EECS 312 - Electronics Circuits I (Spring 2018)

Material for Exam II: Chapter 5 (MOSFET) + section 7.2.1 (small-signal analysis of MOSFET circuits as amplifiers)

***Structure and operation principle of an FET*:**

Basic structure: source, drain, gate and body

Gate is electrically isolated from the body by the oxide layer, and thus the gate current is always zero.

The "*channel*" between source and drain is controlled by the voltage between gate and source

Understand mechanisms of channel *pinch-off*, *channel length modulation* and their impacts.

I-V characteristics of an enhancement NMOS

Three different operation modes: cutoff, saturation and triode

(1) Bias condition for each mode: Relations among V_{GS}, V_{DS}, and V_t

(2) Expression of current for each operation mode

In triode region: $I_D = k\left[(V_{GS} - V_t)V_{DS} - \frac{1}{2}V_{DS}^2\right] = k'\left(\frac{W}{L}\right)\left[(V_{GS} - V_t)V_{DS} - \frac{1}{2}V_{DS}^2\right]$

In Saturation region: $I_D = \frac{1}{2}k(V_{GS} - V_t)^2 = k'\left(\frac{W}{2L}\right)(V_{GS} - V_t)^2$

Where: $k = k'\left(\frac{W}{L}\right) = \mu C_{ox}\left(\frac{W}{L}\right)$

Special characteristics of *I-V* relationship

In triode region, if $V_{DS} << (V_{GS} - V_t)$, I_D linearly increases with V_{DS}: equivalently this is a voltage-controlled resistor

In saturation region, ideally I_D is independent of V_{DS} (if channel-length modulation is not considered). If the effect of channel-length modulation is considered, I_D slightly increases with the increase of V_{DS} even in saturation region, resulting in a drain outputt resistance, so that $I_D = 0.5k(V_{GS} - V_t)^2(1 + V_{DS}/V_A)$.

***Four types of MOSFETs*:**

Enhancement NMOS

Enhancement PMOS

Depletion NMOS

Depletion PMOS

n-type or *p*-type doping for the body, source and drain regions, how these devices operate.

Familiar with conditions of operating modes (cutoff, triode and saturation), and I_D equations for each of mode (*know similarities and differences between these 4 types of devices*)

MOSFET circuit at DC

Steps of circuit analysis: Assume operation mode, enforce conditions according to the assumed operation mode, analyze circuit and check the assumption. ***Exercise is necessary and very important***

Application: MOSFET as an amplifier

Transfer function of a MOSFET circuit (Output as the function of the input)

Small-signal response: small-signal *AC* voltage gain $A_v = v_0(t)/v_i(t)$ of the circuit, and transconductive gain $g_m = i_d/v_{gs}$ of the MOSFET. Both of these are related to DC operation condition of the MOSFET, commonly referred to as the operating *Q* point.

FET small-signal equivalent circuit: for an ideal MOSFET it is a voltage controlled current source. But if channel-length modulation is consider it has an extra output resistance r_0.

Solve circuit problems. Pay special attention to the construction of DC and AC equivalent circuits.

Body Effect: understand its physical mechanism, circuit model, and impact in circuit design