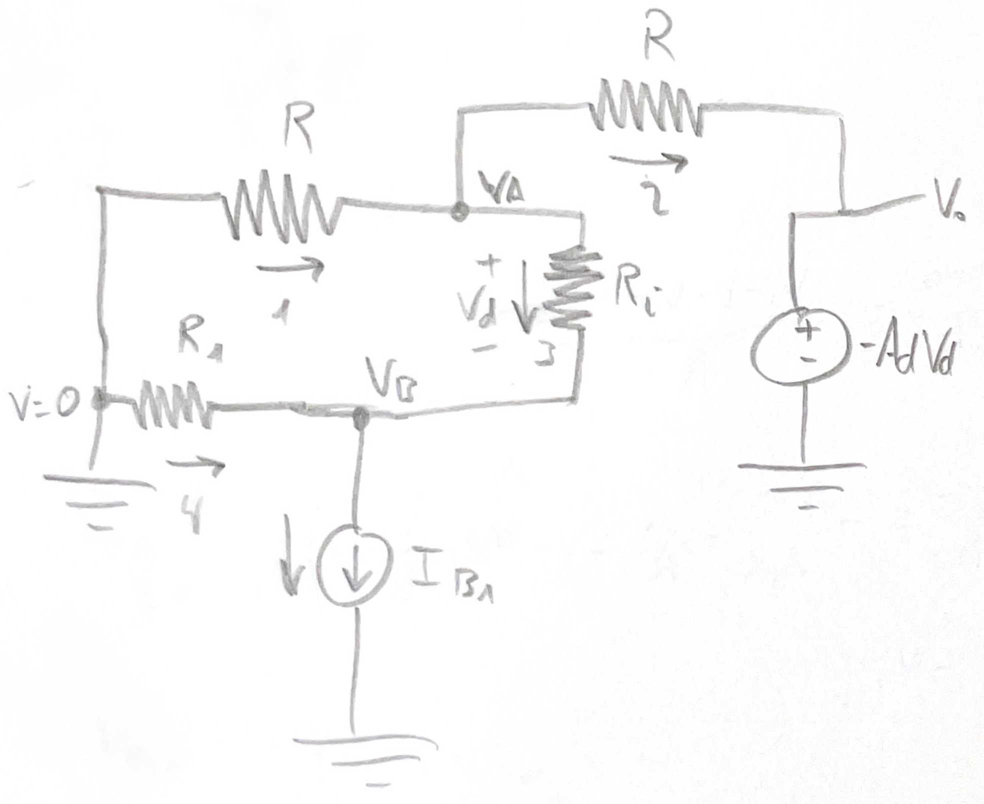
ENERO 2023

① ENERO 2019

②

Calcula el valor de la tensión de salida en el circuito de la figura debido a la corriente de polarización del pin no inversor. Considera el modelo de A.O.R que se adjunta, asumiendo $R_o = 0$, $V_{OS} = 0$ e $I_{B2} = 0$



$V_o = -A_d V_d \;;\; V_d = -\dfrac{V_o}{A_d}$

$V_A - V_B = V_d \;;\; V_A = V_B + V_d$

Buscamos una expresión de la forma $V_o = G I_{B1}$:

$$\frac{V_A - V_D}{R_i} + \frac{0 - V_B}{R_1} = I_{B1} \; ; \quad \frac{V_d}{R_i} - \frac{V_B}{R_1} = I_{B1} \; ; \quad V_B = \frac{R_1 V_d}{R_i} - R_1 I_{B1}$$

$$\frac{0 - V_A}{R} = \frac{V_A - V_B}{R_i} + \frac{V_A - V_o}{R} \; ; \quad \frac{V_o}{R} = V_A\left(\frac{2}{R} + \frac{1}{R_i}\right) - \frac{V_B}{R_i} \; ;$$

$$V_o = V_A\left(2 + \frac{R}{R_i}\right) - \frac{R}{R_i} V_B = \left(\frac{R_1}{R_i} V_d - R_1 I_{B1} + V_d\right)\left(2 + \frac{R}{R_i}\right) - \frac{R}{R_i}\frac{R_1}{R_i} V_d + R I_{B1}$$

$$\frac{V_o}{R} + \frac{V_B}{R_i} = V_A \frac{2R_i + R}{R R_i} \; ; \quad R_i V_o + R V_B = V_A (2R_i + R) = (V_B + V_d)(2R_i + R) \; ;$$

$$R_i V_o + R V_B = 2 R_i V_B + R V_B + V_d (2R_i + R) \; ;$$

$$V_d (2R_i + R) - R_i V_o = -2R_1 V_d + 2 R_i R_1 I_{B1} \; ;$$

$$-V_o\left(\frac{2R_i + R}{A_d} + R_i\right) = +2 R_1 \frac{V_o}{A_d} + 2 R_i R_1 I_{B1} \; ;$$

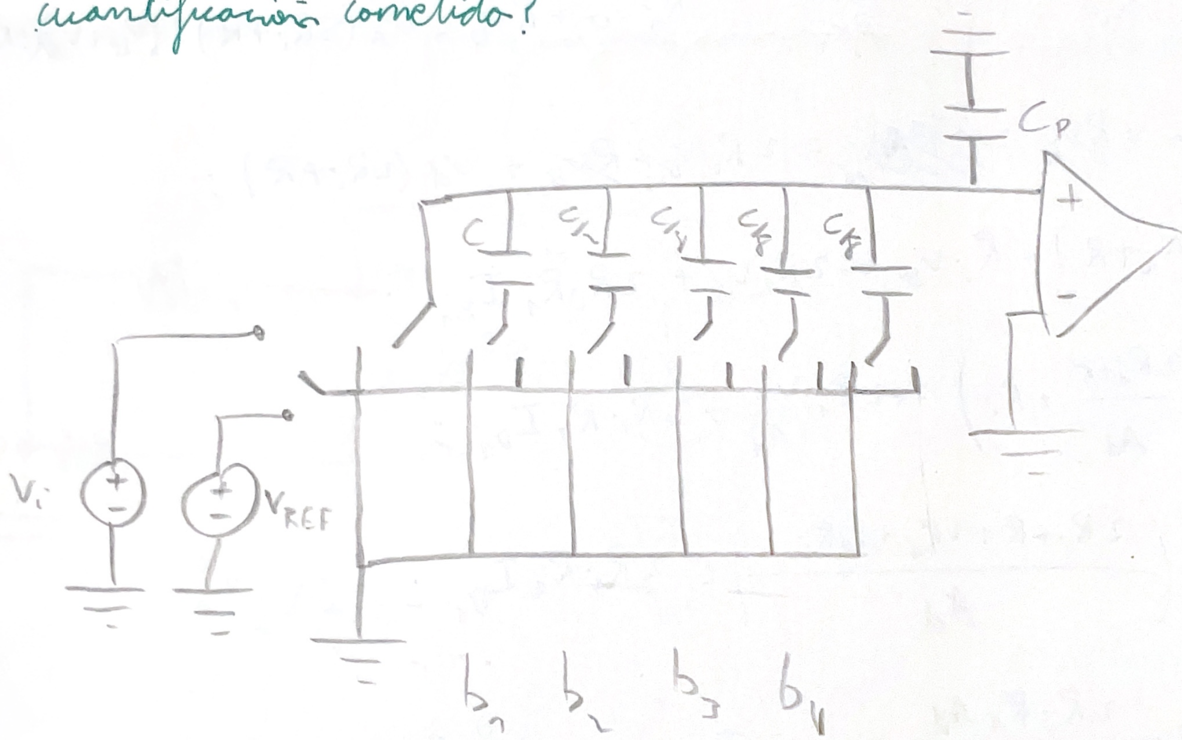
$$-V_o\left(\frac{2R_i + R + 2R_1 + A_d R_i}{A_d}\right) = 2 R_i R_1 I_{B1} \; ;$$

$$V_o = -\frac{2 R_i R_1 A_d}{2R_i + R + 2R_1 + A_d R_i} I_{B1} = -\frac{2 R_i R_1 A_d}{2(R_i + R_1) + R + A_d R_i} I_{B1}$$

(3)

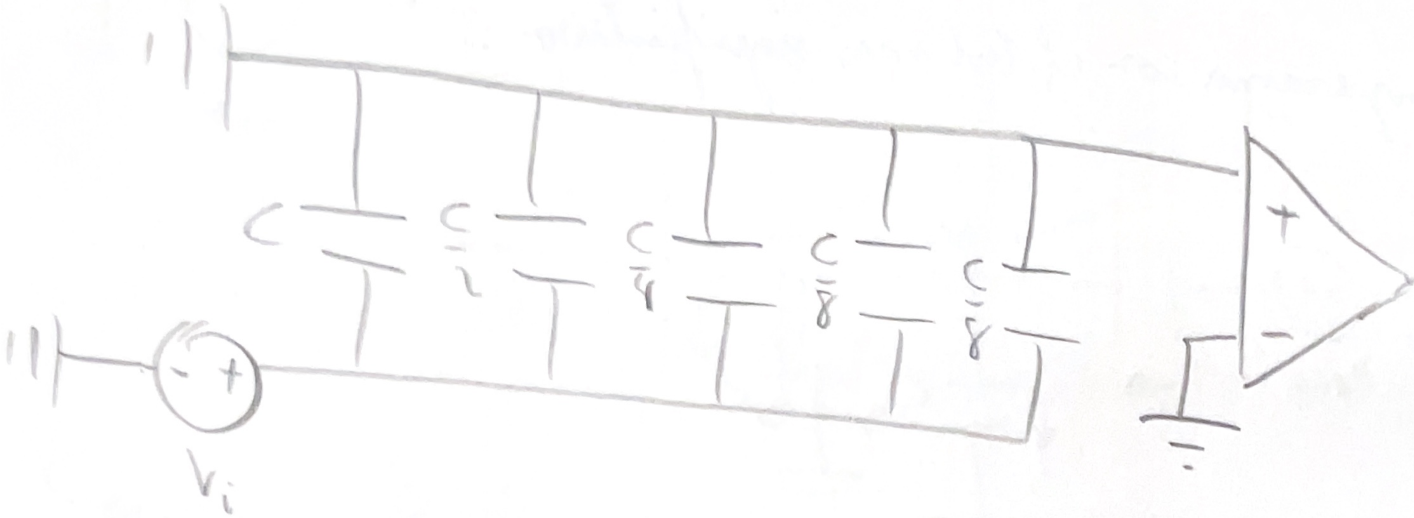
Considera un ADC por redistribución de carga del tipo mostrado en la figura con $n = 4$, $V_{REF} = 3'0\,V$ y $C = 8\,pF$. Suponiendo que el nudo "p" tiene una capacidad parásita de 4pF hacia la tierra, encontrar los intermedios en V_p durante todo el proceso de conversión de $V_i = 2'4\,V$.

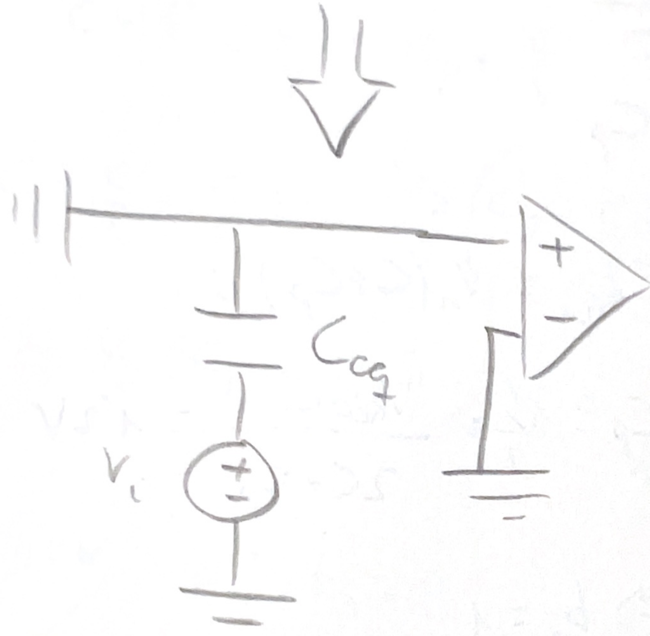
¿Qué código de salida se genera? ¿Cuál es el error de cuantificación cometido?



$$\begin{cases} n = 4 \\ V_{REF} = 3'0\,V \\ C = 8\,pF \\ V_i = 2'4\,V \\ C_p = 4\,pF \end{cases}$$

1) Ciclo de muestreo:



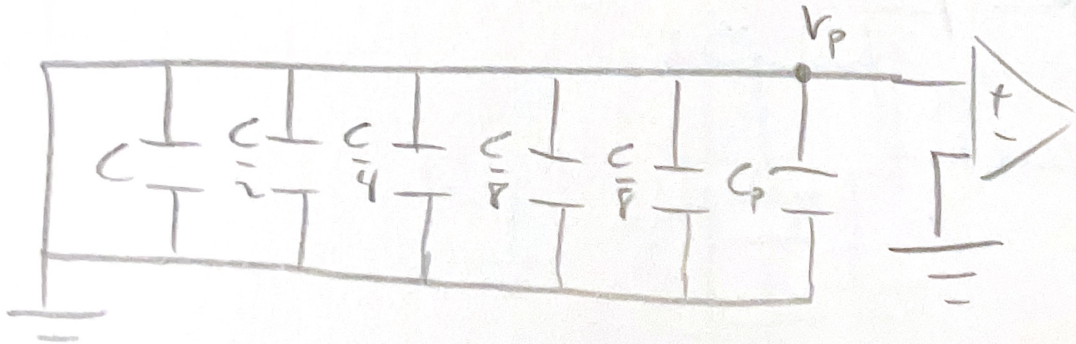


$C + \frac{C}{2} + \frac{C}{4} + \frac{C}{8} + \frac{C}{8} = 2C$

$C_{eq} = 2C$

$Q = C_{eq} \cdot V_i = 2CV_i$

2) Ciclo de retención:



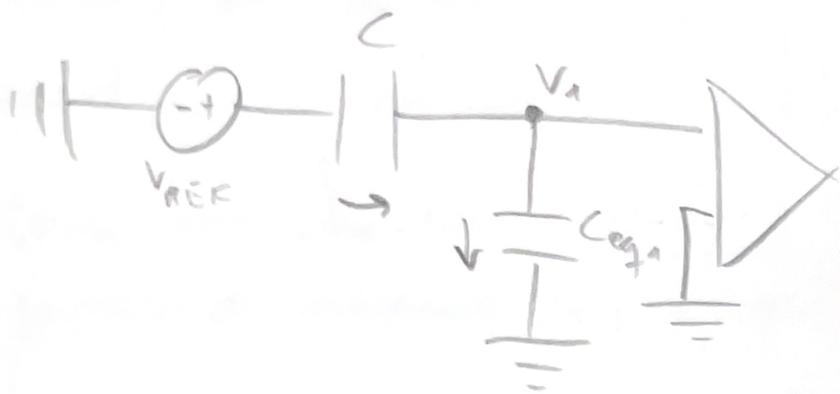
$C'_{eq} = C_{eq} + C_p = 2C + C_p$

La carga debe conservarse: $C_{eq} V_i = -(C_{eq} + C_p) V_p$;

$2CV_i = -(2C + C_p) V_p$; $V_p = -\frac{2C}{2C + C_p} V_i = -1'92V$

3) Ciclo de redistribución de carga:

⇝ Empezamos con el bit más significativo:



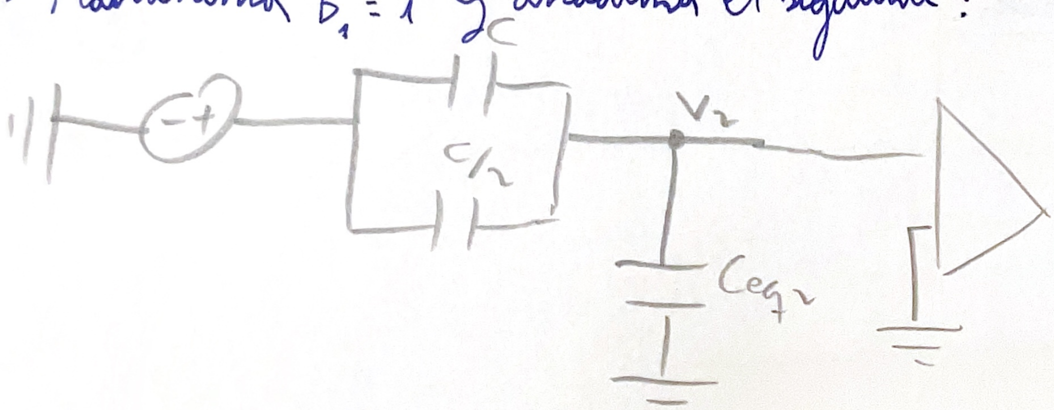
$$C_{eq_1} = C'_{eq} - C = C + C_p$$

$$(V_{REF} - V_1)C = (V_1 - 0)C_{eq_1} = V_1(C + C_p);$$

$$V_{REF}C = 2V_1C + V_1C_p ; \quad V_1 = \frac{V_{REF}C}{2C + C_p} = 1'2V$$

$$V_1 + V_p = -0'72V < 0 \Rightarrow \underline{b_1 = 1}$$

⇝ Mantenemos $b_1 = 1$ y añadimos el siguiente:

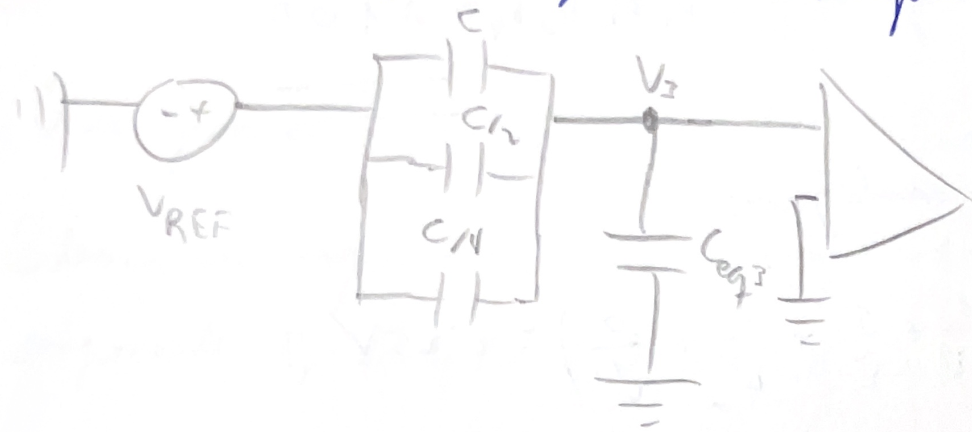


$$C_{eq_2} = C'_{eq} - C - \frac{C}{2} = C_p + \frac{C}{2}$$

$$(V_{ref} - V_2)(C + \frac{C}{2}) = V_2(C_p + \frac{C}{2}) ; \quad V_{REF}\frac{3C}{2} = V_2(C_p + 2C);$$

$$V_2 = \frac{3C}{2(C_p + 2C)}V_{REF} = 1'8V \Rightarrow V_2 + V_p = -0'12V < 0 \Rightarrow \underline{b_2 = 1}$$

→ Mantenemos $b_1 = b_2 = 1$ y añadimos el siguiente:



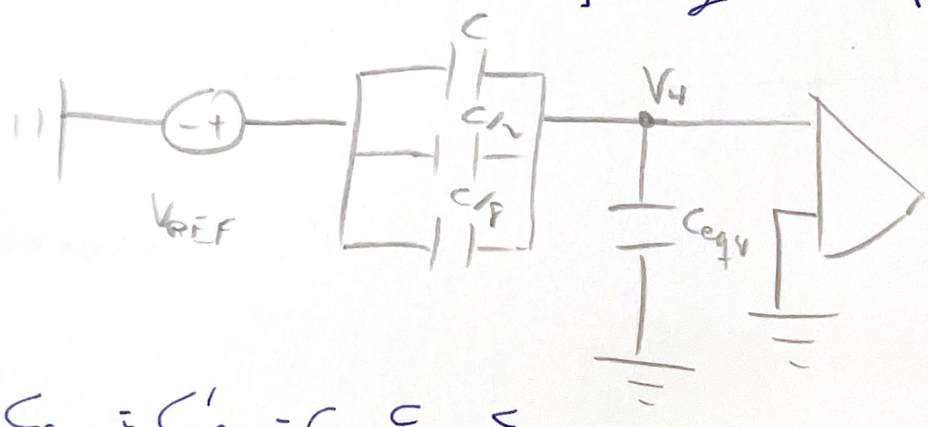
$$C_{eq3} = C'_{eq} - C - \frac{C}{2} - \frac{C}{4} = C_p + \frac{C}{4}$$

$$(V_{REF} - V_3)\left(C + \frac{C}{2} + \frac{C}{4}\right) = V_3\left(C_p + \frac{C}{4}\right);$$

$$V_{REF}\frac{7C}{4} = V_3(C_p + 2C); \quad V_3 = \frac{7C\,V_{REF}}{4(C_p+2C)} = 2'1\,V$$

$$V_3 + V_p = 0'18\,V > 0 \Rightarrow b_3 = 0$$

→ Mantenemos $b_1 = b_2 = 1$, $b_3 = 0$ y añadimos el último:



$$C_{eq4} = C'_{eq} - C - \frac{C}{2} - \frac{C}{8} = C_p + \frac{3C}{8}$$

$$(V_{REF} - V_4)\left(C + \frac{C}{2} + \frac{C}{8}\right) = V_4\left(C_p + \frac{3C}{8}\right); \quad V_{REF}\frac{13}{8}C = V_4(C_p + 2C);$$

$$V_4 = \frac{13C\,V_{REF}}{8(C_p+2C)} = 1'95 \Rightarrow V_4 + V_p = 0'03\,V > 0 \Rightarrow b_4 = 0$$

Por tanto, el código será: $b_1 b_2 b_3 b_4 = 1100$

Lo pasamos a analógico:

$$V_{out} = V_{REF} \cdot \left(\frac{1}{2^1} + \frac{1}{2^2} + \frac{0}{2^3} + \frac{0}{2^4} \right) = 2'25V$$

Lo expresamos en LSB: $V_{LSB} = \frac{V_{REF}}{2^n} = 0'1875V$

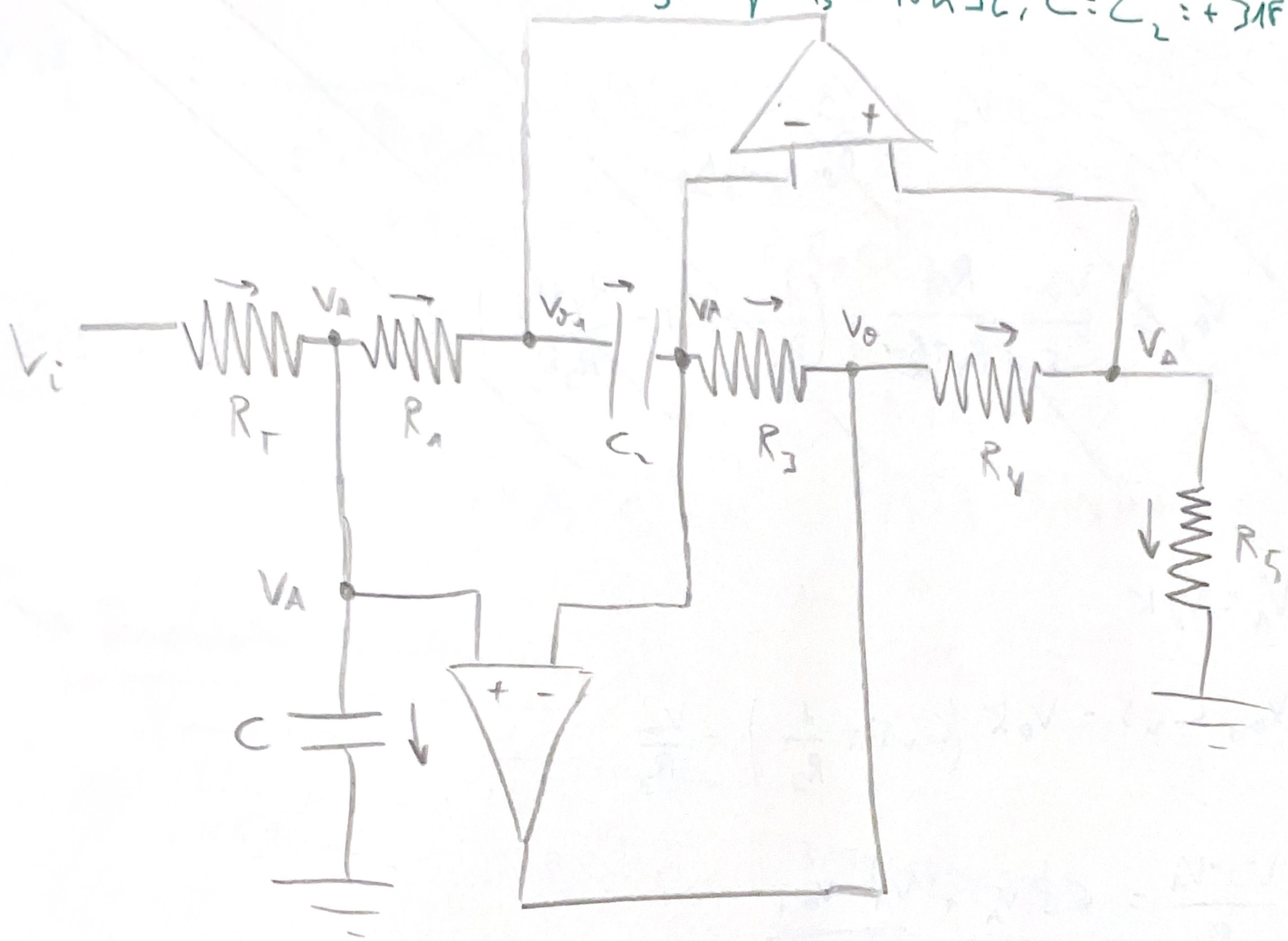
$$V_{out}\Big|_{LSB} = \frac{V_{out}}{V_{LSB}} = 12 \, LSB$$

El error de cuantificación será:

$$E = \frac{V_{out} - V_{in}}{V_{LSB}} = \frac{2'25 - 2'4}{0'1875} = -0'8 \, LSB$$

4

¿Qué función implementa el circuito? Identifica sus parámetros.
Esboza su diagrama de Bode de amplitudes para los componentes: $R_T = 100\,k\Omega$, $R_1 = R_3 = R_4 = R_5 = 10\,k\Omega$, $C = C_2 = 7318\,pF$



Buscamos $G(s) = \frac{V_o}{V_i}$

$$\frac{-V_A + V_i}{R_T} = \frac{V_A - 0}{\frac{1}{Cs}} + \frac{V_A - V_{o1}}{R_1} \; ; \; \frac{V_A - V_i}{R_T} = CsV_A + \frac{V_A - V_{o1}}{R_1}$$

$$\frac{V_{o1} - V_A}{\frac{1}{C_2 s}} = \frac{V_A - V_o}{R_3} \; ; \; (V_{o1} - V_A)C_2 s = \frac{V_A - V_o}{R_3} \quad (2)$$

$$\frac{V_o - V_A}{R_4} = \frac{V_A}{R_5} \; ; \; V_A = V_o \frac{R_5}{R_4 + R_5} = V_o K \; ;$$

$$(2)\ (V_{o1} - V_A)\, C_2 s = \frac{V_A - V_o}{R_3} \ ;$$

$$C_2 s V_{o1} = V_A\left(\frac{1}{R_3} + C_2 s\right) - \frac{R_4 + R_5}{R_3 R_5} V_A = V_A\left(\frac{1}{R_3} + C_2 s - \frac{R_4 + R_5}{R_3 R_5}\right) \ ;$$

$$V_{o1} = \frac{V_A}{C s}\left(\frac{1}{R_3} + C_2 s - \frac{R_4 + R_5}{R_3 R_5}\right) = \frac{V_A}{C s} \cdot \left(\frac{R_5 + R_3 R_5 C_2 s - R_4 + R_5}{R_3 R_5}\right)$$

$$\frac{V_A - V_i}{R_T} = C s V_A + \frac{V_A}{R_1} - \frac{V_{o1}}{R_1} \qquad V_A = V_o \frac{R_5}{R_4 + R_5}$$

$$V_{o1} = \frac{V_o}{C s} \cdot \frac{R_5}{R_4 + R_5} \cdot \left(\frac{1}{R_3} + C s - \frac{R_4 + R_5}{R_3 R_5}\right) =$$

$$=$$

$$V_A = V_o K$$

$$V_{o1} C_2 s = V_o K \left(C_2 s + \frac{1}{R_3}\right) - \frac{V_o}{R_3}$$

$$\frac{V_i - V_A}{R_T} = C s V_A + \frac{V_A - V_{o1}}{R_1}$$

$$V_{o1} C_2 s = \frac{V_o}{R_3}(K - 1) + V_o K C_2 s \ ; \quad V_{o1} = V_o\left(\frac{K-1}{R_3 C_2 s} + K\right)$$

$$\frac{V_i}{R_T} = \frac{V_o K}{R_T} + C s V_o K + \frac{V_o K}{R_1} - \frac{V_o}{R_1}\left(\frac{K-1}{R_3 C_2 s} + K\right) \ ;$$

$$\frac{V_i}{R_T} = \frac{V_o K}{R_T} + C s V_o K - \frac{V_o}{R_1} \cdot \frac{K-1}{R_3 C_2 s} \ ;$$

$$\frac{V_i}{\cancel{R_T}} = V_o K \left(\frac{K R_1 R_3 C_2 s + K R_T R_1 R_3 C C_2 s^2 - R_T (K-1)}{K \cancel{R_T} R_1 R_3 C_2 s} \right) ;$$

$$V_o = \frac{V_i}{K} \left(\frac{K R_1 R_3 C_2 s}{K R_1 R_3 C_2 s + K R_T R_1 R_3 C C_2 s^2 - R_T (K-1)} \right) ;$$

$$G(s) = \frac{1}{K} \cdot \frac{\frac{\cancel{K R_1 R_3 C_2}}{\cancel{K} R_T \cancel{R_1 R_3} C \cancel{C_2}} \cdot s}{s^2 + \frac{\cancel{K R_1 R_3 C_2}}{\cancel{K} R_T \cancel{R_1 R_3} C \cancel{C_2}} \cdot s + \frac{1-K}{R_1 R_3 C C_2}} ;$$

$$G(s) = \frac{\frac{1}{K R_T C} \cdot s}{s^2 + \frac{1}{R_T C} s + \frac{1-K}{K R_1 R_3 C C_2}} \Rightarrow$$

FILTRO PASA BANDA

$$K = \frac{R_5}{R_4 + R_5} \; ; \; \frac{1-K}{K} = \frac{R_4}{R_5 + R_4} \cdot \frac{R_5 + R_4}{R_5} = \frac{R_4}{R_5}$$

⇝ Parámetros característica:

$$w_0 = \sqrt{\frac{1-K}{K R_1 R_3 C C_2}} = \sqrt{\frac{R_4}{R_1 R_3 R_5 C C_2}} = 3144654{,}09 \text{ rad/s}$$

$$f_0 = \frac{w_0}{2\pi} = 500487{,}24 \text{ Hz}$$

$$\frac{w_0}{Q} = \frac{1}{R_T C} \; ; \; Q = R_T C \cdot \sqrt{\frac{R_4}{R_1 R_3 R_5 C C_2}} = 10$$

$$H_0 \frac{w_0}{Q} = \frac{R_4 + R_5}{R_4 + R_5} \cdot \frac{1}{R_T C} \; ; \; \cancel{H_0 = \frac{1}{10 R_T C} \cdot \frac{R_4}{R_4 + R_5}} ;$$

$$H_0 \frac{1}{\cancel{R_T C}} = \frac{R_4 + R_5}{R_5} \cdot \frac{1}{\cancel{R_T C}} \; ; \; H_0 = \frac{R_4 + R_5}{R_5} = 2 \text{ V/V}$$

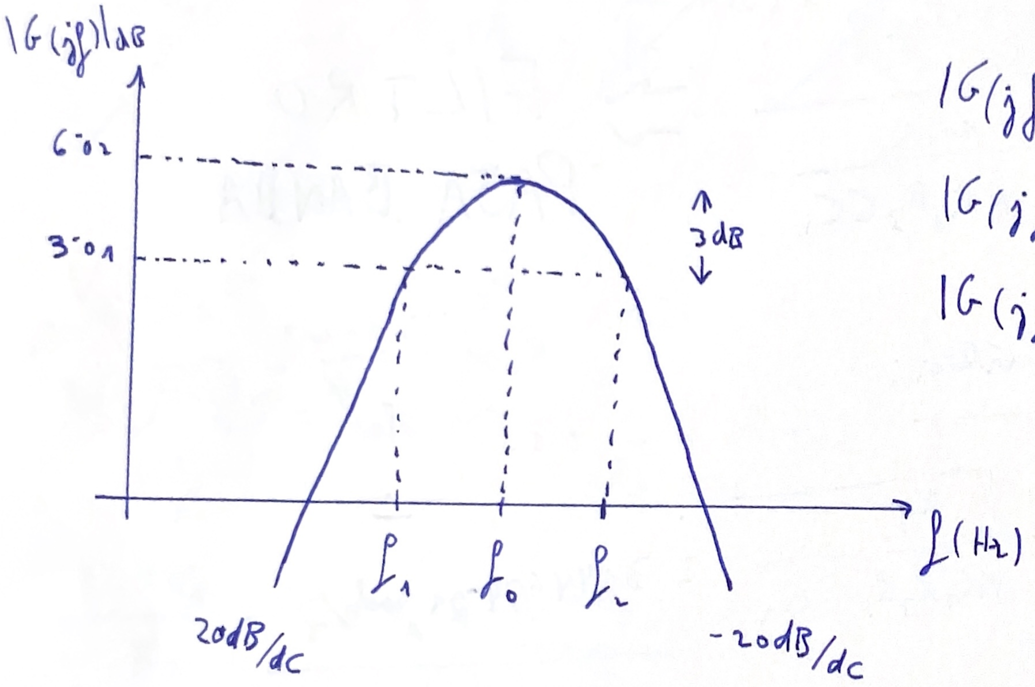
$$BW = f_2 - f_1 = \frac{f_0}{Q} = 5004{'}8724\ Hz$$

$$f_2 \cdot f_1 = f_0^2 \; ; \; f_1 = \frac{f_0^2}{f_2}$$

$$\Rightarrow f_2^2 - 5004{'}8724\, f_2 - 2{'}5\cdot 10^9 = 0;$$

$$f_2 = \frac{5004{'}8724 \pm \sqrt{(-5004{'}8724)^2 + 4\cdot 2{'}5\cdot 10^9}}{2} \Rightarrow f_2 = 52613{'}68\ Hz$$

$$f_1 = 47608{'}81\ Hz$$



$|G(jf_0)|_{dB} = 6{'}02\ dB$

$|G(jf_1)|_{dB} = 3{'}01\ dB$

$|G(jf_2)|_{dB} = 3{'}01\ dB$