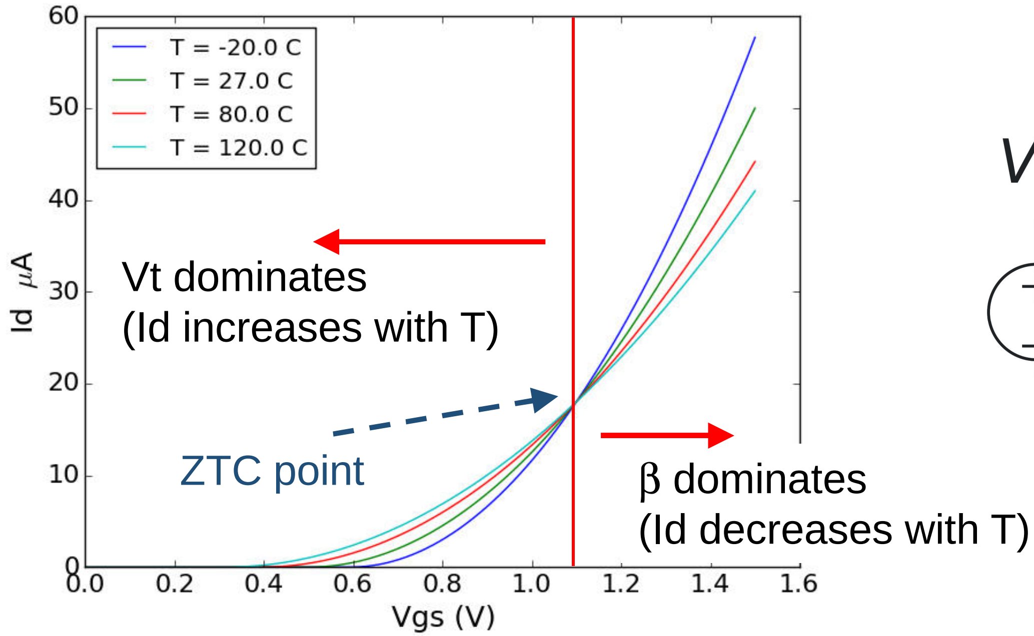
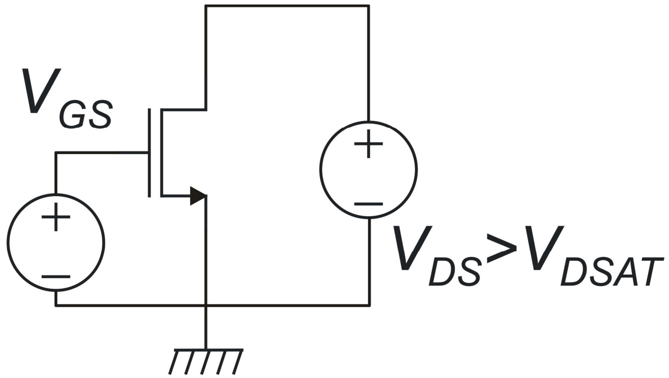
Temperature effects on MOSFET characteristics

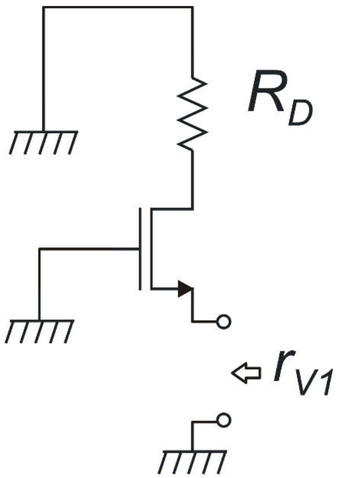
$$\beta_n(T) = \beta_n(T_0)\left(\frac{T}{T_0}\right)^{-\alpha_\mu} \qquad \alpha_\mu = 1.2\ -\ 2.4\ \text{(typical 1.5)}$$

$$V_t(T) = V_t(T_0) - \alpha_{VT}\left(T - T_0\right) \qquad 1\ \text{mV/K} \ \le\ \alpha_{VT} \le 4\ \ \text{mV/K}$$





The six basic (small signal) resistances: MOSFETS

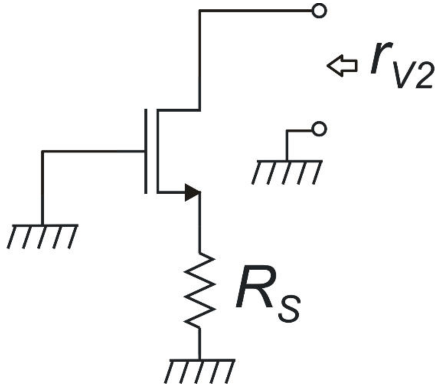


$$r_{v1} \cong \frac{1}{g_m}$$

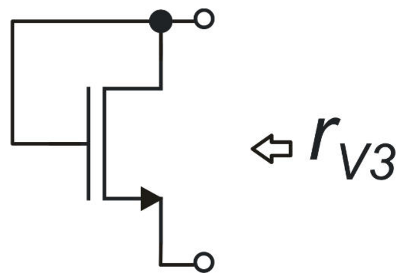
$$r_{v1} = \frac{R_D + r_d}{1 + g_m r_d}$$ exact result

Conditions for approximation

$$g_m r_d >> 1 \quad \text{and} \quad R_D << r_d \quad \Rightarrow \quad r_{v1} \cong \frac{1}{g_m}$$



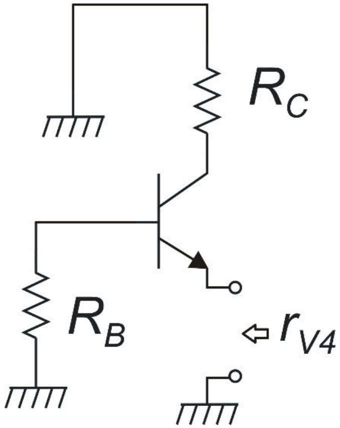
$$r_{v2} = R_S + r_d\left(1 + g_m R_S\right)$$



$$r_{v3} = \quad r_D // \frac{1}{g_m} \quad \cong \frac{1}{g_m}$$

Diode-connected MOSFET

The six basic (small signal) resistances: BJTs



$$g_{meq} \equiv \frac{r_{be}}{R_B + r_{be}} g_m = \frac{h_{fe}}{R_B + r_{be}}$$

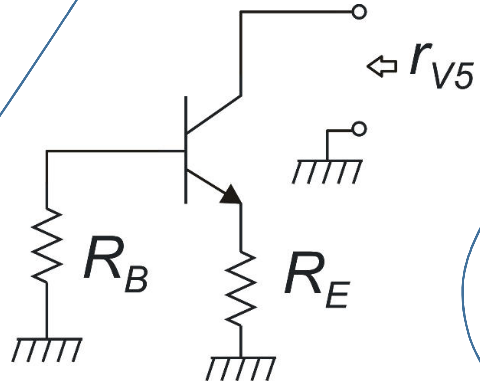
$$r_{v4} \cong \frac{1}{g_{meq}}$$

exact result

$$r_{v4} = \frac{R_C + r_o}{1 + g_{meq} r_o} // \left(r_{be} + R_B\right)$$

Conditions for approximation

$$g_{meq} r_o >> 1 \quad \text{and} \quad R_C << r_o$$



exact result

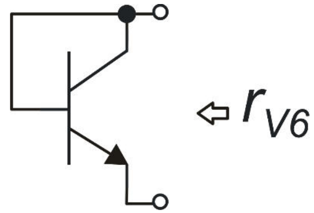
$$r_{v5} = R_{Eeq} + r_o \left(1 + g_{meq} R_{Eeq}\right)$$

$$R_{Eeq} = \left(R_B + h_{ie}\right) // R_E$$

approximations

1) $R_E << \left(r_{be} + R_B\right) \Rightarrow r_{v5} \cong r_o \left(1 + g_{meq} R_E\right)$

2) $R_E >> \left(r_{be} + R_B\right) \Rightarrow r_{v5} \cong r_o \left(1 + h_{fe}\right)$



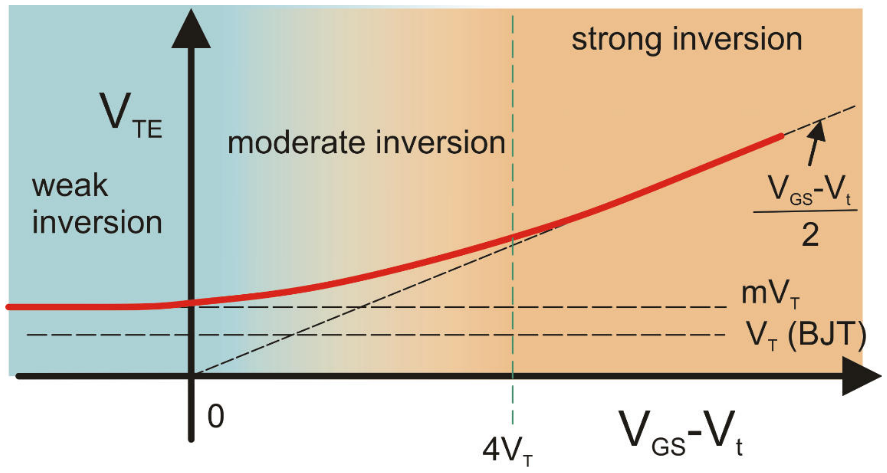
$$r_{v6} = r_o // \frac{1}{g_m} // h_{ie} \cong \frac{1}{g_m}$$

The $g_m r_d$ product (in saturation region)

$$g_m = \frac{I_D}{V_{TE}}$$

$$r_d = \frac{1}{g_{ds}} = \frac{1}{\lambda I_D} = \frac{\lambda^{-1}}{I_D}$$

$$g_m r_d = \frac{1}{V_{TE}} \cdot \frac{1}{\lambda}$$



$$\frac{1}{\lambda} \propto L_{eff}$$

Large $g_m r_d$ products are obtained for small V_{GS}-V_t and large L

$g_m r_d$ is generally of the order of 100

$g_m r_0$ for BJTs in active zone

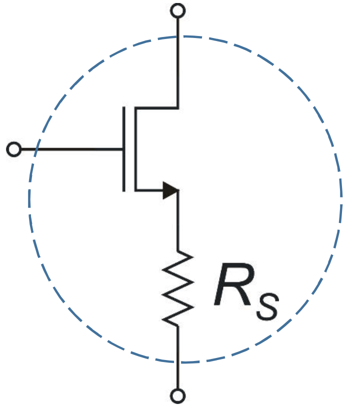
$$g_m = \frac{I_C}{V_T}$$

$$r_o = \frac{V_A}{I_C}$$

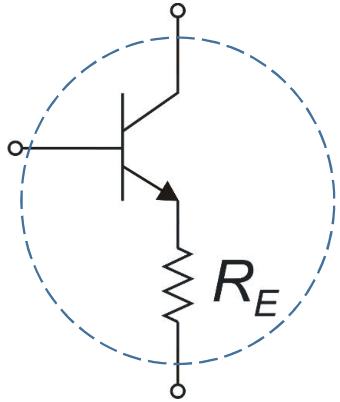
$$g_m r_0 = \frac{V_A}{V_T}$$

$g_m r_0$ may easily reach 1000 (e.g. for V_A=25 V)

Source / Emitter degeneration



- Lower effective g_m for the same I_D (I_C)
- Higher equivalent r_o
- Higher input impedance



reduced gm

$$g_{mrid} = \frac{g_m}{1+g_m R_S}$$

$$\frac{g_{mrid}}{I_D} = \frac{1}{V_{TE}} \cdot \frac{1}{1+g_m R_S}$$

$$g_m R_S = \frac{I_D R_S}{V_{TE}}$$

$$g_{mrid} \cong \frac{g_m}{1+g_m R_E}$$

$$\frac{g_{mrid}}{I_D} \cong \frac{1}{V_T} \cdot \frac{1}{1+g_m R_E}$$

$$g_m R_E = \frac{I_C R_E}{V_T}$$