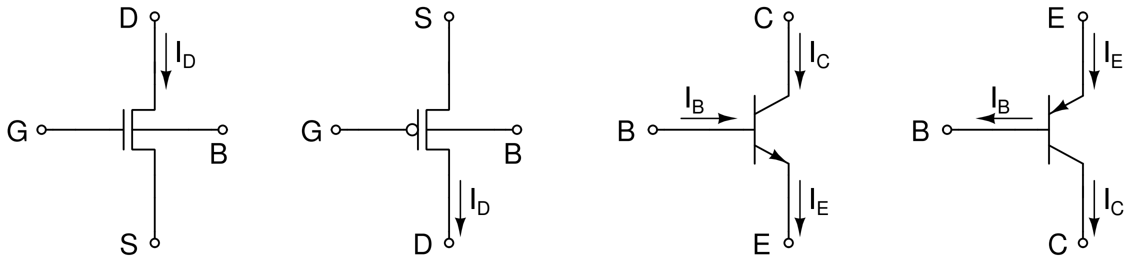
ECE 342 – Equations for Exam 3



1. MOSFETs

	NMOS	PMOS
	$I_D,\, V_{GS},\, V_{DS},\, V_{t_n} > 0$	$I_D,\, V_{GS},\, V_{DS},\, V_{t_p} < 0$
	$k'_n = \mu_n C_{ox}$	$k'_p = \mu_p C_{ox}$
	$V_{t_n} = V_{t0_n} + \gamma_n \left(\sqrt{2\phi_f + V_{SB}} - \sqrt{2\phi_f}\right)$	$V_{t_p} = V_{t0_p} + \gamma_p \left(\sqrt{2\phi_f + \lvert V_{SB}\rvert} - \sqrt{2\phi_f}\right)$
Cutoff	$V_{GS} < V_{t_n}$ $I_D = 0$	$V_{GS} > V_{t_p}$ $I_D = 0$
Triode	$V_{GS} > V_{t_n},\, V_{DS} < V_{GS} - V_{t_n}$ $I_D = k'_n \frac{W_n}{L_n}\left(V_{GS} - V_{t_n} - \frac{V_{DS}}{2}\right) V_{DS}$	$V_{GS} < V_{t_p},\, V_{DS} > V_{GS} - V_{t_p}$ $I_D = k'_p \frac{W_p}{L_p}\left(V_{SG} - \lvert V_{t_p}\rvert - \frac{V_{SD}}{2}\right) V_{SD}$
Saturation	$V_{GS} > V_{t_n},\, V_{DS} > V_{GS} - V_{t_n}$ $I_D = \frac{k'_n}{2}\frac{W_n}{L_n}\left(V_{GS} - V_{t_n}\right)^2 (1 + \lambda_n V_{DS})$	$V_{GS} < V_{t_p},\, V_{DS} < V_{GS} - V_{t_p}$ $I_D = \frac{k'_p}{2}\frac{W_p}{L_p}\left(V_{SG} - \lvert V_{t_p}\rvert\right)^2 (1 + \lambda_p V_{DS})$

2. BJTs

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