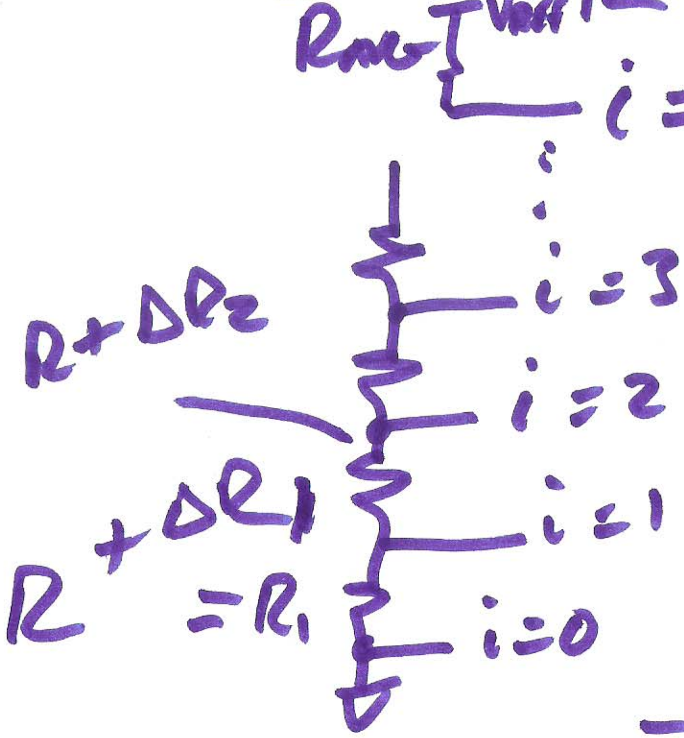
29.1 DACs

Mismatch → $\frac{\Delta R}{R_{AVG}} = 0.01$, 1% mismatch

$\frac{\Delta R}{R_{AVG}} = \frac{\Delta R}{R}$

$R = R_{AVG}\left(1 + \frac{\Delta R}{R_{AVG}}\right)$

$= R_{AVG} + \Delta R$ (R, ΔR)



$$R = \frac{\sum_{i=1}^{2^N} (\Delta R_i + R)}{2^N}$$

990 → 1010

only if $\sum_{i=1}^{2^N} \Delta R_i = 0$

$-10 < \Delta R_i < 10$

↑ random value

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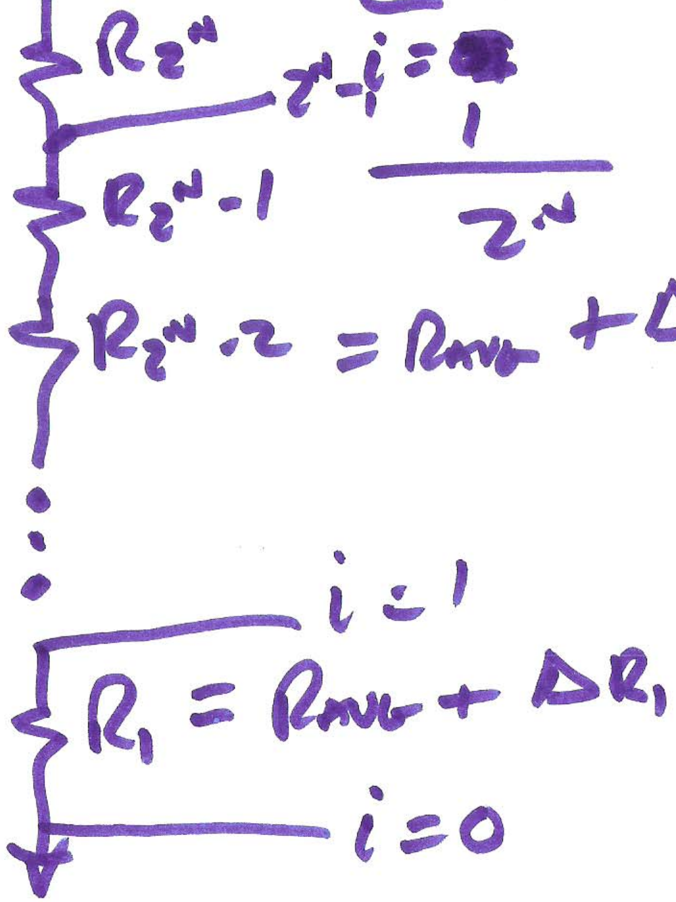
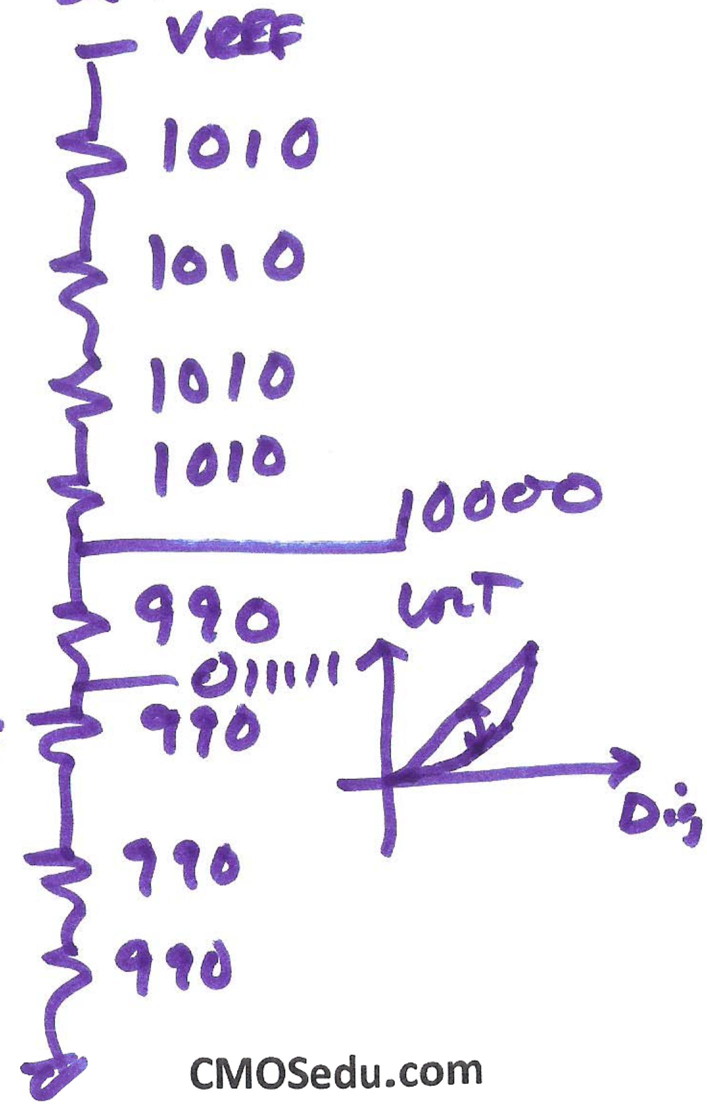
1)

$$\sum^{2^N} R_i = R = R_{AVG}$$

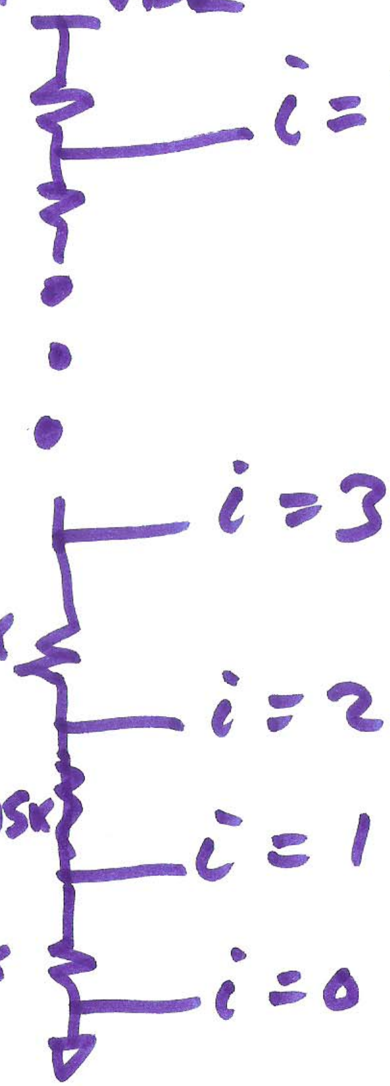


Sec. 21.1



$V_{LSB} = \frac{VREF}{2^N}$ / ideal

A29.1



How many resistors?

$1024 = 2^{10}$

$$R = \frac{\sum_{j=0}^{1023} (1K + 5j)}{1024}$$

$$= \frac{\sum_{j=1}^{1024} (1K + 5(j-1))}{1024}$$

$$1+2+3+4+5+6+\cdots 1024 = \frac{1024(1024+1)}{2} \approx \frac{1023^2}{2} \quad \frac{1023^2}{2}$$

$$= \frac{1K \cdot 1024 + 5 \cdot 102}{1024}$$

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3)

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$$R = \frac{1024 \cdot 1k + 5 \cdot \frac{1023 \cdot 1024}{2}}{1024}$$

$$\sum_{j=0}^{0} \quad j=0 \quad j=1$$

$$= 1k + 2.5 \cdot 1023$$

$$\boxed{R = 3557.5\,\Omega}$$

$$V_{i,actual} = V_{REF} \cdot \frac{\sum_{j=1}^{i}\left(1k + (j\,\text{[illegible]})5\right)}{2^N \cdot 3557.5}$$

$$i > 1$$

$$V_{i,ideal} = \frac{V_{REF}}{2^N} \cdot i$$

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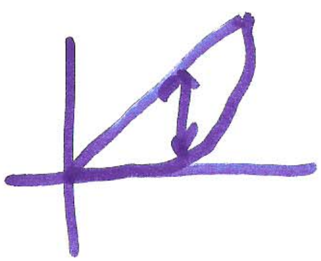
$\frac{DR}{R} = R_{AVG} +$ $\quad V_{i,ideal} = \frac{V_{REF}}{2^N} \cdot i$

$$V_{i,actual} = \frac{V_{REF}}{2^N} \cdot \sum_{j=1}^{i} \frac{(1K + (j-1)5)}{3557.5}$$

$$INL = V_{i,actual} - V_{i,ideal}$$

$$= \frac{V_{REF}}{2^N}\left(i - \sum_{j=1}^{i} \frac{1K + (j-1)5}{3557.5}\right)$$



WORST CASE INL @ $i = 512$

$$= 1\,LSB\left(512 - \frac{1}{3557.5}\left(512K + 5\left(\frac{511 \cdot 512}{2}\right)\right)\right)$$

$1 + 2 + 3 + \ldots \frac{j-1}{K}$

$$= \frac{K(K+1)}{2} = \frac{(j-1)(i)}{2}$$

322?

175 LSB !

5)

$$R_i = R_{AVG}\left(1+\frac{\Delta R}{R}\right)$$

$$1K = 3557.5\left(1+\frac{\Delta R}{R}\right)$$

VREF

$3557.5 + 2557.5K \approx 6.1K$

$$\frac{\Delta R}{R} = \frac{1K}{3557.5} - 1 = -.72$$

3557.5K

2557.5K

Match 72%!

1K

DNL

$V_{i,actual} - V_{i-1,actual}$

$$DNL \quad \frac{V_{REF}}{2^N}\left(\sum_{j=1}^{i}\frac{1k+(j-1)5}{3557.5}-\sum_{j=1}^{i-1}\frac{1k+(i-1)5}{3557.5}\right)$$

$\uparrow$ 1LSB

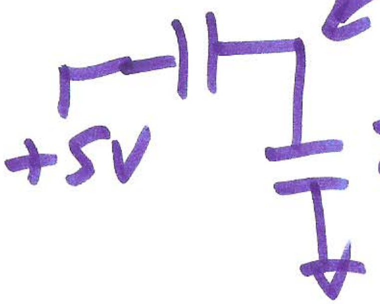
$$= 1LSB\left(\frac{.1k+5(i-1)}{3557.5}\right)$$

$DNL \simeq \frac{1}{3} LSB \quad i=1$

$DNL \simeq -.\frac{1}{2} LSB \quad i=512$

$DNL \simeq -1.2 LSB \quad i=1024$

$2.5 + 1.25 = 3.75\,V$



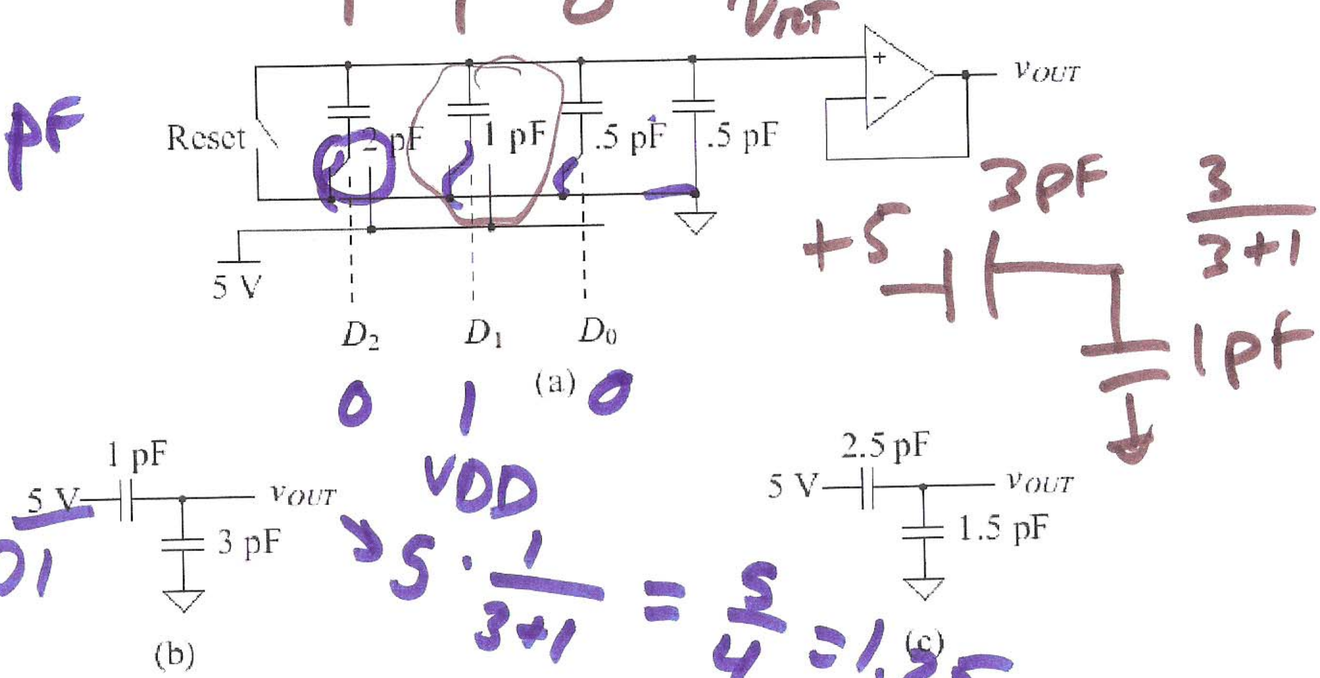
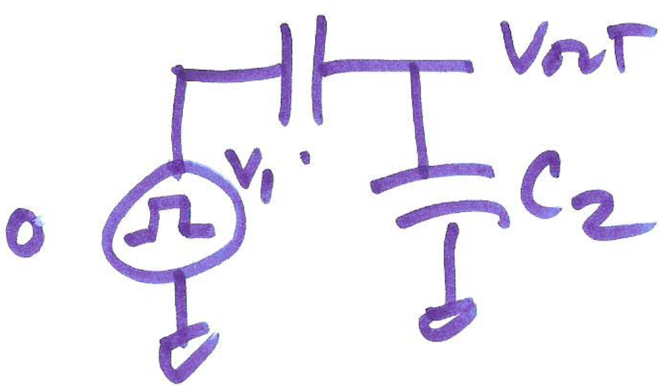


Figure 29.13 (a) A 3-bit charge-scaling DAC used in Ex. 29.6 and the equivalent circuits inputs equal to (b) 010 (c) 101.

$$\frac{3}{3+1}\cdot 5 = 3.75$$

$$\rightarrow 5\cdot\frac{1}{3+1} = \frac{5}{4} = 1.25$$



$$V_{OUT} = V_1\cdot\frac{C_1}{C_1+C_2} = V_1\cdot\frac{1/j\omega C_2}{1/j\omega C_1 + \frac{1}{j\omega C_2}}$$

8)

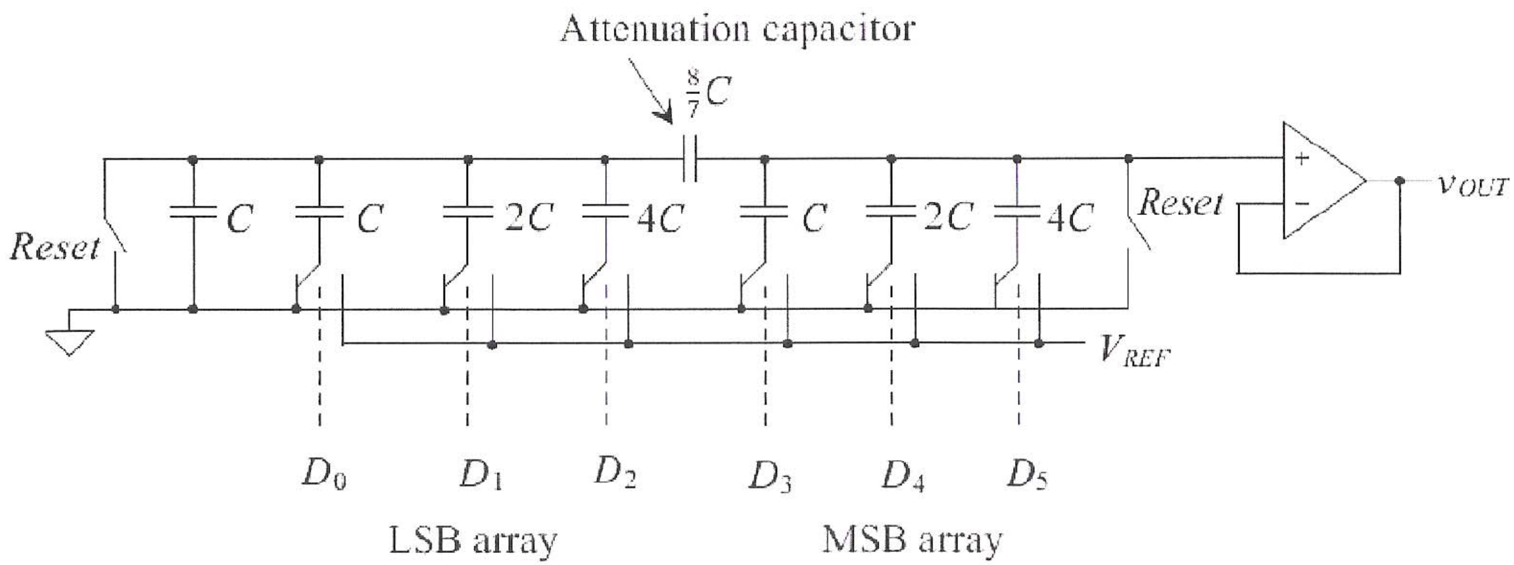
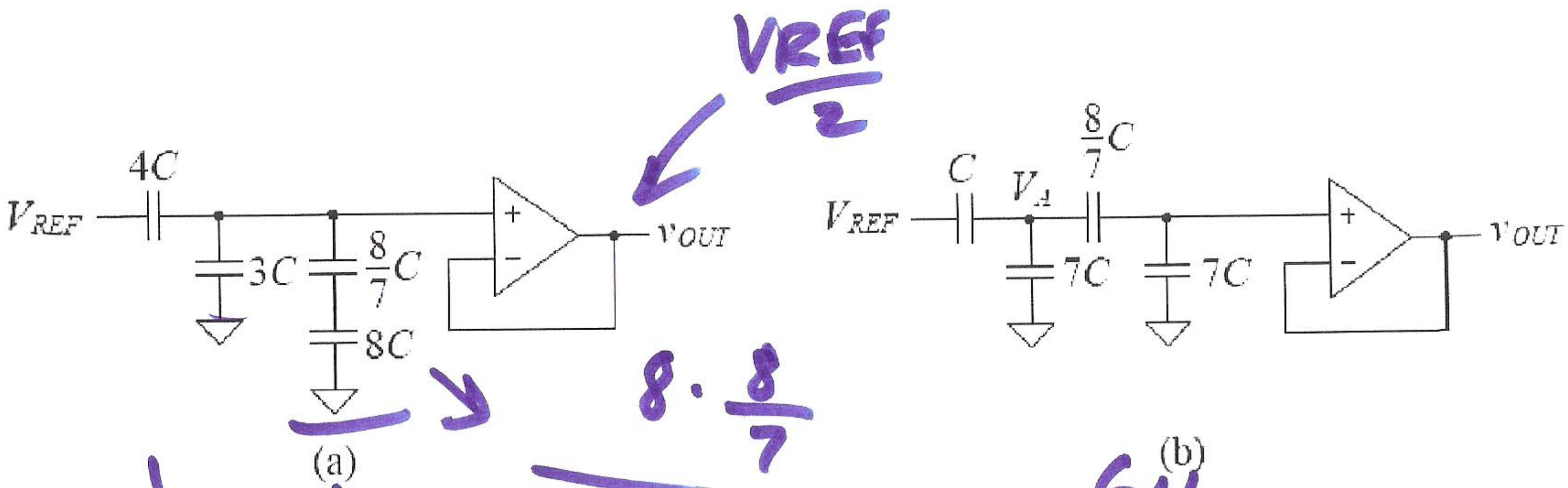


Figure 29.15 A charge-scaling DAC using a split array.



$\frac{1}{4}$ $\qquad \frac{8 \cdot \frac{8}{7}}{8 + \frac{8}{7}} = \frac{64}{56 + 8} = 1$

Figure 29.16 Equivalent circuits for Example 29.7.

Look at 29.7

10)

$N = 3$

$V_{REF} = 1$

1 0 1   0 1 1

$D_2\ D_1\ D_0$

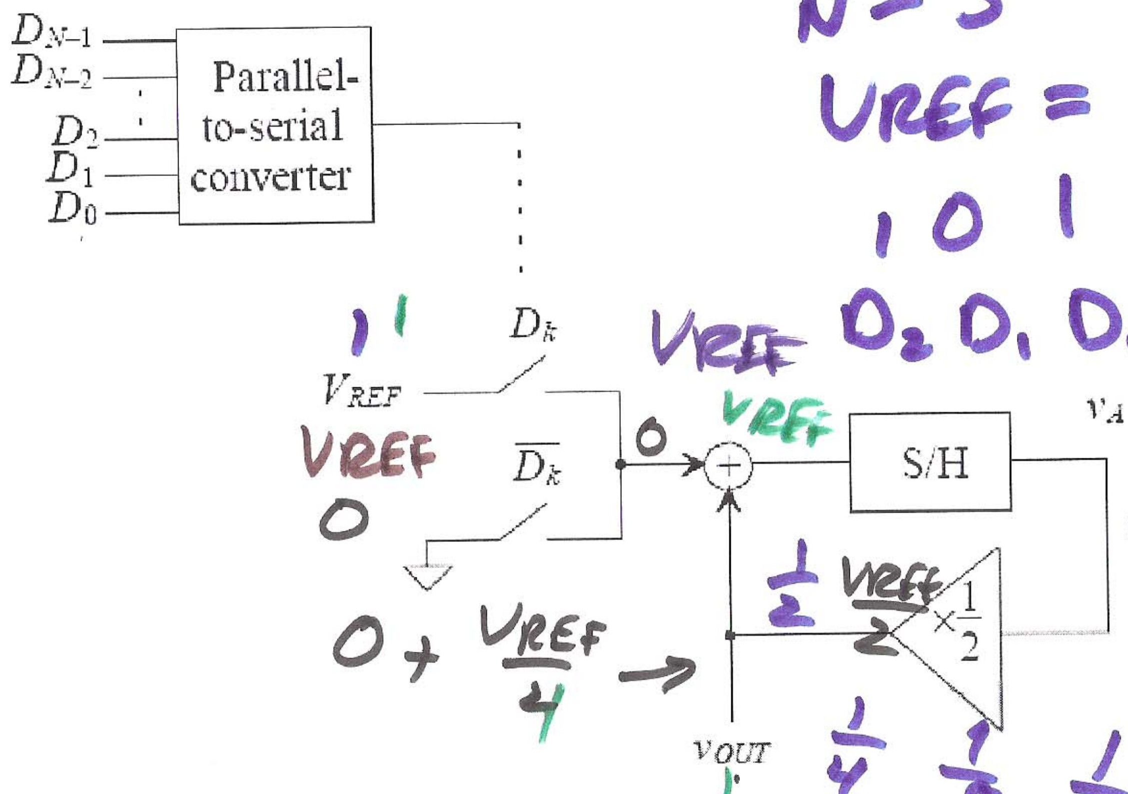


Figure 29.17 A cyclic digital-to-analog converter.

$D_0 \cdot \frac{V_{REF}}{2^N}$

$\frac{1}{4} \quad \frac{1}{8} \quad \frac{1}{16} \quad \frac{1}{2^{10}}$

$\frac{V_{REF}}{2} + 0 + \frac{V_{REF}}{8}$

$0 + \frac{V_{REF}}{4} + \frac{V_{REF}}{8}$

11)

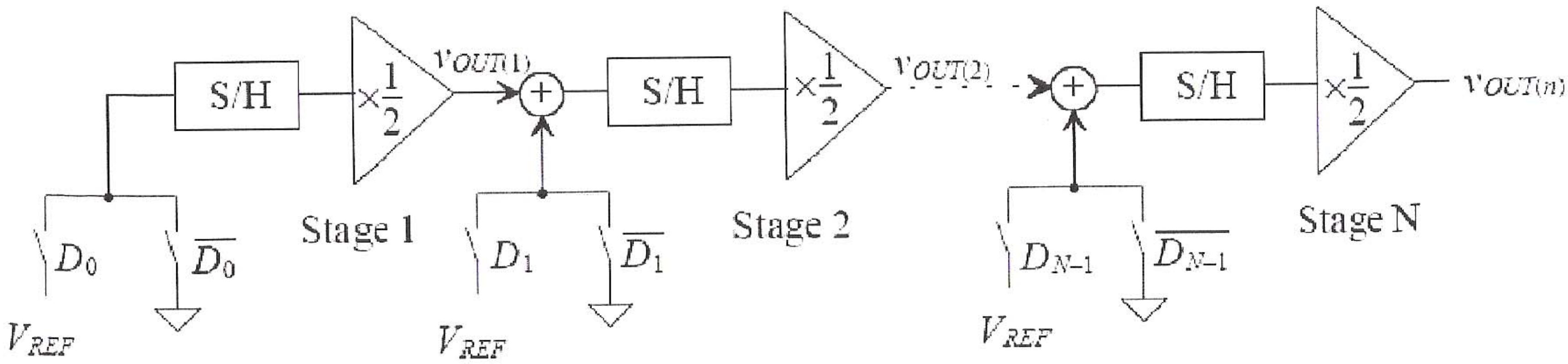


Figure 29.19 A pipeline digital-to-analog converter.

← 2^{N-1} LSBs

$$D_{N-1}\cdot\frac{V_{REF}}{2} + D_{N-2}\cdot\frac{V_{REF}}{4} + \cdots$$

$$\underbrace{D_1\cdot\frac{V_{REF}}{2^{N-1}}\cdot\frac{2}{2}}_{2\,LSB} + \underbrace{D_0\cdot\frac{V_{REF}}{2^{N}}}_{1\,LSB}$$