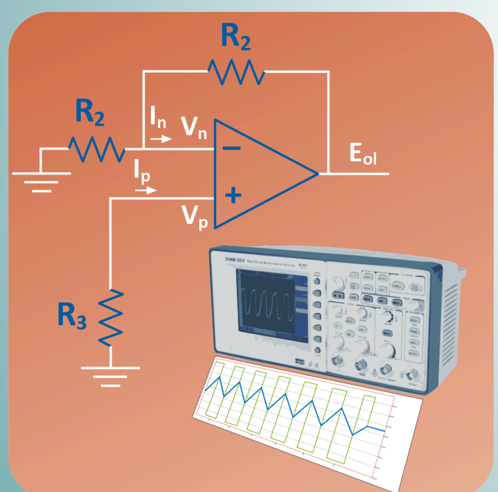
Electrónica Básica

Tema B.2.
Fuentes de Corriente y Tensiones de Referencia



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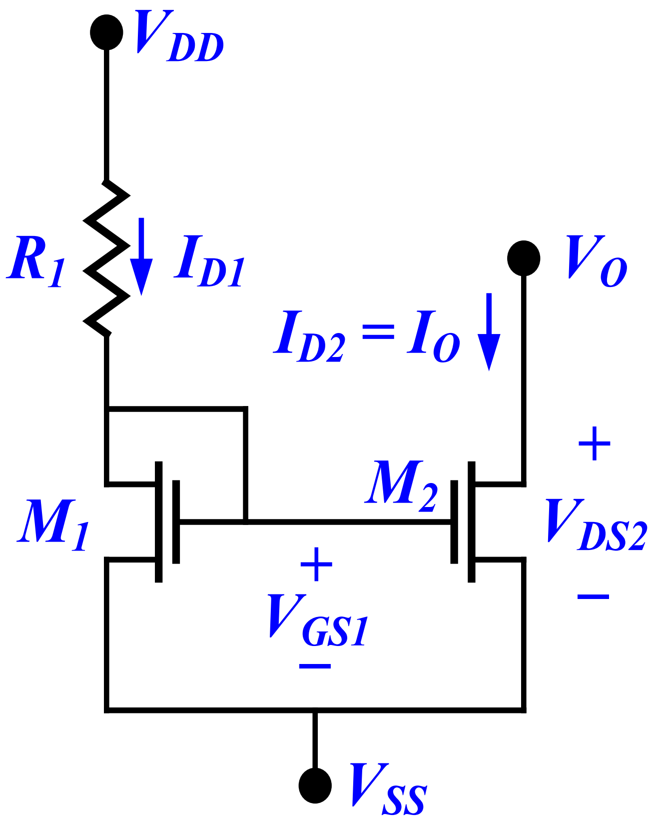
DPTO. DE ELECTRÓNICA Y COMPUTADORES

Espejos de Corriente

- Espejo de corriente básico NMOS:



$$M_1 \; sat: \quad I_{D1} = \frac{\beta_{n1}}{2}\left(V_{GS1} - V_{TN}\right)^2$$

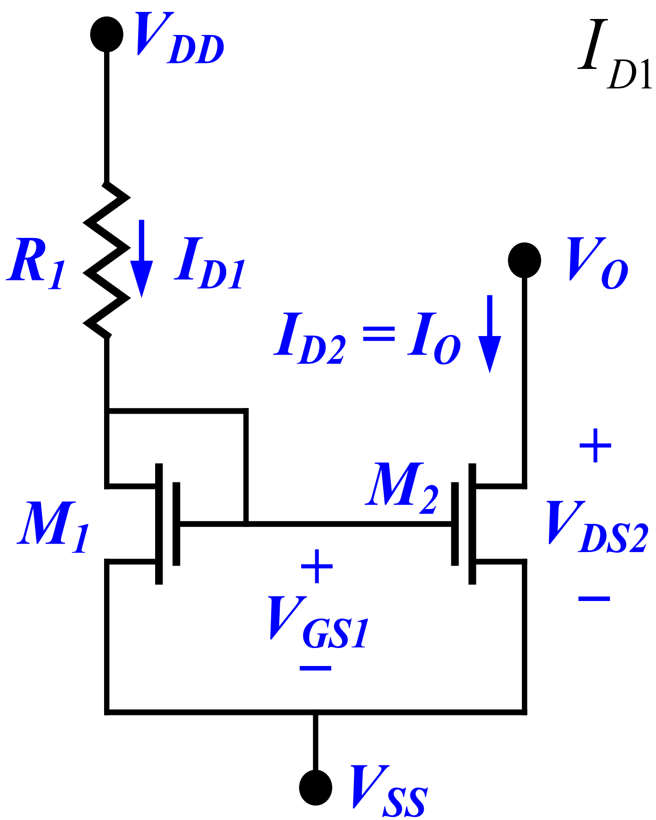
$$Si \; M_2 \; sat: \quad I_{D2} = \frac{\beta_{n2}}{2}\left(V_{GS2} - V_{TN}\right)^2$$

$$V_{GS1} = V_{GS2} \quad \Rightarrow \quad \frac{I_O}{I_{D1}} = \frac{\beta_{n2}}{\beta_{n1}} = \frac{W_2 L_1}{W_1 L_2}$$

$$\beta_{ni} = K'_n \frac{W_i}{L_i} \quad \wedge \quad K'_n = \mu_n C_{ox}$$

Espejos de Corriente

- Ecuaciones de diseño:



$$I_{D1} = \frac{V_{DD} - V_{GS1} - V_{SS}}{R_1} = \frac{K_n' W_1}{2L_1}\left(V_{GS1} - V_{TN}\right)^2$$

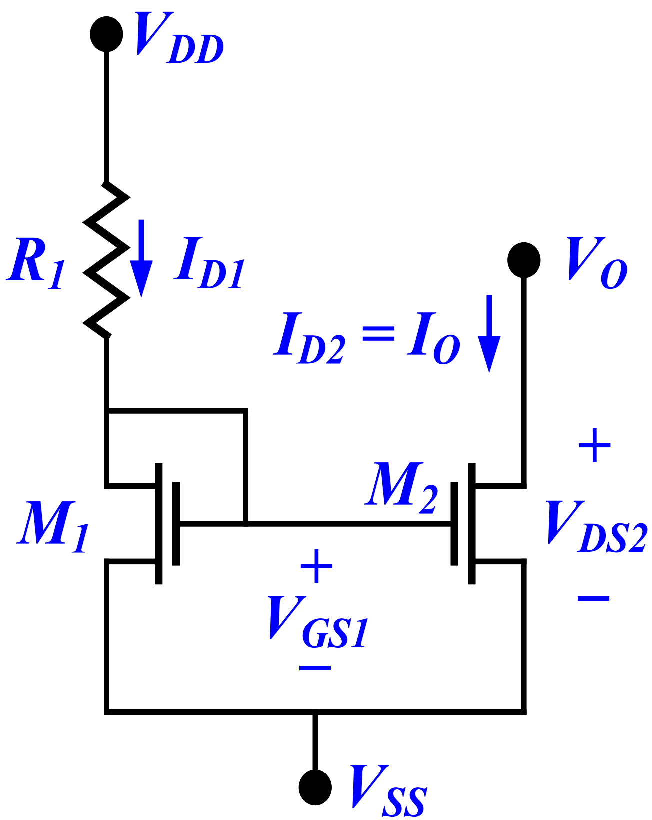
$$\begin{cases} M_2 \equiv eos: \quad V_{GD2} = V_{TN} \\ V_{O(\min)} = V_{GS2} - V_{TN} + V_{SS} \end{cases}$$

$$R_o = r_{o2} = \frac{1}{\lambda I_O} = \frac{1}{\lambda I_{D2}}$$

$$L_1 = L_2 \quad \Rightarrow \quad \frac{I_O}{I_{D1}} = \frac{W_2}{W_1}$$

Espejos de Corriente

- Limitaciones:



$$I_{D1} = \frac{K'_n W_1}{2L_1}\left(V_{GS1} - V_{TN}\right)^2\left(1 + \lambda_{n1} V_{DS1}\right)$$

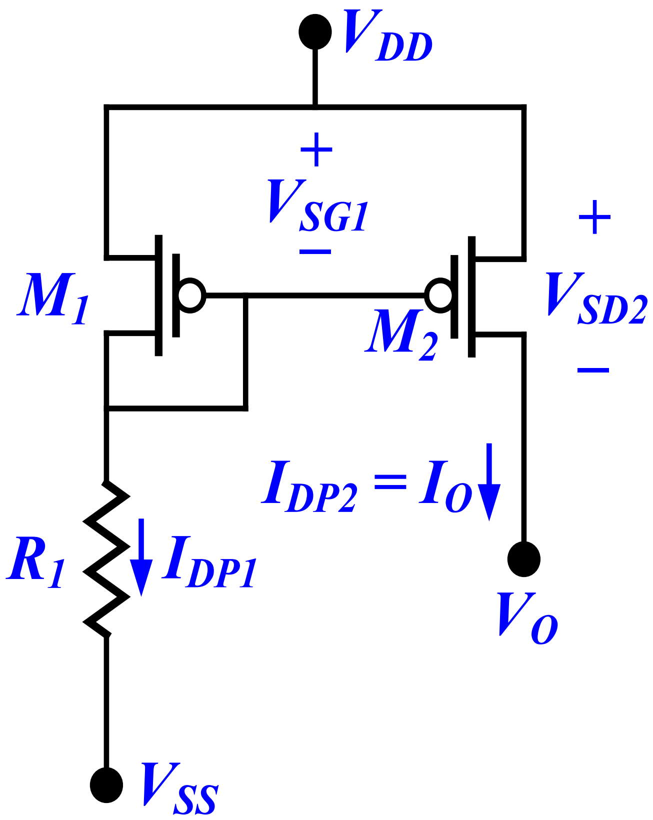
$$I_{D2} = \frac{K'_n W_2}{2L_2}\left(V_{GS2} - V_{TN}\right)^2\left(1 + \lambda_{n2} V_{DS2}\right)$$

$$\frac{W_1}{L_1} = \frac{W_2}{L_2} \quad \wedge \quad \lambda_{n1} = \lambda_{n2}:$$

$$\frac{I_O}{I_{D1}} = \frac{1 + \lambda_n V_{DS2}}{1 + \lambda_n V_{DS1}}$$

Espejos de Corriente

- Espejo de corriente básico PMOS:



$$M_1\ sat: \quad I_{DP1} = \frac{\beta_{p1}}{2}\left(V_{SG1} - \left|V_{TP}\right|\right)^2$$

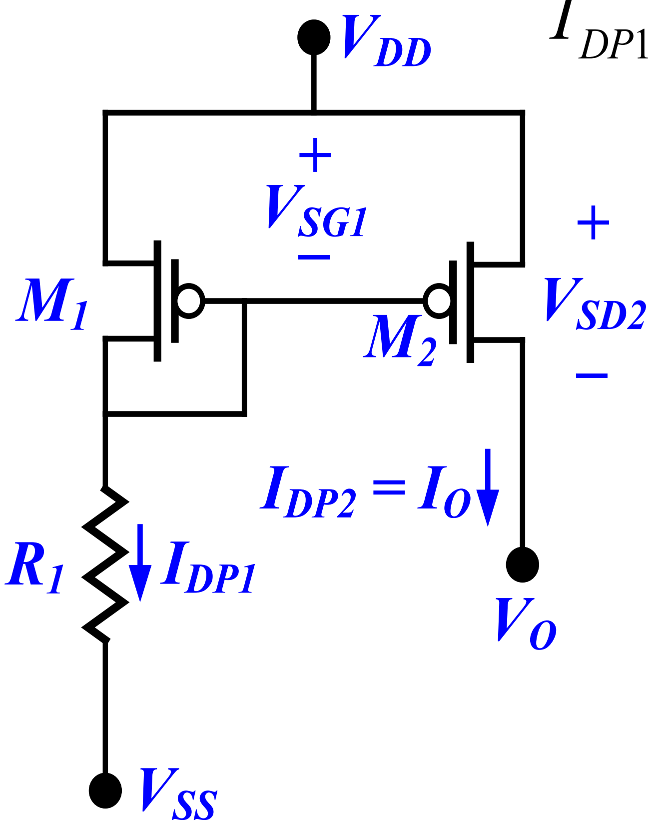
$$Si\ M_2\ sat: \quad I_{DP2} = \frac{\beta_{P2}}{2}\left(V_{SG2} - \left|V_{TP}\right|\right)^2$$

$$V_{SG1} = V_{SG2} \quad \Rightarrow \quad \frac{I_O}{I_{DP1}} = \frac{\beta_{p2}}{\beta_{p1}} = \frac{W_2 L_1}{W_1 L_2}$$

$$\beta_{pi} = K'_p \frac{W_i}{L_i} \quad \wedge \quad K'_p = \mu_p C_{ox}$$

Espejos de Corriente

- Ecuaciones de diseño:



$$I_{DP1} = \frac{V_{DD} - V_{SG1} - V_{SS}}{R_1} = \frac{K'_p W_1}{2L_1}\left(V_{SG1} - |V_{TP}|\right)^2$$

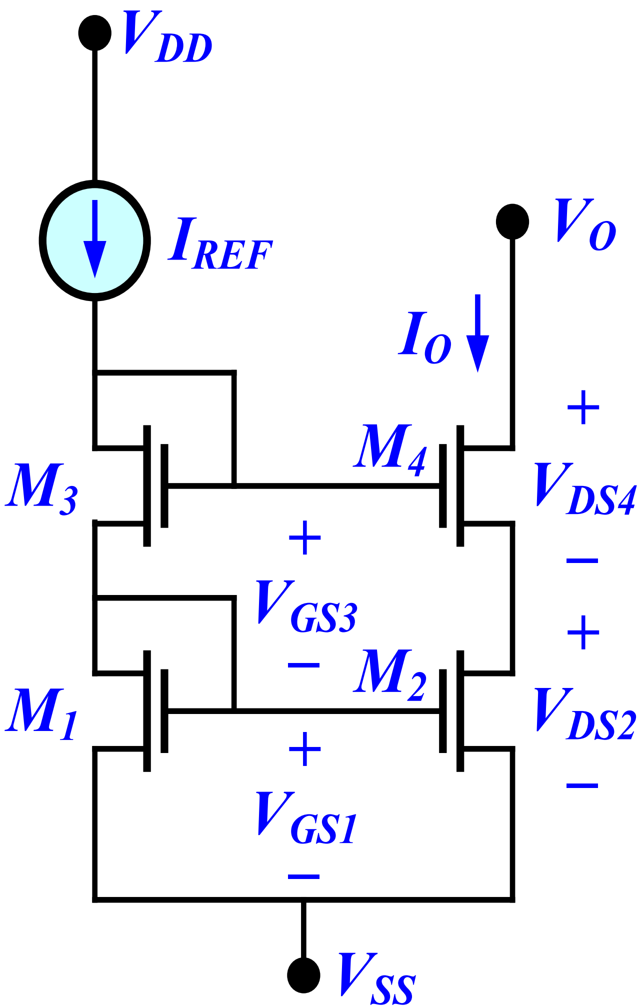
$$\begin{cases} M_2 \equiv eos: \quad V_{GD2} = -|V_{TP}| \\ V_{O(\max)} = V_{DD} - V_{SG2} + |V_{TP}| \end{cases}$$

$$R_o = r_{o2} = \frac{1}{\lambda I_O} = \frac{1}{\lambda I_{DP2}}$$

$$L_1 = L_2 \quad \Rightarrow \quad \frac{I_O}{I_{DP1}} = \frac{W_2}{W_1}$$

Fuente de Corriente Cascode

- Configuración NMOS:

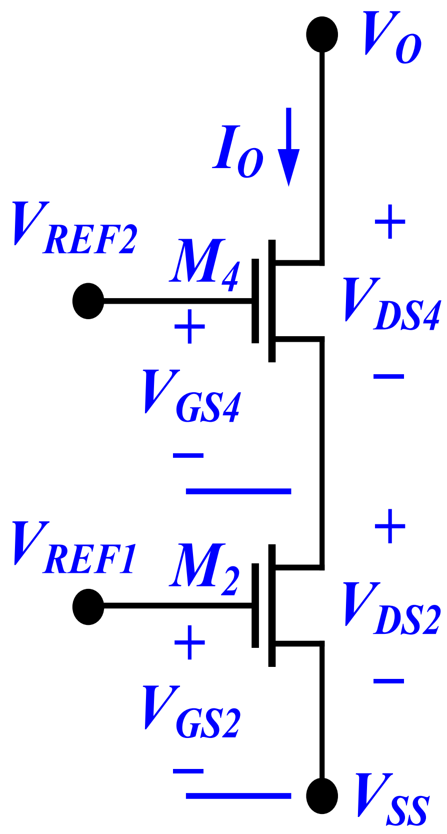


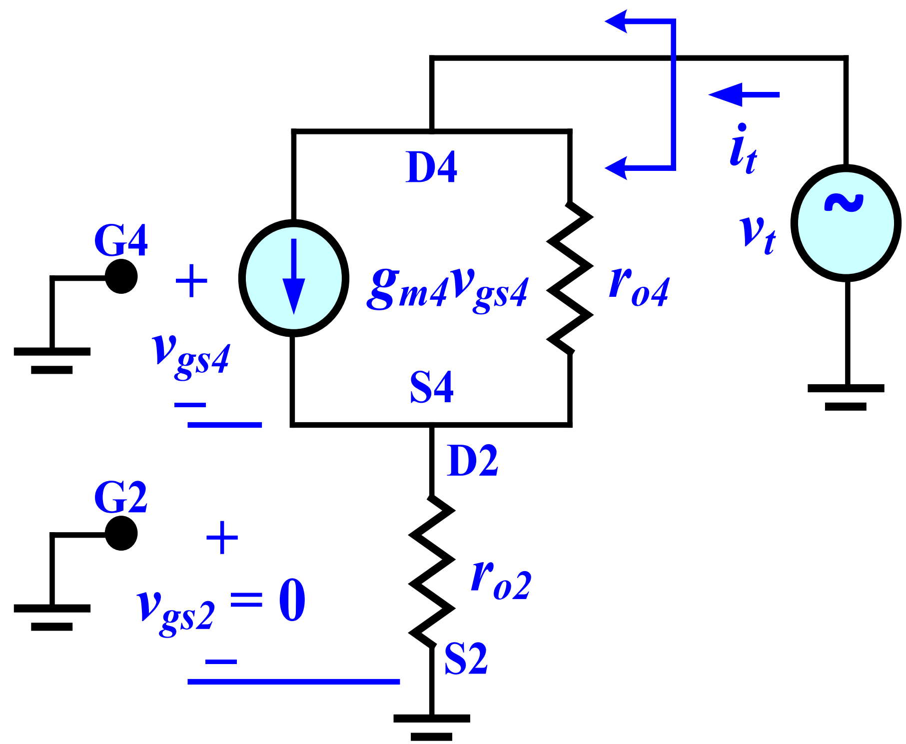
$$\frac{I_O}{I_{REF}} = \frac{W_2 L_1}{W_1 L_2}$$

$$\begin{cases} M_4 \equiv eos: \quad V_{GD4} = V_{TN} \\ V_{O(\min)} = V_{GS3} + V_{GS1} - V_{TN} + V_{SS} \end{cases}$$

Fuente de Corriente Cascode

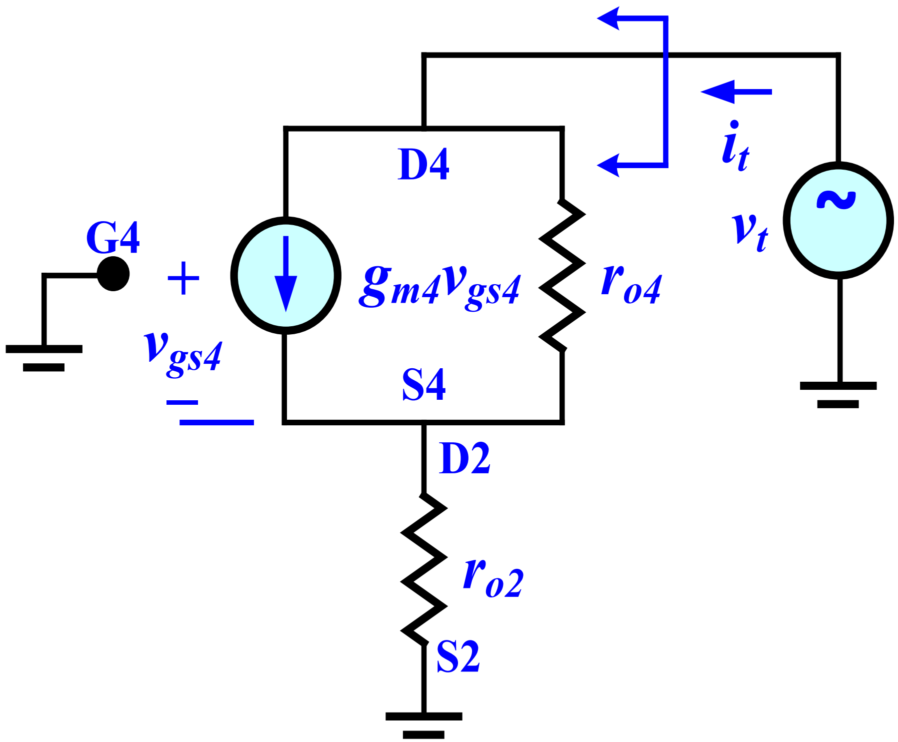
- Resistencia de salida: circuito equivalente.





Fuente de Corriente Cascode

- Cálculo de la resistencia de salida:



$$i_t = g_{m4}v_{gs4} + \frac{v_t - (-v_{gs4})}{r_{o4}}$$

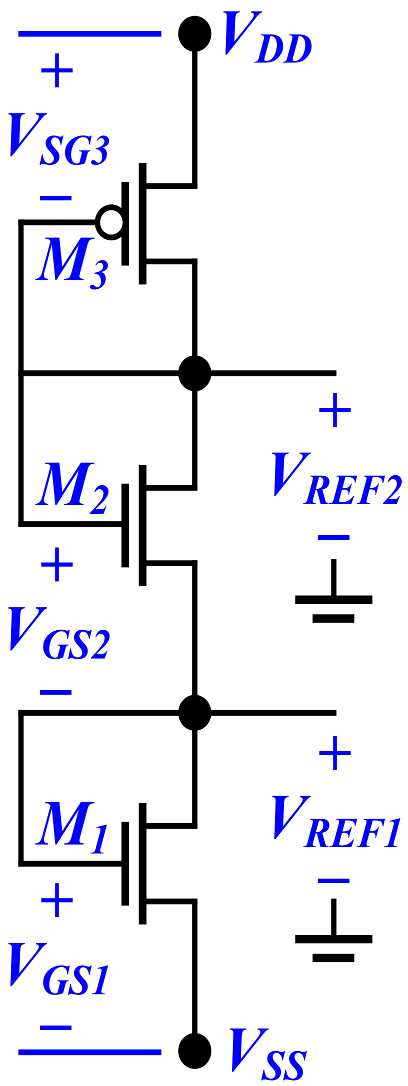
$$v_{gs4} = -r_{o2}i_t$$

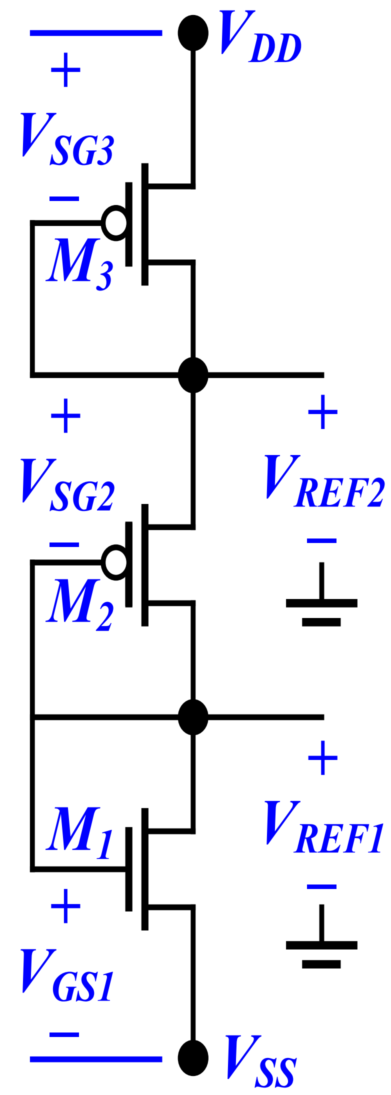
$$i_t = -g_{m4}r_{o2}i_t + \frac{v_t - r_{o2}i_t}{r_{o4}}$$

$$\frac{v_t}{r_{o4}} = i_t\left(1 + g_{m4}r_{o2} + \frac{r_{o2}}{r_{o4}}\right)$$

$$R_o = \frac{v_t}{i_t} = r_{o4}(1 + g_{m4}r_{o2}) + r_{o2}$$

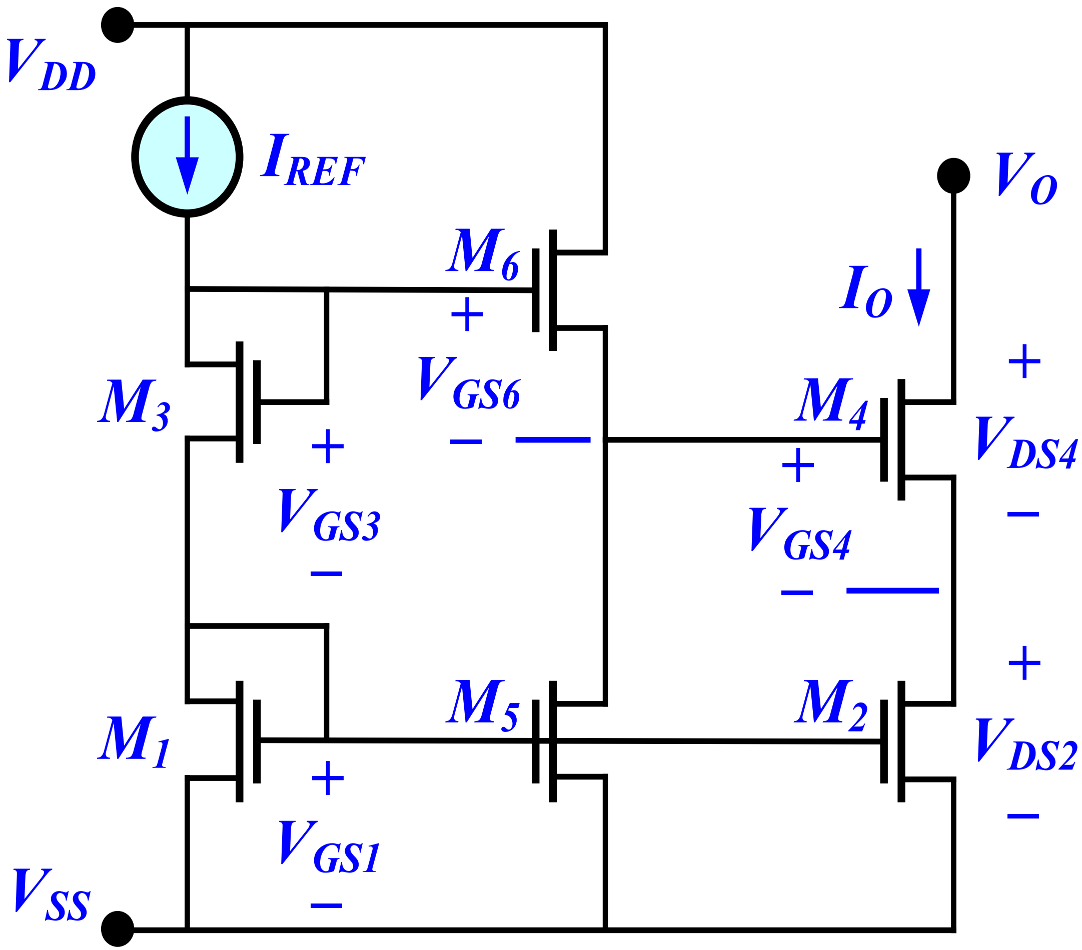
Generación de Tensiones de Referencia





Fuente de Corriente Cascode

- Optimización del rango de tensiones de salida.



$$M_2 \equiv eos: \quad V_{GD2} = V_{TN}$$

$$V_{D2} = V_{GS2} - V_{TN} + V_{SS}$$

$$M_4 \equiv eos: \quad V_{GD4} = V_{TN}$$

$$V_{O(\min)} = V_{GS4} + V_{GS2}$$
$$-2V_{TN} + V_{SS}$$