Chapter5:
DAC and ADC
Part-II
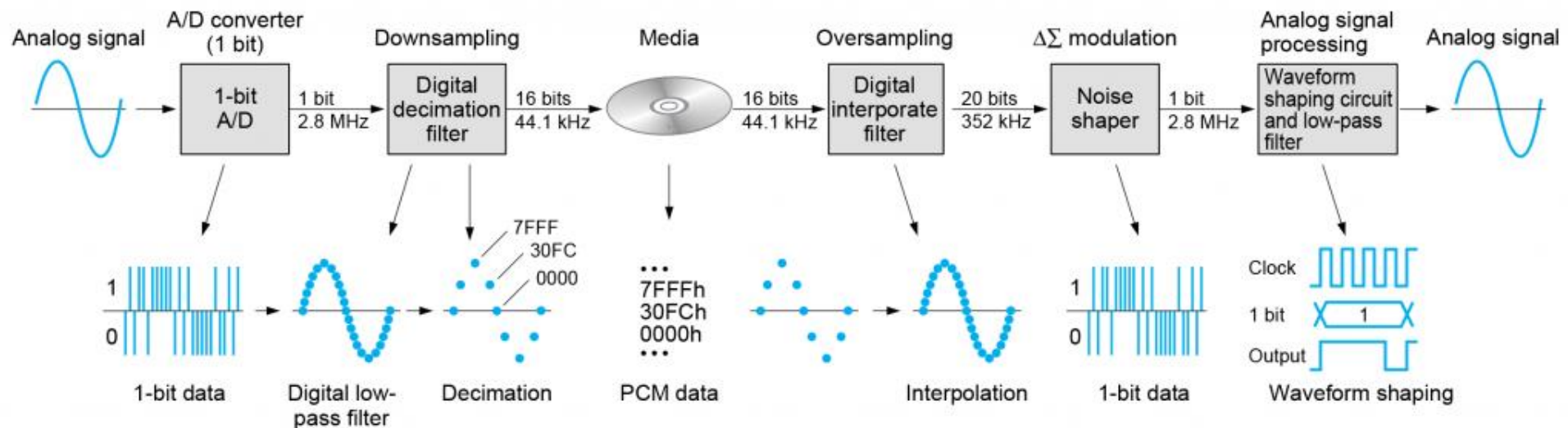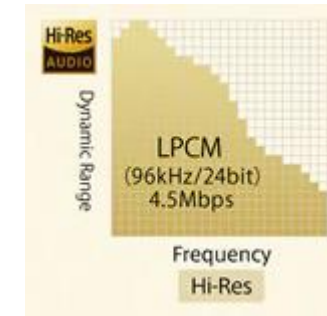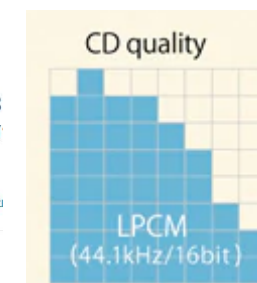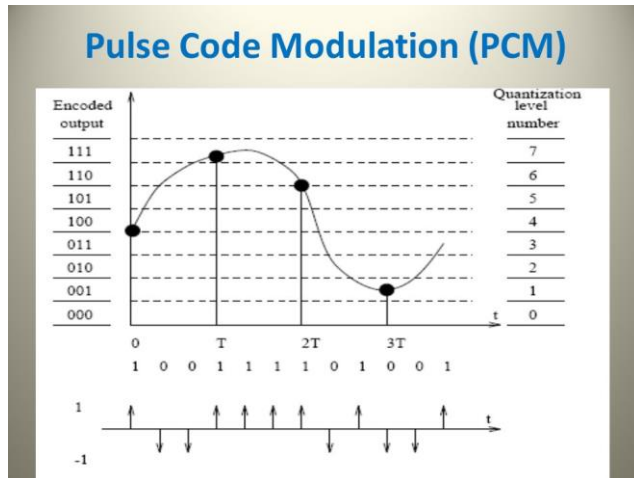
Asst.Prof.Dr.Supakit Nootyaskool

Objective

- To understand the digital to analog conversion and analog to digital conversion.

- To explain converting digital data to analog signal wit R2R circuit.

Topic

- Digital to Analog Conversion
  - R2R ladder
- Analog to Digital Conversion
  - Flash ADC
  - Successive-approximations register (SAR)

DAC CHIP

Overview

MP3 Signal Processor
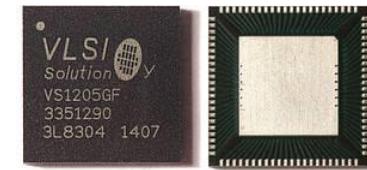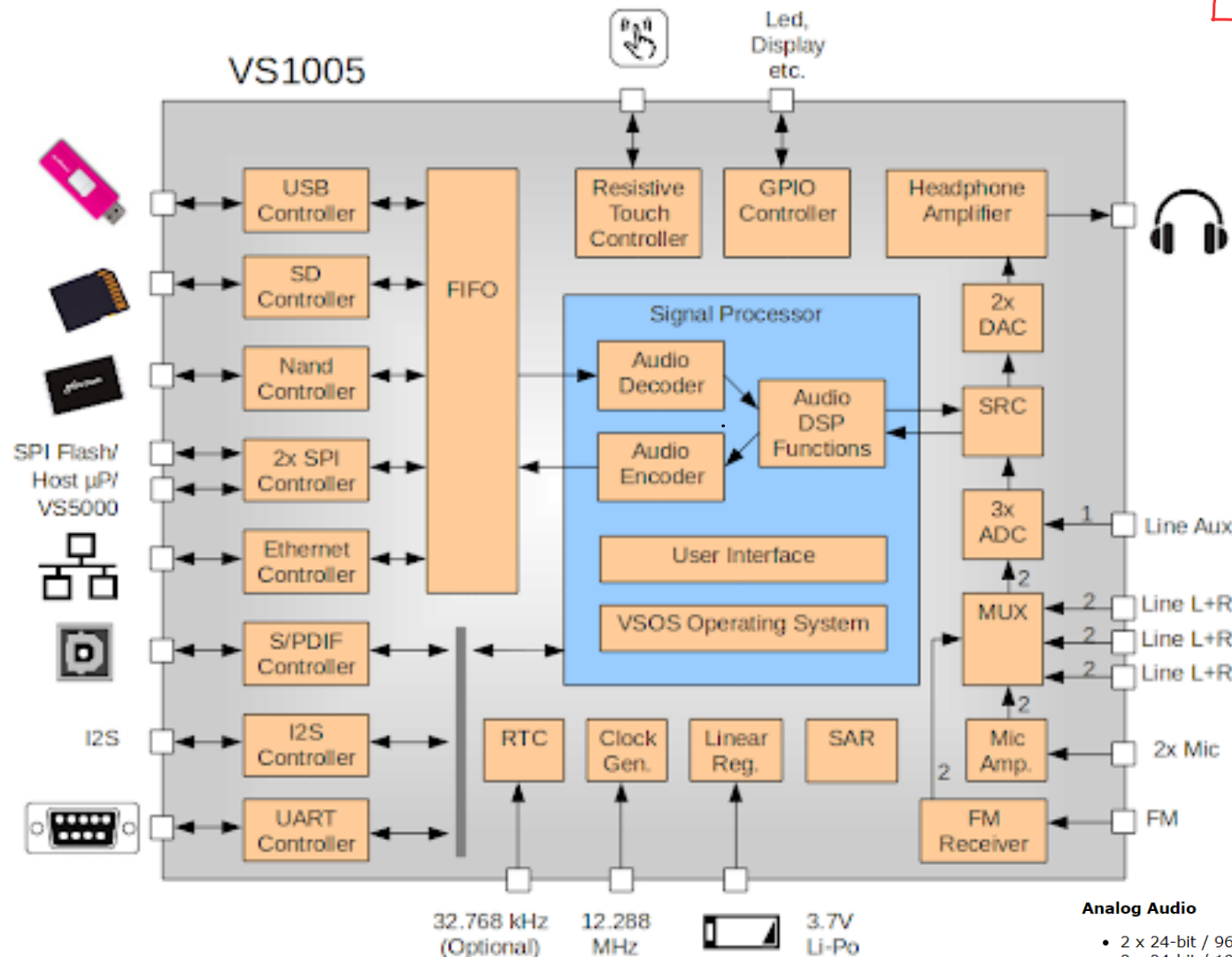
Signal conversion concept

- DAC (Digital to Analog Conversion) } DSP
- ADC (Analog to Digital Conversion)

001100
110011
110001
111000

⇒ DAC ⇒

- -

⇒ ADC ⇐

001100
110011
110001
111000
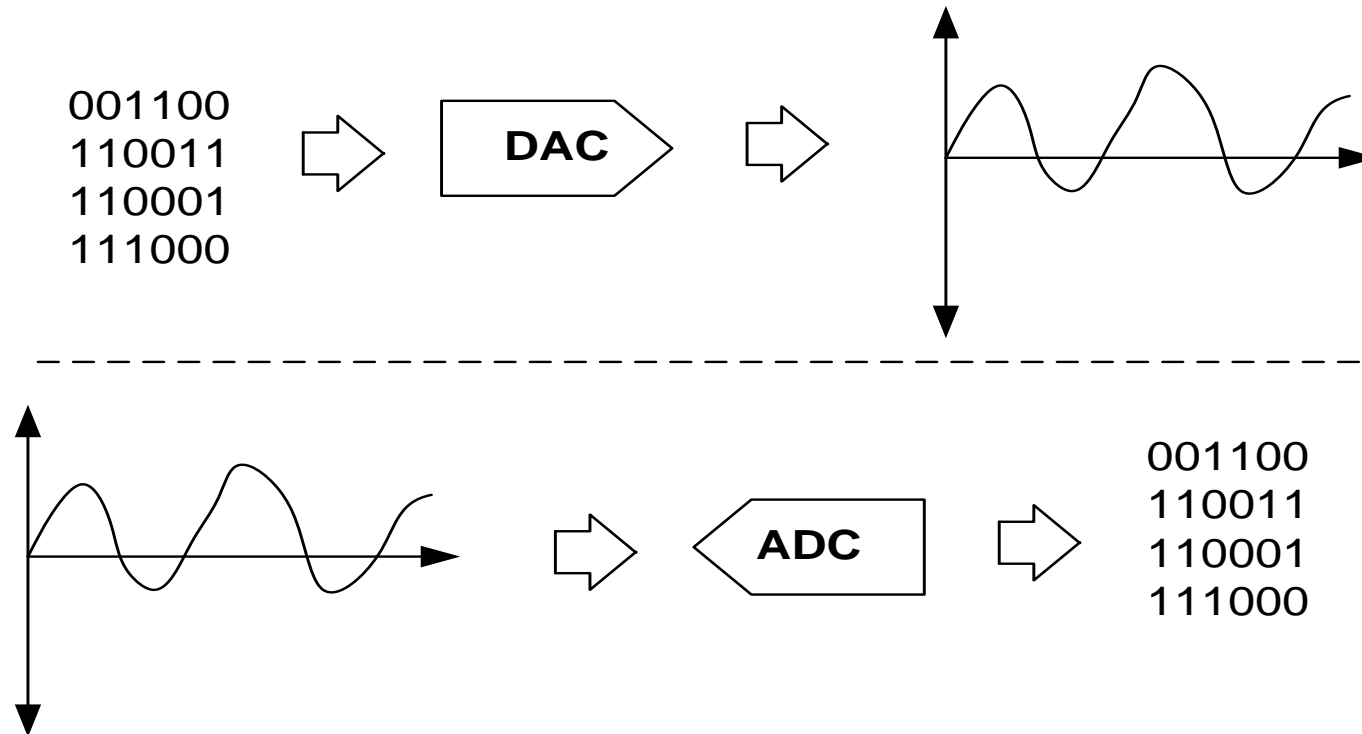
DIGITAL TO ANALOG CONVERSION
WITH R2R LADDER
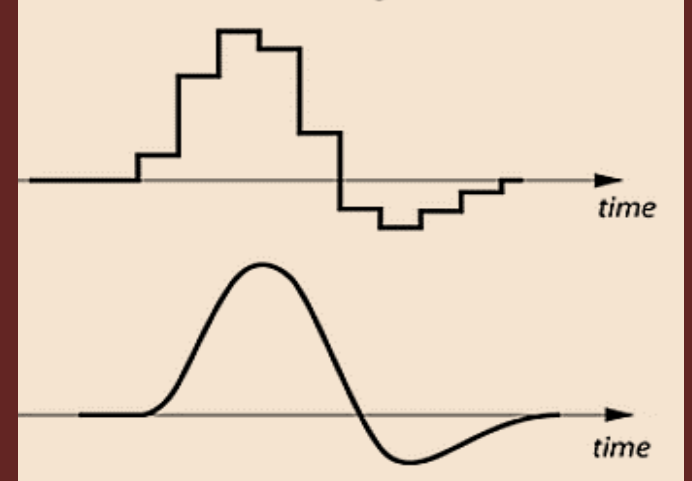
R2R Ladder

- Resistor connected as a network to convert binary number into an analog output signal.

Example DAC design

Supposed

- 4-bits system
- Maximum output voltage at 12v

Example DAC design

Supposed

- 4-bits system

- Maximum output voltage at 12v

2^4 = 16 Levels (0 to 15)

D_0 D_1 D_2 D_3

D3	D2	D1	D0	bitvalue	Voltage
0	0	0	0	0	0
0	0	0	1	1	0.8
0	0	1	0	2	1.6
0	0	1	1	3	2.4
0	1	0	0	4	3.2
0	1	0	1	5	4
0	1	1	0	6	4.8
0	1	1	1	7	5.6
1	0	0	0	8	6.4
1	0	0	1	9	7.2
1	0	1	0	10	8
1	0	1	1	11	8.8
1	1	0	0	12	9.6
1	1	0	1	13	10.4
1	1	1	0	14	11.2
1	1	1	1	15	12

DAC: Resistance and voltage divider

R1   R2   R3

$R_s = R1 + R2 + R3$

R_1 R_2 $R3$

$$R_p = \cfrac{1}{\cfrac{1}{R1} + \cfrac{1}{R2} + \cfrac{1}{R3}}$$

R2   R3

R1

R4

$$R = R1 + \cfrac{1}{\cfrac{1}{R2+R3} + \cfrac{1}{R4}}$$

5V   2R

2R
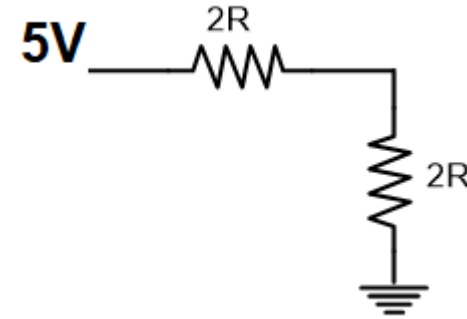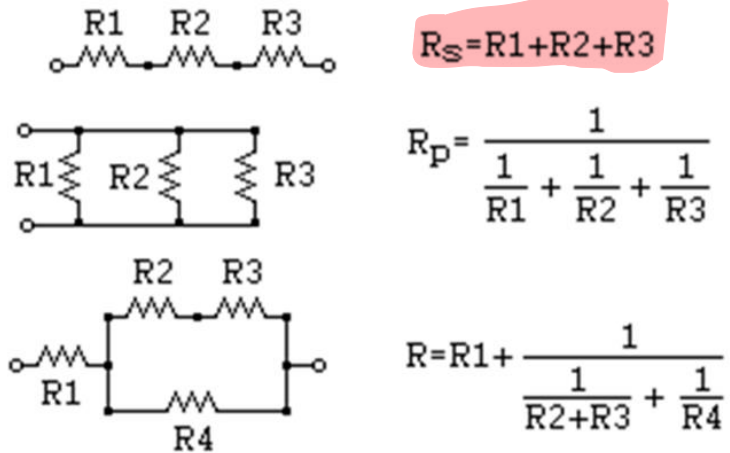
$\dfrac{200}{300}(5) \approx 3.33$

DAC circuit (R2R)
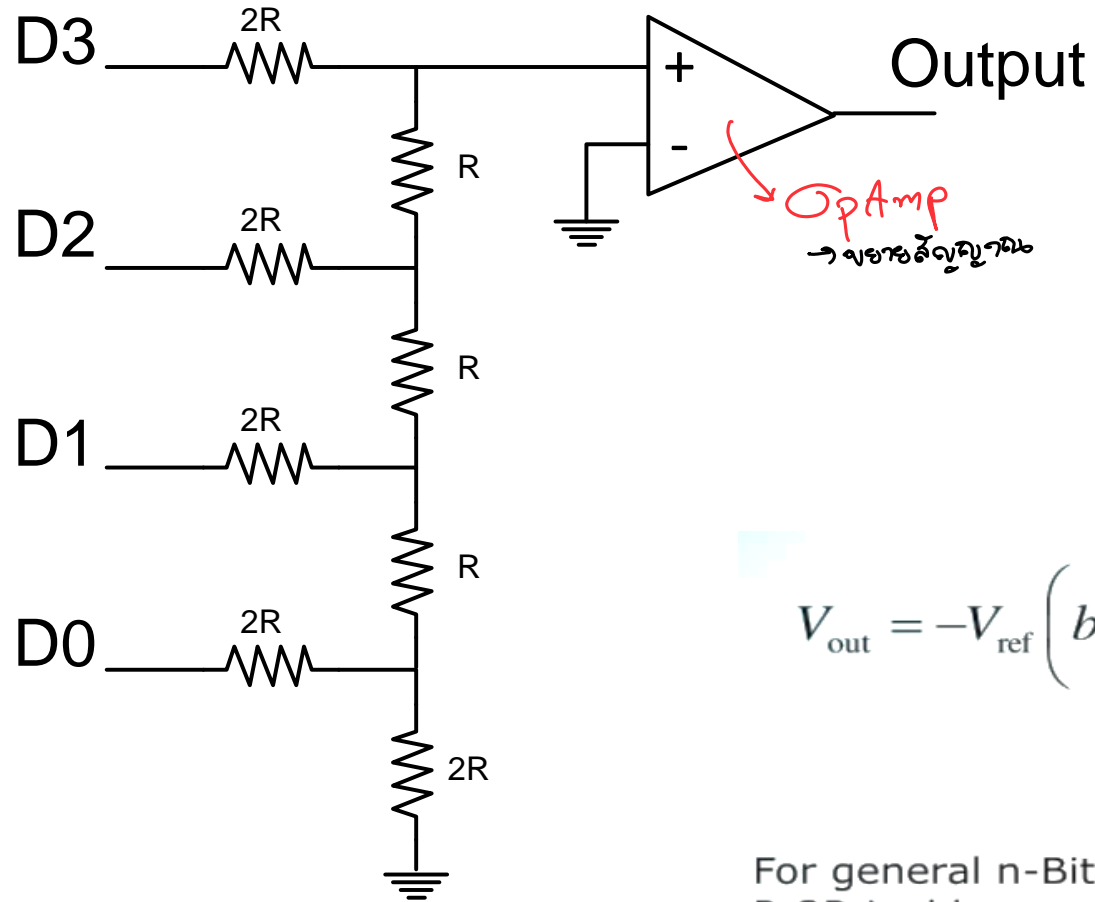
$$V_{out} = -V_{ref}\left(b_3\,\frac{1}{2} + b_2\,\frac{1}{4} + b_1\,\frac{1}{8} + b_0\,\frac{1}{16}\right)$$
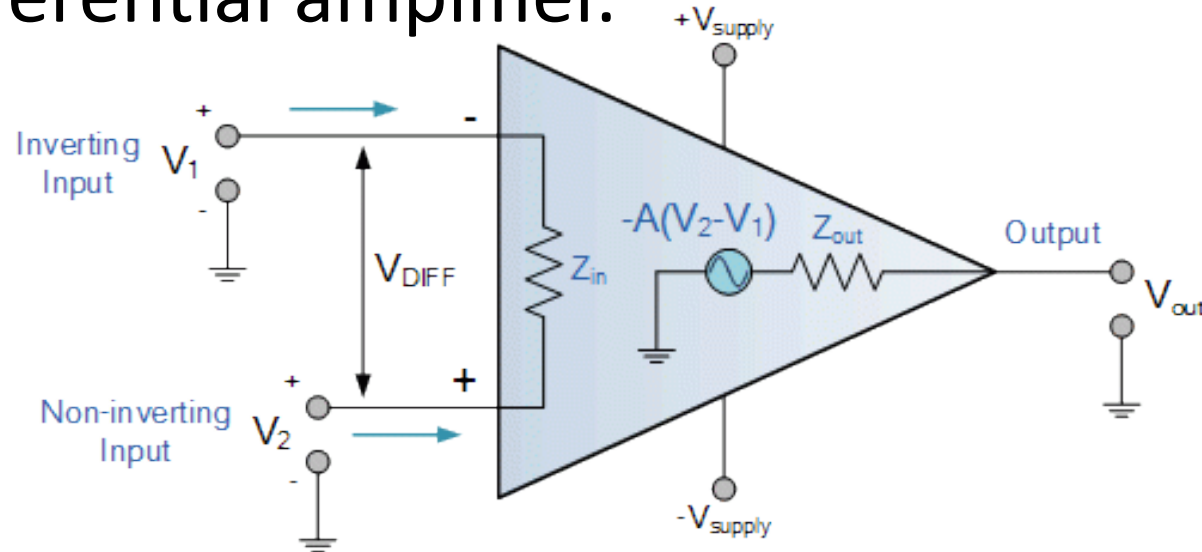
For a 4-Bit R-2R Ladder

For general n-Bit R-2R Ladder Binary Weighted Resister DAC

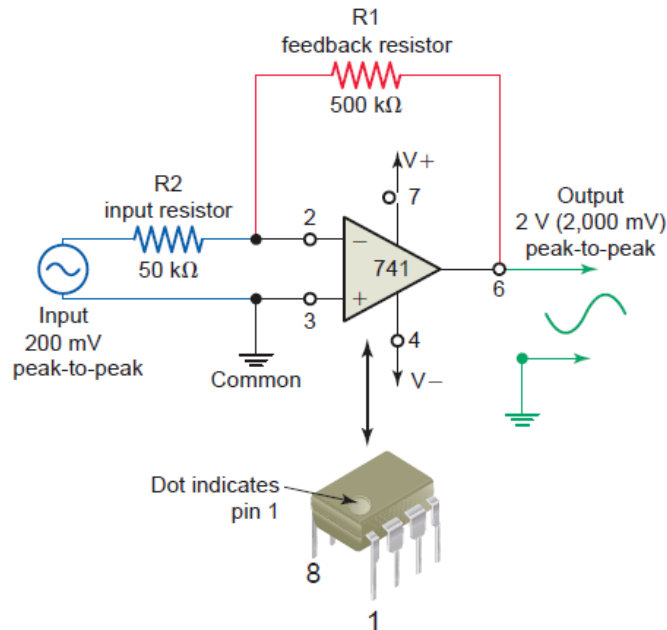$$V_{out} = -V_{ref}\sum_{i=1}^{n} b_{n-i}\,\frac{1}{2^i}$$

Opamp

- Operational amplifiers is an IC amplifying a small signal.

- Opamp has a very-high input impedance and having two input polarities (+) and (-).

- With input characteristic, Opamp uses for differential amplifier.

Opamp in the market

- ## Famous IC code
  - LM324
  - LM741
  - AD822

ANALOG DEVICES

Single-Supply, Rail-to-Rail Low Power FET-Input Op Amp

AD822-EP

FEATURES

True single-supply operation
Input voltage range extends below ground
Output swings rail-to-rail
Single-supply capability from 5 V to 30 V
Dual-supply capability from ±2.5 V to ±15 V

High load drive
Capacitive load drive of 350 pF, G = +1
Minimum output current of 15 mA

Excellent ac performance for low power
800 μA maximum quiescent current per amplifier
Unity-gain bandwidth: 1.8 MHz
Slew rate of 3 V/μs

Good dc performance
800 μV maximum input offset voltage
2 μV/°C typical offset voltage drift
25 pA maximum input bias current

Low noise
13 nV/√Hz @ 10 kHz
No phase inversion

ENHANCED PRODUCT FEATURES

Supports defense and aerospace applications (AQEC standard)
Military temperature range (−55°C to +125°C)
Controlled manufacturing baseline
One assembly/test site
One fabrication site
Enhanced product change notification
Qualification data available on request

APPLICATIONS

Photodiode preamps
Active filters
12-bit to 14-bit data acquisition systems
Low power references and regulators

CONNECTION DIAGRAM

OUT1 1 8 V+
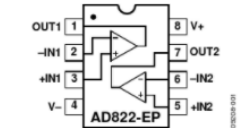−IN1 2 7 OUT2
+IN1 3 6 −IN2
V− 4 AD822-EP 5 +IN2

Figure 1. 8-Lead SOIC_N (R Suffix)

GENERAL DESCRIPTION

The AD822-EP is a dual precision, low power FET input op amp that can operate from a single supply of 5 V to 30 V or dual supplies of ±2.5 V to ±15 V. It has true single-supply capability with an input voltage range extending below the negative rail, allowing the AD822 to accommodate input signals below ground in the single-supply mode. Output voltage swing extends to within 10 mV of each rail, providing the maximum output dynamic range.
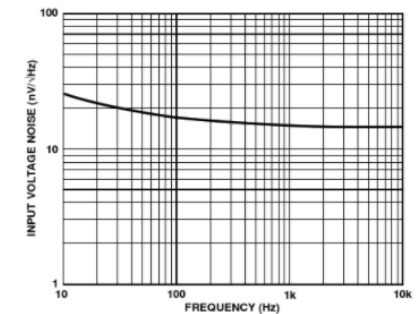
Figure 2. Input Voltage Noise vs. Frequency

Offset voltage of 800 μV maximum, offset voltage drift of 2 μV/°C, input bias currents below 25 pA, and low input voltage noise provide dc precision with source impedances up to a gigaohm. The 1.8 MHz unity-gain bandwidth, −93 dB THD at 10 kHz, and 3 V/μs slew rate are provided with a low supply current of 800 μA per amplifier.

R1
feedback resistor
500 kΩ

R2
input resistor
50 kΩ

V+
7

741

2
−

3
+

6

4
V−

Output
2 V (2,000 mV)
peak-to-peak

Input
200 mV
peak-to-peak

Common

Dot indicates pin 1

8

1

ANALOG TO DIGITAL CIRCUIT

ADC circuits

- Characteristic of ADCs
  - Resolution
  - Conversion speed
- Type of ADC circuit in the present
  - Flash ADC
  - Pipelined ADC
  - Successive Approximation Register
  - Dual-slope convertor
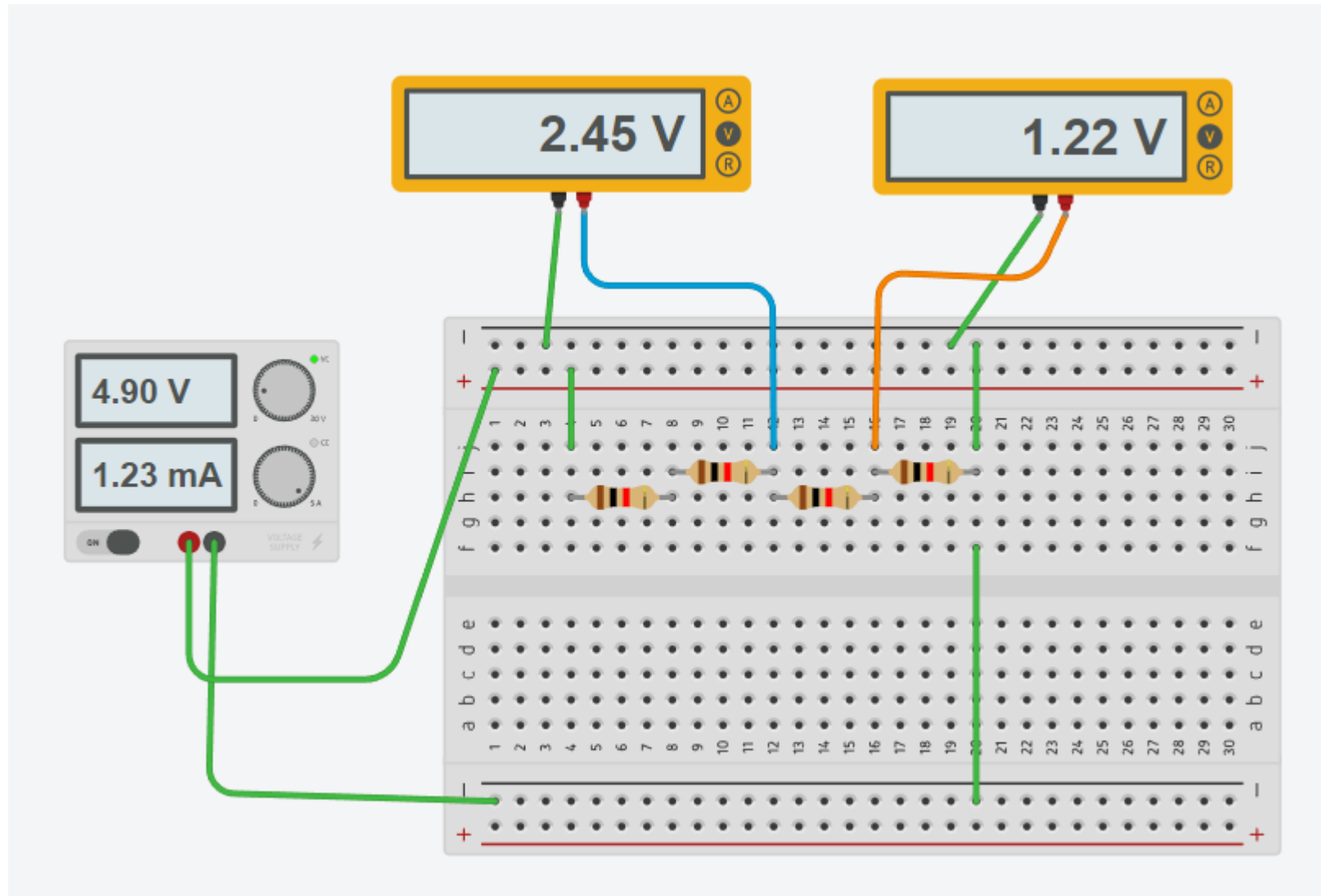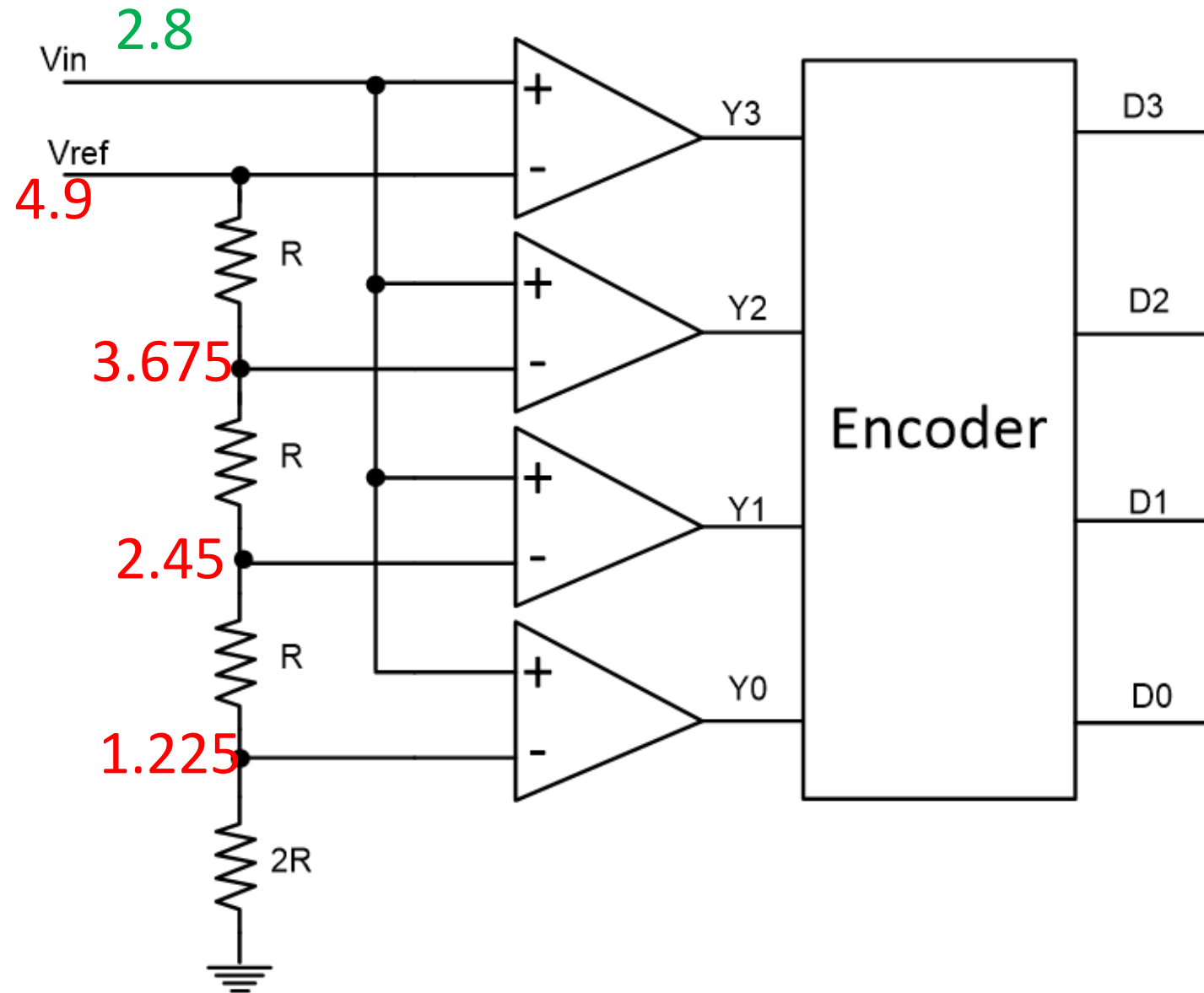 - Sigma-Delta converter

FLASH ADC

Flash ADC

- Serie resistor for voltage dividing to create voltage references
- Compare the voltage reference with an input voltage with Opamps.
- Use encoder circuit convert to BCD data.
- Strength
  - Very fast conversion
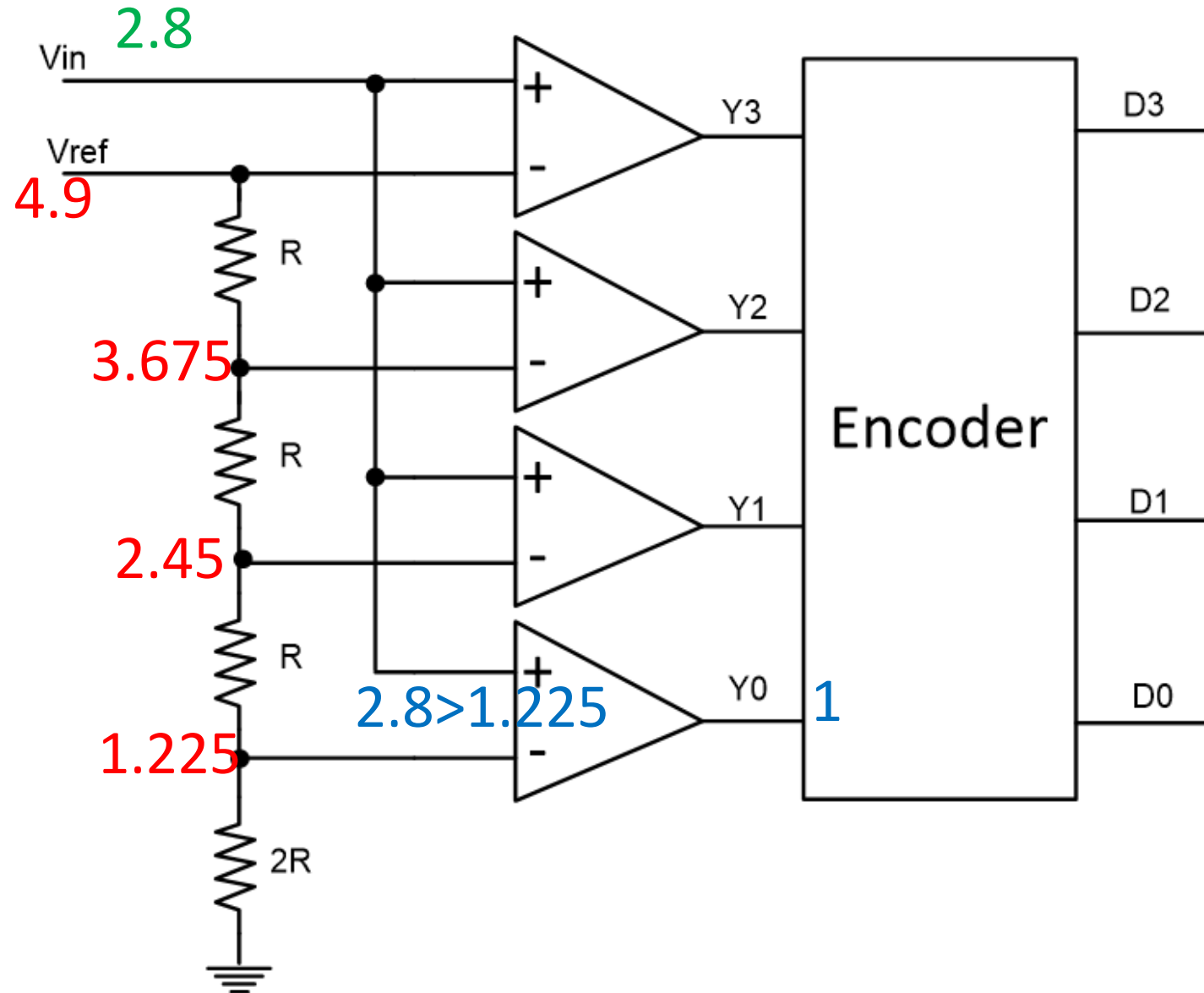- Weakness
  - Number of comparator require 2^{N-1}
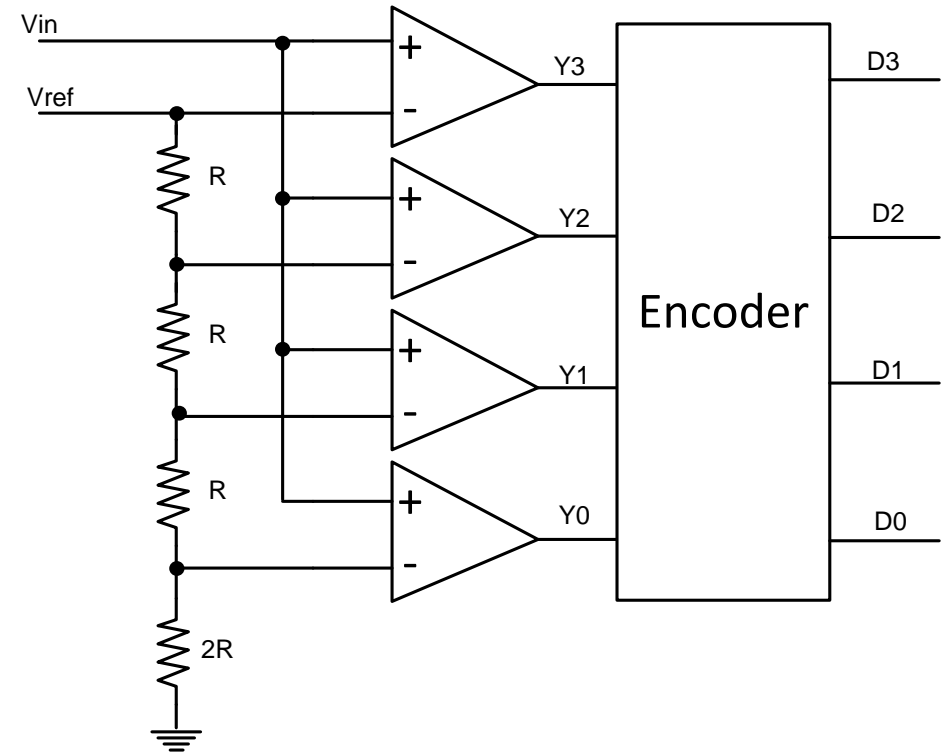
Voltage divider circuit

# Flash ADC: Example

Flash ADC: Example

Flash ADC: Encoder design

No.	Y3	Y2	Y1	Y0	D2	D1	D0
0	0	0	0	0	0	0	0
1	0	0	0	1	0	0	1
2	0	0	1	1	0	1	0
3	0	1	1	1	0	1	1
4	1	1	1	1	1	0	0

Encoder design (added don't care bits)

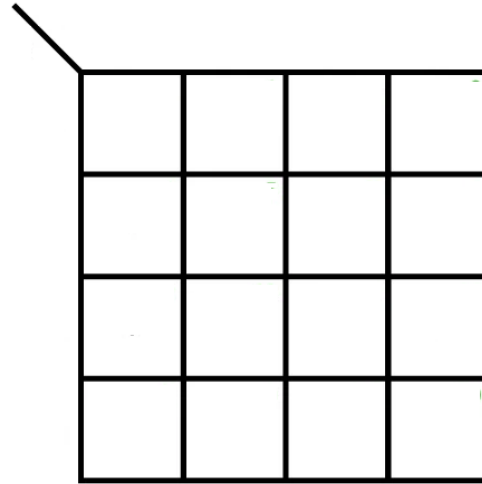| No.	Y3	Y2	Y1	Y0	D2	D1	D0
0	0	0	0	0	0	0	0
1	0	0	0	1	0	0	1
2	0	0	1	1	0	1	0
3	0	1	1	1	0	1	1
4	1	1	1	1	1	0	0
5	1	X	X	X	1	0	0
6	1	X	X	X	1	0	0
7	1	X	X	X	1	0	0

Encoder design (SOP, K-MAP)

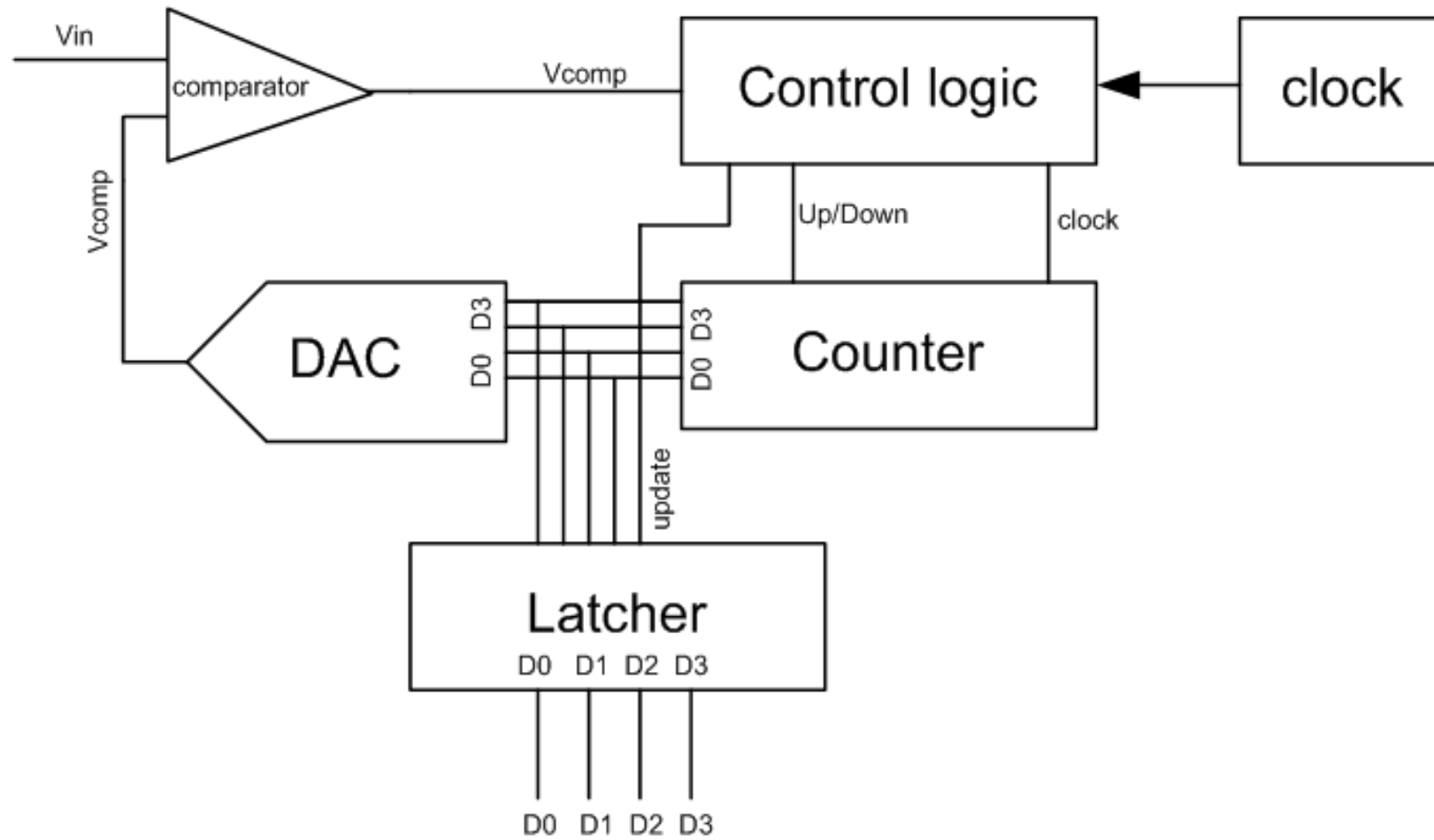| No.	Y3	Y2	Y1	Y0	D2	D1	D0
0	0	0	0	0	0	0	0
1	0	0	0	1	0	0	1
2	0	0	1	1	0	1	0
3	0	1	1	1	0	1	1
4	1	1	1	1	1	0	0
5	1	X	X	X	1	0	0
6	1	X	X	X	1	0	0
7	1	X	X	X	1	0	0
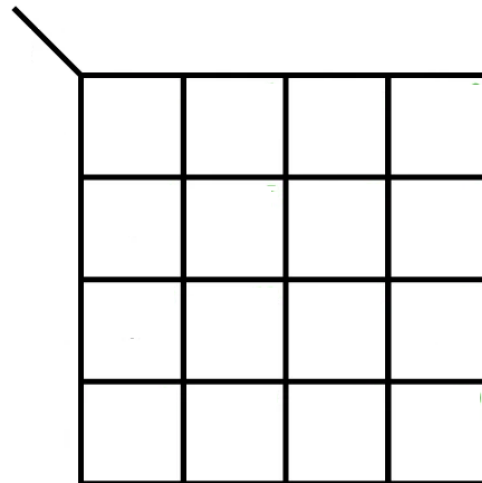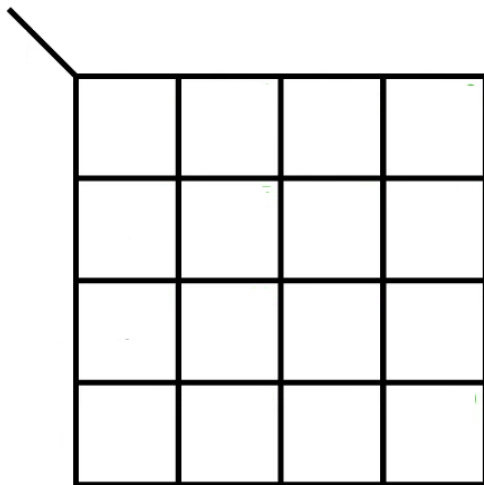
Flash ADC applied Arduino decoder
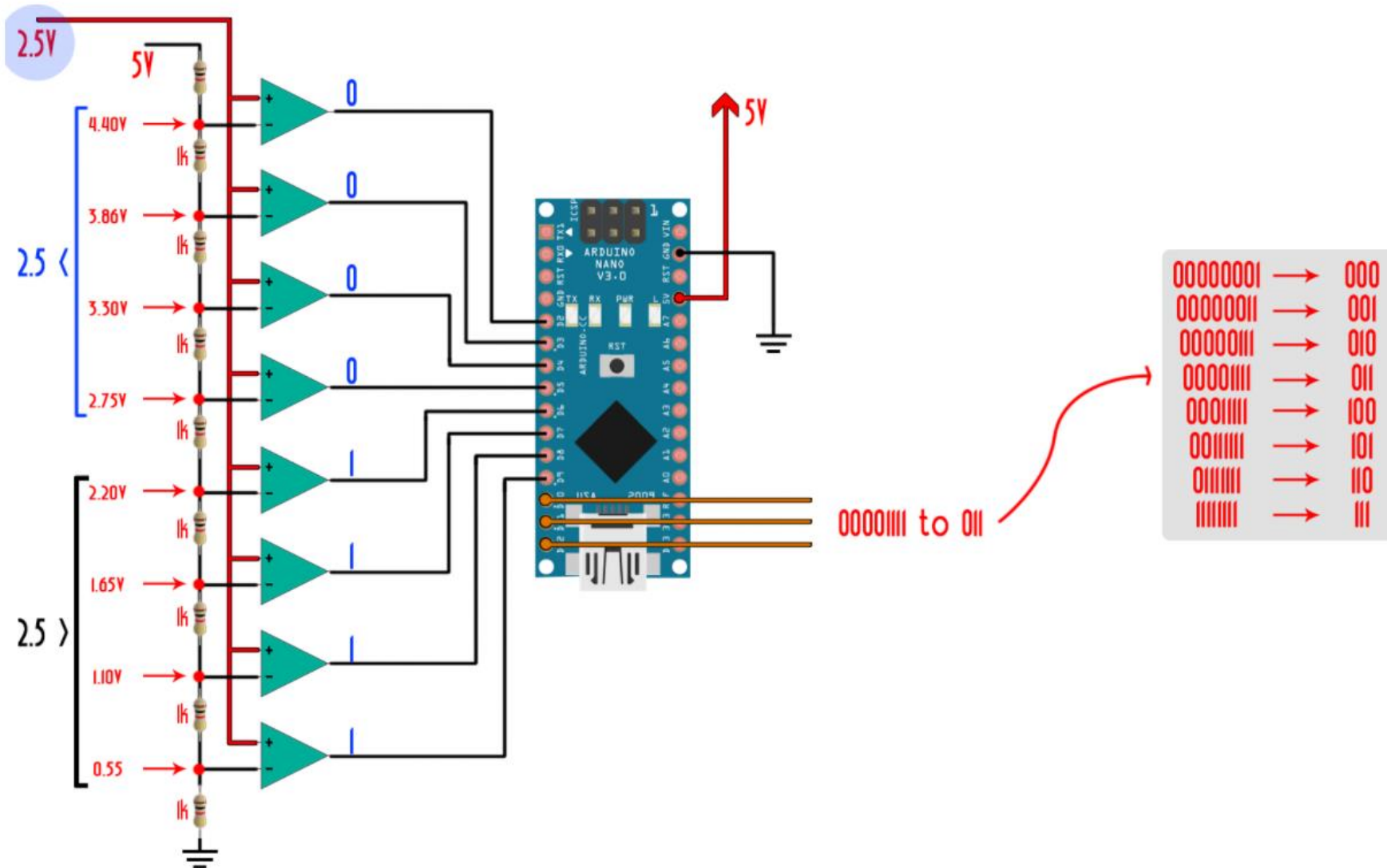
ADC: SUCCESSIVE APPROXIMATION REGISTER (SAR)
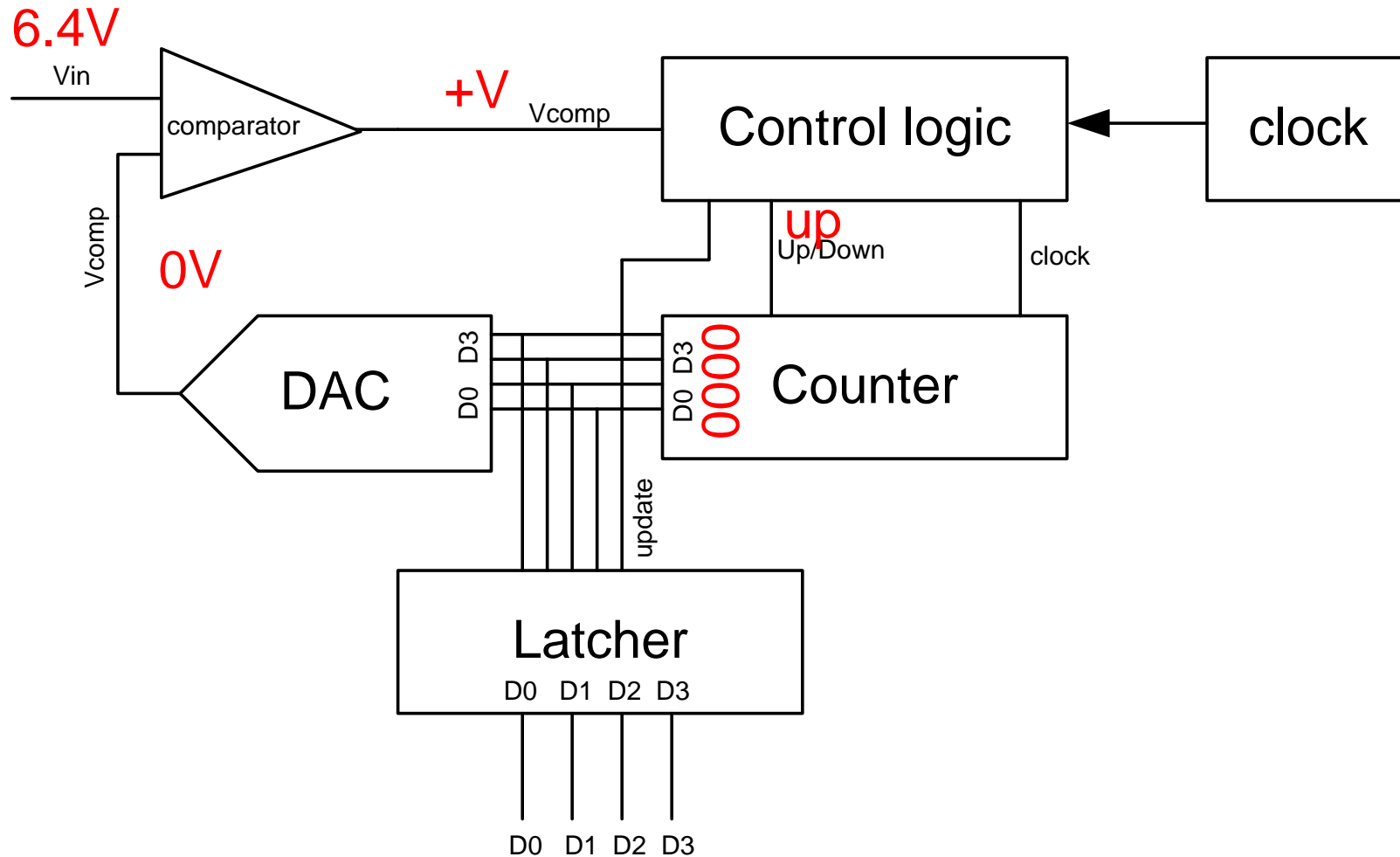
Successive Approximation Register (SAR)

Features

- Low energy.

- Interesting for digital circuit studying cause of having a counter, DAC, latch, and a comparator build to the system.
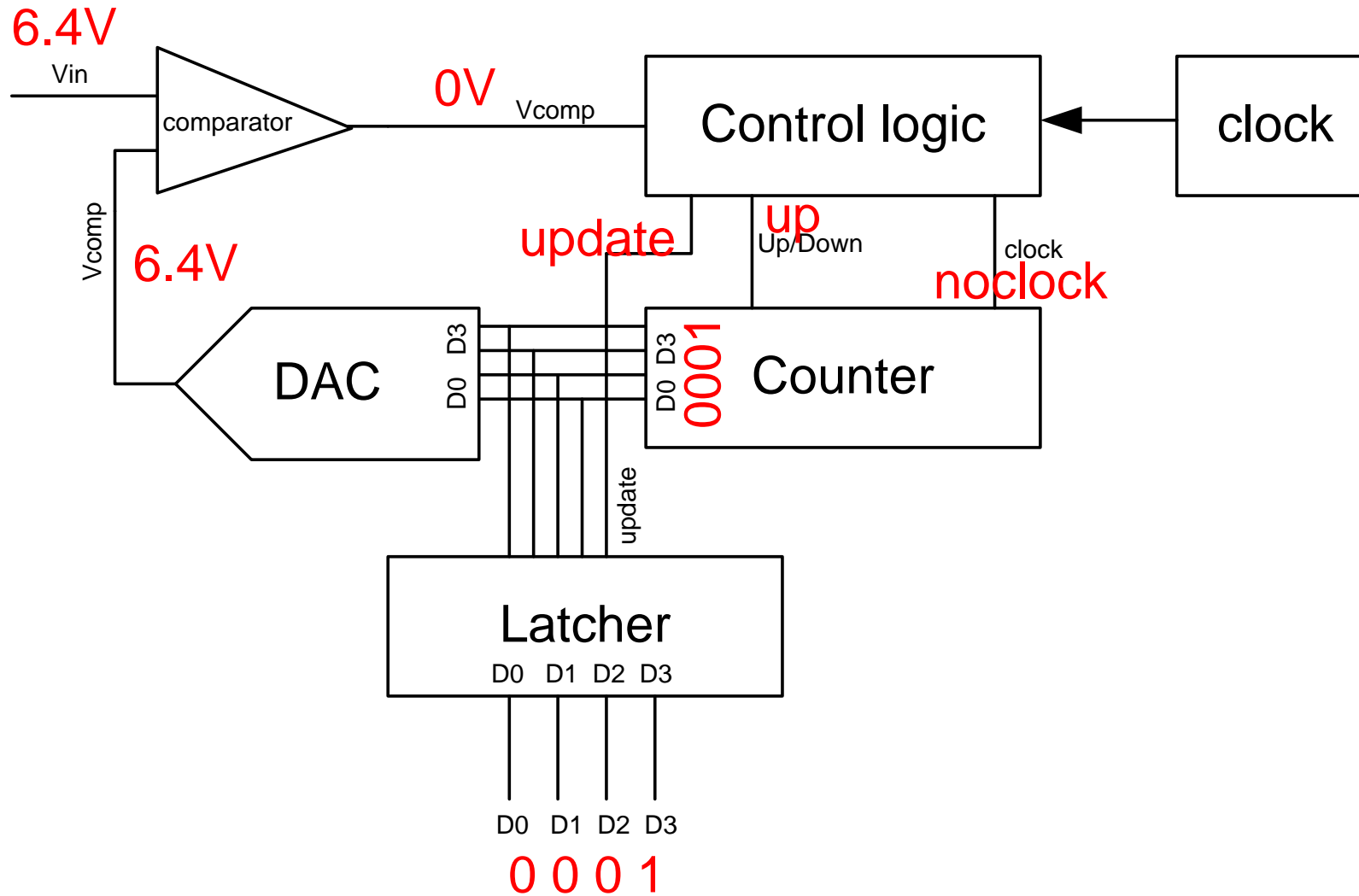
SAR-ADC

SAR-ADC: Example running

SAR-ADC: Example getting data

References

Content	Links
Tutorial digital circuit	https://www.tutorialspoint.com/digital_circuits/digital_circuits_conversion_of_flip_flops.htm
K-map online	http://www.32x8.com/index.html
Encoder circuit design	https://www.geeksforgeeks.org/encoder-in-digital-logic/
3bits flash ADC applied Arduino encoder	https://www.electronoobs.com/eng_circuitos_tut15_2.php
Flash ADC	https://www.allaboutcircuits.com/textbook/digital/chpt-13/flash-adc/
Example ADC with simulation	http://www.onmyphd.com/?p=analog.digital.converter#h3_resolution