Analog Circuits(EE3300)
Simulation Exercise 1

EE19BTECH11041,
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1 Problem statement

1. MOS transistors in nano-scale CMOS processes don't quite follow quadratic I-V characteristics we studied in the class. Their exact models (BSIM, PSP) contain hundredsof parameters, and it is almost impossible to use these models for hand calculations.In this exercise, we will try to extract a simple quadratic model for MOS transistorsfrom the available BSIM4 model.

Download model files and corresponding LTspice files from the class website.

Determine the following for NMOS (L=65nm, W=1um) and PMOS (L=65nm, W=1um) transistors from the given model files:

(Given supply voltage,V_{dd}=1.1 V. Use V_{ds}=V_{ds0}=$V_{dd}/2$, when not specified.)

. • V_{gs0}:V_{gs} value in the middle of the quadratic region of I_{ds} V_{gs} curve.Use derivative function available in waveform viewer.

. • g_{m0}:g_m at V_{gs0}.

. • V_T: x-axis intercept of tangent at V_{gs0} in g_m V_{gs} curve.

. • $\beta = \mu C_{ox}$: Using above extracted values and assuming quadratic behaviour.

. • g_{ds0}:g_{ds} at V_{gs0}.

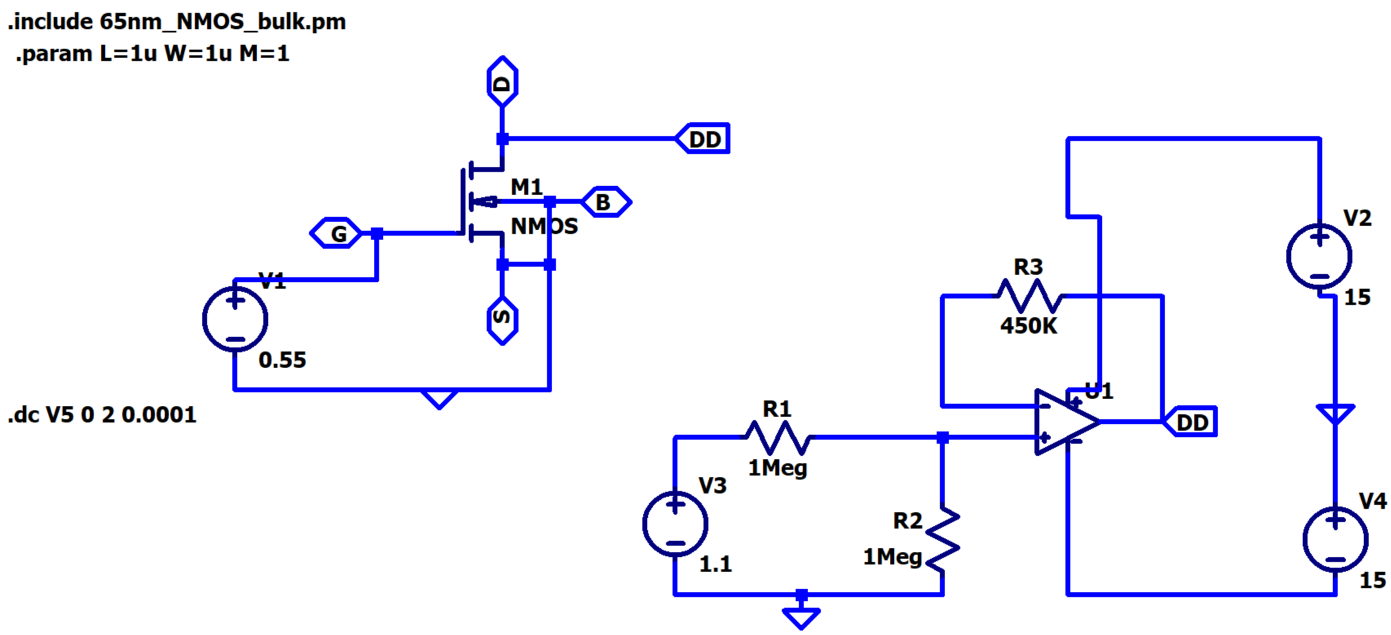
. • λ: Channel-length modulation parameter. (V_{gs}=V_{gs0}).

What is the range of V_{gs} for which error in estimated g_m is less than 50 %?

2. Repeat the above exercise for longer channel length devices. NMOS (L=1um, W=1um)and PMOS (L=1um, W=1um).

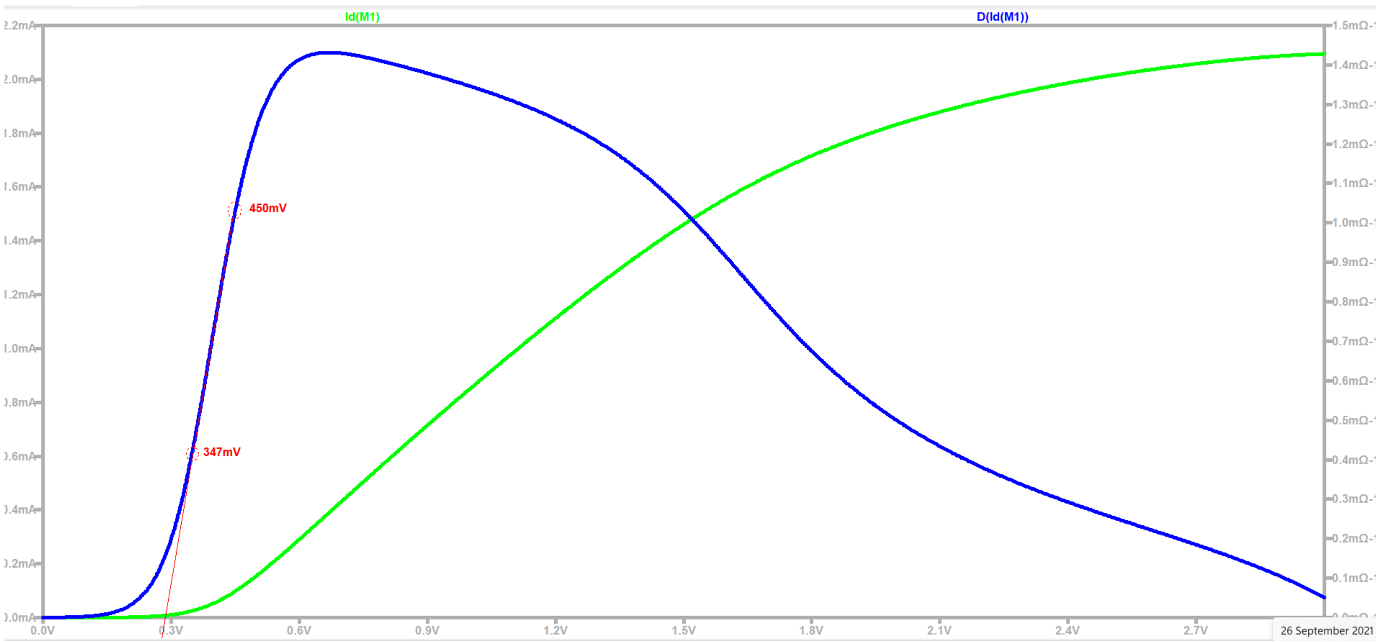
Question 1

Schematic of NMOS



Circuit schematic

I_{ds} Vs V_{gs} and g_m Vs V_{gs} Curves



From the graph we can see that the derivative is linear for V_{gs} in range of 347mV and 450mV.

$$V_{gs0} = \frac{347mV + 450mV}{2} = 388mV \tag{1}$$

$$g_{m0} = g_m|_{V_{gs0}} = 714\mu\Omega^{-1} \tag{2}$$

From the extension of tangent to x-axis we get

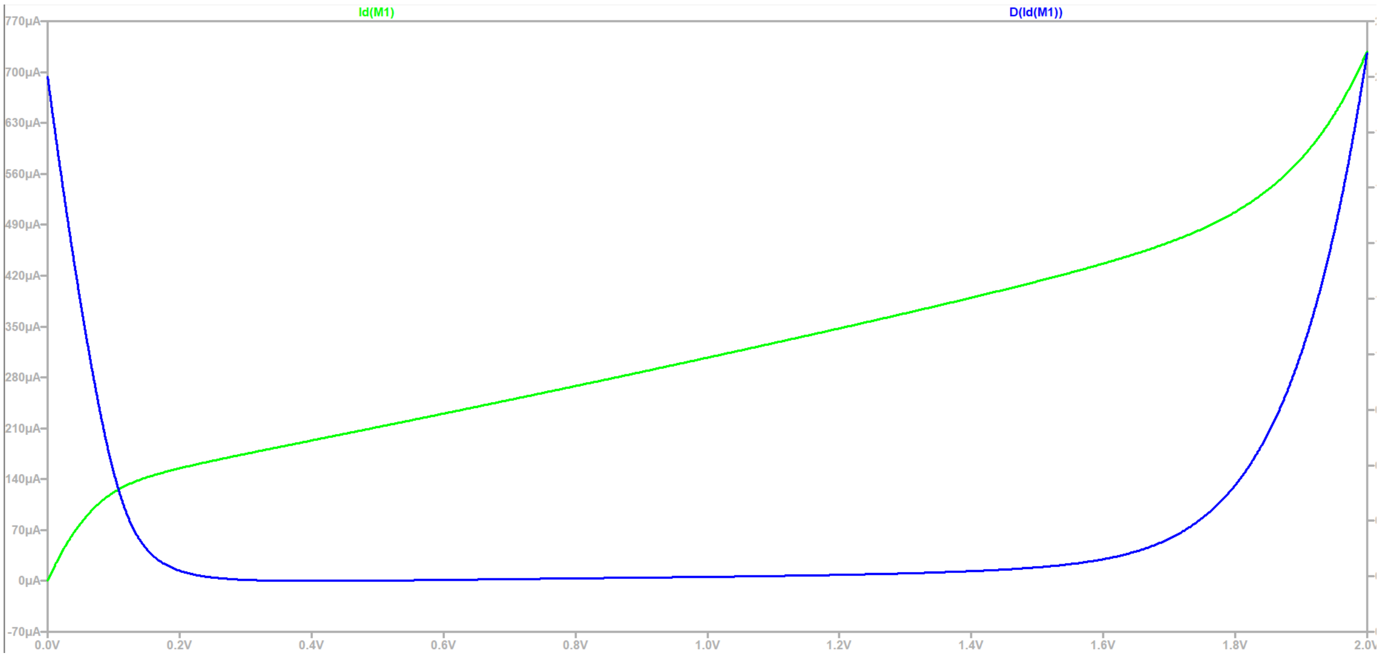
$$V_T = 288mV \tag{3}$$

Now using the below equation

$$\frac{\beta W(V_{gs0} - V_T)}{L} = g_{m0} \tag{4}$$

β = 569 μ

I_{ds} Vs V_{ds} and g_{ds} Vs V_{ds} Curves



from the graph g_{ds0} : g_{ds} at V_{gs0} and $V_{ds} = 0.55$V.

$$g_{ds0} = 185\mu\Omega^{-1} \tag{5}$$

From the below equation we can calculate λ.

$$I_{ds}\lambda = g_{ds} \tag{6}$$

$\lambda = 0.87$.

Now to find range of V_{gs} with less than 50 % Error we need to find values in range of ($g_m/2$,$3g_m/2$).

V_{gs} range = (337mV,458mV)
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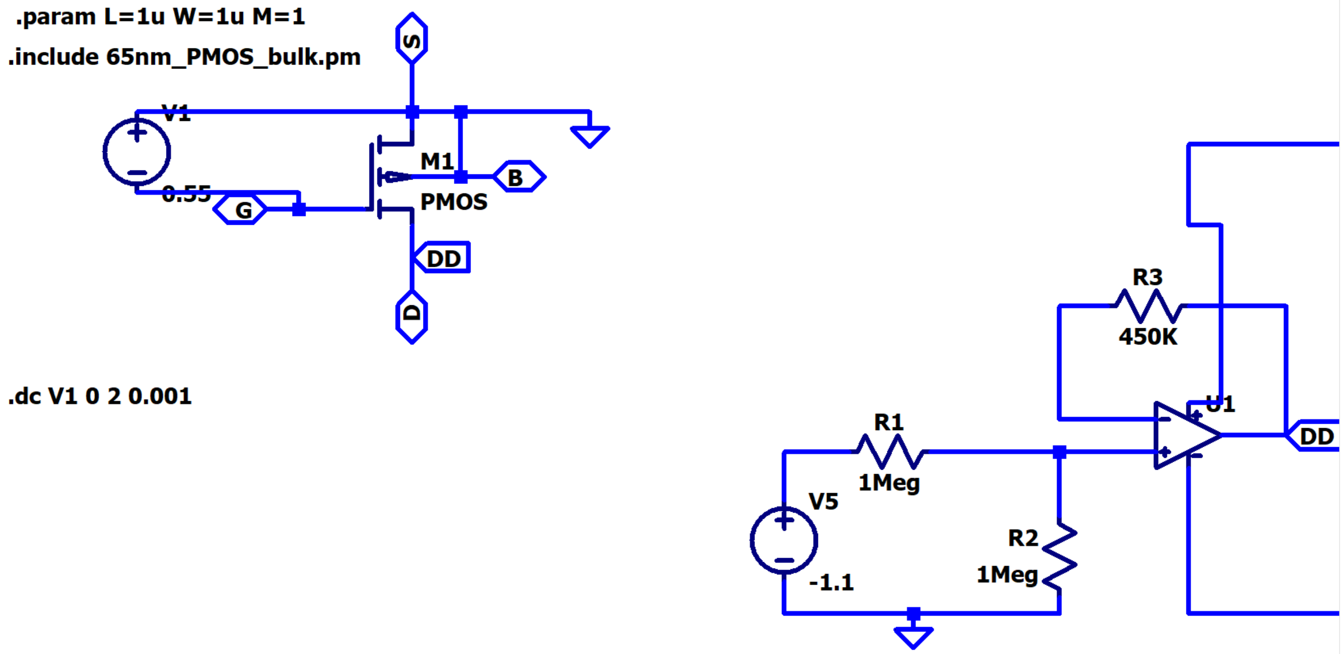
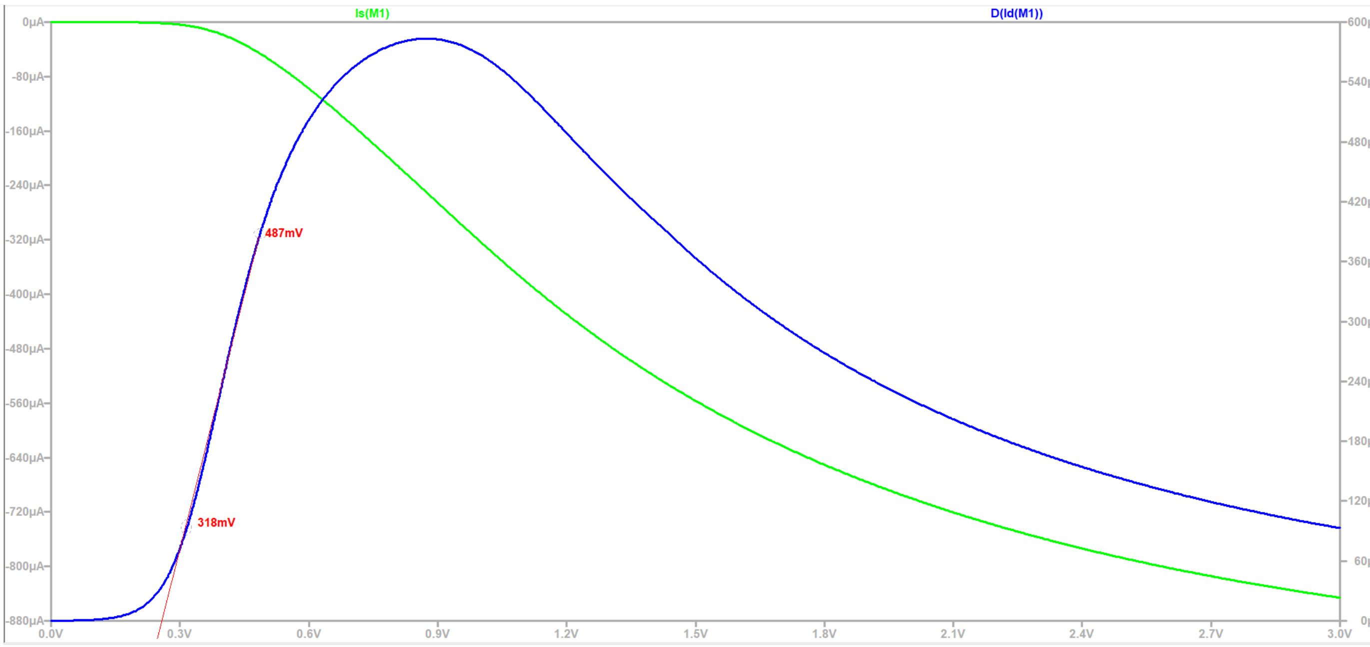
Schematic of PMOS



Circuit schematic

I_{ds} Vs V_{gs} and g_m Vs V_{gs} Curves



From the graph we can see that the derivative is linear for V_{gs} in range of -318mV and -487mV.

$$V_{gs0} = \frac{-318mV - 487mV}{2} = -395mV \tag{7}$$

$$g_{m0} = g_m|_{V_{gs0}} = -232\mu\Omega^{-1} \tag{8}$$

From the extension of tangent to x-axis we get

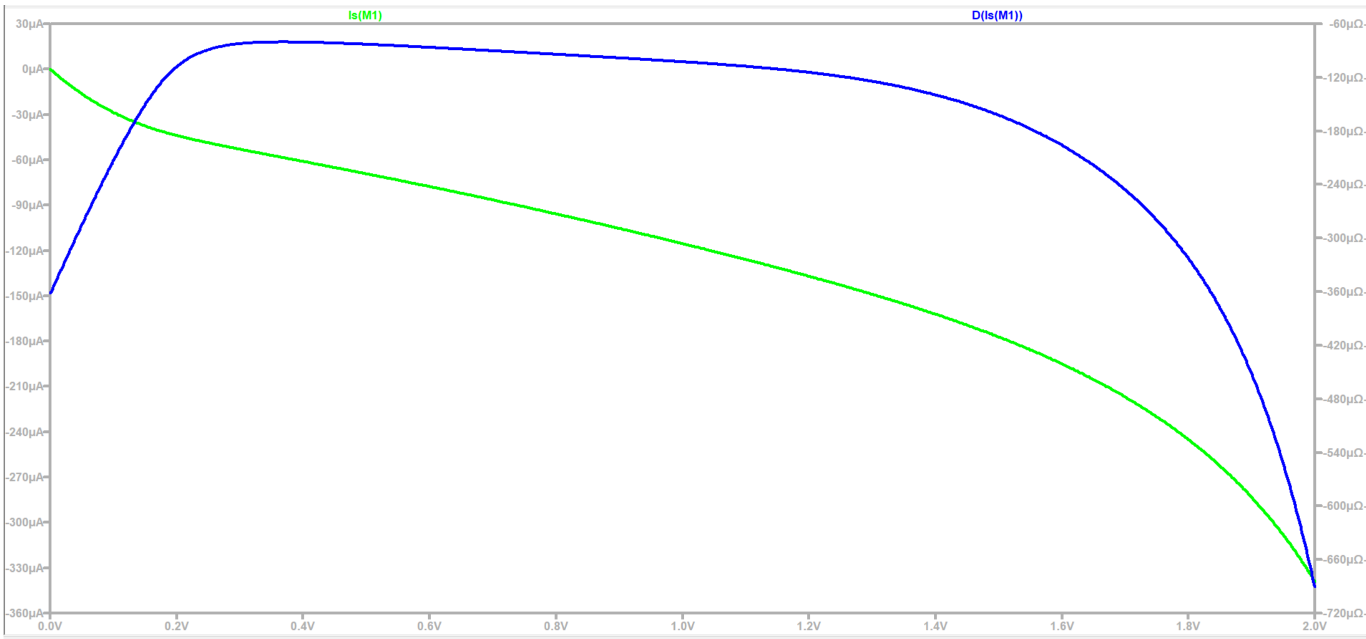
$$V_T = -280mV \tag{9}$$

Now using the below equation

$$\frac{\beta W(V_{gs0} - V_T)}{L} = g_{m0} \tag{10}$$

β = 184.8µ

I_{ds} Vs V_{ds} and g_{ds} Vs V_{ds} Curves



from the graph g_{ds0} : g_{ds} at V_{gs0} and V_{ds} = 0.55V.

$$g_{ds0} = -84.99\mu\Omega^{-1} \tag{11}$$

From the below equation we can calculate λ.

$$I_{ds}\lambda = g_{ds} \tag{12}$$

λ = 1.14.

Now to find range of V_{gs} with less than 50 % Error we need to find values in range of (g_m/2,3g_m/2).

V_{gs} range = (-332mV,-460mV)

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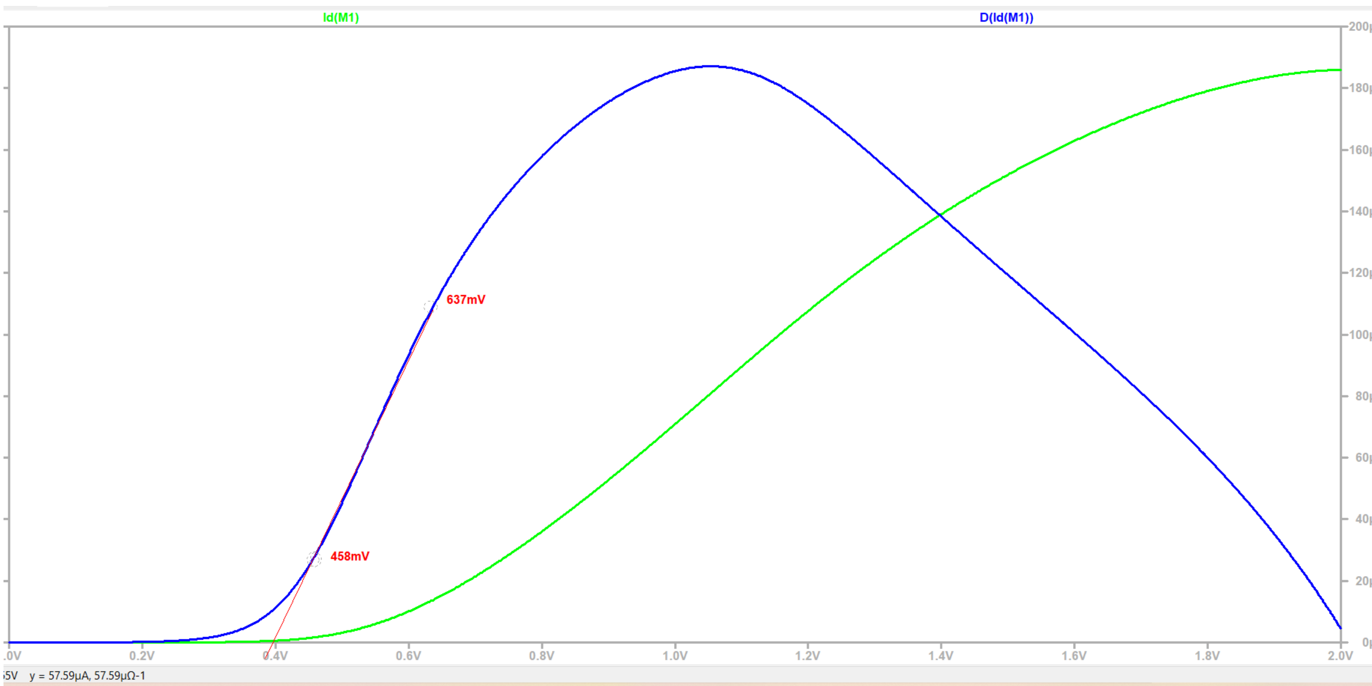
Long channeled NMOS

I_{ds} Vs V_{gs} and g_m Vs V_{gs} Curves



From the graph we can see that the derivative is linear for V_{gs} in range of 458mV and 637mV.

$$V_{gs0} = \frac{458mV + 637mV}{2} = 550mV \tag{13}$$

$$g_{m0} = g_m|_{V_{gs0}} = 69.35\mu\Omega^{-1} \tag{14}$$

From the extension of tangent to x-axis we get

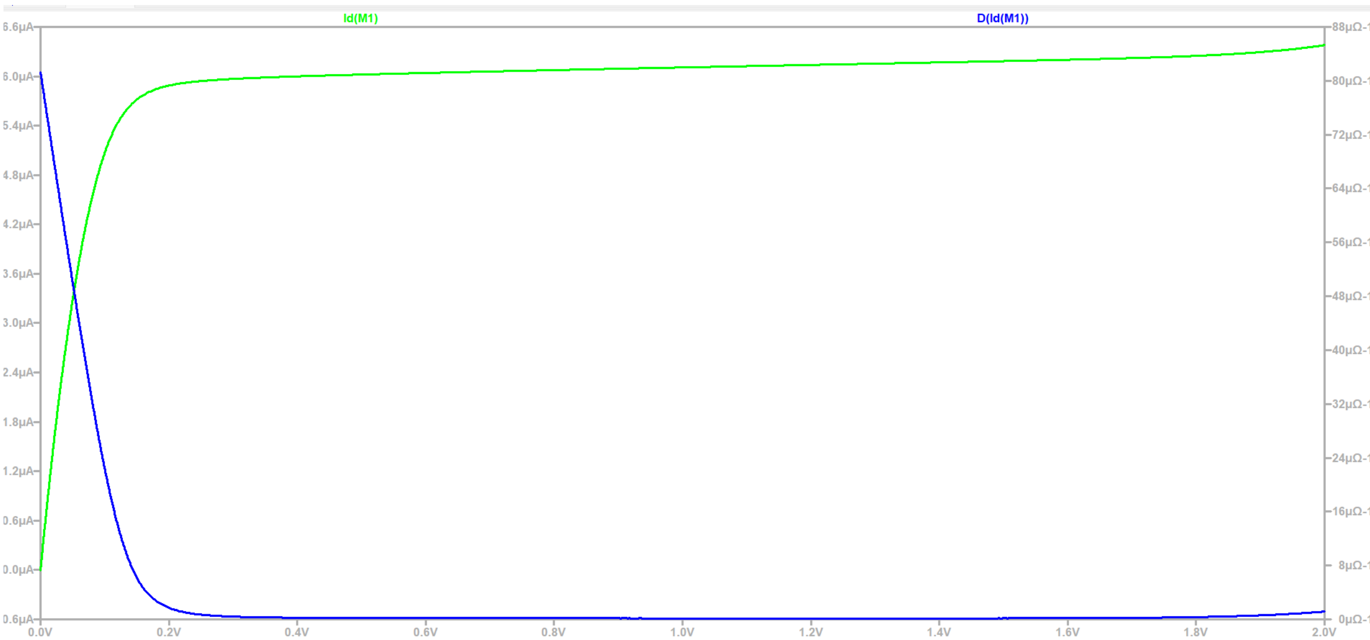
$$V_T = 400mV \tag{15}$$

Now using the below equation

$$\frac{\beta W(V_{gs0} - V_T)}{L} = g_{m0} \tag{16}$$

β = 541 μ

I_{ds} Vs V_{ds} and g_{ds} Vs V_{ds} Curves



from the graph g_{ds0} : g_{ds} at V_{gs0} and V_{ds} = 0.55V.

$$g_{ds0} = 191 n\Omega^{-1} \tag{17}$$

From the below equation we can calculate λ.

$$I_{ds}\lambda = g_{ds} \tag{18}$$

λ = 0.0316.

Now to find range of V_{gs} with less than 50 % Error we need to find values in range of ($g_m/2$,$3g_m/2$).

V_{gs} range = (475mV,626mV)

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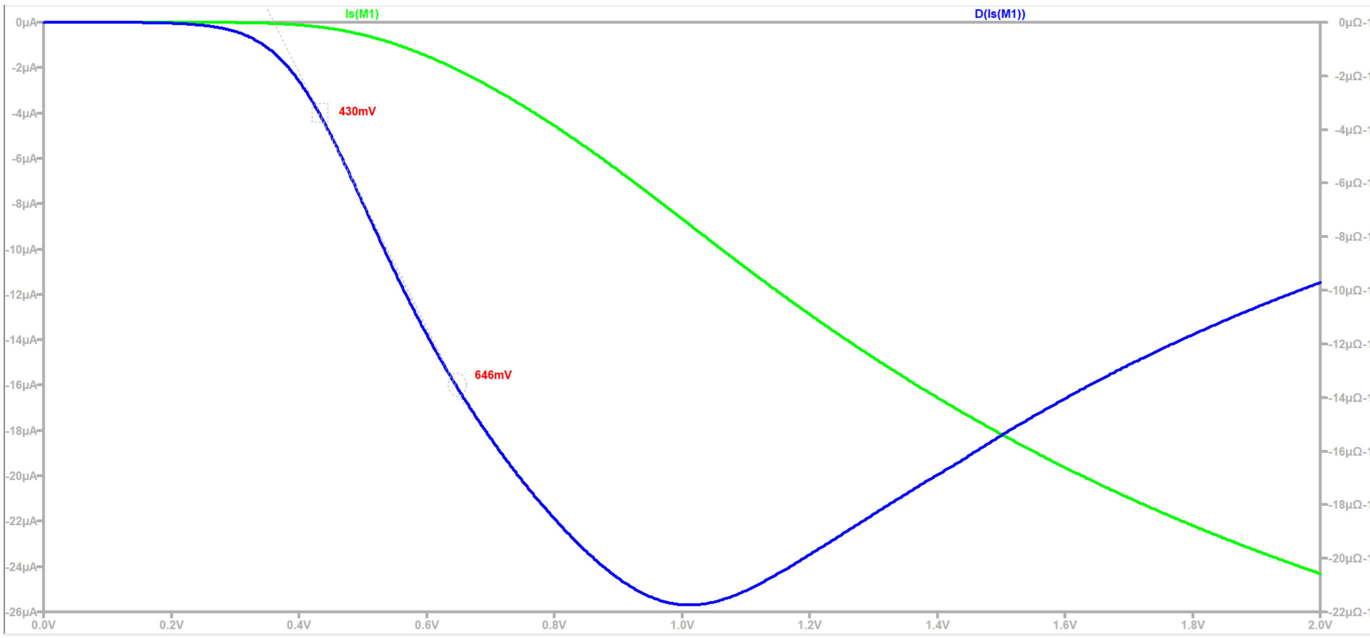
Long channeled PMOS

I_{ds} Vs V_{gs} and g_m Vs V_{gs} Curves



From the graph we can see that the derivative is linear for V_{gs} in range of -430mV and -646mV.

$$V_{gs0} = \frac{-430mV - 646mV}{2} = -538mV \tag{19}$$

$$g_{m0} = g_m|_{V_{gs0}} = -8.68\mu\Omega^{-1} \tag{20}$$

From the extension of tangent to x-axis we get

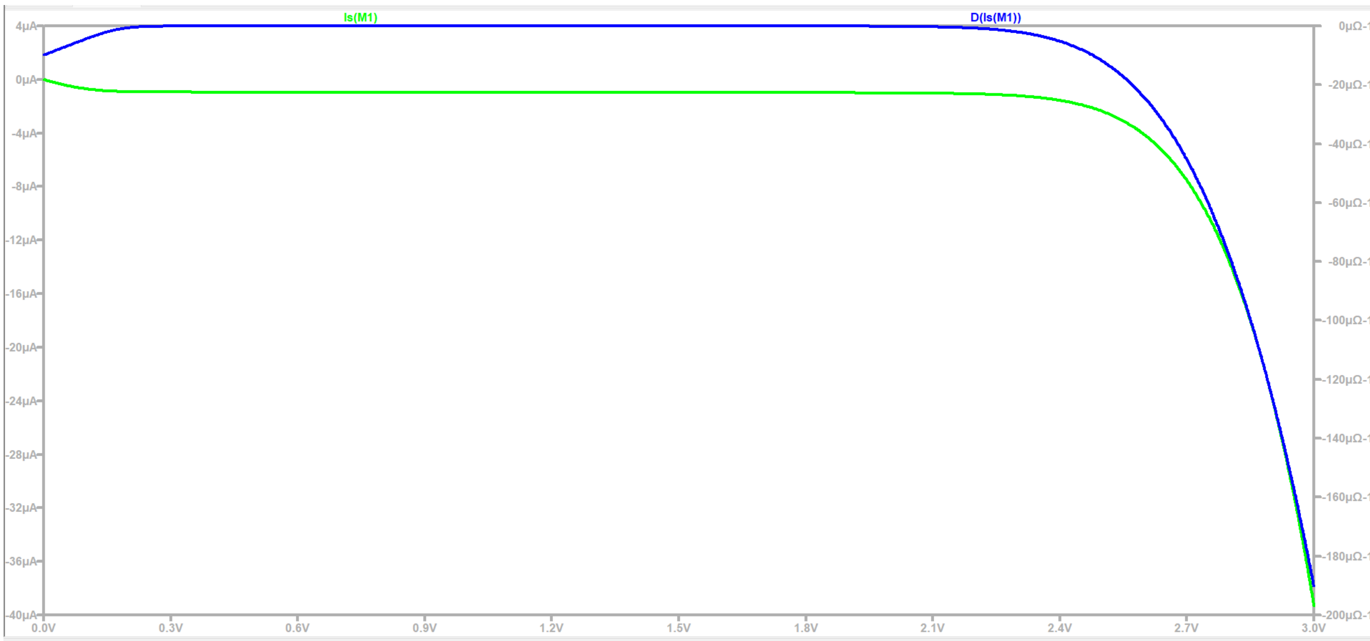
$$V_T = -350mV \tag{21}$$

Now using the below equation

$$\frac{\beta W(V_{gs0} - V_T)}{L} = g_{m0} \tag{22}$$

$\beta = 491\mu$

I_{ds} Vs V_{ds} and g_{ds} Vs V_{ds} Curves



from the graph g_{ds0} : g_{ds} at V_{gs0} and $V_{ds} = 0.55$V.

$$g_{ds0} = -30n\Omega^{-1} \tag{23}$$

From the below equation we can calculate λ.

$$I_{ds}\lambda = g_{ds} \tag{24}$$

$\lambda = 0.0315$.

Now to find range of V_{gs} with less than 50 % Error we need to find values in range of ($g_m/2$,$3g_m/2$).

V_{gs} range = (-452mV,-633mV)

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thank you