Analog Circuits
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Lecture – 07
Amplifiers

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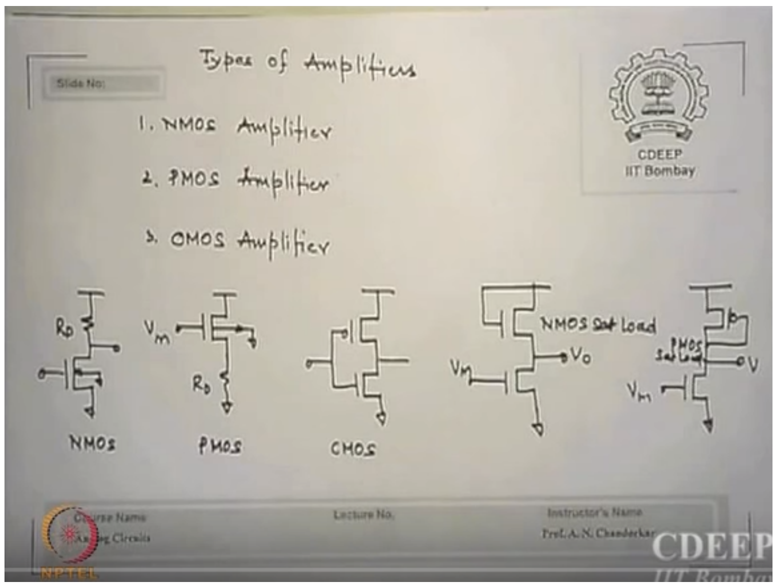

Okay, let us start what we left last time we are looking for amplifiers another said this course or the first time maybe I do not know we will concentrate more on MOS technology, MOS device based amplifiers oscillators opamps though I then when I need I will give you something equivalence of bipolar as well okay, so not that bipolar is out I keep saying every time.

So today we shall look into typically MOS amplifiers we are already solve one problem for MOS but just to give you more details there can be three possibilities of an amplifier made in MOS with MOS devices one is NMOS amplifier, so the word here is the transistor which gives you gm transistor which gives you a gm is called the driver is that word correct.

The driver transistor is the one where input is received and which gives you gm time something at the output so for example during the first figure this transistor is called driver transistors, so if it is N channel kind it is called NMOS amplifier if it is a second quad like it is a P channel device that is called PMOS amplifiers if there are both P channel and N channel gates are connected this will be called CMOS you already done CMOS.

I do not know that you may be doing now in your digital course so this is called CMOS amplifiers and then the first part of course are the driver what kind of driver you are decides the name NMOS, PMOS or CMOS and there are other names also we give one is called based on loads, so you are an NMOS amplifier with first one is the resistive loads you can see resistance is the load resistance in the case of fourth the resistance is replaced by a transistor okay.

That is equivalent of that and this transistor acts like a resistor okay, so it is called and this transistor we shall see the later this is devices always in saturation and it is artesian transistor resistance we know why it is higher in saturation because the characteristics are very flat R0 is roughly resistance so typically by changing the size of the distance transistor.

I can change the W/L of this transistor and hence the resistance, so the resistance of the load is varied by changing the size of the load transistors if instead of N channel device as a load I can also have a P channel the circle stand for sorry, I should have made this is where I will differentiate between N channel and P channel a circle at the gate is a P channel device no circle at the gate is a N channel device.

So if you are a P channel device and to make N channel device this was my gate this was my drain this was my source can you tell me since MOS transistors are identical from source to drain most cases they isometric in some case but otherwise source drain can be interchange, so why did I call this as drain and not as source why this upper lead here was not called so because they are identical.

I can call this drain and this source but I did not in N channel device which carriers make transport electrons is that correct since electrons come from source to drain the actual current will flow from where positive terminal to negative since the actual current is going down the electron current is going up that means source should be lowered and they upper side because otherwise electrons cannot move up is that clear that is where they are given such names.

So in same logic can you think what I did here which will be source here upper one because now holes also travels in the same directions as the normal current positive polarity down, so this is source this is drain and again gate is connected to drain.

So whenever gate is connected to drain, whether in N channel or P channel transistor will in enter saturation and as equal and resistance can be evaluated by finding the W value right the equation will do that and we know what if the resistance we are offering, so what exactly we did we replace. This is so called RD by equivalent resistors.

What is the advantage we get you are not done any technology unaware but just for the heck of it any idea why I am trying to replace resistances by transistors less area typical values of this resistance will be 40 K okay 20 to 40 K. Now if I substitute if I put actual silicon it will take more than 20 transistor area for one resistor okay.

So to an integer circuit what is our importance as many transistors I can pack per unit area that is the density of the transistor and that is what I am increasing every year okay that is what Moore's law said pack so if I put resistor all that advantage I will loose, so I am trying particularly integrated circuits will normally never use RD but for our circuit course as much if I put RD does not really matter because it is external.

I can go to the breadboard and by and I take some 40K resistors from the rack and put them okay we can test it but in real life when it goes to chip we never put any resistances on chip any day unless it is necessary in case of RF circuits so is that correct there are two kinds of loads N channel saturation P channel and the third one which I thought maybe I can show you here.

Which is this load transistor is there is a line shown here means already transistor is on without VGS applied and it enhancers VGS increases where does it shut off at minus VT ok at –VT, so this is called depletion loads, so there are three possibilities of course you can always say another one which is maybe more generic.

Let us say only N channel loads and this I call VGG if VGG=VDD then what is the status of this transistor VGG=VDD that means I am connecting to power supply it is a saturation that is what we did if VGG>VDD/1 VT more than a VT then what it will be status of this it is in linear mode.

So what is the resistance in linear mode extremely lower so linear and R is very low, so in some requirement if you want lower resistance what do we do we do not put it to VDD but put it to higher voltage and actually use linear a linear device there is that correct.

So that R can be further reduced in case as I am not saying where do you think R smaller will be required what R smaller means does current increase or decrease increase, so if you have this is what digital people do if you have a capacitive load here and this is to charge this what will be if R is larger what is the time constant larger, so switching frequency will be lower.

So if R is lower switching frequencies are higher, so is the bandwidth it connected to it is that correct somewhere power and frequency are getting related did you get the point larger the current higher is the switch okay lower the currents that is low power lower speeds coming up is that correct, so this is somewhere connected to us.

So our choice is not in our normal circuit we hardly care of power because we say a breadboard **(FL: From 08:55 to 08:56)** nothing can be done inside a shape like this so we have to be extremely worried about what power we actually dissipate per unit area on silicon chip and I if you have seen my graph microprocessor these days are considered.

So huge a power is like a rocket nozzle of a huge launcher rocket launchers see so many thousand degrees of centigrade there, so one has to understand that why we are worried to power specifically on a chip is that clear but not in so much in like if you have seen it desktop computers you see it is a big box a huge fan is sitting backside cooling it all PCBs are cooled by huge fans there it is running at very high speed around 600 rpm.

So what is it wonder there you have a space you have a fan you have power supply 220 volt no problems on a chip 1.2 volts supply or 2 or 1.5 volt supply of it battery inside and that is that so you have nowhere to run a fan there, is that clear and therefore on the this fact has to be understood because when you go ahead you should realize why sometimes we are so catchy about power because there on that chip.

We are only worried about power, as of now in our course I may not say so much but just to make you point why all this difference were shown because these are the kinds of amplifiers we may use in chip as well as on the bread put it that is called discrete and integrated circuits discrete we may never use this kind why do I use is I have a good register.

So this has to be understood that why I am showing you both all the time because in future you will be hardly working on a breadboard you will actually work on ships that correct, so you must know what is the difference when I go on chip designs or chip circuits there is a just, now I say different kinds of loads some of them I showed some others are also can be shown here.

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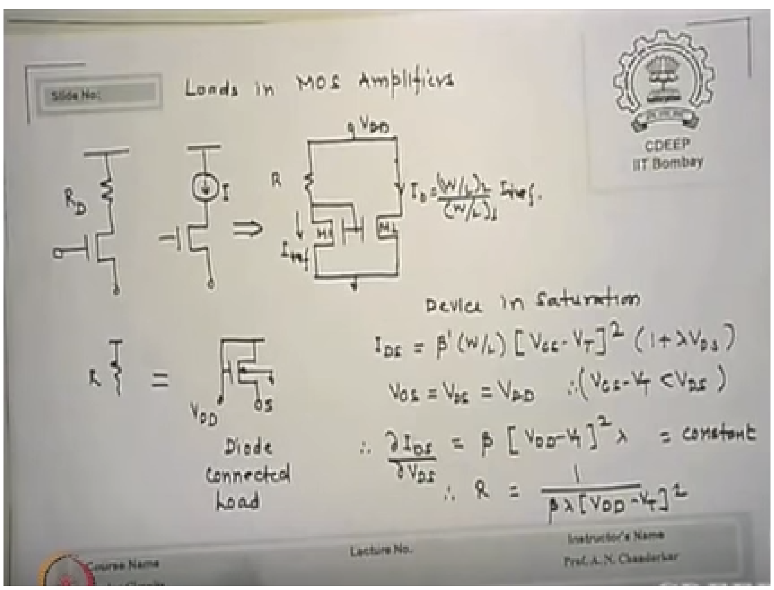

This early can be replaced by a current source since you say odd is higher a current source the output resistance is higher or lower higher if it is the current source the output resistance is very high, so I say if I put a current source here fixed current source which I can create from where a mirror you can see if I push a current here reference current this current.

I can adjust to any value is that clear this I can I will show you in a define how do I actually bias but just take it equal and current source can be transferred to an amplifier at the load by simple current mirrors okay simple current mirrors, now another thing which I just now said about the saturated loads.

How do I calculate resistance I connect gate and drain to VDD write the equations device if it is in saturation first assume in saturation let us say it is because VGS-VT>VDS=VDS-VGS-VT is always less than VDD this if I use this Delta IDS/Delta VDS is essentially the 1 upon R of this which is if I differentiate this so R is beta lambda VDD-VT is that clear.

So by what is beta contains beta dash into W/L, so changing the size I can change the resistance lambda is the technology parameter beta dash mu COX is the technology parameter VT is a device parameter technology parameter, so all that you can do is change W/L so different sizes of transistors will give different resistances is that okay is that okay.

So this is how the loads are created in MOS amplifiers last people is it clear loads can be created out of transistors themselves okay and what is the advantage I will say the area of this will be 100th of the area of the same for equivalent value of resistances okay and that is what we are really looking for how do suggest the entire by Delta V and inverse of that is your odds.

So nothing great happens just write equations differentiate and get your resistance that okay, of course this equation which I run you need not ready just want to show you that what is it you just I mean I just need not have it and on that I would have directly written here but I thought you should know why how do I cannot do it this is only to show you methods this formula is not relevant this is the method which I am showing how to evaluate RS in a transistors okay okay or something you can see okay.

Thanks for suggesting if you leave lambda Persie lambda is 0 for example this equation is quadrant I mean it is a parabolic equation okay.

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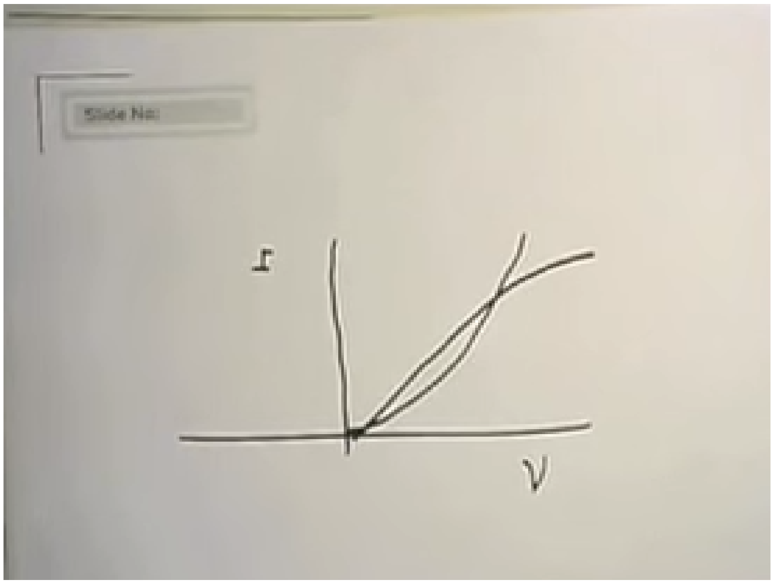

Now if you see a IV characteristics of a diode how does it look it is something like this and if I put a parabolic equation it is something like this, so it closely replicates the diode characteristics it is actually opposite depends on the parabola city it may be much higher or much lower than that but it in normal cases.

It would be almost as if following diode equivalence of that that is why it was called diode connected is that clear please remember this this is only valid when VGS-VT is small enough okay. If it is too high then it will go like this then it may not actually look like diode characteristics is that okay.

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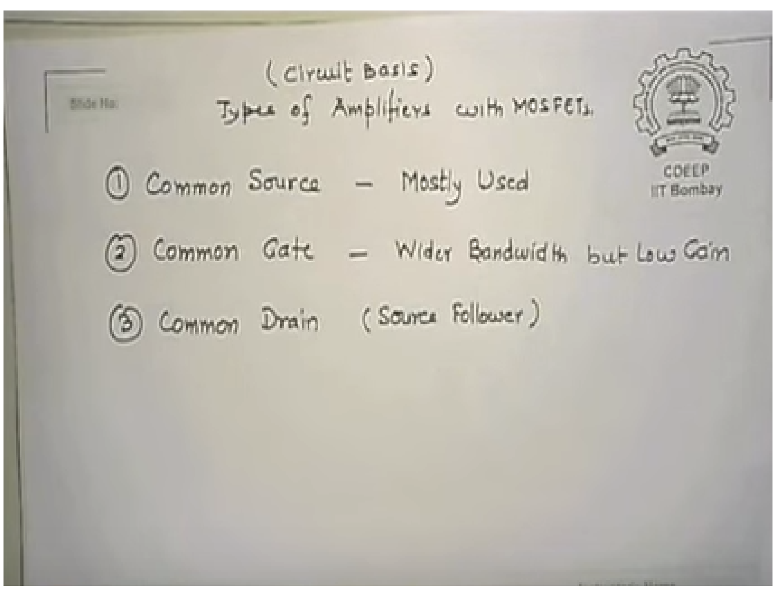

Why do I would connect it okay there are other ways of defining the amplifiers which is basically circuit based and these are in amplifier can be have a common source terminal what do we make common between input and output whichever terminal is common we say it is a common that, so if source common between input side and a drain side output side and we say common source the other possibility it may be a common gate okay.

Common gate is essentially what means the gate is common between input and output, so where will be input at the source side and where we will your output at the drain side gate is common between input and output and the last is common drain okay. Now this common drain is very important circuit for every one of us okay and it is also called source follower in BJT.

What it will be called equivalently source in BJT is what emitter so it is called emitter follower emitter follower is identical at least in nature has common source amplifier our common drain amplifier which is called source follower we will do some analysis for common source please read the mill ma of this server it does with book for bipolar circuits equivalent okay okay.

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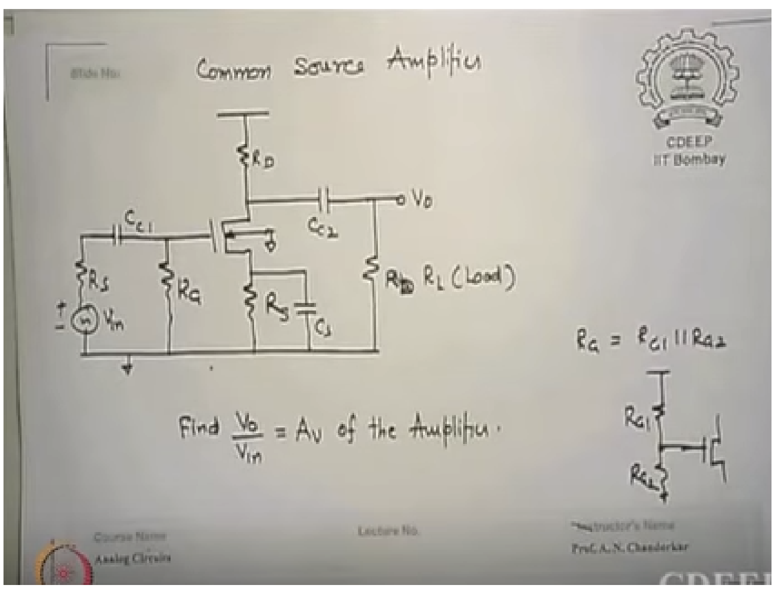

So here is the first amplifier which we did partly last time but repeat again you have a common source please remember now here is gate here is drain and here is the source okay now you are the source which is common to input and common to output therefore it is given a name common source amplifier.

Now the only difference between this and the other one is this source has a source resistance RS source has a source resistance RS which is shunted by a source capacitance S is that okay, so DC what will happen to this CS he has a DC means frequency zero is the impedance lower or higher I open circuit so for a DC as if capacitance does not exist CS does not exist is that okay.

1 upon Omega C if Omega is 0 the impedance offered it is infinite this CS will offer infinite impedance against RS, RS means open circuit 2 RS or it is the only resistance, so we say a DC capacitances are this capacitance is open circuited but there are two more capacitances I have put here their values also should be such that at DC value they should act like an open circuit what does that mean that the DC voltages.

Which I am going to apply should not get connected to power supply they should be blocked to power supply they may modulate other side than is that correct this DC value here should not get directly connected to input source, so what should we do there put a capacitance which is called series capacitance called coupling capacitance.

What does the decoupled in fact it should be called actually decoupling capacitors what did decouples these AC source from DC source is that clear source from DC source similar may from the output this is VCC VDD I want to remove this I do not want to couple this VDD which is the power supply DC power supply to the AC output which is V0 okay.

So is that point clear do at this point what will be the signal DC+AC I do not want DC to be outputted I want to only see AC amplifiers okay, so what should I do I should block DC this CC 2 is again the same blocking capacitor or a decoupling capacitor between power supply and the AC signal IC outputs so what should be their values should be 1 upon Omega C I want to be very high sorry circuit but for a lower frequencies or moderate frequencies.

What she did act whenever for AC signal it should get in, so what should be the impedance offered by these practically zero practically zero so what should be the values of them because

Omega are not going to be very high they are you going to use smaller frequencies as of now so C should be very high.

So typically some micro farad be decoupling capacitors are the is that some extra you may be doing you can think why we are putting a larger value of C in the series connections send therefore this at all the AC frequencies it should it should not actually should attach open circuit so what should be the value here.

Please remember I repeat for DC it should be open but for AC it should actually we are like a short circuit to RS I do not want RS to be part of my AC circuit, so what should be the value of CS please think of it 1 upon Omega C okay I want at a given frequency of operation this should act like a short circuit C should be again high in amp because then only it will act like a and which capacitors.

Normally, you put there have you seen there say electrolyte large value capacitors which we put across this device is that clear so this cease purposes at AC frequency it will short what RS but for DC frequency itself will open up and only RS will appear in the DC network is that correct this is how a amplifier biasing will be done not bias is done as usual it is a fixed bias are shown here are RG1 RG2 to to VGD and to the gate and equivalent resistance.

How much but from their own ends please remember here it is very easy no gate current divider is RG2 upon RG1+RG2 x VD that your eminence bias what you are want VS and how much is resistant will offer the parallel combination or that value. I have kept here as RG is that correct RG is nothing but RG1 parallel RG2 is that correct.

So that is but that resistance is not shorted or opened by capacity its bias it must sit here if if if RG does not exist what will not exist the DC bias for this will not exist is that correct DC bias will not exist this is the most important part in the actual circuit when I draw so having shown you a common source amplifier what do I have what is the my ultimate aim I must like I will like to find V0/ ok.

I think I we are making mistakes so we call it RS dash here because you know this RS is the source resistance so we start calling I our series R source or because R source is sitting here, so that name is should not get confused okay is that okay maybe they call it in the book I think if I am not wrong they are calling our signal okay our signal generator okay.

Our Sigma is what they are talking about okay fine if I had this circuit then I can draw equivalent of that at the input side you have an input source V in you have a series resistance of the signal source RS dash you have the RG larger resistance of bias Network RG and they have a gate here is that okay.

This is if you are just seen the circuit you can see this is the input side okay from gate okay this is my source from gate to source there is no connection as far as AC is concerned there is no connection between gate to source please look at the circuit again if you just a minute between gate to source there is an insulator.

So there is no connection between which is in contrast what if this were your base current how much current do probably going here beta+1IB so, there is a much easier case in the ones because nothing actually comes out from the other side so ideally device in some sense now for this other site at the output equivalent of that side you can see what is the output model.

We have said whatever is the VGS signal appearing here at the gate with reference to source which is grounded gm x VGS is the current source gm x VGS is the current source shunted by mod R0 which is the output resistance of the transistor ok output resistance of the transistor.

So this is actually equal on transistor source GM VGS parallel R0 what is this RD RD is the drain resistance which we have put there and what is this additional RL I am showing you here this is external load which I do not know this may be coming from external side so that is my actual load which may be RL okay.

So if I shall show you now it is R0 of parallel RD parallel RL now we also need to find apart from gains two more parameters what is the problem I said in connecting the two circuits in bipolar the output impedance and the input impedance are sometimes equal or bad okay one is much lower than the other so it is called loading effect.

Now I want to see how much is the RN and how much is the are out of my circuit so that can I cascade what do mean I cascade the output of the first stage is given to the input of the next stage is that kind it is called cascade so can I cask it another word which I am going to do after this is cascade what could it be different from what is the word I used earlier on I once said cask or amplifiers have one advantage.

What does what is the use over the normal amplifiers I said you something non we are not talking backwards so you are will not remember it immediately we said gain band width product of an amplifier is constant okay this is called figure of Merit if you increase gain bandwidth goes on we will see the expression later Cascode.

What it does it breaks this limit that is exactly what she doing the gain can be enhanced without losing turned width and that is exactly what all these years we were looking for I do not want to lose my again at the cost of increasing the banner or retaining bandwidth at higher gains okay this is exactly what Cascade okay so we will go to cascade amplifier later but let us right now think that this word should not be confused anything okay.

So what is VGS value if you look at this is there I hope that you have done basic circuit course reasonably good it is a simple mesh equation this voltage equal to this Plus this into being a potential divider and so it is our G upon RG-RS dash VN is your VGS and which is the case when it is equal to VN when RG is much larger than RS dash you can say okay.

All that input signal is at the available at the as VGS not this condition must be met is that correct this condition must be met if not you should use whatever value are GRS dash you use there it is something like sailing since there will be something in denominator larger than numerator it will be less than VGS will be less than vein but it may be 0.9999 volts.

So why should I worry about 0.59 I say we okay so the idea is to know where to end use these are all things which I am trying to show you in real circuits what do I assume in this course since you are doing analysis please write everything okay I am not giving you values so in analysis you should show what it is but in real life.

I do not use that I say okay this is past okay this has to be understood why we quickly do things many much earlier than others not because we cannot solve this we just know anyway that say okay at the output side what is the current only current sources gm VGS but the direction of current is what from drain toward source is that correct gm VGS but the output is always shown as +-.

So what should be the sign should be given opposite because gm VGS will actually go from like this but voltages are measured like this so we say V0-this minus is very important what does it mean in circuits minus means invert or a phase of 180 degree phase off 180 degree so if your input signal is in one phase the output is always 180 degree out of phase from the input this is the most important characteristics of a transistor that the output is 180 degree out of phase from the input which is always 180 degree okay.

If you manipulate some external circuit this 180+- you can do additionally and that is exactly what we do in our real life to change this phase I want but done the step per se will always give you 180 it cannot change it to 170 now in a 185 this is fixed 180 degrees - sign - is coming from where J square is that correct J is 90 J square is 180 is that current this J vector J is 90.

So J square is 180 J x J okay is that clear this is coming from very simple circuit theory so this is our 0 all these resistances look to be in parallel R0 R DRL everyone is in same across this so gm x R0 RDR l x V in is the output V0/VN is the voltage gain which is minus gm times ours parallel or d+ already.

However, this was under the assumption that VGS is Vin is that correct it was an under assumption that VGS is been otherwise what would I come here VGS and then what should I replace with our G multiplied our G upon RG+RS to make it same value as the gain is that correct.

If I would have said this is not V in but then RGS and I would rather pledge this VGS biology upon RG+RS times we in and another factor I would have multiplied here is our G upon RG+RS is not beauteous is that okay this is as simple as that okay.

So now you got the gate mosque gain so what it depends on R 0 is not in your hand to some extent it is in your hand what is it how does it how r 0 gets controlled by the lambda is fixed I'm like some fixed so ID1 upon lambda ID is IDS is R from where the bias Network ideas DC bias current is decided by the bias network VGS-VT.

Now that value is giving you capital ids is that correct DC value and that meant decide what the gm 2 pi R2 beta ids is gm so gm actually decides how did under your please remember gm is proportional to root of ids R0 is inversely proportional to ideas so by adjusting ids I can say it somewhere gm x R0 can be modified RDR a rod external ok.

So, the fact normally what will happen Rd and RL will be smaller much smaller compared to R 0 how much will be R 0 typically mega ohms we'll be already RL 300 tens of colognes in normal case Rd parallel RL will be smaller than our zero so you can even neglect our zero is that correct neglect our zero but otherwise there's a theory you can retain it.

So, by changing the bias current what does bias current means in essentially biasing point your operating points if you vary your gains will also correspondingly is that okay that is what exactly we were trying to show is that okay everyone has seen ok there are two more parameters of interest as I say for input impedance and an output impedance okay.

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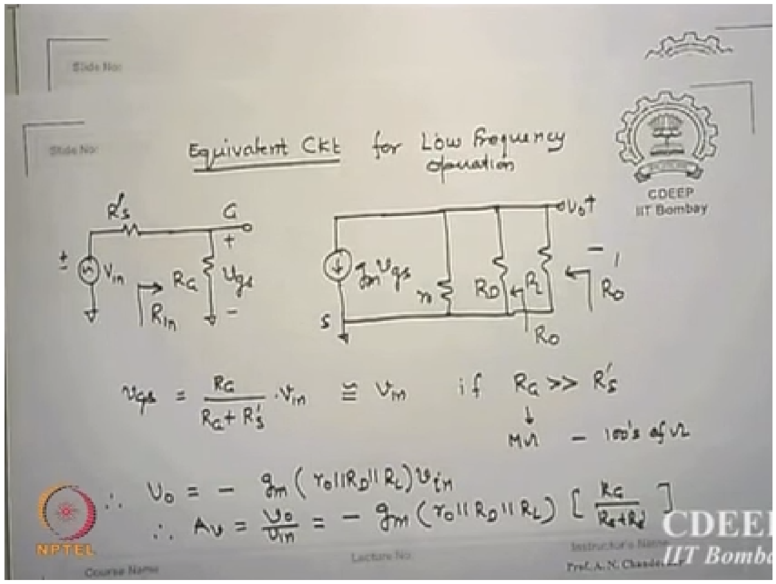

We show it I will give detailed little how to calculate for any network I think you must have done it if you are given a network you can always find the output impedance and an input how do I calculate these impedances short the outputs okay and from the input side apply an input source with an input resistance RS of you can even mix 0.

Whatever current and comes out of this VX/RX its input input by same logic short circuit all voltage sources at the input side is that clear open all current sources independent currents please remember this is independent actual sources short the voltage source open the current source apply VX at the output find the current entering from the dot node VX/X is R0.

So, the method is identical to the circuit theory which we are done sometimes by observation we'll use it otherwise you can always do this for any larger circuit is that correct this time this is so obvious so I did not do analysis so I just want to show you that this is what I am going to do normally RL is not considered to be part of output resistance Y it is external I do not know what people would give me okay.

So normally R0 is taken across RD even some people believe actually a should measure in SiC r0 also that is without even the drain resistance is that correct so it will be always r0 in most cases okay so okay if I do that then one can see from the circuit sorry there is no HL as seen from here this is the only resistance it is seeing.

So whatever current entering V/RG whatever is voltage here divided by r as RG is the current so this divided by that current is same as RG so input resistance is RG input resistance is RG very high how much it will be and my gowns because RG1 are digital and so are in mega ohms because of them will always there RG very very high is that correct RG very very high.

So input resistance of a MOS amplifier is normally decided by the bias network and typically is the order of few is that correct typically why I am saying typically because values you choose are generally I do not know if they smaller then it will be smaller as well okay what will be the output resistance seen again from here the same logic chard here then the VGS is only coming from here.

So, what is the resistance will be offered here you open this RD parallel R0 forget about RL if you see a resistance coming from the outside and if I put a voltage source and find current V by parallel this is the current this I am opening okay this I am opening so if I put a V0 and two paths that means parallel

So, V0 by is the parallel combination of R0 R parallel RD so the output resistance is R 0 parallel Rd typically R 0 is of the order of RD of the order of few kilo ohms tens of pinnacle ohms so what is the actual output resistance can be talked as RD so output resistance of a mass amplifier in a common source technique is just the drain resistance which I apply and that drain resistance decide what apart from it all.

So, please remember drain resistance also decide the operating point is that correct VDD/RD but this is doing the maximum current the load line is decided by the RD and the RD is essentially is the output resistance if you want accuracy you say RD parallel or 0 yes so what is that clear since I did not do actual calculations I probably messed up but otherwise you can think that by observation that is correct.

So, if RG is not RS dash I repeat RG upon RG dash is this is the gain of a mass common source amplifier is that okay this is most important in the case of if this amplifier will be having larger gain on a smaller gain okay the three amplifiers I told you which are the three I said common source common drain and common key gate.

What do you believe which will a highest voltage means gate is common to source and drain whatever is source will pass to drain that is what source drain current is same now so it is a unity roughly okay it depends on the load value that the input and output I say in both sides is that correct.

So, it will have it dependent on the values of already and I ask you are actually used whereas there is no GM factor there is no booster there in the case of source follower what does that follower means one so for follows what if it is a source follower what does that mean the output voltage follows input voltage as it is that means need unity.

So common source amplifier is the only amplifier which will you reasonable amount of voltage gains okay is that point clear so do you have to understand but then why the other two are so much talked about they must have something additional with them at the cost of what gains okay I do not have gain but I must be giving you something bitter which may still require you to use.

Otherwise, I will not study common gate and common drain why should I if I there are no gains no additional advantage so why should I use them so their wheels like to see if I change over from common to other do I achieve something else at the cost of something else is that clear to you this is what we are looking for other two amplifiers there is another common source amplifier which is very popular okay.

Another before we quit here this equation you can see there are 0 hat is equal to how much 1 upon lambda ID is that correct lambda is what parameter we called technology this is decided by the technology gm under root 2 beta dash, what is beta dash again technology W for external circuit like that has no controls for you and that is fixed by someone else all that I can various ideas is that correct.

So, if there is a change in this so-called technology parameters because of what environment let's say basically temperature even humidity changes but it is basically temperature if those value will change what will happen to this gain they will also change with thee particularly with the temperature is that correct.

So, if you are a design and amplifier in a system they should have a gain of say 100 or you know 40 it may either go down depend on the temperature beside those or may go up either way and then the next circuit will see different input voltage than what you actually plant - okay and they itself.

They also will get corresponding changes so at the end of the day cascading circuit may not show that actual gauge may be either much smaller or much higher in which it may saturate and it may not even amplified that is that correct so I am clearly worried that the gain function should not be a very strong function of technology if that happens then I say I am safe because then I know what gain I am using is that correct.

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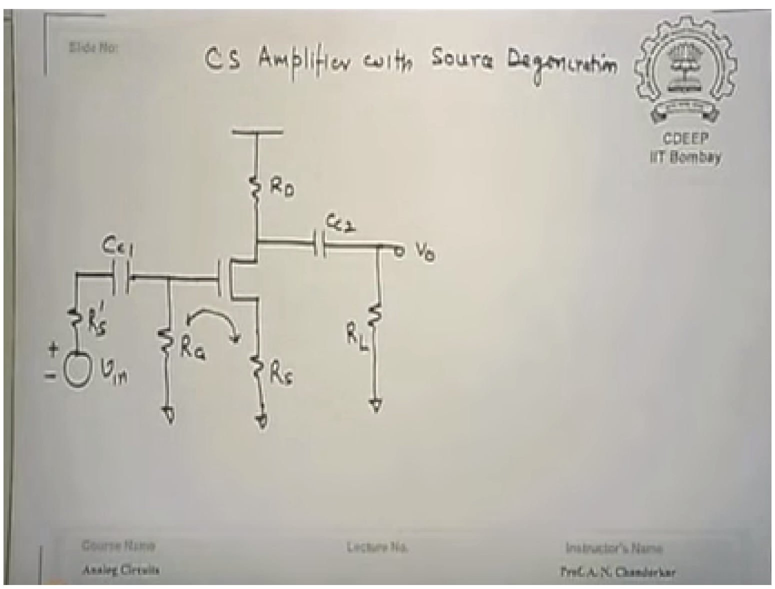

But, let us see whether this the next circuit does that I not what cost now if you see a what is the difference between the last circuit and this circuit no no everything else is same except the source resistance is not bypassed by CS that clear source resistance is now available to you both in DC as well as in AC is that correct is it okay.

Source resistance is not bypassed by any capacitance so this is called source amplifier with source degeneration okay now can you see RS for that AC equivalent circuit will short droid this will be now part of the input as well as part of the output earlier I have getting bypass so nobody is now you have a problem that RSA is common to both sides okay.

Let us say if I draw an equivalent circuit of this where does this RS appear and why should it then say the gain will be independent roughly independent of technology parameters is that clear why I am worried about technology parameter because the temperature is a strong which will increase do what you okay.

Even if you put a fan, why fans cannot cool very quickly all that which law does not allow that to happen Newton's law of cooling it is proportional to the difference of temperature nothing much I can accelerate it by removing the heat around but the actual cooling will go by a law of cooling is that kind proportional to the difference you are looking is that clear do you know you still they collect your loft Newton's law of cooling that their rate of cooling is proportional to the difference of the temperatures.

So, initially it will faster and then it starts cooling as you come closer to room temperature 20 or degree 2 23 degrees close because the difference is very small now so the worry is with us it is that ambient temperature you may remove but the actual cooling will be slowest is that correct now that means there will be a variation of gains irrespective whether you like you do not know but I would like I will not like that.

So I should do something which this circuit probably does the circuit analysis is almost identical the only difference do you see something difference in equivalent I have drawn down this RS I had drawn from source to the ground but remember this already and RL are not going to source now is that clear.

Where are they going in the actual circuit Rd going to the ground RL going to the ground but not going to the source because source is not grounded source has an RS going to the ground so equivalent have you seen this please look at this circuit this RD going to the grounded this RL going to the grounded this is of course your V0 and this is your source which is not grounded.

What is it so I should not parallel R0 from the Laurel now is that point clear the difference what is going to get is this that our DRL are parallel but not tunnel to R0 is that correct because they are to ground it R0 is only going to source because that is how I define R0 for the sake of it maybe we can say lambda is very small first case we may say RG is much larger than RS sorry.

This is called RS and we say R0 first simplicity this is your Vin with reference to the ground ok please remember this vein or this value is not same as VGS it is please look at the circuit again this VN because this is grounded but this is not rounded is that correct is that clear then is grounded but this terminal is not going to the source it is not going to ground but to this source so I now write a kiss-off law ok.

I start from here VN and I calculate the voltages how it falls so first case VM=Vgs this is vain so Vgs+ what is the current flowing in gm RS gm x VGS is the current flowing in the others that okay this is Vgs+ this drop I want to know what is their V into the ground this voltage Plus this voltage Vgs+IRS whatever flowing through this this is my Vin is that okay how much is Vgs I will find out so this is Vgs+GM x Vgs x RS=Vin is that okay.

I repeat this voltage Plus this voltage is the ground to this voltage is that okay the order this Plus this is this so gm Vgs x RS+Vgs=Vgs x 1+GMRS so how much isVgs now Vgs is Vin upon 1 + GMRS is your Vgs is that okay just solve this equation so Vgs=Vin upon 1 + GMRS is that correct if RS is 0 what is the condition we will get VNA's Vgs that is what we did if RS is 0.

Now I say RS presents all that it has to reduce something this is called degeneration the word is degeneration input is degenerated now by 1+GMRS okay compared to earlier but what is the advantage of doing all this I must waiting something out of it if this is open circuited same current passes through RS.

So GMVgs x RS is the drop across RS+Vgs must be equal to VN solve it and you get this expression okay simple circuit analysis.

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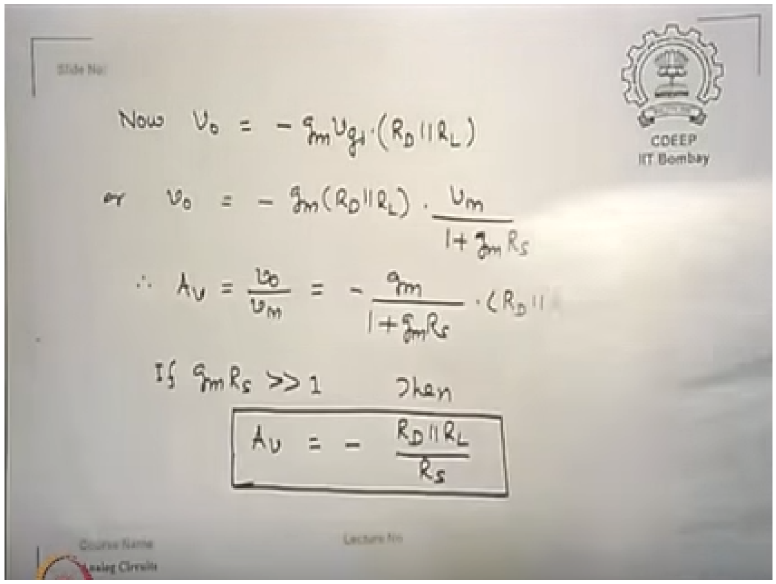

How much is V0 from here from our circuit analysis this current is actually putting gm Vgs is the only current source which is also passing through RDR l if I0 is infinite again the idea is are 0 to infinite so i write GM Vgs RD parallel RS is V0 then I replace V0 by how much VN upon1+GMRS.

So I get AV=V0/Vin-gm 1+gmRS x RD parallel RL ok I repeat if RS GM RS is much larger than 1 what is gmrs is larger it may be gm is typical of the order of how much tend to call - three or kind RS maybe 10 kilo ohms so it will be around 10 okay so you may say if gmRS is larger than 1 gm upon 1+gm RS is 1 and then you get a sorry then gm RSrs gm cancels then I get Rd parallel divided by RS can you now see the voltage gain does not have a term.

Which is technology related is that okay the voltage gain of a common source amplifier with source not bypassed or degenerated source so this then we get a gain which is ratio of load to the source resistance that correct none of these two terms are anywhere technology dependent what is the criteria only to do this GM RS should be larger than 1 or RS should be larger than 1 upon GM.

That is what I guess how to make it RS value so RS is should be greater than 1 upon gm gm is decided by the currents you are already passing in the DC currents so you find out the choice so now it said you must understand there is a problem in calculate on a bias Network you need an RS value and to get R>gm also you are neither any inequality going on there.

So, altogether says that both conditions are simultaneously satisfied is that clear what I said in calculation of a bias point operating point RS is appearing there also but the condition I am now say and gm is you are using so condition I am saying use gm 1 upon gm should be smaller than Rs okay.

So, you make some choice of RS first get that bias point using this and recheck whether that satisfies your proper by saturation active mode conditions and then also see that this value is equal right is that correct if that does not happen then you may have a problem of instability this doesn't happen normally we know how much to keep.

So that value 10 times is good enough for all cases okay so what is the advantage of this again all these will be order of our DRL will be order of few tens of kilo ohms RS will be of the same order so what will be typical gains will be two three four five typically the gains will be two three four five even one if they are equal okay so what does that mean we are achieved something at what cost and the cost of voltage gain I say okay.

I am stabilizing it okay I am getting now an amplifier which is temperature independent okay why it is temperature independent because even these are temperature dependent term R has a positive temperature coefficient but since they are in the same assuming same material carbon resistor the temperature coefficient of r and numerator denominator may almost be similar and therefore they are independent of temperatures is that correct is that clear.

So, what is the advantage I got if I want a very stable gain but not very large gains then I should use common source the D generated source resistance this is how so a very large cost I prayed I would have got a gain of I am now saying which we only though gain three that is exactly what circuit people want okay they want to know is it stable is it fixed okay that okay.

So ,come take so wherever the first phase of amplifier or wherever you feel that it is more prone to ambience there you first use a low gain amplifier which is common source degenerated source amplifier then I heard you may use normal amplifier for next boost which probably is away from it so that it is not that much temperature dependent is that clear.

So, this particularly happens in instrumentation or measure systems the sensor part is in an environment which may be bad okay so there when I boost the signal I must have a constant gain signal is that current once I come out of that then I can amplify because I have come out of the system is that clear.

So,the whenever there is an instrumentation sensor measurements the first stage should be this kind because it should give you almost stable outputs is that correct and then as views give the signal you have a 1 microvolt signal and you say now you are a 5 micro volt fixed signal the next stage may be a normal or common source amplifier is that okay.

So, I am not really worried about large boost but I want to get out of this temperature variation and have a good signal for me okay this is what essentially beautiful so two amplifiers we saw one is common source the other is common source with source degeneration here is some quick problems and not solid fillet I just want to show you how they are typically you are given a value of this is given from minimum or this our sorry say dismiss bit.

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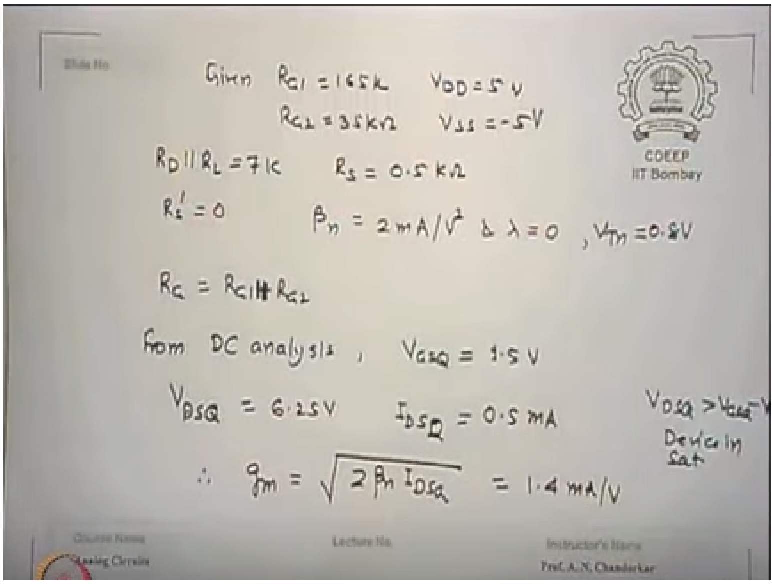

So, you can see the values RG is 5 volt okay in analog circuit in my first slide I show it is a dual oil supply what does that mean I said you may have a power supply on the top we decide + and at the source side dash but the actual voltage will be VDD-VSS and since it is dash actually of sums so if a 5 volt supply I want to use total.

So what should we do DVI says if they have to be equal to n 2 point 5 plus minus 2 point 5 done is that it has some advantage maybe in the quiz I will ask you today why I should have 5-0 is not as preferred at 2.5-2.5 there must be some advantage no differences in pipe.

So why I want to 0.5-2, there must be something more to it look at it okay right now the value chosen in from say does me these RD parallel RL is given to you 7 K source degenerative resistance is 1/2 K source resistance signal source resistance is 0 beta and is 2 millivolt, but lambda is taken 0 threshold is 0.8 okay.

What does this beta n means it includes W by L it includes W/L beta and –W/L together I have given your value of 2 milli ampere volt square so what is the RG value in our equivalent circuit RG 1 parallel RG to whatever the parallel combination from there the VC analysis by doe which I did VgsQ is given 1.5 volt vdsq is can I am directly in your DC points VgsQ is 1.5 VgsQ 6.25 ID current flowing is given to us how much somewhere given to us point five okay.

If not given assume it now okay o point five million then gm=2 beta and IDSQ which is is that okay if these values are given for given RG1 IDSQ I am given as point five milliamps then gm can be calculated as one point four million per volt is that correct please remember you must write correct units in circuits please do not say marks have been deducted for circle only unit oh it is correct sir Taher but correctly.

I make this but Mars may not okay so please remember every place your units must be correct okay, Aziza is given lambda 0 to infinite so what is the gain for this amplifier gm upon 1 +gm RS Rd parallel RL substitute all values the gain is 5.76 how much gain I told you it will be around 4 5 2 3 4 5.

So how much gain I got 5.76 are around 6 you can say if you one plus gmrs EMRS then our look at the valley now since GM RS is not very large compared to the other ones very large compared one without if I use this expression then I get gain of perp I am saying you this essentially means this identity is not correct in the value given to you here is that clear.

If gm RS is not much larger than one you may land in such situation you may get only you will get much larger gains which actually does not exist okay so in calculations do not a priori believe that gm RSA rather than one and remote okay.

So I intentionally chose this value from the book such that I will show you that I keep saying it is RD/RS RD/RS but do not believe me every time because the value is given will decide whether but if you do not know this and only do this it will take automatically correct value irrespective whether it is lower or smaller or whatever it is is that correct.

So this example was just to make a warning signal to you that do not go by just my statements because unless you verify this okay since we are as I say through our pedagogy who any Chinese equivalent common emitter source amplifier common emitter amplifier okay all this the amplifier shown last time also what is the what things.

I left in all equivalent circuits capacitances why I left it I say I am working at low frequencies and all of them are open or short as far as the requirements I am not considering them but where where I consider to them the high bandwidths I say up to where this will work at that time I will use full this and that is our next frequency response of an amplifier is our next topic.

So I am avoiding that just here to show that because that anyway is going to come here also CC1 CC2 CER so chosen that it acts like a short circuit for ace a short circuit for AC short circuit point you see otherwise for DC they are all open circuited I repeatCC1 CC2 and CER so chosen that they act like a short circuit for AC signals and open circuits for DC signals do you see this is identical to MOS there is if you replace this transistor by a master on this router they differ there is some difference is happening.

What is the difference happening this terminal there was how much gave to source open is that correct now there is a our pi is that clear to you the first thing you are now seeing that base is getting connected to an emitter through our PI which in the case of gate is that clear this is the major difference you are getting from bipolar 2 long as a reverse to bipolar now you can see sorry.

I forgot this I had still draw re for AC so I what did I do I actually put a short across to show re shorted this evil by path by path DC at the time but AC it will short the re itself in the circuit here this is R pi this is gm VBE drop across R pi this is R0 this is your RC this is your external load as what is shown earlier what is this RD or may be shown here what is this resistance RB be the bias Network are we want Arnold RB to RBB is RB 1 parallel RB2 same fixed bias.

We are done okay bias networks are b1y a journal a disc a parallel network hey our since in this case re is bypassed this is essentially grounded so one can say this hole is one connection everywhere which one for sorry I'm very sorry ah oh I told you no activity reveals so I told you that actual there is a RE small resistance emitter resistance is obvious emitter is not exactly the lead output there is a small re resistance there parasitic.

So we gave a name emitter dash inside to separate it from actual emitter need ups I repeat what I said this was a emitter dash and this was actually a lead outside since this terminal was given earlier books by Shockley the person who actually gave : he called emitter - so burst to emitter - is VB dash it can be called deep I it can be called VI it can be call anything this voltage across this is called BB dash because this terminal was given a name dash emitter dash.

Why because there is a re small capital R RS or whatever re as I said small to the small resistance associated with the emitter region itself in actual right now if not given all parasitic serve 0 RC0 this is 0 RS is 0 that okay if given then you use that huh so this is ground now because emitter is bypass now see will bypass the 4 AC.

So this is ground right now is that okay this point is ground I already said by at low frequency this is 0 this is 0 this is infinite please remember SC je+ see this should be infinite I want to open that across any capacitance the impedance should be very high okay Cirie's they should be short and in parallel they should be open is that ok.

So these are the conditions if I use the solutions now o RN is being my III which is you can see from equivalent circuit RN is taken this resistance and in this resistance in series r v RB parallel our IRB is RB 1 parallel this how much is RI can you see from here between this how much is the resistance seen our PI R PI so actual RI is only RPI is that correct but that will be paralleled by Harvey V.

So the actual resistance is RB parallel R pi and if RB is larger then what will be RB parallel R5 R be larger than R pi then it is only R pi is that correct so actual value you may see in your calculation whether it is coming close to our pi but in problem solving do not make any kinds of conclusions just parallel and see what value get is that correct okay.

So how much is the voltage across VR by this value VB-RN upon RN+ or dish or now RS is okay because there is no source there so this is signal source resistance so R in upon please take it this value please remember if this is our in RN upon Rin+RS x VN is your VB is that okay this voltage is this this Plus this into being as simple divider.

So that is the expression I use so typically it can be written as R in upon R in RS v in or VIN RB parallel or PI RS RB parallel R/ID everything and if it is less than RPI upon our purpose when if RB is also larger so what is the purpose of doing this why I want to know this PPD - why I want this voltage because of the output the current source is gm times that value so I want to know what is the value which I am receiving there okay is that okay is that okay so I calculate VB dash as just now I said and now.

So what is VB - it is just the divider between our PI and the source resistance you may Harbor I say Allah Allah expression I am giving you the real values quick check how much is you can see from how much is the actual value you are getting this we keep giving you all rinses because then you solve you know many time long expressions you forget some terms somewhere here there and then your value becomes very ordered.

So you should be able to know whether this values which you are getting is visible because it should be close to that value accuracy may be little more one point zero zero one is first one so if are you getting close to one or you get PI then why are you doing on that there were some bigger mistake you did is that correct so here these numbers which I am showing you is for this purpose roughly you know where you are okay, last part with a finish now.

So now the G outputs out your current source of course this is also grounded because emitter is grounded GM BB dash is the current source R0 RC RL are the 3 resistances in parallel output is V0 I0 is the current here entering like this since I 0 is entering like this for the parallel combination sorry not here it should be shown here.

So I0 is minus GM BB dash so what is V0 what is V0 I0 times combination of the 3 resistance is that okay that 3 resistance are is the output okay I see row are zero panel are see how her eyes eros - GM BB - is minus GM R0 parallel RC+RL VB dash so one gain at they are VB does it sell you can say called AV0 dash V0 upon VB dash - GM R0 RC parallel RL but I am interested in what gain not with Vvdash.

What gain I am interested in V 0 by VIN so I wrote a V is equal to V 0 by V in just multiplied by R PI upon R PI plus RS BN is VV dash, so V0/gm R pi upon R pi +RS R0 parallel RC Paula what is JL not pi dash in by beta let us call this whole resistance parallel combination is RL - then this gain is minus beta RL dash upon our PI plus RS more specific Araya plus RS ok.

Is this game technology dependent, beta is a temperature dependent term okay beta is so if I do not bypass re what will be gained now as we did last assuming that that resistance takes care of 1+gm is higher than gm 1 then what will you the value will get the load resistance divided by the source I mean the emitter resistance is that correct let us say R0 is very high which will be.

So RC parallel RL divided by re will be the gain in case emitter resistance is not bypassed and again it will be independent of temperature or external and is that correct that will be called what degenerated emitter resistor okay no bypass but the gain will fall from how much huge number hundreds to 5, 6, 8, 10 kind of thing here.

B ties how much 100 plus if the ratio is higher or even equal the gain is please remember even if load is equal to RI+RS because a 100 the gain you are getting is hundred if I use by an bypassed I get emitter resistor it maybe it is just RC RL divided parallel divided by RE that is it but it is independent of beta is that okay.

This is common emitter amplifier the emitter degenerated emitters okay earlier degenerated source okay what is degenerate word it is you reduced it okay the effect was correspondingly reduced on the gain okay therefore you degenerated by advantage you buddy see you then okay the final value.

I am sorry all 0 are out you see from here please remember external resistances are not evaluate akin care in calculation our output is y because our I do not know really okay R0 parallel are sealed that the only 2 resistances I have which is the output resistance is that clear is that okay.

So, 3 parameters you must tell me every time you do amplifier analysis which are the three the voltage gain the input resistance and the output all three parameters must be evaluated before we say amplifier design is or analysis okay, is that okay.

Now, so today we will stop here, next time we will continue with it little more on most other 2 losses.