Fall-2020 UM-SJTU JI Ve311 Homework #8

Instructor: Dr. Chang-Ching Tu

Due: 11:59 am, November 25, 2020 (Wednesday)

Note:

(1) Please use A4 size papers.

(2) Please use the SPICE model on page 2 for simulation and calculation.

1. [Current Source and Cascode Current Source]

(a) [20%] ($\lambda \neq 0$ and $\gamma = 0$) Derive analytical expressions for the output impedances of current source (i) and (ii) below, respectively.

(b) [40%] ($\lambda \neq 0$ and $\gamma = 0$) For $V_X = 2$ V, $V_a = 1.2$ V, $V_b = 2.2$ V, $(W/L)_1 = 20$ μm / 2 μm, $(W/L)_2 = 100$ μm / 2 μm, what are the output impedance values of current source (i) and (ii) below? Does the cascode structure significantly increase the output impedance?

(c) [10%] What are the minimum values of V_X for M_1 of circuit (i) and M_2 of circuit (ii) to stay in the saturation region?

(d) [30%] For circuit (i) and (ii) below, plot the I_X as a function of V_X (from 0 V to 5 V) using Pspice in DC sweep mode. Confirm whether the hand-calculation results in (b) and (c) are consistent with the simulation results here.
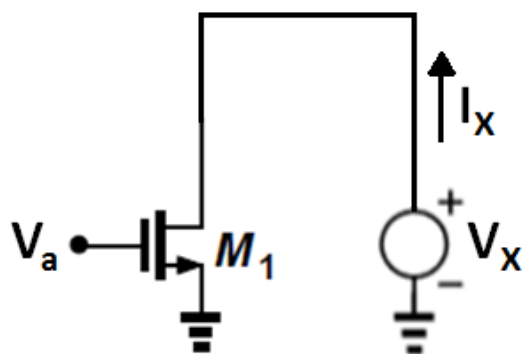
(i)   **(ii)**
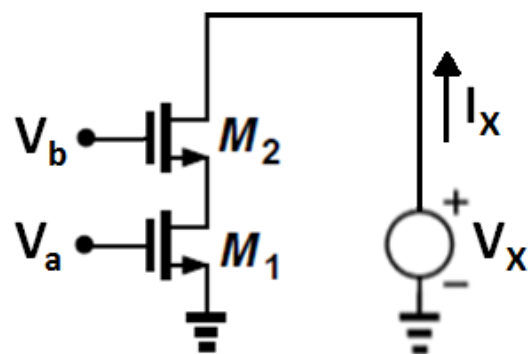
NMOS Model

LEVEL = 1	VTO = 0.7	GAMMA = 0.45	PHI = 0.9
NSUB = 9e+14	LD = 0.08e−6	UO = 350	LAMBDA = 0.1
TOX = 9e−9	PB = 0.9	CJ = 0.56e−3	CJSW = 0.35e−11
MJ = 0.45	MJSW = 0.2	CGDO = 0.4e−9	JS = 1.0e−8

PMOS Model

LEVEL = 1	VTO = −0.8	GAMMA = 0.4	PHI = 0.8
NSUB = 5e+14	LD = 0.09e−6	UO = 100	LAMBDA = 0.2
TOX = 9e−9	PB = 0.9	CJ = 0.94e−3	CJSW = 0.32e−11
MJ = 0.5	MJSW = 0.3	CGDO = 0.3e−9	JS = 0.5e−8

VTO: threshold voltage with zero V_{SB} (unit: V)
GAMMA: body effect coefficient (unit: $V^{1/2}$)
PHI: $2\Phi_F$ (unit: V)
TOX: gate oxide thickness (unit: m)
NSUB: substrate doping (unit: cm^{-3})
LD: source/drain side diffusion (unit: m)
UO: channel mobility (unit: $cm^2/V/s$)
LAMBDA: channel-length modulation coefficient (unit: V^{-1})
CJ: source/drain bottom-plate junction capacitance per unit area (unit: F/m^2)
CJSW: source/drain sidewall junction capacitance per unit length (unit: F/m)
PB: source/drain junction built-in potential (unit: V)
MJ: exponent in CJ equation (unitless)
MJSW: exponent in CJSW equation (unitless)
CGDO: gate-drain overlap capacitance per unit width (unit: F/m)
CGSO: gate-source overlap capacitance per unit width (unit: F/m)
JS: source/drain leakage current per unit area (unit: A/m^2)

Vacuum permittivity (ϵ_o) = 8.85×10^{-12} (F / m)
Silicon oxide dielectric constant (ϵ_r) = 3.9