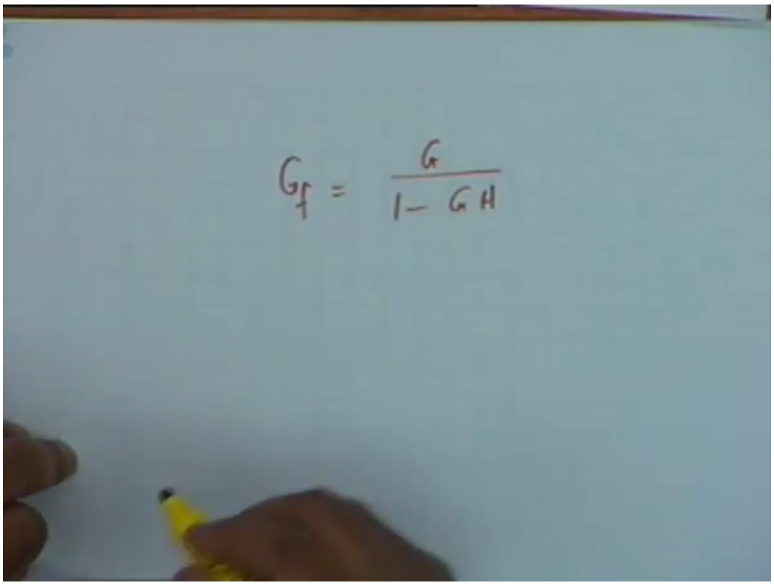


Now let us go back to this expression Gf equal to G by 1 minus GH, feedback gain is equal to G by 1 minus G H. Suppose GH at some frequency, GH normally shall be a function of frequency.

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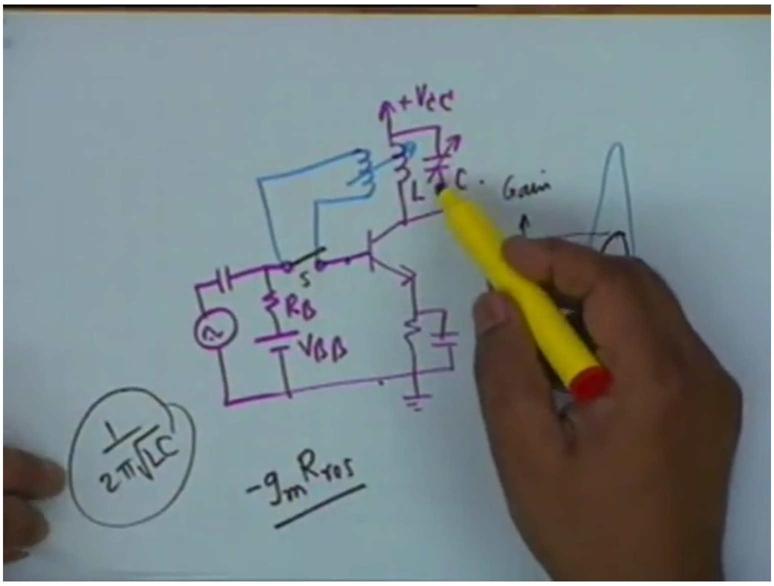


Here G was a function of frequency, the gain. Without this coil the gain is a function of frequency and H could be a constant, H is the fraction of the output voltage that will determine the trans ratio between these 2, alright. If this is 10 is to 1 then 1 10th of the voltage would have been fed back to the input, okay. So G is frequency dependent, H is not.

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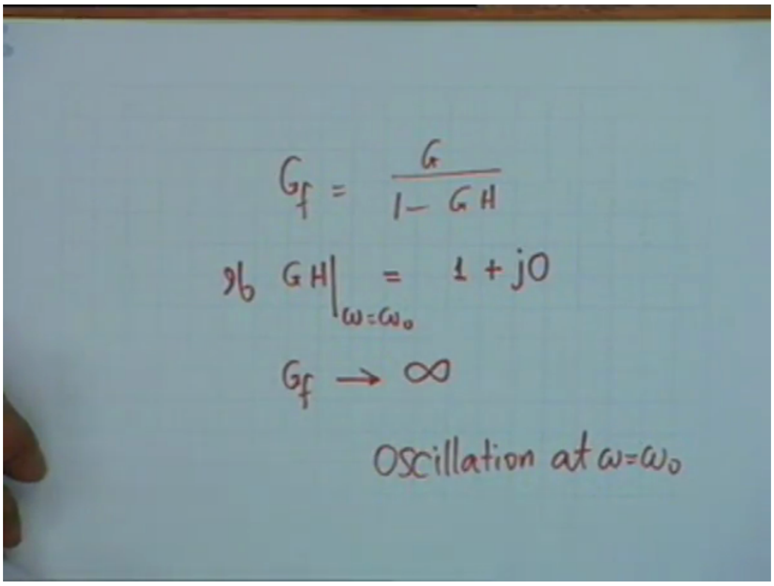


On the other hand there are systems in which G is frequency independent and H is frequency dependent. In either case if at some frequency let us say Omega equal to Omega 0, GH is equal to 1 plus j0, that is if GH has a magnitude of 1 at an angle of 0 at some frequency, what you think shall happen to Gf? It shall go to infinity.

Now what does infinity, infinite gain means? That means the amplifier can give an output without an input which means that the amplifier generates its own input and this is the condition for oscillation in the circuit, the circuit then oscillates at Omega equal to Omega 0, oscillates at this particular frequency and this is how one makes oscillators.

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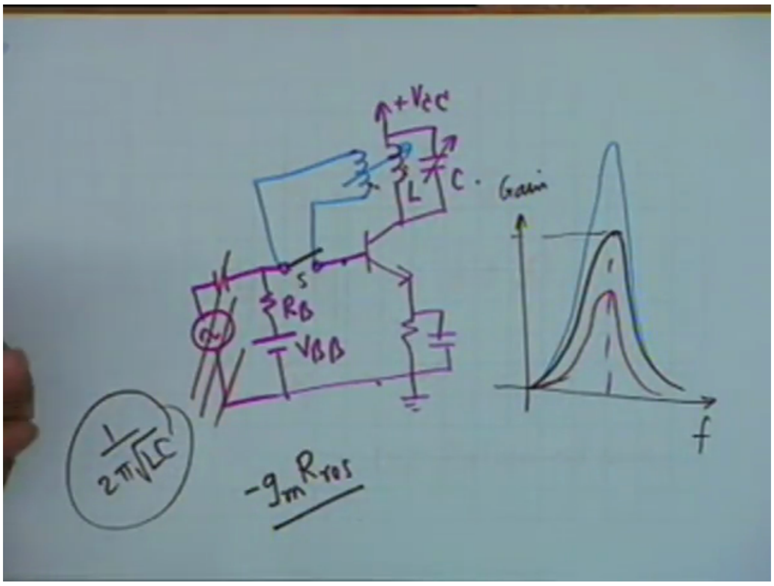


For example, in the previous circuit if feedback is enough then this circuit shall oscillate. In other words we shall not require this Vi, this source shall not be required if you couple and (()) (34:41-34:44) this is how one generates sinusoidal frequencies such an oscillator is called a tuned oscillator because there is a tuned circuit here, there is a resonant circuit here, alright.

A tuned circuit oscillator is not practicable at low frequencies, if you want 1 kilohertz oscillator then the values of inductance and capacitance required are very large and they cannot be obtained from the ready stock in the laboratory therefore what we do is, we use alternative means.

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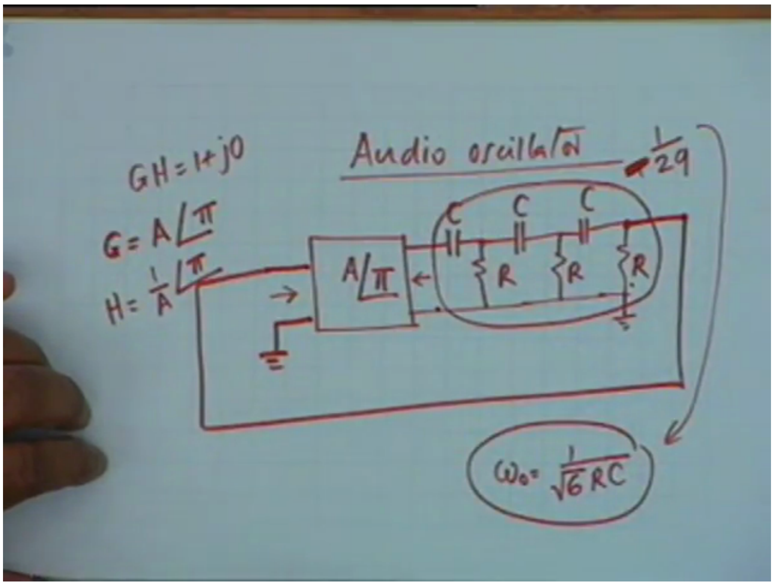


Let us look at some of the audio oscillator circuits and let us consider an idealized amplifier. Let us consider amplifier A, okay. Which gives again A and the phase angle of pi, for example a single state BJT amplifier gives a gain and phase shift of 180 degrees, okay. If this circuit is connected to a circuit like this 3 RC, 3 capacitors and 3 resistors, capital R, R, capital R than it can be shown that if you feedback the output of this circuit to the input then the circuit shall oscillate.

Now the reason is the following, we have assumed that this amplifier has a gain A and phase shift of pi and therefore if you want GH equal to 1 plus j0, G is obviously A angle pi, if you want to make it GH equal to 1 plus j0, what do you require H should do? H must be equal to 1 by A an angle pi, alright. This network this 3 stage CR network can give a gain of 1 by 29, can give a gain of minus 1 by 29 at the frequency which you can analyze.

The frequency is given by 1 by root 6 RC, it can be shown by circuit analysis that if you put an input voltage here the output voltage shall be exactly out of phase at this frequency and the attenuation is 1 by 29 therefore can you tell me what gain shall be needed for the amplifier? 29, right? So an amplifier if you design for a gain of 29, a single stage amplifier which gives you 180 degrees phase shift and you connect this that will be the story.

Unfortunately if you use a single transistor the output impedance output resistance of the transistor is not 0. Here we are assuming that the output resistance is 0, the amplifier is ideal which is not the case. Similarly the input impedance of the transistor is not infinity that is capital R is affected by the input impedance of the transistor; input impedance of the transistor approximately is rpi, alright.

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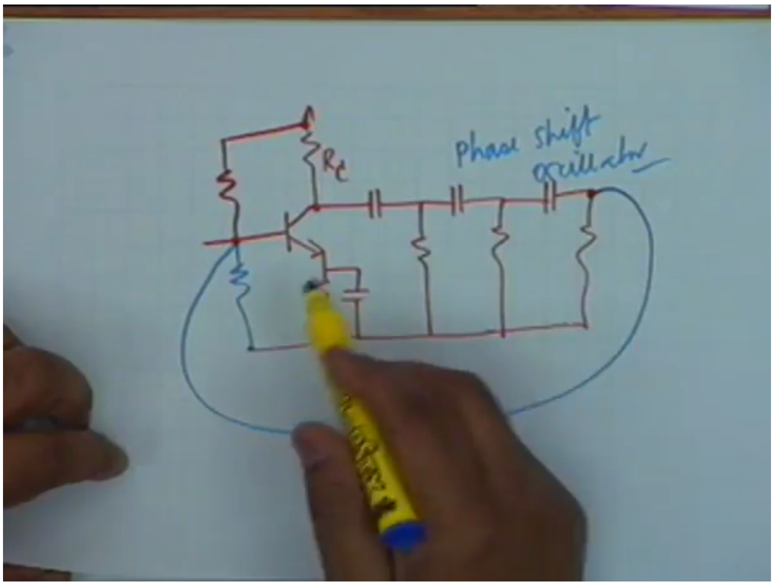


Therefore the calculation shall be a bit more involved and the actual circuit of BJT oscillator, the actual circuit will be like this, you have BJT then you have an R sub C, CR this is the feedback network now, CR and this goes to, do you need another resistance here? Because we are going to bring this our feedback, you are going to bring this over here. So you do not need another resistor, this resistor could serve the purpose of, alright.

If you want for specified frequency you might use another register but this may not be needed, anyway I will show another resistor here. This is the actual circuit of BJT, so-called phase shift oscillator why is it called a phase shift oscillator because each circuit shifts the phase by 180 degrees, pardon me. This circuit, this 3 stage CR shifts the phase by 180 degrees.

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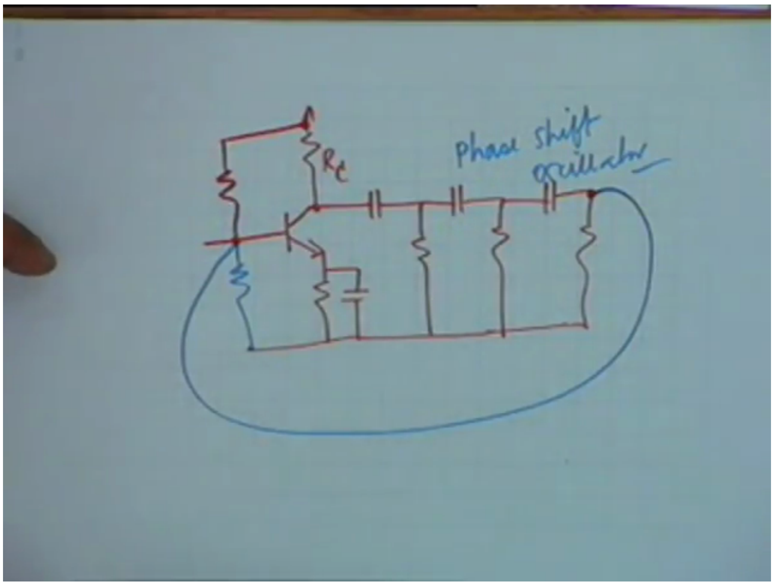


Now if you wish to analyze this circuit, the analysis strategy is the following, yes.

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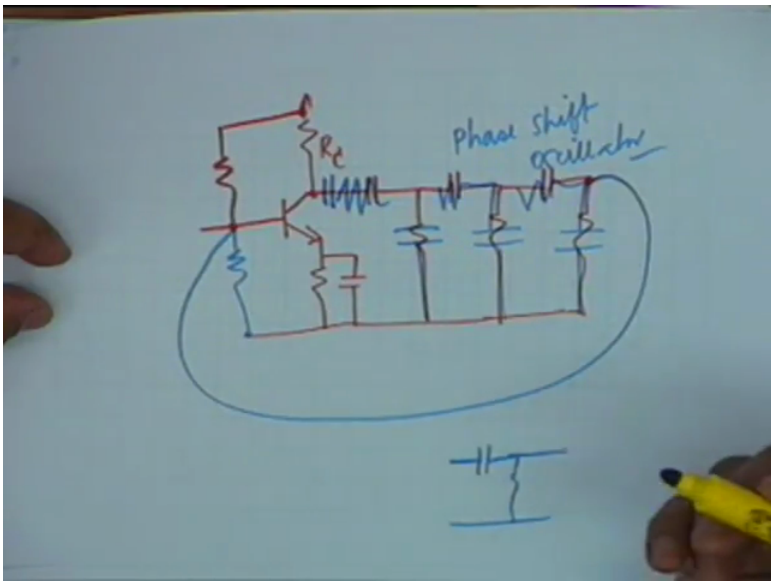


Professor: Right, correct, we can do that we, can write that we also, if that satisfies (()) (40:40) what we shall do is, R here and C here, it gives the same result except that you require an extra capacitor here, is not that right? Because otherwise you cannot block out DC that is why the CR circuit is preferred. This would be a mid circuit by 180 degrees leading, is not that right? Because the CR circuit, the output is leading the input.

On the other hand if it is an RC circuit the output shall lag the input and therefore if we take RC, RC and RC it shall be minus pi, agreed? Plus pi or minus pi it does not matter either way it shall work.

“Professor-Student conversation ends”

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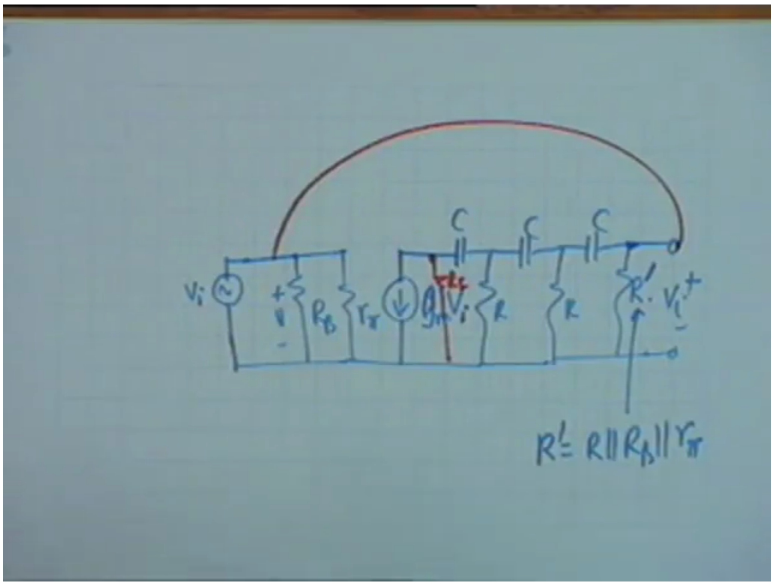

But the problem is how to analyze this circuit? What is the frequency oscillation? Because the amplifier is not ideal, so what we do is like this, we assume that there is a signal source Vi and at the input then we have the RB and we have the input impedance of the transistor that is rpi, okay. At the output it is beta, now let us work in terms of gmV, this is V, V is the same as Vi, alright.

I am drawing the equivalent circuit of the single state BJT phase shift oscillator. I had gmV then I have CR, no, not quite I had an RC, okay. I forgot about that, I must have an RC here then CR, then CR and CR, what you want is, that this should be coupled to the input, when can you couple this point to the input for oscillation? When GHB equal to 1 0 degree that means this voltage should be precisely equal to Vi, that is correct and then you can forget about it.

So all that you have to do is analyze this circuit gmVi, V is equal to Vi, gmVi in parallel to RC which you can convert to a prevalence equivalent, a voltage source in (()) (43:21) then you have 3 stage ladder network which you analyze and equate the output to Vi this will give the condition for oscillations and this condition shall not be exactly 1 by 29 and 0 degree, it will be affected by RC, alright.

It shall be affected by RC and since this is going back here you should in fairness shunt R by R prime shall be R parallel RB parallel rpi, is the point clear? No, after all in an oscillator you are going to connect this point to this point and therefore this R the last resistance shall be parallel by RB and rpi and you have to analyze under that condition.

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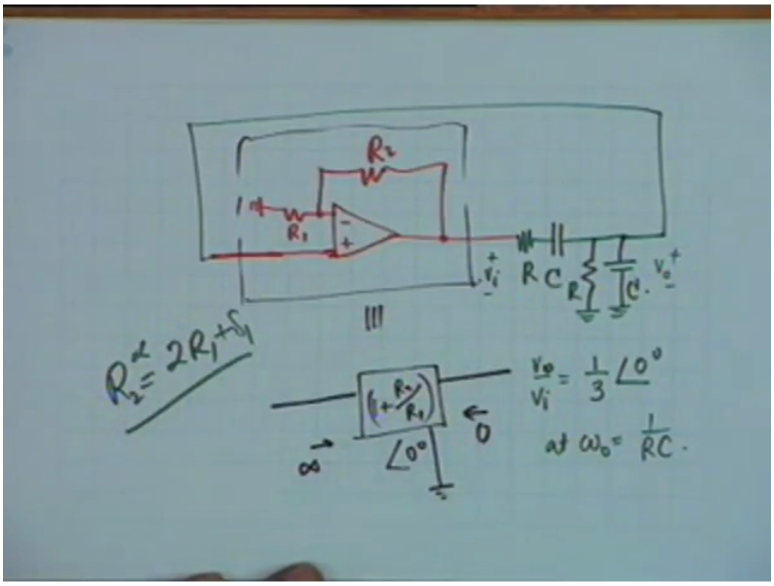

Let us take another case of an oscillator, is there any question on this? I am not doing the analysis because by this time you should be an expert in circuit analysis, alright. Let us consider another, let us say we have an op AMP, now forget about BJT, let say we have an op amp which has been adjusted for non-inverting (()) (44:47) this is R1 and this is R2, okay. And the input is applied here, I want to make this into an oscillator and one of the ways, you see this block is equivalent to an amplifier of gain 1 plus R2 by R1 and the phase shift is 0 degree because it is non-inverting.

What is the input impedance? Input impedance is infinity, what is output impedance? 0, so it is an ideal amplifier. Now I want to make this into an oscillator, so what I do is this is an alternative circuit I use an RC, obviously here G is frequency independent, I use a series RC and a parallel RC, RC and RC, what should be my aim now? This is 0 degrees, so my aim should be to get 0 degree phase shift from the each network.

And (()) (46:13) 1 by A, is that okay? Then I will connect this to this point, now by analyses of this network that this happens that is the gain of this network is exactly 1 3$^{rd}$, the gain of this network if you call this V0 and if you call this Vi then V0 by Vi, it is very easy to show, it is a simple potential division, okay. It can be shown that V0 by Vi is 13rd 0 degree, phase shift is 0 at Omega 0 equal to 1 over RC, alright.

No, no under root, under root in the case of LC circuit, in the case of RC circuit no under root, alright. Omega is simply the inverse of the time constant.

“Professor -Student conversation starts”

Professor: Now can you tell me what should be the value of R2 in relation to R1. Obviously for this to oscillate R2 should be equal to twice R1 and this circuit it contains 1, 2, 3, 4 resistors 2 capacitors, you can make it out in the laboratory in10 minutes and you can see oscillations, beautiful sinusoidal oscillations. One op Amp you take 741 and make connections R2 and R1.

Now for sturdy oscillations this must be remembered, if you make exact R2 and 2 R1 it may not sturd the oscillations because this is the condition for oscillation that is a marginal condition, you should use slightly greater than 2 R1, so that the gain is slightly better than 3 this is a practical truth, the gain has to be slightly greater than 3 then only the oscillation shall sturd.

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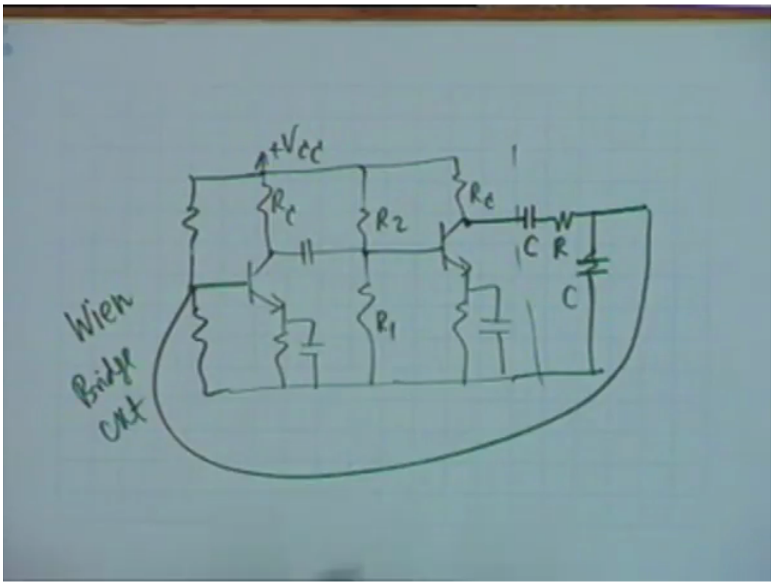


Now I showed you an op Amp circuit, what about BJT? Obviously if you use BJT you cannot do it in a single state you shall require 2 stage CE amplifier and therefore you will require something like this R sub C, R2, R1, second BJT, RE, CE combination and R sub c here plus VCC then you require the feedback circuit CR and a parallel C and a resistance. Well, once again this resistance could be the second biasing resistance required here. You might use an extra resistance you may not use, alright.

Here however the ideal conditions are not met, the input impedance of this amplifier is not infinity it is rpi. Output impedance of this amplifier, what is the output impedance? What is the output impedance of this amplifier? It is R sub C approximately, this one and therefore the input impedance and the output impedance are not ideal therefore the frequency oscillation shall not be 1 by RC it would be modified. It would be modified to some other (()) (50:17) and this circuit further oscillator is known as the Wien bridge circuit.

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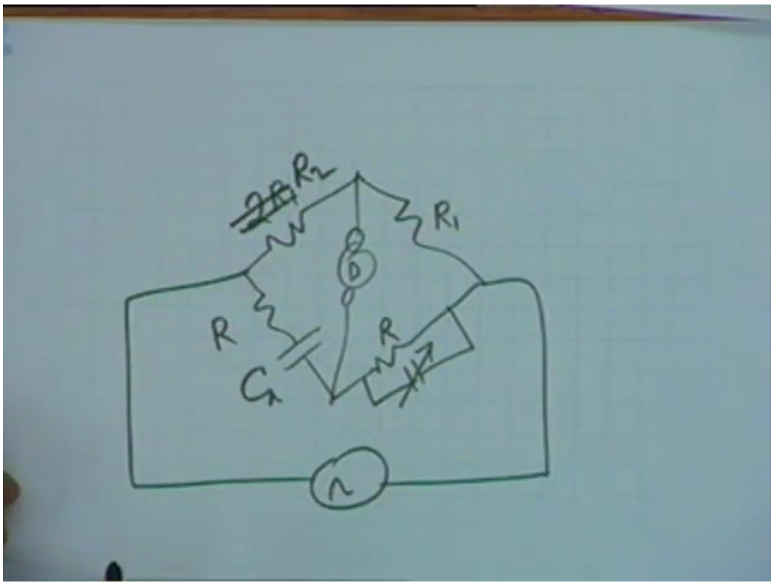

If one remembers, you know what is a Wheatstone bridge? No, well it is a very useful circuit for measurement of capacitors. What one does is, a Wien bridge then an Rc and parallel RC, this is the unknown capacitor Cx this is R, this is R, R1, R1. Now let us call it R2 and R1, alright. The source is somewhere here and other detect there is somewhere here, of course now, it is not (()) (51:23), do not you? Yes, okay, so this is an AC bridge in which an unknown capacitor is to be measured.

So what one does is, one uses an RC series and an RC parallel and then adjust these capacitors, so as to obtain balance and under balance condition you can show that Cx is equal to, the unknown capacitor is equal to the non-capacitor, that is they are equal divided R2 is equal to twice R1. Wien bridge circuit is a very popular circuit in many measurement techniques, measurement of non-Electrical quantities by first converting the capacitance and then measuring a capacitance.

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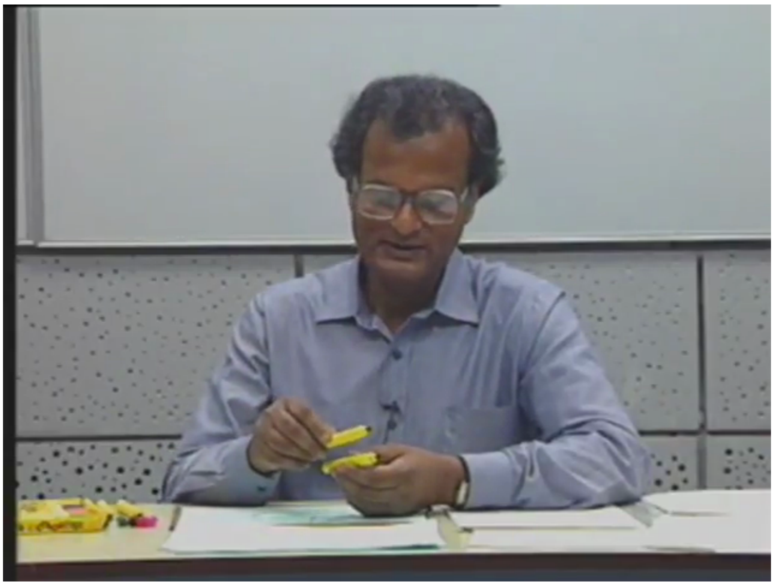

For example you can measure mechanical displacement, what you do is you put a parallel plate capacitor and if this is displaced, if this is loaded then the distance decreases then the capacitance increases and that capacitance could be measured by the help of this circuit. Wien-bridge is a very popular circuit for instrumentation. Next time that means tomorrow, we will consider negative feedback and its effects.