

## ELEC 401, Exam Equation Sheet, Fall 2014

(You are responsible for ensuring the accuracy of these equations.)

### N-channel MOSFETs

Nonsaturation (Triode) Region ( $v_{DS} < v_{DS}(sat)$ )

$$i_D = K_n[2(v_{GS} - V_{TN})v_{DS} - v_{DS}^2]$$

Saturation Region ( $v_{DS} > v_{DS}(sat)$ )

$$i_D = K_n(v_{GS} - V_{TN})^2(1 + \lambda v_{DS})$$

Transition Point:  $v_{DS}(sat) = v_{GS} - V_{TN}$

Enhancement Mode:  $V_{TN} > 0$

Depletion Mode:  $V_{TN} < 0$

Conduction Parameter:  $K_n = k'_n \frac{W}{2L}$

### P-channel MOSFETs

Nonsaturation (Triode) Region ( $v_{SD} < v_{SD}(sat)$ )

$$i_D = K_p[2(v_{SG} + V_{TP})v_{SD} - v_{SD}^2]$$

Saturation Region ( $v_{SD} > v_{SD}(sat)$ )

$$i_D = K_p(v_{SG} + V_{TP})^2(1 + \lambda v_{SD})$$

Transition Point:  $v_{SD}(sat) = v_{SG} + V_{TP}$

Enhancement Mode:  $V_{TP} < 0$

Depletion Mode:  $V_{TP} > 0$

Conduction Parameter:  $K_p = k'_p \frac{W}{2L}$

### MOSFET Small Signal Parameters

NMOS:  $g_m = 2K_n(V_{GSQ} - V_{TN}) = 2\sqrt{K_n I_{DQ}}$

PMOS:  $g_m = 2K_p(V_{SGQ} + V_{TP}) = 2\sqrt{K_p I_{DQ}}$

$$r_o = \frac{1}{\lambda I_{DQ}}$$

### BJTs

Current Relationships:

$$I_E = I_B + I_C \quad I_C = \beta I_B = \frac{\beta}{\beta+1} I_E \quad I_E = (\beta+1) I_B = \frac{\beta+1}{\beta} I_C \quad I_B = \frac{I_C}{\beta} = \frac{I_E}{\beta+1}$$

Small Signal Parameters:

$$r_\pi = \frac{\beta V_T}{I_{CQ}} \quad g_m = \frac{I_{CQ}}{V_T} \quad r_o = \frac{V_A}{I_{CQ}}$$
$$r_e = \frac{r_\pi}{\beta+1} \text{ (for T-model)}$$