ECE 627

Midterm Examination

May 9, 2014

Open book

1. In the DAC shown, the opamp is ideal, and $V_{ref} = 2$ V.

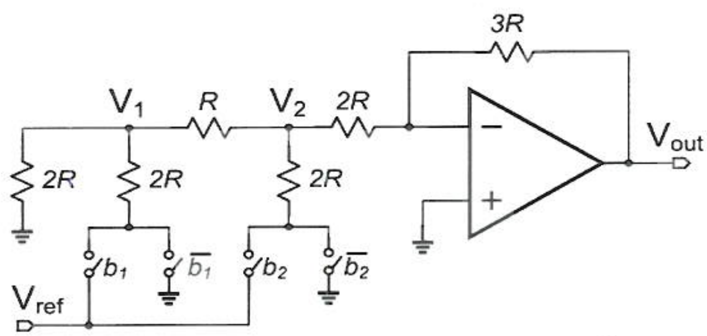
a. Find the input-output relation of the DAC.

b. What are the LSB voltage steps in V_{out}?

c. Is the DAC monotonic?

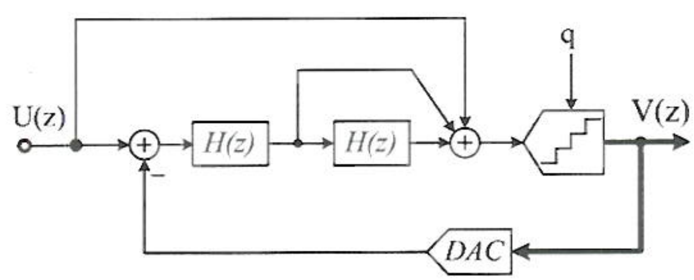
d. What will be the values of the voltages V_1 and V_2 if the input word is 11?

e. Find V_{out} if the opamp has a gain of 60 dB. (Difficult, for extra credit only!!)

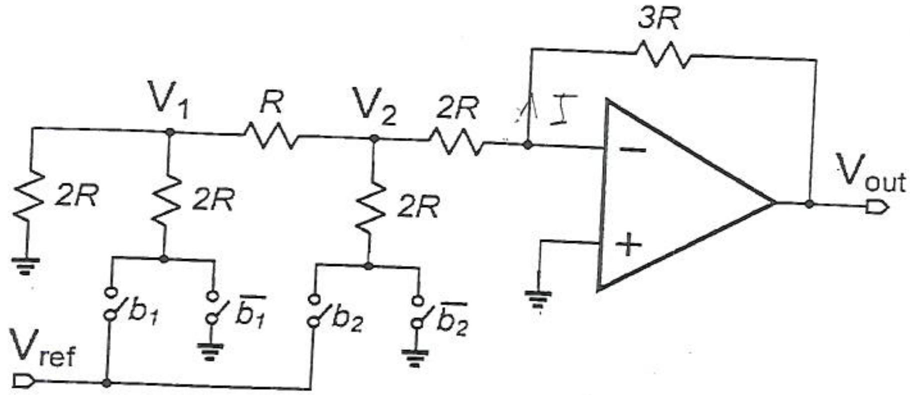


2. a. Find the STF and NTF of the ΔΣ ADC shown. Use $H(z) = z^{-1}/(1-z^{-1})$.

b. What is the value of |NTF| at dc, and at $f_s/2$?



1.



a. For $b_2 = 1$, $b_1 = 0$

$I = V_{ref}/6R$, $V_{out} = -V_{ref}/2$

For $b_1 = 1$, $b_2 = 0$

$I = V_{ref}/12R$, $V_{out} = -V_{ref}/4$

By superposition

$$V_{out} = -(V_{ref}/4)(b_1 + 2b_2) = -\frac{b_1}{2} - b_2 \text{ (V)}$$

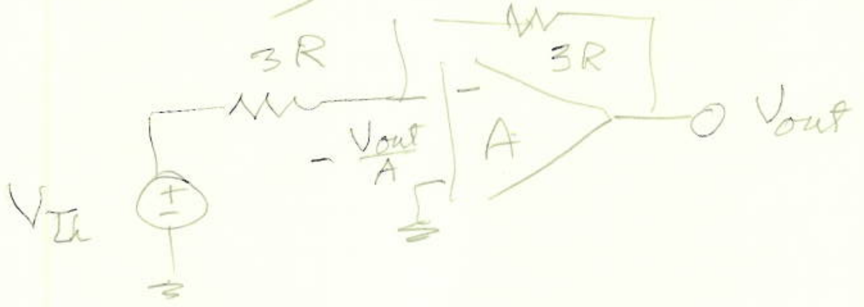
b. $V_{LSB} = V_{ref}/4 = 0.5\,V$

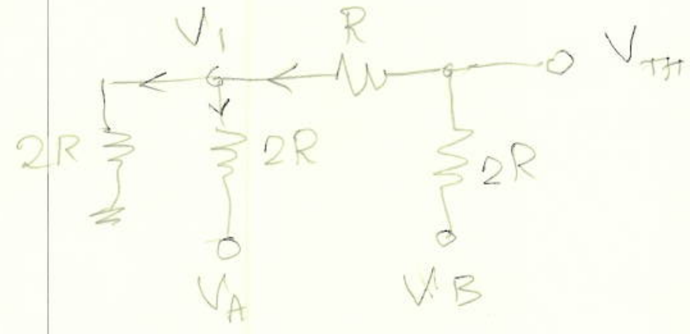
c. Yes, under practical conditions.

d. By symmetry, for $b_1 = b_2 = 1$, $V_1 = V_2$.

No current through R, so $V_1 = V_2 = V_{ref}/2 = 1\,V$

Théoenin eq. of R-2R input branch





$$\frac{V_1}{2R} + \frac{V_1 - V_A}{2R} = \frac{V_B - V_1}{3R}$$

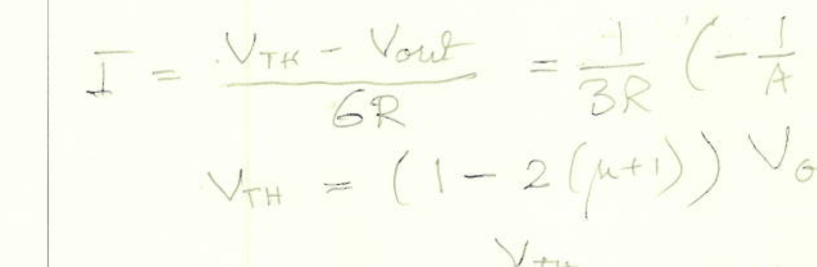
$$V_1\left(\frac{G}{2} + \frac{G}{2} + \frac{G}{3}\right) = V_A \frac{G}{2} + V_B \frac{G}{3}$$

$4/3$

$$V_1 = \frac{3}{8} V_A + \frac{1}{4} V_B \quad , \quad V_A = b_1 V_{ref}, \quad V_B = b_2 V_{ref}$$

$$V_{TH} = V_B - \frac{2}{3}(V_B - V_1) = V_A/4 + V_B/2$$

$$= b_1/2 + b_2$$



$1/A$

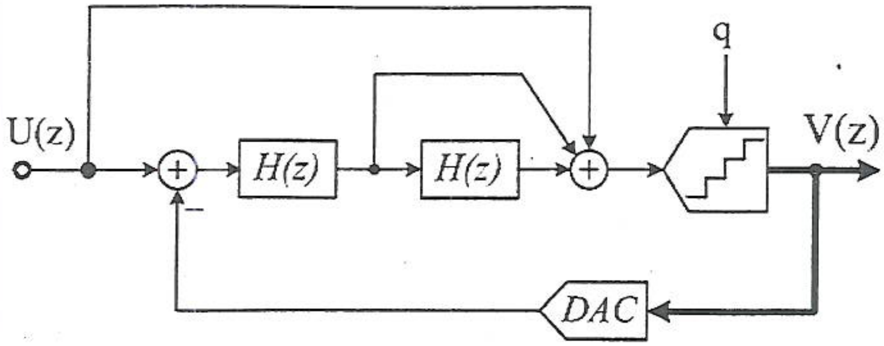
$$I = \frac{V_{TH} - V_{out}}{6R} = \frac{1}{3R}\left(-\frac{1}{A} - 1\right) V_{out} = -\frac{\mu+1}{3R} V_{out}$$

$$V_{TH} = (1 - 2(\mu+1)) V_{out} = -(1+2\mu) V_{out}$$

$$V_{out} = -\frac{V_{TH}}{1+2\mu} = -(1+2/A)^{-1} V_{ref} (b_1/4 + b_2/2)$$

$$\cong -0.998(b_1/2 + b_2)$$

2.



2. a. $V = Q + U + H(H+1)(U - V)$

$$V(1 + H + H^2) = Q + U(1 + H + H^2)$$

$$STF = 1$$

$$NTF = (1 + H + H^2)^{-1} = \frac{(1 - z^{-1})^2}{(1 - z^{-1})^2 + z^{-1}(1 - z^{-1}) + z^{-2}}$$

$$= (1 - z^{-1})^2 / (1 - 2z^{-1} + z^{-2} + z^{-1} - z^{-2} + z^{-2})$$

$$= \frac{(1 - z^{-1})^2}{1 - z^{-1} + z^{-2}}$$

b. dc: $z = 1$, $|NTF| \sim (\omega T)^2 \sim 0$

$f_s/2$: $z = -1$ $|NTF| = 4/3$