MIDTERM EXAMINATION
ECE 627

May 16, 2008
3:00 - 3:50 pm

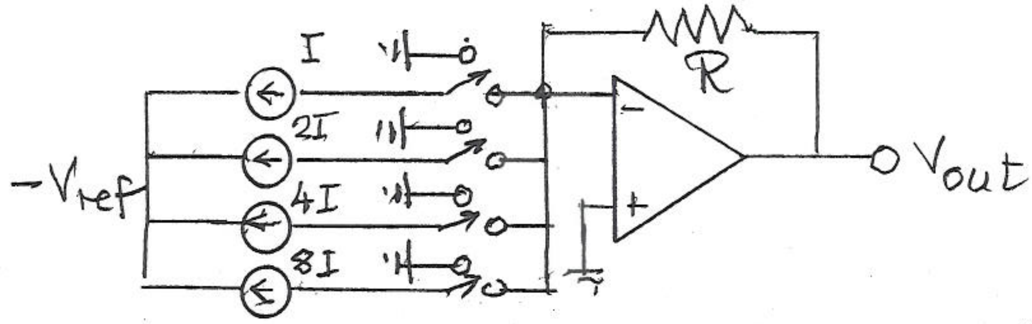
Open Book

1. A binary-weighted current-mode DAC is shown below. The values are I = 50 μA, R = 2 kΩ.

   (a) If the current sources have a tolerance ± 5%, what is the worst-case INL if the endpoints of the characteristics are matched?

   (b) How large may the input offset of opamp be so the worst-case error it causes is less than 0.5 LSB?

   (c) What is the minimum value of the opamp gain if the worst-case error caused by the finite gain is to be also less than 0.5 LSB?



2. The noise transfer function of a delta-sigma ADC modulator is NTF = $(1 - z^{-1})^3$; the STF = 1. The RMS value of the input signal is u_{rms} = 0.5 V, and the LSB voltage of the quantizer is V_{LSB} = 0.12 V.

   What is the mean-square value $\overline{y^2}$ of the input to the quantizer, if the linear model holds?

(a) If the endpoint of the characteristics are matched, then the worst case INL happens when code is 1000 and 0111.

$$E_{gain} = 8 \times 0.05 - 7 \times 0.05 = 0.05\,LSB.$$

At code 1000, $INL = 8 \times 0.05 - \frac{8}{15} \times 0.05 = 0.3733\,LSB$

At code 0111, $INL = -7 \times 0.05 - \frac{7}{15} \times 0.05 = -0.3733\,LSB.$

$V_{LSB} = IR = 50 \times 10^{-6} \times 2 \times 10^{3} = 0.1V$

Therefore, worst-case INL is $\pm 0.03733V$

(b) $V_{LSB} = RI = 50 \times 10^{-6} \times 2 \times 10^{3} = 0.1V$

So $V_{os} < 0.5\,LSB = 50\,mV$

(C) Assume the current through R is i, then

$$V_{out} + \frac{V_{out}}{A} = iR$$

$$V_{out} = \frac{iR}{1 + \frac{1}{A}}$$

The ideal value of V_{out} is iR, then the error is

$$E_{V_{out}} = \frac{iR}{1+A}.$$

So the maximum error happens at code 1111 which should be less than $0.5\,LSB$,

$$\frac{15IR}{1+A} < 0.5\,LSB \Rightarrow A > \frac{15 \times 0.1}{0.5 \times 0.1} - 1 = 29$$

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

$v[n] = u[n] + e[n] - 3e[n-1] + 3e[n-2] - e[n-3]$

$y[n] = v[n] - e[n] = u[n] - 3e[n-1] + 3e[n-2] - e[n-3]$

So $\overline{y^2} = \overline{u^2} + (9+9+1) \cdot \overline{e^2}$

$= 0.5^2 + 19 \cdot \frac{\Delta^2}{12}$

$= 0.2728\, V^2$