MIDTERM EXAMINATION

ECE 627
Friday, May 4, 2007, 3:00 - 3:50 pm

Open book, open notes.

1. Fig.1 shows a segmented 10-bit resistive DAC. The MSB switches connect the fine divider across one of the resistors (determined by the MSBs) in the coarse resistor string, and the LSB switches connect the output node to the appropriate tap in the fine resistor string.

The values of all resistors in the coarse divider are Rc = 100 ohm; in the fine divider they are Rf = 50 ohms. What should be the value I of the current sources used to achieve (ideally) linear operation?

2. In the 12-bit current-mode DAC shown in Fig.2, the load resistance is R = 50 ohms. Each current source has an output resistance Ro. What is the minimum value of Ro, if the maximum value of the endpoint INL is to be 1/2 LSB?

3. In the multiply-by-2 stage shown in Fig.3, the capacitors have a mismatch error of 0.1%.

(a) What is the gain error?

(b) The error can be reduced by performing the operation a second time, with the
roles of C1 and C2 interchanged, and finding the average of the two outputs. What will be the gain error now?

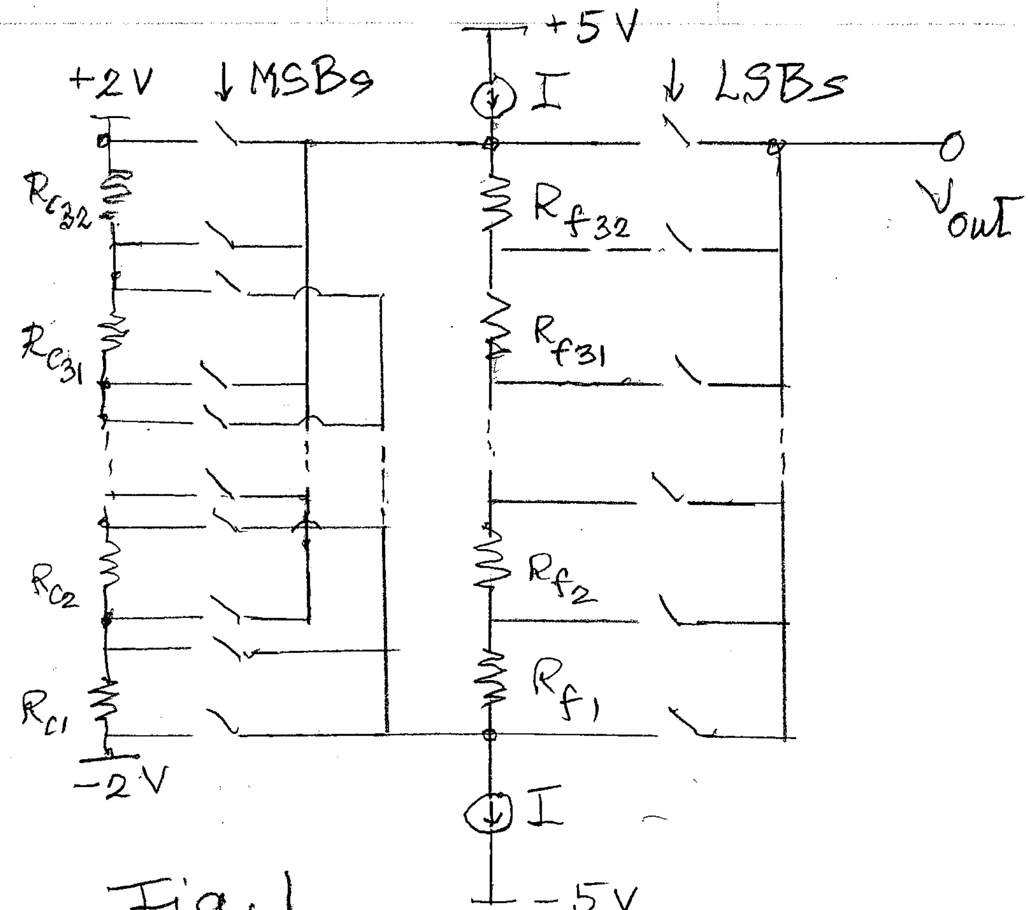


Fig. 1

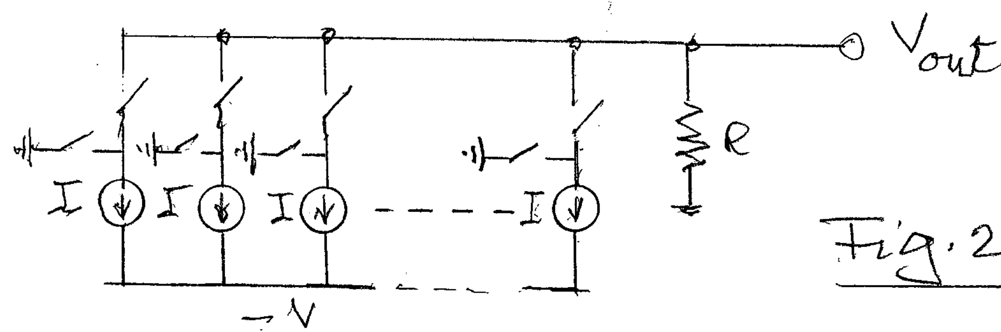


Fig. 2

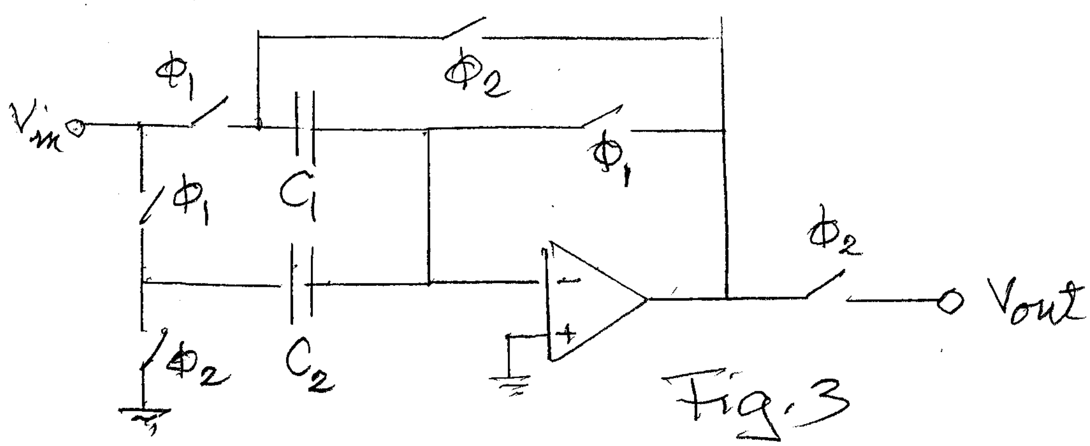
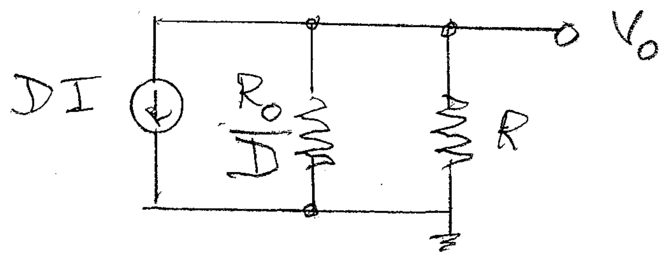


Fig. 3

1. The voltage drop across $R_{f_1} - R_{f_{32}}$ must equal that across one of the R_i. So $I \cdot 32 \cdot R_f = 4/32$, giving $I = 78.125\,\mu A$

2. For a digital input D:



$$-V_o(D) = DI/(G + DG_o)$$

Full-scale output:

$$-V_{OFS} = \underbrace{(2^{12}-1)}_{N} I/(G + NG_o)$$

End-point INL for code D:

$$V_{INL}(D) = V_o(D) - \frac{D}{N} V_{OFS}$$

$$= DI\left[\frac{1}{G+DG_o} - \frac{1}{G+NG_o}\right]$$

At midpoint, $D = N/2$

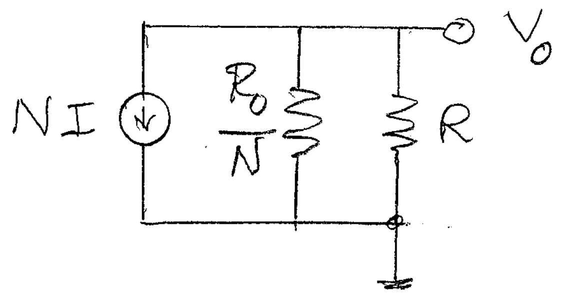
$$V_{INL,MP} = \frac{N}{2} I \frac{(N/2)G_o}{(G+\frac{N}{2}G_o)(G+NG_o)}$$

$$\approx I\left(\frac{N}{2}\right)^2 \frac{G_o}{G^2} = \underbrace{\frac{I}{G}}_{V_{LSB}} \left(\frac{N}{2}\right)^2 \frac{G_o}{G}$$

$$\left(\frac{N}{2}\right)^2 \frac{R}{R_o} \le \frac{1}{2}, \quad \frac{R_o}{R} \ge \frac{N^2}{2} \simeq 8.4 \times 10^6$$

$$R_o \ge 420\,M\Omega$$

2. Other interpretation, at FS



$N = 10^{12} - 1$
$N \cong 10^{12}$

$$V_0 = -NI/(NG_0 + G)$$

Ideally $V_{0_i} = -NI/G$

$$LSB_i = -I/G$$

$$INL = NI\left[\frac{1}{G} - \frac{1}{NG_0 + G}\right] \times \frac{G}{I} \quad \text{in LSBs}$$

$$INL = N\frac{N\cancel{G}G_0}{\cancel{G}(NG_0+G)} = N^2\frac{R}{NR + R_0} \overset{!}{\leq} \frac{1}{2}\ \text{LSB}$$

$$\cancel{NR} + R_0 \geq 2 \times N^2 R \cong 1.68\ G\Omega$$

3. Ideally, $V_{O_i} = V_{in}(1 + C_2/C_1) = 2V_{in}$

(a) If $C_2 = (1+\varepsilon)C_1$, $V_{O\varepsilon} = (2+\varepsilon)V_{in}$,
so the gain error is $\varepsilon = \pm 10^{-3}$.

(b.) The corrected output is

$$V_{O,C} = \frac{V_{in}}{2}\left(2 + 1 + \varepsilon + \frac{1}{1+\varepsilon}\right).$$

Since $1/(1+\varepsilon) \cong 1 - \varepsilon + \frac{\varepsilon^2}{2}$,

$$V_{O,C} = V_{in}(2 + \varepsilon^2/2)$$

The gain error is now $\approx \varepsilon^2/2 = 5 \times 10^{-7} = 0.5$ ppm