

## Formula Sheet

### DIODE

$$I_D = I_S (e^{V_D/V_T} - 1), \text{ where } V_T = \frac{k_B T}{q} = 26 \text{ mV}$$

| NMOS   | PMOS  |
|--|---|
| <p><b>Cut-off</b></p> $V_{GS} < V_m, \quad I_D = 0$ <p><b>Triode Region (Linear)</b></p> $V_{GS} > V_m \ \& \ V_{DS} < V_{DSP} = V_{GS} - V_m$ $I_D = \frac{W}{L} \mu_n C_{ox} \left( (V_{GS} - V_m) V_{DS} - \frac{V_{DS}^2}{2} \right)$ <p><b>Active Region (Saturation)</b></p> $V_{GS} > V_m \ \& \ V_{DS} \geq V_{DSP} = V_{GS} - V_m$ $I_D = \frac{W}{L} \frac{\mu_n C_{ox}}{2} (V_{GS} - V_m)^2 [1 + \lambda V_{DS}]$ | <p><b>Cut-off</b></p> $V_{SG} <  V_{tp} , \quad I_D = 0$ <p><b>Triode Region (Linear)</b></p> $V_{SG} >  V_{tp}  \ \& \ V_{SD} < V_{SDP} = V_{SG} -  V_{tp} $ $I_D = \frac{W}{L} \mu_p C_{ox} \left( (V_{SG} -  V_{tp} ) V_{SD} - \frac{V_{SD}^2}{2} \right)$ <p><b>Active Region (Saturation)</b></p> $V_{SG} >  V_{tp}  \ \& \ V_{SD} \geq V_{SDP} = V_{SG} -  V_{tp} $ $I_D = \frac{W}{L} \frac{\mu_p C_{ox}}{2} (V_{SG} -  V_{tp} )^2 [1 +  \lambda  V_{SD}]$ |

### Body Effect

$$V_i = V_{to} + \gamma \left( \sqrt{|V_{SB}| + 2\phi_F} - \sqrt{2\phi_F} \right)$$

### Small Signal Characteristics (NMOS):

$$g_m = \sqrt{2\mu_n C_{ox} \frac{W}{L} I_D}; \quad r_{ds} = \frac{|V_A|}{I_D} = \frac{1}{\lambda I_D}$$