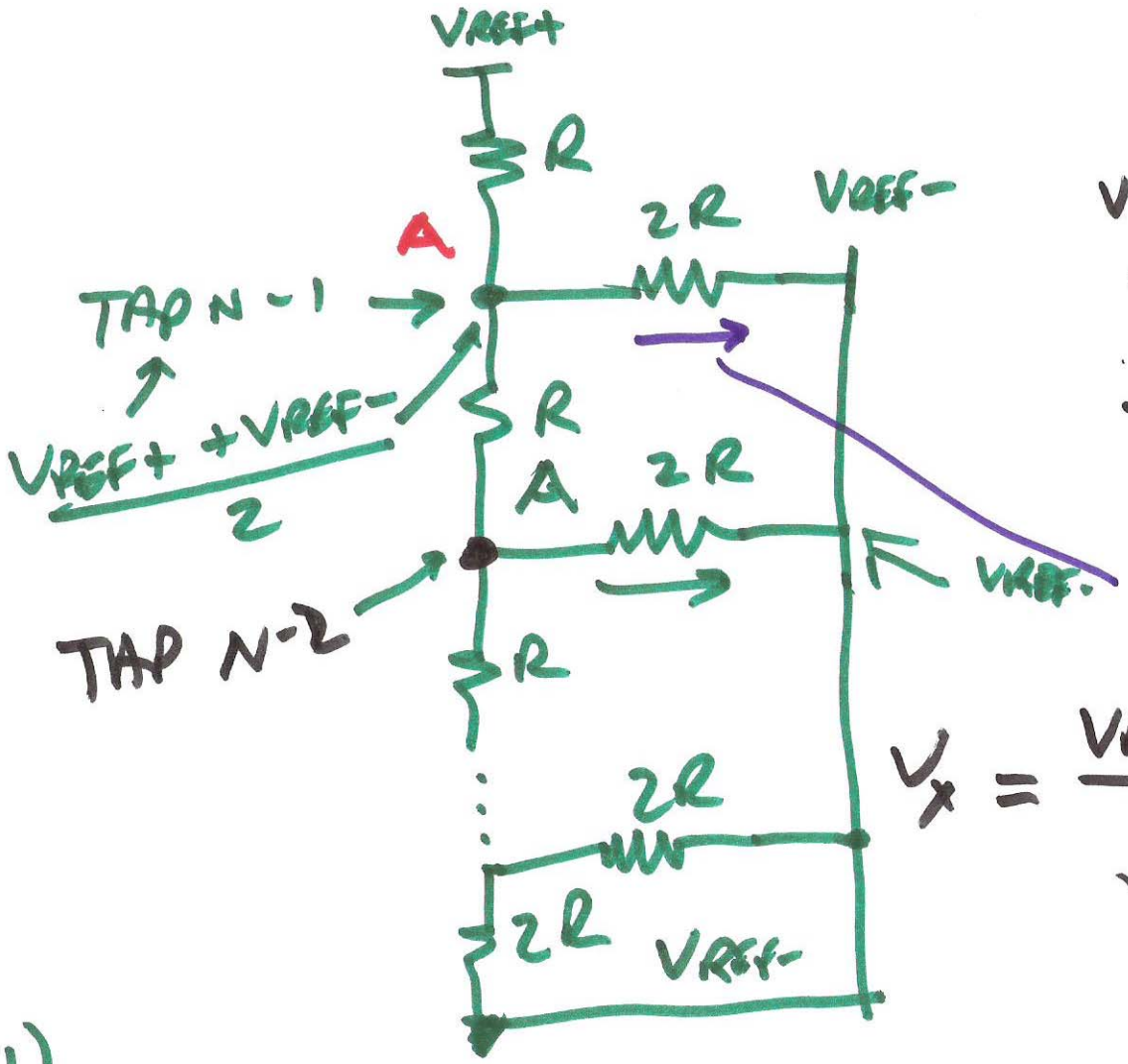
Lecture 20 ECE 614

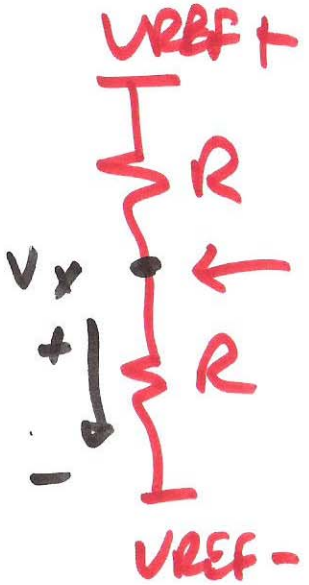
BOISE STATE UNIVERSITY

NOV. 1, 2011

11/1/11

Advanced Analog IC Design





$$\frac{V_{REF+}+V_{REF-}}{2} = TAP\,N-$$

$$V_{REF+} - V_{REF-}$$

$$V_x = \frac{V_{REF+} - V_{REF-}}{2R} \cdot R + V_{REF-} = I \cdot R + V_{REF-}$$

I

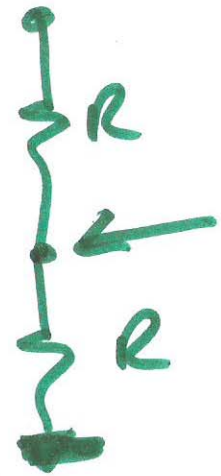
1)

$$V_x = \frac{V_{REF+} - V_{REF-}}{2} + \frac{V_{REF-} \cdot 2}{2}$$

$$= \frac{V_{REF+} + V_{REF-}}{2}$$

TAPN-1

TAPN-2



$$\frac{\frac{V_{REF+} + V_{REF-}}{2} + V_{REF-}}{2}$$

V_{REF-}

$$\frac{V_{REF+}}{4} + \frac{V_{REF-}}{4} + \frac{V_{REF-}}{2}$$

2)

$$I = \frac{1}{R}\left(\frac{V_{REF+}}{4} + \frac{3}{4} V_{REF-} - V_{REF-}\right)$$

Voltage at tap X =

$$\frac{2^X}{2^N}\left(V_{REF+} - V_{REF-}\right) + V_{REF-}$$

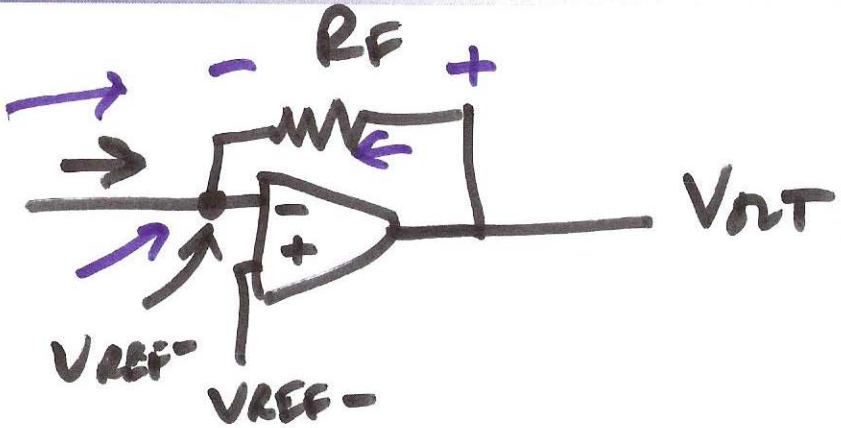
$$0 \le X \le N-1 \quad ***$$

$$\frac{2^{N-2}}{2^N}\left(V_{REF+} - V_{REF-}\right) + V_{REF-}$$

$$I_{TAP X} = \frac{1}{R}\left(\frac{2^X}{2^N}\left(V_{REF+} - V_{REF-}\right) + \cancel{V_{REF-}} - \cancel{V_{REF-}}\right)$$

↑ EQ. 30.2

3)

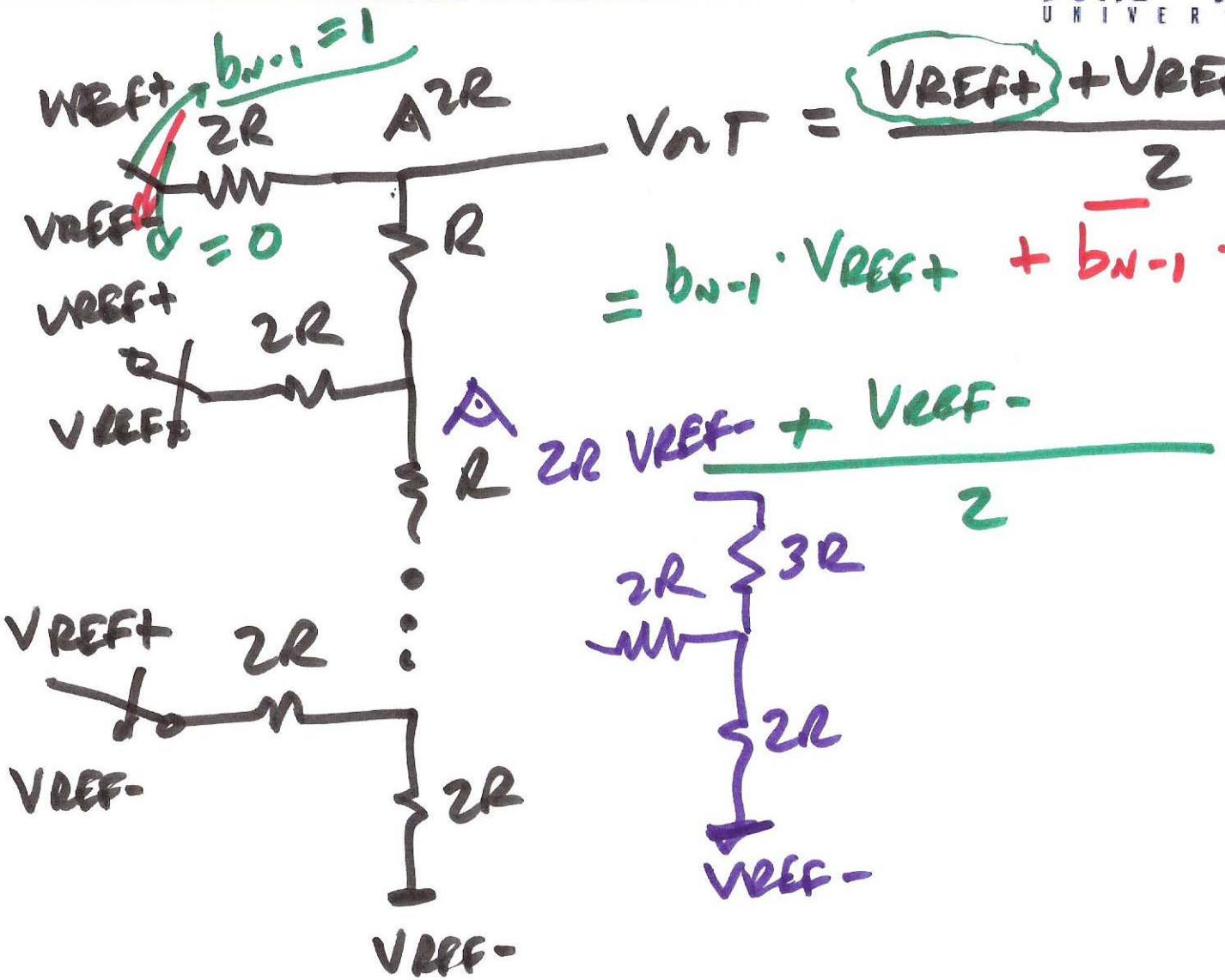


$$V_{OUT}\Big|_{\substack{\text{due}\\ \text{to tap x}}} = -\frac{1}{R}\left(\frac{2^x}{2^N}\left(V_{REF+} - V_{REF-}\right)\right)R + V_{REF-}$$

$$V_{OUT} = V_{REF-} + \sum_{x=0}^{N-1}\left(b_x \cdot I_{TAP\,x}\right)\cdot R'$$

$V_{REF+} > V_{REF-}$

4)

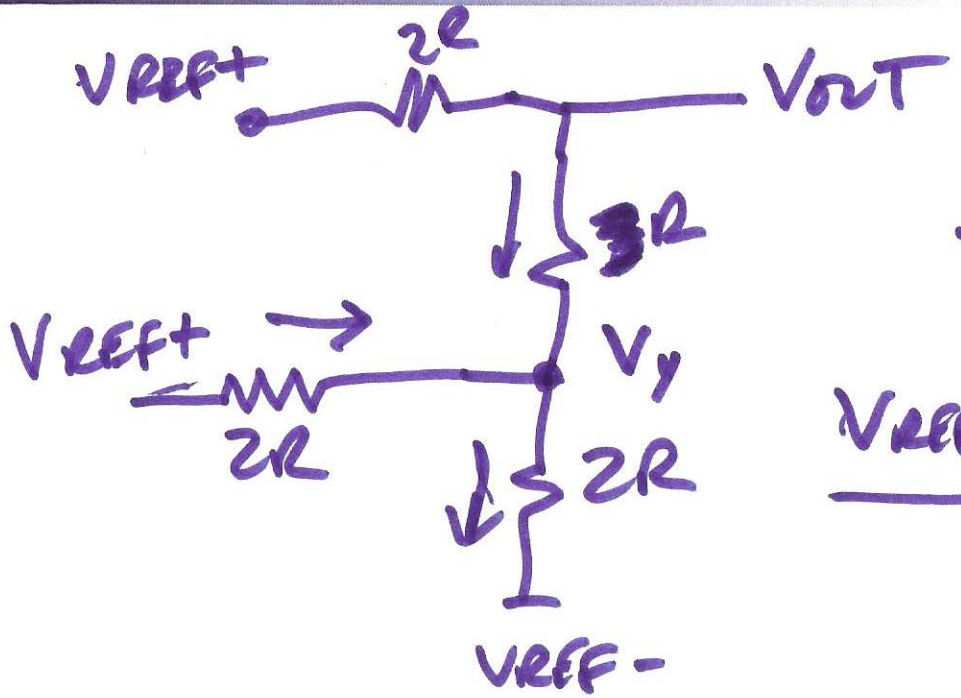


$$V_{out} = \frac{\overbrace{V_{REF+}}^{b_{N-1}=1} + V_{REF-}}{2} + \overline{b_{N-1}}$$

$$= b_{N-1} \cdot V_{REF+} + \overline{b_{N-1}} \cdot V_{REF-}$$

$$\frac{2R\, V_{REF-} + V_{REF-}}{2}$$

5)



$$+\frac{V_{OUT}-V_Y}{R}=\frac{V_Y-V_{REF-}}{2R}$$

$$\frac{V_{REF+}-V_Y}{2R}$$

$$V_{OUT}=\left(\frac{V_{OUT}-V_Y}{R}\right)R+V_Y \;\ddot{\smile}$$

$$2V_{OUT}-2V_Y=V_Y-V_{REF-}+V_{REF+}-V_Y$$

$$V_Y=\frac{2V_{OUT}-V_{REF+}+V_{REF-}}{2}$$

6)

$$V_{OUT} = V_y \cdot \frac{R}{2R+R} + V_{REF+}$$

$$= \frac{V_y}{3} + V_{REF+}$$

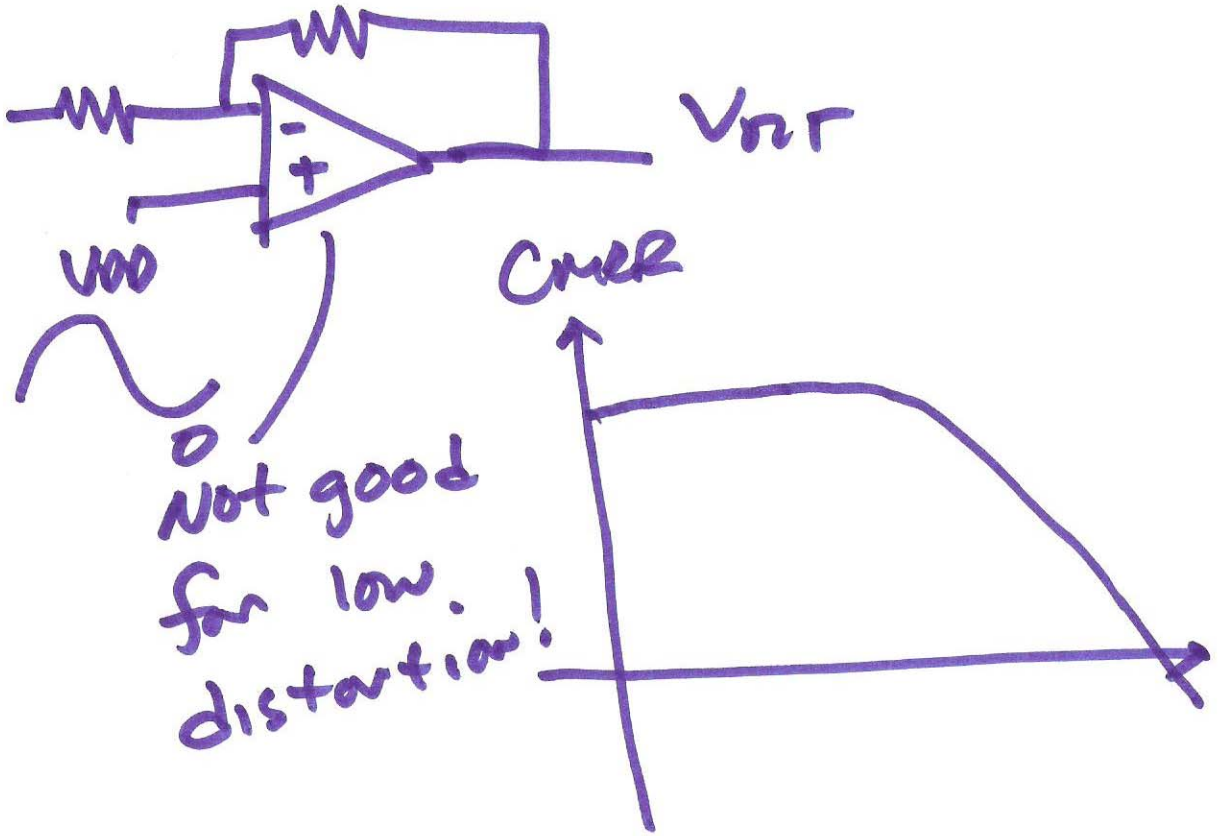
$$V_{OUT} = \left(V_{OUT} - \frac{V_{REF+}}{2} + \frac{V_{REF-}}{2}\right)\frac{1}{3} + V_{REF+}$$

$$3V_{OUT} = V_{OUT} - \frac{V_{REF+}}{2} + \frac{V_{REF-}}{2} + 3V_{REF+}$$

$$V_{OUT} = -\frac{V_{REF+}}{4} + \frac{V_{REF-}}{4} + \frac{3}{2}V_{REF+}$$

$$= \frac{5}{4}V_{REF+} + \frac{1}{4}V_{REF-}$$

$$= \frac{1}{4}(V_{REF+} + V_{REF-}) + V_{REF+}$$


V_{out}
V_{DD}
0
C_{MOS}
Not good for low distortion!

$$\Delta I = \frac{V_{REF+} - V_{REF-}}{2(R-\Delta R)}\left[1 - \frac{1}{2^{N-1}}\right]$$

$$- \frac{V_{REF} - V_{REF-}}{2(R+\Delta R)} \simeq$$

INL Calculation. $\left|\frac{\Delta R}{R}\right| \leq \frac{1}{2^{N-1}}$

$\frac{\Delta R}{R} \leq \frac{1}{2^{N-1}}$

10 bit converter

1LSB INL $\frac{1}{2^9} = \frac{1}{512} = .\overline{5}\,0.2\%$

mismatch

9)