Formulae for the Memory-Challenged

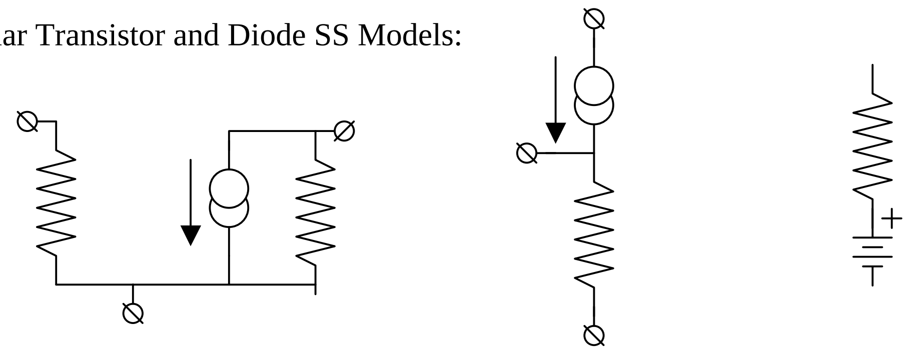
General: $\frac{kT}{q} = 0.0256$ volts at room temperature (300° K).

$$R = \frac{\rho l}{A} \qquad C = \frac{\varepsilon A}{t}$$

Biasing: $I_C = h_{FE} I_B$

$$I_C = \frac{h_{FE}(V_{BB} - V_{BE} + R_{BB} I_{CBO})}{R_{BB} + (1 + h_{FE}) R_E} \qquad I_{COPT} = \frac{V_{CC} - V_{CESAT}}{R_{DC} + (1 - \gamma)|Z_{AC}|}$$

Bipolar Transistor and Diode SS Models:



For BJTs: $r_e = \frac{kT}{qI_E}$, $g_m = \frac{I_C}{\frac{kT}{q}} = \frac{\alpha}{r_e}$, $r_\pi = r_b = (1 + h_{fe}) r_e$, $\alpha = \frac{h_{fe}}{1 + h_{fe}}$, $\beta \leftrightarrow h_{fe}$, and

$r_o = \frac{V_A + V_{CEQ}}{I_{CQ}}$. The full non-linear Shockley equation at constant V_{CE} and $I_C > 0$ is:

$I_C = I_S' \exp\left(\frac{nqV_{BE}}{kT}\right)$ where $n \geq 1$ and $I_S' \propto T^3 \exp\left(\frac{qV_G}{kT}\right)$.

Stage Type	Sign of Gain	Qual Gain	G(s)	Qual. z_{in}	Z_{in}	Qual z_{out}	Z_{out}
Common Emitter	-	high	$\frac{-\alpha Z_C}{r_e + Z_E}$	high	$R_{BB} \parallel [(1 + h_{fe})(r_e + Z_E)]$	high	Z_C
Common Base	+	high	$\frac{\alpha Z_C}{r_e + Z_1}$	low	$r_e + Z_1$	high	Z_C
Common Collector (Emitter Follower)	+	< 1	$\frac{Z_E}{r_e + Z_E}$	high	$R_{BB} \parallel [(1 + h_{fe})(r_e + Z_E)]$	low	$Z_E \parallel [r_e + Z_S/(1 + h_{fe})]$

Notes: 1.) Z_{BG} is the entire source impedance of the signal driving the base of the Common Collector stage.

2.) Z_1 is the impedance of any passive components in series with the input.

High frequency effects: parasitic capacitances

$$f_T = \frac{1}{2\pi r_e\left(C_\pi + C_\mu\right)} \quad \text{and} \quad f_\beta = \frac{1}{2\pi r_e C_\pi\left(1+\beta\right)}$$

Equivalent input impedance at high frequencies of a CE or CC circuit exclusive of the Miller effect from C_{OB} and the base series resistance $r_{bb'}$ is: $z_{tr}(s) \cong \frac{z_{tr}(0)}{1 + jf / f_\beta}$ and is equivalent to an effective capacitance $C_{eff} = \frac{r_e C_\pi}{r_e + Z_E}$ across the low frequency input resistance $z_{tr}(0)$.

Widlar current sources (bipolar) have reduced output I_O from an emitter resistor R_E satisfying the equation: $I_O R_E = \frac{kT}{q}\ln\left(\frac{I_{REF}}{I_O}\right)$.

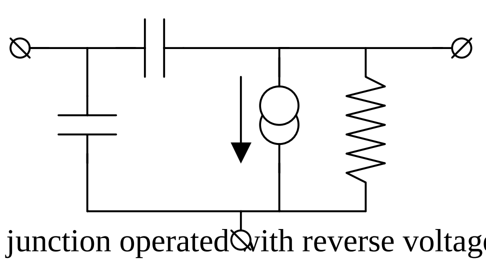
For long-channel MOSFETs:

$$I_{DS} = \frac{W}{L}\cdot K_N \cdot \begin{cases} 0 & \text{if } V_{GS} \le V_{TH} \\ \left(V_{GS} - V_{TH} - \frac{(1+a)}{2}V_{DS}\right)V_{DS} & \text{if } V_{DS} \le \frac{\left(V_{GS}-V_{TH}\right)}{(1+a)} \\ \frac{\left(V_{GS}-V_{TH}\right)^2}{2(1+a)}\left(1+\lambda V_{DS}\right) & \text{if } V_{DS} \ge \frac{\left(V_{GS}-V_{TH}\right)}{(1+a)} \end{cases}$$

$I_D = \frac{W}{L}K'\left(V_{GS} - V_{TH}\right)^2\left(1+\lambda V_{DS}\right)$ where $\lambda = 1/V_A$ in active operating mode.

MOSFET small signal model: $g_m \approx \frac{2I_{DQ}}{V_{OV}}$ and $r_o = \frac{1+\lambda V_{DSQ}}{\lambda I_{DQ}} = \frac{V_A + V_{DSQ}}{I_{DQ}}$

"Overvoltage" is defined as: $V_{OV} \equiv \left|V_{GS} - V_{TH}\right|$ when the device is biased for operation above threshold.



A diode with an abrupt junction operated with reverse voltage V_{REV} has capacitance:

$$C_D = \frac{C_0}{\sqrt{1+V_{REV}/V_{BI}}}$$