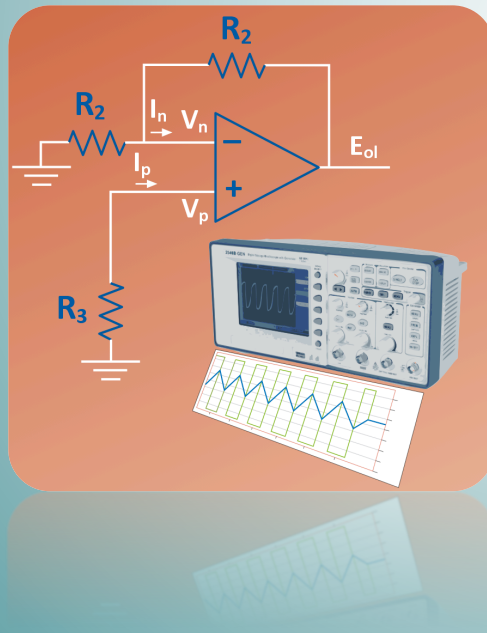


Electrónica Básica

Tema B.5. El Amplificador Operacional



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DPTO. DE ELECTRÓNICA Y COMPUTADORES

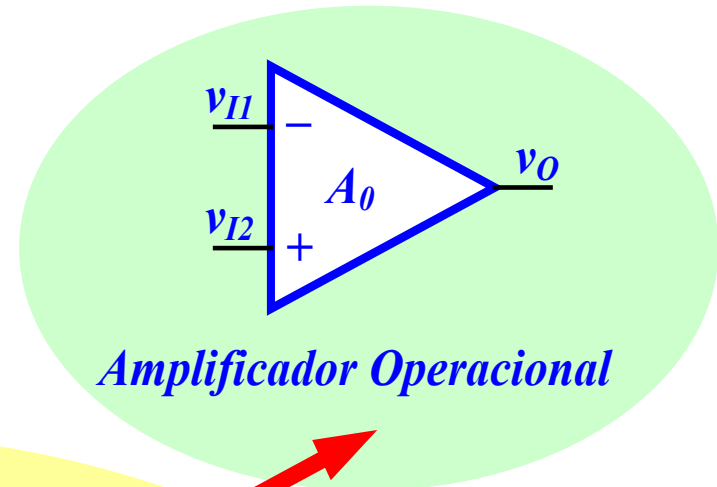
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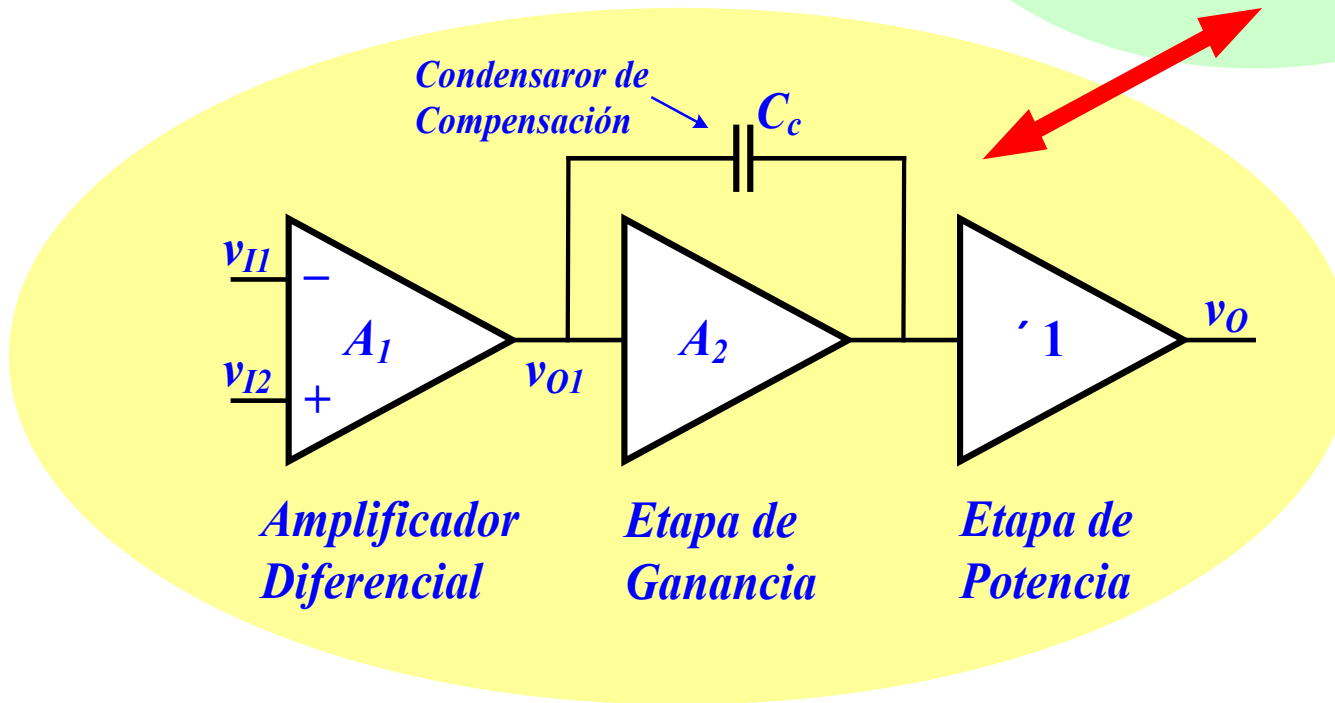


Amplificador Operacional

- Diagrama de bloques:

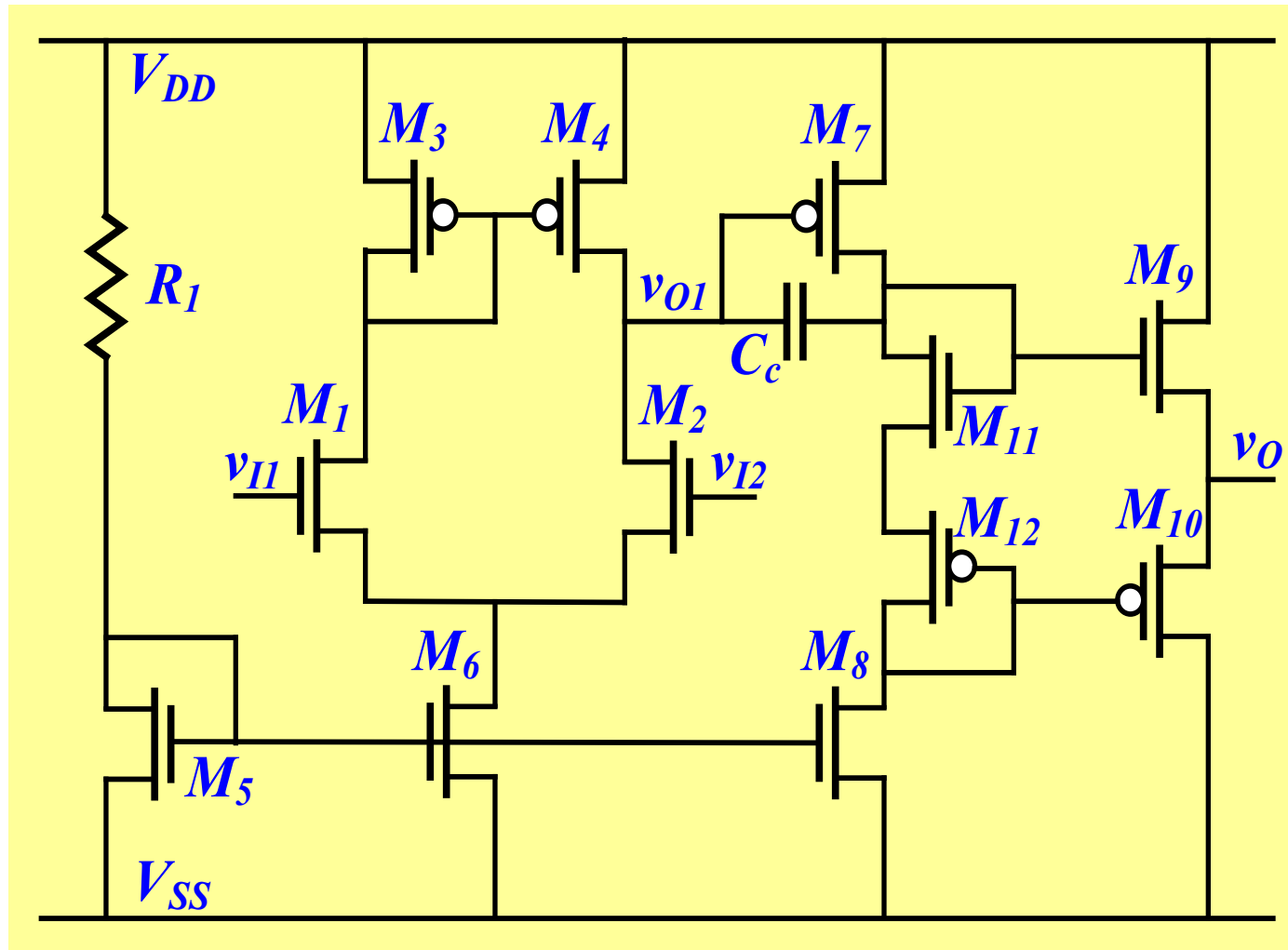


Amplificador Operacional



Amplificador Operacional CMOS

- Esquema de circuito:



- **Esquema de circuito:**

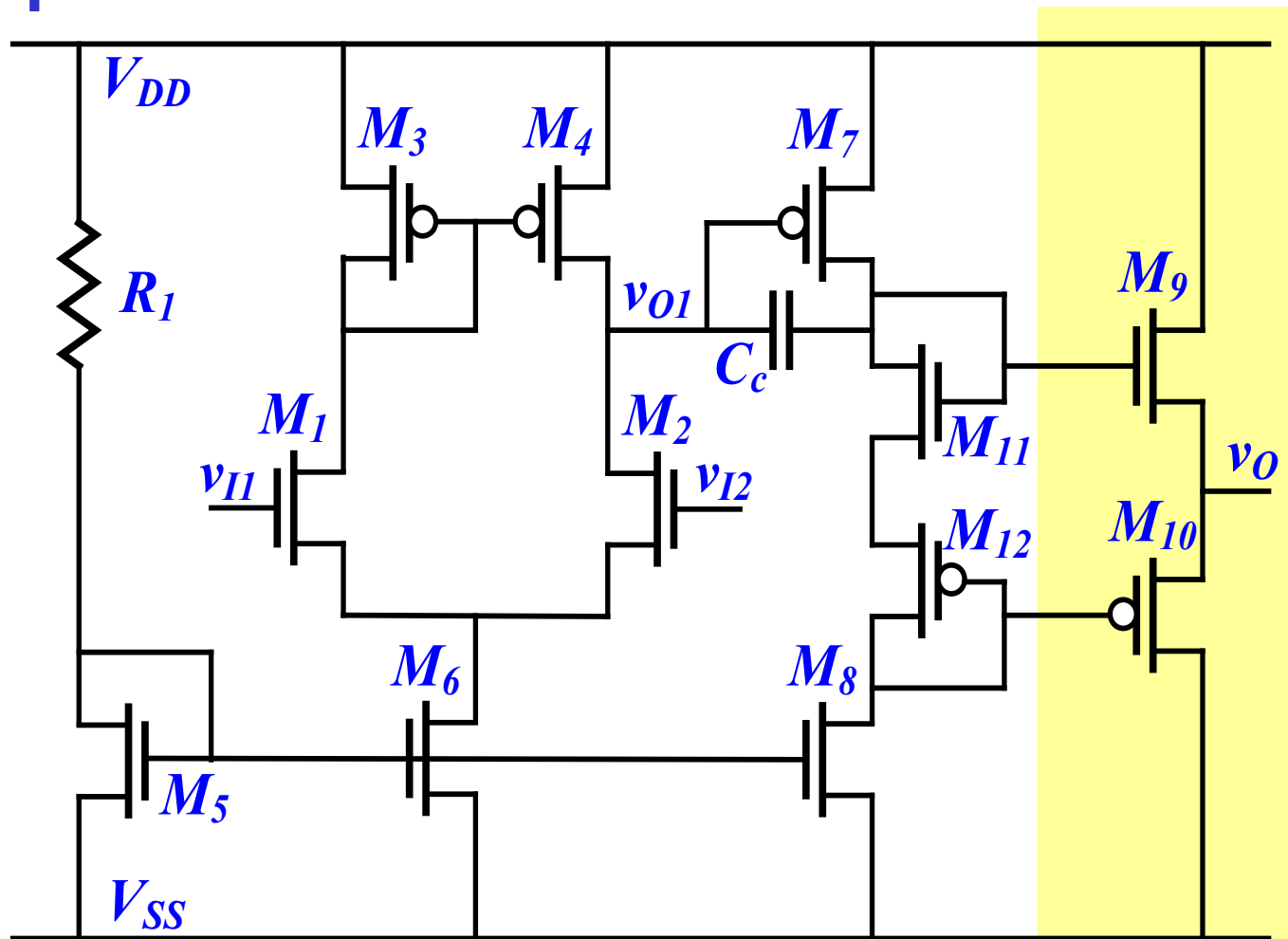


- **Esquema de circuito:**



Amplificador Operacional CMOS

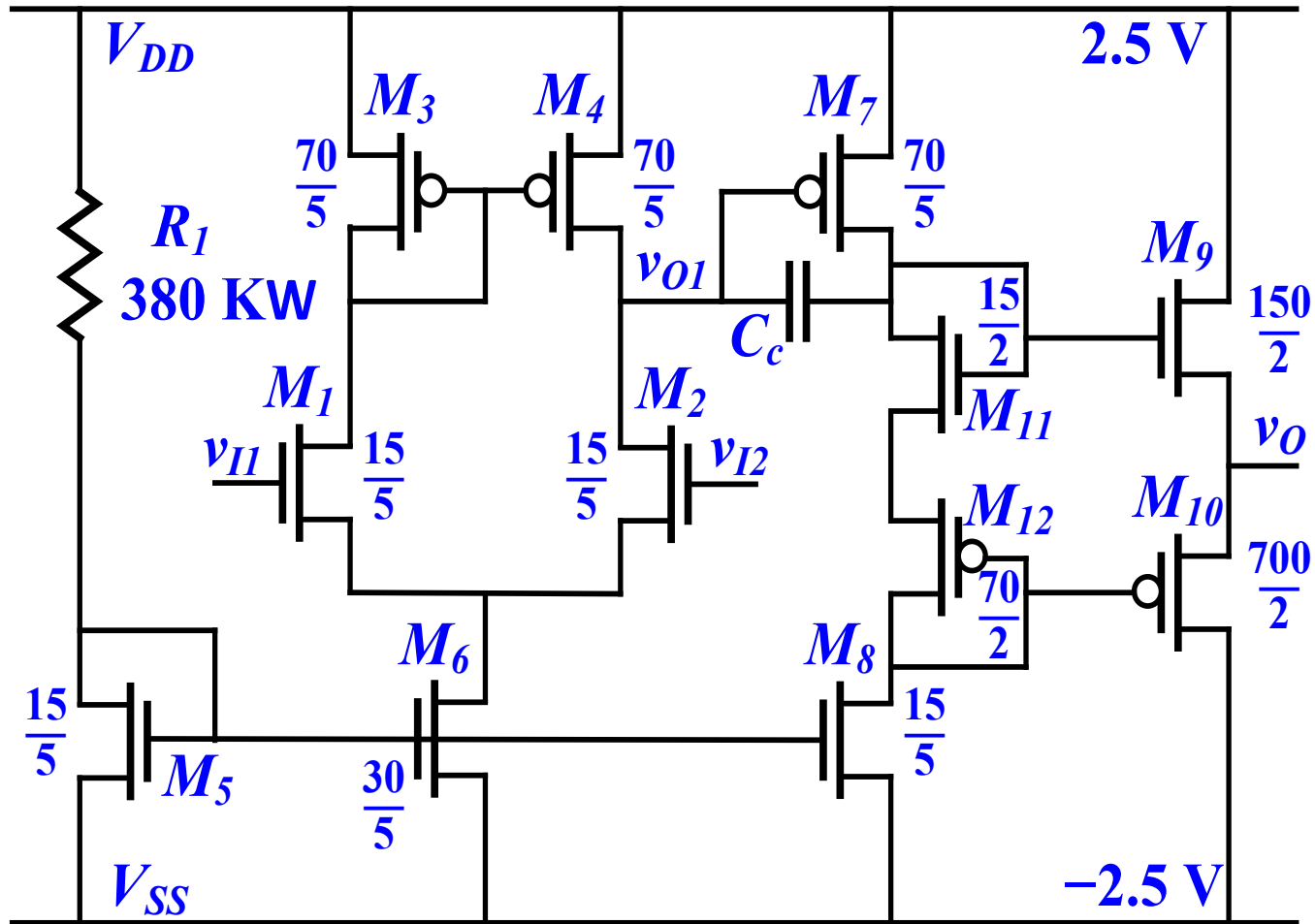
- Esquema de circuito:



Etapa de Potencia

Amplificador Operacional CMOS

- **Ejemplo (*):** $I_{D6} = 20 \mu A$, $K'_n = 50 \mu A/V^2$, $K'_p = 17 \mu A/V^2$



(*) Extraído del libro: R. J. Baker, H.W. Li and D.E. Boyce. "CMOS Circuit Design, Layout, and Simulation", IEEE

Press, 1998

Amplificador Operacional CMOS

- Etapa de entrada (amplificador diferencial):

$$I_{D2} = I_{DP4} = 10 \mu\text{A}, g_{m2} = 54.77 \mu\text{A/V}, g_{ds2} = g_{ds4} = 0.6 \mu\text{A/V}$$

$$A_{v1} = \frac{v_{o1}}{v_{i1} - v_{i2}}; \frac{g_{mi}}{g_{oi} + g_{ol}} = \frac{g_{m2}}{g_{ds2} + g_{ds4}} = 45.6$$

- Etapa de ganancia:

$$I_{D8} = I_{DP7} = 10 \mu\text{A}, g_{m7} = 68.99 \mu\text{A/V}, g_{ds7} = g_{ds8} = 0.6 \mu\text{A/V}$$

$$A_{v2} = \frac{v_{o2}}{v_{o1}}; -\frac{g_{m7}}{g_{ds7} + g_{ds8}} = -57.5$$

Amplificador Operacional CMOS

- Etapa de salida:

$$A_{v3} = \frac{v_{out}}{v_{o2}} ; \frac{g_{m9} + g_{m10}}{g_{ds9} + g_{ds10} + g_{m9} + g_{m10}}$$

$$g_{m9}, g_{m10} \gg g_{ds9}, g_{ds10} \Rightarrow A_{v3} ; 1$$

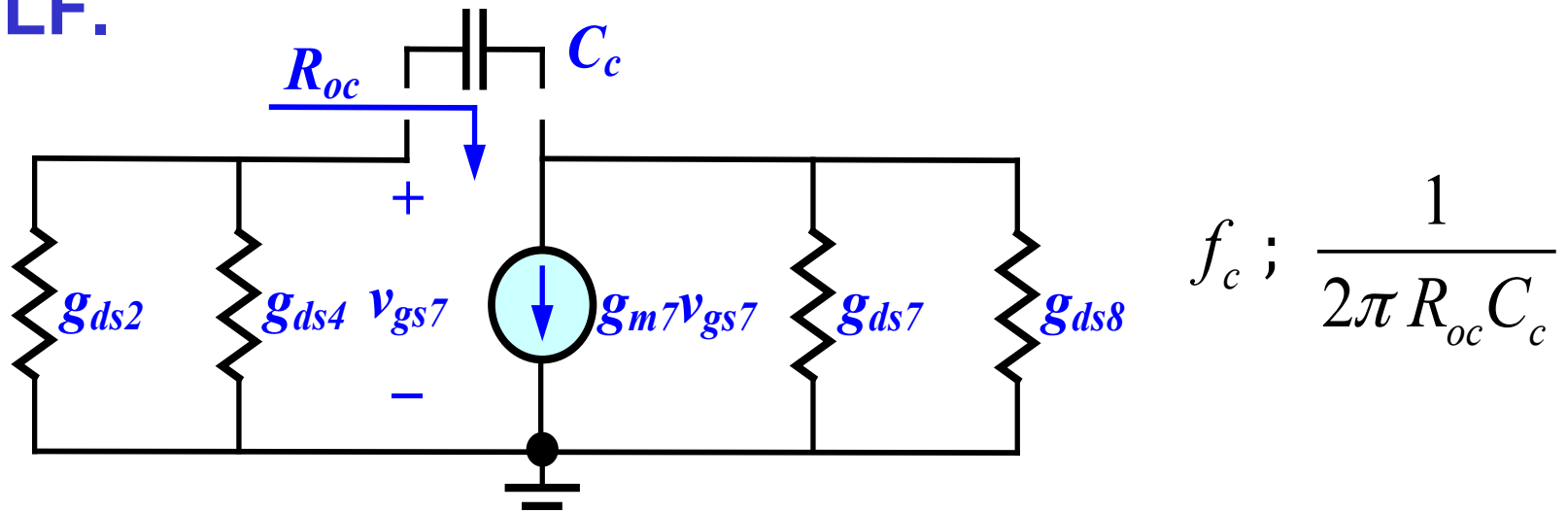
- Amplificador completo:

$$A_v = \frac{v_{out}}{v_{I1} - v_{I2}} = A_{v1} \times A_{v2} \times A_{v3} ; -2624$$

$$R_{out} = (g_{ds9} + g_{ds10} + g_{m9} + g_{m10})^{-1}$$

Amplificador Operacional CMOS

- Respuesta frecuencial: polo dominante en LF.



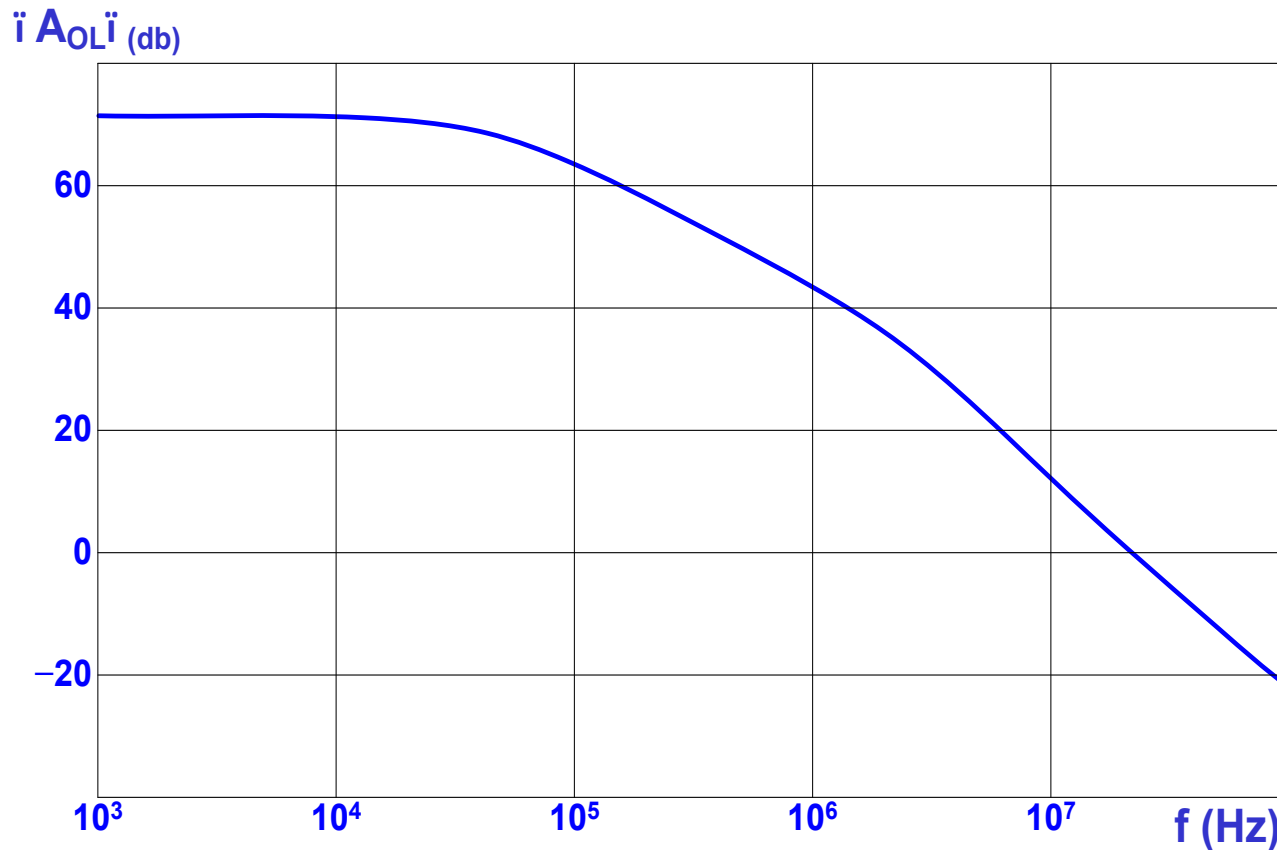
$$f_c ; \frac{1}{2\pi R_{oc} C_c}$$

$$R_{oc} = \frac{1}{g_{ds2} + g_{ds4}} + \frac{1}{g_{ds7} + g_{ds8}} \left(1 + \frac{g_{m7}}{g_{ds2} + g_{ds4}} \right)$$

$$R_{oc} = 49.57 \text{ M}\Omega, \quad C_c = 8.75 \text{ pF} \quad \rightarrow \quad f_c ; 366 \text{ Hz}$$

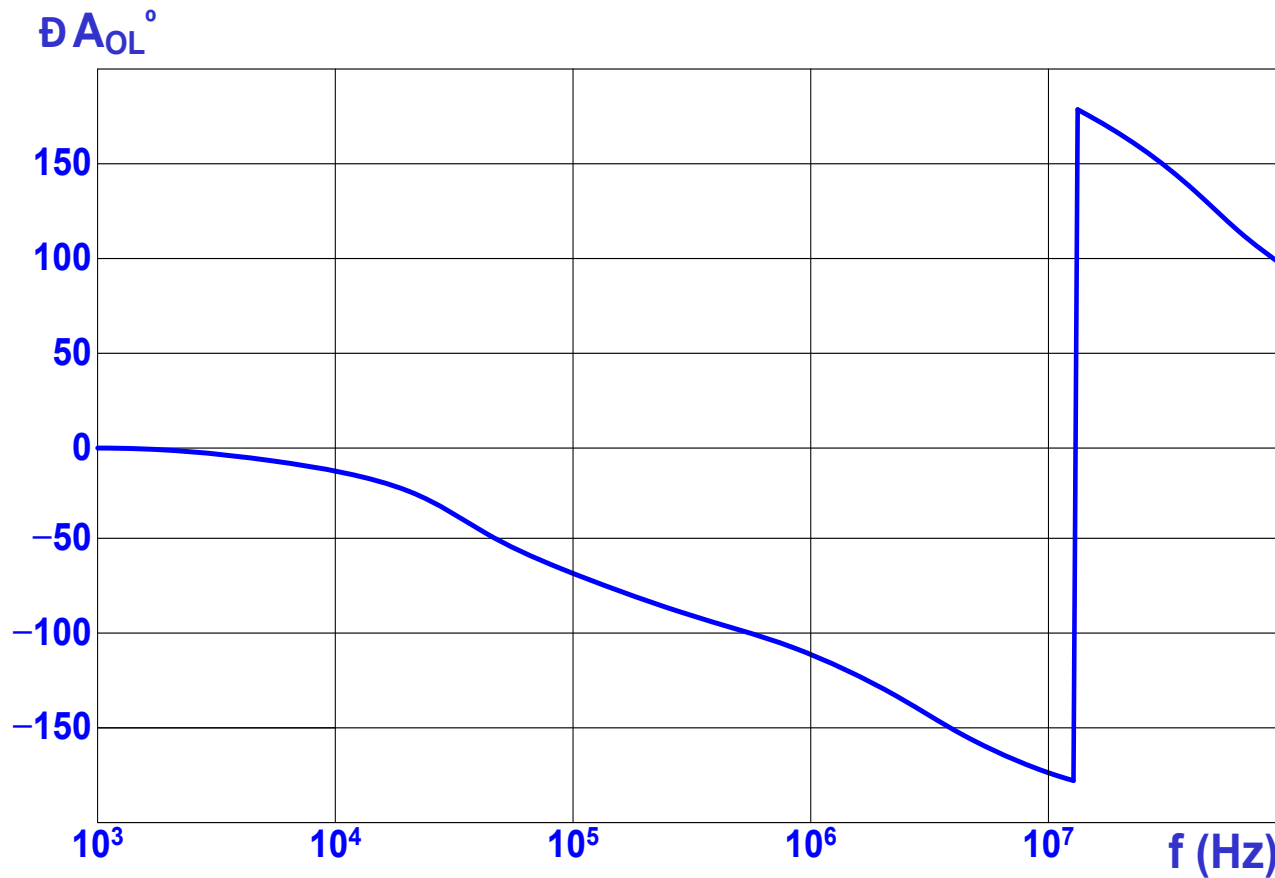
Amplificador Operacional CMOS

- Respuesta frecuencial sin C_c .



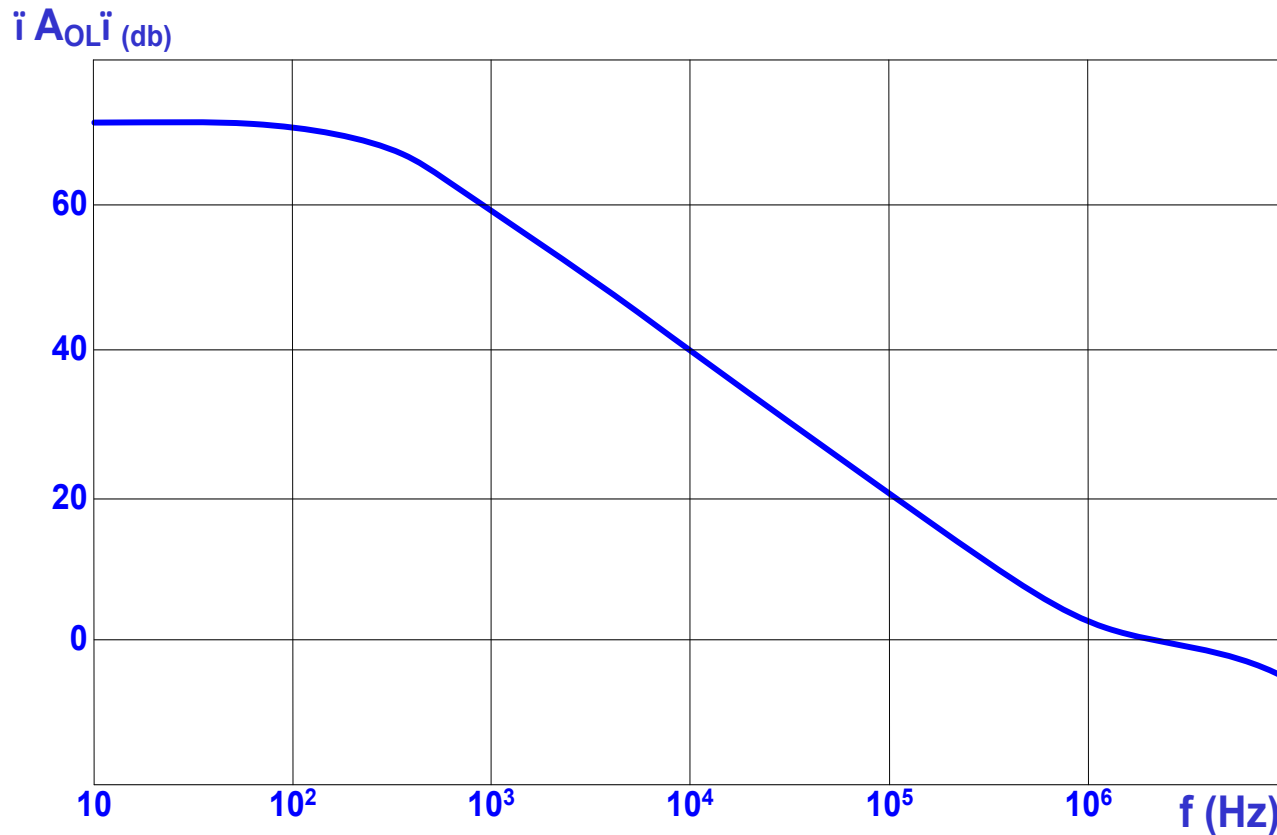
Amplificador Operacional CMOS

- Respuesta frecuencial sin C_c .



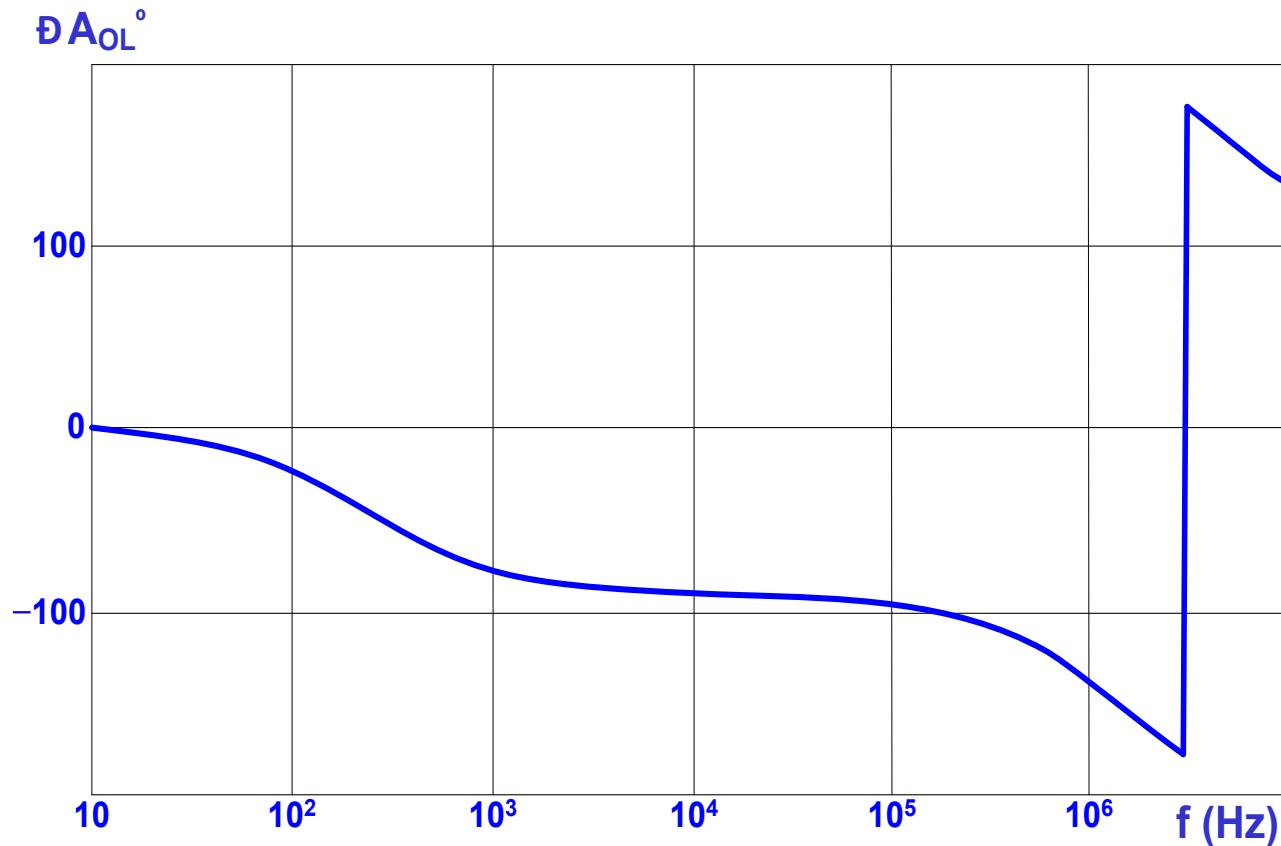
Amplificador Operacional CMOS

- Respuesta frecuencial con C_c .



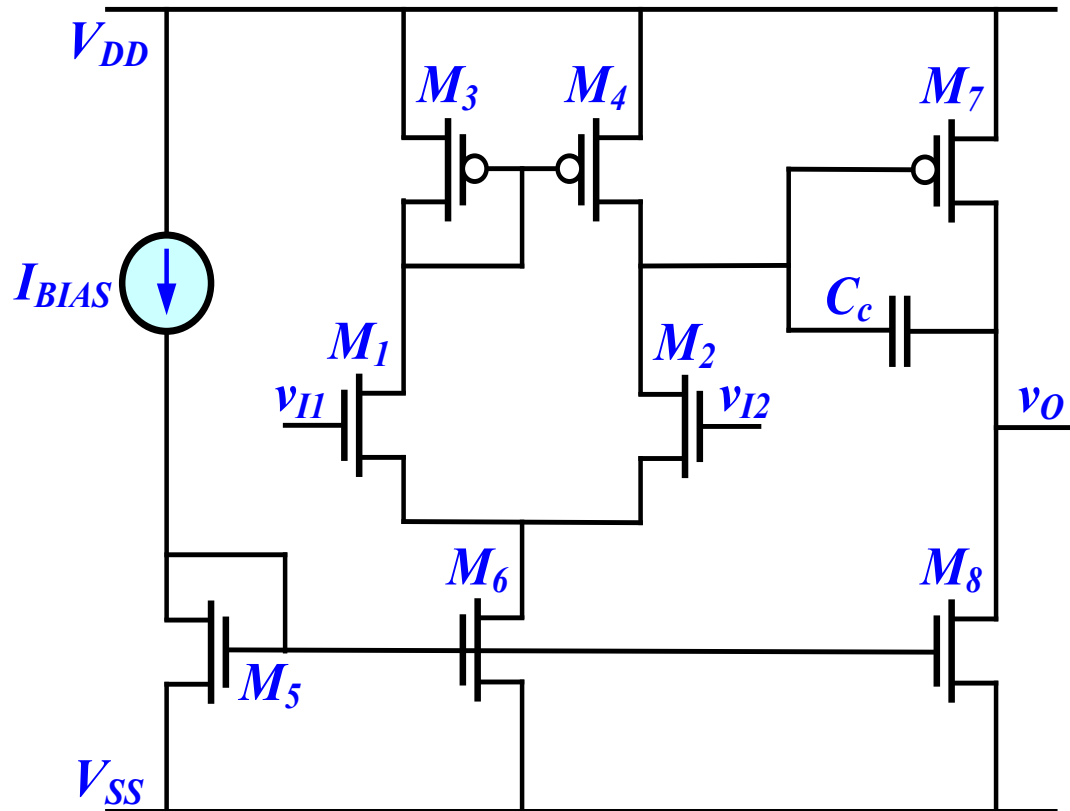
Amplificador Operacional CMOS

- Respuesta frecuencial con C_c .



Amplificador Operacional CMOS

- Amplificador operacional de dos etapas.



$$A_v = \frac{v_o}{v_{i1} - v_{i2}} = - \frac{g_{m2}}{g_{ds2} + g_{ds4}} \cdot \frac{g_{m7}}{g_{ds7} + g_{ds8}}$$