

## ECE 342 – Equations for Exam 3

### 1. MOSFETs

	NMOS	PMOS
	$I_D, V_{GS}, V_{DS}, V_{t_n} > 0$	$I_D, V_{GS}, V_{DS}, V_{t_p} < 0$
	$k'_n = \mu_n C_{ox}$	$k'_p = \mu_p C_{ox}$
	$V_{t_n} = V_{t_{0n}} + \gamma_n (\sqrt{2\phi_f + V_{SB}} - \sqrt{2\phi_f})$	$V_{t_p} = V_{t_{0p}} + \gamma_p (\sqrt{2\phi_f +  V_{SB} } - \sqrt{2\phi_f})$
Cutoff	$V_{GS} < V_{t_n}$ $I_D = 0$	$V_{GS} > V_{t_p}$ $I_D = 0$
Triode	$V_{GS} > V_{t_n}, V_{DS} < V_{GS} - V_{t_n}$ $I_D = k'_n \frac{W_n}{L_n} \left( V_{GS} - V_{t_n} - \frac{V_{DS}}{2} \right) V_{DS}$	$V_{GS} < V_{t_p}, V_{DS} > V_{GS} - V_{t_p}$ $I_D = -k'_p \frac{W_p}{L_p} \left( V_{GS} - V_{t_p} - \frac{V_{DS}}{2} \right) V_{DS}$
Saturation	$V_{GS} > V_{t_n}, V_{DS} > V_{GS} - V_{t_n}$ $I_D = \frac{k'_n W_n}{2 L_n} (V_{GS} - V_{t_n})^2 (1 + \lambda_n V_{DS})$	$V_{GS} < V_{t_p}, V_{DS} < V_{GS} - V_{t_p}$ $I_D = -\frac{k'_p W_p}{2 L_p} (V_{GS} - V_{t_p})^2 (1 + \lambda_p V_{DS})$

### 2. BJTs

	NPN	PNP
Cutoff	$V_{BE} < 0.4 \text{ V}, V_{BC} < 0.4 \text{ V}$ $I_C = I_E = I_B = 0$	$V_{EB} < 0.4 \text{ V}, V_{CB} < 0.4 \text{ V}$ $I_C = I_E = I_B = 0$
Saturation	$V_{BE} = 0.7 \text{ V}, V_{CE} = V_{CE_{sat}} = 0.3 \text{ V}$ $I_C = I_S e^{(V_{BE}/V_T)} - I_{SC} e^{(V_{BC}/V_T)}$ $\beta_{forced} = \frac{I_C}{I_B} \Big _{saturation} < \beta$	$V_{EB} = 0.7 \text{ V}, V_{EC} = V_{EC_{sat}} = 0.3 \text{ V}$ $I_C = I_S e^{(V_{EB}/V_T)} - I_{SC} e^{(V_{CB}/V_T)}$ $\beta_{forced} = \frac{I_C}{I_B} \Big _{saturation} < \beta$
Active	$V_{BE} = 0.7 \text{ V}, V_{BC} < 0.4 \text{ V}$ $I_C = I_S e^{(V_{BE}/V_T)} (1 + \frac{V_{CE}}{V_A})$ $I_B = I_C/\beta, \quad \beta = \frac{\alpha}{(1-\alpha)}$ $I_E = I_C/\alpha, \quad \alpha = \frac{\beta}{1+\beta}$	$V_{EB} = 0.7 \text{ V}, V_{EC} < 0.4 \text{ V}$ $I_C = I_S e^{(V_{EB}/V_T)} (1 + \frac{V_{EC}}{V_A})$ $I_B = I_C/\beta, \quad \beta = \frac{\alpha}{(1-\alpha)}$ $I_E = I_C/\alpha, \quad \alpha = \frac{\beta}{1+\beta}$