ELEG 309 FINAL EXAM SPRING 2018 EQUATION SHEET

NMOS FET Equations

Triode Region

$$i_D = k_n'\left(\frac{W}{L}\right)\left(v_{OV}v_{DS} - \frac{1}{2}v_{DS}^2\right) = k_n^{'}\left(\frac{W}{L}\right)\left((v_{GS} - V_t)v_{DS} - \frac{1}{2}v_{DS}^2\right)$$

Saturation Region

$$i_D = \frac{1}{2}k_n^{'}\left(\frac{W}{L}\right)v_{OV}^2 = \frac{1}{2}k_n'\left(\frac{W}{L}\right)(v_{GS} - V_t)^2$$

PMOS FET Equations

Triode Region

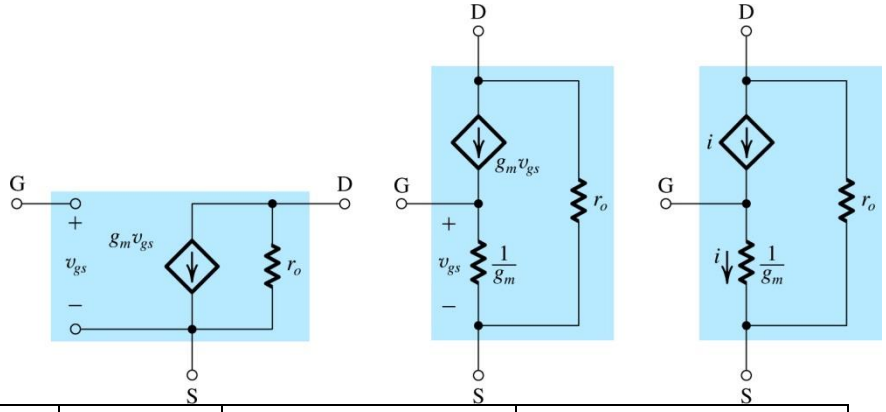
$$i_D = k_p'\left(\frac{W}{L}\right)\left(|v_{OV}|v_{SD} - \frac{1}{2}v_{SD}^2\right) = k_p^{'}\left(\frac{W}{L}\right)\left((v_{GS} - |V_t|)v_{SD} - \frac{1}{2}v_{SD}^2\right)$$

Saturation Region

$$i_D = \frac{1}{2}k_p^{'}\left(\frac{W}{L}\right)v_{OV}^2 = \frac{1}{2}k_p'\left(\frac{W}{L}\right)(v_{GS} - |V_t|)^2$$

$$g_m = \frac{2I_D}{V_{OV}} = k_n'\left(\frac{W}{L}\right)(V_{GS} - V_t)$$

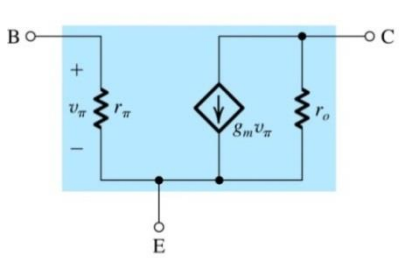
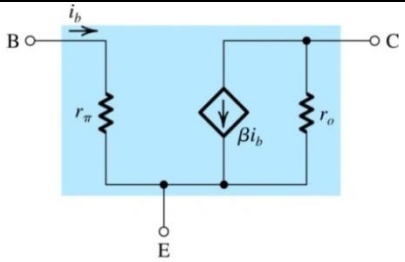
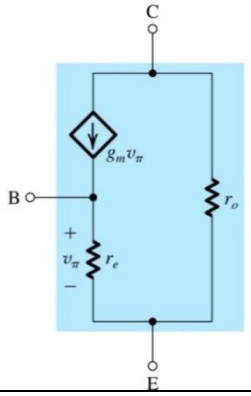
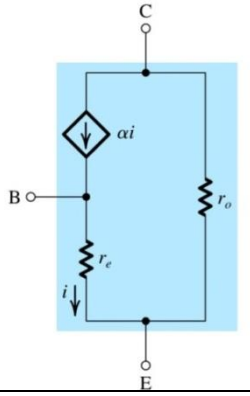
$$r_o = \frac{1}{\lambda I_D} = \frac{V_A}{I_D}$$



Characteristics of MOSFET Amplifiers

Amplifier type	R_{in}	A_{vo}	R_o	A_v	G_v
Common source	∞	$-g_m R_o$	R_D or $(R_D \| r_o)$	$-g_m(R_o \| R_L)$	$-g_m(R_o \| R_L)$
Common source with R_S	∞	$-\frac{g_m R_o}{1+g_m R_s}$	R_D or $(R_D \| r_o)$	$-\frac{g_m(R_o \| R_L)}{1+g_m R_s}$	$-\frac{g_m(R_o \| R_L)}{1+g_m R_s}$
Common gate	$1/g_m \| R_s$	$g_m R_o$	R_D or $(R_D \| r_o)$	$g_m(R_o \| R_L)$	$\left(\frac{R_{in}}{R_{in}+R_{sig}}\right)g_m(R_o \| R_L)$
Common drain or source follower	∞	1 w/o r_o or $\frac{r_o}{r_0+(1/g_m)}$	$1/g_m \| R_s$	$\frac{R_L \| r_o}{(R_L \| r_o)+(1/g_m)}$	$\frac{R_L \| r_o}{(R_L \| r_o)+(1/g_m)}$

BJT Small Signal Models and parameters:

($g_m v_\pi$) Version	**(βi_b) Version**
	
	

$$g_m = \frac{I_C}{V_T}$$

$$r_\pi \equiv \frac{v_{be}}{i_b} = \frac{\beta}{g_m} = \frac{V_T}{I_b}$$

$$r_e \equiv \frac{v_{be}}{i_e} = \frac{V_T}{I_E} = \frac{\alpha}{g_m}$$

$$r_o = \frac{|V_A|}{I_C}$$

Characteristics of BJT Amplifiers (with and without r_o):

Amplifier type	$\boldsymbol{R_{in}}$	$\boldsymbol{A_{vo}}$	$\boldsymbol{R_o}$	$\boldsymbol{A_v}$	$\boldsymbol{G_v}$
Common emitter	$(\beta+1)r_e$ or r_π	$-g_m R_o$	R_C or $(R_C \| r_o)$	$-g_m(R_o \| R_L)$	$-\left(\frac{R_{in}}{R_{in}+R_{sig}}\right) g_m (R_o \| R_L)$
Common emitter with R_e	$(\beta+1)(r_e+R_e)$	$-\frac{g_m R_o}{1+g_m R_e}$	R_C or $(R_C \| r_o)$	$-\frac{g_m(R_o \| R_L)}{1+g_m R_e}$	$-\left(\frac{R_{in}}{R_{in}+R_{sig}}\right)\frac{g_m(R_o \| R_L)}{1+g_m R_e}$
Common base	$r_e \| R_E$	$g_m R_o$	R_C or $(R_C \| r_o)$	$g_m(R_o \| R_L)$	$\left(\frac{R_{in}}{R_{in}+R_{sig}}\right) g_m (R_o \| R_L)$
Common collector or emitter follower	$(\beta+1)(r_e+(R_L \| R_o))$	1 w/o r_o or $\frac{r_o}{r_0+r_e}$	$r_o \| R_E$	$\frac{R_L \| r_o}{(R_L \| r_o)+r_e}$	$\left(\frac{R_{in}}{R_{in}+R_{ig}}\right)\frac{R_L \| R_o}{(R_L \| R_o)+r_e}$ $R_{out} = r_o \| R_E \| \left(r_e + \frac{R_B \| R_{sig}}{(\beta+1)}\right)$

Quadratic Equation:

Roots of $ax^2+bx+c=0$ are $\frac{-b \pm \sqrt{b^2-4ac}}{2a}$