Analog Circuits
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Module – 06
Lecture – 12

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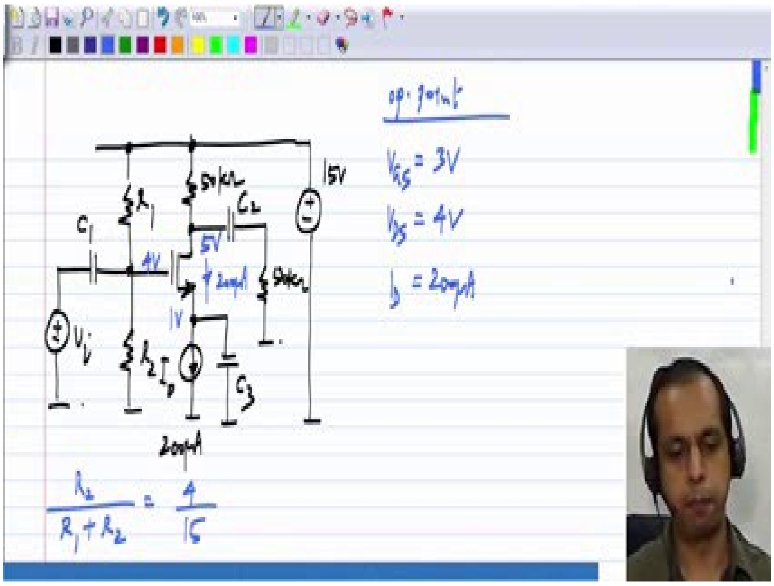

Now we evaluate the swing limits of this amplifier; what I shown here is a common source amplifier with source feedback biasing. The swing limit depend on the total quantities that is when the total drain source voltage becomes smaller than total gate source voltage minus the threshold voltage, it enters triode region. Similarly, when the total drain current become zero it enter cut off. So, first thing we have to do is to evaluate the total quantities in this that is operating point plus the incremental values. And I have shown in the full picture here what I will do first is to write down the operating point values.

The operating point values are V_{GS} will be 3 volts, V_{DS} will be 4 volts, because this node here I will assume that R_2/ (R_1 + R_2) is 4 by 15, so this will be at 4 volts. This will be at 5 volts, because this 200 microamperes flow through 50 kΩ to give a drop of the 10 volts, so (15 - 10) = 5 volts over here, and because 200 microampere current requires 3 volt gate source voltage in this MOS transistor the source will be at 1 volt. So, V_{GS} is three volts and V_{DS} is 4 volts at the operating point, and the drain current I_D, this is 200 micro amperes. So, I_D is 200 microamperes.

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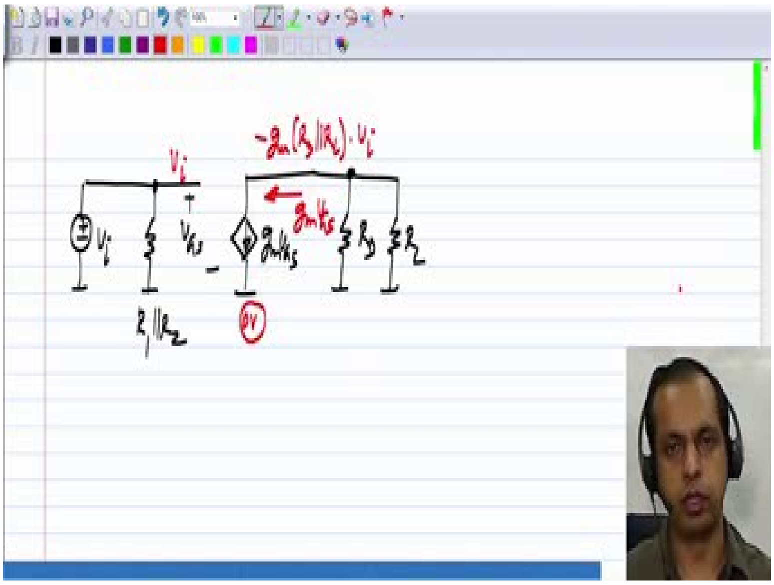

Now, what about the incremental quantities we can write down the incremental picture and evaluate. Like we discussed at the very beginning of the course, the usefulness of the incremental picture is to calculate only increments. And then we add to the operating point to get the total. v_i is here . I will assume that all the capacitors are large enough for them to behave like short circuits. And we have $R_1 \parallel R_2$, since the input source has no internal resistance this place no role at all. And we have the transistor v_{GS} with the source shorted to ground in the incremental picture. We have gm*v_{GS} and R_D and R_L. In the incremental picture, the source is at zero volts that is the incremental source voltage is zero which means that the source voltage does not change at all. At the operating point it was at one volt the increment is zero it will remain at 1 volt. The incremental gate voltage is v_i , and the incremental drain voltage is -gm*($R_D \parallel R_L$)* v_i . And of course, the incremental drain current i_D is nothing but gm* v_{GS} .

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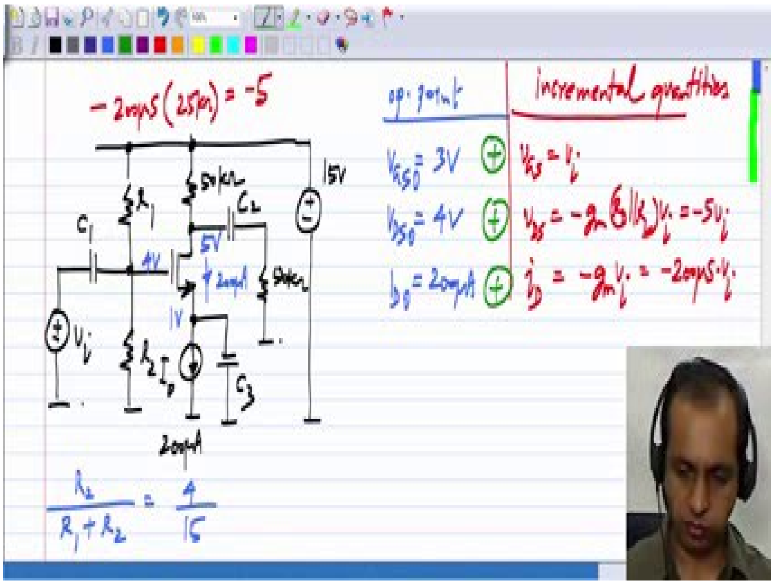

Let me refer to the operating point quantities as V_{GS0} and V_{DS0} and I_{D0}, and the incremental quantities will be $v_{GS} = v_i$, because at the gate you have v_i , the source you have zero, and $v_{DS} = - g_m*(R_D \parallel R_L)*v_i$. And this particular case it is $- 200\mu S*(25k\Omega)* v_i = -5v_i$ and the incremental drain current $i_D = - g_m* v_i = -200\mu S* v_i$.

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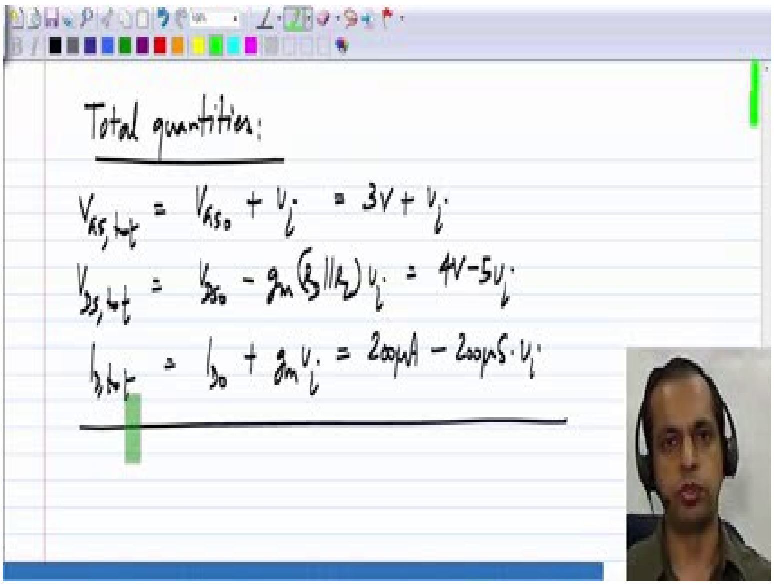

Now to get the total quantities what we have to do is to add the operating point to the incremental quantities $V_{GS(total)}$ is $V_{GS0} + v_i$. In this particular circuit which is 3 volts + v_i and $V_{DS(total)} = V_{DS0} - g_m *(R_D \parallel RL)* v_i$ which is 4 v - 5 v_i and the total drain current($I_{D(total)}$) = I_{D0}

+ g_m*v_i = (200 μA) - (200 μS)* v_i. So, now, that we have the total quantity as $V_{GS(total)}$, $V_{DS(total)}$, $I_{D(total)}$) this means that whatever the variation of v_i is at every instant we know $V_{GS(total)}$ and $V_{DS(total)}$. So, we can calculate when it is enters triode region or when it is enters cut off and so on.

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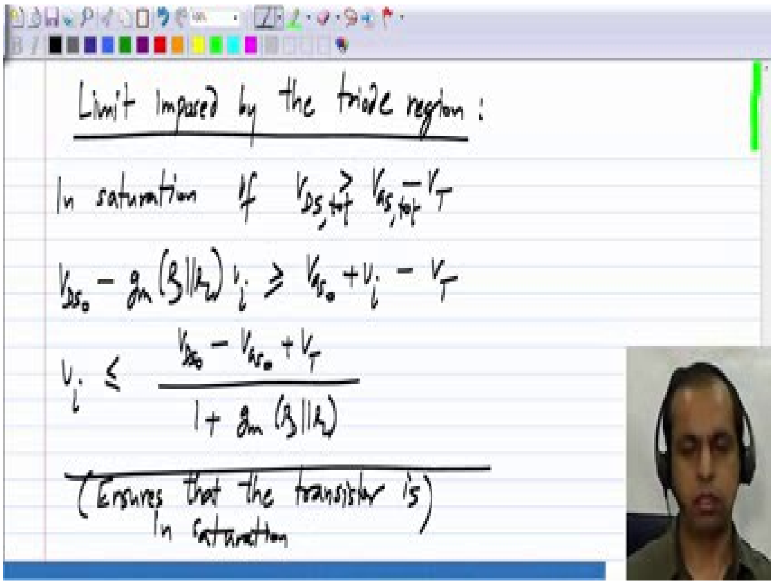

First let us look at the limit imposed by a triode region. Now the transistor remains in saturation. If $V_{DS(total)} \geq V_{GS(total)}$ - V_T and otherwise a $V_{DS(total)} \leq$ $V_{GS(total)}$ - $V_{T,}$ it enters triode region. Now to evaluate this limit, we just have to substitute the total quantities in here. So, for it to remain in saturation $V_{DS(total)}$ which is V_{DS0} - g_m*($R_{D||}$ R_L)* $v_i \geq V_{GS(total)=}$ .V_{GS0} + v_i - V_T . By rearranging this inequality, we get

$v_i \leq$ (V_{DS0} - V_{GS0} + V_T) /(1+. g_m*($R_{D||}$ R_L)).

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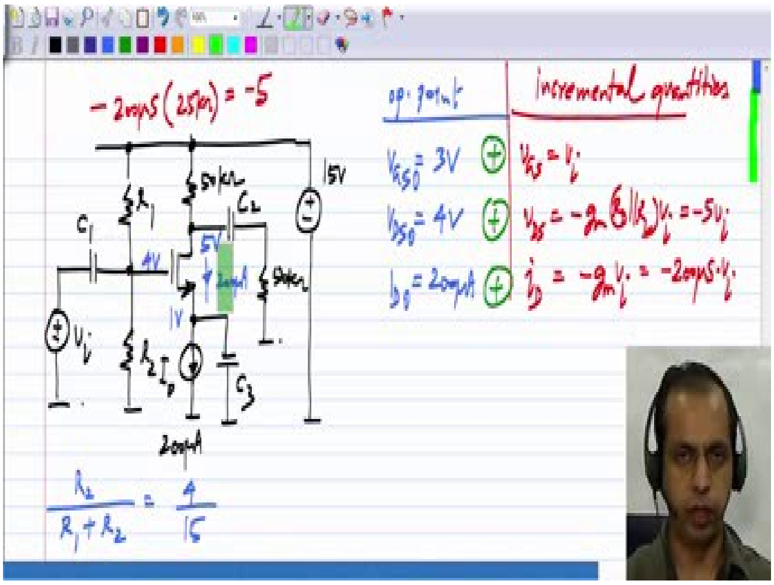

So, this is the limit as long as v_i is less than this the transistor will be in saturation region, Now intuitively it is clear why the transistor may enter the triode region, it happens when the gate swings positive that is when v_i positive the gate voltage increases beyond it is quotient voltage and as the gate voltage increases the drain current increases and as a drain current which is being pull this way increases the drain voltage will fall down. It is also obvious from the incremental gain of the common source amplifier, which is negative which means that when v_i is positive the increment here will be negative. So, as the gate goes up the drain comes down.

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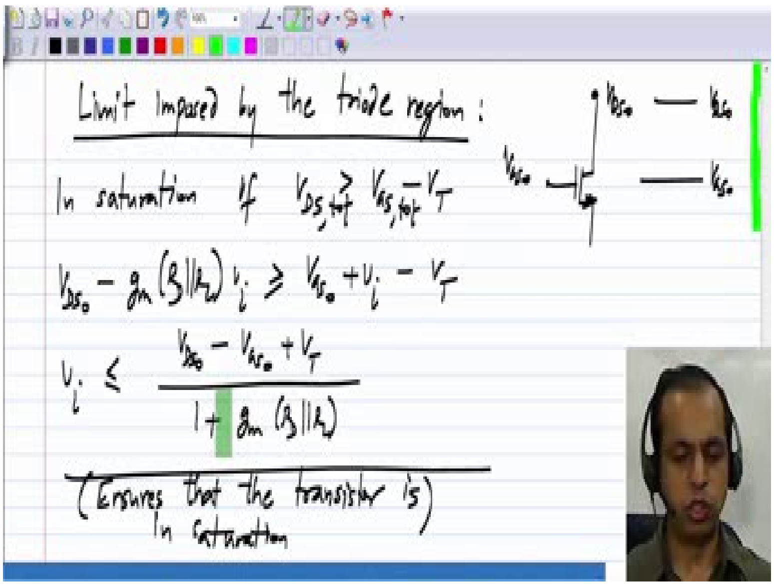

So, you can see that it is kind of moving towards triode region why does this limit make sense? First of all what is this (V_{DS0} -V_{GS0}). It is the separation between drain and gate in quotient condition that is at operating point at the operating point. This is at V_{DS0} and this is at V_{GS0} . let us say V_{DS0} is over there . I indicate these levels V_{GS0} over there. So, the larger separation you start with the large the limit will be for v_i because then there is lot more room to go . gate voltage has to increase and drain voltage has to reduce until it enters triode region. So, if you start with a big separation between drain and gate the limit will be larger and then there is plus V_T because the drain can go below the gate voltage, but not by more than one V_T.

So, we have an additional V_T and in the denominator we have gain g_m* ($R_D \parallel R_L$) also plus one why do we get this we are first of all evaluating the limit on the input. So, if the gate voltage goes up by one unit, the drain voltage falls down by gain units. And if you look at the separation between the two the gate has gone up by one unit the drain has fallen by gain units. So, the separation between the two has actually decreased by one plus gain units. So, this goes up a little this falls down a lot. So, we have one plus gain in the denominator. So, this expression does make sense and to increase this swing limit because of this triode region condition, you have to operate with a large V_{DG0} that is the large separation between drain and gate in the quotient condition. The drain should we bias sufficiently about the gate so that it is very far from triode region so then you get a very large swing limit.