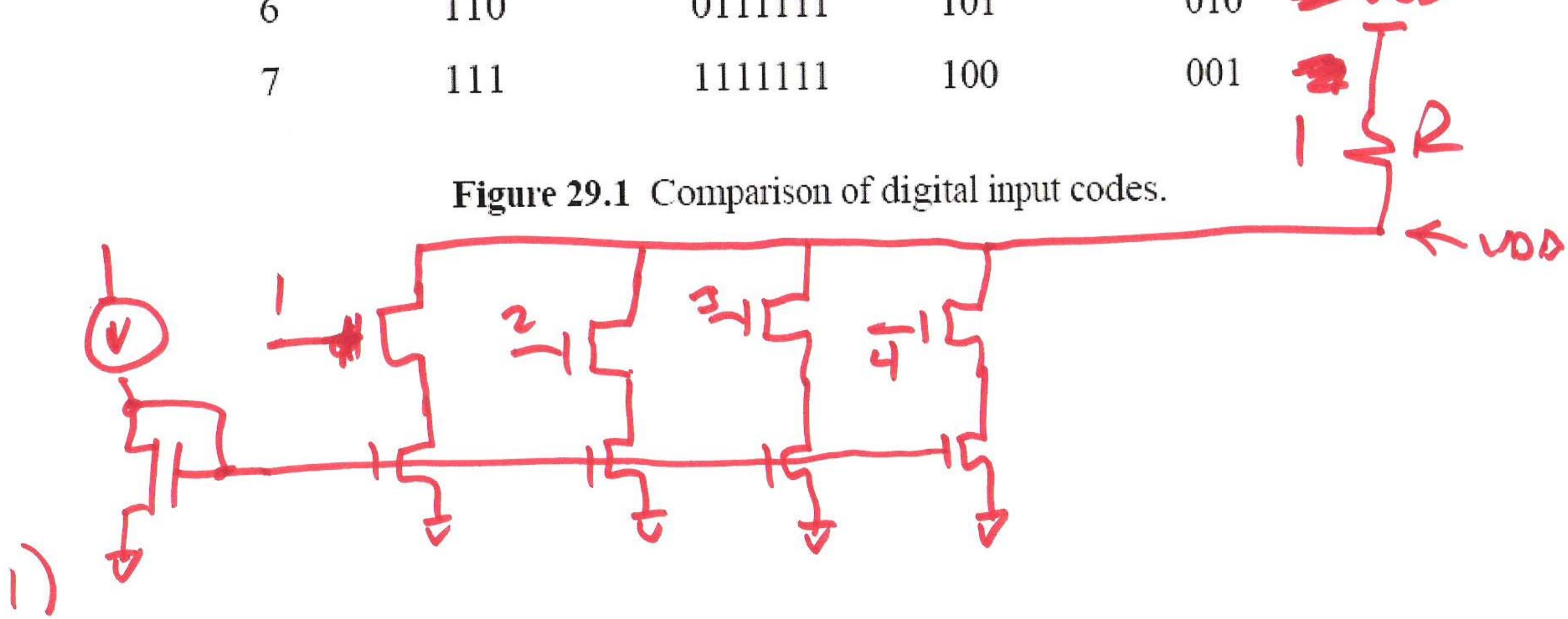
ECE 614 Advance Analog IC Design

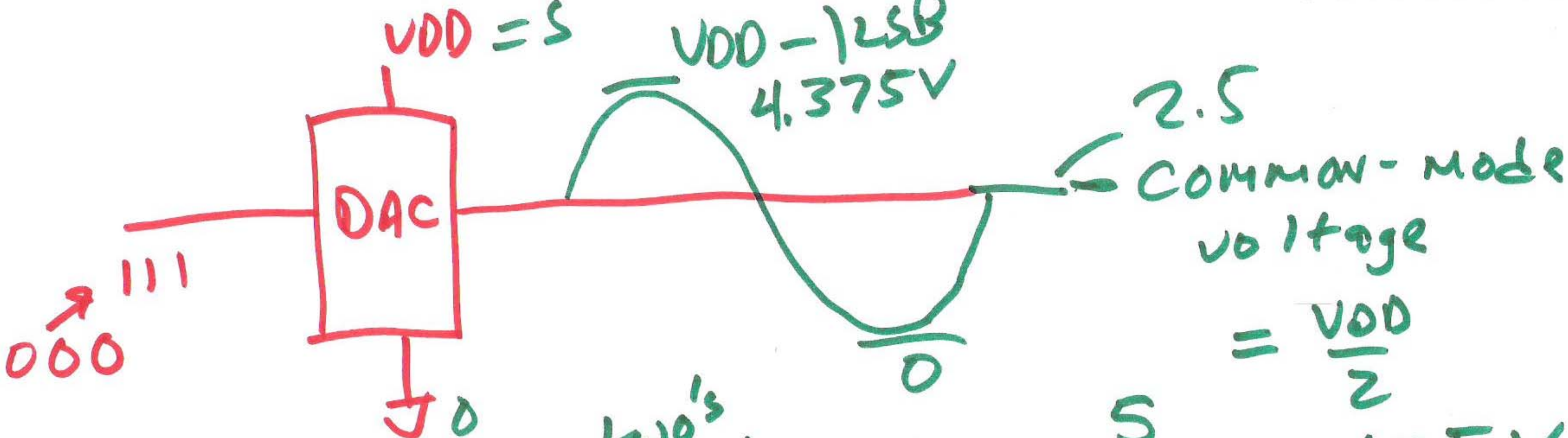
Oct. 20, 2011 Lecture 17

DAC

Decimal	Binary	Thermometer	Gray	Two's Complement	
0	000	0000000	000	000	0
1	001	0000001	001	111	-1
2	010	0000011	011	110	-2
3	011	0000111	010	101	-3
4	100	0001111	110	100	-4
5	101	0011111	111	011	3
6	110	0111111	101	010	2
7	111	1111111	100	001	

Figure 29.1 Comparison of digital input codes.





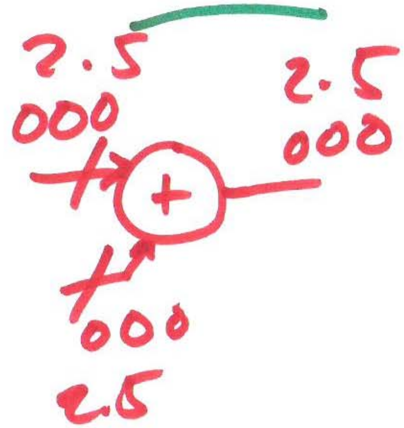
two's comp / 1LSB = $\frac{5}{8}$ = .625V

BINARY

000 → 0
001 → 0.625
010 → 1.25
011 → 1.875
100 → 2.5
101 → 3.125
110 → 3.7850
111 → 4.375V

100 → −4
101 → −3
110 → −2
111 → −1
000 → 0
001 → 1
010 → 2
011 → 3

2's COMP



2)

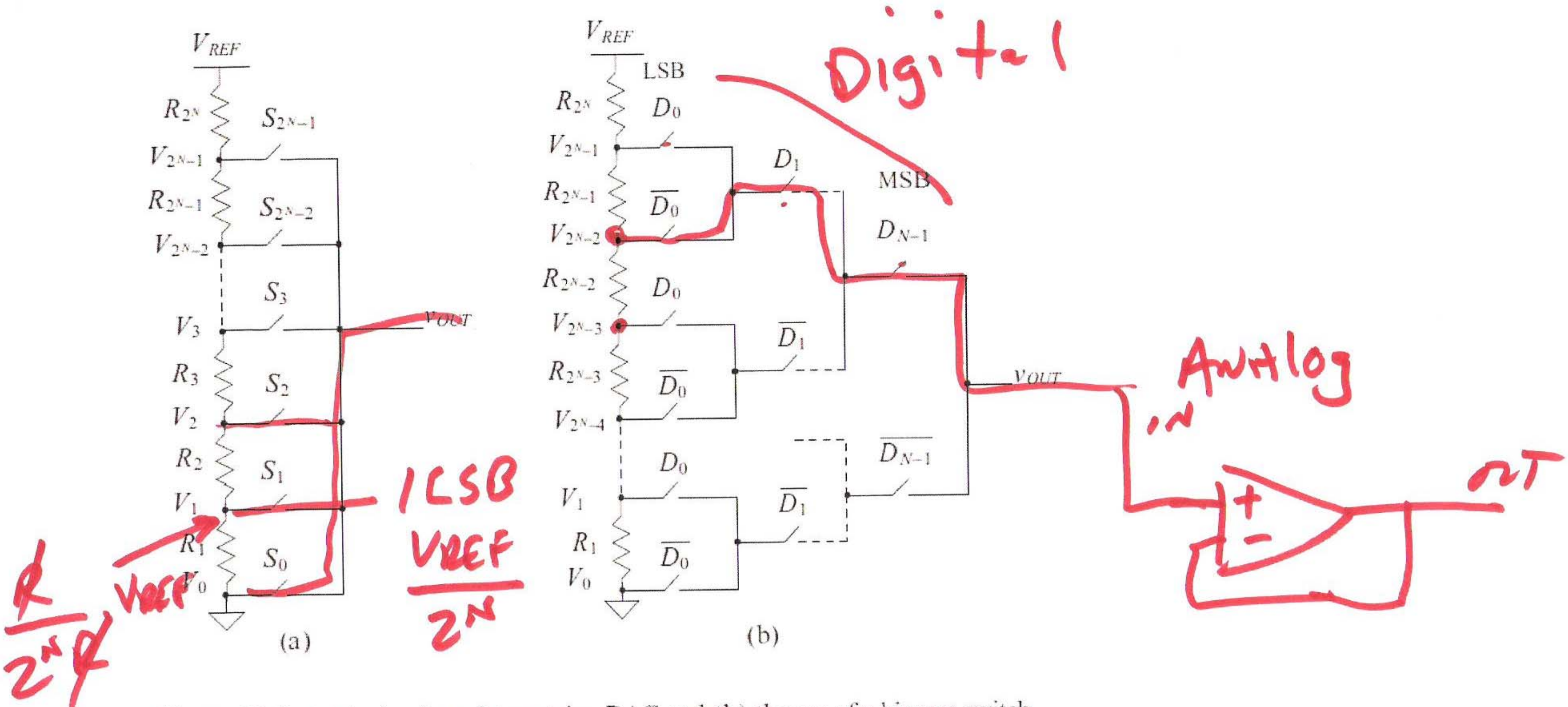


Figure 29.2 (a) A simple resistor-string DAC and (b) the use of a binary switch array to lower the output capacitance.

3)

$D_2D_1D_0$	v_{OUT}
000	0
001	0.625
010	1.25
011	1.875
100	2.5
101	3.125
110	3.75
111	4.375

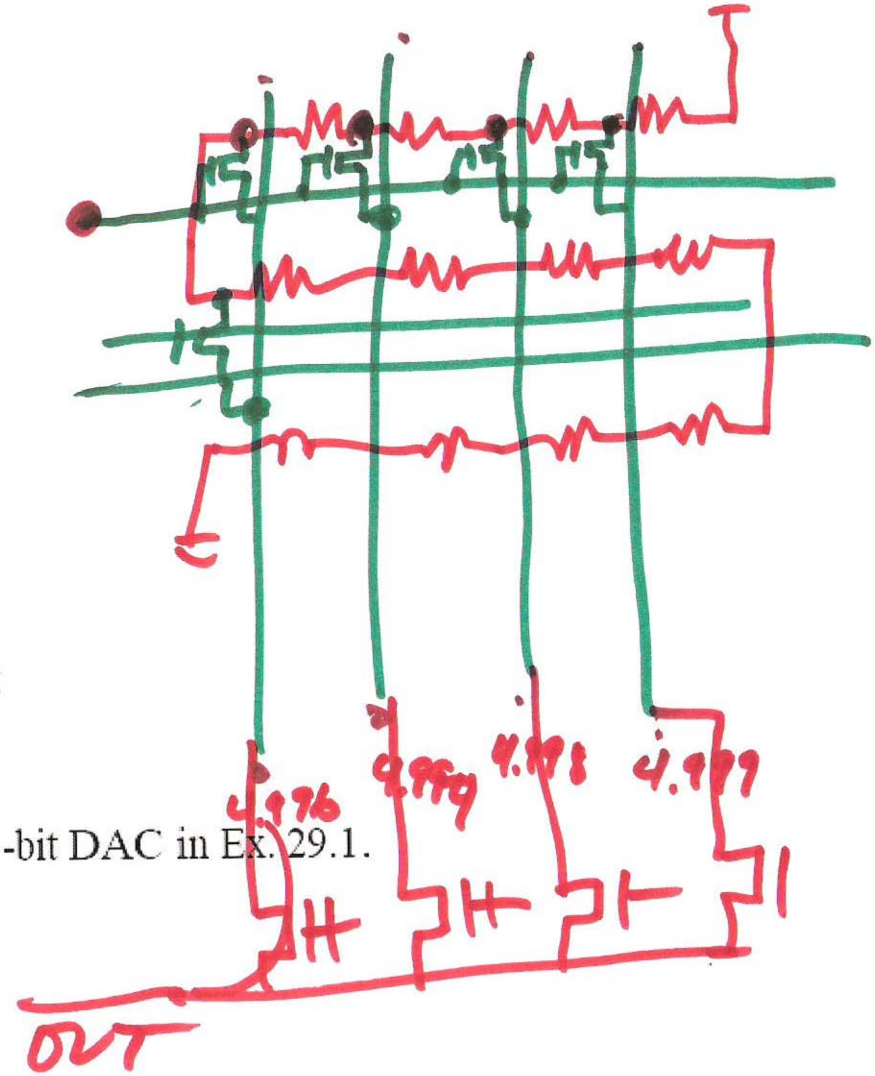
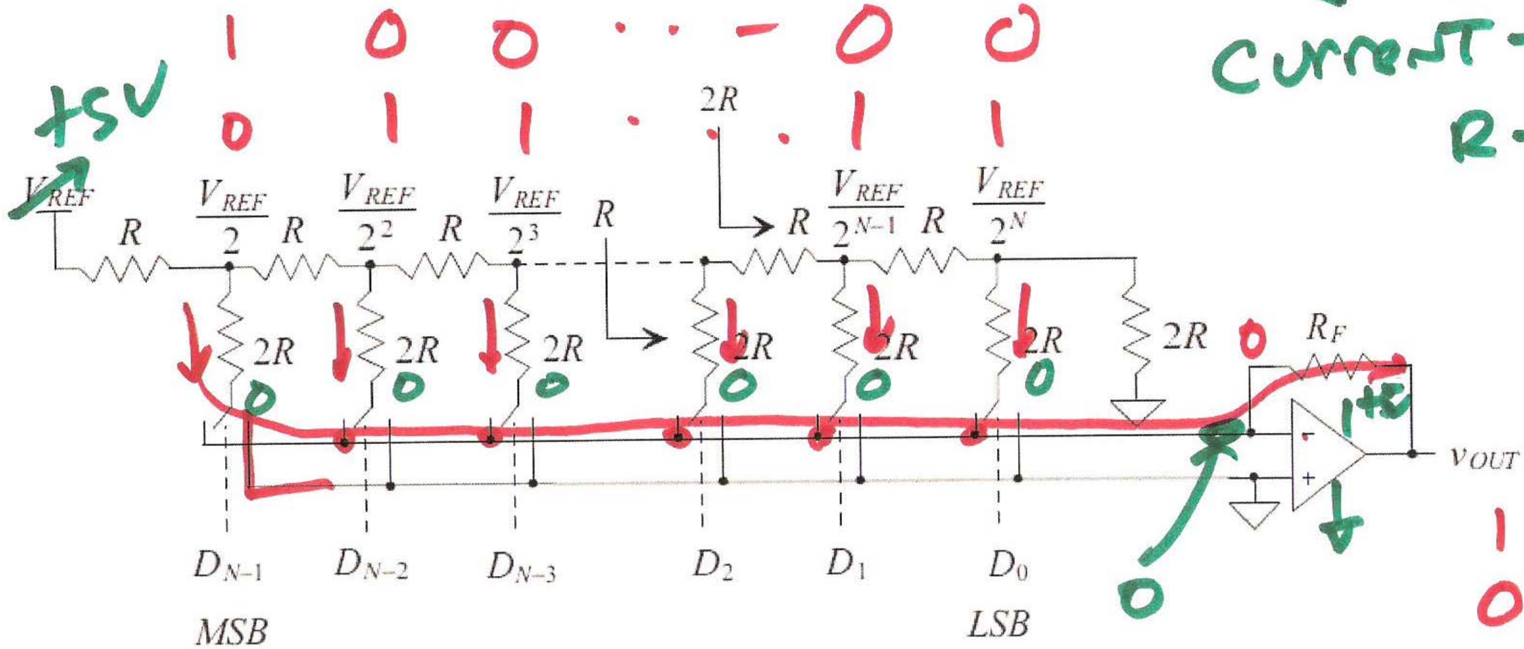


Figure 29.4 Output voltages generated from the 3-bit DAC in Ex. 29.1.

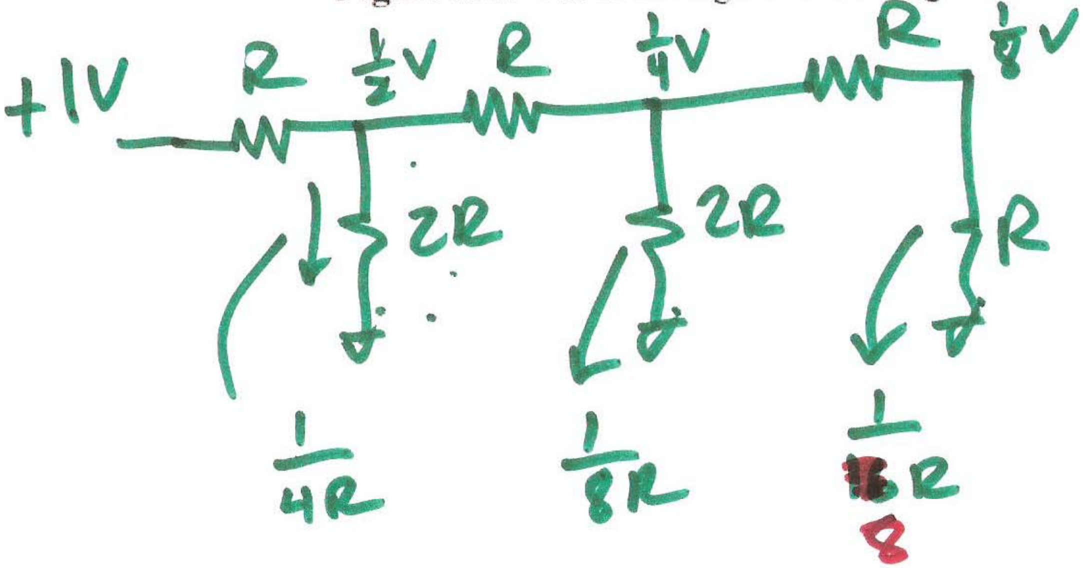
4)

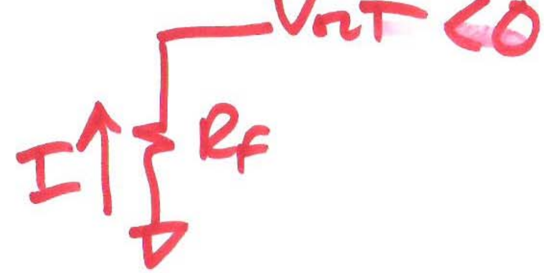
traditional → current-mode R-2R DAC



1 0000
01111

Figure 29.5 An R-2R digital-to-analog converter.





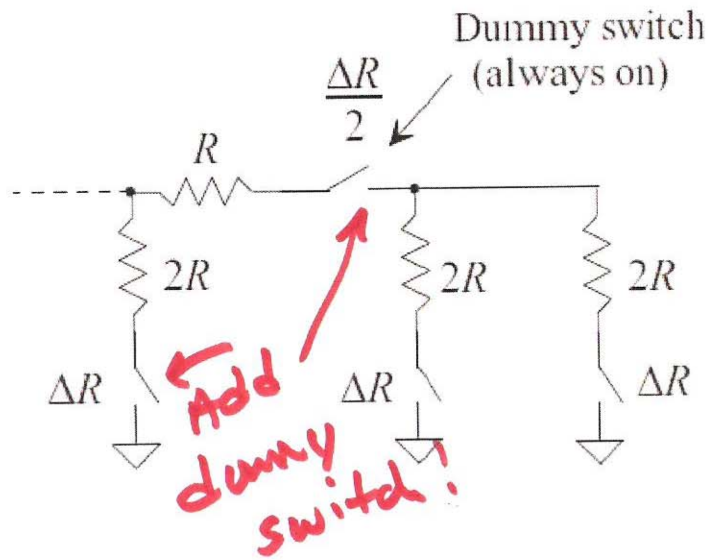


Figure 29.6 Use of dummy switches to offset switch resistance.

6)

Matching

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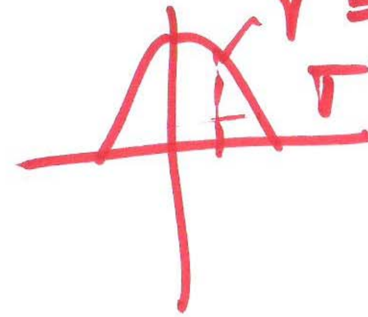
Resistor string, Page 967

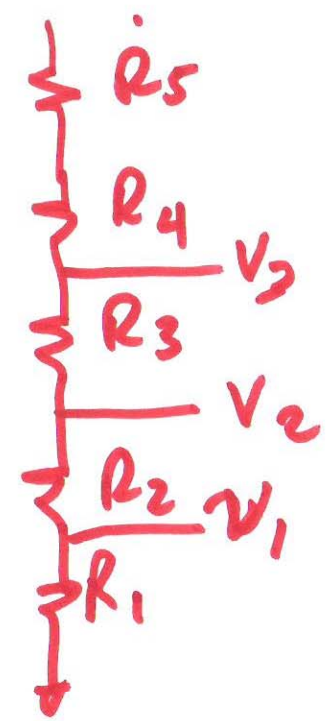
R
1K

R + ΔR ← neg or pos.
.997
1.02K



$\sigma = \text{RMS}$

$\sigma^2 = \text{VAR}$



$$R_i = R + \Delta R_i$$

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

$$\frac{1}{2^N} \sum_{i=1}^{2^N} R_i = R$$

$$V_i = V_{REF} \cdot \frac{\sum_{k=1}^{i} R + \Delta R_k}{2^N \cdot R}$$

$$V_i = V_{REF} \cdot \frac{\sum_{K=1}^{i} (R + \Delta R_K)}{2^N \cdot R}$$

$$= \underbrace{\frac{V_{REF}}{2^N}}_{1LSB} \cdot \left[\sum_{K=1}^{i} \underbrace{\frac{R}{R}}_{=1} + \sum_{K=1}^{i} \cdot \frac{\Delta R_K}{R} \right]$$

2% mismatch

$-.02R \le \Delta R \le .02R$

1%
1K
$\Delta R = 10$

$$\text{overall} = \underbrace{1 \cdot LSB \cdot (i)}_{\substack{\text{ideal output} \\ V_{i,ideal}}} + 1LSB \cdot \sum_{K=1}^{i} \frac{\Delta R_K}{R}$$

MISMAtch

$$\frac{\Delta R}{R} = \frac{10}{1000} = 0.01 = 1\%$$

8)

INL

$i = 256 \qquad = V_i - V_{i,\text{ideal}}$

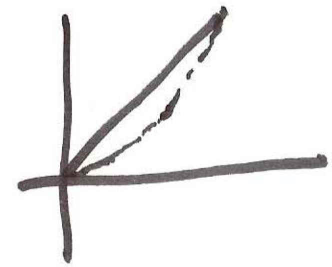
$N = 8 \qquad 2^8$

$i = 1 \rightarrow i = 256$

2^0

$$INL = \frac{V_{REF}}{2^N} \cdot \sum_{K=1}^{i} \frac{\Delta R_K}{R}$$

$$i \cdot 1LSB = i \cdot \frac{V_{REF}}{2^N}$$



Worst INL occurs when

$$i = \frac{2^N}{2} = 2^{N-1}$$

$$< \frac{i}{2} \rightarrow \frac{\Delta R}{R} = -.01$$

$$> \frac{i}{2} \rightarrow \frac{\Delta R}{R} = +.01$$

9)

$$INL_{max} = \frac{V_{REF}}{2^N} \sum_{K=1}^{2^{N-1}} \frac{\Delta R_K}{R}$$

$1\% \rightarrow \cdot \frac{1}{2^N}$

$.01$

$N \rightarrow 6bit$

$\frac{1}{2^N} \geq$ MISMATCH %

$$= \overbrace{\frac{V_{REF}}{2^N}}^{1 LSB} \cdot 2^{N-1} \cdot \frac{\Delta R_K}{R}$$

for $< \frac{1}{2}$ LSB INL

$$\overset{1}{\cancel{\tfrac{1}{2}}} LSB \geq \cancel{\tfrac{1}{2} LSB} \cdot 2^N (\% \text{ mismatch})$$

$$\% \text{ mismatch} \leq \frac{1}{2^N}$$

$N = 10$ $\% \text{ mismatch} < \frac{1}{1024} = .1\%$

$.02 \geq \frac{1}{2^N}$, $N = 5$ % mismatch

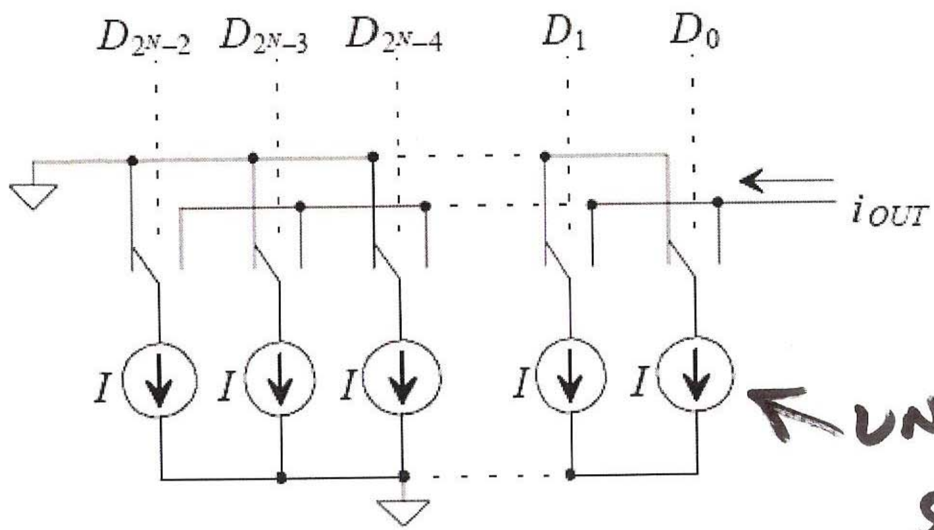
10)

DNL

$$V_i - V_{i-1} = 1LSB\left[1 + \frac{\Delta R_i}{R}\right]$$

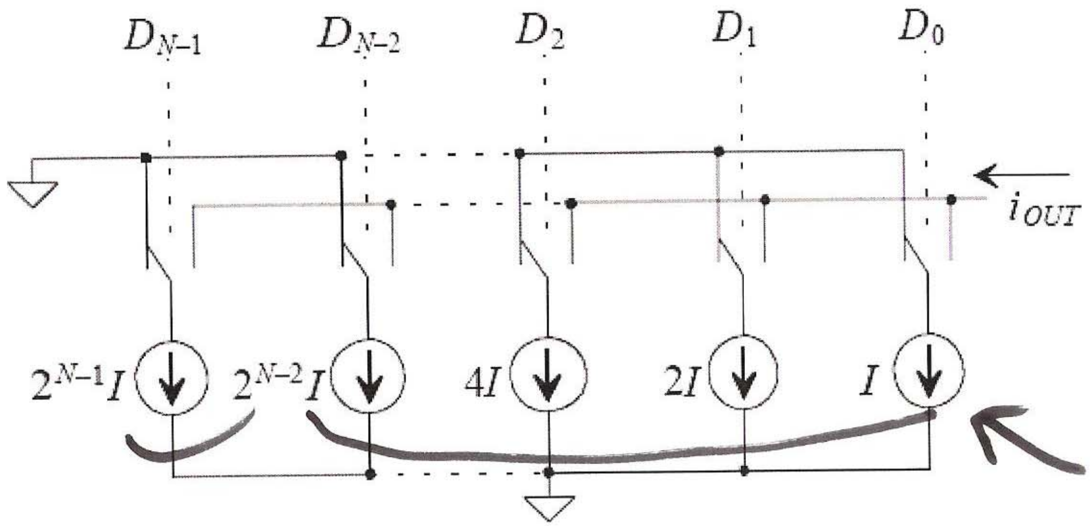
$$\boxed{DNL_i = 1LSB \cdot \frac{\Delta R_i}{R}}$$

DNL is good!



unit cell
see page 1 !

Figure 29.9 A generic current steering DAC.



Binary weighted DAC

Figure 29.10 A current steering DAC using binary-weighted current sources.

Smaller AREA

potential for LARGE DNL!