

EE 2019

13/4/2017

Analog to digital converters (ADC)

N-bit ADC

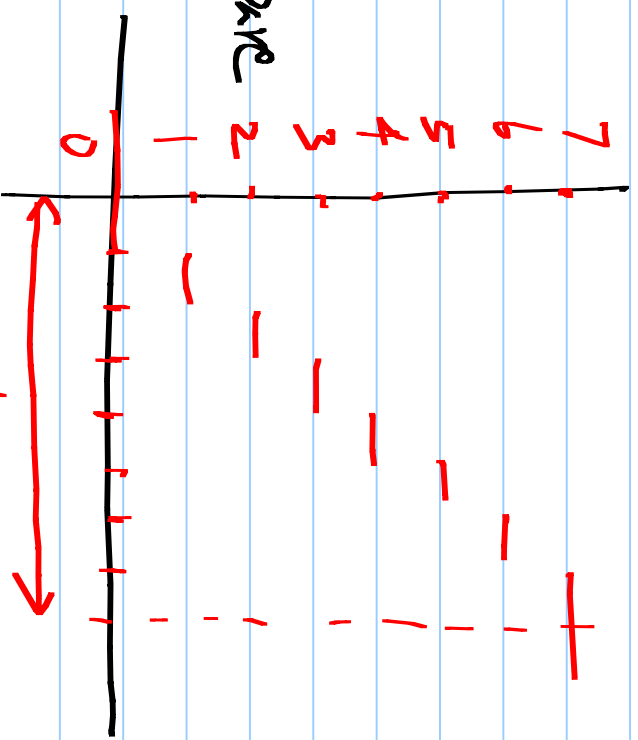
Binary search

$2^N - 1$ transition points

1 comparator,

Simultaneously compare with

N-steps for N-bit-



conversion

Flash ADC

≤ 7 bits, very fast

3-bit converter: output b_2, b_1, b_0

Binary search

Step # Compare

$$1 \quad V_i - \frac{V_{ref}}{2} \rightarrow b_2$$

$$2 \quad V_i - b_2 \cdot \frac{V_{ref}}{2} - \frac{V_{ref}}{4} \rightarrow b_1$$

$$3 \quad V_i - b_2 \cdot \frac{V_{ref}}{2} - b_1 \cdot \frac{V_{ref}}{4} - \frac{V_{ref}}{8} \rightarrow b_0$$

N-bit converter: output $b_{N-1} b_{N-2} \dots b_0$

Binary search

Step # Compare

$$1 \quad V_i - \frac{V_{ref}}{2} \rightarrow b_{N-1}$$

$$2 \quad V_i - b_{N-1} \cdot \frac{V_{ref}}{2} - \frac{V_{ref}}{4} \rightarrow b_{N-2}$$

...

$$N \quad V_i - b_{N-1} \cdot \frac{V_{ref}}{2} - b_{N-2} \cdot \frac{V_{ref}}{4} \dots - \frac{V_{ref}}{2^N} \rightarrow b_0$$

In every step compare V_i with V_{k_2}

$$V_{k_2} = b_{N-1} \frac{V_{x_f}}{2} + b_{N-2} \frac{V_{x_f}}{4} + \dots + b_1 \frac{V_{x_f}}{2^{N-1}} + \underbrace{\frac{V_{x_f}}{2^N}}_{b_0 V_{x_f}}$$

Output : V_{k_2}

Inputs : $b_{N-1} \dots b_1$

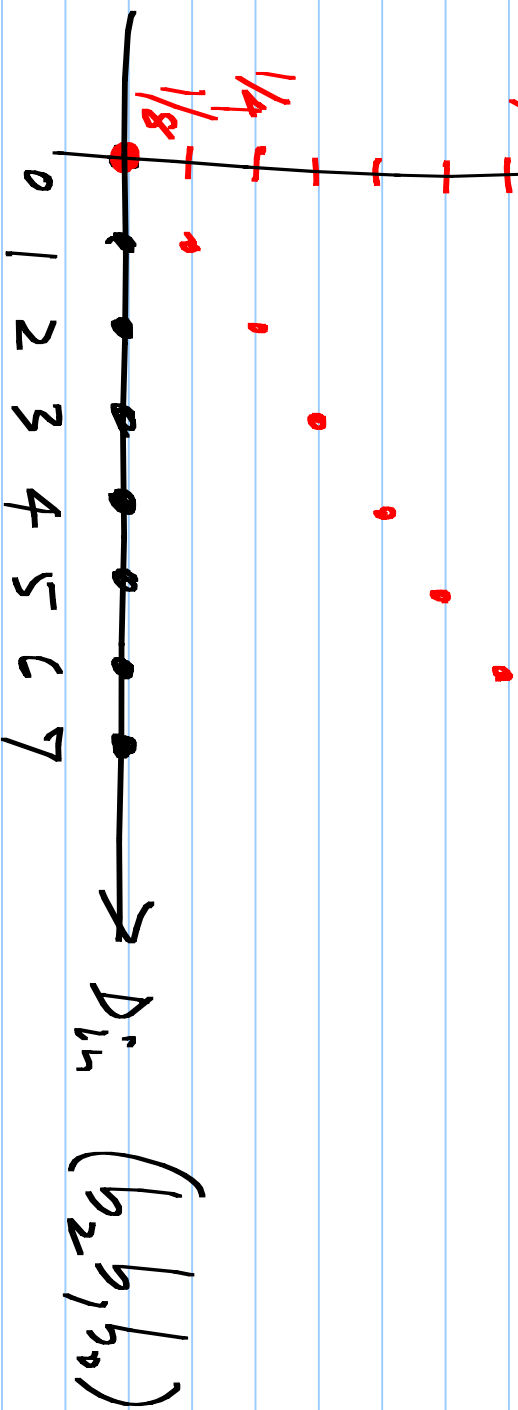
Scale factor : V_{x_f}

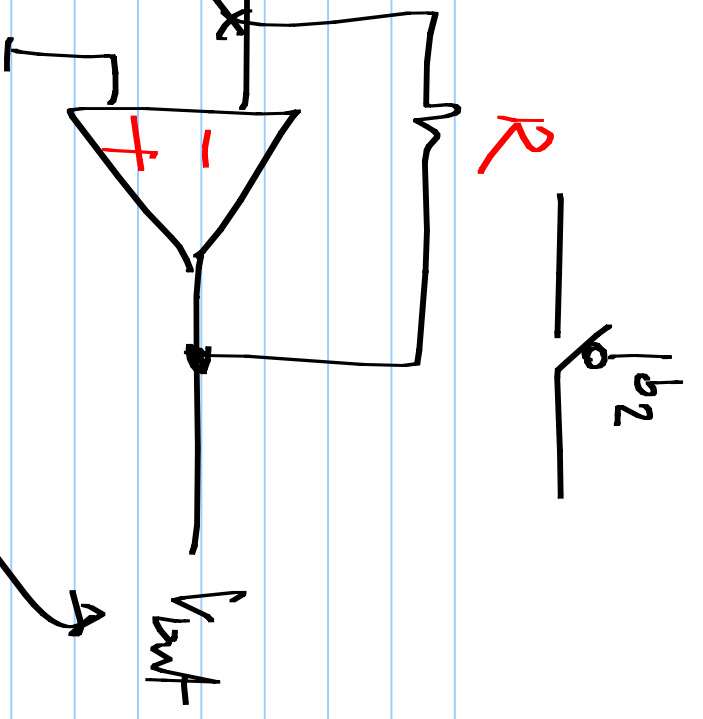
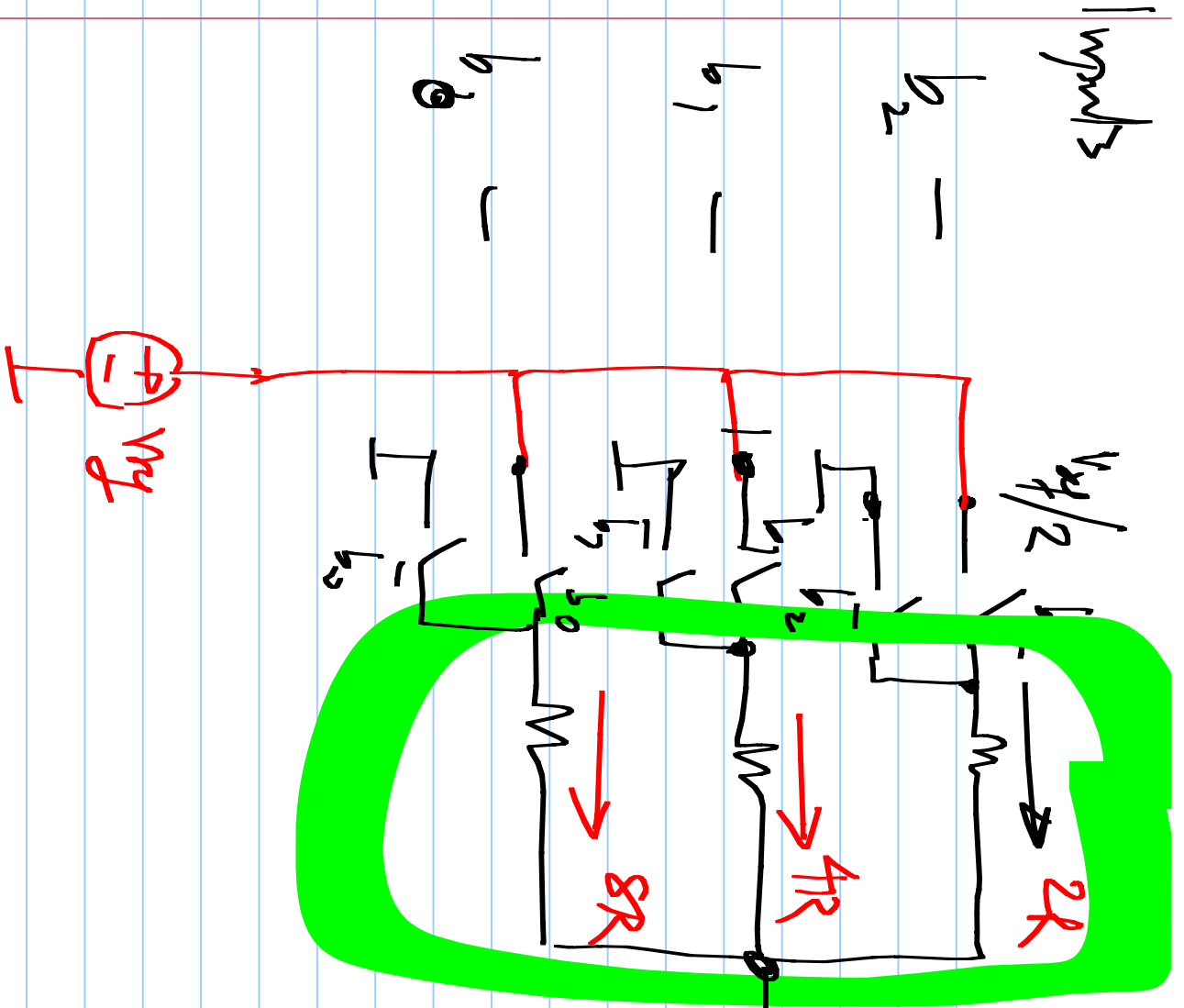
Digital-to-analog converter: (DAC)

$$V_{out} = b_{N-1} \cdot V_{ref} \frac{V_{ref}}{2} + b_{N-2} \frac{V_{ref}}{4} + \dots + b_1 \frac{V_{ref}}{2^{N-1}} + b_0 \frac{V_{ref}}{2^N}$$

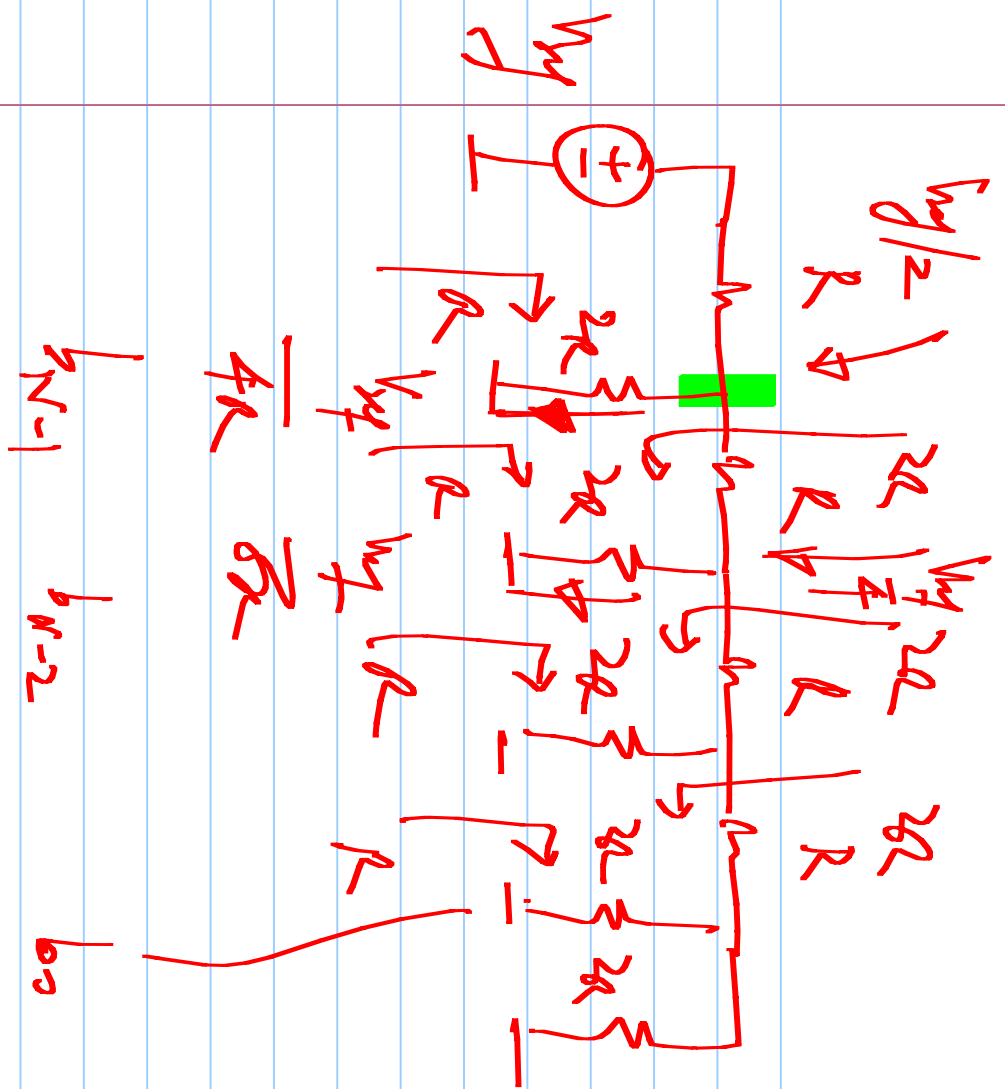
V_{out} / V_{ref}

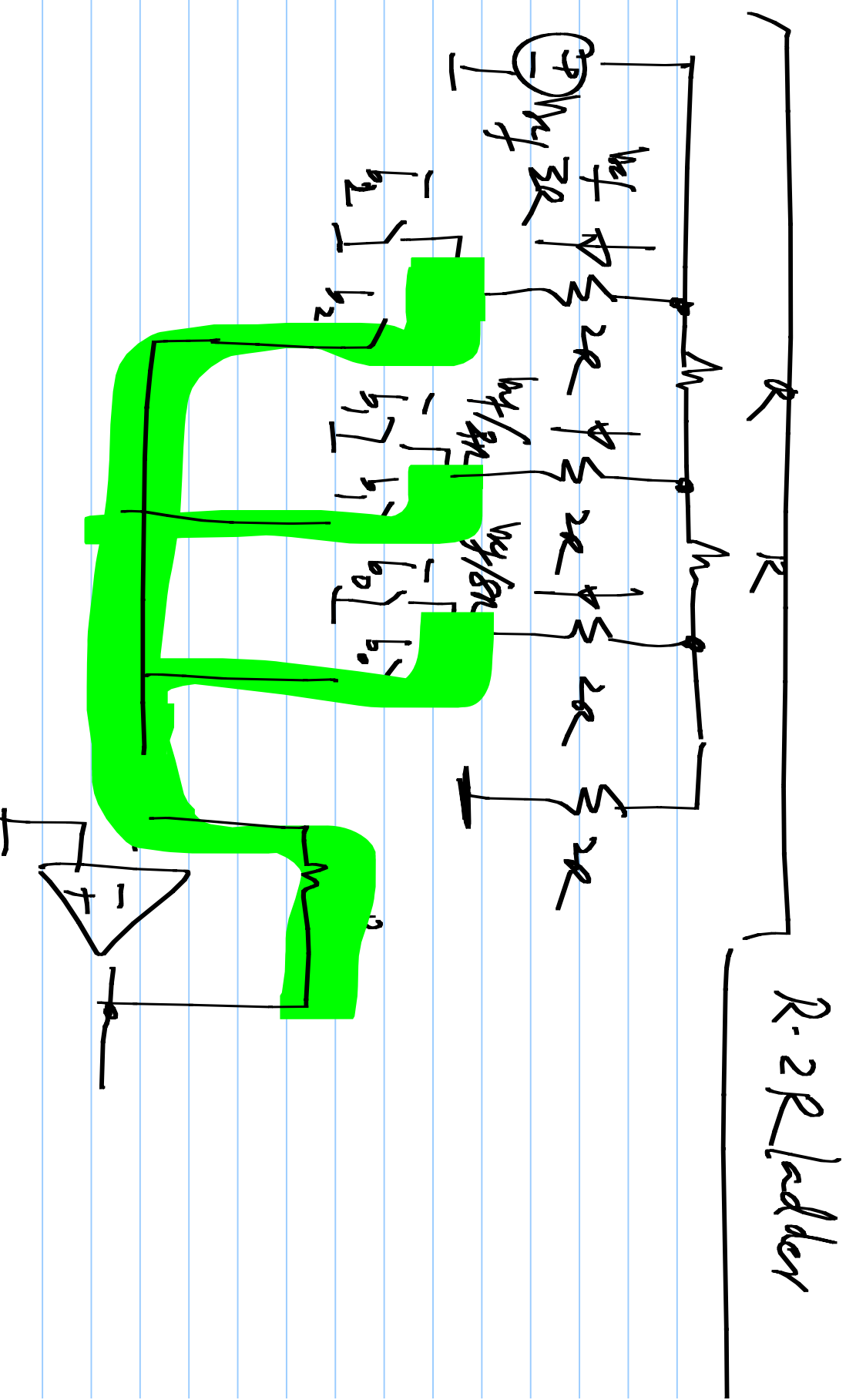
3-bit example



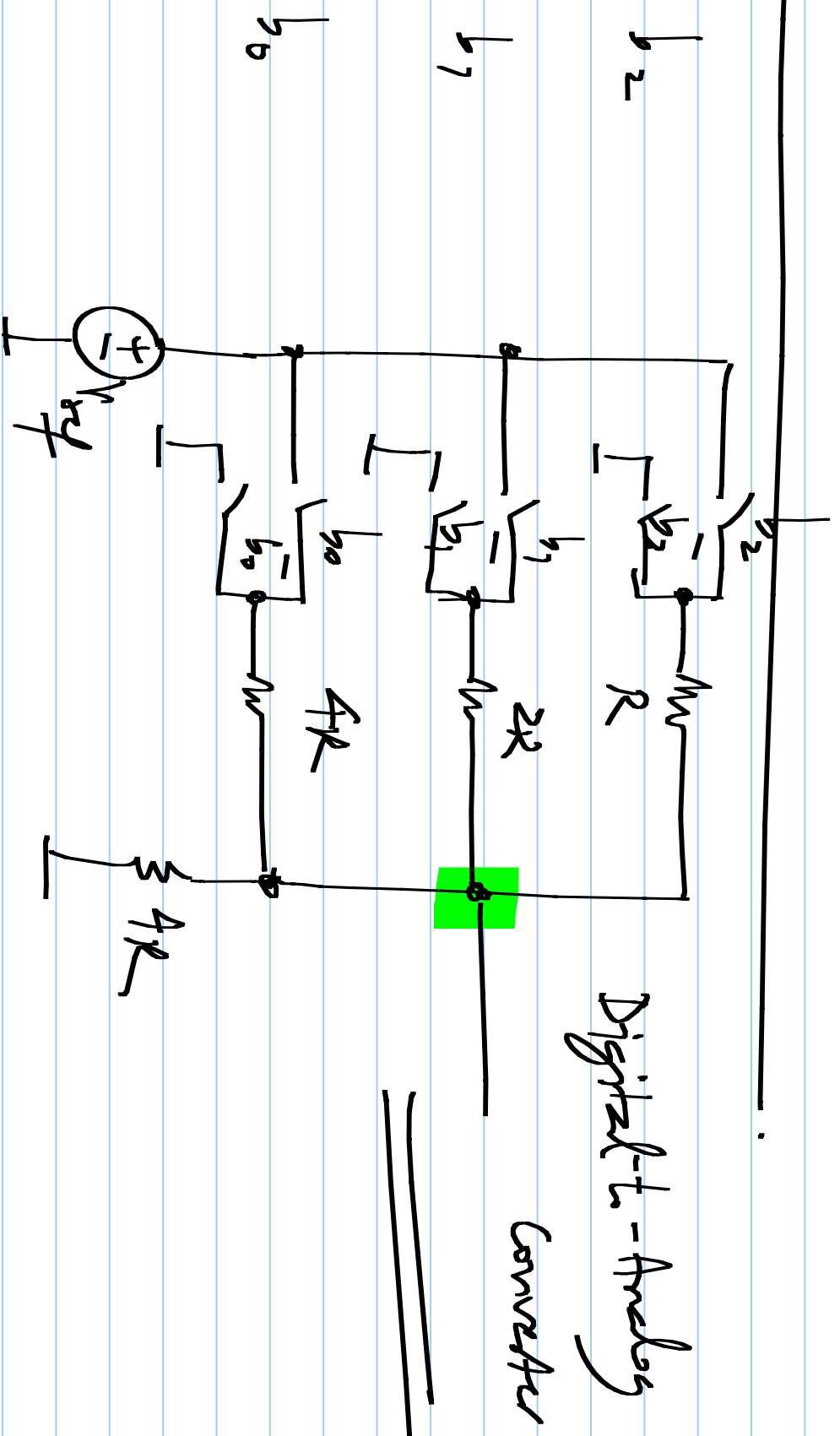


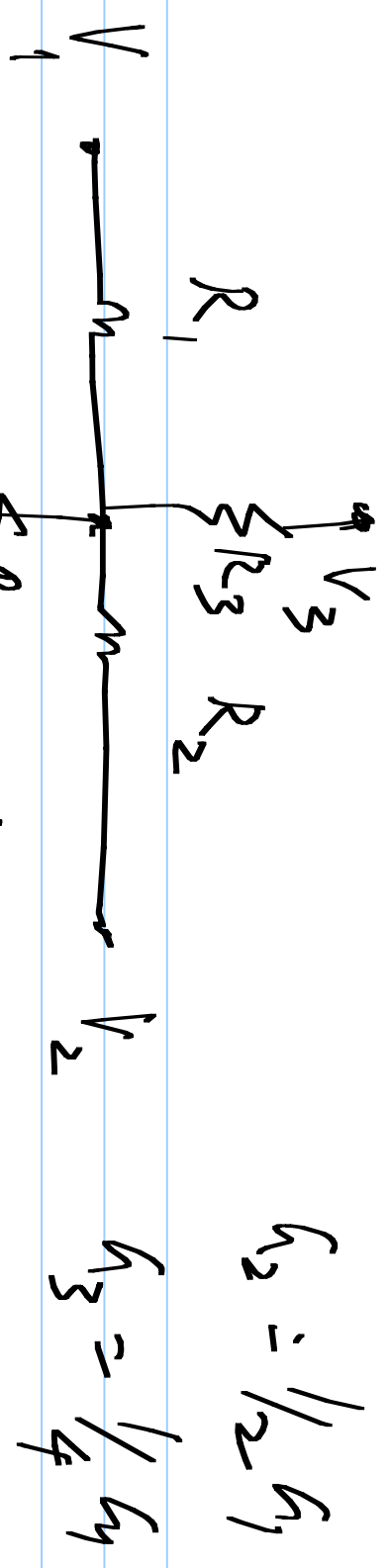
$$V_{out} = \left(b_2 \frac{V_{xy}}{2} + b_1 \frac{V_{xy}}{4} + b_0 \frac{V_{xy}}{8} \right)$$





$$V_{out} = b_2 \cdot \frac{V_{ref}}{2} + b_1 \cdot \frac{V_{ref}}{4} + b_0 \cdot \frac{V_{ref}}{8}$$





$$G_2 = 1/2 G_1$$

$$G_3 = 1/4 G_1$$

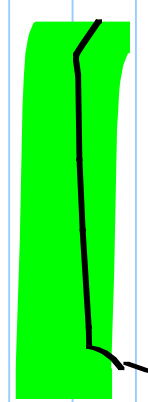
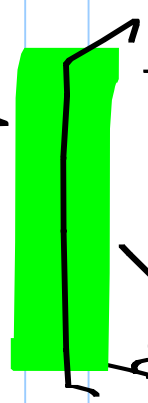
$$G_4 = 1/4 G_1$$

$$b_2 \cdot V_{np} \frac{1}{G_1} +$$

$$b_1 \cdot V_{np} \frac{1}{G_2} +$$

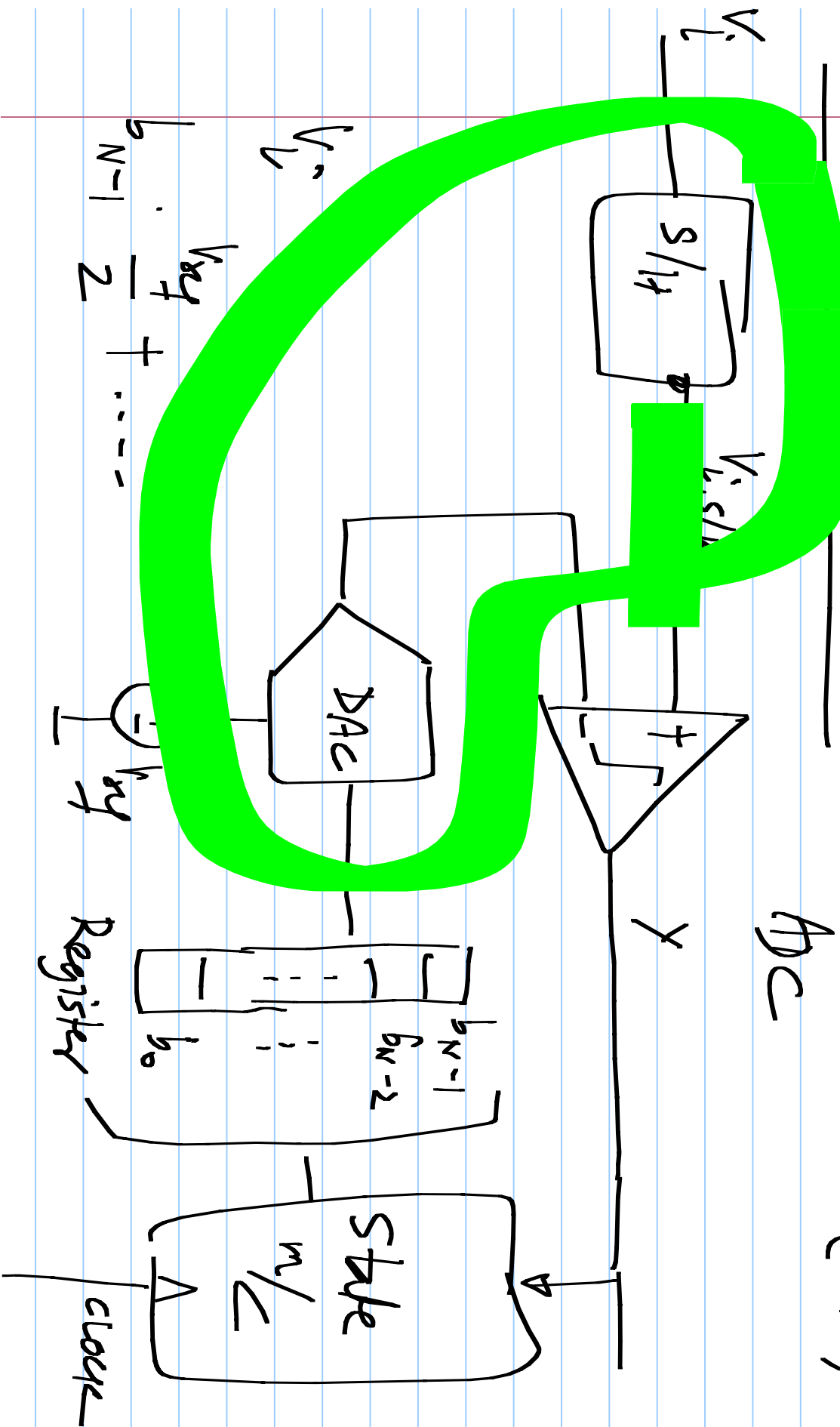
$$b_0 \cdot V_{np} \frac{1}{G_3} +$$

$$\frac{1}{G_1 + G_2 + G_3 + G_4}$$



$$\frac{1}{8}$$

Binary search ADC Successive Approx Register (SAR)



$$b_{N-1} \cdot \frac{V_{ref}}{2} + \dots$$

Successive Approx. Register

the result

Stg #	b_{N-1}	b_{N-2}	b_{N-3}	...	b_1	b_0
1	1	0	0		0	0
2	\hat{b}_{N-1}	1	0		0	0
3	\hat{b}_{N-1}	\hat{b}_{N-2}	1		0	0
\vdots	\vdots	\vdots	\vdots		\vdots	\vdots
N	\hat{b}_{N-1}	\hat{b}_{N-2}	\hat{b}_{N-3}		\hat{b}_1	\hat{b}_0

Update based on

$$\hat{b}_{N-1} \leftarrow Y$$

$$\hat{b}_{N-2} \leftarrow Y$$

Digital output