Small-Signal Model Parameters

- ***Transconductance*** (g_m):

$$g_m \triangleq \left.\frac{\partial I_D}{\partial V_{GS}}\right|_{V_{DS} \text{ and } V_{SB} \text{ constant}}$$

$$= k_N V_{GT}\left(1+\lambda V_{DS}\right) = \sqrt{2k_N I_D\left(1+\lambda V_{DS}\right)}$$

➢ ***If $\lambda V_{DS} < 0.1$***:

$$g_m \simeq k_N V_{GT} \simeq \sqrt{2k_N I_D}$$

- An important ***Figure of Merit*** is ***transconductance to current ratio***
  - For ***MOSFETs***: $g_m/I_D = 2/V_{GT}$
  - For ***BJTs***: $g_m/I_C = 1/V_T$
  - Thus, ***BJTs produce more g_m per unit current***
- As we will see later, a ***high value of g_m is highly desirable***, since it ***dictates the gain***
- ***g_m/I_D can be changed by changing the bias current and/or aspect ratio***
- ***g_m/I_C is a function only of temperature***

- ***Body Transconductance*** (g_{mb}):

$$g_{mb} \triangleq \left.\frac{\partial I_D}{\partial V_{BS}}\right|_{V_{GS}\ \text{and}\ V_{DS}\ \text{constant}} = \chi g_m$$

$$\chi = \frac{\gamma}{2\sqrt{2\phi_F + V_{SB}}} = \textbf{\textit{Body factor}} \quad (\sim 0.1\text{-}0.3)$$

  - ***Note***: ***As*** $V_{SB}\uparrow$, $V_{TN}\uparrow \Rightarrow I_D\downarrow$
  - $\partial I_D/\partial V_{SB}$ ***would have yielded negative*** g_{mb}
  - ***If both B and S are tied to fixed DC potentials*** (***including ground***), g_{mb} ***won't matter***!

- ***Output Conductance*** (g_0)/
  Output Resistance (r_0):

$$g_0 = r_0^{-1} \triangleq \left.\frac{\partial I_D}{\partial V_{DS}}\right|_{V_{GS} \text{ and } V_{SB} \text{ constant}} = \frac{\lambda I_D}{1+\lambda V_{DS}}$$

  - ***If $\lambda V_{DS} < 0.1$***:
    $g_0 = 1/r_0 \approx \lambda I_D$
  - ***λ has a very wide range*** ~ 0.01-0.5 V^{-1}
  - ***When $\lambda \rightarrow 0$, $g_0 \rightarrow 0$, and $r_0 \rightarrow \infty$***
    - ***Device starts to behave like a constant current source***