ECE 614 Advanced Analog IC Design

NOV. 8, 2011

Lecture 21

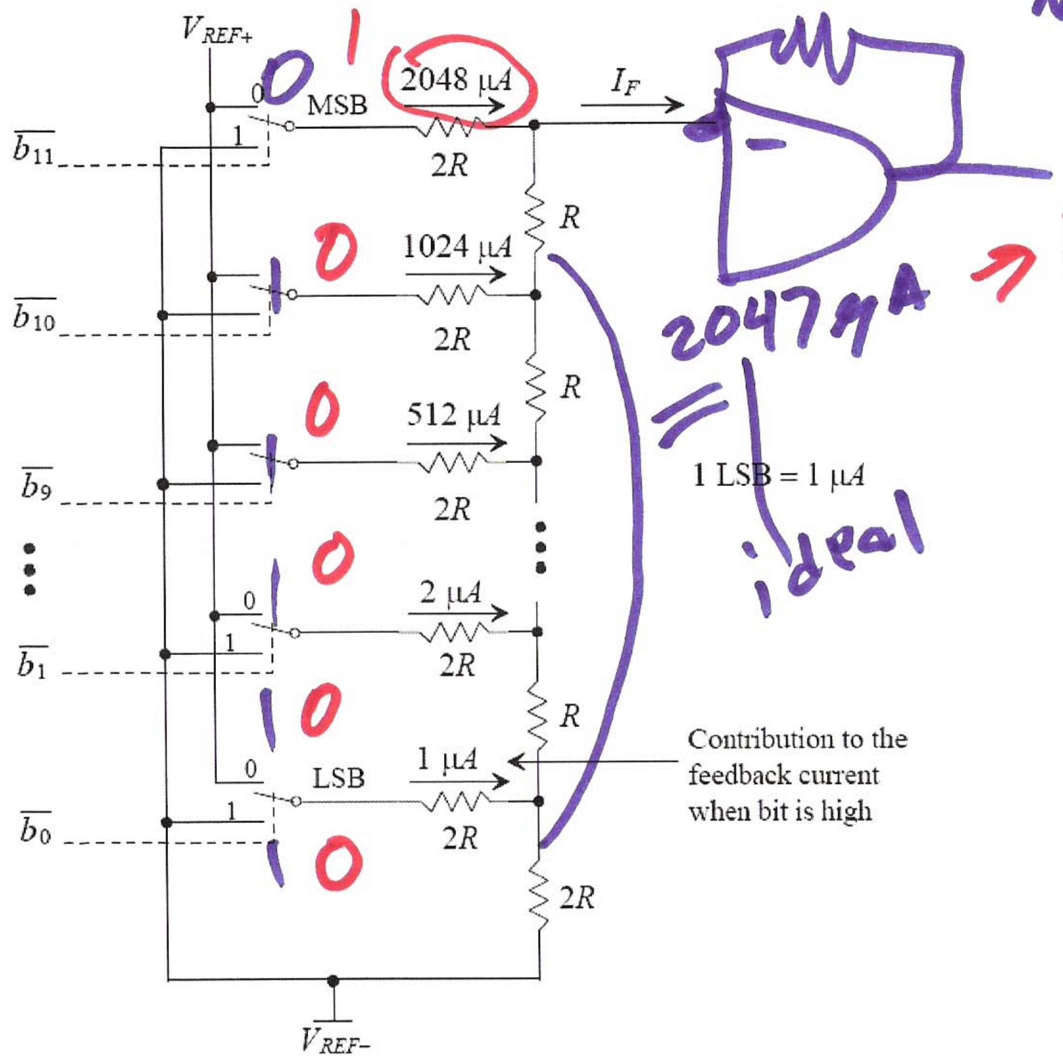


Figure 30.5 Showing how currents sum into the feedback current.

→ 2048μA

1 LSB = 1μA

1)

16 segments

$$\begin{array}{r} 4{,}096\,u A \\ -\,256 \\ \hline 3840\,u A \end{array}$$

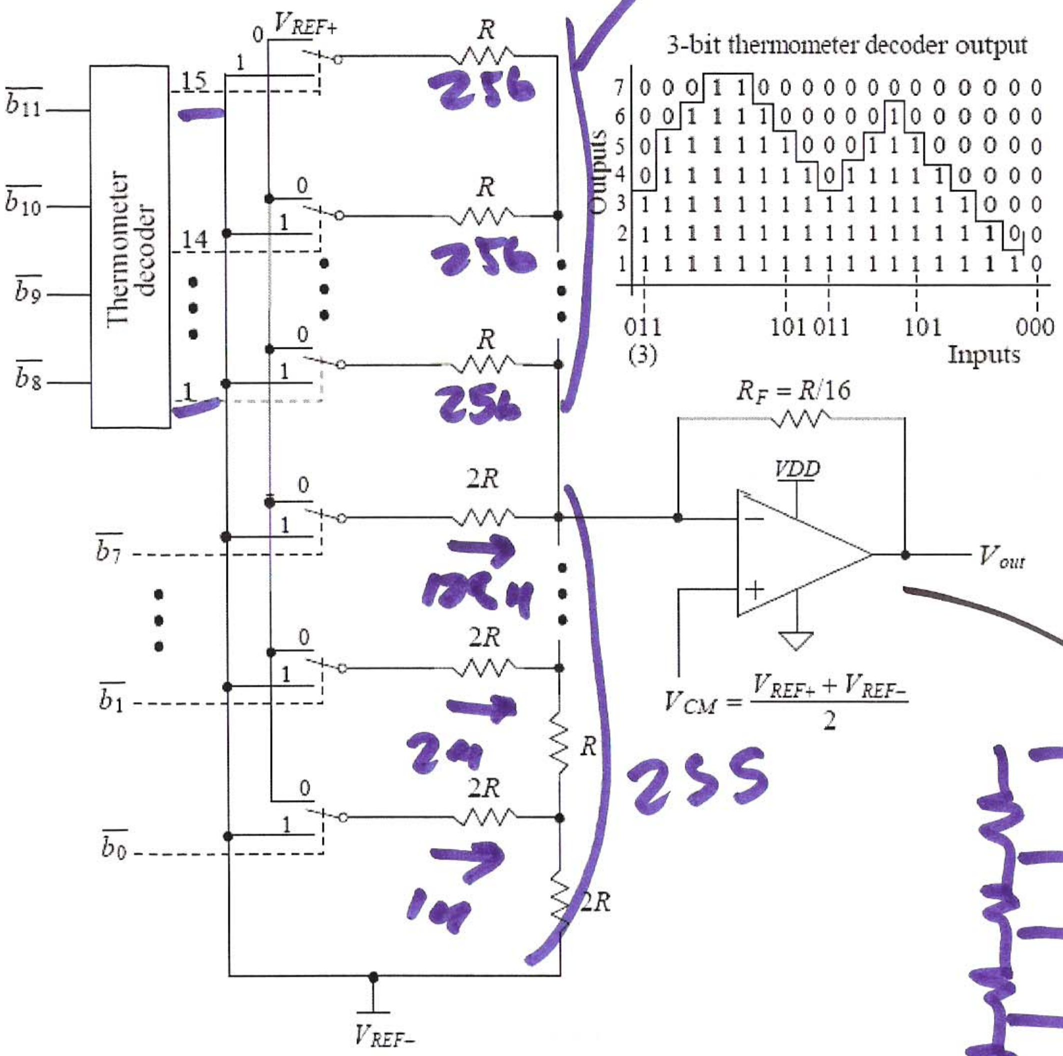


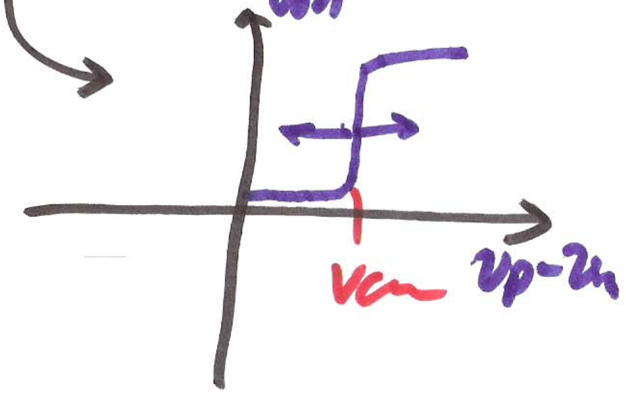
Figure 30.6 Segmentation in a wide-swing R-2R DAC.

2047 → 2048

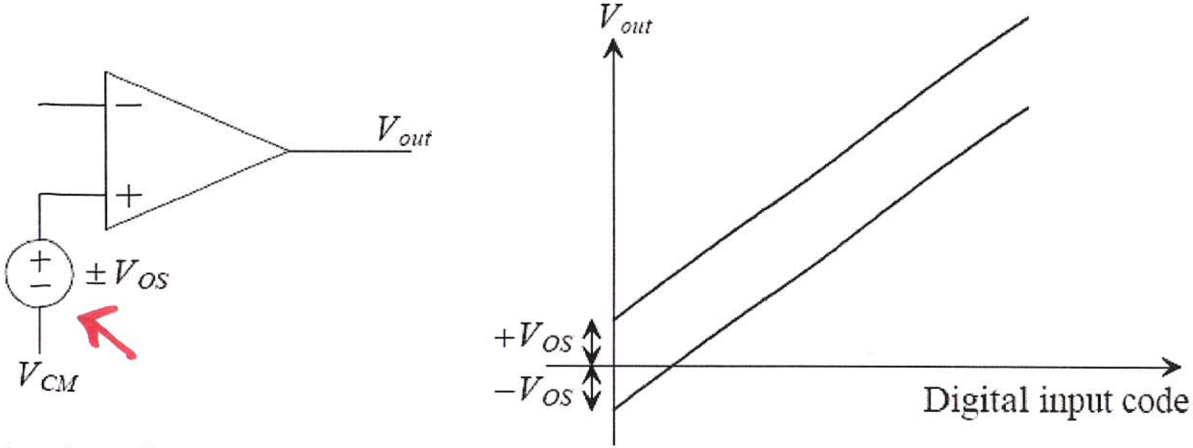
$$\frac{1u}{2048\,u}$$

255 → 256

$$\frac{1u}{255\,u}$$



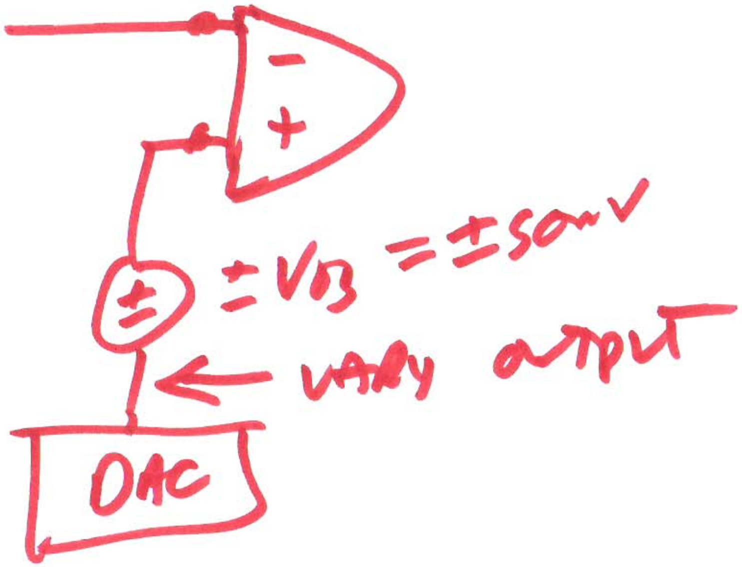
2)



(a) Showing offset voltage in an op-amp.

(b) DAC transfer curves showing offset.

Figure 30.7 Showing how an op-amp offset affects the DACs transfer curves.

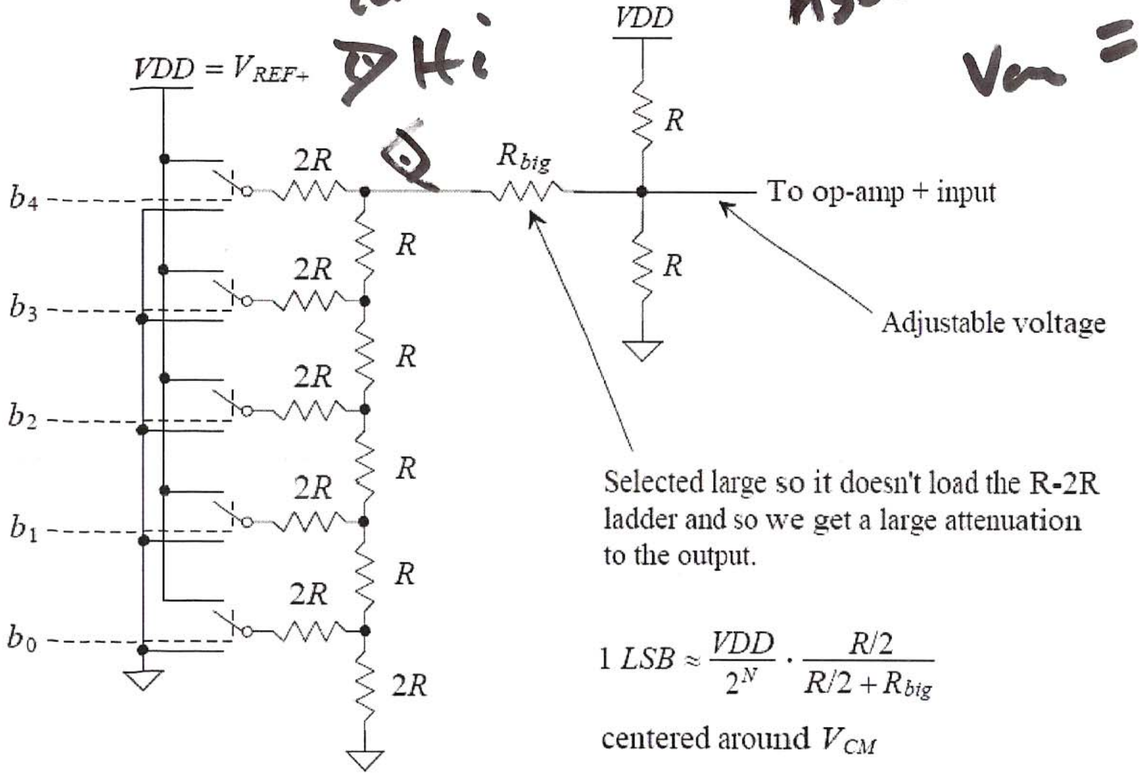


3)

low

⊕ Hi

Assumes $V_{cm} = \frac{VDD - 0}{2}$



Selected large so it doesn't load the R-2R ladder and so we get a large attenuation to the output.

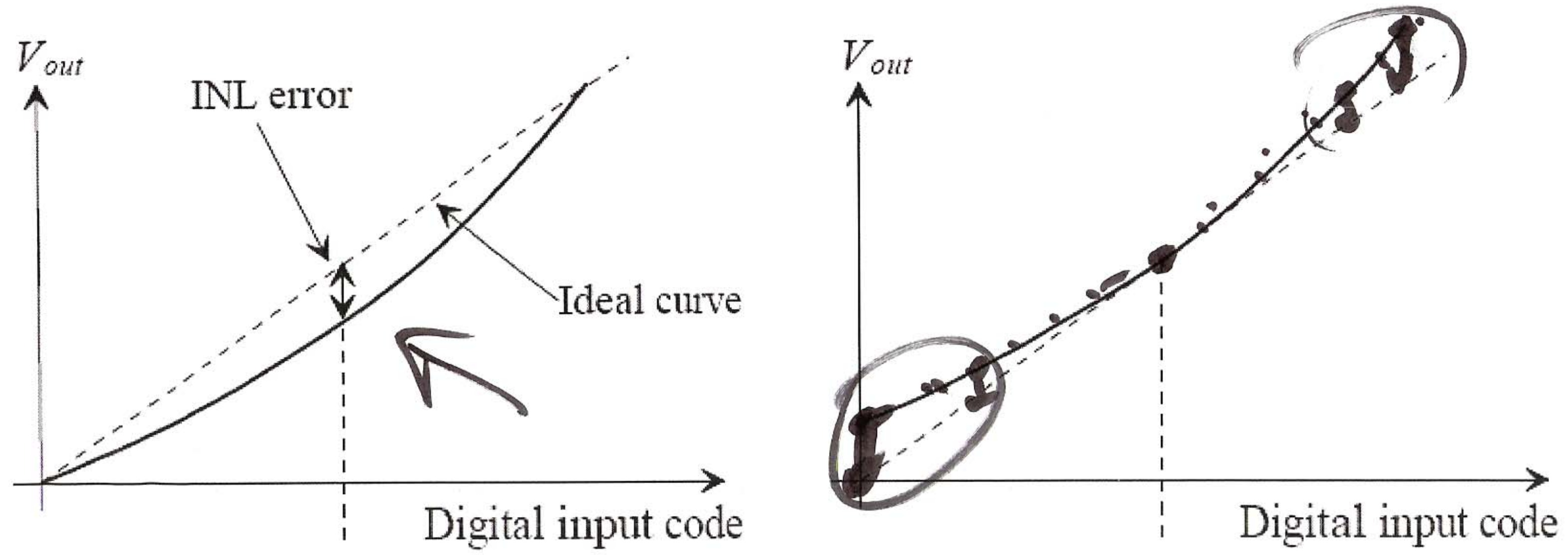
$$1\ LSB \approx \frac{VDD}{2^N} \cdot \frac{R/2}{R/2 + R_{big}}$$

centered around V_{CM}

Voltage-mode R-2R DAC

Figure 30.8 Trimming circuit for DAC offset.

4)



(a) DAC transfer curves before calibration. (b) DAC transfer curves after offset calibration

Figure 30.10 Showing how INL can be seen as an offset error.

5)

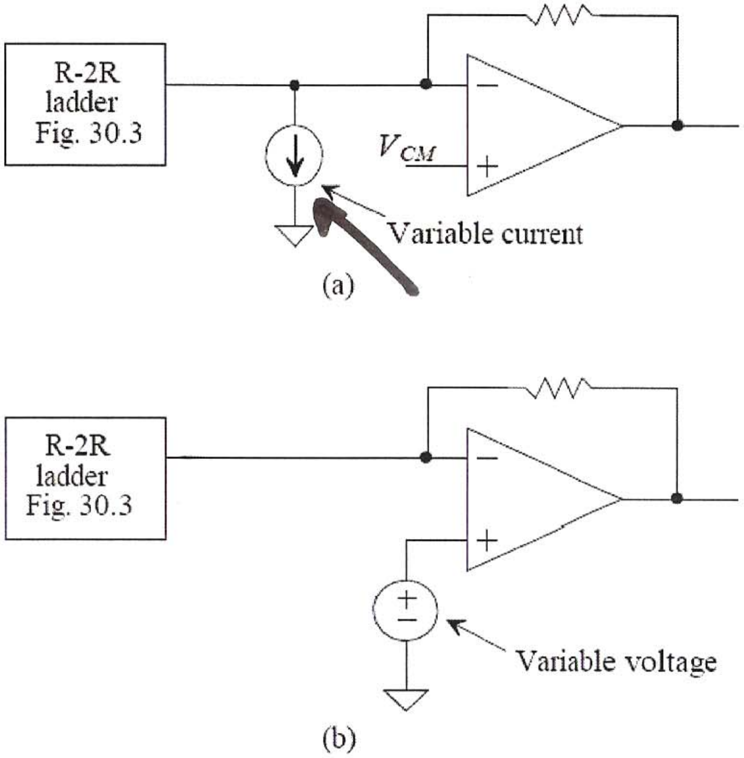
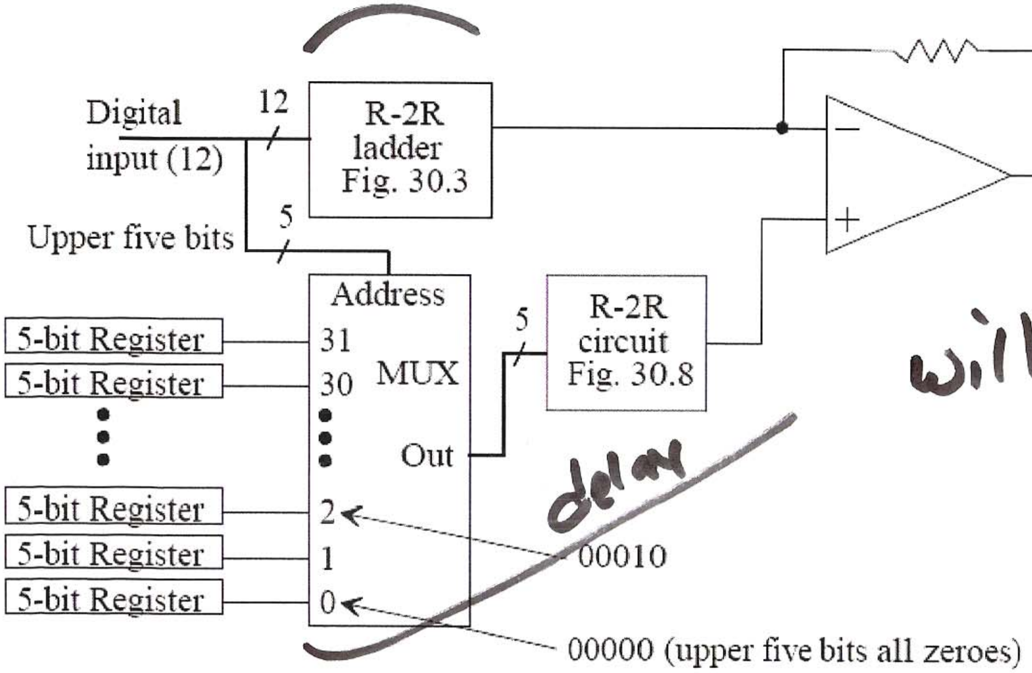


Figure 30.12 Trimming the output of the DAC using (a) current and (b) voltage.

6)

Glitch area V·s



help with

will correct

INL

offset

gain

Figure 30.13 Calibration scheme for 12-bit DAC.

0000 0100 0000

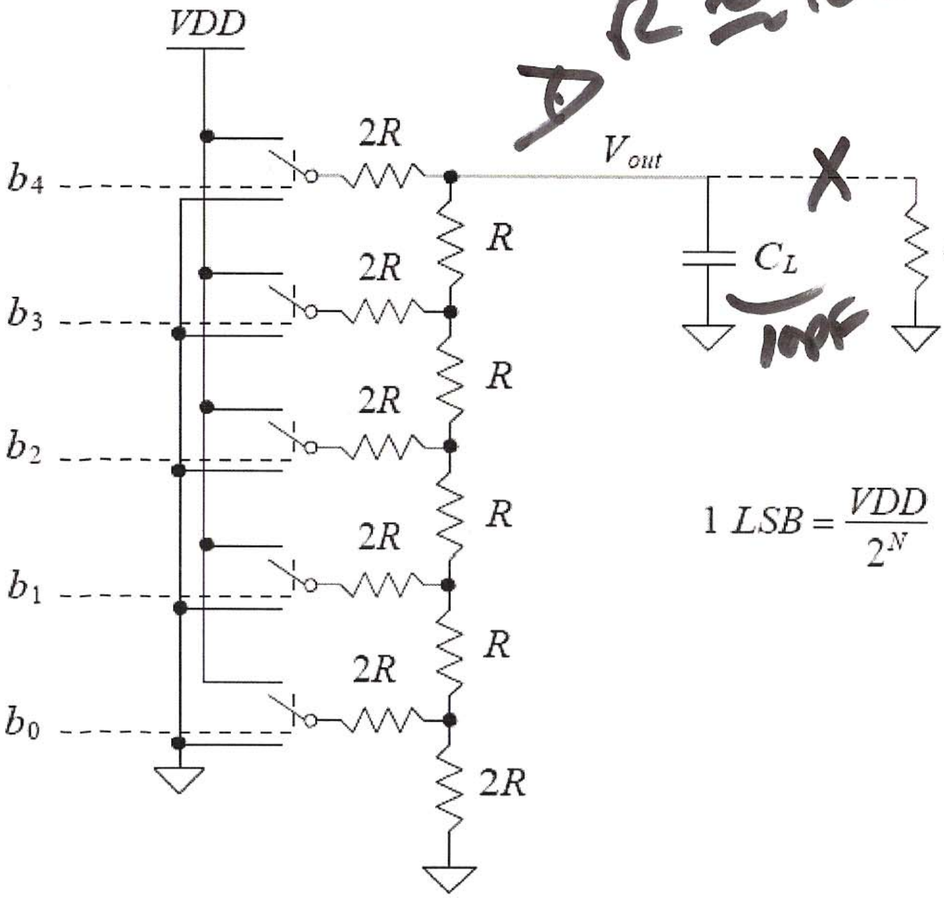
64

0 → 128

1

128

7)



$R \approx 10K$

$RC = 100ns$

X

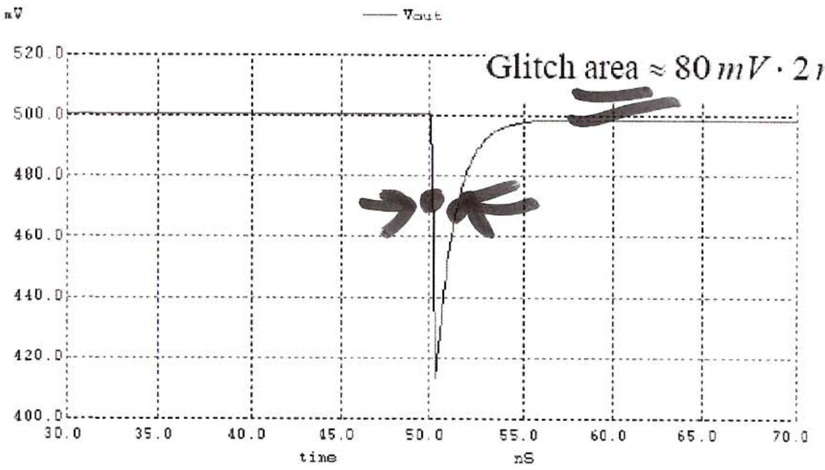
unless $\gg R$

10pF

$$1\ LSB = \frac{VDD}{2^N}$$

Figure 30.14 Voltage-mode (5-bit) DAC without an op-amp.

8)



Glitch $\underline{\text{area}} \approx 80\,mV \cdot 2\,ns = \underline{160\,ps \cdot V}$

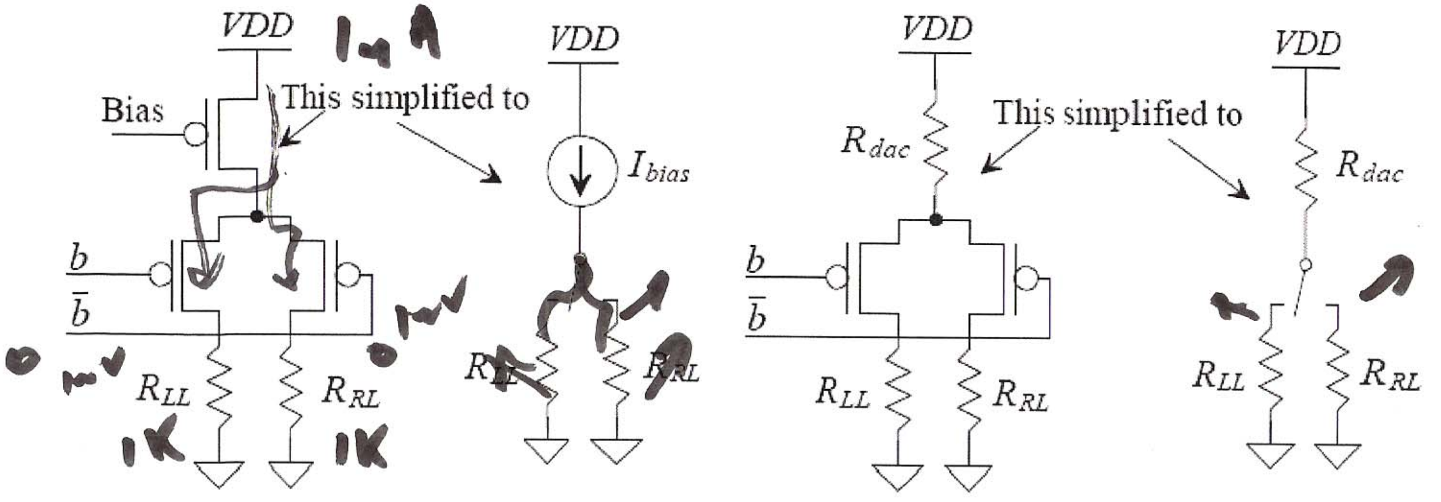
F W H M
u i ~~a~~ a
L d L x
L t f
  h

Figure 30.17 Showing glitch if the lower 9-bits are skewed by 200 ps in Ex. 30.2.

don't use

~~Glitch~~- Energy -

9)



Current-source-based cell.

Resistor-based cell.

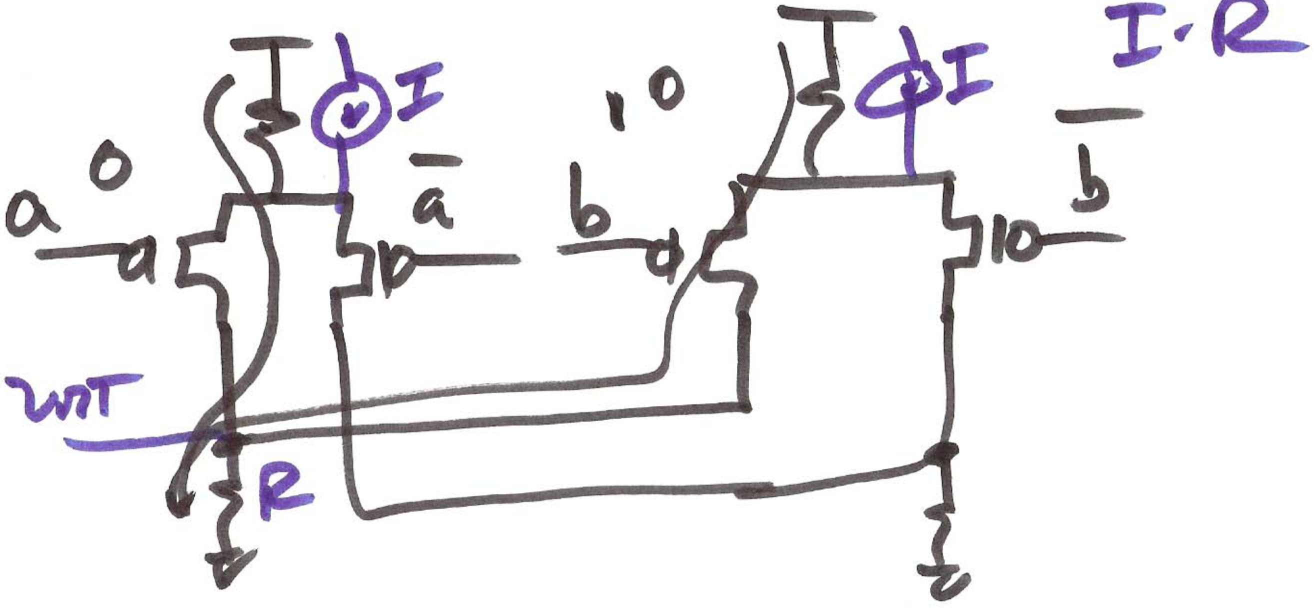
Figure 30.18 Basic cell used in a current-mode DAC.

$\frac{R}{2R}$

OR [illegible]

$\frac{R}{\frac{3R}{2}+R}$

10)



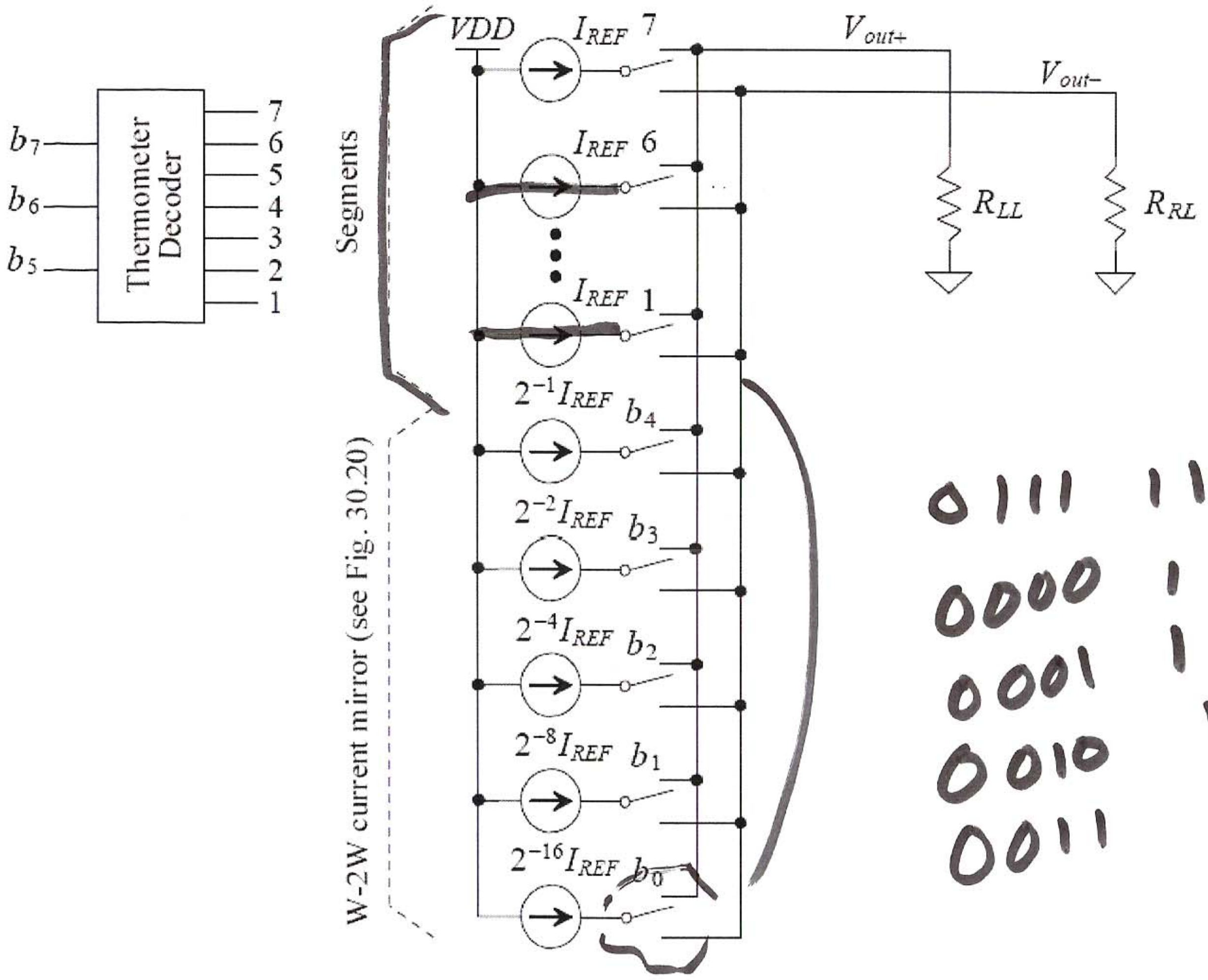
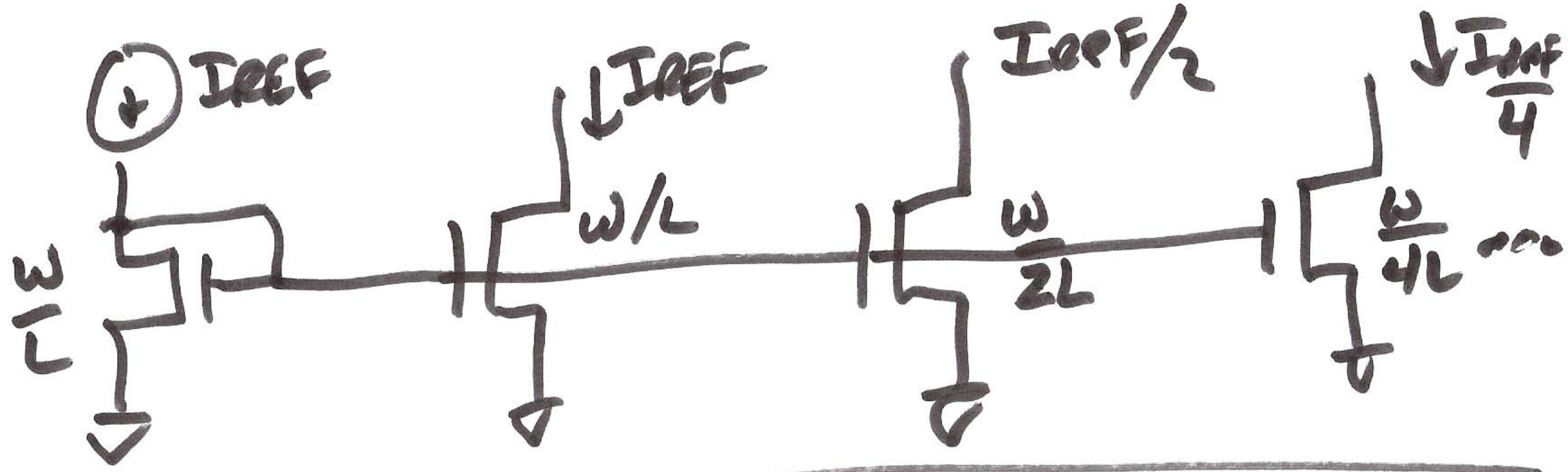


Figure 30.19 Implementation of a current-mode DAC.

0111 11111 — No seg.
0000 11111 — 1 seg.
0001 11111 — 2 seg.
0010 11111 — 3 seg.
0011 11111

11)

How not to implement binary weighted DACs using current sinks



Have to use same size device!

to implement the DAC!

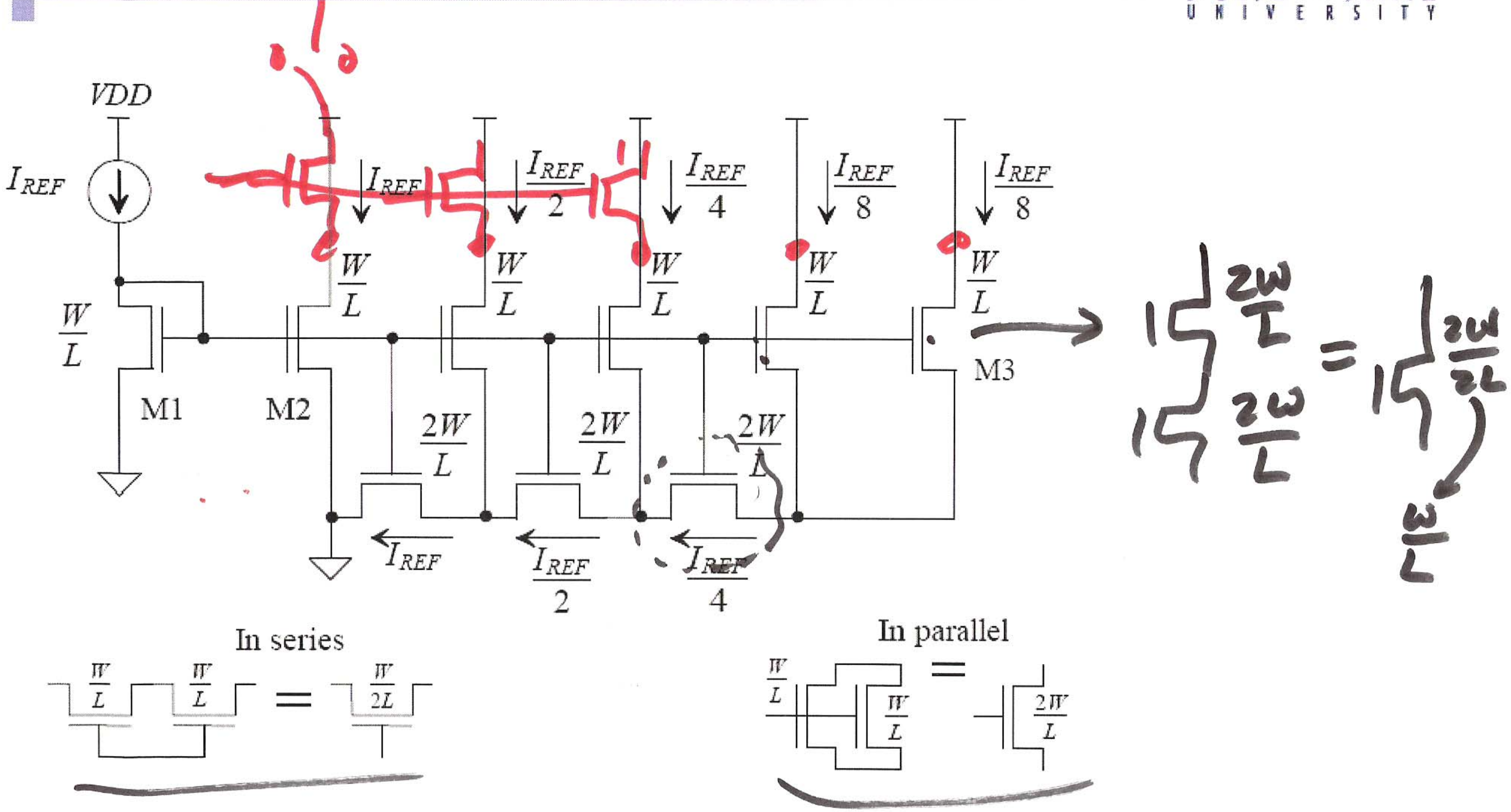
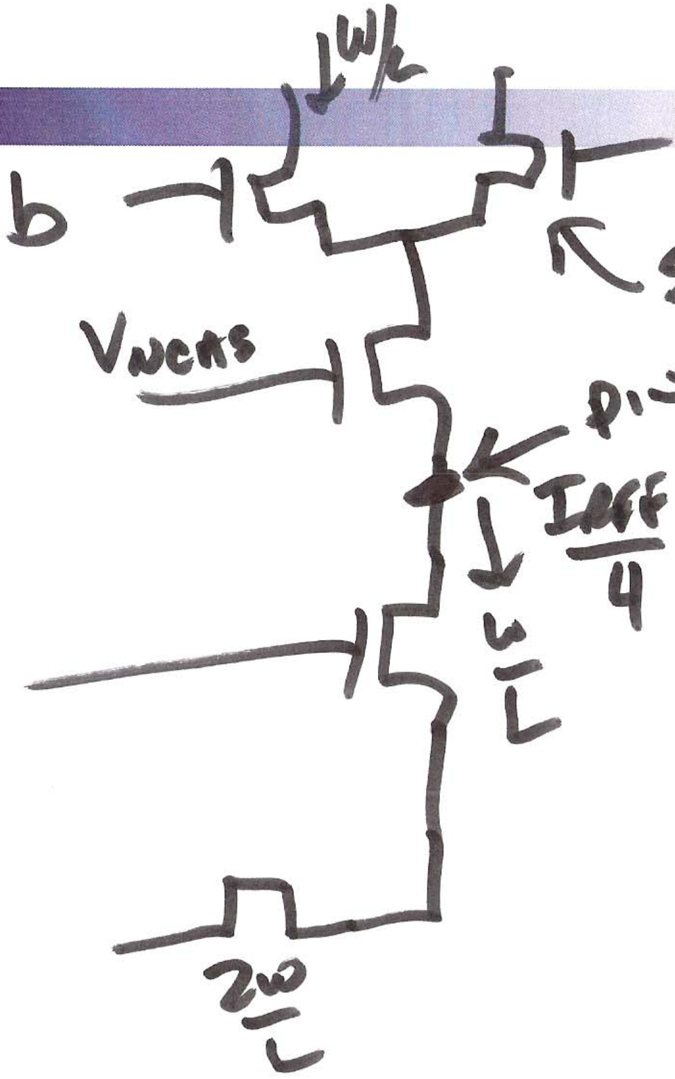
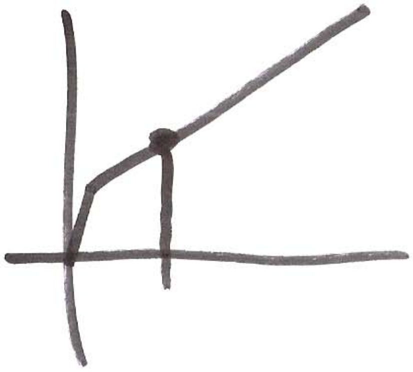


Figure 30.20 W-2W current mirror.

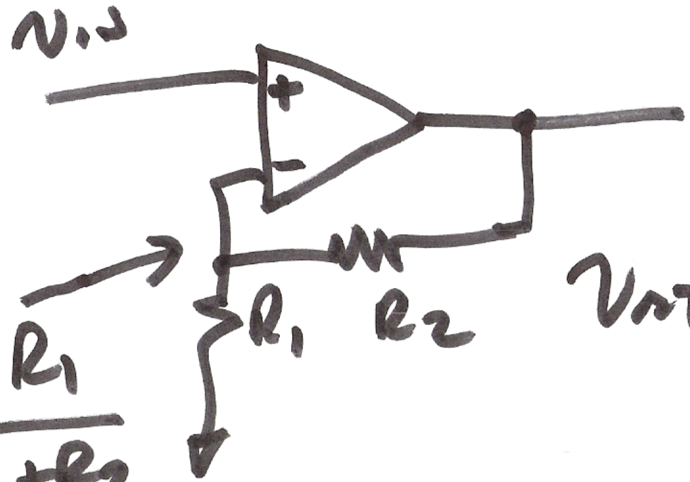
13)



switches pin the voltage across the current sink.



OP-AMPS in data converters



$$v_{OUT} = A_{DC}(v_{IN} - v_f)$$

$$v_f = \underbrace{v_{OUT}\cdot\frac{R_1}{R_1+R_2}}_{\beta}$$

$$v_{OUT} = A_{DC}\left(v_{IN} - v_{OUT}\cdot\frac{R_1}{R_1+R_2}\right)$$

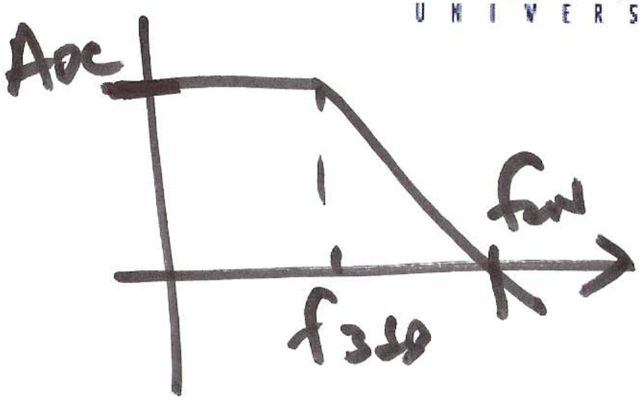
$$\frac{v_{OUT}}{v_{IN}} = \frac{A_{DC}}{1 + A_{DC}\cdot\beta} = \frac{1}{\frac{1}{A_{DC}}+\beta}$$

$$\overset{\frac{1}{\beta}}{\underset{CL}{A_{ideal}}} - \overset{\frac{1}{\beta}\cdot\frac{1}{2^{N+1}}}{\Delta A} = \frac{1}{\frac{1}{A_{DC}}+\beta}$$

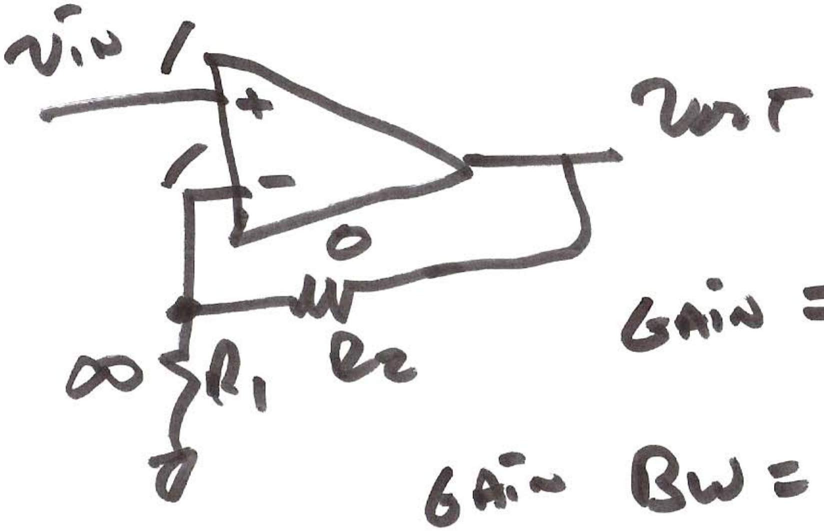
$$V_{OUT} = V_{OUT,ideal} - \frac{1}{2}LSB$$

15) $$\frac{1}{\beta}\left(1-\frac{1}{2^{N+1}}\right)\cdot 2^{N+1} \simeq \frac{1}{\beta}\left(2^{N+1}-1\right) \simeq \underline{\underline{\frac{2^{N+1}}{\beta} < A_{OL}}}$$

$$f_{un} \approx A_{DC} \cdot f_{3dB}$$



Series - shunT



$$GAIN = \frac{1}{\beta} = \frac{R_1 + R_2}{R_1}$$

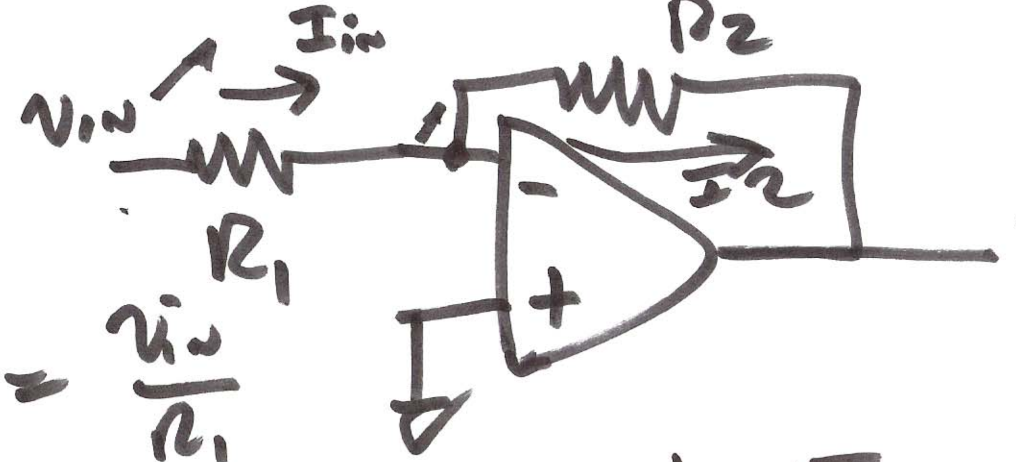
$$GAIN\ BW = \underbrace{f_{3dB} \cdot A_{DC}}_{f_{un}} = f_{3dB,CL} \cdot A_{CL}$$

$$BW = \frac{f_{un}}{A_{CL}} = f_{un} \cdot \beta =$$

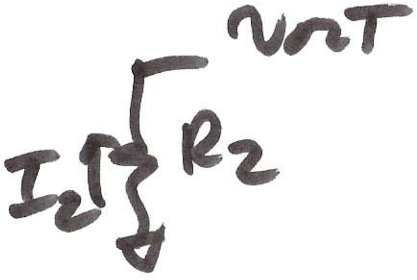
$$f_{un} \cdot \frac{R_1}{R_1 + R_2}$$

$$\boxed{GAIN \cdot BW\big|_{CL} = f_{un}} \longleftarrow$$

$+1$



$= -R_2 I_2$



$$I_{IN} = \frac{v_{in}}{R_1}$$

Shunt − Shunt

I − V → transimpedance

from slide 16

$$v_{OUT} = (0 - v_-)\cdot A_{OL}$$

$$f_{CL}\Big|_{3dB} = \frac{R_1}{R_1+R_2}\cdot f_{un}$$

$$A_{CL} = \frac{v_{OUT}}{I_{IN}} = -R_2$$

$$A_{CL} = \left|\frac{v_{OUT}}{v_{IN}}\right| = \left|\frac{-R_2}{R_1}\right|$$

$$\text{GAIN}\cdot f_{CL}\Big|_{\text{Shunt-shunt}} = \frac{R_2}{\cancel{R_1}}\cdot\frac{\cancel{R_1}}{R_2+R_1}\cdot f_{un}$$

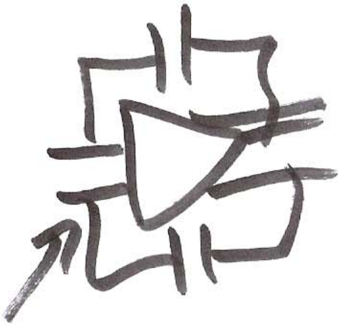
17)

$$f_{CL}\cdot \text{Gain}\Big|_{-1\text{ gain}} = \frac{f_{un}}{2}$$

$$\text{GAIN}\cdot\text{BW} = \frac{R_2}{R_1+R_2}\cdot f_{UN}$$

inverting

$$\text{GAIN} = \left|\frac{R_2}{R_1}\right| \qquad \text{BW} = \frac{R_1}{R_1+R_2}\cdot f_{UN}$$



$-1,\ R_2 = R_1 \qquad \text{BW} = \dfrac{f_{UN}}{2}$

$-10,\ R_2 = \overset{10}{}R_1,\ \text{BW} \simeq \dfrac{f_{UN}}{11}$ (inverting)

NON-inverting

$+1,\ R_2 = 0,\ R_1 = \infty \qquad \text{BW} = f_{UN}$

$+10,\ R_2 = 9K,\ R_1 = 1K \qquad \text{BW} = \dfrac{f_{UN}}{10}$