MIDTERM EXAMINATION

ECE 627

May 15, 2009, 3-3:50 pm

KEAR 305

Open book, open notes

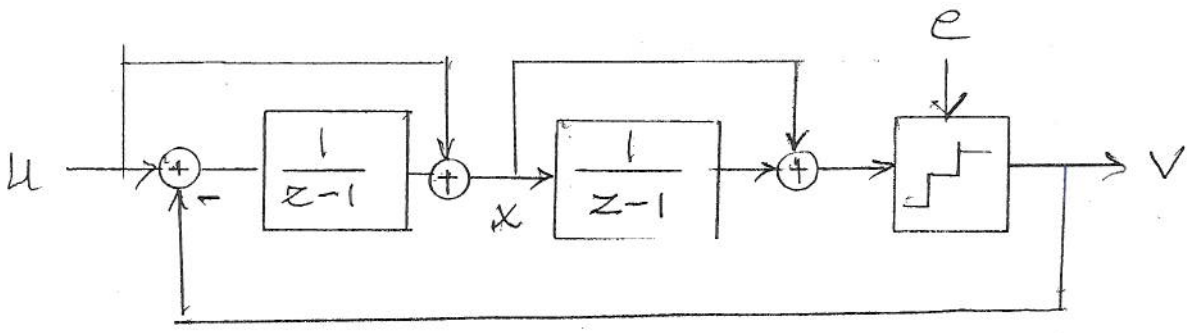
1. In an 9-bit DAC constructed from binary-weighted capacitors all capacitors may have a relative error r. What is the maximum value of $|r|$ if the DNL must be below ½ LSB? What is the largest INL for this r?

2. What is the restriction on the offset errors of the comparators in an 8-bit flash ADC if no missing codes are allowed? Assume $V_{ref} = 1$ V.

3. a. Find the NTF and STF of the delta-sigma modulator shown.

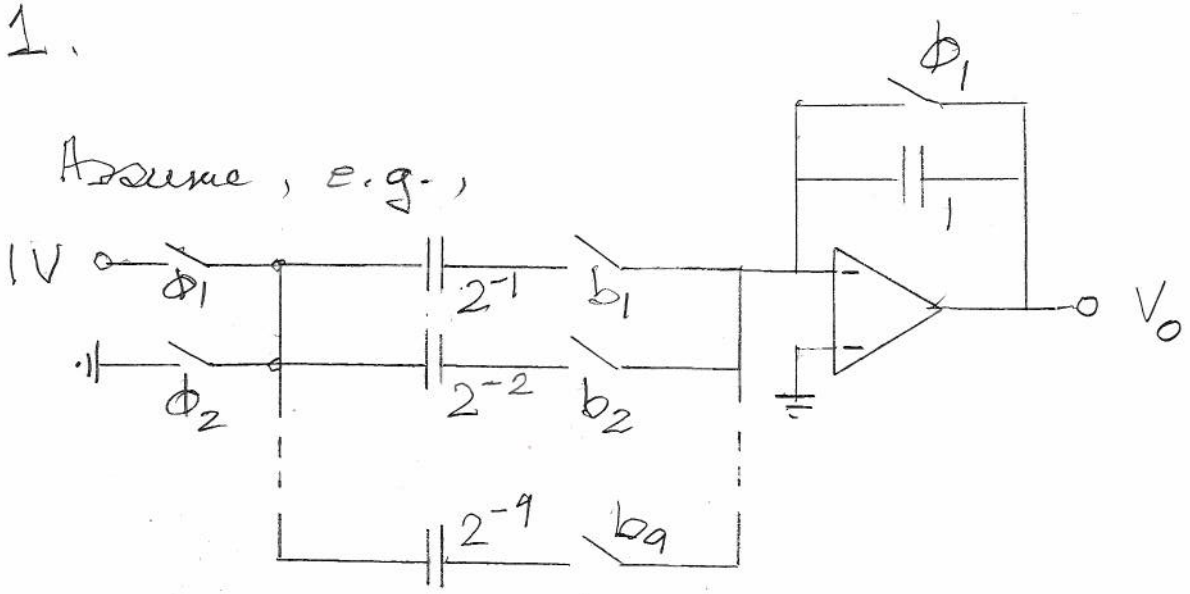
   b. Find the value of the internal signal $X(z)$.

   c. How do the NTF and STF change if an amplifier of gain A is placed in front of the quantizer?



Solutions.

1.



$$V_o(n) = \sum_{i=1}^{9} b_i(n)\, 2^{-i} \quad \text{for ideal caps}$$

If the input caps have relative error r_i

$$V_o(n) = \sum_{i=1}^{n} b_i(n)\,(1+r_i)\,2^{-i}$$

DNL max. for 10000... $\leftrightarrow$ 0111..., if $C_{MSB} \to (1+r_{max})\,2^{-1}$, and all others become $(1-r_{max})\,2^{-i}$. Then

$$DNL_{max} = r_{max} \sum_{i=1}^{9} 2^{-i} = r_{max}(1-2^{-9}) \quad (V)$$

$1\,LSB = 2^{-9}\,V$, so

$$DNL_{max} \cong 2^9 r_{max}(LSB) \doteq 0.5\,(LSB)$$

So $r_{max} \cong 2^{-10} \cong 0.9766 \times 10^{-3}$

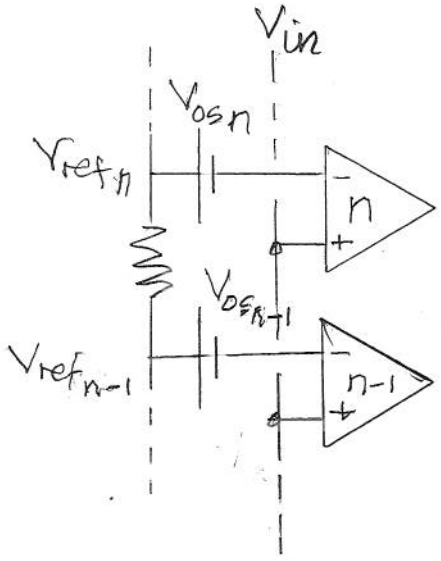
For absolute INL with r_{max}, 111...1

$$INL^{a}_{max} = DNL_{max} \cong 0.5(LSB) \cong 0,977(\text{m}$$

Endpoint DNL max occurs for 1000...0

$$INL^{e}_{max} = 2^{-1} r_{max} \cong 0,488\ mV \cong 0.25\ LSB$$

2.



The ref. input of comparator n must be higher than that of comp. n-1, So

$$V_{ref\,n} - V_{os\,n} > V_{ref\,n-1} - V_{os\,n-1}$$

For worst case, $V_{os\,n} = +V_{os\,max}$ and $V_{os\,n-1} = -V_{os\,max}$. This gives

$$2V_{os\,max} < V_{LSB} = 2^{-8}\,V \cong 3.9\,mV$$

$$V_{os\,max} \cong 1.953\,mV$$

3.a $X = U + I(U-V)$, where $I = 1/(z-1)$

$$V = E + X(1+I)$$

$$V = [E + (I+1)^2 U] / [1 + I(I+1)]$$

$$STF = \frac{1}{1 - z^{-1} + z^{-2}}, \quad NTF = \frac{(1-z^{-1})^2}{1 - z^{-1} + z^{-2}}$$

b. $X = U + I(U-V) = \frac{1-z^{-1}}{1-z^{-1}+z^{-2}} [U - z^{-1} E]$

c. X as before.

$$V = E + AX(1+I) = \frac{AU + (1-z^{-1})^2 E}{1 + (A-2)z^{-1} + z^{-2}}$$

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

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