Analog Electronic Circuits.
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Lecture-42.
Widebanding by Using Compound Devices.

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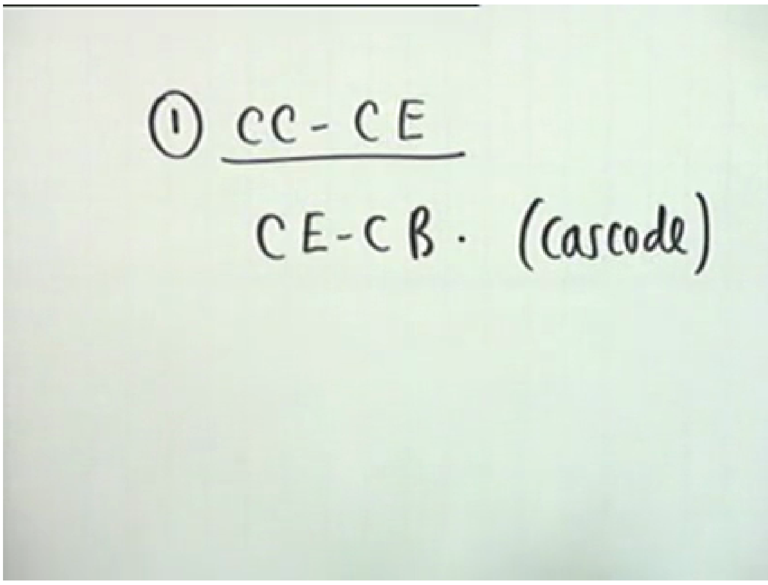

This is the 42nd lecture and we continue our discussion on Widebanding techniques. We have already learnt how to use an inductance for Widebanding, today we will study Widebanding by using compounds devices. That is more than one device connected in a suitable fashion. And one of these as we have already discussed while discussing tuned amplifiers is the CC CE combination. CC CE, in which the effect of C mu is minimised, that is what we discussed, okay, then we will discuss now CC CE combination, 1. And the other is a CE CB combination, common emitter, common base, CE CB combination which is also known as, which is also configured in the cascode configuration.

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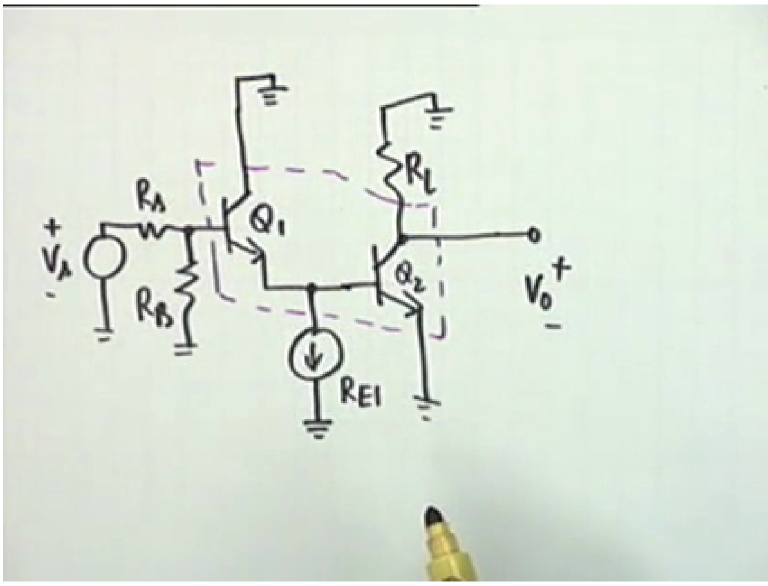

That is the common base sits upon the common emitter, okay. 1st we take the CC CE combination and the actual circuit shall look like this. You have a VS, RS, then you have the transistor Q1, it is a common emitter transistor and usually in integrated circuits the biasing is done through a current source, through a current so, to the DC bias. This current source could simply be another transistor, held at a certain base current, fed with a certain base current, okay. We shall assume that the equivalent resistance of this current source is RE 1, which is, as you know is very high, okay.

Then this is a common collector, in other words for AC this is ground, common collector. And therefore the coupling is to be through the emitter, I do not want that murmur. In addition there may be a biasing resistance here, from the supply there may be 2 biasing resistances, so the AC equivalent circuit would give you an R sub B. Okay. This is then fed to the common emitter, common emitter, the emitter is grounded and the load is in the collector R sub L, this is also grounded and the output is taken from here, this is my V0.

And this is the compound device, 2 transistors, which is available as a chip, a CC CE combination, Q1 and Q2. And the reason why this acts a wideband amplifier is not difficult to imagine. This is usually available as a as a chip is the time even the component of RE 1, the current source is also integrated inside the chip, okay, it is a wideband chip. Motorola has this and several other companies have this. The now the reason why this is a wideband device can be easily guessed. You see as far as C mu 1 is concerned, C mu 1, is usually, is actually connected to ground, curve R2.

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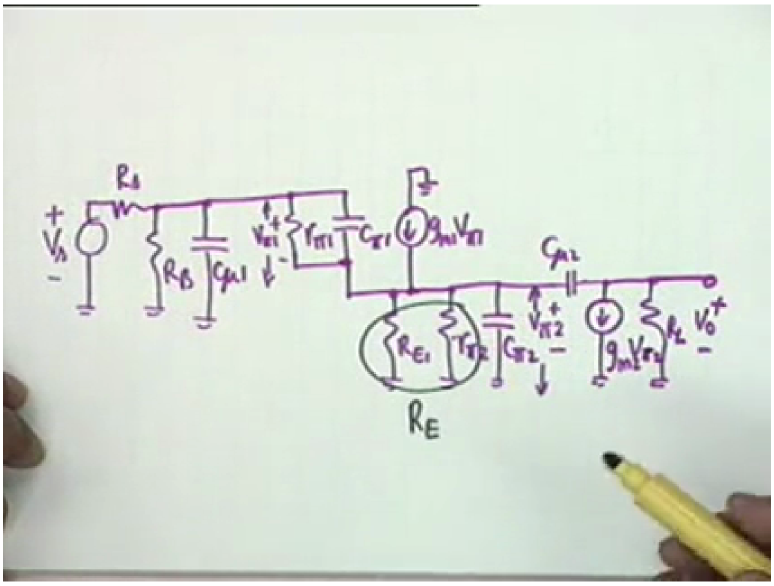

So C mu 1 is therefore virtually grounded. Now as far as signal 2 is concerned, well, it will be from here to here and it shall have an effect, let us see, C what the effect is. The equivalent circuit, you have to draw it very carefully, the equivalent circuit is like this. You have VS, RS, RB, then you come to the base of Q1 and from the base of Q1 to ground there shall be the capacitance CB 1, the capacitance CB 1, then our pi 1 and C pi 1 shall not go to ground, R pi 1 and C pi 1, they are connected to RE 1 and in addition the base of Q2 to emitter, that would be R pi 2 and C pi 2.

But before we go further, let us look at this voltage, this voltage is V pi 1, with this polarity, v pi one and therefore there is a gm 1 v pi 1, a current source from the ground the collector is grounded to the emitter gm 1 v pi 1. And if this voltage is considered as v pi 2+ minus, is the polarity all right? From V2 to ground, that is right, from V2 to E2, the polarity is all right, then you have C mu 2 which goes to the collector and from the collector the emitter, that is to the ground there shall be a gm 2 v pi 2, gm 2 v pi 2 and what else, we shall have an RL of course, that goes to ground, anything else, that is the end of it, V0, okay.

Now, have I missed everything? No. Now you can decouple the input and output of this through Miller effect and therefore you can write C mu 2, you can bring C mu 2 here as C mu 2, 1+ gm RL, the usual way and have a C mu 2 here if necessary, if C mu 2 RL is not very small, have a C mu2 here. You also can combine these 2 resistances into let say resistance R left, let us call this an RE. Then is there any other combination possible? C pi 2 can be combined with CT2, all right, so my equivalent circuit simplified one shall look like this.

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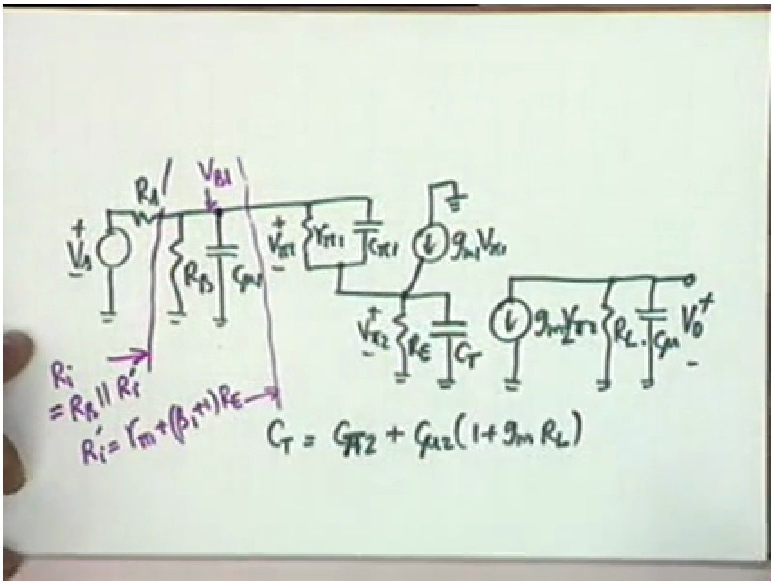

I have a V S, RS, then RB, C mu 1, R pi 1, C pi 1, voltage is V pi 1, this goes to RE and a capacitance CT where CT, what do we do with R pi 2, R pi 2 is combined with RE 1. Okay, CT is C mu, I beg your pardon, C pi 2 plus C mu 2, 1+ gm RL. Okay. This is V pi 2 and then you have the gm v pi 2, then RL, gm 2.

Sir C mu.

Yes, there is a C mu and this goes to V0. Anything else that we have missed?

gm 1 V pi 1.

Yes, that current source must come here, gm 1 V pi 1, this goes to ground. Now let us make some obvious conclusions which will be required later. If I look here, if I look here, what is the input resistance, mid band input resistance? It is R pi 1 + beta 1 + 1 times RE, mid band. So this is, we require this because we will calculate the time constants later, okay. This is R pi 1, beta 1+1 times RE, mid band input resistance. And if for a moment we bring, okay, if for a moment we say that the mid band input resistance here is called, is RI, then obviously R I is equal to RB parallel R I prime, all right.

Let us call, what is this point, this is a base of transistor 1 V1, so let us call this voltage is VB 1. Then the mid band gain, mid band gain analysis is extremely simple. Mid band gain levels is, just by looking at this amplifier, looking at this equivalent circuit, without deleting the capacitances you can very easily see what the mid band gain would be. For example, V 0 by

V pi 2 will be minus gm RL, gm 2 RL, okay. Then V pi 2 divided by VB 1 would be beta plus, beta 1+1 RE pi 1+ beta 1+ RE. And VB 1 by VS would be RI divided by RI plus RS.

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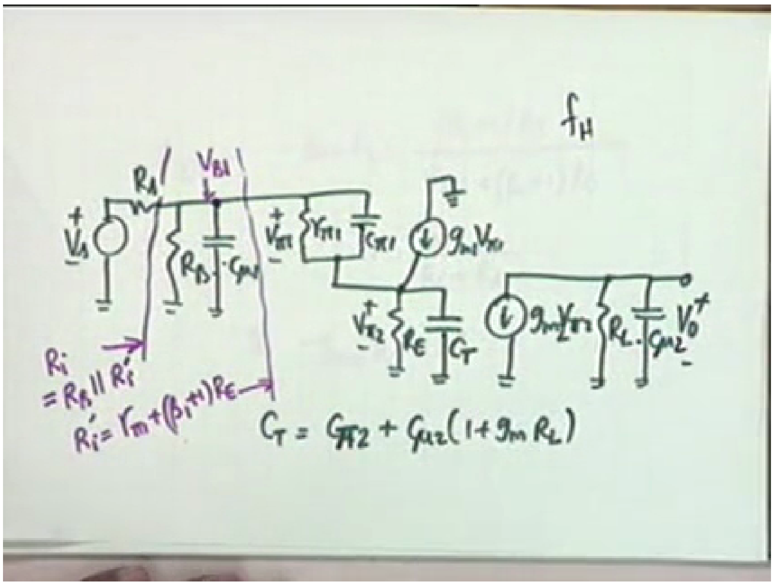

Therefore the mid band gain AV0 would be equal to minus gm 2 RL, I write by inspection multiplied by beta 1+1 RE divided by R pi 1+ beta 1+1 RE multiplied by RI divided by RI plus RS, that is, that is the mid band gain. Then you can see that in usual practice, usual practice, R pi 1 would be a very small quantity as compared to beta +1 RE, therefore this will be approximately equal to1. This factor, since it is a voltage, RS will be small compared to RI and for this vector is also approximately 1, in other words the gain of the compound circuit, the mid-band again is actually controlled by RL and gm 2, nothing else in the circuit. Okay.

The next question is of finding out the high-frequency 3 dB point. This is of major concern, we want to find out what is the high-frequency 3 dB point and see to what extent we have achieved broadbanding. For that you see if we go back to the equivalent circuit C mu 2, there are even with simplifications, even with Miller simplification, I have 1, 2, 3, 4 capacitors. If I did not do Miller simplification, I would have…

3.

No, 5. If I did not used Miller simplification here, I did not have to do it here because C mu 1 comes in parallel with RB.

Why 5?

Why 5, 1, 2, there would have been a C pi here, C pi 2, then C mu, 4, okay, I stand corrected. If it is there, if it is there, we are not considering that. But anyway this is bad enough 1, 2, 3, 4, so we do not increase by any, we do not increase the number of capacitance, is not it. There is no strong point therefore in calculating FH to take recourse to Miller effect. Is the point clear? Miller effect itself is an approximation. Now I can calculate FH from this equivalent circuit which is a Miller effect equivalent circuit but since the number of capacitors is not decreased, therefore there is no point, not much of a point in calculating FH by using Miller effect.

We could as well go back to the original circuit and replace this by C pi 2, bring C mu 2 here and take C mu 2 off from there, either way, this is slightly simpler because there is no cross connection because this time constant is simply C mu 2 times RL, okay. It is slightly simpler but one can calculate the other way also. Let us calculate from here, if you want to write the exact equations, the exact equations you see, C pi 1 CT, they are coupled together and of course this art can be written very simply but this part will require a coupling of 3 capacitors C mu 1, C pi 1 and CT and therefore it would be very very involved.

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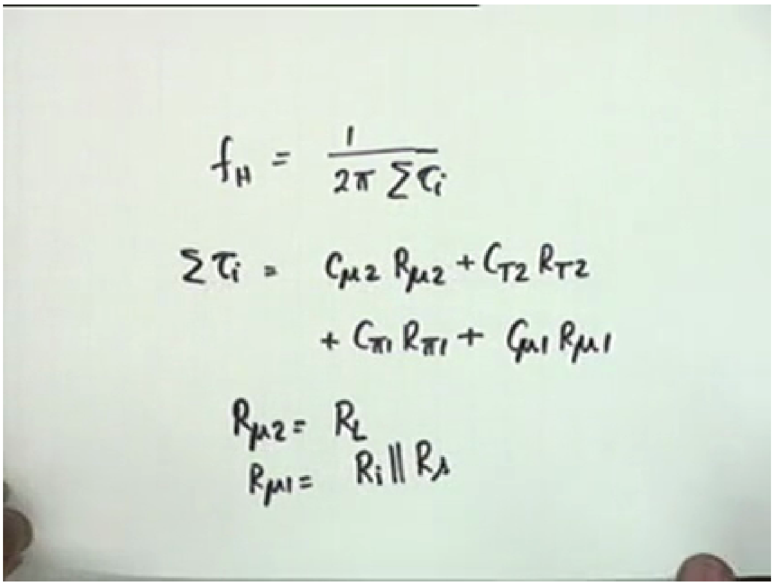

And the method of open circuit, is it open or shorted, open circuit time constants is a better way to deal with FH of the circuit. And if you recall in the map, in the method of open circuit time constants, what we have to do is, we have to find FH as 1 over 2 pi summation Tao i. Is that the, is that the method? Where summation Tao I here would be C mu 2 times effective resistance across it, R mu 2+ C T2 R T2, we are going back, plus C pi 1 R pi 1+ C mu 1 R mu

1. I have not yet found out these resistors, we will have to find out, okay. Now as far as R mu 1 is, no, R mu 2 is concerned, no, we have already seen R mu 2 is equal to RL, okay.

We also know what is R mu 1, let us go back to this circuit. R mu 1 would be simply RB, RB parallel RS, what about from this side?

(())(18:04).

That is R I prime, okay. Which would be RI prime plus, not parallel, or parallel, parallel, okay. So let me write that down immediately. R mu 1 would be equal to, why do not we take RI parallel RS, it is the same thing, okay, RI parallel RS. Now the other 2 are not very simple. For example to determine R pi 1, to determine R pi 1 we have to draw the equivalent circuit with all capacitors open and resistance have to be measured across C pi 1.

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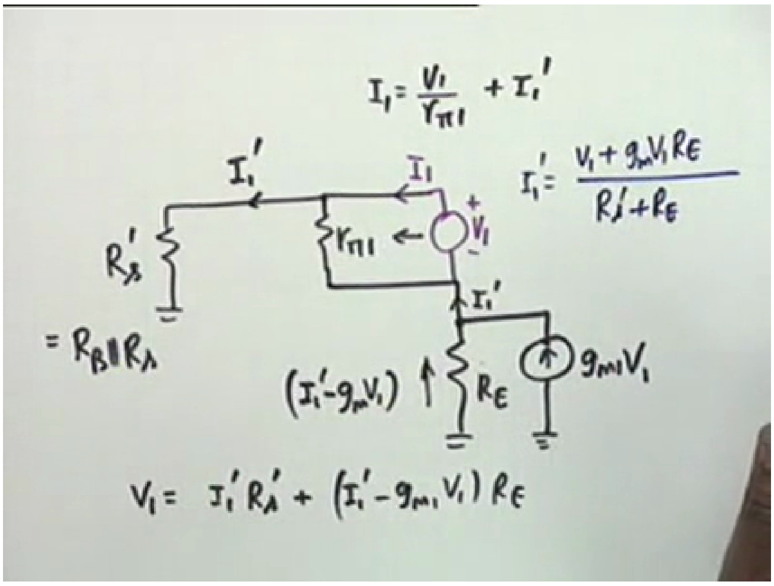

So let us see the equivalent circuit. If you if you short VS to ground, you shall have RS prime which is equal to RB parallel RS, okay, RS prime, then you shall have R pi 1, it is across this that you want to measure the resistance because C pi 1 occurs here. Then you have RE to ground and what else, you have a gm 1 V pi 1, well you have to connect a voltage source here, let us call this voltage source as V1 and let this current be I1, then obviously gm 1 V1 because that is the voltage across R Pi 1 and this goes to ground, all right.

You have to measure the resistance seen by V1, this voltage source, in other words we have to find out V1 by I1, right. And this can also be done by Inspection, it is not a very complicated circuits but one has to be a bit careful. The care that one has to survive is the following. 1 is to recognise that I1 is let me write it down, I1 is V1 by R pi 1, that is this current plus J this current is I1 prime, right, I1 prime. Now what is I1 prime? To find out I1 prime we write a KVL around this loop, there are many ways of doing this. I can argue that this current, what will be this current, this current? I1 prime, it has to be, I1 prime is coming out, so I1 prime was going.

And therefore what is this current? I1 prime minus gm V1, therefore my KVL would look like V1 is equal to I1 prime RS prime, this drop plus the drop in RE which is I1 prime minus gm 1 V1 times RE, agreed, which gives me I1 prime. Now instead of doing this, if you are a little smarter, you could argue that this parallel combination could be could be converted to its Thevenin's source. Then you have gm 1 V1 RE in series with RE, so it was a single look circuit and the current I1 prime could be obtained by Inspection.

It would be, tell me what would be Inspection, it would be V1 plus gm V1 RE divided by RS prime plus RE. And this would not have required writing the loop equation at all, it is by Inspection. And therefore whatever you do, you see that V1 by I1 shall build up parallel combination of R pi 1 and the resistance which would be RS prime plus RE divided by, does it look like… 1+ gm RE, gm 1 RE, is not that right. Okay.

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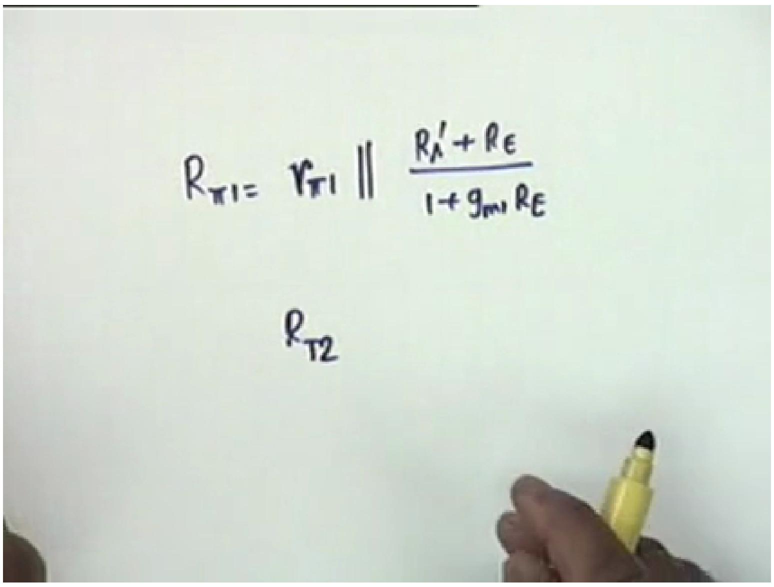

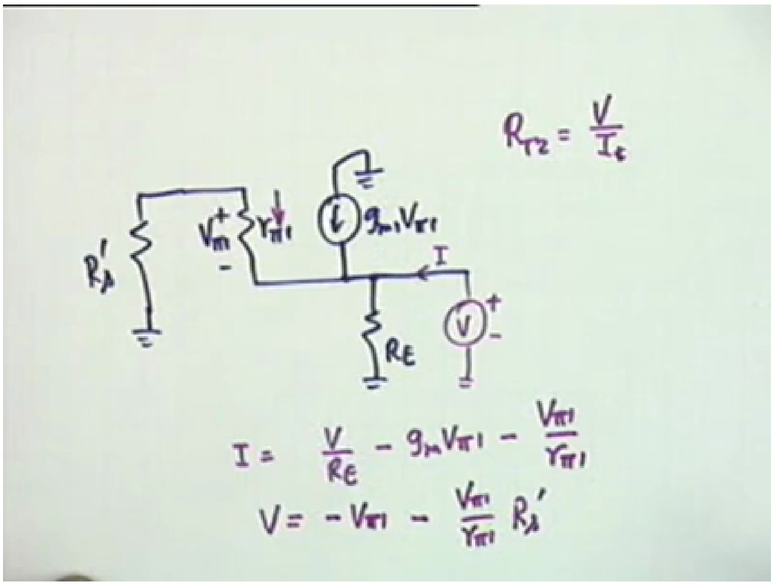

So R pi 1 is equal to small r pi 1 parallel RS prime plus RE divided by 1+ gm 1 RE. Once you identify the equivalent circuit, it is a very simple equivalent circuit, then you have to proceed with caution. It is not R pi when parallel RS prime plus RE because there is a control source there. It is very easy to make that mistake, you make that mistake saying, oh, current source, it is infinite impedance anyway but it is not an independent current source, it is a dependent 1 and therefore that contributes. In fact the equivalent resistance is reduced by a large factor gm 1 RE, 1+ gm 1 RE, okay. It is very easy to make a mistake here, so I calculated this exactly.

The other calculation that is needed is for RT 2, that is the resistance seen by C T2. If it was the equivalent circuit for RT 2, well we come from the input RS prime which is the same as defined previously RB parallel RS, then you have R pi 1, the voltage is V pi 1+ minus, then you have a gm 1 V pi 1 from ground to this point, then you have an RE and it is across this that CT appears, C T2 and therefore what you do is connect a voltage source here V plus minus and find out this current I. RT 2 shall be equal to V by I, V by I, all right. RT 2 shall be equal to V by I.

Now I obviously is equal to V by RE, the current that goes here minus gm 1 V pi 1, then another current, another current comes like this, so minus V pi 1 by R pi 1, that is it and finally you have to find out V pi 1 because this is the unknown and if you write KVL, this V should be equal to drop in this plus drop in this, so V is equal to minus V pi 1, right, then minus, the current through this is V pi 1 by R pi 1 multiplied by RS prime. So you can find out V pi 1 from here, substitute here to get the equivalent resistance.

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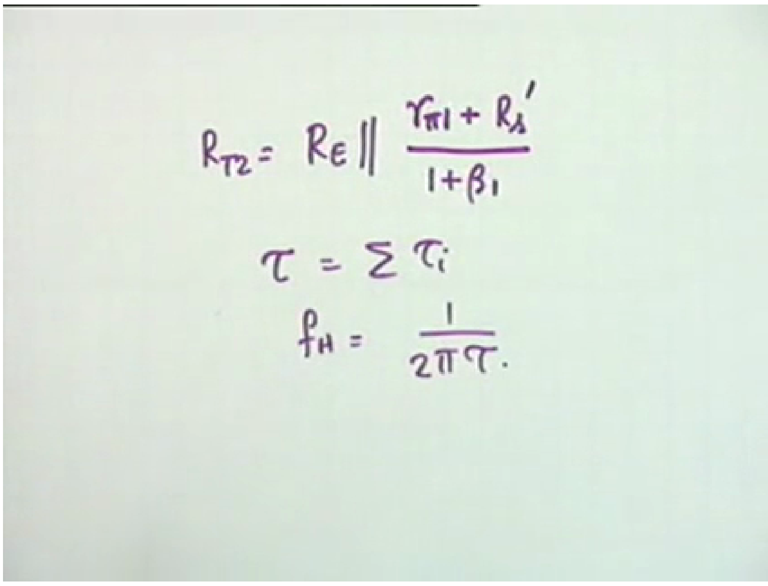

If you clear this algebra, then the equivalent resistance RT 2 comes as RE parallel R pi 1+ RS prime, again it is very easy to make this mistake, it is not the parallel combination of this but this comes reduced by the factor 1+ beta 1, okay. And that is it, what else do I have to calculate? I know R mu1, I know R mu 2, I know C pi R pi 1 and I have know RT 2, these are the 4 capacitors and therefore I can calculate my Tao by summing up all these and Tao sub I and FH which is equal to 1 over 2 pi Tao. Let us take a specific example. I will not write this again, this whole expression, you can collect them and collate them.

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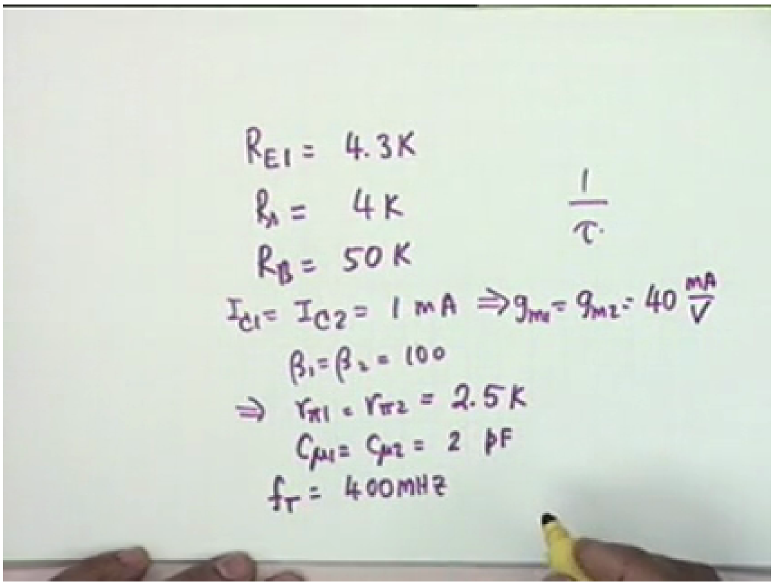

Let us take an example in which the current source is a poor current source, okay. RE 1 is equal to 4.3 K, the current source is not a good one, okay, or maybe it is a lumped resistance

4.3 K. To see how good, how good things are, you see if RE one was an exact, was a good current source then instead of RE we should have had something R pi 2, this RE has a shunting effect. Now is it good or bad? Do you want low value of resistance or high value of resistance? We want a low value, is not that right, 1 over Tao, so the lower the value of the resistance, the higher would be the cut-off frequency.

On the other hand if it is an IC chip, the biasing is to be, if preferred to be done by a current source. Why? Because you do not require external resistances. On the other hand if you want a lumped resistance, you can use as small evaluate possible. But anyway let us say the current source is such that RE one is 4.3 K.

Excuse me Sir.

Yes?

What is the cause of widebanding in this circuit?

What is the cause, because of cutting of C mu 1.

C mu 1.

Yeah, that is right. There is a decoupling between the input and output through C mu 1, C mu 1 is grounded, okay. Now let us go through the calculation and then we will see how good or how bad it is. Now RS is 4K and RB, the usual story, it is about 50 K, the biasing resistances. The 2 currents I C1 and I C 2 are equal, both of them are 1 milliamperes, which means that gm 1 and gm 2 are equal and they are equal to 40 milliamp per volt. 1 divided by 25 is 0.04 millimhos or 40 milliamperes per volt.

Now beta 1 and beta 2 are given as 100 and therefore R pi 1 and R pi 2 equal to 2.5 K. In addition that transistors are identical transistors, there made on the same chip and maybe a million of them, C mu 1 and C mu 2, are both 2 picofarads. And ft, the transition frequency is given as 400 megahertz, this means that you have to find out C pi 1 and C pi 2, C pi 1 is equal to C pi 2 is gm divided by, remember this, gm divided by Omega T minus C mu, okay.

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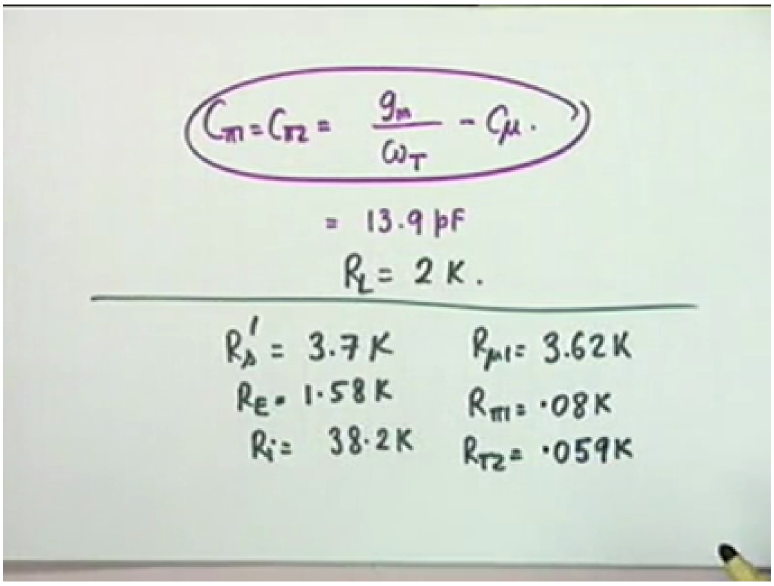

gm is 40 millimho and Omega T is 2 pi times 400 times 10 to the 6, from that you subtract C mu and the result is 13.9 picofarads. You recall this formula, many a times C pi shall not be given, what is given is FT but CU is required. If C mu is not given, what will you do? Ignore it, if it is not given, ultimately be 0. Good strategy, yes. In addition, what else do you need, you need RL, RL is given as 2K.

Then I have calculated all the intermediate step, let me simply give you the results. The 1st thing you do is calculate RS prime which is RS parallel RB, this comes as 3.7 K, these are calculated values now, RE is 1.58K which is the parallel combination of RE 1 and R pi 2, RE, then R sub I, parallel combination of RB and R pi 1, Ri dash. This comes out as 38.2 K, R mu 1, which is the parallel combination of RS and R pi, that is the resistance seen by C mu 1, this comes has 3.62K, then R pi 1 which is a resistance seen by C pi 1, parallel combination of R pi 1 and RS plus RE divided by 1+ gm RE, this comes out as a low value, 0.08K.

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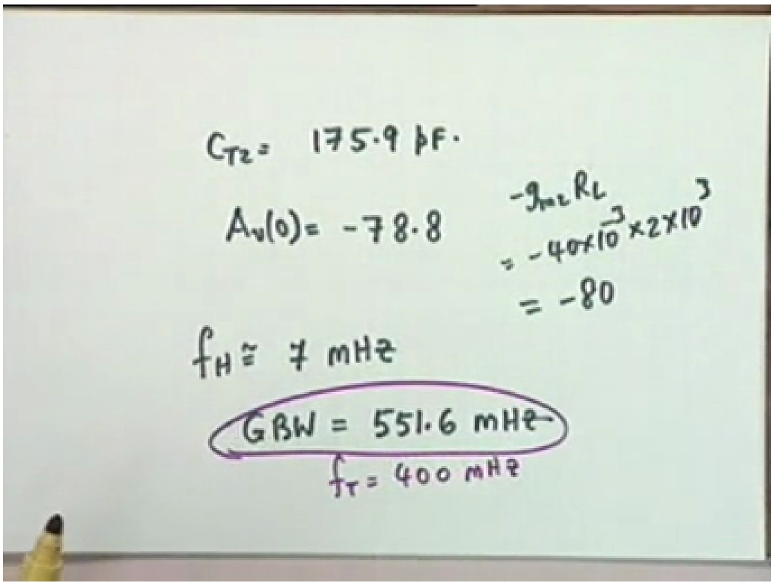

RT2, which is the resistance seen by CT2 is also a low value, 0.059K, okay, you require, then you require CT 2, CT2 comes as 175.9 picofarads, the mid-band gain AV0 is calculated from the, from inspection of the equivalent circuit as -78.8, by taking everything into account. Where the approximate value is minus gm 2 RL, this will be -40 times 10 to the -3 multiplied by 2 times 10 to the 3, which is equal to -80, so it is not too bad, okay. -80 is fairly good approximation to -78.8 and FH, by calculating all the time constants and clearing of fraction, FH comes as 7 megahertz.

So the gain bandwidth product is, if you multiply 7 megahertz by 78.8, this comes as 551.6 megahertz, gain bandwidth product in hertz. Compare this with FT, FT is 400 megahertz, okay. The GBW therefore exceeds the FT of a single transistor, by using 2 transistors in this particular configuration you can go to a gain bandwidth product of 551.6 megahertz. If only one transistor is used, you could not go beyond 400 megahertz, okay. In fact 400 megahertz you could go only with current gain, all right. If the current gain is 1, then the bandwidth will be 400 megahertz and that is the condition, condition for short-circuit current gain.

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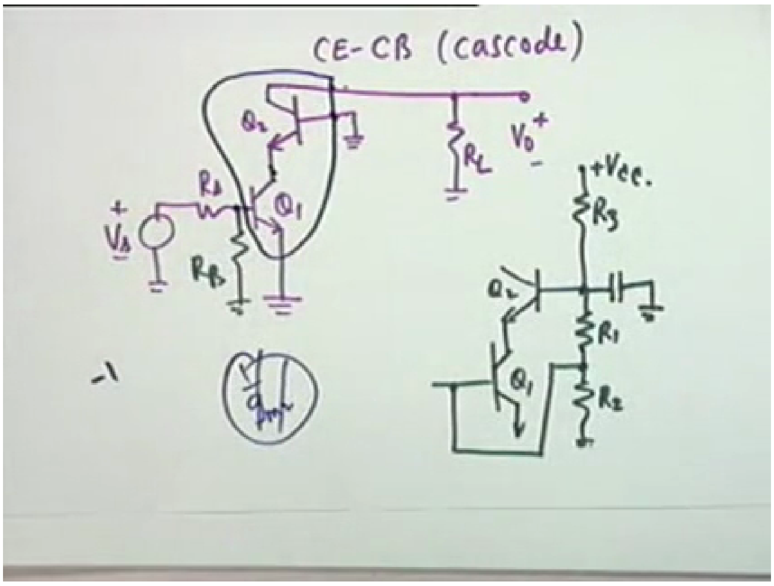

The actual gain bandwidth product would have been much less than 400 megahertz, this is how widebanding has been performed. The 2nd circuit is the more interesting circuit, once again we have talked about this while talking about tuned amplifier is, this is the CE CB configuration or the so-called cascode configuration. The circuit is like this, you have VS, RS, Q1, this is grounded, this is the common emitter and then you have a common base sitting on it, another transistor Q2 whose base is virtually grounded, okay and the load is on the collector of Q2, RL, I have shown the AC equivalent circuit and this is my V0.

Q1 is the common emitter and Q2 is common base, so it is a CE CB combination or a cascode combination because Q2 sits upon Q1.

It has RB also?

You have an RB, okay, the base is usually biased like this, yes you are right, there would be an RB, the base is usually biased like this. Let us say, it is a good question, let us say this is Q2, okay, Q2 then this goes to Q1 and this is the other base. Now both the bases have to be biased, so what is done is plus VCC, a resistance is brought here, then this resistance, this resistance should have gone to ground, but we want this base also to be biased, so what we do is we split this into 2 parts and connect this base here, okay. This is the actual biasing arrangement and therefore from this base there should come a resistance R sub B.

Now this base is not connected to ground, whereas we want it connected to ground, so what we do is we connect a large capacitors from here to ground, that will mean that if this resistance is R3, this is R1, this is R2, then RB would be the parallel combination of R1 and

R2 because this is virtually grounded. Is the point clear? This is how it is made but the IC chip that is available is this, is the one that is contained within this blue area, the IC chip that is available. It is available, this has to be, this cannot be connected to ground inside the chip because we have to connect a high-value capacitor, so this is out.

And there the pins are marked, this is B2, this is C2 and these are not brought out, there is a B1 and then E1, okay. The collector and emitter, the collector of Q1 and emitter of Q2 are internally connected to each other, this is the chips that is available, cascode chips, the CE CB chips. Now how it achieves, okay, the 1st question that I ask is what is the relationship between gms of the 2 transistors?

Same.

They should be same, if beta is large, then IC2 and IC1 or approximately the same if beta is large, okay. And therefore gm 1 and gm 2 are approximately the same. Now at mid-band, at mid-band what is the load seen by Q1. The load seen by Q1 is R pi 2 divided by beta-2 which is equal to 1 by gm 2. All by inspection, I am not analysing anything, 1 by gm 2, okay, 1 by gm 2, then what is the gain of this circuit Q1? Minus gm RL, so minus gm1 multiplied by gm, 1 by gm 2, so the gain would be, the gain of Q1 would be minus1, agreed.

It is like an emitter follower but with the gain of minus, negative, okay, it is an inverting, not emitter follower, it is an inverting buffer, inverting buffer, okay. Therefore the C mu 1, now follow me carefully the C mu 1 which appears between B1 and C1 shall be reflected at the input as, as what, C mu 1 multiplied by 1+ gm RL, so it would be 2 C mu 1. Instead of getting multiplied by gm RL, which is a, which may be a large quantity, because we have restricted the load of Q1 to be very small quantity, 1 by gm 2 and because gm 1 and gm 2 or equal, only twice C mu 1 comes in. And that twice C mu 1 also is reflected across C pi 2, is not that right? So C pi 2 incremented by twice C new one, all right. Now let us go into the circuit, into the exact equivalent circuit and see what the gain is then what is FH. Well as far as…

(())(40:47). It should be only C mu.

C pi 2 is here, from here to here.

You are talking about the input side.

No, at input side it is twice C mu 1 but as far as this side is concerned, instead of, yah, this requires an explanation. Instead of, it should be C mu 1, no.

C mu 1 + C mu 2 because C mu 2 would also be coming in parallel to C mu 1.

C mu is from collecter to ground.

(())(41:18).

No, that will not come there. You see it would simply go, C mu 2 will simply go across RL but, but you can see that there is C pi 2 win this point and this point, all right. Which will be supplemented, C pi 2 is virtually 1 by gm 2 parallel C pi 2 is the load of Q1, all right. So C pi 2, in the previous case, in common emitter transistor, RL was supplemented by C mu 2.

Where is C pi 2?

C pi 2 is from the base to the emitter of Q2 and reflected on the emitter side it will be C pi 2 multiplied by, multiplied by beta, is not that right. You have divided R pi 2 by beta and that is why you wrote 1 by gm 2, so if it is C pi 2, then it should be multiplied by beta since it is a larger capacitance and C mu 1 across is negligible. Is the point clear? Okay. Let us see the exact equivalent circuit, then perhaps things will be clear.

The other thing that I wanted to explain to you, not only the Miller effect of Q1 is reduced to twice C mu 1 only, we Miller effect due to Q2 is absolutely absent, nothing is reflected to the input side because the collector there is C mu to appear between the collector and base which is grounded. And therefore the CE CB cascode is an extremely popular combination for wideband amplifiers. An equivalent circuit, it will not come in one place, so I will bring it down, I will try to compress it as much as possible but decision not see it, please do point out.

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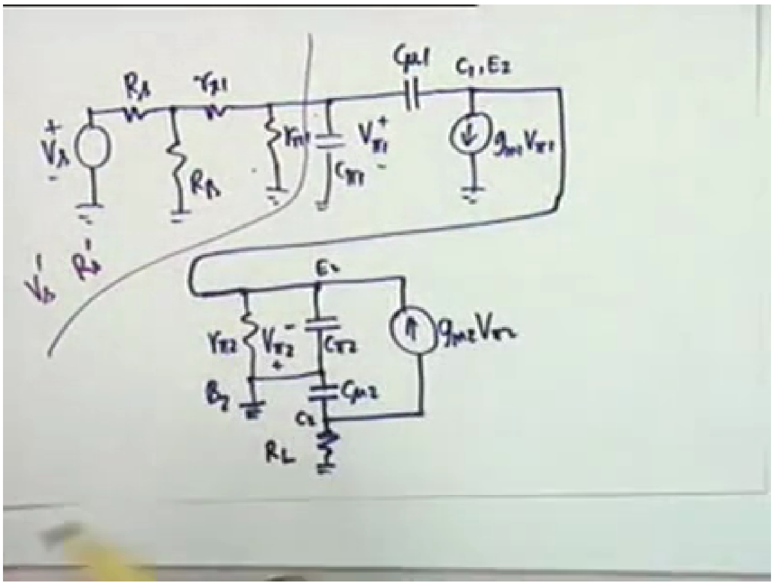

What we have is VS, RS, then RB, then I should go to R pi 1, but in high frequency analysis sometimes RXs do come into effect, particularly when the capacitors are small, I am sorry capacitors are large. Now in this particular case it is convenient to be able to take care of RX, it is possible, so let us do that, you will see why. RX 1, then we have the B1 prime, internal base and so we have R pi one which goes to ground, C pi 1 which goes to ground, this voltage is V pi 1, then we have C mu 1, we will come to Miller effect equivalent circuit a little later, C mu 1, this goes to collector 1 which is the same as emitter of 2.

From collector 1 to ground to emitter 1 there shall be the current source gm 1 V pi 1 and from the emitter from the emitter to ground, well let us bring it over here, I cannot go this way and it is important to recognise this circuit, do not make a mistake. From base 2 which is ground, from B2 there shall be a resistance of R pi 2 with the voltage V pi 2 of this polarity, agreed. Then from R pi 2 that shall also be a capacitance C pi 2 which we have been talking about, all right. Then this is base 2, from base 2 you shall have, to collector 2 you shall have a capacitance of C mu 2, this is collector 2, C2.

And from collector 2 to ground, you shall have a resistance of RL, all right. Current source is from C2 to E 2, you see the complication, current source is this gm 2 V pi 2, this is the equivalence. I have gone exactly according to the architecture.

So C mu 2 has ground on either sides.

No, no, it is only on this side. C mu 2 is only from C2 to B 2, B2 is grounded, but on this side it is RL which is grounded, agreed. RL is on the collector 2, from collector 2 to the ground.

Okay. If there is no question, if this is okay, then you should recognise that the 1st simplification that we can do is that the circuit to the left can be converted to its Thevenin equivalence and therefore this would be some VS prime in series with some resistance RS prime, we can do that. And you can very easily find out what is VS prime. VS prime, 1st application here, VS RB by RB plus RS, in series with RB parallel RS, then RX 1, then R pi 1 and therefore things are absolutely clear.

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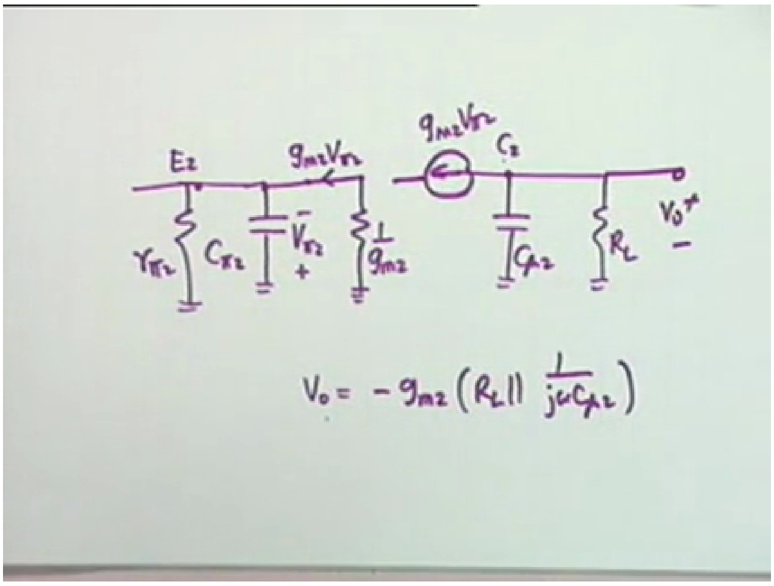

Okay, the 2nd simplification that we do, if you look at the last part of this, all right, now you see we will play a trick but perfectly valid trick, we have not played it so far, let us do it now. You see as far as E2 is concerned is concerned, we are looking at this part of the circuit, the lower part of the circuit, all right. So we will see how it simplifies. As far as E2 is concerned, E2 sees C pi 2 to ground and what else, R pi 2, okay, again R pi 2 to ground and at this point there comes, what is the voltage across this V pi 2 with what polarity, plus and minus.

And at this point, as far as the point E2 is concerned, that is a 3rd connection and that connection comes from a current source whose value is gm 2 V pi 2, okay. This current is to be equal to the gm 2 V pi 2. So instead of a current source, because the voltages is V pi 2, I can use a resistance here to value is 1 by gm 2. Is this trick clear?

No.

No. Instead of the current source, what we have done is, we have replaced a current source by a resistor. How can we do that? If the current source depends on this voltage V pi 2, obviously all we care about interacting KCL, KVL or whatever it is, what current is coming. The same cannot will come if include a resistance of 1 by gm 2 and that is the trick.

(())(49:04) parallel combination of RL and C mu 2.

Well…

(())(49:16) This is not going to ground…

Right, we will come back, we will come back to this. So if you are taking care of the node E2, you should also take care of the node C2, okay because the current source is between E2 and C2. So let us be fair, we have considered E2, as far as E2 is concerned, there is nothing wrong with this but we must now take care of C2. Now at C2, let us look at this terminal C2. At C2 we have C mu 2 to ground, agreed and RL to ground, in addition, well this voltage is T0, in addition we have a current source coming out of C2 and this current source is gm 2 V pi 2, okay.

Does it matter where it goes? So long as the current is excited from here, it does not matter where it goes, right. Is the point clear? V pi 2 is not here, V pi 2 is not a voltage in this part of the circuit. There is a current which is extracted from the load C2, I do not care where it goes, I can leave it like that I can connect it to ground, I can connect it to resistance and then to ground, it does not matter. All that I am concerned with is that V0 would be equal to minus gm 2 RL parallel 1 by J Omega C mu 2 and then you can forget about the output circuit. Is the point clear?

The current gm 2 V pi 2 must come from the parallel combination of RL and C mu 2. Once we have taken care of this, we forget about the output circuit, all right. This is the check.

What about the resistance 1 by gm 2…

1 by gm 2 was necessary at E2 because we have to take care of this current.

Voltage drop across that is V by 2.

That is right, that is how you can replace it by 1 by gm 2. It voltage V pi 2, therefore the current through this is gm 2.

(())(51:33) because across the current source we do not want the voltage.

I do not care, I only include this current is the circuit. That is it. There is a current source gm 2 V pi 2 and I have a voltage V pi 2 and therefore I connect a resistance 1 by gm 2. The current source has been completely taken care of and this is a trick, this is an equivalence here, there is a name for it in the literature but we do not want to go into that but this is a trick. And with this trick you see the output circuit cannot be completely forgotten. Even the input circuit, the current source is taken out, replaced by a resistance and now you can combine R pi 2 with gm 2, 1 by gm 2.

Excuse me Sir.

Yeah.

But from the point C2 to E2, I have a voltage drop of V0 plus V pi 2.

I have a voltage drop of V0 plus V pi 2, no.

In the actual circuit, the previous one.

Now, it is not, this is V0, plus minus, okay and V pi 2 is the opposite polarity, yah, fine.

I have a voltage drop of V0 plus V pi 2, to take care of that voltage drop in the equivalent circuit, the simplified trick circuit?

Simplified circuit, it is not necessary, I am not measuring between C2 and E2, I am only measuring the voltage across RL, is not that right. You see I measuring the voltage across RL, so as long as the voltage across RL is the same, I do not care.

Whatever be the voltage.

Whatever be the voltage, do not we care of that. All right, agreed, the trick is valid, do apply the trick wherever you get into a tricky situation like that. I think this is a good point to stop, we will continue this next time.