Analog Electronic Circuits
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Lecture – 50
Common Base and Common Gate Amplifiers: Analysis (Part B)

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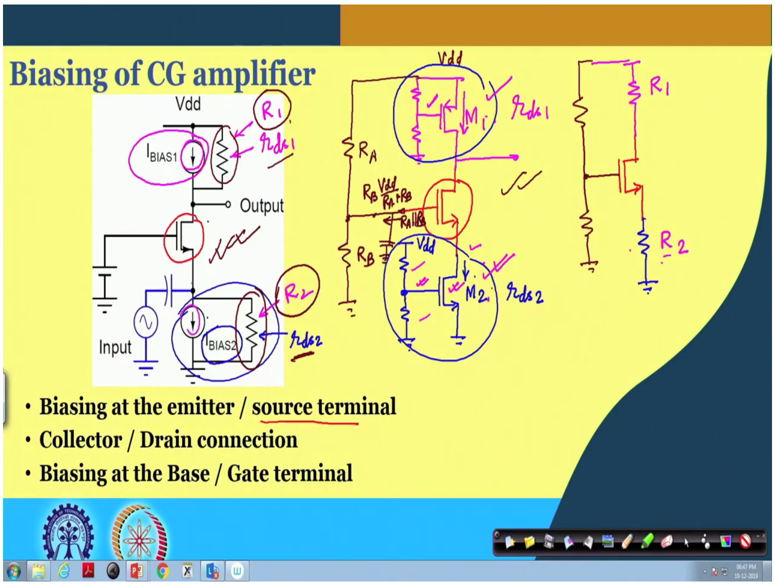

Biasing of CG amplifier

- Biasing at the emitter / source terminal
- Collector / Drain connection
- Biasing at the Base / Gate terminal

Yeah. So, welcome back after the short break. So, we are talking about the biasing of Common Gate and Common Base circuits. Now we are going to discuss about the small signal analysis.

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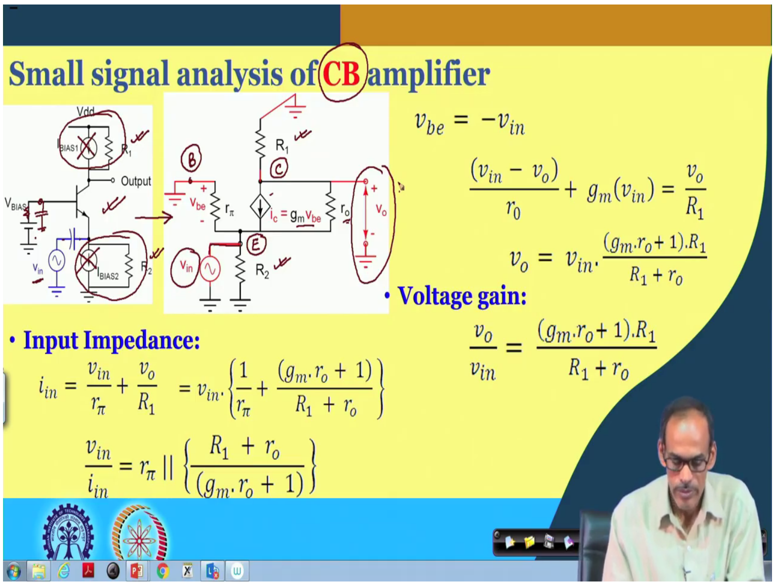

Small signal analysis of CB amplifier

$$v_{be} = -v_{in}$$

$$\frac{(v_{in} - v_o)}{r_0} + g_m(v_{in}) = \frac{v_o}{R_1}$$

$$v_o = v_{in} \cdot \frac{(g_m . r_o + 1).R_1}{R_1 + r_o}$$

- **Voltage gain:**

$$\frac{v_o}{v_{in}} = \frac{(g_m . r_o + 1).R_1}{R_1 + r_o}$$

- **Input Impedance:**

$$i_{in} = \frac{v_{in}}{r_\pi} + \frac{v_o}{R_1} \quad = v_{in} \cdot \left\{\frac{1}{r_\pi} + \frac{(g_m . r_o + 1)}{R_1 + r_o}\right\}$$

$$\frac{v_{in}}{i_{in}} = r_\pi \,||\, \left\{\frac{R_1 + r_o}{(g_m . r_o + 1)}\right\}$$

So, let me go to the corresponding circuit here yeah. So, we do have common base circuit here. So, this is the common base amplifier and this is the corresponding small signal equivalent circuit. For to save some time what I have done is that I have drawn this circuit, but I will explain that what are the things I have done.

If we see here the bias circuit in the small signal equivalent circuit, we have dropped this DC current and we consider only the resistance here R1. So, likewise here at the emitter side, the DC current we have dropped and we have considered only this R2 here. Then this is the small signal which is getting coupled through the capacitor. So, we simply have shorted it, signal it is coming to the directly coming to the emitter and then at the base, we do have DC voltage.

Even if it is having Thevenin equivalent resistance, we assume that that is getting grounded by grounded by capacitor here. So, even if you are having source Thevenin equivalent resistance that is ignored and the base terminal, it is grounded.

At the collector side we do have g m into Vbe that voltage dependent current source flowing from collector to emitter terminal and then of course, we do have the r naught. So, that is the small signal equivalent circuit. Input we are giving at the emitter and output we are observing at the collector. In this diagram we are showing that output it is voltage input is also voltage. Now we are going to analyze these circuits step by step.

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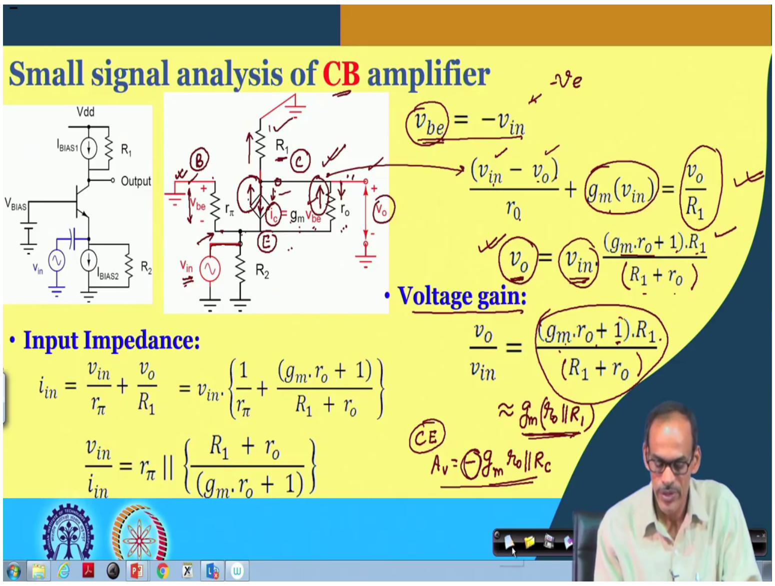

Small signal analysis of CB amplifier

$$\boxed{v_{be}} = -v_{in}$$

$$\frac{(v_{in} - v_o)}{r_o} + \boxed{g_m(v_{in})} = \boxed{\frac{v_o}{R_1}}$$

$$\boxed{v_o} = \boxed{v_{in}} \cdot \frac{(g_m.r_o + 1).R_1}{(R_1 + r_o)}$$

- **Voltage gain:**

$$\frac{v_o}{v_{in}} = \boxed{\frac{(g_m.r_o + 1).R_1}{(R_1 + r_o)}}$$

$$\approx g_m(r_o \| R_1)$$

CE

$$A_v = \boxed{-} g_m r_o \| R_c$$

- **Input Impedance:**

$$i_{in} = \frac{v_{in}}{r_\pi} + \frac{v_o}{R_1} = v_{in} \cdot \left\{ \frac{1}{r_\pi} + \frac{(g_m.r_o + 1)}{R_1 + r_o} \right\}$$

$$\frac{v_{in}}{i_{in}} = r_\pi \, \| \left\{ \frac{R_1 + r_o}{(g_m.r_o + 1)} \right\}$$

So, by considering this small signal equivalent circuit, let us see what are the now what are the conditions we are getting. First of all we do have v be, base node it is grounded and emitter it is having some signal and that signal is incidentally v in. So, we can say v be is essentially 0 minus v e. So, and v e it is same as v in. So, in fact, v in is v e.

So, we can say that v be it is minus v in. So, this is the first thing we obtain. The next one it is if you see at this node the collector node, we do have three current elements. One is one current is flowing through this r o another current is flowing through on this device and then also we do have a current flowing through this R1.

So, the current flowing through this R1 it is v o divided by R1. So, v o divided by R1, it is summation of these two currents. So, if I consider this is the polarity of the positive direction of the current, then this current it is v e minus v o divided by r o and v e it is nothing, but v in. So, the current flow here it is v in minus v o divided by r o.

On the other hand g m into v be which is now it is g m into minus v in and the current flow here it was from collector to emitter. So, minus sign we can remove and then you can say that the current flow it is in this direction and it is g m into v in.

So, the second term here it is representing this IC current voltage dependent current source. So, what we have it is the this current, it is equal to summation of this two current. So, by applying the applying k c l at the collector terminal collector node rather we obtain this equation. So, if you rearrange this equation it is it is having v in and v out only. So, we can write the expression of v o in terms of v in. So, with the rearrangement property rearrangement what we are getting here it is v o equals to v in multiplied by g m into r naught plus 1 multiplied by R1 divided by R1 plus r o.

So, this relationship it is helping us to get the voltage gain expression. So, what we are getting is that voltage gain of this circuit, it is g m r naught plus 1 into R1 divided by R1 plus r o. In fact, you may approximate that this 1 it is very small. So, we can simply say that this is g m into r o in parallel with R1 and further to that if you recall the common emitter amplifier voltage gain, it is similar.

So, and its gain it was g m into r o in parallel with Rc and Rc it is in fact, Rc and R1 it is in this circuit and common emitter amplifier their synonym. So, for common emitter amplifier, the voltage gain it was g m into this one, but of course, with a minus sign. So, that is the difference. So, we can say that if we are if we can successfully feed the signal at the emitter in the voltage form and if you observe the corresponding output at the collector in the voltage form. Then the gain of the circuit it is same as whatever the gain we can get from common emitter except of course, this minus sign which means, that here input and output they are in same phase; in common emitter the input and output they are in outer phase.

In fact, if you see here if you closely look into this circuit, for common emitter we feed this signal at the base and emitter it was grounded. So, whatever the v be it was there it was producing this active current it was flowing through this Rc and maybe r o in parallel and it was producing the output voltage. So, here on the other hand for common base configuration we are feeding the signal here and we are making it ground. So, that is the only difference how we are feeding the signal whether it is at the base or at the emitter, other part of the circuit it is identical. So, that is why it is giving us the same level of voltage gain, but of course, the polarity of the input it was different opposite. So, that is why here we do not have the minus sign.

So, that is about the voltage gain, but we need to be careful here. Here we have assumed that there is no source resistance.

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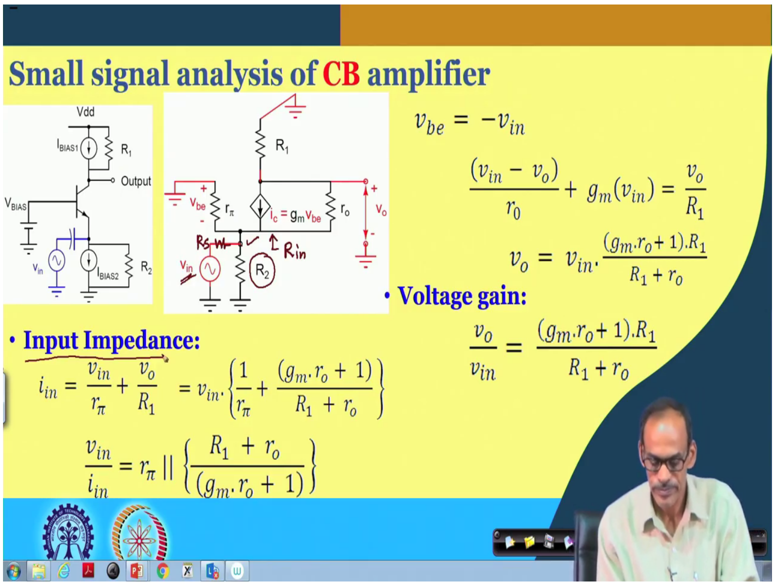

Small signal analysis of CB amplifier

$$v_{be} = -v_{in}$$

$$\frac{(v_{in} - v_o)}{r_0} + g_m(v_{in}) = \frac{v_o}{R_1}$$

$$v_o = v_{in}.\frac{(g_m.r_o + 1).R_1}{R_1 + r_o}$$

- **Voltage gain:**

$$\frac{v_o}{v_{in}} = \frac{(g_m.r_o + 1).R_1}{R_1 + r_o}$$

- **Input Impedance:**

$$i_{in} = \frac{v_{in}}{r_\pi} + \frac{v_o}{R_1} = v_{in}.\left\{\frac{1}{r_\pi} + \frac{(g_m.r_o + 1)}{R_1 + r_o}\right\}$$

$$\frac{v_{in}}{i_{in}} = r_\pi \,||\, \left\{\frac{R_1 + r_o}{(g_m.r_o + 1)}\right\}$$

And as a result we are saying that entire v in it is coming here and then R2 is not having any role and then we are really not bothered about the input resistance and so on. But practically if you see that if we consider source resistance signal source resistance and if we look into the input resistance of this circuit, then we will be we will be getting a surprise.

So, to get that surprise, let us look into the expression of the input impedance of the circuit ok. So, to get the input impedance what we can say?

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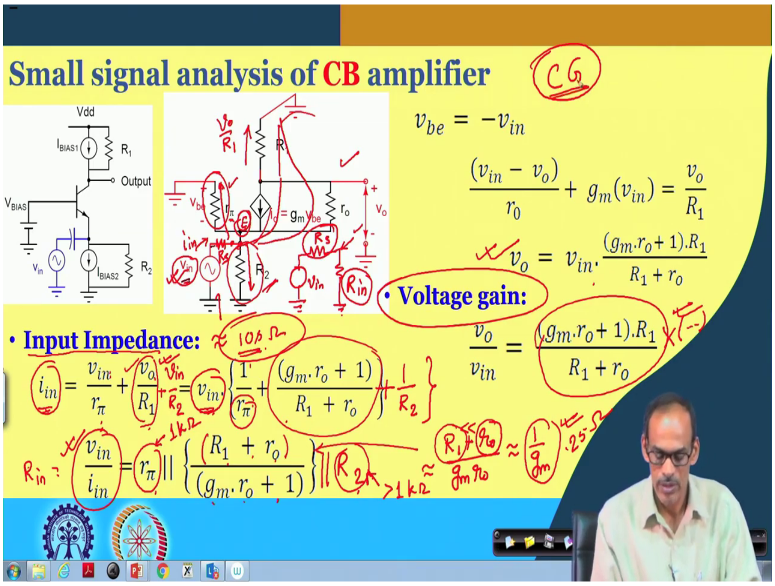

Small signal analysis of CB amplifier

CG

$$v_{be} = -v_{in}$$

$$\frac{(v_{in} - v_o)}{r_0} + g_m(v_{in}) = \frac{v_o}{R_1}$$

$$v_o = v_{in} \cdot \frac{(g_m \cdot r_o + 1) \cdot R_1}{R_1 + r_o}$$

- Voltage gain:

$$\frac{v_o}{v_{in}} = \frac{(g_m \cdot r_o + 1) \cdot R_1}{R_1 + r_o} \times (--)$$

- Input Impedance: $\approx 10s\,\Omega$

$$i_{in} = \frac{v_{in}}{r_\pi} + \frac{v_o}{R_1} + \frac{v_{in}}{R_2} = v_{in} \left\{ \frac{1}{r_\pi} + \frac{(g_m \cdot r_o + 1)}{R_1 + r_o} + \frac{1}{R_2} \right\}$$

$$R_{in} = \frac{v_{in}}{i_{in}} = r_\pi \,||\, \left\{ \frac{(R_1 + r_o)}{(g_m \cdot r_o + 1)} \right\} || R_2$$

$1\,k\Omega$ $>1\,k\Omega$ $\approx \frac{R_1 + r_o}{g_m r_o} \approx \frac{1}{g_m}$ $.25\,\Omega$

If I stimulate the circuit by say v in and then if we observe the corresponding current here say i in then if I take the ratio of v in divided by i in that will be giving us the input resistance. So, if you see that i in for a given stimulus of v in, it is having three components: one is this current, another one is this current and the other part it is it is going together; finally, it is going to that ground and then it is coming back to this ground.

So, the first part or this current of this i in it is v in divided by r pi. So, voltage at the emitter node we do have v in here. So, naturally this current it is v in divided by r pi. So, likewise the second part it is v in divided by R2. And the other part whatever the current is flowing, it is same as whatever the current is flowing through this R1 and incidentally this current it is v o divided by R1.

So, that makes our analysis simple. So, the third part of the current it is v o divided by R1 and we already obtained the expression of v o in terms of v in. So, this is the corresponding expression. So, we can plug in that expression here and we can say that i in it is v in, it is a function of v in multiplied by 1 by r pi and then we do have this part the middle part and the third part it is we need to consider which in my equation previous equation I have not considered. So, we can consider this part also.

So, if I take the ratio of this v in and i in to get the input impedance of the circuit, what we are getting here it is r pi coming in parallel with this impedance namely R1 plus r o divided by g m into r o right and then of course, we do have this R2. In fact, if you look into this circuit carefully the input impedance is having three part; one is this conductance this conductance and the conductance through the active device.

So, this is the r pi and this is the R2 and the middle portion if you see if you further simplify, it is R1 plus r o divided by g m into r o. And if you further simplify it, you may say that this part in case if it is dominating over R1 if I consider this is much higher than R1, then you may approximate that this is 1 by g m. So, why I am writing like this, because to indicate that the typical order of magnitude of this input resistance series 1 by g m.

So, if 1 by g m it is coming in parallel with r pi and R2 this 1 by g m it will be dominating. Typical value we already have seen before that this may be in the order of say 25 ohms and the on the other hand r pi maybe in the kilo ohms. This resistance depending on what kind of biasing arrangement we are considering here, this may be higher than kilo ohms. So, we may say that input impedance it is quite low, it may be in 10s of ohms ok.

So, depending of course, it depends on the DC condition, but important note is that the resistance is very small and whatever the if I consider the source resistance then this input resistance and source resistance it will be making this voltage coming to the emitter of the transistor very weak. So, we will see that what may be the consequence if I consider source resistance of this circuit.

So, basically we like to say that this voltage gain it will not remain so, nice. In fact, voltage gain from emitter to output it will be having the same expression, but from the primary input to the emitter because of Rs and input resistance here there will be a big attenuation. So, if I call this is v in followed by say resistance of the signal source Rs followed by the R in, R in is the equivalent input resistance we or just now we have derived.

So, if I see the signal here if the value of this Rs, it is much higher than R in the signal here it will be very small. So, as a result we have to consider another attenuating factor. So, we will see its consequence. Before that let me consider the common gate configuration because whatever the analysis we have done so far for the BJT version quite and extent it is applicable for the common gate amplifier.

So, let me go into the common gate configuration, yes.

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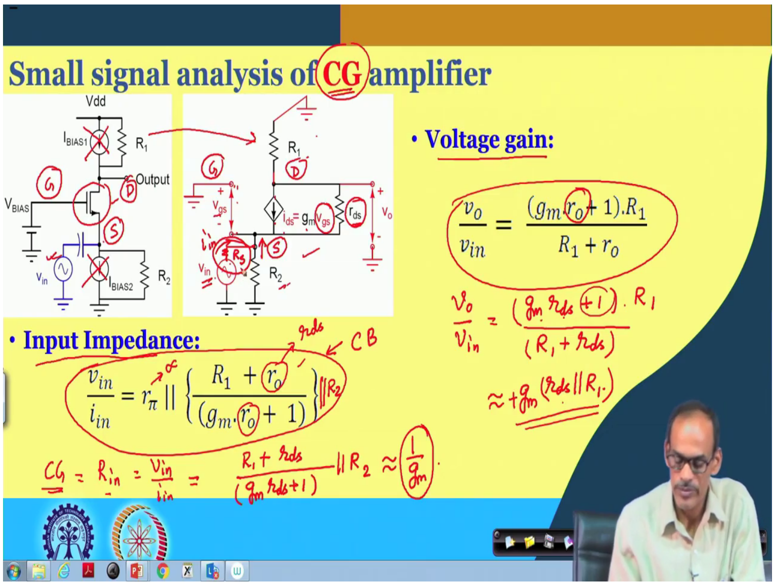

Small signal analysis of CG amplifier

- Voltage gain:

$$\frac{v_o}{v_{in}} = \frac{(g_m r_o + 1).R_1}{R_1 + r_o}$$

$$\frac{v_o}{v_{in}} = \frac{(g_m r_{ds} + 1).R_1}{(R_1 + r_{ds})}$$

$$\approx + g_m (r_{ds} \| R_1)$$

- Input Impedance:

$$\frac{v_{in}}{i_{in}} = \overset{\infty}{r_\pi} \| \left\{ \frac{R_1 + \overset{r_{ds}}{r_o}}{(g_m . r_o + 1)} \right\} \| R_2 \quad \text{CB}$$

$$CG = R_{in} = \frac{v_{in}}{i_{in}} = \frac{R_1 + r_{ds}}{(g_m r_{ds} + 1)} \| R_2 \approx \boxed{\frac{1}{g_m}}$$

So, in our previous analysis namely for common base, we obtain this relationship v out to v in and here we do have the common gate configuration. So, this is the main transistor, signal we are feeding at the source through the capacitor, gate is biased at DC voltage and then at the drain, we are observed in the corresponding output.

So, here we do have the small signal equivalent circuit. Again same thing, this bias circuit we have dropped in the small signal equivalent circuit; similarly, this bias circuit the bias current DC bias current, it is dropped and we are just keeping only R2 and R1 here. The small signal equivalent circuit of the mass transistor it is given here by g m into v g s that is the drain to source signal current and then we also have r d s here. Of course, we do not have r pi here and then voltage here from gate to source it is v g s.

So, instead of v be in whatever we have seen for common base configuration, we do have v g s and instead of r o we do have r d s, rest of the things are similar. So, whatever the previous circuits analysis we have done that can be utilized namely to get the voltage gain of the common gate. So, for common gate configuration, the input to output gain it is g m into r d s instead of r o; I have to consider r d s plus 1 into R1 divided by R1 plus r d s. Again this can be we will approximated by ignoring this one part with respect to g m into v g s and it can be written as g m into r d s coming in parallel with R1.

This is again, it is having the similar gain of common source amplifier where the expression of the gain it was g m into r d s into r d, but of course, with a minus sign here, we do not have any minus sign here rather input and output they are in same phase. Now similar to the voltage gain the expression of the input impedance of this circuit can be obtained from the derivation of the common base circuit. So, this is the derivation, we already have out of the common base circuit, of course, there we are having R2 also.

Now, if I consider common gate: so, common gate circuit configuration. There the input resistance R in which is defined by v in divided by i in, where v in we are applying here and then the corresponding current here it is we call this is i in. So, this current this ratio can be obtained from the same analysis whatever you have done, except we have to make this is in finite and we have to make this is r d s. So, this is r d s and this is also r d s. So, that gives us the input resistance expression, it is R1 plus r d s divided by g m into r d s plus 1 in parallel with R2.

Again here we can we can approximate this input resistance by 1 by g m and even though this 1 by g m of mass transistor and b j t they are having different order of magnitude, but still 1 by g m it is quite low. So, since the input resistance it is low, the same problem it will arise if I consider source resistance signal source resistance Rs and this voltage signal it will be having difficulty to reach to the common source.

So, if I consider say this Rs here, what kind of voltage gain will you get? So, let us see what will be the voltage gain if I am having this finite value of the source resistance.

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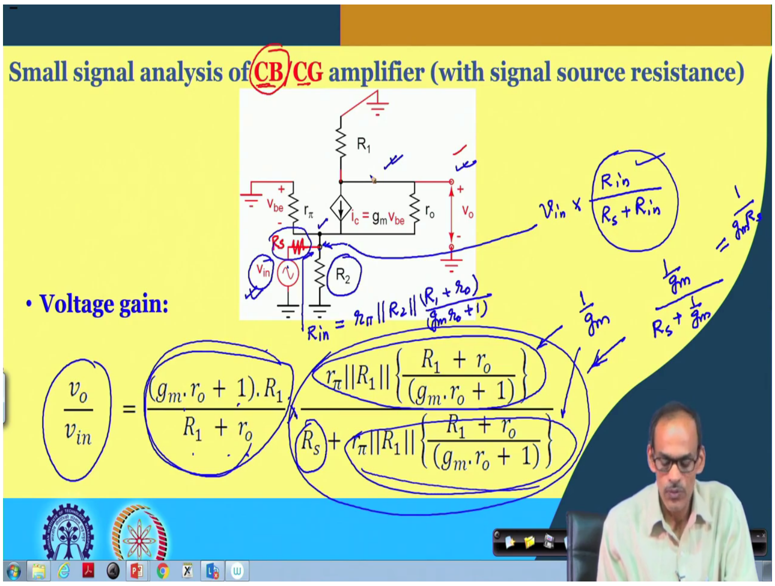

Small signal analysis of CB/CG amplifier (with signal source resistance)

- **Voltage gain:**

$$\frac{v_o}{v_{in}} = \frac{(g_m . r_o + 1) . R_1}{R_1 + r_o} \cdot \frac{r_\pi || R_1 || \left\{ \frac{R_1 + r_o}{(g_m . r_o + 1)} \right\}}{R_s + r_\pi || R_1 || \left\{ \frac{R_1 + r_o}{(g_m . r_o + 1)} \right\}}$$

$$R_{in} = r_\pi || R_2 || \frac{(R_1 + r_o)}{(g_m r_o + 1)}$$

$$v_{in} \times \frac{R_{in}}{R_s + R_{in}}$$

$$\frac{1}{g_m} \qquad \frac{\frac{1}{g_m}}{R_s + \frac{1}{g_m}} = \frac{1}{g_m R_s}$$

So, this is the corresponding circuit here the analysis it is very similar for common base and common gate. So, let us start with the common base. So, this is a corresponding circuit. We already have discussed this circuit before.

Now, if I consider along with that if I consider it is having a source resistance of Rs and this circuit it is having input resistance looking into the source node R in which is we already have discussed that this is r pi coming in parallel with R2 in parallel with R1 plus r o divided by g m into r o plus 1. So, the attenuation coming from this network namely this v in part of the v in it is arriving here and the signal coming here.

It is I should say v in multiplied by this resistance R in divided by Rs plus R in. And after that from this point to the output whatever the gain we are having that remains the same and we know that the gain from source node to collector node its gain it is given here. So, the overall gain from the primary input to the primary output it will be this attenuation factor multiplied by this gain.

So, we can say that the overall gain v o divided by v in, it is g m r naught plus 1 into R1 divided by R1 plus r o multiplied by this part, where this is the R in this is also R in. Now it will be having a serious problem and we already have discussed that this can be well approximated by 1 by g m. So, likewise this is also 1 by g m. And if this Rs it is significantly large, then we will be having an attenuation here which is 1 by g m divided by Rs plus 1 by g m right.

So, that gives us. So, this is coming 1 by g m into Rs plus 1. So, there will be huge you know attenuation depending on the condition if the Rs, yeah if the Rs it is sufficiently large then there will be large amount of attenuation. As a result the voltage gain this circuit may not be (Refer Time: 25:13) working as a voltage amplifier. In fact, this is true for the common gate configuration as well.

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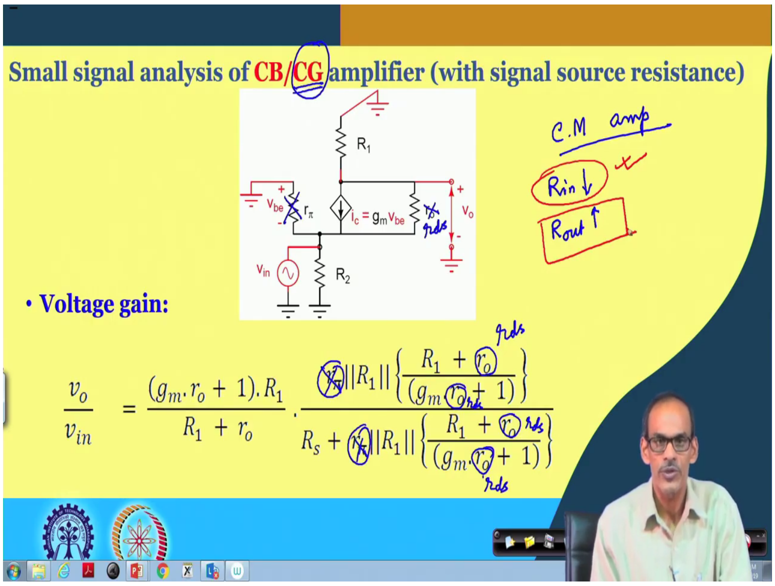

Small signal analysis of CB/CG amplifier (with signal source resistance)

C.M amp

Rin ↓

Rout ↑

- Voltage gain:

$$\frac{v_o}{v_{in}} = \frac{(g_m.r_o + 1).R_1}{R_1 + r_o} . \frac{\cancel{r_\pi}||R_1||\left\{\frac{R_1 + \overset{r_{ds}}{r_o}}{(g_m.\underset{r_{ds}}{r_o} + 1)}\right\}}{R_s + \cancel{r_\pi}||R_1||\left\{\frac{R_1 + r_o\,r_{ds}}{(g_m.\underset{r_{ds}}{r_o} + 1)}\right\}}$$

So, even if I consider common gate the analysis it will be similar. Only difference is that we will not be considering this part and then we have to consider we have to consider r d s instead of r o because for common gate this is r d s and this is I should say it is infinite. So, this is r d s and so and so.

But the consequence or the overall conclusion remains the same, namely, this circuit common gate also may not be a good idea to utilize as voltage amplifier ok. So, what may be then the other alternative? Can I use this circuit as current mode amplifier? First of all for current mode amplifier what we are looking for it is idealistically the input resistance should be has small as possible, output resistance should be has high as possible and we already have seen that this circuit is having input resistance quite low. So, we already have this property.

Now, we can see that do we have this property. So, in the next slide we can see that, what is the expression of the output resistance of this circuit.

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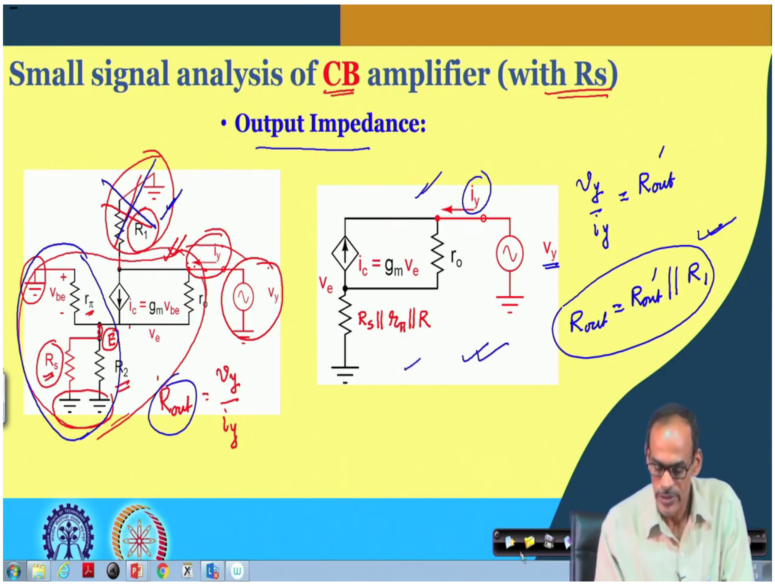

Small signal analysis of CB amplifier (with Rs)

- **Output Impedance:**

$R_{out} = \frac{v_y}{i_y}$

$\frac{v_y}{i_y} = R'_{out}$

$R_{out} = R'_{out} \parallel R_1$

So, let us start with the common base configuration and in fact, the analysis it is similar for common gate also and let you consider finite value of this Rs. So, we are keeping the source resistance Rs and this is the corresponding small signal equivalent circuit of the common base amplifier. To find the output resistance what we are doing here, it is we are stimulating this circuit by a voltage called vy and then we are observing the corresponding current i y.

And if I know the their relationship, then from that if I take the ratio of this vy by iy that gives us the output resistance. So, the output resistance it is essentially vy divided by iy. Now in this circuit if you look it look at this circuit carefully, it can be simplified. Say this part it is a parallel branch to ground whereas, this part it is another branch. So, whatever the resistance we can get out of this lower part if you if you analyze this part and then if you find its corresponding resistance and then that resistance if you simply make a parallel connection of this R1 that gives us the overall resistance.

So, to simplify the analysis probably we can presently, let you drop this part and let me analyze only this lower part. Further to that this R2, Rs and r pi all are connected to the emitter node and the other part other end of those registers are connected to ground. So, all of them we can say that they are parallely getting connected and equivalently you can say that from the emitter node we do have a resistance which is Rs in parallel with r pi in parallel with R2.

So, in summary; if we drop this part and if we club all these three registers into one then the corresponding circuit it becomes very simple like this. So, let us analyze this circuit and then let me consider this is our stimulus and this is the corresponding observation and then from that whatever there be vy divided by iy we will be getting we call this is a R out maybe dash.

Then the total resistance here of course, this will be this R out dash in parallel with this ignored part this one. So, let me do this analysis then finally, to write the expression of output impedance, we will be considering this R1. So, in the next slide we will be analyzing this circuit.

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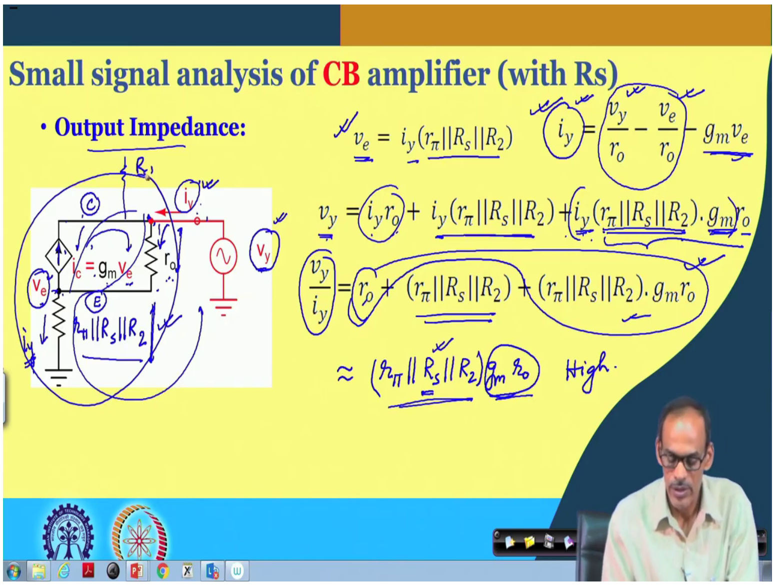

Small signal analysis of CB amplifier (with Rs)

- **Output Impedance:**

$v_e = i_y(r_\pi || R_s || R_2)$ $i_y = \frac{v_y}{r_o} - \frac{v_e}{r_o} - g_m v_e$

$v_y = i_y r_o + i_y(r_\pi || R_s || R_2) + i_y(r_\pi || R_s || R_2) . g_m r_o$

$\frac{v_y}{i_y} = r_o + (r_\pi || R_s || R_2) + (r_\pi || R_s || R_2) . g_m r_o$

$\approx (r_\pi || R_s || R_2) g_m r_o$ High.

So, you do have the circuit copied here and this is r pi in parallel with Rs in parallel with R2.

Now, how do we find the relationship of this vy and iy? First of all the voltage here it is at the emitter it is v e and the current here it was g m into v be and v be it is essentially minus v e. So, we have dropped the minus sign here and we have changed the polarity of the current here. So, the current flowing from emitter to collector it is g m into v e and so, here if you see this current iy it is probably, it is going through this part and this part and finally, it is coming back here.

So, the current flowing through this total resistance here it is also same as whatever the iy we do have. So, we can say that the voltage v e it is iy multiplied by this resistance. So, the first equation we obtain here it is v e equals to iy multiplied by the total resistance on the other hand if you see at this node and this node we do have the different. So, at this node if I apply say k c l what we are getting here, it is iy it is summation of this current and this current.

So, the current here flowing through r o it is vy minus v e divided by r o. So, that is this part and then the current here it is in this direction from emitter to collector it is gm into v e or you may say that collector to emitter it is minus gm into v e. So, the iy it is having this expression. So, what do you have here it is iy it is written in terms of vy and v e, whereas, v e it is written here in terms of I y. So, if I combine these two equations this equation in this equation what we get here it is; vy equals to iy into r o plus iy into the total resistance here plus iy into the total resistance multiplied by gm into r o.

So, if you see that various terms here in fact, the voltage vy if you see here it is having this drop and also this drop. So, this drop it is straight forward. In fact, if you see here this is the this part this drop and then if I combine this part and this part that gives us the drop across this r o because this current is also flowing through this and this current it is its expression it is gm into this resistance multiplied by this r e.

So, that gives an idea that the voltage here it is having this iy multiplied by a big resistance here. In other words if I take the ratio of vy divided by iy what we can what we are getting here it is having this resistance in series with this big resistance. In fact, compared to this part it is very small it is rather I should say this is dominating. So, we may approximate this by r pi in parallel with r is in parallel with R2 into gm r naught.

So, if you observe carefully this Rs even if the Rs it is not very big, but whatever the value it is there that is getting multiplied by gm into r naught. So, even if I say that r Rs it is not so, big and whatever the value we do have since it is getting multiplied by gm into r naught which is intrinsic gain of the amplifier that gives the output resistance very high, at least from this part the resistance is very high

So, now to get the output resistance we need to consider the other part, namely, R1 part. So, that is what we are summarizing in the next slide.

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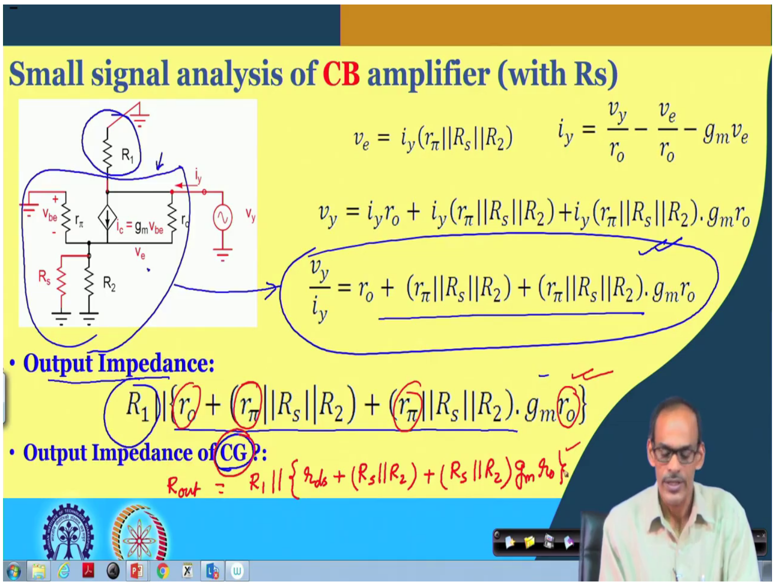

Small signal analysis of CB amplifier (with Rs)

$v_e = i_y(r_\pi||R_s||R_2)$ $\quad i_y = \frac{v_y}{r_o} - \frac{v_e}{r_o} - g_m v_e$

$v_y = i_y r_o + i_y(r_\pi||R_s||R_2) + i_y(r_\pi||R_s||R_2).g_m r_o$

$$\frac{v_y}{i_y} = r_o + \underline{(r_\pi||R_s||R_2) + (r_\pi||R_s||R_2)}.g_m r_o$$

- **Output Impedance:**

$$R_1||\{r_o + (r_\pi||R_s||R_2) + (r_\pi||R_s||R_2).g_m r_o\}$$

- **Output Impedance of CG ?:**

$R_{out} = R_1||\{r_{ds} + (R_s||R_2) + (R_s||R_2)g_m r_o\}$

So, what we have said is that we already got the expression of vy divided by i y. So, it is having the impedance coming from this part. So, that is the impedance it is given here and then we do have R1. So, the output impedance of this circuit it is whole thing in parallel with R1.

So, I should say that this common base configuration. This portion it is having very high resistance. Now if this bias circuit it is also having high resistance by implementing say by active device then you can say that its output resistance is very high. Now whatever the analysis we have done that can be utilized to get the output resistance or output impedance of the common gate configuration also, namely, the mass counterpart and its output resistance it will be obtained from this expression only by dropping these parts and replacing this r o by r d s.

So, I am just writing that R1. So, this is the output resistance of the common gate configuration; R1 in parallel with r d s plus rs in parallel with R2 plus Rs in parallel with R2 into gm into ro right. So, again the output resistance here it is high. So, we are convinced that for common base or common gate the output resistance is very high. So, let us see this circuit either common base or common gate as current amplifier.

So, we do have the a corresponding analysis to find the expression of the current gain.

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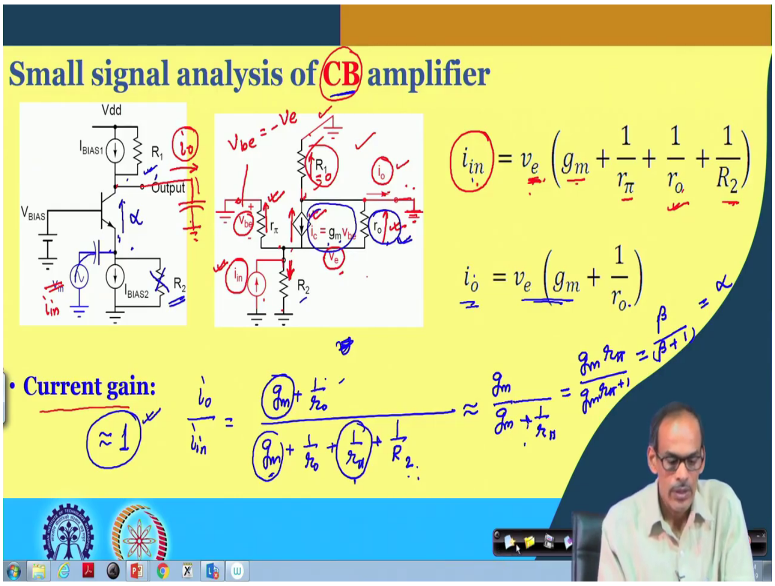

Small signal analysis of CB amplifier

$$i_{in} = v_e\left(g_m + \frac{1}{r_\pi} + \frac{1}{r_o} + \frac{1}{R_2}\right)$$

$$i_o = v_e\left(g_m + \frac{1}{r_o}\right)$$

- **Current gain:** ≈ 1

$$\frac{i_o}{i_{in}} = \frac{g_m + \frac{1}{r_o}}{g_m + \frac{1}{r_o} + \frac{1}{r_\pi} + \frac{1}{R_2}} \approx \frac{g_m}{g_m + \frac{1}{r_\pi}} = \frac{g_m r_\pi}{g_m r_\pi + 1} = \frac{\beta}{(\beta+1)} = \alpha$$

So, here we do have the common base configuration. We do have the corresponding circuit here and to get the current gain what we have to do? At the output node we have to make their corresponding terminal unloaded. What do you mean by unloaded? We have to basically short this node to ac ground and then we have to find how much the current it is coming from the circuit signal current. We are putting this capacitor, so that the operating point of the transistor it is not getting affected and at the same time signal wise we are observing the short circuit output current.

And we know that if the signal it is in current form unloaded condition should be the corresponding impedance or the terminating impedance should be 0. So, small signal model if you see the corresponding situation here it is this node the corresponding collector node it is ground and we are observing the corresponding signal current i naught, for their input signal it is i in. In fact, in this case we are stimulating the circuit by signal current.

Now if you see this circuit again the base node it is grounded, voltage at the emitter we do have v e. So, the v be it is vbe it is minus v e right and part of the current is also flowing here. So, we can say that i in, it is having different component; one is this part another is this part right and then we also have this current and this current.

So, the if you see one by one this current it is gm into v. So, that is why gm into v e is the first part and then the second part here flowing through r pi, it is voltage here v e divided by r pi. So, there is a second part and then we do have this part third part which is v e divided by r o and then through this by a circuit which is v e divided by R2. So, in summary we can say that i in it is it can be directly written in terms of v e.

On the other hand if you see the current at the output terminal here. So, if this is the current. In fact, this current of course, this node it is grounded. So, the current here it is actually 0 because this is also ground this is also ground. So, the current here it is 0. So, the I naught on the other hand, it is summation of only these two currents we do have this current and we do have this current. So, I naught it is v e into gm and then we do have v e divided by r naught.

So, if I take ratio of this two what we are getting here it is the v this is getting cancelled. So, the current gain i o divided by i in equals to gm plus 1 by r o divided by gm plus 1 by ro plus 1 by r pi and then plus 1 by R2. In fact, if you see because this gm it is dominating we may consider rest of the things it is very small. In fact, you may call this is practically it is gm by gm. If you want you can probably keep this part or to be more precise it is we may drop this part. So, we can written this part and we can written this part.

So, it will be g m divided by g m plus 1 by r pi. Of course, this R2 can be ignored, definitely it can be ignored with respect to g m, but whether this is ignore able with respect to r pi r naught that depends on what kind of biasing arrangement we do have for the emitter terminal. But, whatever it is or we can write in this form and you can further simplify this as gm into r pi divided by gm into r pi plus 1.

In fact, you may recall that g m into r pi is nothing but the beta of the transistor. So, this beta divided by beta plus 1. In fact, you may recall this is nothing, but alpha of the transistor that is very obvious. If I ignore this resistance if I feed a signal current here at the emitter whatever the current will be getting at the collector side, it depends on how much the current gain we do have from for this transistor from emitter to collector and that is nothing, but the alpha of the transistor.

So, we know that this alpha it is very close to 1. So, we can say that this current gain it is less than 1, but it is very close to 1. So, that gives us good you know conclusion that this circuit namely the common base, since its input resistance is low output resistance is high and the current gain it is it is close to 1. So, it is a good circuit for current mode buffer.

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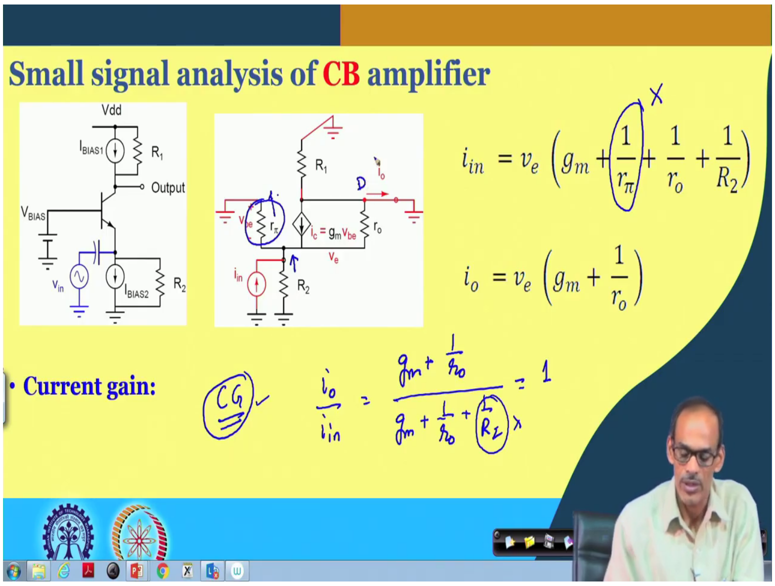

Small signal analysis of CB amplifier

$$i_{in} = v_e \left(g_m + \cancel{\frac{1}{r_\pi}} + \frac{1}{r_o} + \frac{1}{R_2} \right)$$

$$i_o = v_e \left(g_m + \frac{1}{r_o} \right)$$

- **Current gain:** CG ✓ $\frac{i_o}{i_{in}} = \frac{g_m + \frac{1}{r_o}}{g_m + \frac{1}{r_o} + \cancel{\frac{1}{R_2}}} = 1$

The similar kind of analysis it can be done for common gate also. I think you can do yourself just by dropping this part for that for common gate we simply remove this part and that gives us the corresponding current gain; i out divided by i in equals to gm plus 1 by r naught divided by gm plus 1 by r naught plus 1 by R2. In fact, for this case it is if I if I ignore this R2 then it is exactly equal to 1 that is a very obvious. For BJT we do have this path which is taking some part of the current, but for most we do not have the get to source resistance.

So, as a result at the source whatever the current we give the entire current it is arriving to the drain terminal. I think most of the things [vocalized- noise] we have covered.

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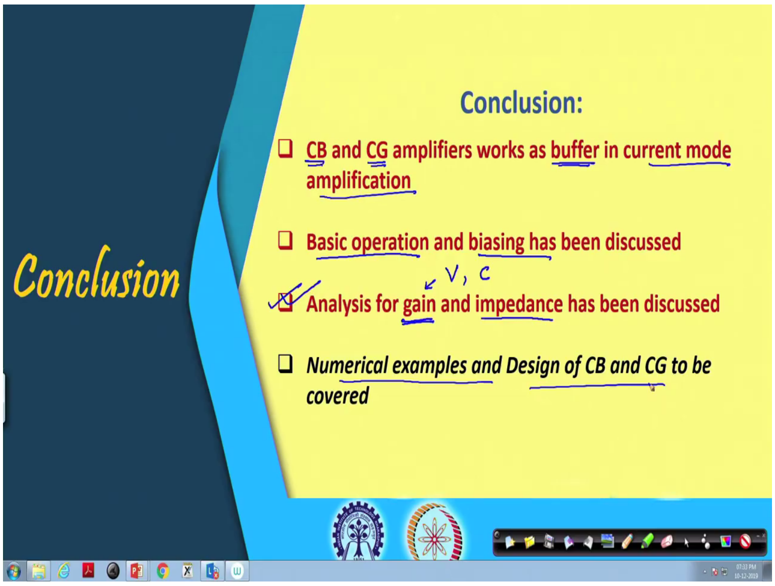

Conclusion

Conclusion:

- ☐ CB and CG amplifiers works as buffer in current mode amplification
- ☐ Basic operation and biasing has been discussed
- ☑ Analysis for gain and impedance has been discussed
- ☐ *Numerical examples and Design of CB and CG to be covered*

V, C

So, what are the things we have covered today? It is we have discussed about the common base and common gates amplifiers or configurations. It works as a buffer particularly for current mode amplification. What we have covered today it is the basic operation of these two configurations and we also have discussed a little bit about the different biasing schemes. Numerical discussion it will be done later. And then we have done full set of analysis of the small signal analysis of common base and common gate configurations to find the gain particularly voltage gain, input impedance and output impedance and also current gain. So, both voltage as well as the current gain, we have discussed. Numerical examples on these two configurations will be covering later. I think that all we need to cover.

Thank you.