Analog Circuits
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Lecture – 08
MOS Amplifier

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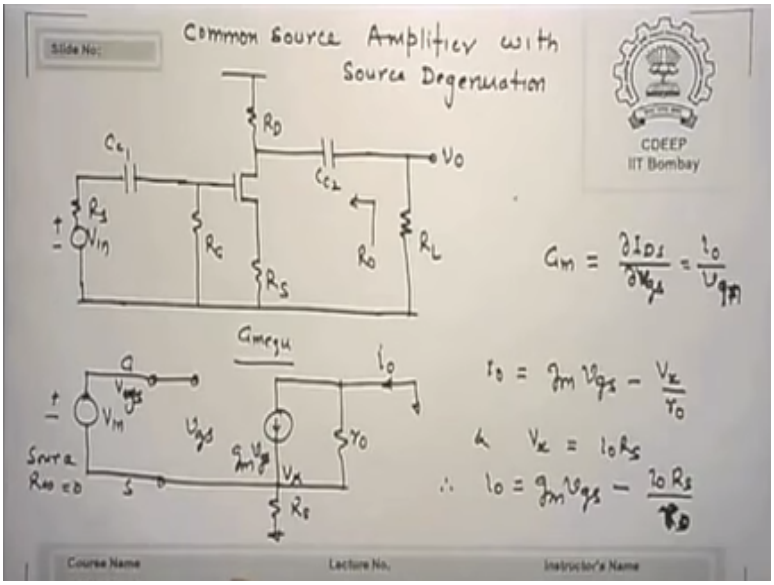

I just want to show what we did last time we calculate the actually put an equivalent circuit of that all that is difference now between the earlier comments first was that there is a source resistance which is not bypassed by the capacitor even for AC ok yesterday's question was asked something, where is the by thing that RG were actually was RG1 parallel RG2 to the VDD and it is equivalent for a AC RG is appearing okay is that clear someone are very the bias.

So you should know that it must have been coming from the bias network those who are there are many people ask me what is it the word origin stand from where it comes from okay so some parameter is in the equivalent circuit coming, so from where it comes from so for example a capacitance why it is there or how from where it comes okay in the circuit device sides how it comes okay so that was the word origin.

So I do not know why there was a confusion but if so please remember **(FL: From 01:18 to 01:19)** okay so, this is what we did last time we calculated the gain function last time the current

voltage gain is roughly equal to RD parallel RL/RS and we said what is the advantage of this the advantage is that that none of the 2 parameters have been of the 2 numerator denominator terms.

Have device parameter dependence no beta no gm or whatever it is and therefore it is even temperatures therefore it is very stable amplifier at the past of reduction of gain okay.

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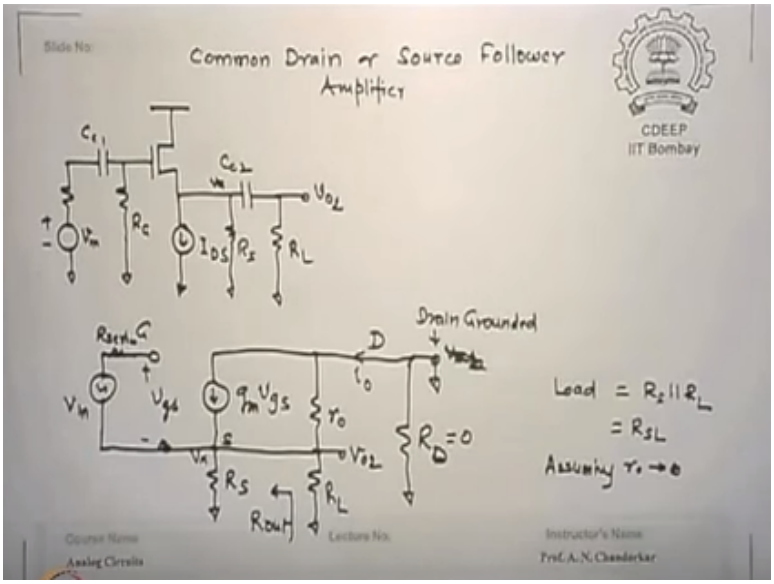

So this is why we still use these amplifiers then we also did something about the common drain or source follower essentially the difference between the last one and this is that this there is no drain resistance RD is 0 in this case RD is 0 that is why it is common drain it is going to the ground drain is going to the ground and the output is taken at the source itself output is taken at the source and this is that first resistance RS this is additional load resistance.

If it is there this is that RG1 which is the bias equivalent register RG2 this is our signal or our series whatever you call as the source resistance that source word is coming common source in the signal source resistance okay and then we say we want to find the gain of this amplifier initially we assumed R0 is very large infinite we opened it and this is your RD I made it 0 that means drain is grounded.

So, this already even if it would have been there it does no matter but essentially this node itself is grounded I am picking voltage at the source end there is a RS and there is the external load RL

okay and the please remember I am taking simplicity R0 is much larger what the technology wise it means R0 is very high 2 possibilities exist.

When are they will be very high lambda is very small close to zero or IDS is very small you are operating at very small drain source current but at that what is the risk you may have if the currents are very low what does that mean the device may not be in active mode of this may be just the age of active mode it may be closer to off state okay.

So, to lower current is not possible and to higher current will take the voice out of saturation into the linear mode and therefore gain we do not want to work there okay so this is the equivalent circuit what is the advantage of by MOS/bipolar one of the interesting thing it gives you that there is no connection between gate and source okay.

DC current there is no DC current between gate and source because of insulator in the case of bipolar what was that base collector base emitter junction exist okay and that means IB flows both through the emitter as well as through the base this path is not there in mass so it is much easier to evaluate because if there is a current common to 2 sides then you have a problem to hold okay.

So this is what we were doing last time its source follower and y1 follower I said output must follow the input can you tell me what 2 things it should do when I say output follows input for any such voltage or current gain or transfer gains. What are the 2 parameters are associated with that one is the magnitude one is the magnitude the other is phase okay phase.

So when I say output follows input it should follow in both sense what does that mean amplitude wise it should be roughly same and phase vise also it should be same is that means zero phase difference between input and output this is a major different from common source amplifier, which we did what is the difference there different that it will be and therefore it is much easier because gain is unity and phase is zero.

So now you can connect some input side to the output side without any great difficulty all that we must do is input resistance and output resistance should be tolerable, so that we can use them as a in-between buffer **(FL: From 06:17 to 06:27)**you know that RS the same old this idea I will write sorry you are correct okay.

You know that is how we do because then we serve in okay the next equation will come that then this Vin is equal to how much this volt plus drop across RS is that you what your point of view is taken care if this is not grounded then there is an issue will come be here will be equal to vein in fact okay but that is not true but what you are saying is very correct this input volt is done it and assuming our series is 0.

This voltage + this voltage is actually the Vin is that correct we understand of this no RG of course is across so does not have any problem across that this Vgs at cross Vgs is across RG so voltage across RGS VGS + drop across RS equal to input voltage if this resistance is 0 is that okay.

So this his point of view is very correct and all of that equations will go adios okay very good thank you okay having then all that analysis one can immediately say one can write RSL is the parallel combination of RS and RL R0 is treated infinite.

So gm Vgs RSL upon 1+gm RSL and VGS is way in IG0 a VA GM RSL upon 1+gm RSL if gm are actually you need not say you on or FL we should at least should be larger than 1 and 1 can be neglected the gain will be close to but it will always be less than 1 is it clear it will always be less than 1 because 1 plus something even if that quantity is much larger than 1 still numerator will be smaller than the denominator by small quantity.

If not greater, so any will be always lower the one that not need never reach 1 and since the gain is positive here. What does that mean is zero same phase so output and input has gain of one miss output follows input bounded utilize as well as phase vice this is therefore called source follower is that here in between equations.

I am not doing because we did it please remember circuit solving is identical use this voltage equal to this current is only flowing through this please remember R0 is only applying to RS and RL okay bad current=gm Vgs okay, just write the equations as we did for common source and same equations similar equations can be derived.

In case if I wrote somewhere it is wrong because essentially okay I think that that term should not occur this is not you all right but away this may not be correct that this other terms are correct no no it should be then we you know we are then you must actually replace Vgs/Vin in terms of please remember then I must replace Vgs in terms of then okay.

Then substitute being assumption is emitted always gm RS is smaller RF is smaller drawers are small that mean that this gain will come close to 1 otherwise this one will not be 1 it will be 0.95, 0.93 or 0.98 maximum value which I had calculated to show close to one so I wanted to remove things.

So that it becomes but in real life what she said we must solve a network as it is and get V0/Vin whatever terms you get is that correct this was done to show my only aim was to show you that it is close to 1 so I made me sheets that I can get close to one okay, what for example here is something if you have an RG and R series the Vgs will be something related to that okay.

As we did earlier and then we must find our energy again as normal devices okay, please look at it this solution I do not want to do it I just want to show you how do we worry about the solving a network is that clear what is the game just draw equivalent circuit put weight David as given to you and see which loops are you are getting to solve a 2, 3 equations.

If 3 unknowns come 2 unknowns 2 equations you should be always able to solve all parameters in terms of the other is that correct that is the technique we will follow throughout the course is that okay that is the books for example even in a common source someone asks you to find the disk not common so this source resistance follower there is a RS here there is a R0 here and please remember that RF is the source resistance R0 is the load resist.

I mean output resistance and why did I show you the opposite sign drill is down and sources up please look at the drain is down and source is up common gain please look at the circuit it is a common range you throw us a kilometer yet drain is grounded drain is grounded, so it is the opposite this from here.

This is current is entering the source side so from here the RS is going to the ground so, RS and these 2 are in parallel doing RL RL is external so these 2 are in parallel because this phase is now coming from ground your source, so the signs which are used there if you see clearly it is showing approach then this is RS.

How do we calculate the output resistance what is the method I suggests short R inputs all sources independent sources put at the output VX at the source assume I IX is the current starting from here the ratio of VX/IX the output is we are looking into this side okay so what we do is we write we change this equivalent circuit this side I already grounded okay.

They said we already grounded, so I get all X+ remember where is VGS not this VGS is here please look at this is gate this is the source is that correct output resistance is calculated where please keep looking at the source is that you are looking at the source this is my output so the output resistance is looking at the output side which is my output side this is my output side.

So I must look alright is that is output taken from the source so the output impedance should also be seen in to the source okay so if I do that which I did here the output this is my source this is my drain and this is my R0 is that okay, so this is so this is drain this is current source this is R this is R0.

So all right IX + gm Vgs is VX upon RS current through this VX upon R0 but VXS-Vgs why this is grounded no current between any of them okay this is grounded, so no current between source RG, so this is equal to minus VGS this is minus terminal this is plus terminal why it should be plus at the gate otherwise no current can flow VJ should be greater to make it current flow in the transistor.

So, Vgs has to be plus here minus here that okay so if I put VX=-VS then I resolved with expressions I get R0 is VX upon R so you can see it is gm VX+VX upon 1 upon RS + on gm can be written 1 upon 1 upon gm can be written as 1 upon 1 upon gm+1 upon RS+1 upon R0 what does the 3 1 upon 1 upon means the 3 are in parallel.

So 1 upon gm parallel RS parallel R0 this is the output of course here are actually converted back but otherwise these 3 resistances are in parallel that is the output resistance of a source follower can you now see is R0 very large compared to RS which one, no this is R0 will be this is R0 yeah perfect 1 upon G1 parallel.

Just write RS1 yeah well perfect that that is a parallel combination so 1 upon R is 1 upon R1+1 upon R yeah you are perfect okay for the calculation of low output resistance we should say loads outside because it is not our making it is someone else is going to connect, but when I want to have a lower voltage calculation I use that why because I want to know if that appears how much is I am going to actually get the output voltage is that clear but the measurement is R0 for what.

This device has an amplifier how much output resistance it is giving and with, which it should get compared then your point is well taken, all is parallel to RL and now we must see whether this is good enough or not good enough to change the output for the input for the next stage is that clear to you that is exactly. what we are looking how much is this R out compared to the wave which will be affected of not affected is that clear that is what we are really looking ok.

So we first find out what is the available R0 for us okay, so this roughly finishes the source follower what is you have to do it common source then we will get common source sorry this is me it is no current between these 2 this is grounded this was around it but the sounds are plus minus is that okay so this would ensure is minus of VRS.

This is zero input is zero no current between resistances this potential is therefore equivalent of a ground this is zero and this is V X but the definitional this is plus Vgs, so VX must be -Vgs is that okay circuit, why that okay yeah sure I am sorry you should load it thank you very much

keep doing this yeah always looking at therefore the vol cell nodes not externally leave it all of us look at insult their transistor okay.

I will look inside the transistor okay if you someone may ask you actual output resistance as seen by the main external live then clip RL parallel to that verities okay arrow dash you may call it and then power load up actually I guess terminal board with this R0 you have calculated this will be older than problem okay but in common so the output is taken in the brain enough, so we look at the drain and output wherever your output as you look into the at that point okay here it is in source.

So, I looked into source is that okay always remember wherever is the output without external or whatever impedance seen there is the output resistance okay whether the actual game later will want to do here we are going to work on something called feedback systems and what are we trying to do there we actually want to change gains I mean we do not want to change in that they will change the do we will be able to control this are in and all out that is exactly what feedback does okay.

We say why other feedback feedbacks are more important for what we call stability we are not done multistage so far and we will see what happens if there are more than 2 or 3 stages of an amplifier they offer so amplified output of that is given to the second trailer amplifier output of that given the first stage amplifier maybe I am stages how can we go in stages what are the maximum number of stages.

You can use and if there are are stages and if there are even stages what will happen to the output input relationship that is exactly what we will do in multistage okay and then we will see oh then it is becoming like your syllabear are not even oscillating what is the wall I said what does that mean can anyone think I said way is not an oscillator but it is oscillating.

What does that mean cylinder is fixed frequency is that clear you see nothing does not mean that it is a fixed really sir, it is varying amplitude is varying and phase also is very okay that is called oscillating systems what is the oscillator it oscillates at one frequency factor that is the difference

so amplifier the difficulty amplifier designs is something like this when I try to make a good amplifier is star docility it is called unstable okay.

Whenever I will start actually design and also no way that it should work as good this it will start getting amplification then we are worried it is amplifying, so design is interesting that when you want to control this something goes away so control that this goes away so how do you match that is all the circuit design okay here another last configuration maybe will do, which is common gate configuration.

We are done common source common drain finally common gate without thinking too much just draw the circuit and think why someone should do common gate at all this current source is given to V dash, this load sorry this is all D is going to be DD, this is IQ is going to dash we are common to VSS it can be also 0, but I guess other generalize I say it goes to minus please remember it cannot go to plus why current direction each other to perfection if oh I found an analysis cut the down or the current.

So, each other carry the polarity as unit you for positive potential niche and ETA - energy otherwise we took a well what I say its current source direction is at then current source is receiving B minus voltage okay it can be 1 0 okay it can be also 0, but it should not be positive and I told you yesterday there was a query all one of the five queries the major thing in analog circuit.

Which is different from digital it is all we need a times out of silicon JL to power supply is plus we ready dash vases or the VA says, which is the dash of that ok this is always analog circuit uses the advantage have anyone found this what is going on why should have a total supply in the case of analog digital we do not want it because there is nothing called dash video detector at 0 okay.

So I will not want that okay but in the analog I will prefer if it is dash delta plus that means zero shifted, there must be some something I am doing advantage by putting 2 wheels typically motor difference may be same they saw a power pole, so output we need a 2.5 VSS minus 2.5, so the

net difference is still Pikeville okay but I prefer instead of 5 to 0 which is called single power supply device circuits single power supply circuits.

They are also possible but a reference to them I say instead use bad VSS hop up or whatever difference you are even in value and half up there may be different values can be given is that okay so we like to see if not next where is the first thing I will tell you why dash you did okay in analog blocks do you see any disadvantage of this having dash in the case of silicon circuits if I make on chip do you see any problem in fire.

This now, we take a going on C dash power supplier to create one is plus and one is dash either externally I must supply you - and + or internally I have to create some by shifts something level shifters I will have to put curly and I have a water problem that I have 2 lines running everywhere every micron or every nano no is of importance if I unnecessarily then power supply lines.

Everywhere, I am losing that much area I am not doing anything with them so I would actually be for one minute but still analog people say please bye bye if you can us to power supply dash dual rates that is most important not that it is great advantage either I am trying to make do not think that will be gone honey melon nothing but there is still positive advantage.

If there is something problem of something I make you one word also reliability issues there is something happens if otherwise so think of it why we still go for dash voltages ok RS is the actual part of the world capacitance is for the external load when the signal goes to the external side I want to know how much is the external load then I do not want DC to be connected at the output which is external to me okay.

There are than 1 DC to go is that clear now here it is not, so here this CG is different from that no this is my device this is no actual load of the transistor this is external load so before I good external load here I want be covered this VDD should not go to the output this VDD should not go to the output.

So, always decoupled it is that ok this VDD should not go to V0 far stopped it is that ok at this point please remember there is a DC+AC is that correct we are only calculating yes he is fine but at this point both AC+DC are available to you that means on this water and DC voltage AC is running over it and that DC I want to make it zero so I pass through a capacitor and only AC is my past okay is that clear.

So that is what exactly what we are doing okay what is the purpose of this CG compared to this RG because whenever DC part is concerned I want this to operate but when I want AC I do not want that true means are considered in my calculations because if there is no RG this current source cannot provide that bias to you.

So I must show you there is energy sitting there if you wish you can see the way circuit could be also looked into I have it except sorry I mean II I saw the con operation okay this is so side this is the inside and this is good side is that correct suppose this is gate this is drain okay in a 90 degree RD a circuit because I want to draw equivalent of that.

So, J so please remember how they are all equivalent circuits I actually see the main circuit and equivalent Li put the components down is that correct that is easier to do if I do something and then I start drawing our 90 degree then that is why I always try to show you that the way I draw main circuit the equivalent should follow okay that is easier to draw no reason why you cannot show circuit like this you can always show like this there is absolutely correct okay

But for my simplicity I always show it take a breath of banana and I say input we want to view from here at this side so input output you want to collect here this should be common gate is that okay drawing the circuit is identical only thing is 90 degree shift at okay, this is your signals are the source resistance okay.

This is of code DC so nothing to be drawn here between source and gate is grounded please remember gate is grounded RGH bypass for this or gate is grounded source if this terminal Vgs exists between source and gate okay what should you polarity of Vgs J+ source- this has to be always correctly drawn okay.

Vgs is from source to gain there is a current source and how does it flow from drain to source after circuit nor the drain prefer silicon okay I suck up nervous So do into source so this is gm times Vgs okay this is your RD and this is your external load which is also grounded is that okay so the equivalent circuit is that clear there how do I do why or draw a circuit like this because then I can draw this circuit almost identically done is that correct.

So, please remember that this is not relevant per se as for a circuit and a bird is concerned okay but for drawing this if you draw this you know much better how to draw equivalent we are not interested in this we are interested in this so we want to know what is it okay where yeah right between source and drain there is a as you know right now.

R assumption is R0 is very high absolutely no problem no no it it only creates problem of solving equations now you remember not in the current path is this but also part in the are 0 okay part in the engine we all right what did I tell you in the class first day I will solve simple problems and I will ask you higher difficult problems now merely a mini up now simplification okay is that okay.

So, let us do that with no analysis now keep that circuit in front of you then doing another view if this is the iron current this drug Plus this one that is it they all this drop and why - and I put because this is minus plus Vg s from here on the top it is minus region so this job minus Vgs is your Vin is that okay last people is that okay.

This voltage is equal to this + this okay those are drawn okay from the input loop however this I will call HR I will be calling IRI any same is there any other source you see from here what is our in actually current this circuit if she hard problem in and then little different, but that is R0 is infinite that this current and this current are identical button opposite polarity GL Vgs is entering here.

I is entering here there are some currents there is no other current source here okay so you say I are arriving maybe -gm Vgs and therefore I substitute this iron here is - gm J so here is gm Vgs

gm r SE +1 x Vgs is that okay so how much is Vgs - how much is Vgs-VN upon 1+gm RSC is that correct so how much will be vgs be related if RSC is 0 they will be equal okay.

So, V0 is how much is V 0 from the circuit can you tell me -gm will pass through this is a correct the current out from here so the draw the cross this is –gm Vgs R0 parallel RL gm, Vgs are not our RD parallel RL bridges are just calculated VS I have just calculated is it ok, third bench is it ok.

So Vgs-Vm+gm RSE and V0-gm Vgs(Rd parallel RL) okay so what do I now go put this Vgs here then VJ in terms of V0 in terms of then is it okay what is the first difference in the case of mass transistors between drain current and source current so, V0 being gained a positive on Athena okay a key direction many change our rehearsal and put a drain the output same sense Madonna say after exactly there is that good say they are going to sales current the film direction.

If I will input at shows and color to the same side on the book there they should be of the same signs let us see whether it comes it is a because it is so that may become plus so V0-gm RD parallel RL x - V in upon 1 +gm RC so the voltage gain is press GM Rd parallel RL upon 1+RC please remember once again V0 and Vin are in phase.

So, in common gate what is that we achieved in phase outputs okay how much if the gain really will be assuming RS is 0 it is still gm x RD parallel RL as normal amplifiers is that correct but what is important here where this will be used very often is this find the current gain for this I0/I the exercise all amplifiers though I did not calculate maybe next some of them.

I was here, we must calculate all 4 terms which are 4 terms I said can you tell me voltage gain current gain input resistance and output and if there are capacitance what should be meu name should be input impedance and output impedance ok.

So we must calculate all 4 quantities in some cases we may know pour quantities also which can be to more in gains input current output voltage input voltage output current I0/Vin then V0/IN

so 4 trans conductance trans resistance voltage gain current gain there are 4 possible gains in an amplifier is that clear.

Now at times we want to use them as a current amplifiers at times I want to use them as voltage amplifiers at times I want to use amplifier the transconductance amplifier and at times I want to use the trans resistance amplifier each has a different applications then we will save one of them which dominates when so I want this kind so common gate is better or this is better or that is better which I should use for this there were 3 of this kind with of course.

So degeneration 4th one but any one of them should be chosen corresponding to the kind of gain maximization you are looking for okay is that clear in analog what are we looking 4 possible gains and see whether it matches one of you have 4 combinations available okay whichever gives you better results use that for us whatever you have an equivalent circuit we can always calculate anything to anything ratio of anything you tell us okay.

So we must evaluate all 4 of them and keep ready so such tables are available in books that is what all designers, Califf a Swiss Dominic Alec Callie can you take yes that is all 80% designer has pain in the life picture because they never think that your condition is whether exactly same as what they wrote R0 is current through the load okay.

But that see the other resistance is Pamela the net current the output please remember to share that I think I must honor her words we should not take there is something like this is that correct this is the output they may have done divisions is that correct the current output is here is that correct so you must take output at the output net current.

So, it may divide into RNA if we divide 2 are current is IC is that okay knowing that in parallel why should it only be there will be 3 parts coming will actually divide into 3 parts so the r0 is actually at the output terminal and not through the load resistance the output terminal you are you are very correct but let us look at it see the current in base whatever current coming from here will divide into this.

So, this current is what is outputted from the transistor this ratio I am looking are always connected from the drain side volt over everything we measure here at the drain current coming out is how much is that correct so this is my I0 and this we divide so the net current if I put a 1 node here not current is essentially entering through paths what you are.

So,why not only this okay you calculate even could this does not matter this will be a current which you are looking this is also possible but then I say something I say I0 here okay, yes for the in oh it is called short circuit current I always RSE okay that is another way of seeing soldering a circuit.

Maybe one day I will spend on how to use a new open circuit on a short circuits values that is a much easier method of solving larger circuits and I am allowing all of them simply because in my opinion if you do this kind of analysis it never gets into an error that is the method I suggest you because in my his shuffling is the easiest on such the systems is that clear I wish aggressive got 3 more methods.

I can show you well grounded people do not do giants when you are gm R0 as the output voltage sources, but different ways of doing things I am showing you my simpler method to tell you that if you want to make 0 error free solutions use this equivalent circuit and salt which will never get into an error is that okay.

For this the input resistance is vgs by iron but i win as minus gm be yes so Rn is 1 upon gm is that correct -Vgs has been that is what we said gm Vgs, Vgs by in is the Orang Harden is 1 upon G, how much is the output resistance output resistance method is what is the methodology short the inker input source since there is no current here this is grounded this is very small no Vgs therefore, no gm Vgs.

So RD is the only resistance there the are out is RD okay VX/Rx is already only how much is the gm value in transistors other day we calculated not in bipolar in the case of MOS transistor what is typical value of geodes order q IC/KT.

So gm high which may be millions math you know which keep the 38 millivolt million per volt Moss make, where you come over gamma, so it is of the order of 10 to power -4 or 10 to power -5 fans per volts is that clear, so RN1 upon gm is of the order of key is that clear that value should know typically a the order of 10k to 100k.

Depends on the bias current you are using is that it will decide on that and already of course if there are D value used for biasing as well as for the load so whatever is all D is your output resistance is that okay, so what is the advantage of common gate you saw from here the voltage gains how much was the voltage and we said gm already Karla Lauren is that correct that was the voltage so which is like a normal amplifier, but it is in phase with output resistance is low as input resistance is high is that clear.

What did we do by common gate the gain is like a normal amplifier it is in resistances of and its output resistance is now controllable by me how much already high pitch that is my R0 okay, that is exactly what it and it is input and therefore no problems of connectivity is that correct circuit can be connected directly from left to right okay.

That is the biggest advantage common gate gives another thing which is not showing here and we are not started which is called frequency response something else will happen for all 3 amplifier some larger bandwidth somewhere smaller bandwidth okay, so when the bandwidth issue comes again we will have to make a choice which one to use so that is the way we must look at okay.

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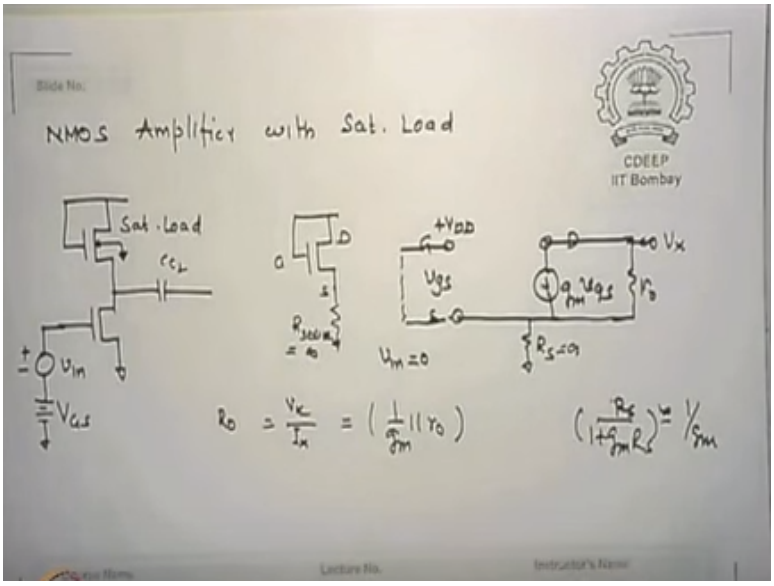

Before we quit this area quickly I will I will not solve all of it there are different kinds of load I say in the case of loss amplifiers one of the mass amplifier will have okay by the way this terminology you should use their input is connected that transistor is called driver okay and the resistance is replaced by a transistor that is called load.

It is like a load okay this is called that is called load this is actually equivalent of this nothing great and nothing very big okay this is our load this is input this is my driver this is my output this is the symbol this is what we will do so how to make saturated load I think gate is connected to drain Vgs-VT will be always less than VDS by design.

Therefore always in saturation so normally this source is equal and I say I shot this to get the resistance here this is like an infinite resistance here which means if this RS in a common source with source not bypassed is equivalent so you do this analysis for this VX/RX RX=1 upon gm parallel R0.

Which one will be dominating in this orbit for a given R gm 1 upon gm get 10k typically this will be always equal to 1 upon gm is that correct so it is equivalent deploys concept and 1 upon gm so that correct a saturated transistor load is equal and 1 upon gm of course if R0 is not very high then parallel whatever it comes okay.

But if it is R0 is very high then you can say it is almost 1 upon gm at first many African Indian this driver act like a series resistance for this amplifier or this transistor and so there is no current will flow because beam is going to be 0 this is equivalent of infinite resistance okay that is what occur, why I do not say everything look I thought you should think.

When our hints of wrong, this is called equivalent resistance is the source of a node which is infinite I just know her think of it why this is equivalent of in infinity this RS is tending to infinity for us so tip flowing sauce which K equivalent when I am in effect technique high key may I said they keep with me about other I saw a book when a Milligan.

What I am showing you is not given in a book on this is what you will do how do I would you know that means this is equivalent of that this is what I give a hint how to visualize let us go quickly on the games of this.

Here is very interesting equivalence of this gm Vgs is the source city there is no source resistance so directly Vgs is VN g MV years what is this R0 driver output resistance what is these 2 why I am drawing from the same terminal this is the drain please look at it this terminal is the brain this is ground for AC.

So whatever this load resistance is appearing here across to the ground is that where is that point clear Cooper Brown Eric those cognitive hold for ground nature now so that is exactly what this circuit shows this is ground lower terminal ground.

So gm Vgs is ROD 1 upon gmL ROl, I repeat this RL can be larger or not larger compared to living or not living terms alternately if you say ro D is much larger than 1 upon gmD ROL is much larger than 1 upon gm then one can show and this also has not so feel that V0/VN is gm do not have to say you remove these 2 arrow and a low D then gm it through 1 upon gmL is that clear.

If you open ro D and RL this current passes through only gmL is that one upon gmL so the output resistance output voltage is 1 upon gmD upon gmL l, what is gmD the transconductance

of the driver to beta and – W/driver into the bias current idsq/gmL 2 beta and IWI IDS what is this idsq the operating which we are not sure DC bias part.

We are not shown that is the bias current okay so how much is the gain essentially in the case of n MOS these amplifiers under root off size of driver W/L of driver divided by W/L of loads, so gain Veronica Lake a garnet a size of driver should be higher compared to the load is that okay so driver W while it is number of enough or load it nothing at all.

So gain whatever that is how we do gain adjustment in silicon chips and n mass amplifier on a silicon all that I will design an amplifier of this kind and will change the sizes to get my gains is that correct do you also see interestingly here there is no device parameter device basic technology device program except W/L.

Which is size which is controlling it sizes of course can vary this also the problem this w buyer and these W bias may not be accurately put on the silicon then the actual game may not be exact but this under root may help you please remember under it reduces something but it also reduces the error that is the advantage you must look into something which is bad for you who is not checking you know come on is that okay.

So this is called what are the others loads I can use this was an mass enhancement mode what the other load I can use and mass linear mode PGG which curve I have already calculate are for linear circuits so could that are there 1 upon beta Vgs- VT that value we know so we know what is our load for that what is the third possibility the accordant depletion road assets that you can deploy depletion load.

Finally we can use P channels with and channel together and that is what CMOS inverters are all about we normally use CMOS amplifiers for full range we call it inverter if you only use the transition we sampling there is no difference between the 2 okay the other amplifiers please look into the book which has my name also okay.

Before we quit for the day there is one interesting thing I said you earlier for a normal amplifier Omega T which is the figure of Merit what is the main Omega t means unity gain into bandwidth or it is called gain bandwidth okay, Omega T is essentially gain bandwidth how much is that I said roughly gm/CCN or whatever equal on okay.

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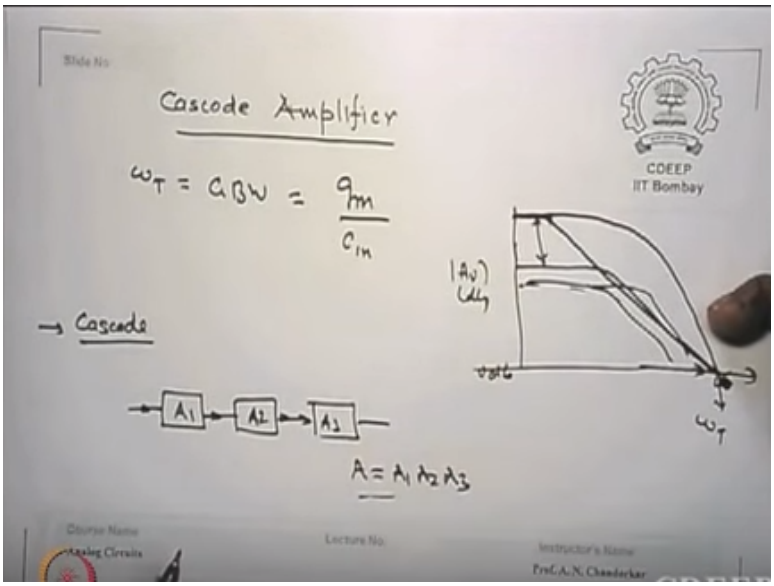

This is what we said fair enough so what is the figure of Merit I say Omega T okay, so if I increase gain I reduce bandwidth if I increase bandwidth if I increase gain reduce bandwidth I increase bandwidth and reduce gain because this is fixed is that clear, but that is limitation you said now, so essentially I said that is the maximum frequency up to which one gain at place should be seen all right this is creating applause I want larger gains okay.

I do not want bandwidth to be lost so something let is say we are not talked about right now gain versus frequency okay but what we are essentially this is sorry this is Omega T this is 0 DB this is called but which you are going to do soon okay frequency response of a gain function.

So, whenever gain becomes unity we say it is their FT or Omega what really I want is or if not this is that correct what I am looking for I may have this frequency where fall offers will be slightly reduced but the gain is however but it should hold on exactly at the same point is that correct so I want what is they call gain boosting what we did here is gain wood stick, but what we did not lose ft that correct normal amplifier method.

I saw a nice antenna this cake either bead out again to come here, so I want to see can I do this mischief now or can I break this what is called as technology constraint what if constraint this is constraint I want to break this here is the circuit this does that please remember what the amplifier.

Which is now going to be taught is essentially what is it going to do it it may boost again but will not affect ft is that correct me if I do that then what I did it broke on this technology constrained okay but some cost schedules go over point, but if can I can still do that that may be still acceptable to me then I have gained most impossible okay this is essentially done by an amplifier called cost code.

What is cascade I repeat if someone says cascade which we have to do but we are not done essentiallyA1, A 2, A3, input output next input lesser output next kind put this is called cascade a little drain it kept each a cascading ok what is again in such cases a will be A1, A2, A3 is that correct in casco, but then as you boost again what will according to this will happen the bandwidth

Now I want to see gain boost but not losing back okay so let us see whether difference between cask remember why I showed you immediately this what is that I am achieving cusp or enhanced gain is that correct Here I am enhancing the gain is that good so enhancement of gain is my aim but in the first case I do not lose my bandwidth or I do not lose my WT but in the neck next I will finally we got to a load start pulling down earlier and earlier.

So finally it may actually become somewhere like this I do not want that to happen sorry, so I do not want to use that kind of things okay.

So okay was I introduced skeptic next time calculator is barfly a figure of an and attend, idea like Jackie make ohms or why I showed you this common gate will be now visible here is the device okay.

Another source another way of biasing mass transistor if you recollect I showed you by mirrors or what we saw as current sources so many a times bias I that okay this is biased by current source i from this current from where it can come from the mirror from the mirror okay.

So let us see I take an easier case first maybe I will can replace the understood letter p channel or in channel this is the current source ids which is biasing the device.

Now I have two transistors in series first is driver and second I actually apply what we call V reference V reference is DC volt is that year V reference is the DC bias forward cleared VS/here okay which is for AC what is the terminal going this terminal ground common get my gate is common to both gate is common to this get it common to this does that weird.

So, here the common source lower transistor is acting like a common source call it M1, M2 for example M1, M2, so M1 sorry m1 is common source system, but M2 is common gate is that okay actually a digital circuit well actually the anthem bragging up for me what is this con this is called transmission gate or a pass gate whole logic depends on this path gate so whatever is being will be transferred to be out.

When the pi goes 1, if pi is 0 way out is the last way out is that there is a translator then conduct okay, this is called pass gate in digital this is one being used very often in digital here this is like now think of it if this so-called M2 would not have been there this is like a normal amplifier a bias equivalent resistor R0 of this series to this driver this is R0 of this series to this okay.

So, this is a normal M and mass amplifier with a load of R0 but now I put M2 in between so what is the way gain can be improved in this because there is no external load in the case of such circuits the gain I said you how much pain of such amplifiers are gm x R0 please remember R0 is the resistance of thoughts I mean current source okay.

So gm times R Escobar at a hill so it is quick I can increase by increasing sizes, but if I increase sizes what will happen capacitance will go I have so gm/Z will not improve for me okay so what

I say okay, care about this but can I boost R 0 please enough what I am trying I will boost are 0 so that my this increase the gm R0 and ances if this is R0 dash okay.

But gm1I kept roughly same as what earlier without this with this together gm if what is the gm for this full of this Delta IDS/delta Vgs is still gm together karma so if I maintain gm NU equal to gm old what I am going to get bandwidth will be WT will be affected or not effective no area change Jim is same ceasing.

So ft I fixed it otherwise but what I boosted is R0 so what I boost I will boost gain so now I have broken I improve the gain ran on empty so this circuit essentially and on says the output resistance is that correct this circuit essentially and on says output resistance huge number gain times R0 this will be gain times R0 gain of this into R0 will be occurring as the new R0 with not he is that clear the game if I change GM.

Then, I have a problem because then I change both okay but if I fix my gm then I do not change if they do not change bandwidth for that matter but our die change gains are 0 Bona Dea Costco's enhances the output resistance without losing genes, so this m2 allowed what is called Cascode allows you to boost the r0 of the circuit is that correct next time we will calculate this okay you.