Analog Circuits
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Lecture – 06
Biasing of Circuits

Okay, let us start we want to do a major work in this course is to do some circuits, which amplifier, so we are looking for amplifiers and as I said last time both technologies are possible using a BJT or using a MOSFET, we will both concentrate on MOSFET, but as pedagogy or as the word things went through bipolar came first.

So, let us give him some credit to it and then go over to MOSFET so I will not actually show you a bipolar amplifier I will say okay, if I change from MOSFET equivalent circuit to this equivalent circuit you can as well evaluated for bipolar but before that let me quickly see the biasing assembly in either cases.

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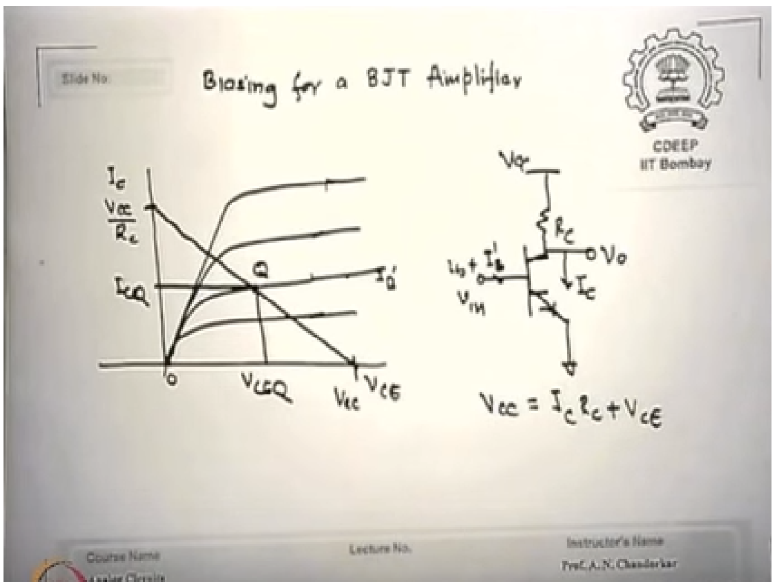

So, let us say I will do you have done it but I quickly want to go through for a BJT we already discussed earlier that if I have a circuit which is to act as an amplifier, I must some see that this transistor remains in active mode, so if I draw a characteristics IC versus VCE which is nothing but V0 and if I write this equation VCC=ICRC+VCE so this is a straight line this is a straight line.

So, if I draw the straight line on the same characteristics maybe somewhere something like this okay this value is of course VCC and this is VCC/RC this is called what load line so if I have fixed the transistor for a given capital IB that is the base current over, which small ib is going to be imposed let us say this is my IB, which is IB dash, we may call then the device has fixed bias current of base.

Which is IB dash which I can fix that is what I want to fix this is the characteristic at which on which I want to operate for the transistor IB dash is the base current IB dash is the base current, which is DC current. I want to fix the DC current for the transistor which is on this characteristics and if I done connect RC on this then I have a load line like this which intersects this ICVC characteristics at this point.

We know this point is called the operating point or the quiescent point and for this value the DC value of VCE we call VCQ and this current we call ICQ these are the DC currents a DC current and voltages at which the device is going to operate for given load of RC is that clear this is called the operating point or the quiescent point this is cause this is what we want to bias I want to fix for a given RC given I be dash.

So that I will have now this valve is fixed so what is the typical criteria VCEQ should have I can have a different load lines for example I may have a load line something like this or I may have a load line something like this what does J it changes the intersection of load line with the transistor current characteristics that means it can be here or it can be here sorry here or it can be somewhere else depends on RCI choose essentially.

That is going to change the value of VCEQ as well as ICQ if the device has to remain in active mode what should be roughly where VCE should be always it should not be close to 0 or small value because there the device will enter on this side saturation, if I have a very small base current that the device VB on may not be not turn on is that correct.

So I cannot have RC such a value that I have a characteristic somewhere like this then there is no base current available there is no transistor action available so choice of RC must be such that this VCQ should be roughly between or I should not say exactly but how roughly half of the VCC.

So if you keep around half the VCC it need not be exactly at VCC VCC/2 but around VCC/2 if you get your VCQ you are ensuring for any value of IB. You are always you will always remain in active mode so choice of VCQ should be such that you are always in active mode and typical value should be such that it is roughly half and done see if it is 12 volt or 10 volt supply is it 4 volt you have 4 volt is still well within the range of active mode okay.

So do not insist that it has to be 6 volt but it can be as close as possible to 50% VCC it will be ideal for you because it will guarantee your device to remain in active mode okay the reason we are not very much worried is too much because change in IB which I shown here is how much it will be small IB few millivolts.

So that variation in this IB value across this is so small that for the same RC value change in IC values will be also very small larger because there is a beta gain going on, so it will be larger than change in IB but still it will be small enough but that also should remain within active mode of the transistor to answer should not come out of this and therefore once I said that IC I cannot have large input signal because it may then swing device to the saturation or cutoff side okay.

So since we normally will never use larger signals this cause we may not actually work on large signal amplifier there are issues they are requirements but as of now let us say small signal we must therefore assume that by same logic will show you later that it must transistor if it has to remain in the saturation which is similar characteristics it should be half the VDD please remember it is not happy there I am close and number okay fire it can be 0.6 it can be away from the linear side.

It should be away from the cutoff side as long as device remains in active mode your amplification is guaranteed okay so these are the issues when I decide what value of RC I should choose or given and RC what VCC if I given where I am going to be to find the operating point this is what we are essentially saying when I say I want to know whether I am in active mode is that clear this is what essentially we say evaluate VCEQ and ICQ once this DC values are fixed.

We are done small signal analysis what do we do then we can calculate GMR the everything value required once I know by DC values I have my everything available on my platter to evaluate the small signal values and therefore small signal gains and small signal whatever we want is that clear.

So the idea behind fixing this is very crucial and therefore it is called quiescent point fixing or BJ amplifier biasing is very crucial for our small signal analysis that clear the small signal characteristics are governed by the DC or bias DC points and therefore they should be within your control, so that you can fix the other values as per your requirement of these small signal gains or impedances or whatever you are looking or bandwidths that okay.

So having told the importance of biasing let us quickly look for an example there are a few methods in which BJT biasing is done one of the simplest method you can see something like this is to actually connect a resistance RB and of course there will be RC okay. This may go to actually VCC sorry this is RC sorry this is your VCC point okay.

VCC point and this is your VBE let us take a case VCC is say 12 volt I have chosen some values so beta is 100 for the sake of it and what is VB on you shall always assumed in the bipolar 0.7 why what is the criteria we chose that that is the value H which diode will be sufficiently forward base emitter Junction is sufficiently forward biased is that some emitter collector currents are available to us okay 0.6 just on 0.75 saturation.

So we must remain in between 0.65 to 0.75 which is 0.7 okay please actually if you want to evaluate may not be 0.7 in real calculate if you do measurement may find 0.69, 0.71, 0685 do not worry too much evaluation is for assuming that this close to 0.7 okay, so that I assume 0.7 volt okay.

Now let us say we want this device to have VCEQ=6 volt and ICQ of 1 million this is the operating point I want to have that okay so that I is that layer this is 6 volt is roughly half of the VCC therefore will be roughly no it we are always in active mode okay then how much is VCE VCE is now by formula VCC-IC RC. VCC- drop across the load by a current IC is the remainder VC so VCE=this-drop across RC is that okay.

This voltage minus drop across RC which is IC RC must be the remainder is VCE is that correct and VCQ is what we have been given but this is the equation we should ah we can also say from this side let us say current in this is IB tell me what is the mesh you are getting from VCC to IB to this to the ground.

So anyone can give me another equation VCC=IB x RB+VBEon so our one equation here I have second equation here is that clear if I substitute the values given to me and how much is IB ICQ given to me is one milliamp therefore IBQ is one milliamp i 100 so it is 10 micron okay. So what is the value we are trying to find from this I want to know what is the value of RB and what is the value of RC 2 equations 2 unknowns.

We should be able to evaluate both values is that equation 2 equation 2 and everything else is known to us VCK is known to us VCC is known to us IC is known to us RC we want to know here this is known to us this we are we know now are we, we do not know but this we know 2 equations.

Which are 2 unknowns RC an RB 2 equations 2 unknowns always solvable one find IV value from here beta times that substitute here and evaluate for IV there or vice versa IC by something you substitute here and get the value of RB so I did this analysis is that where 2 equations 2 unknowns should be easily solvable and I get a value of RC which is typically six colognes and RB I got is 1 mega ohm or 1. 0.1 kind of thing this is a single resistor biasing okay.

Now there is some problem in this which you read in the book why this is not really preferred by C now one must understand what is the word I am saying why is not preferred is that point clear why valid not be preferred by saying or writing something go can go wrong with circuit you can see IC and IV are related through which term beta is that correct even actually VB on both this terms are temperature dependent VBEon may not be that strongly dependent but IC of this beta is very strongly depend beta is also function of I see the level of IC also decides beta.

So if there is a variation in beta what will happen from this what will what will shift accordingly there is a variation in beta values for the same RCRB values you have chosen what will be moving out the VCEQ and ICQ may not be same as what we actually designed for is that clear, so this is external environmental dependent the operating point is not always fixed is that clear to you is that clear as beta varies ICI.

We will vary accordingly and you are evaluated for a given value of beta RC RB values but now they are fixed but beta varied so VCQ and ICQ will actually not is same as what they were earlier this means the device characteristics or device parameter has interfered in your biasing is that correct and we will not like this to happen this is why I said such a this is if I say if X radiation happens here in denominator there is another same variation occurs it cancels.

Some if you say ratio of circuits okay what every there it may also vary here also beta is not coming into my final picture of biasing then I say okay I have a very stable bias points okay not that any system has that kind of 100% stable points but closer to this or better than this is what we are looking for never say that it is always fixed it will never be fixed but how much we can tall it how much we should be allowed to tolerate that the beta value.

Which is IC/IB small ic/IB there for the signal we are assuming that should remain constant within that range if something is not changing I dam care what else it changes as long as the slope there does not change very greatly I say fair enough okay, so I should always say in engineering that variation is going to come how much you should be able to tolerate is that your expertise okay.

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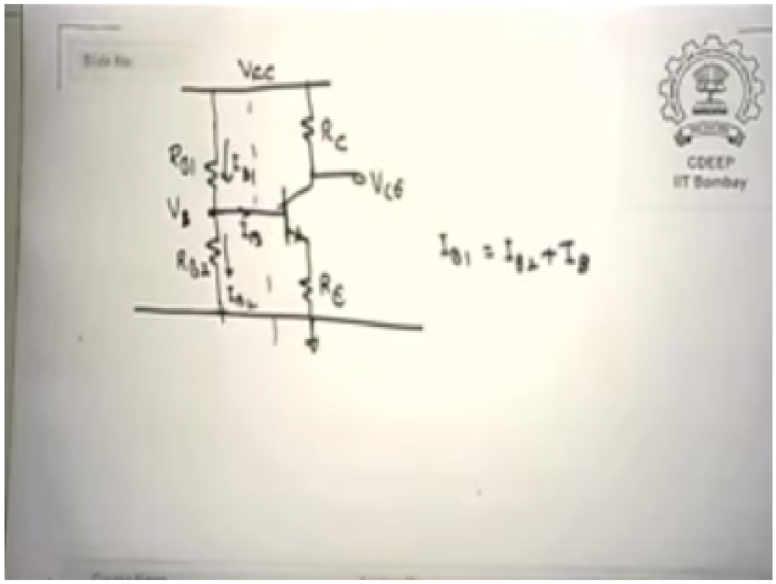

How good you can get is that one clear so this is something very trivial but has to be understood as analog designers or analog circuit people okay so other method which is most popular fixed bias methods is this sorry is that okay call this RB1 call this RB2 there are 2 ways you can solve this circuit you can solve this circuit or maybe one third way which is approximation.

What are the 2 ways I will say one circuit one way of doing is around this you apply to the left of this line what you can apply equivalently you can create an equivalent Thevenin source and the resistance for this, this is the VCC and there are 2 resistances that here this is a VC and there are 2 resistances so I can actually make it happen in source and Thevenin series resistance to that voltage source the other method.

Which you may solve later call you summon ins let us say this is IB1 and let us say this is IB2 but this current is the actual base current, so what is the relationship we have IB1 is IB2+ IB yes I agree with you the way it is at the we are applying at this node the Thevenin point at this node.

So a loop as if is only on this set is that correct the mesh is essentially on this side I agree with you but during whatever I put it when I calculate the currents that value will be taken care through the RE and other VBE values, so I will find what x equal and voltage I am going to get at actual VB value I am going to get I will evaluate that will be finally anyway I am I will first get a BB Thevenin and from there I will get VB value which is what exactly I am getting okay.

So as long as I get that value that that is what I am trying to say different methods will lead to a small variations one of this is if what is the current in IB1 will be VCC/VB/IRIB1 is that correct this voltage minus this voltage divided by RB1 is ib1 VB upon RB2 is IB dash sorry VB upon RB2 is IB2. If I know these 2 current in terms of VCC and resistances but I do not know IV right now.

I do not know I be but I have another equation if I look at the outside what is the other equation on the output side VCC is ICRC+ VC+ how much IE but I ib and IC double eight various weights one of course is this which you can use if you wish anytime or ie=beta plus one times IB and IC is beta times you can use I any of these expressions okay IC is beta times IB I is beta plus 1 or we can also say I is IB+IC now one can see from here.

What if there is a current flowing here okay is V will be now normally sources climb emitter is grounded there is no voltage drop we say this is grounded but now there is a resistance here current is flowing so this VE value will be how much IERE, so VE how much is this voltage then we will be IERE+VB on is that correct and if I am evaluating a VB from this side as well and I equate them is that clear.

So I can I will be able to get the exact value of IB I am evaluating at that point for a given VV I am fixing from there IERE+ VBE0 is VB, so I now 2 equations to evaluate VV equate them and I can then be able to get the IV value and therefore once I know IB, IC is known I is known I know everything else is that clear.

So the tricks of the trade is one method is use this technique I use this equation and substitute IB in terms of IC or I is okay or convert everyone into IVs which you are ready and solve for equations is that kind but there is a simplified method I can give you which is called alternate method you say when doing this if you say your beta is very high how high 100+ 200 150 100 or plus at least unread or move about how much typical.

I see you can get let us say we see says 5 volt how much I see you expect the highest of IC, VCC/RC so let us say RC is 1 kilo ma 5 Q which are let us say 1 kilo so 5/1 kilo ohm is how much current I can flow 5 minions, so the maximum current I am a flow for a 5 volt supply with RC of 1 K is 5 millions that divided by 100 how much it will be are at least one order or to order means how much 10 times is one order 100 times is 2 orders.

If IB1 and IB2 are at least an order or about 2 orders more than IB I can neglect IB is that clear I can neglect IB and solve so every time you need not do long calculations if your beta is given large enough but only thing in this codes do not do right now saying that I forgot and left IB no I tell you assume it is always value will automatically see that value is small enough but for a quick calculation people say how much.

So I can tell you how much because IVs will be smaller, so this current IB1 will be done equal to IB2 and short that is the divider okay that is a simplest divider, so I know VB without much thinking is that correct this is what when you will do in the lab when you go to the lab and let us say we are by seeing you need not worry too much about IV that time just use R1, R2 for a given VB you are looking for is that correct.

We not be exact but that is not needed because in numbers 10.001 is 11 irrelevant okay 10 is as much as 10.0 but 10.1 or 10.2 or 10.15 may not be different I mean they should not be said they are no different there is it equivalence change and for when to leave some things has to be verified is that, so I will give you some idea if beetle are higher IB1=IB2 just resistor ratio is good enough for is that correct.

This is what actual circuit designers do and they are on the board they just connect them and they say oh is coming why we are allowed to do this because we are not interested in VCQ or VBEQ or VICQ exactly what do we want to confirm that device remains in active mode if it is 5.5 or 3.2 how we are damn careful as long as I am within that, so even with this calculations if I get value of VC Q I CQ good enough to remain in active mode, I have no compunctions.

I do not worry on those is that clear so when you go on the I hope you are started your lab and some excellent have been performed when you do amplifier designs hopefully you will then you must someone ask you your TA I may not be knowing but LTS very easy sir you also learned from me okay quickly if I both elements equivalent. If I do Thevenin VTHV are sorry RTH at the base for R1R2 this I am calculating for this RD1RD2.

Now if I do this can you suggest how much would be VTH RB2/RB1+RB2 x VCC and how much is all short the source okay short the source these 2 if you shot this RB1 RB2 are in parallel ok so if I now substitute this equivalent circuit is that point clear what I only applied for the biasing network at Thevenin source and heaven is equivalent of a circuit is that clear last people is that clear simplest this is only representation of bias network as Thevenin source plus evidence resistance.

If I do so oh maybe we will draw the other circuit right here so that RTH, VTH and then from here you have a standard resistance RE RC this is your VC this value is known to us so this current is IB okay. I will give some values and solve for it now in circuit I know this if I am given RV1 and RV2.

I am given re and RC what values I will be given they were benign either the values of resistances will be given then I can find the operating point if I am for given an operating point then I will not be given RC and are being allowed to evaluate by design inverse operation for the same is that correct. What is the difference between analysis and design I repeatedly saying if the values are given when you solve for final operating point we say you analyze the circuit and got this operating point but in real life.

What is fixed important for you not the values of resistances or capacitance we are interested in operating point you know this is the point I want to operator if I want to operate at this point what should go values this while call it as design is that point the inverse of that is design if you go down from top to bottom you say you analyze okay, this course is mostly analysis sometimes I will show you the design aspect of the circuit okay.

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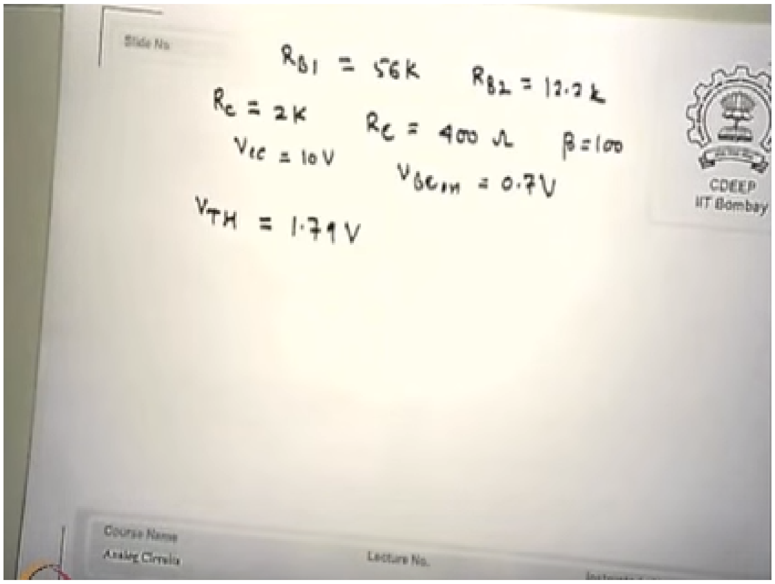

So I solve this maybe if you are noted I will just give some values I have chosen okay these values are not again very synchro angular taken from a book though this is a unsolved problem in I do not know one of the book notes I checked so but these are unknown I mean unsolved problems.

So I solved for my own sake whether I still do it on can do it or not hopefully I am able to do it every time I choose a problem okay oh sorry so I will calculate VTH which is 12.2 upon 56+12.2 x 10 volt and that comes out to be1.79V. What is the formula given RB1 upon RB2 upon RB1+RB2 x VCC is the Thevevin choice.

So that is 1.79 RTH parallel combination of RB1 and RB2 that I valuated as 10k so here is my circuit finally which you should look 10K, Thevenin source VTH=1.79 volt okay then this is my IBQ this is my transistor. This is my 400 ohms this is my 2k and this is my VCEQ so this is the equivalent circuit equivalent still not done government because we are not interested in small signal.

So we need not expand this transistor area a transistor this into equivalent small signal is that one clear why I did not draw the small signal of transistor I am only looking for DC values is that correct if I am looking for AC value then what should I do first I should break this into r dash everything which yesterday we did and then solve the circuit is that okay.

In this way are not done that because you are not interested in GM or R this value right now so we are only looking for DC this value is VBE on sorry which is 0.7 volt have we please remember I be Q dash into 10k+I x 400 is that okay so I would say VTHQ is 1.79=IBQ x RTH +V BEon + IE x RE how much is IQ I said in terms of IV beta+1 beta all practical purposes yes otherwise I must specify beta DC independent of AC beta okay.

Now using this equation I have valuated IBQ, so substitute IEQ/IBQ here IBQ here RTH I know this I know this I know this I know so I calculate IBQ as 21.6 my Crone's correspond ICQ is beta times 100 times 21.6 my cram which is 2 point one six million and if you wish I can also calculate IQ x 101, instead of 100 this is 2.18 just to get an idea.

We now let us calculate first the VB or VCQ how much is VCQ VCC-ICQ x RC+IEQ x RE known VCC is known so this value I get 4.8 volt so what is the operating point for this how do I specify operating point i CQ is 2.16 milli amp and VCQ is 4.8 volts what is VCC value 10 volts okay or how much I 10 volts are we close to half, so obviously these values must be concocted by me, so that I come close to VCC/2 okay I mean are they inverter I did I find where should be I close to that okay.

so is that correct the choice of RCRE, RB1, RB2 should be such that you come close to 50% of the VCC please remember this is not exact 50% less than good enough less because VC will be in linear. When it will be less than 0.6 volts anything less than 0.6 0.7 volt VC is now in saturation device is getting saturated is that correct.

So as long as you are less than Dow drop you are not in saturation is that correct so you can be safe as long it is more than one word was still in active mode but there the swings are very small because you are very at the smaller characteristic ends okay, so you should go a little ahead so around 3 , 4, 5, 6 is good enough to large RC what will it a to larger this what will it from create problem.

Let us say I choose eight words what will it means no just think of it in that characteristics our seeds should be very small so that the current because now you are looking for this point at much higher value so, where it will actually hit very high base currents is that correct at those currents the maximum current which device can supply from the power supply is not availability, so RC will requires the 10 ohms ok.

So the power dissipation will be so high that your circuit may not function is that good so too much VC is also not good to smaller VC also not good so halfway is what you should look is that as a decision maker you should decide. Where you should be around is half okay.

So this finishes bipolar the similar things can be done by other this type are the value also and leave ID and solve again and you will find that in all cases these value will be very close I must tell you if I leave I will be and solve for this I may get little bit 4.8 you may get 4.7 or 4.9 kind of thing not great changes will happen.

So what is the method and suggesting if you do rigorously also if you get close to same whether if you know unambiguously also will get the same but then you should do rigorous initially because you are not aware how bad or how would the system given to you but after an experience you know this is good enough okay. So this we start with our first wave of the this which is MOSFET amplifier.

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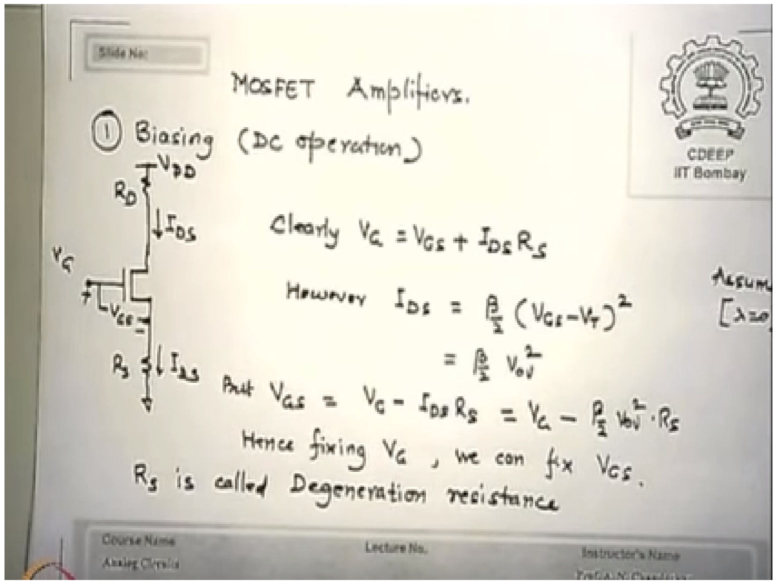

So before looking into other MOSFETs amplifiers which have different kinds first look for its biasing I repeat I keep saying by DC first why because DC decides the AC value small signal value so firstly look for DC values one of the circuit shown here are the biasing URF okay. The difference between bipolar and this the voltages are called VDD VDS VGS kind of thing or VSB if not stated VSB is 0 is that point clear if not stated VSB is what is VSB the substrate bias or bulk bias is if not stated.

So essentially if I am not setting you anything this is what I am doing is that clear if static then you will have to evaluate things at least what things you will have to evaluate for such cases if ESB exists the capacitance says those are direct functions our substrate bias yesterday we did that is not it otherwise for this biasing case we need not worry because these are DC cases capacitors do not play any role.

So we just look for DC biasing how much is the gate voltage from that this this is VGS+IDS x RS RS drop across this Plus this drop across RS+VGS is the gate voltage is that correct or in America say given a gate voltage first it will subscribe with yes and the remainder will allow us PS/RS as your ideas is that correct is that equation clear.

However how much since this is the DC case, I am solving how much is ideas devices in assumption is devices in you want to make it in saturation, so we start yesterday someone there is an issue correct but we wanted it so we assumed it okay and see that we do get that so we idea sis beta/2VGS-VT, what is the assumption I am doing in all DC cases lambda equal to 0 in small signal also I may use lambda 0 but where I will not use lambda 0 yesterday.

I said which case I will not use R0 because that makes it infinite okay, so only for that I will keep lambda otherwise on analytical solutions I may not use lambda often unless lambda is high point 0.0201, I said damn is that clear to you should sometimes you may say sir all that big things you talked about lambda and all that and now you are making every time 0.

So this is analytical solution otherwise it becomes nonlinear situation and difficult to analytically solve okay so this is beta/2VOV square VGS-VT is over voltage or excess voltage over drive so VGS is VG-ID SRS or VG-beta/2VOV square into RS is that correct so if I fix VG and I know how much VOVI normally will operate for a give value of RS what I am fixing VGS in I am fixing VGS.

Otherwise also from where if I have fixed my VOV what i am fixing VS because VGS-VT is VOV if I say VO is through 200 milli volt or 400 milli volts plus VT is the VGS is that correct, so VGS can be fixed from way varieties of way by actually right now I should not use VOV should write VGS-VT VGS on the other side because it will be 2 terms VGA is that here this VGS-VT will appear from here.

This is VGS a quadratic equation will appear in VGS and you will have to solve for it is that clear in their life right now. I would say ok the basic idea is I can get VGS of my choice by making a choice of RS and making a choice of VT and this is always if I am given a VT I am given b touch.

Then I know for a given RS what will be my VGS is that correct this RS will use this letter and very important is called degeneration resistance RS is called t generation is a very important role both in biasing as well as in the amplifier designs RS, RS is very important parameter that is source resistance which is extra this is not that RS is RS value which is source resistance of the device this is external input resistance which is RS this is external put drain resistance RD.

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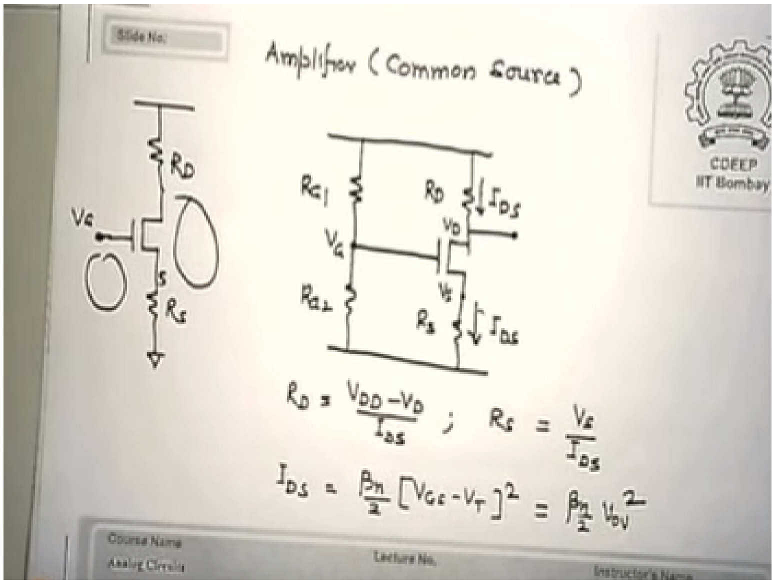

Now why I am showing you this the way I am now we will start by seeing is this okay I have an amplifier which is a common source is that point where why it is called common source is going to be grounded or at least going down and source is also on the 2 loops. Which 2 loops I am tying meshes 2 meshes I am talking source is on this side and is on this side source is available to you on.

So it is a common source between output and input is that where that is why it is given a name common source is common to output and Comma source is also common to input and therefore it is called common source is that clear, so if I have in common source amplifier this will look biasing will be something of this kind okay do you see it is similar to what we did just now for bipolar.

You can see there it was RB1 RB2 here I made it RG RC that it is already as far as Max is concerned I do not see anything different from what we did but what is the added advantage we got here they are in the bipolar this current and this current we also have this current IB is IG available within this no because MOSFETs do not have DC currents.

So then can you tell me how much is VG RG2 upon RG2+RG1 x VDD is this voltage divider potential divider is it okay since there is no current here that is what the case which case I am now talking I will be 0k small IV case is same as this case so this VG is nothing but RG2 upon RG1 RG2 x VDD is my VG now you see other equations RD.

Let us say this potential is VD so VDD-VD/IDS is already then RS is how much VS/IDS now here also one more advantage IE and I see they are not same that there is small change but there is an IB in between whereas in the case of MOSFET the current in source to drain is saved okay. so IDS is same part so side as well as drain side.

So, IBS upon IDS is RSVD-VD upon ideas is RD what is the grade our actual transistor current be TYN/2VGS-VT square or beaten by2VOV square this is the drain current IDS crank for the transistor I know this if I know this and if I am not given this I must be given VD obvious if I am given this I know the value of RDN RS or given value of RD and RS I will be able to get VDN this okay.

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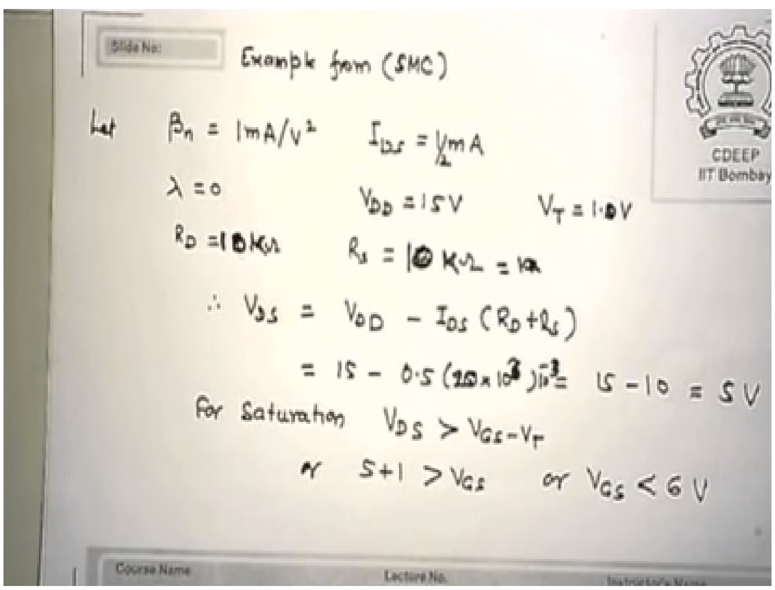

So let us do some calculations an example given from say Brian Smith and me okay here in the problem leads this is very relevant for us because this is what we are going to use often you are an example of same transistor biasing MOSFET which is n channel MOSFET unless stated otherwise all MOSFET I am going to use an MOS.

Otherwise, I will specifically say it is P MOS otherwise all transistors are used in this are n MOS beta n so even if I do not put N word where I should be done okay given to me it beta and what is beaten actually in numbers beta and - into w by l of the transistor.

So right now sizes have been taken EM, U COX is known and the total product of all that you see are W/L is 1 milli amp would slow let us say the bias current I am looking for is 1/2 million bias current I am looking for is 1/2 million I show right now lambda 0 VDD is 15 volt okay.

VT is 1 volt-high value at us but does not matter because this is given in the books I chose the same value Rd is it is not 10 it is a 1 kilo those are you both are tempted sorry. I am very sorry let it be Bolton I get any M so how much is VDS VDD-IDRD+R as in this case we do not have to IRS or I see and I hear same so it is IDS x RD+RS so I get VDS=5 volt VDS=5 fold.

Now for saturation VG VDS must be greater than VGS-VT, so VDS+VT should be greater than VGS so VGS should be less than 6 volt is that correct for device to remain in saturation VGS must be less than 6 volts.

So let us see now that R1 have to given to us whether that gives me VG which is less than 6 is the crowded at where to you given this current biasing for you I evaluated VDS which is my output is my operating point half milliamp and 5 volt are my DC operating point VDSQ and IDS squeeze half milli amp and 5 volt okay. Now for this I want to know what is that RG1 RG2 is that provide VGVGS which should be less than 6 volts is that here.

So let us do that calculations how much is VG how much is VG v JS VGS+IDS RS so our substitute VGS+0.5 milli amp x 10K, so VGS+5 is VG we also know ideas from this characteristics beta N/2VGS-VT so I evaluate VGS=2 volt is that correct VGS=2VG is 7 volt please remember.

How much is VG7 volt is that correct this is VGS is the voltage at the gate terminal I am looking DC5+2 7 volt how much is my VGH2 volt is it less than 6 volt it is less than 6 foot so whatever value you are looking for we already got now VGS>6 volt which means transistor is in sorry but it is saying other are you assume saturation and you are getting yes but as long as both side agree it is fair enough it is like a loop this changes that that changes.

This if stability occurs the values are okay is that correct it is something like this feedback system i change that you tell me but if you stabilize these are valid on both sides is that clear so assumptions are not very absurd though initially it looks or you are assumed and you are so proved obviously okay.

So for given what is VG value from the network we could find please remember what is VG we said if you see this expression how much is VG RG2 upon RG1+RG2 times VDD divided is that clear it is a divider, so if I use this expression I get VG is equal to RG to RG1 into VDD so 7 is RG2 plus this into 15 I evaluate a relationship 8 RG2 is 7 RG1 is that clear 8 RG2=7 RG1.

So I assume one of the values ofRG1 RG2 and therefore other is known to me using RG1 and our G 2 values what value I am going to get VG is always equal to 7 volt from this VG 7 volt how much is VGH too old for which my value guarantee that VG should be less than 6 volt is also met for which my current VGS-VT is going to be half million and for this my GDQ will be 5 volts.

So I achieved the bison by making a choice of RG1+RG2 if given values of already n RS is that clear to you so this is called design this is a bias network because that design word here I evaluated the value of RG1 and R-for a given as if I want this I want idea or 1/2 million I specified you okay why I am interested in IDQ what is it going to decide in mass transistor and a small signal GM under root 2 beta ids is going to be my gm.

So if I fix my IDS I know how much gm I am looking gm decides what again so essentially this ideas choice is the gain requirements is that correct the bias point which I fix is essentially I am looking at some gains which as someone is asking from me to design for is that clear, so universe problems you got it wire we do once why this one because someone will tell I want a gain of 100 again a 100 of 50 or 50.

Then I will have to do reverse calculation and see how much am I must provide you okay how much power I will dissipate so I should not go beyond this wattage so I will pick some values and start calculating back till I get some numbers of everyone say ok will meet all your specs this is what design is about ok.

So I do this ok before liquid another biasing which is very important for normally we may not do this in the case of discrete yes ok, you have a point because normally will come in the ratio okay typically it should be RG1+parallel RG2 should be as high as possible ok the choice of RG1 and RG2 should be such that their parallel combination is sufficiently much higher in value ok.

Typical even exactly the reason why I want that value to be higher will show you in a small signal case because that is first resistant I do not want to use ok it is not clear if that is smaller than that RS will hurt me here all but if it comes. I will use it I am care if it is smaller but it should not be very low because in consumed then power at this gate in which I do not know is that correct please remember the power is not only on the transistor side but from power supply to the ground through our g1 our g2 also is going.

So if I choose smaller values it may still give me a ratio of what I am looking for and therefore VG may be still correct but the power dissipation maintains because it is VCC upon RG1+RG2 a service is a square upon RG1+RG2, so I am worried about the power also which are them say but essentially that decides.

How much RG should be kept if I keep too high energy person you cannot get accuracy on those Argent no one makes those ton those resistances okay. So you have a problem you should be somewhere in between which is available possible and something which is good enough problem is that current and should be large enough compared to the source system ok some crap may engineering it exact question a choice code ok.

Then another way of biasing a transistor must understand this let us say this is that one is called current biasing or current source by see the word which is shown here is this but what I am really looking for is current source by see yesterday I had some days ago. I have solved the circuit for you amplifier which I showed you this kind of biasing do you recollect this amplifier first day I showed you a MOS amplifier and I say it is biased by fixed IDs this is called current source biasing.

What is it called that is the DC current in the transistor is fixed okay that is why it is called current source what is the advantage of current source what is the resistance it will offer equivalent of infinity square cross resistance in finite why I am worried this is that some people initially are 0.

They were asking what is the output resistance of mass constant RB R0 here and the resistance of this which I call ours our current source will be shunted across this RCS is that clear, how do I calculate this is for AC what is the power supply value we give you or what is the status due to VCC value for AC ground.

So if this terminal goes to ground this terminal goes to ground so these 2 resistors are in parallel so do you expect that if this RCS is less than R0 then this R0 has no value because this will going to decide RC is that correct output resistance of amplifier I want very high let us see but this okay.

So what should be this value should be higher than r0 at least a zero that is R0/2 Italy then I will get is that correct so the current source which I am going to use should have higher resistance of itself well as resistant as a Norton's equivalent is that correct. Now this how do I get is one of the method which I am suggesting is that clear to you ok let us look at it this is called current mirror what do you mean by mirror.

If I have something here is a mirror and I put something here I will see a image optics so if something in this arm I know a current this is my actual device which I want to use on an amplifier m2 is the transistor which I am going to use as a amplifier I want to fix this current IDs to for this fixed ok but I want to see that this current is controllable because bias point must be controllable.

So I see I have another current source I put somewhere here which reflects into this I can change this and then correspondingly this can be changed okay but once I fix this current is also fixed this is called and neither is that point clear this is called current measure now let us see why how it mirrors let us say I have a power supply a resistance R and 2 mass transistor M1 and M2.

How am how am I connecting them the 2 gates are connected is that is that layer 2 gates are connected but this common point of the 2 transistor gate is connected to the gray not and one is that correct is connected to the drain of m1 however if I connect then nothing will happen so this is my actual amplifying transistor and this is my major part there I connect like this now since the gates are common source is common which is right.

Now connect remember in many times in the transistor theory VSS may not be 0 it may be - also okay but right now we assume 0 but it can be - so VDD-VSS will actually adds really maybe 2.5 volt VSS maybe dash flying v polls is that clear right now assume VS is 0 okay. So how much is IDS 1 flowing in this circuit VDD please look at it VDD dash please remember there is no gate current.

So whatever current is flowing in are is same current flowing in transistor there is no gate current it is not a transistor biasing base current is not there also an neglect in case of bipolar mirrors we neglect that but assuming right now MOS transistor loan. So there is no wave current so this current is 0 so whatever current is coming from here is going down so this current is VDD-VSS dash please remember.

How much is this voltage VDS that says this point is connected to the gate so it is VGS1 is that point clear VGS1 is also VGS-and VDS1=VGS please remember this point is the VGS1 but this point then this point are same. So VDS1 is same as VGS1 I am shorting on this side is that correct so VDS1=VGS1 that VGS1=VGS2 because you are also conducting the gates is that clear.

So that is also equal to VDS1 ok but I do not know VDS2 right now I know VDS1=VGS1=VGS2 this is guaranteed by B by connecting like this since VDS1 is same as

VGS1 sorry I am sorry since VDS1 is now equal to VGS1 it is larger than VGS-VT so transistor is in saturation, so here one worry all the time whether transistor in saturation is met okay is that clear transistor is in saturation.

This mirror is most important in all integrated circuits okay so what is the current in the transistor beta N1-W/L x 1VGS-VT square assuming lambda 0 this is what I started with what is the current in the second transistor d time transistor ratio of size W/N VGS2-VTN square is that correct simple MOS currents are given for both transistors what is the conditions.

We are looking into beta and dash is same for all N channel transistors is that gravy COX is not different from different transistors so beta N dash is same, so these are seen W/L may not be same M1 may have a different W/L and M2 may have different W/L may not be seen however VGS=dash is that clear VGS on a are actually connecting gate.

So VG s 1 is equal to VGS dash this is same VTS are same this is same so if I take a ratio of IDS 2 by IDS1 what is the ideas to current yes transistor inner technology will have same thresholds is that clear unless absurd bias is provided for a specific transistor it is VT cannot be modified is that clear all change channel transistors will have unless stated otherwise will have same VT okay or at least VT0 will be seen is that clear all.

P channels may have a different VT but will also have same because since you said it yeah there are new circuits in digital where we are using multiple VTS but in analog no one and done so far so this is common these are equal these are equal so the ratio of IDS to buy IDS/W/L of 1 is that clear dash W/ratio of sizes, So let us say I want ideas dash same as IDS1 so what should be the size of M to the main transistor same as M1 okay all.

So I must know at least M1 sighs ok I must know M1 sighs then I know my M2 size for the ratio I am looking for if I want why it is called me read the word given what if ideas - is same as IDs 1 then same current which I have a reference is now given to the biasing current is that white is called mirror the current in my M1 which is called reference current.

Which I am fixing is same as what is in the M2 are in proportional to that twice thrice ratio of W bias is that clear man this ratio may be 2, 3, 4, so if it is for than 4 times the reference current I am biasing at the main why I want this game to be done because I am a choose smaller reference current for different circuit transistors amplifying parts I may actually bias them at different bias currents is that correct.

Let us say I am differential amplifier we will see next time or next time whenever you there the bias current will be different and a common source amplifier may have a different source current a bias current, so we must have one generation of current source which multiples of that can be given to different parts of the circuit.

So this gives you allows me to that is that correct however I know IDs one which I call my reference which is VDD-VGS1 dash visas which is equal to beta and W1 by this since I know all the values here I will be able to evaluate the reference given a reference current I will be able to evaluate VGS and therefore I know what exactly is the values.

I am choosing are for that once I fixed my R1 know my reference can if I know my reference current I know proportionately the output current or the trunk main transistor current which is being biased is that point clear, so why it is called mirrored because whatever in reference is mirrored to okay another interesting circuit which I did not show may be interest for something I can do something like this.

I have another set our transistor here okay and extend this here and what will be current in IDS 3 now while 3 by W/L 1 is that correct so now I that is what I say about you the choice different the proportional current in different I can keep changing is that here this is multiple areas can be given current from same source and this is a good current source because this I assaulted that this R1 have adjusted such that this acts like a good current source that we will see next time.

How to make this as a good current source there will be because this currents which I am using are H ensuring same VGS values reference is the first one the other one will be because biasing is done by current now naught by VG else current is proportional VGS-VT, so I fix the current I give into VGS, which means saturation is that correct that is the way I am doing now this is done in where integrated circuits.