MOS I-V characteristics

From ① & ② in previous pages,

$I_{DS,\,linear\text{-}region} = I_{DS,\,sat\text{-}region}$, at $V_{DS} = V_{DS,sat}$

$$\mu_n C_{ox} \frac{W}{L} \left\{ (V_{GS}-V_{th}) V_{DS,sat} - \frac{1}{2} V_{DS,sat}^2 \right\} \frac{1}{1+\frac{V_{DS,sat}}{E_c \cdot L}}$$

$$= \frac{1}{2} \mu_n C_{ox} \frac{W}{L} (V_{GS}-V_{th})^2 \frac{E_c \cdot L}{(V_{GS}-V_{th}) + E_c \cdot L}$$

$$\Rightarrow V_{DS,sat} = (V_{GS}-V_{th}) \boxed{\frac{E_c \cdot L}{(V_{GS}-V_{th}) + E_c \cdot L}}$$

→ This is always < 1

∴ $V_{DS,sat}$ of short channel is always smaller than that of long channel

⊛ Some remarks

For 0.13 ~ 0.18 μm CMOS, $E_c \cdot L = 0.5 \sim 1V$ range and overdriving voltage $(V_{GS}-V_{th})$ ~~usually smaller than 0.5 V for small signal circuit designs such as LNA and mixer.~~ ~~V_{DS}~~ ~~But it could be comparable~~ Could be comparable to $E_c \cdot L$. ~~V_{DS} is~~ V_{DS} also could be reached to $E_c \cdot L$.

⇒ We need short channel DC-model for hand analysis.