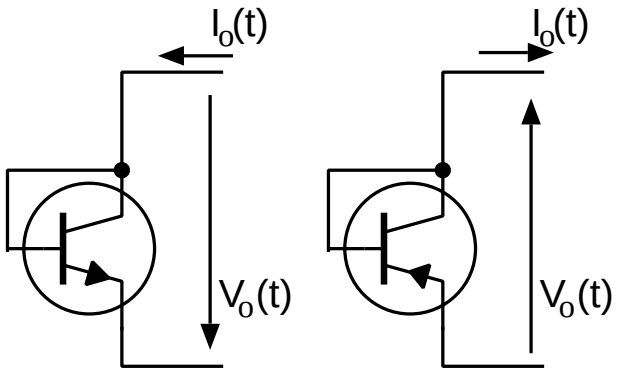
Tema 2. Bloques Constructivos

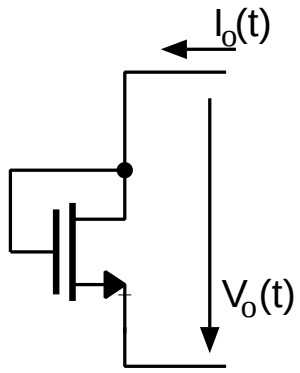
- Conexion Diodo
- Fuente de Corriente
- Espejo de Corriente
- Repaso transistor bipolar
- Repaso transistor MOSFET

Bibliografia

"VLSI Design Techniques for Analog and Digital Circuits", Randall Geiger, Noel Strader, N. R. Strader, McGraw-Hill

Conexión diodo (*Diode Connected Transistor*)

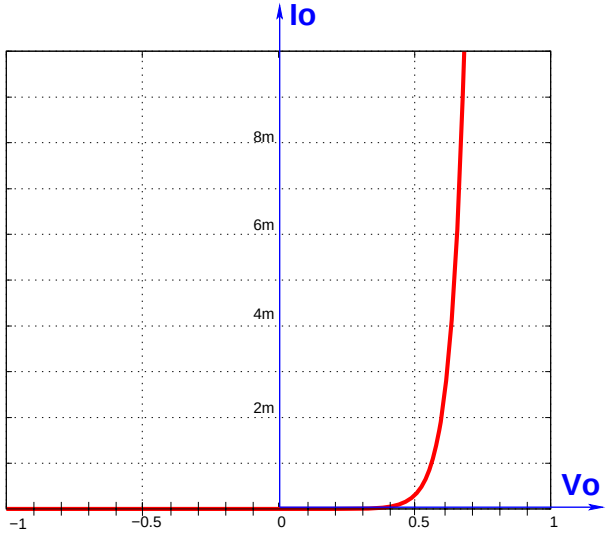




Modelo DC (Estático)

Supongamos el bjt en activa directa:

$$I_o = I_s\, e^{V_o/V_t}$$



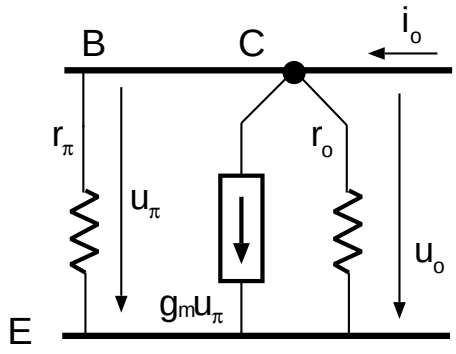
Modelo AC(dinámico)

$$u_o(t) = R\, i_o(t)$$

metodo A

$$R = \frac{\partial V_o}{\partial I_o} = \frac{V_t}{Is\, e^{V_o/V_t}} = \frac{V_t}{I_o}$$

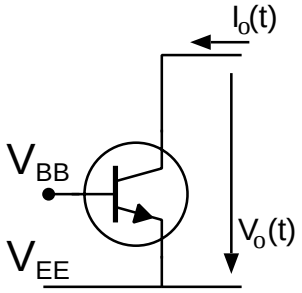
metodo B



$$R = \frac{1}{g_m} ||r_\pi||r_o$$

Fuente de Intensidad (*Current Source*)

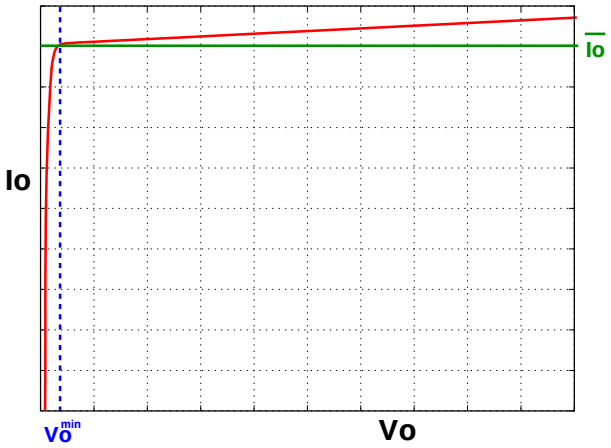
Fuente de corriente simple con bipolar
(*Bipolar Simple Current Source*)



Modelo DC (Estático)

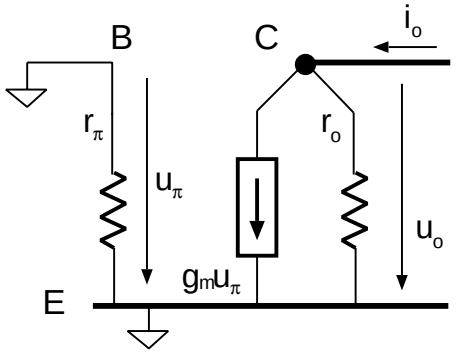
Supongamos el bjt en activa directa:

$$I_o = I_s\, e^{V_{BE}/V_t}$$
$$V_{BE} = V_{BB} - V_{EE} = cte$$



Modelo AC(dinámico)

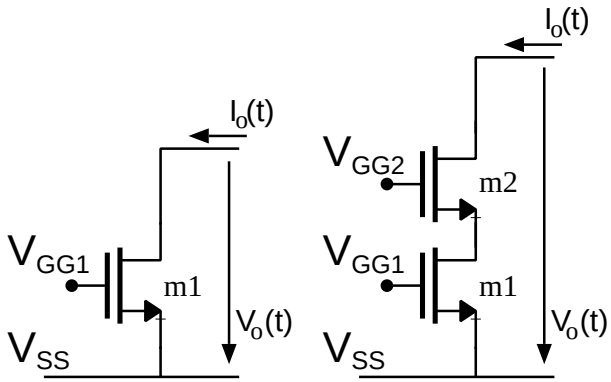
$$u_o(t) = R\, i_o(t)$$



$$R = \mathrm{r_o}$$

Fuente de corriente con MOSFET (*MOSFET Current Source*)

Simple Current Source



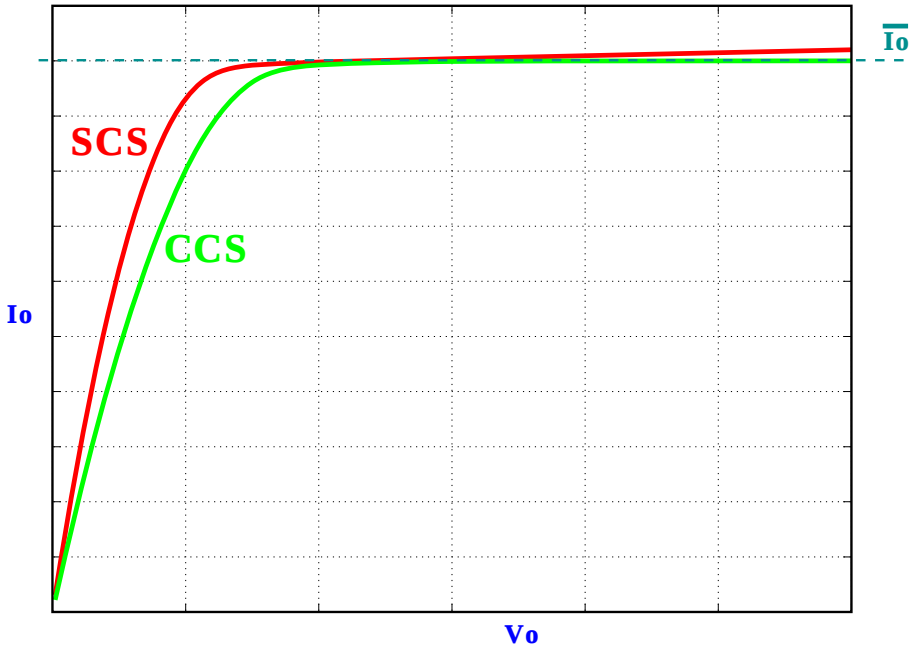
Cascode Current Source

Modelo DC (Estático)

Supongamos el MOSFET en saturación:

$$I_{d1} = \frac{1}{2} K \frac{W}{L} (\mathrm{V_{gs1}} - \mathrm{V_{th1}})^2$$

$$\mathrm{V_{gs1}} = V_{GG1} - V_{SS}$$



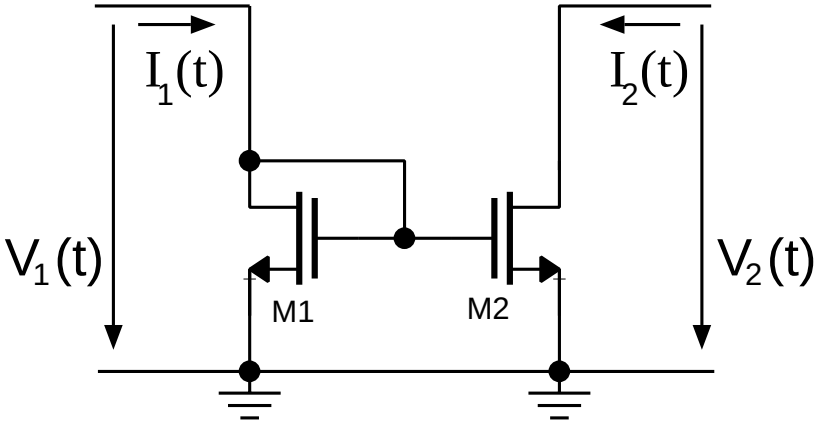
Modelo AC(dinámico)

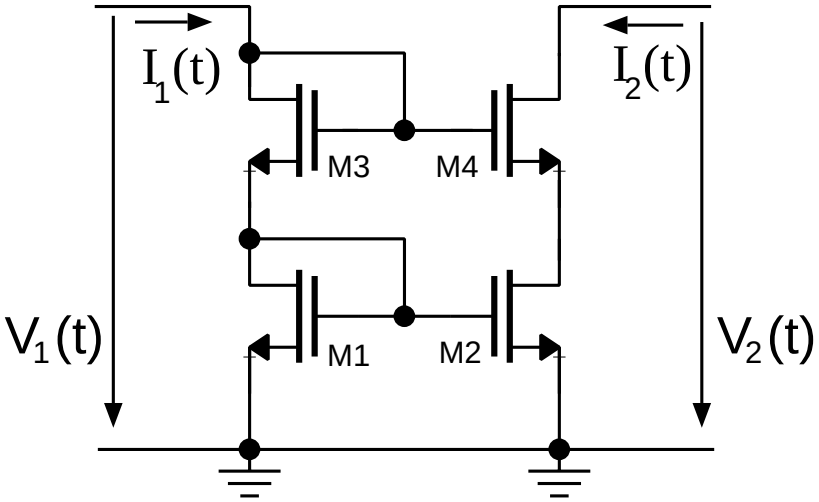
$$u_o(t) = R\, i_o(t)$$

SCS: $R = \mathrm{r_{o1}}$

CCS: $R \simeq \mathrm{r_{o1}\, g_{m2}\, r_{o2}}$

Espejo de Corriente (*Current Mirror*)



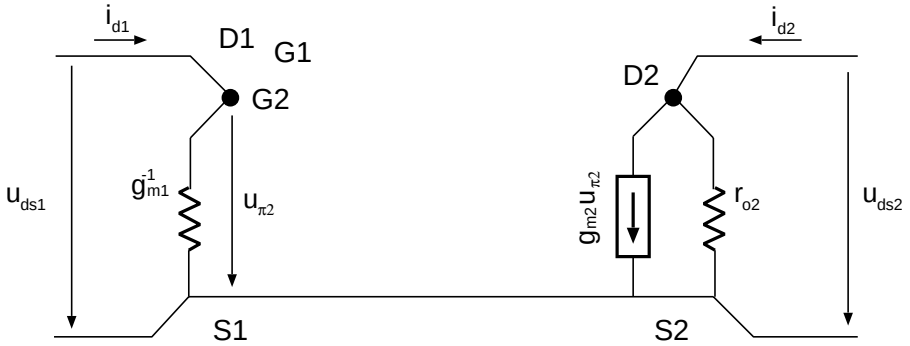


Modelo DC (Estático)

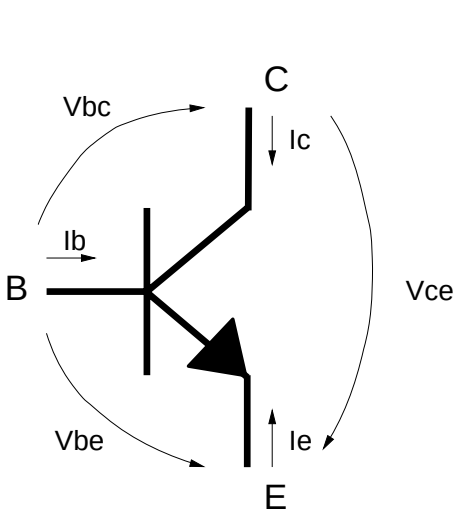
Supongamos MOSFETs en saturación:

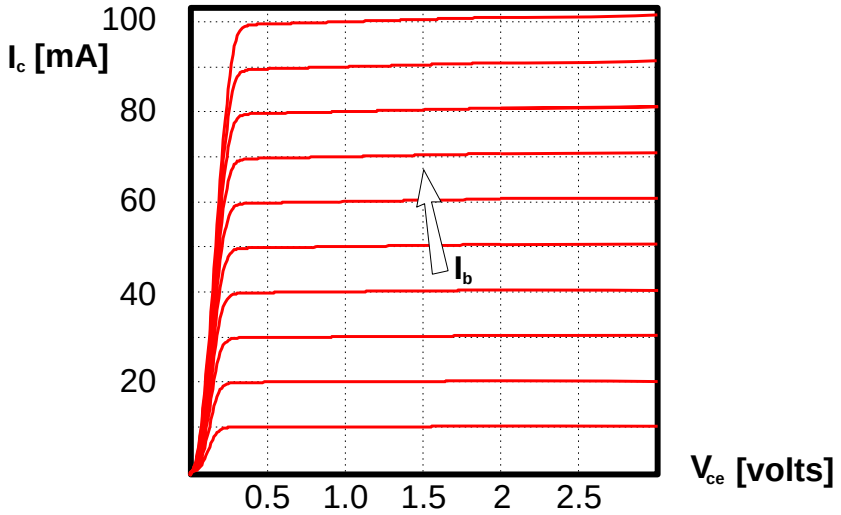
$$\frac{\overline{I_1}}{\overline{I_2}} = \frac{(W/L)_1}{(W/L)_2}$$

Modelo AC(dinámico)



Modelo Transistor Bipolar





Modelo DC
Ecuaciones de Ebers-Moll

$$I_c = +I_s\left[\exp\left(\frac{V_{be}}{V_t}\right)-1\right] - \frac{I_s}{\alpha_r}\left[\exp\left(\frac{V_{bc}}{V_t}\right)-1\right]$$

$$I_e = -\frac{I_s}{\alpha_f}\left[\exp\left(\frac{V_{be}}{V_t}\right)-1\right] + I_s\left[\exp\left(\frac{V_{bc}}{V_t}\right)-1\right]$$

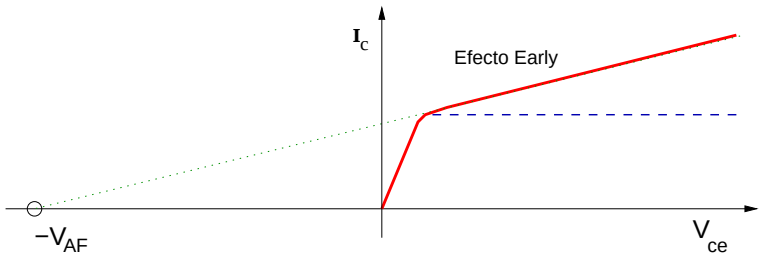
Suponiendo **activa directa**: $V_{be} >>$ y $V_{bc} <<$ y definiendo la ganancia directa en corriente $\beta_f = \alpha_f/(1-\alpha_f)$:

$$I_c = I_s \exp\left(\frac{V_{be}}{V_t}\right)$$

$$I_c = \beta_f I_b$$

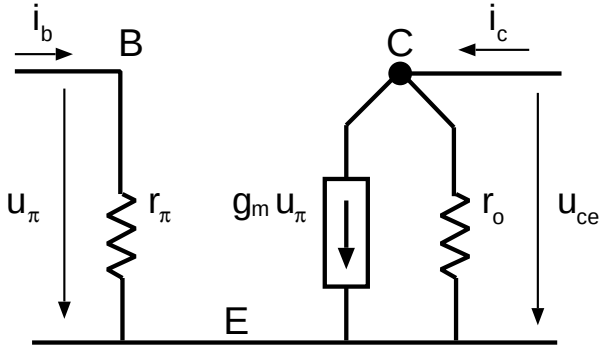
Efecto Early

$$I_c \simeq I_s \exp\left(\frac{V_{be}}{V_t}\right)\left(1+\frac{V_{ce}}{V_{AF}}\right)$$



Modelo AC

Suponiendo el transistor polarizado en activa directa



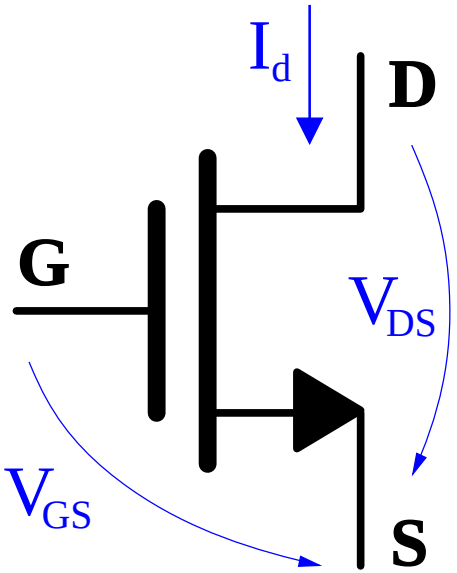
La dependencia de los parametros AC con el nivel DC es:

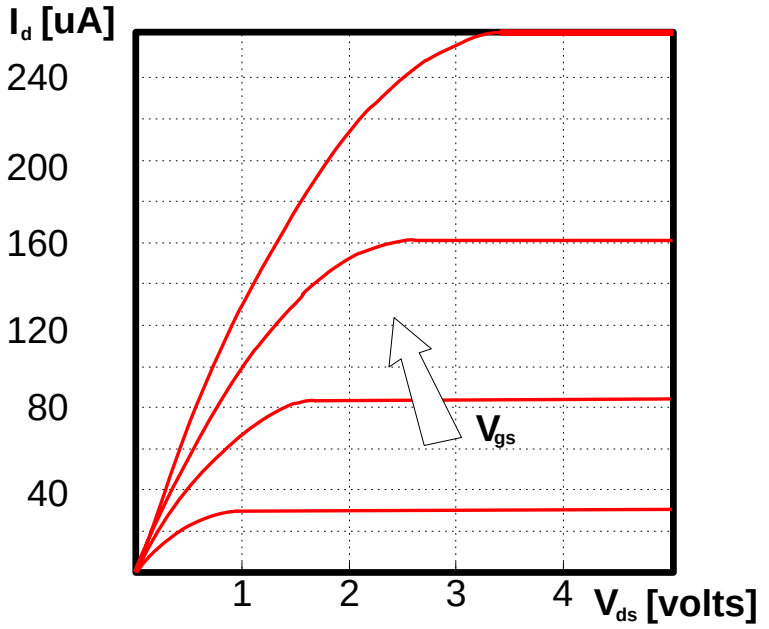
$$r_o = \frac{V_{AF}}{I_c}$$

$$\frac{1}{g_m} = \frac{V_t}{I_c}$$

$$r_\pi = \frac{h_{fe}\, V_t}{I_c}$$

Modelo Transistor MOSFET





Modelo DC

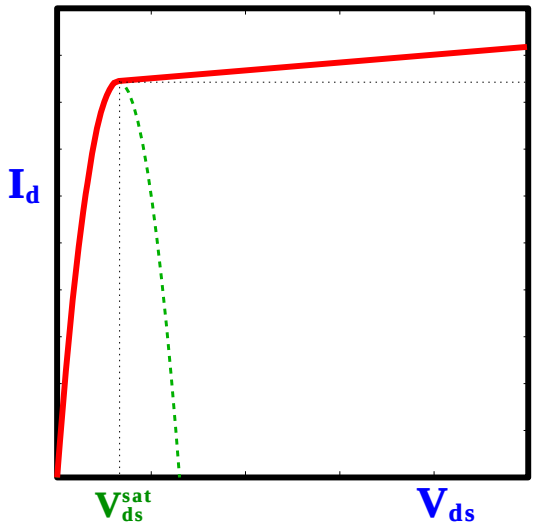
En la **zona de saturación** tenemos que:

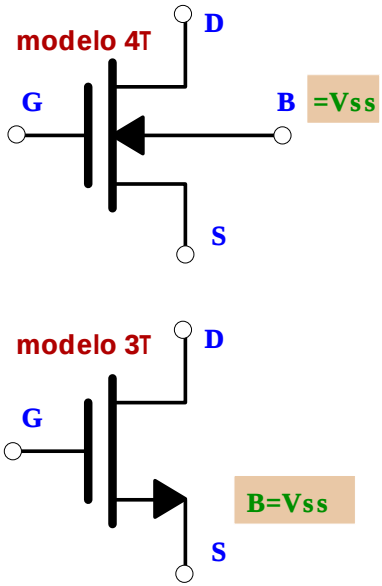
$$\mathrm{I_d} = \frac{1}{2}\,\mathrm{K}\,\left[\frac{\mathrm{W}}{\mathrm{L}}\right]\left[\mathrm{V_{gs}} - \mathrm{V_{th}}\right]^2$$

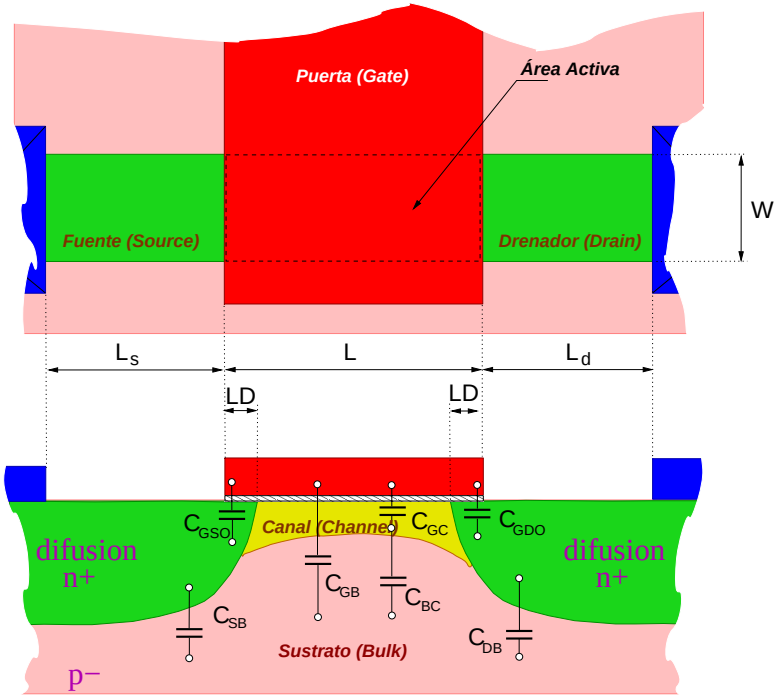
siempre que $\mathrm{V_{gs}} > \mathrm{V_{th}}$ y $\mathrm{V_{ds}} > \mathrm{V_{gs}} - \mathrm{V_{th}}$

.

- $\mathrm{K}\left[\frac{\mu A}{V^2}\right]$ **Parámetro de transconductancia** (*transconductance parameter*). $\mathrm{K} = \mu_o\,\mathrm{C_{ox}}$
- $\left[\frac{\mathrm{W}}{\mathrm{L}}\right]$ **relación de aspecto** (*aspect ratio*)
- $\mathrm{V_{th}}$ **tensión umbral** (*threshold voltage*)





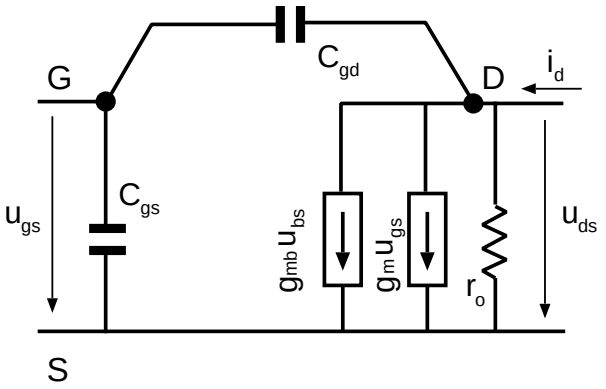


Modulación del Canal

$$I_d = \frac{1}{2} K \left[\frac{W}{L}\right] \left[V_{gs} - V_{th}\right]^2 (1 + \lambda V_{ds})$$

Efecto Sustrato

$$V_{th} = V_{to} + \gamma \left[\sqrt{\Phi_f + V_{sb}} - \sqrt{\Phi_f}\right]$$



Modelo AC

$$g_m = \sqrt{2 K \left[\frac{W}{L}\right] I_d}$$

$$r_o = 1/(\lambda I_d)$$

$$g_{mb} = \eta g_m$$