FINAL EXAMINATION

ECE 627

June 9, 2009, 2-3:50 pm

KEAR 305

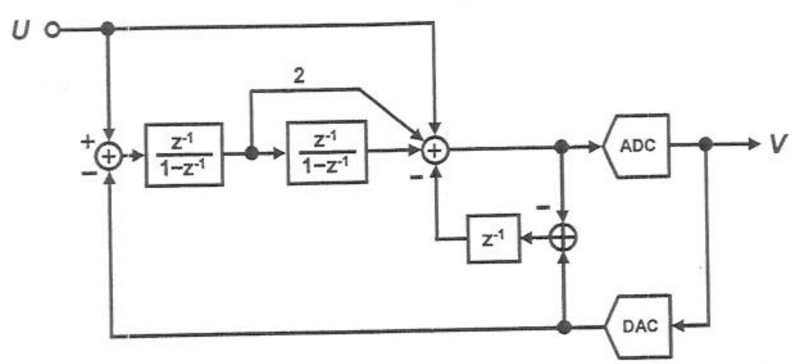
Open book, open notes

1. An M+1 level DAC contains M unit current sources. The i^{th} source has a value $I + dI_i$, where I is the ideal value, and dI_i is the error.

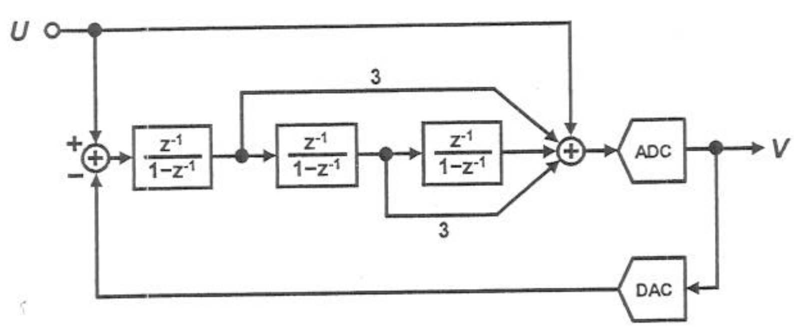
a. Find the expression for the end-point matched INL_n in terms of the dI_i when n sources are being used.

b. Find the mean-square value (MSV) of INL_n when the dI_i are uncorrelated, and the MSVs of all errors are equal to dI^2. For what value of n is the mean-square conversion error the largest? How large is it?

2. Find the NTF and STF of the ADC shown below.



3. The input of the delta-sigma ADC shown below satisfies -1 V < $u(n)$ < 1 V; the LSB voltage of the quantizer is 0.4 V. What is the output voltage range of the first integrator?



Solutions.

1. An M+1 level DAC contains M unit current sources. The i^{th} source has a value $I + dI_i$, where I is the ideal value, and dI_i is the error.

a. Find the expression for the end-point matched INL_n in terms of the dI_i when n sources are being used.

b. Find the mean-square value (MSV) of INL_n when the dI_i are uncorrelated, and the MSVs of all errors are equal to dI^2. For what value of n is the mean-square conversion error the largest? How large is it?

a. Actual output:

$$A(n) = \sum_{i=1}^{n} (I + dI_i) = nI + \sum_{i=1}^{n} dI_i$$

End-point ideal output:

$$A_e(n) = \frac{n}{M} \sum_{i=1}^{M} (I + dI_i) = nI + \frac{n}{M} \sum_{i=1}^{M} dI_i$$

$$INL_n = \sum_{i=1}^{n} dI_i - \frac{n}{M} \sum_{i=1}^{M} dI_i = \left(1 - \frac{n}{M}\right) \sum_{i=1}^{n} dI_i - \frac{n}{M} \sum_{n+1}^{M} dI_i$$

b. $$\overline{INL_n^2} = \left[n\left(1 - \frac{n}{M}\right)^2 + (M-n)\frac{n^2}{M^2}\right] dI^2$$

$$= \frac{M-n}{M^2}\left[n(M-n) + n^2\right] dI^2 = \frac{n(M-n)}{M} dI^2$$

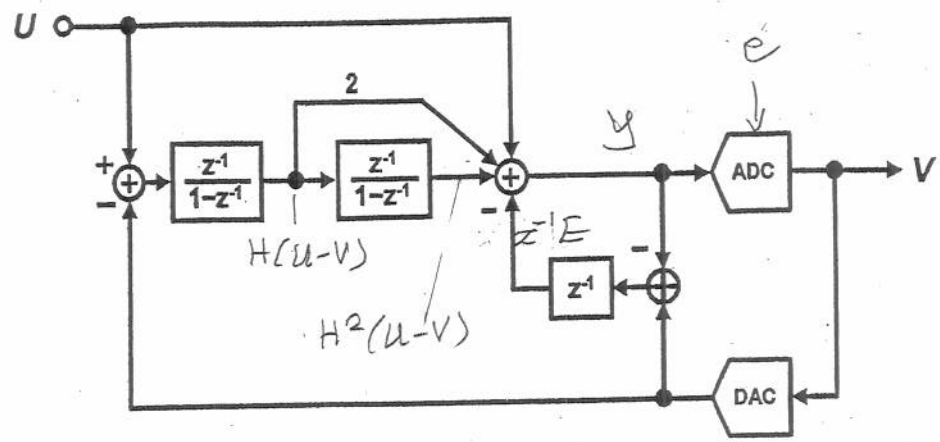
$$\frac{\partial \overline{INL_n^2}}{\partial n} = 0 \rightarrow n_{max} = M/2 \quad (\text{or } M/2 \pm 1/2)$$

$\overline{INL^2_{max}} = M dI^2/4$, Relative MS error $\varepsilon^2 = \frac{dI^2}{I^2}$)

FS output power $M^2 I^2$ Relative MS error

$$\frac{\overline{INL^2}}{A^2_{FS}} = \frac{(M/4)\varepsilon^2 I^2}{M^2 I^2} = \frac{\varepsilon^2}{4M} \rightarrow 10 \log_{10}(\varepsilon^2/4M)\ dB$$

2.



$$Y = U + 2H(U-V) + H^2(U-V) - z^{-1}E = V - E$$

$$\cancel{V} = E + (H+1)^2 U - [(H+1)^2 - \cancel{1}]V - z^{-1}E$$

$$(H+1)^2 V = (H+1)^2 U + (1-z^{-1})E$$

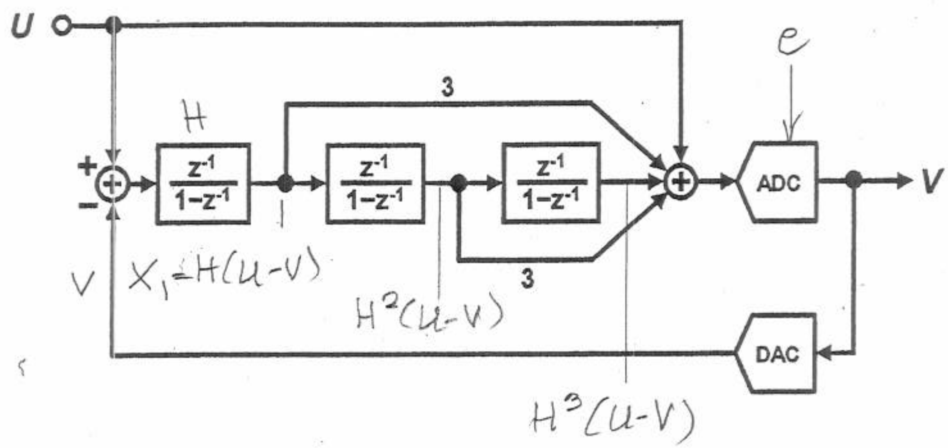
$$(H+1)^{-2} = (1-z^{-1})^2$$

$$V = U + (1-z^{-1})^3 E$$

$$NTF = (1-z^{-1})^3$$

$$STF = 1$$

3.



$$V = E + U + 3H(U-V) + 3H^2(U-V) + H^3(U-V)$$

$$V = \frac{E}{(H+1)^3} + U = U + (1-z^{-1})^3 E$$

$$H(U-V) = -z^{-1}(1-z^{-1})^2 E \rightarrow -e(n-1) + 2e(n-2) - e(n-3)$$

$$|x_1(n)| \le 4|e|_{max} = 4V_{LSB}/2 = 0.8V$$