

Fall-2021 UM-SJTU JI Ve311 Homework #8

Instructor: Dr. Chang-Ching Tu

Due: 10:40 am, December 8, 2021 (Wednesday)

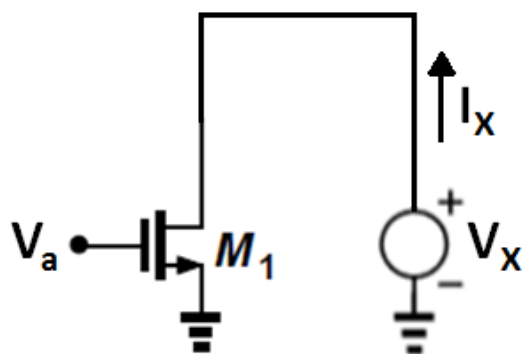
Note:

- (1) Please use A4 size papers.
- (2) Please use the SPICE model on page 2 for simulation and calculation.

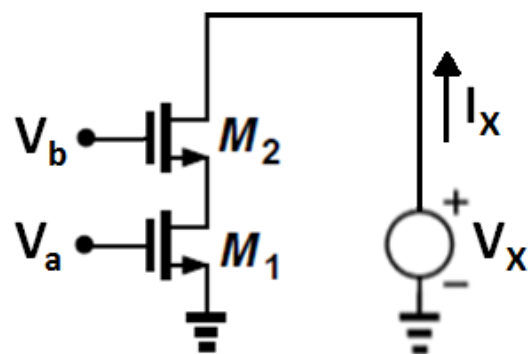
1. [Current Source and Cascode Current Source]

- (a) [20%] ($\lambda \neq 0$ and $\gamma = 0$) Derive analytical expressions for the output impedance of current source (i) and (ii) below.
- (b) [40%] ($\lambda \neq 0$ and $\gamma = 0$) For $V_X = 2$ V, $V_a = 1.2$ V, $V_b = 2.2$ V, $(W/L)_1 = 20 \mu\text{m} / 2 \mu\text{m}$, $(W/L)_2 = 100 \mu\text{m} / 2 \mu\text{m}$, 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: $\text{cm}^2/\text{V/s}$)

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_0) = 8.85×10^{-12} (F / m)

Silicon oxide dielectric constant (ϵ_r) = 3.9