ECE 627

Spring 2011

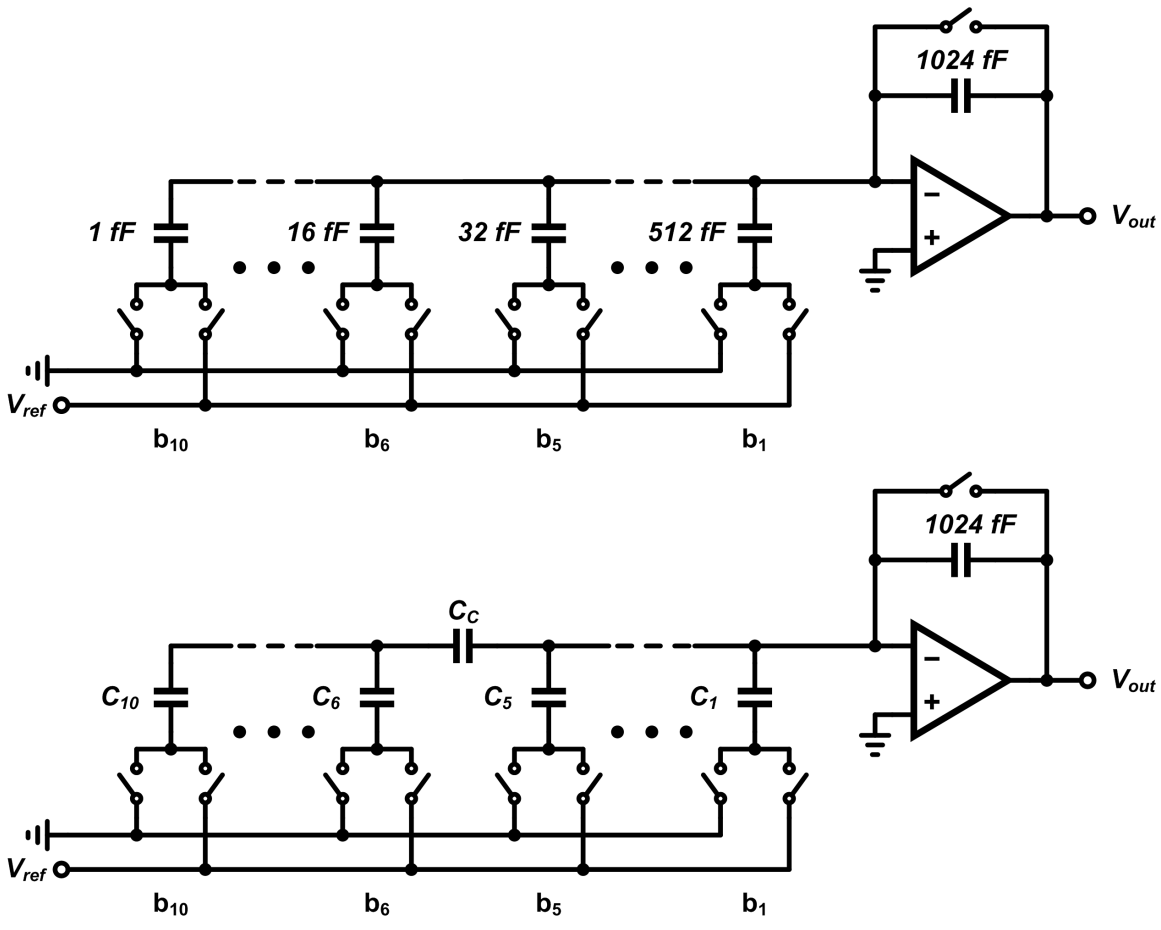
Midterm Examination

May 11, 2011, 3-3:50pm

1. In the binary-weighted 10-bit DAC shown on top, the capacitor array can be replaced as shown below.

a. Find the element values in the new DAC. Choose $C_6 = C_1$.

b. What are the advantages and disadvantages of the new circuit?

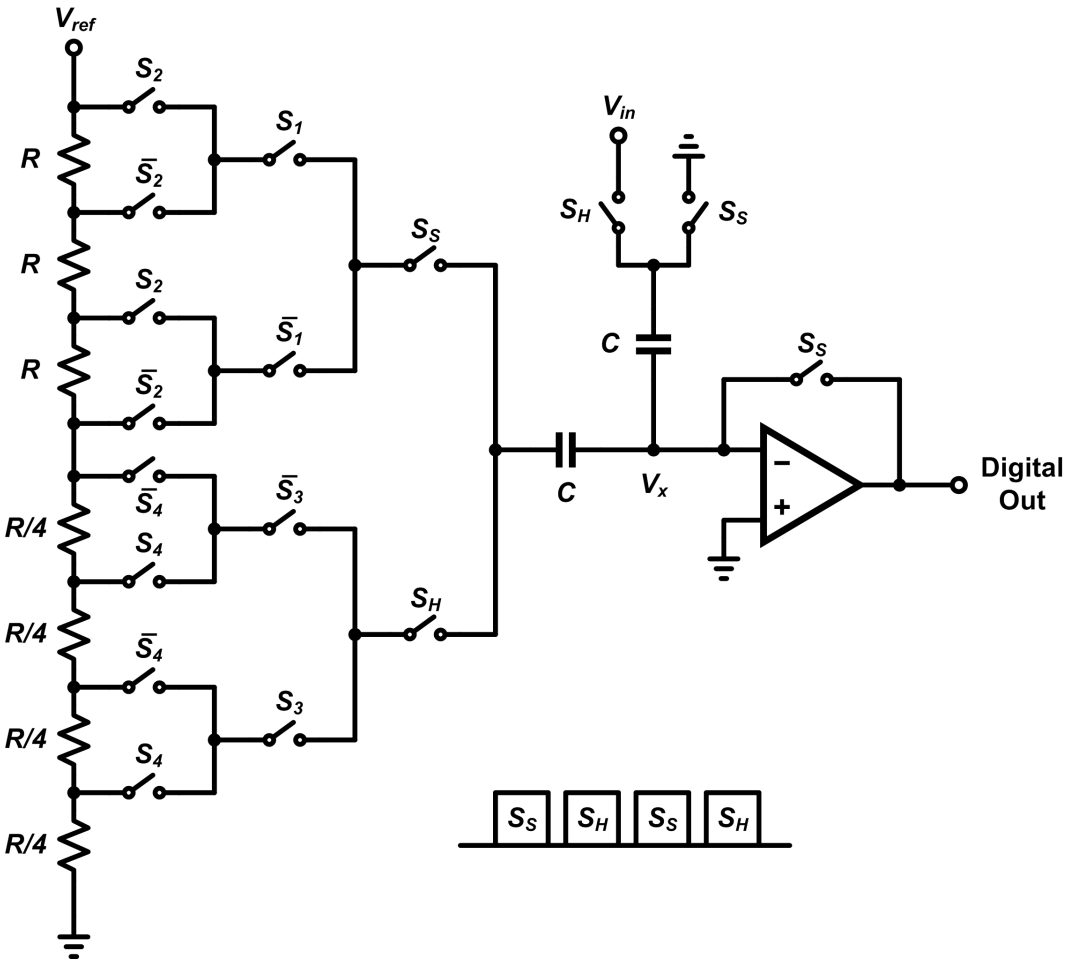


2. In the 4-bit SAR ADC shown, during the sampling phase the S_S switches are closed; during the next (hold) phase, the S_H switches are closed. After the hold phase, switches S_1, S_2, S_3, and S_4 are used to test for the MSB, next MSB, etc.

   a. Which of these switches will be closed when the MSB is found?

   b. Which switches are closed when the next bit is found if the MSB was 1?

   c. Which switches are closed when the next bit is found if the MSB was 0?



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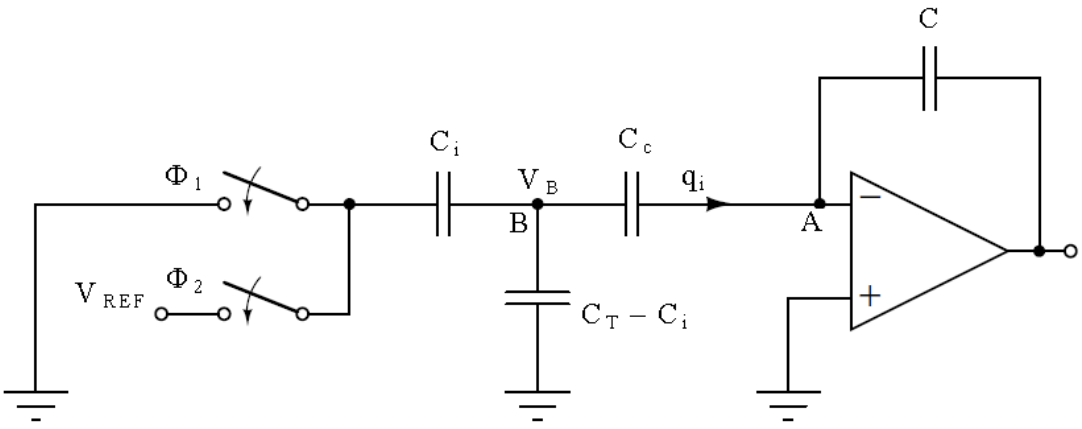
Solution

1.

a. Since $C_1, C_2 \ldots C_5$ are connected in the same way as $\frac{C}{2}, \ldots, \frac{C}{2^5}$ elements, and deliver $q_i = +C_i V_{ref}$ in to the virtual ground A, $C_i = 2^{-i}C$, for $i = 1, 2, \ldots, 5$.



For $6 \leq i \leq 10$, we have

$$+q_i = C_c V_B = \frac{C_c C_i V_{REF}}{C_c + C_T} = \frac{C_i V_{REF}}{1 + \frac{C_T}{C_c}} \doteq \frac{C V_{REF}}{2^i}$$ where

$$C_T = \sum_{i=6}^{10} C_i$$

Since by assumption, $C_6 = C_1$, for $i = 6$,

$$\frac{C}{2} \frac{V_{REF}}{(1 + \frac{C_T}{C_c})} = \frac{C V_{REF}}{2^6}$$

$$\frac{C_T}{C_c} = 2^5 - 1 = 31$$

For $i = 7, 8, 9, 10$ therefore

$$\frac{C_i V_{REF}}{32} = \frac{C V_{REF}}{2^i}$$

$C_i = 2^{5-i}C = C_{i-5}, C_7 = C_2, \ldots$

$$C_T = \sum_{i=1}^{5} C_i = C\left(\frac{1}{2} + \frac{1}{4} + \cdots + \frac{1}{32}\right) = \frac{31}{32}C$$

$$C_c = \frac{C_T}{31} = \frac{C}{32} = C_{10} = 32fF$$

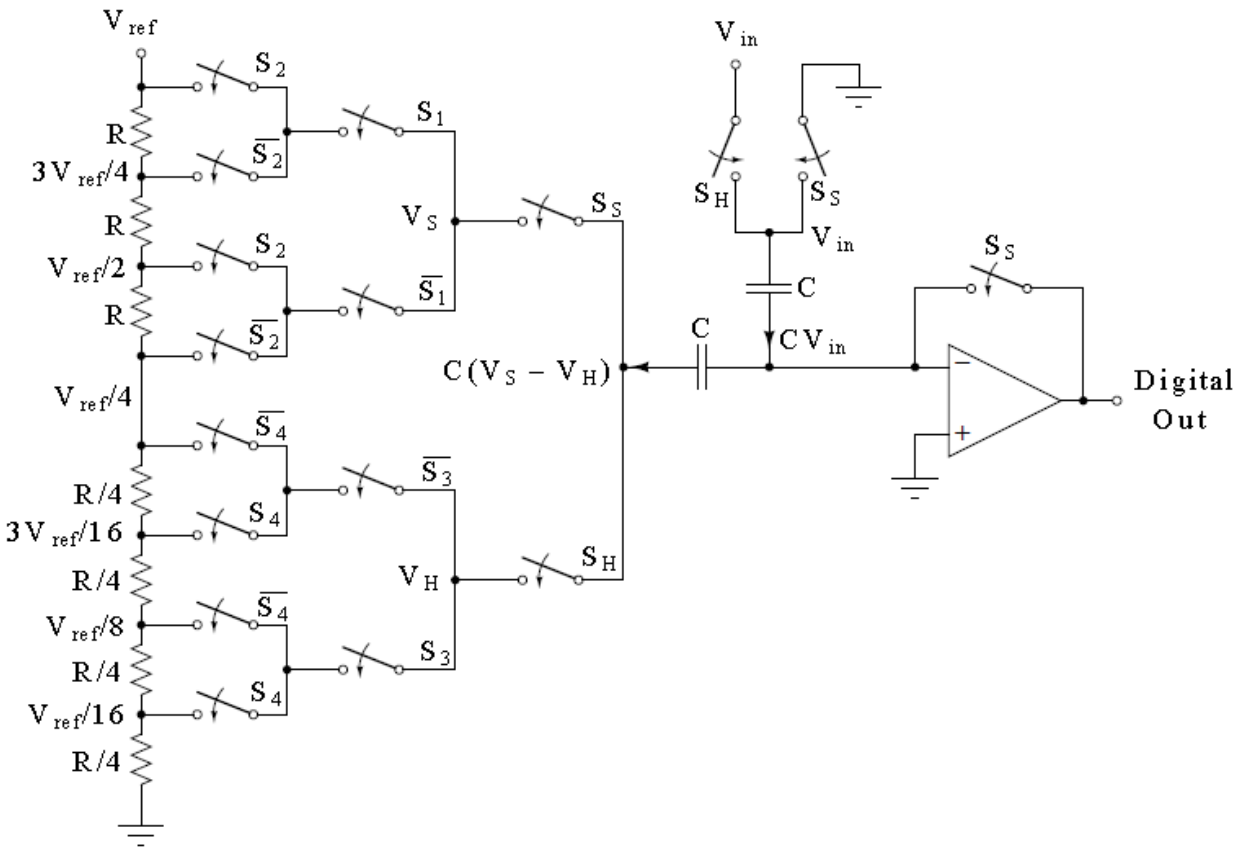
b. The new circuit has one more capacitor. Spread of capacitors reduced by half, may be possible to scale all capacitors by $\frac{1}{2^5}$. Circuit is stray sensitive at left side terminal of C_c. Circuit is also sensitive to C_c. Monotonicity and glitch of the new circuit is possibly better. The new circuit is faster.

2. Charge flow through the capacitor in to $V_x = V_{os}$ as $S_H \to 1$.

$$q = CV_{in} - C(V_S - V_H)$$

a. For MSB, $V_S - V_H \doteq \frac{V_{ref}}{2}$ obtained if $V_S = \frac{3}{4}V_{ref}$, $V_H = \frac{1}{4}V_{ref}$

$$S_1 = 1, S_2 = 0, S_3 = 0, S_4 = 0$$



b. If $MSB = 1$, next $V_S - V_H \doteq \frac{3}{4}\, V_{ref}$ obtained if $V_S = V_{ref}$, $V_H = \frac{1}{4} V_{ref}$

$$S_1 = 1, S_2 = 1, S_3 = 0, S_4 = 0$$

c. If $MSB = 0$, next $V_S - V_H \doteq \frac{1}{4}\, V_{ref}$ obtained if $V_S = \frac{Vref}{2}$, $V_H = \frac{1}{4} V_{ref}$

$$S_1 = 0, S_2 = 1, S_3 = 0, S_4 = 0$$