Chapter5:
DAC and ADC
Part-II

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Objective

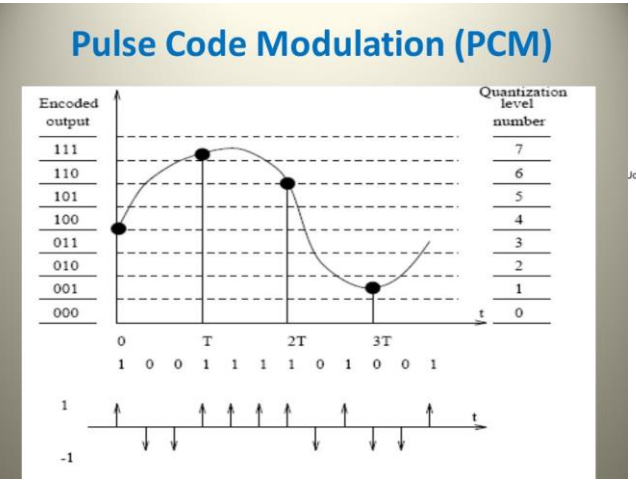
- To recognize mechanism of conversion from analog signal to digital signal, with digital circuit.
- To explain a R2R circuit to convert digital data to analog signal.
- To understand concept of convert analog signal to digital signal and digital to analog signal.

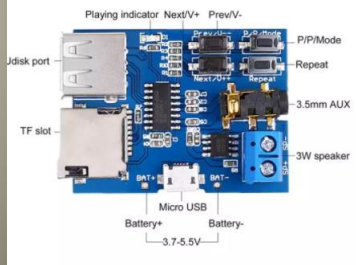
Topic

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

DAC AND ADC
IN COMPUTER SYSTEM

Overview


Pulse Code Modulation (PCM)
Encoded output
Quantization level number
111 7
110 6
101 5
100 4
011 3
010 2
001 1
000 0
0 T 2T 3T t
1 0 0 1 1 1 1 0 1 0 0 1
1
-1
t


Playing indicator Next/V+ Prev/V-
Udisk port
TF slot
P/P/Mode
Repeat
3.5mm AUX
3W speaker
Micro USB
Battery+
Battery-
3.7-5.5V


LazGlobal
สดชื่น 5V 3W MP3 เสียง BOARD ยูเอส
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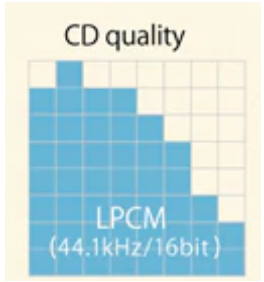
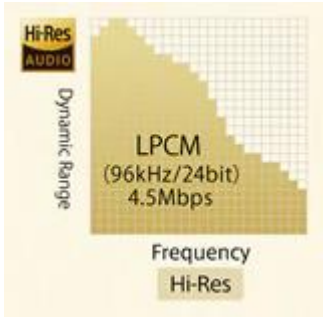
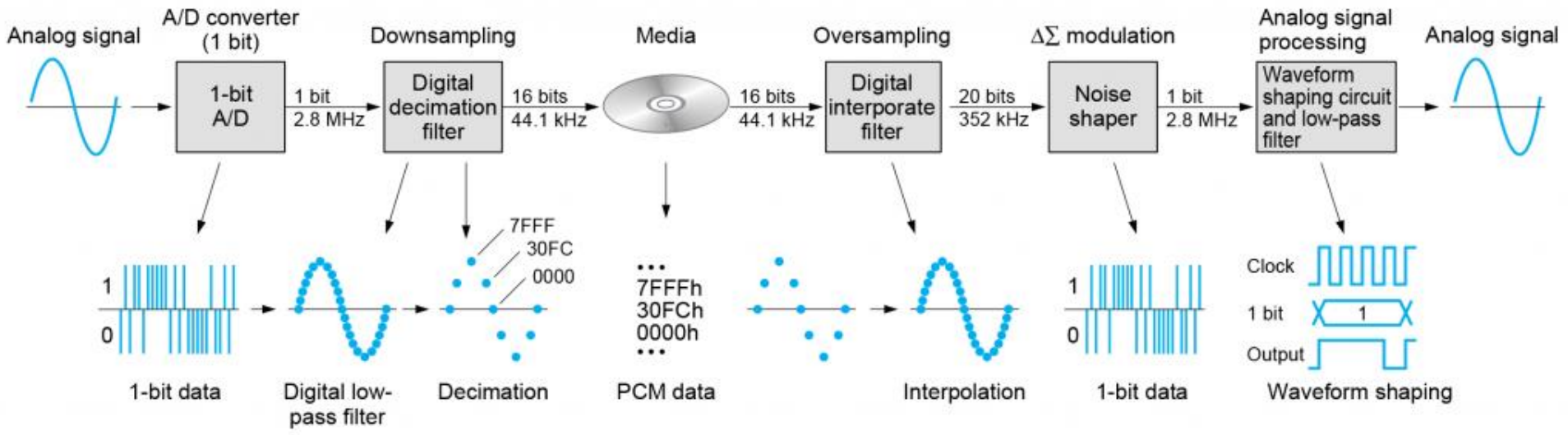
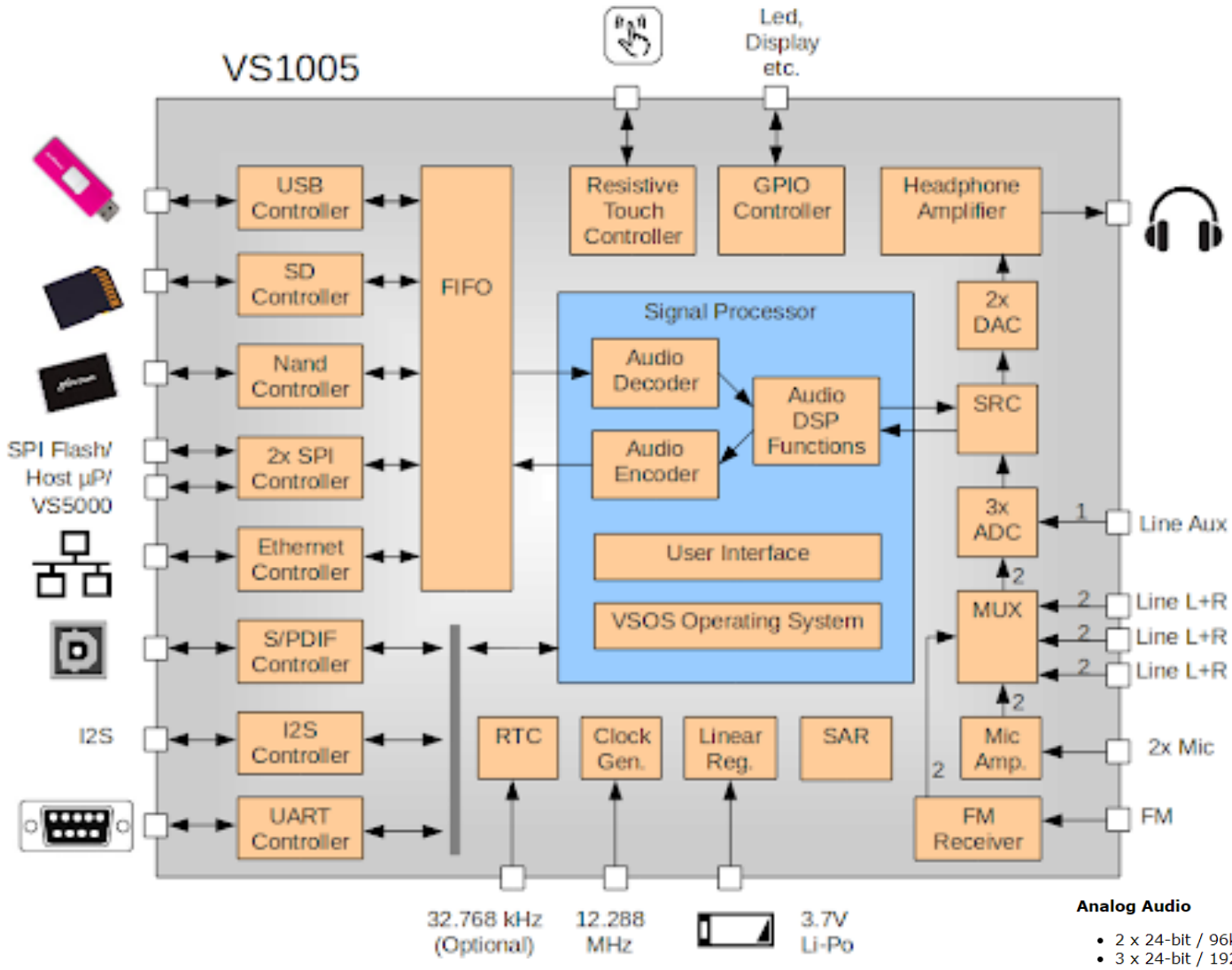
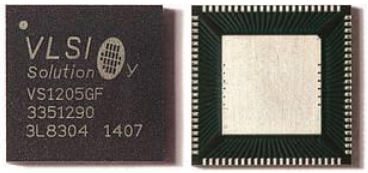

CD quality
LPCM
(44.1kHz/16bit)


Hi-Res
AUDIO
Dynamic Range
LPCM
(96kHz/24bit)
4.5Mbps
Frequency
Hi-Res


Analog signal
A/D converter (1 bit)
1-bit A/D
1 bit
2.8 MHz
Downsampling
Digital decimation filter
16 bits
44.1 kHz
Media
16 bits
44.1 kHz
Oversampling
Digital interporate filter
20 bits
352 kHz
ΔΣ modulation
Noise shaper
1 bit
2.8 MHz
Analog signal processing
Waveform shaping circuit and low-pass filter
Analog signal
1
0
1-bit data
Digital low-pass filter
7FFF
30FC
0000
Decimation
7FFFh
30FCh
0000h
PCM data
Interpolation
1
0
1-bit data
Clock
1 bit
1
Output
Waveform shaping

MP3 Signal Processor



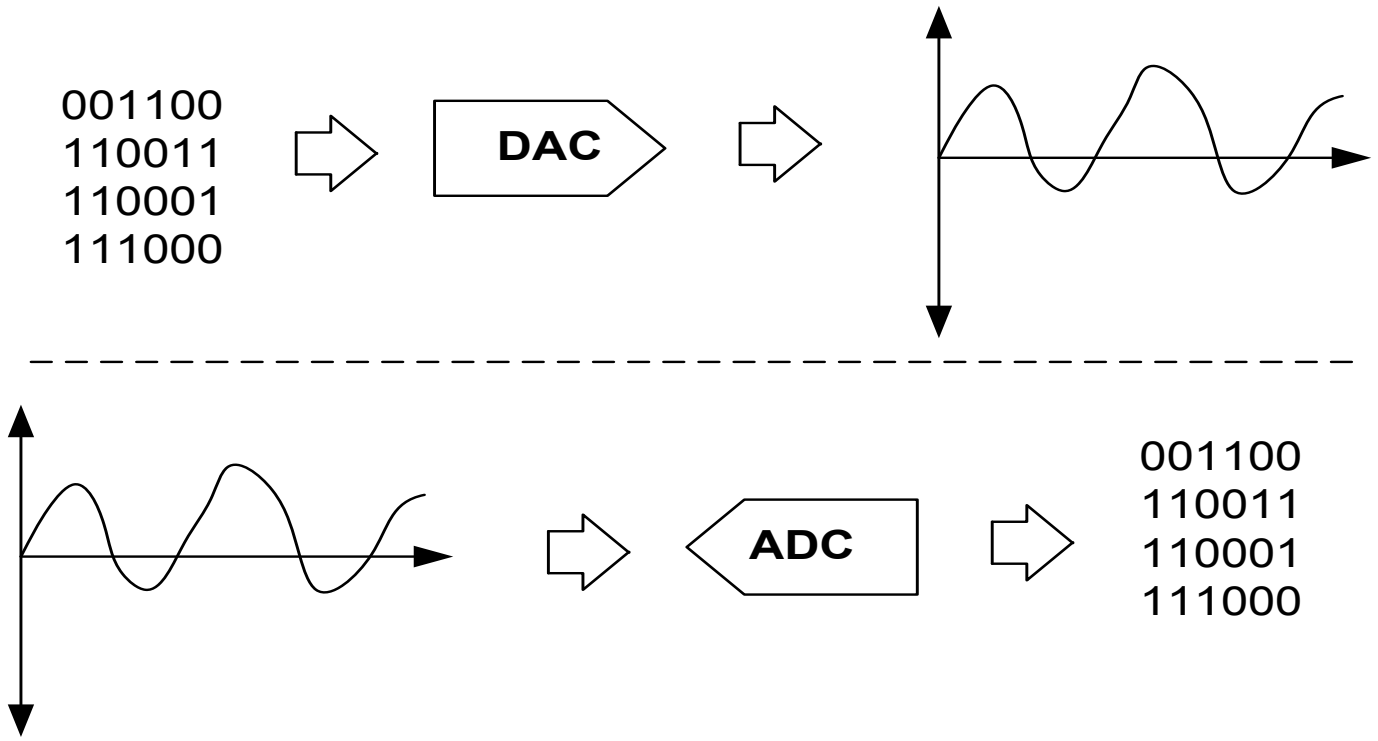


Analog Audio

- 2 x 24-bit / 96kHz DAC
- 3 x 24-bit / 192kHz ADC
- Integrated FM tuner with RDS, Japanese band included (76-108 MHz)
- Stereo headphone output
- Stereo microphone amplifier

Signal conversion concept

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



time
time

R2R
DIGITAL TO ANALOG CONVERSION

Example DAC design

Supposed

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

Example DAC design

2^4 = 16 Levels (0 to 15)

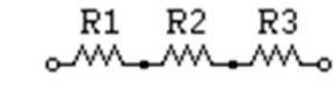
D_0 D_1 D_2 D_3

Supposed

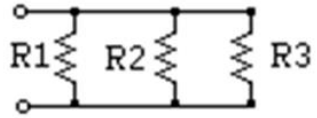
- 4-bits system
- Maximum output voltage at 12v

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

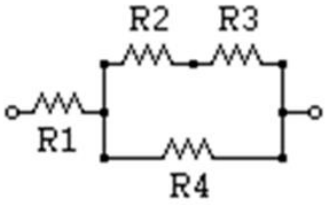
DAC: Resistance and voltage divider



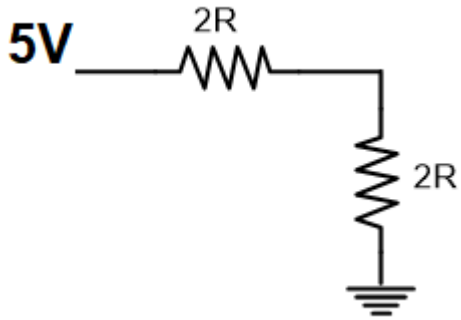
$$R_S = R1 + R2 + R3$$



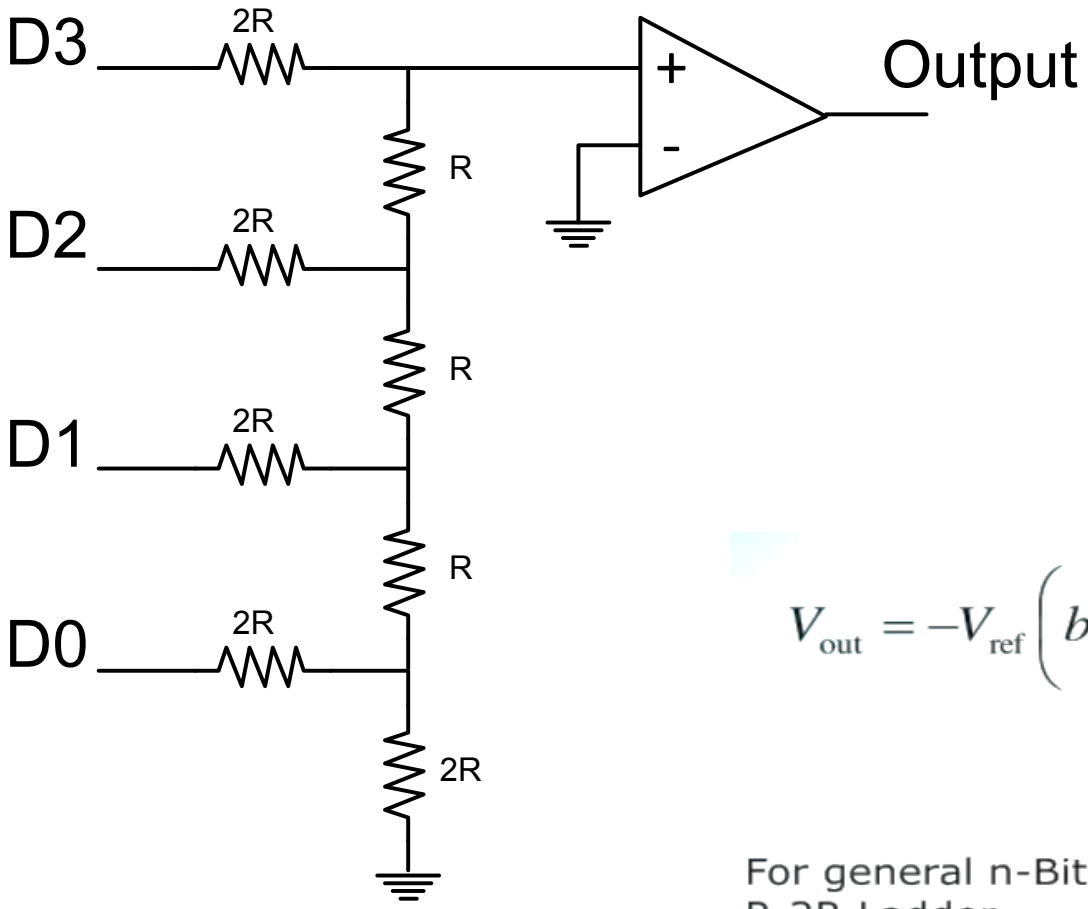
$$R_P = \frac{1}{\frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3}}$$



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



DAC circuit (R2R)



$$V_{out} = -V_{ref}\left(b_3\frac{1}{2} + b_2\frac{1}{4} + b_1\frac{1}{8} + b_0\frac{1}{16}\right)$$

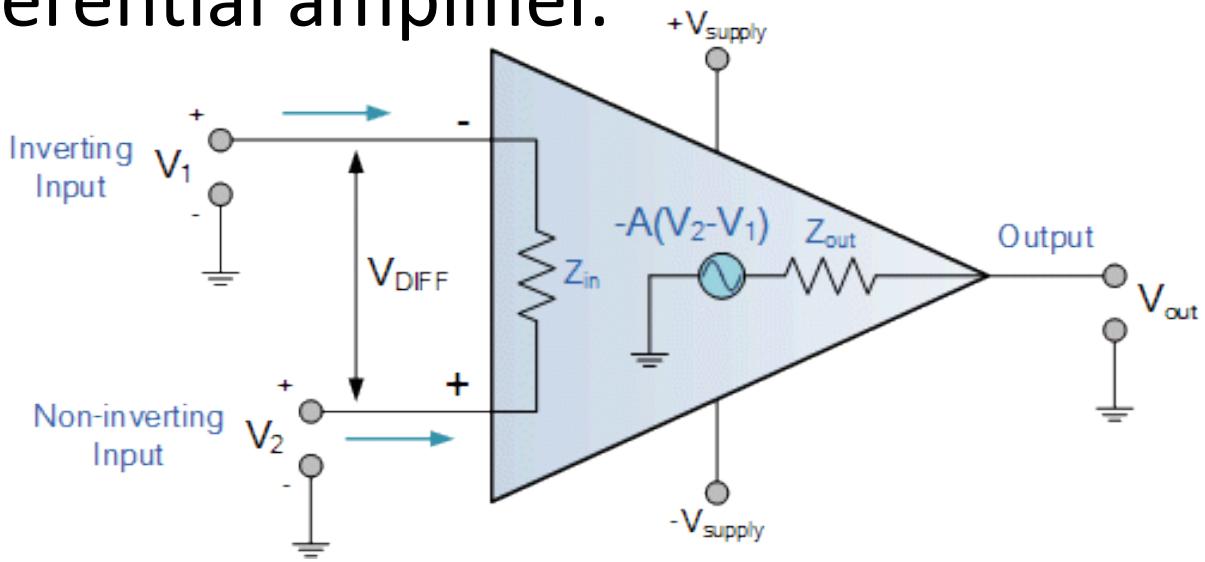
For a 4-Bit R-2R Ladder

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

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

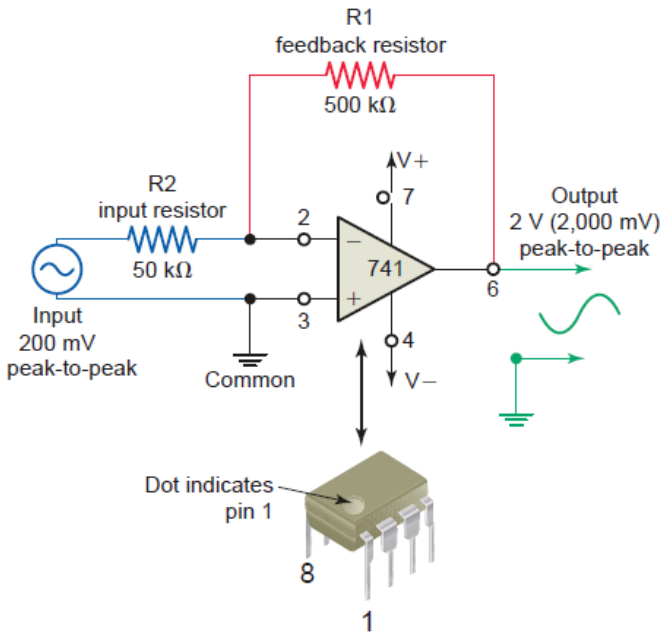
Opamp

- 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

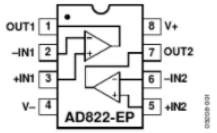


Figure 1. 8-Lead SOIC_N (R Suffix)

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.

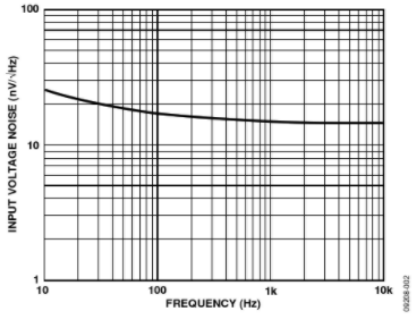


Figure 2. Input Voltage Noise vs. Frequency

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.

time

time

TYPE OF ANALOG TO DIGITAL CIRCUIT

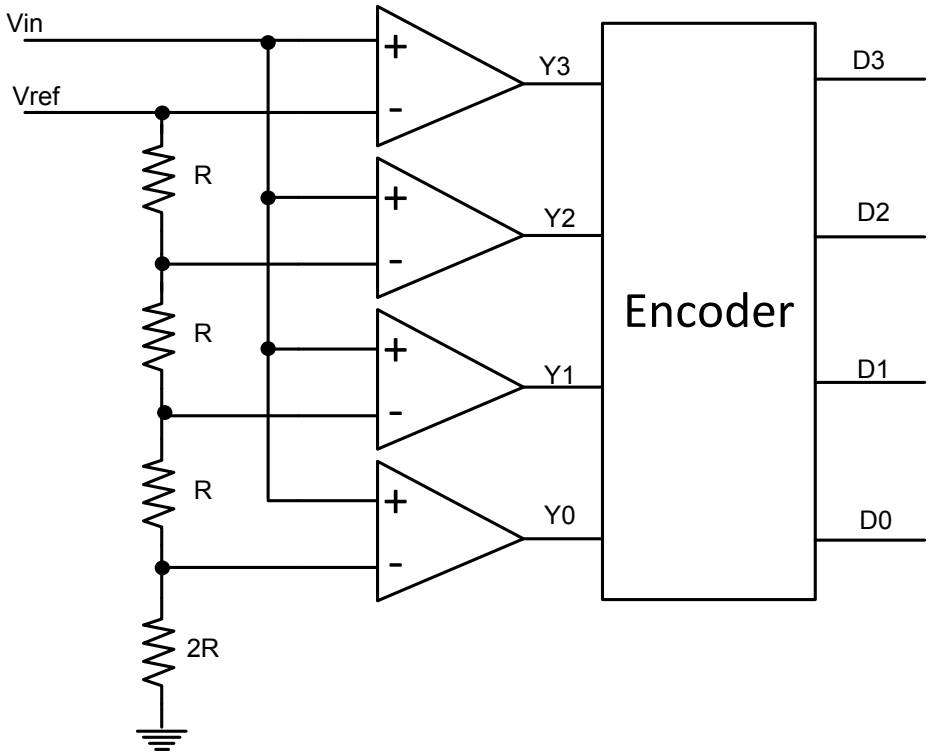
ADC circuits

- 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

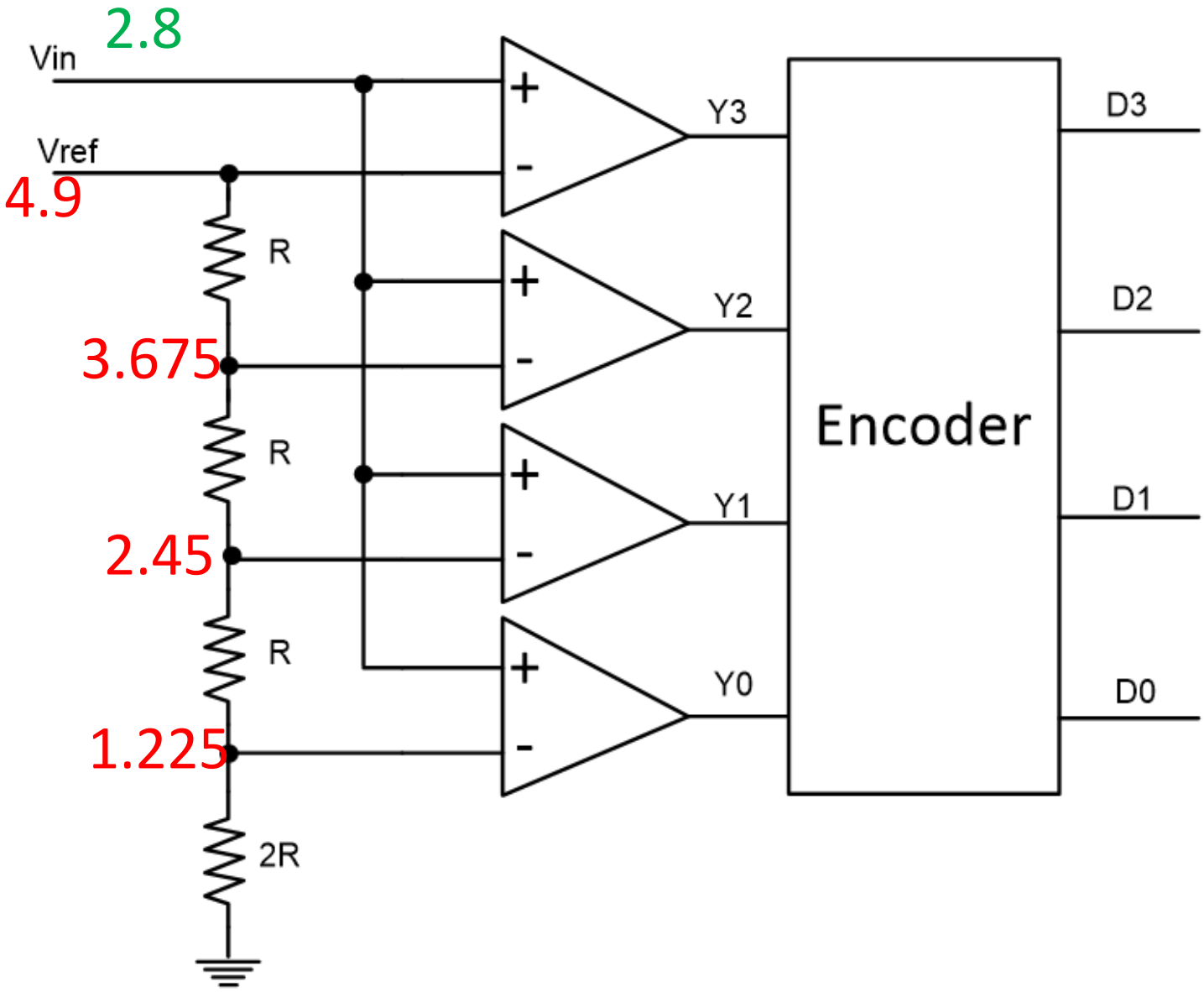
FLASH ADC

Flash ADC

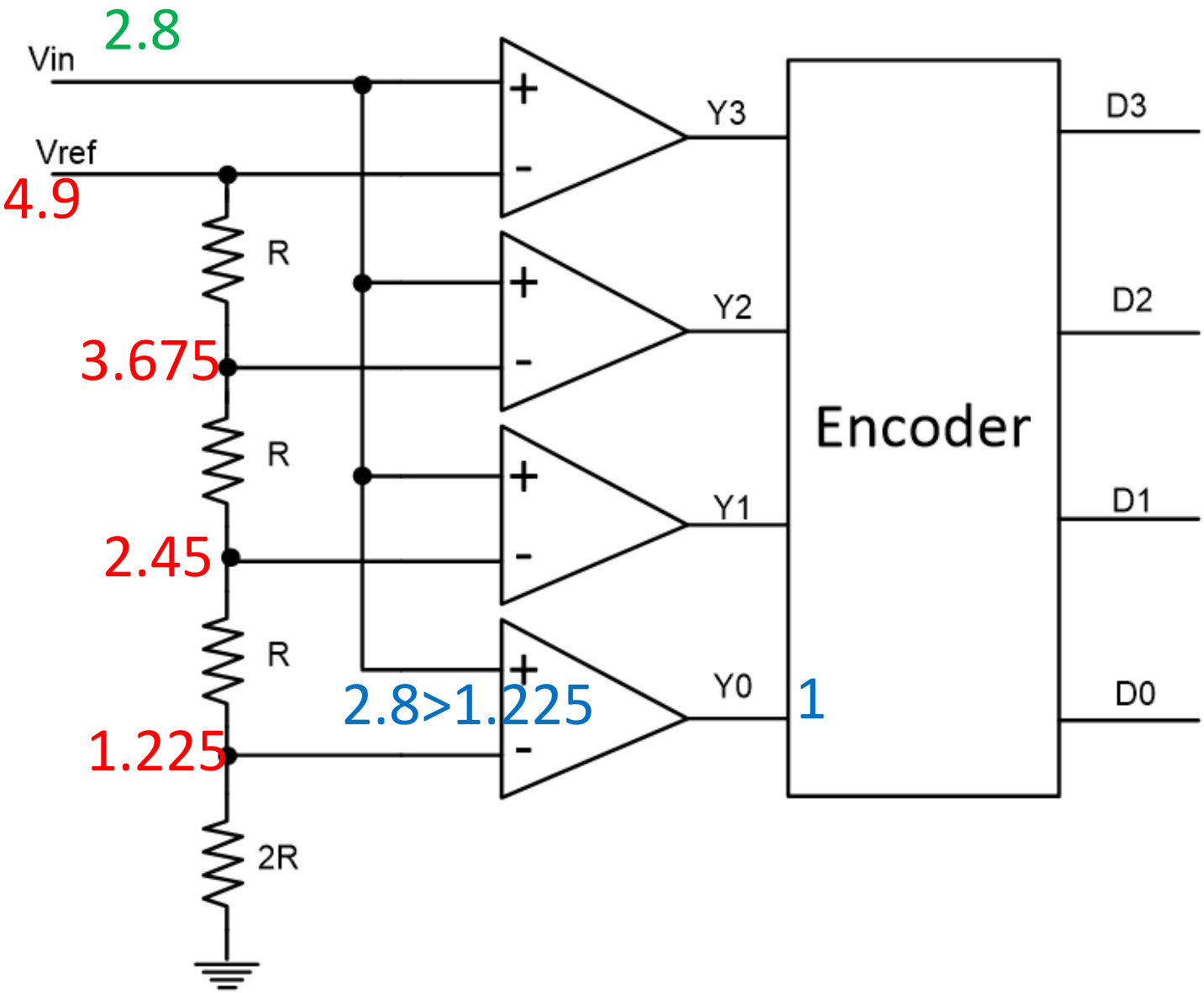
- Serie resistor for voltage dividing to create voltage references
- Compare the voltage reference with an input voltage with Opamps.
- Use encoder circuit convert to BCD data.
- Strength
  - Very fast conversion
- Weakness
  - Number of comparator require 2^{N-1}



Flash ADC: Example



Flash ADC: Example



Flash ADC: Encoder design

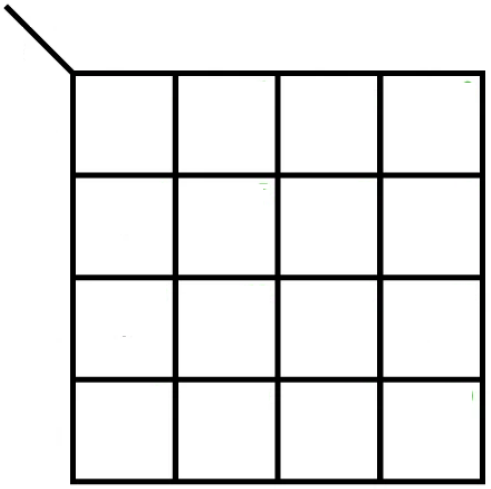
No.	Y3	Y2	Y1	Y0	D2	D1	D0
0	0	0	0	0	0	0	0
1	0	0	0	1	0	0	1
2	0	0	1	1	0	1	0
3	0	1	1	1	0	1	1
4	1	1	1	1	1	0	0

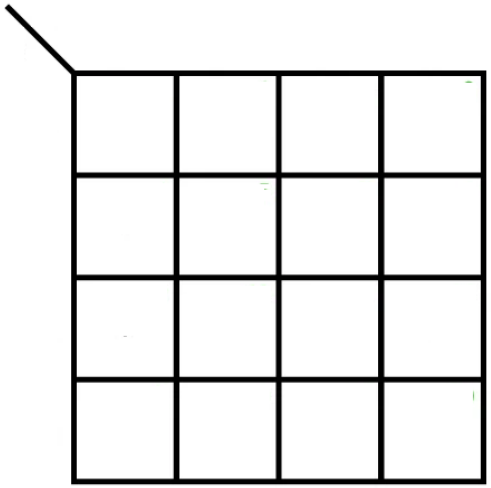
Encoder design (added don’t care bits)

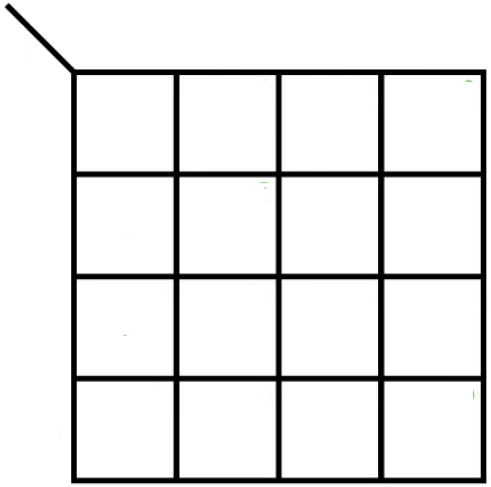
No.	Y3	Y2	Y1	Y0	D2	D1	D0
0	0	0	0	0	0	0	0
1	0	0	0	1	0	0	1
2	0	0	1	1	0	1	0
3	0	1	1	1	0	1	1
4	1	1	1	1	1	0	0
5	1	X	X	X	1	0	0
6	1	X	X	X	1	0	0
7	1	X	X	X	1	0	0

Encoder design (SOP, K-MAP)

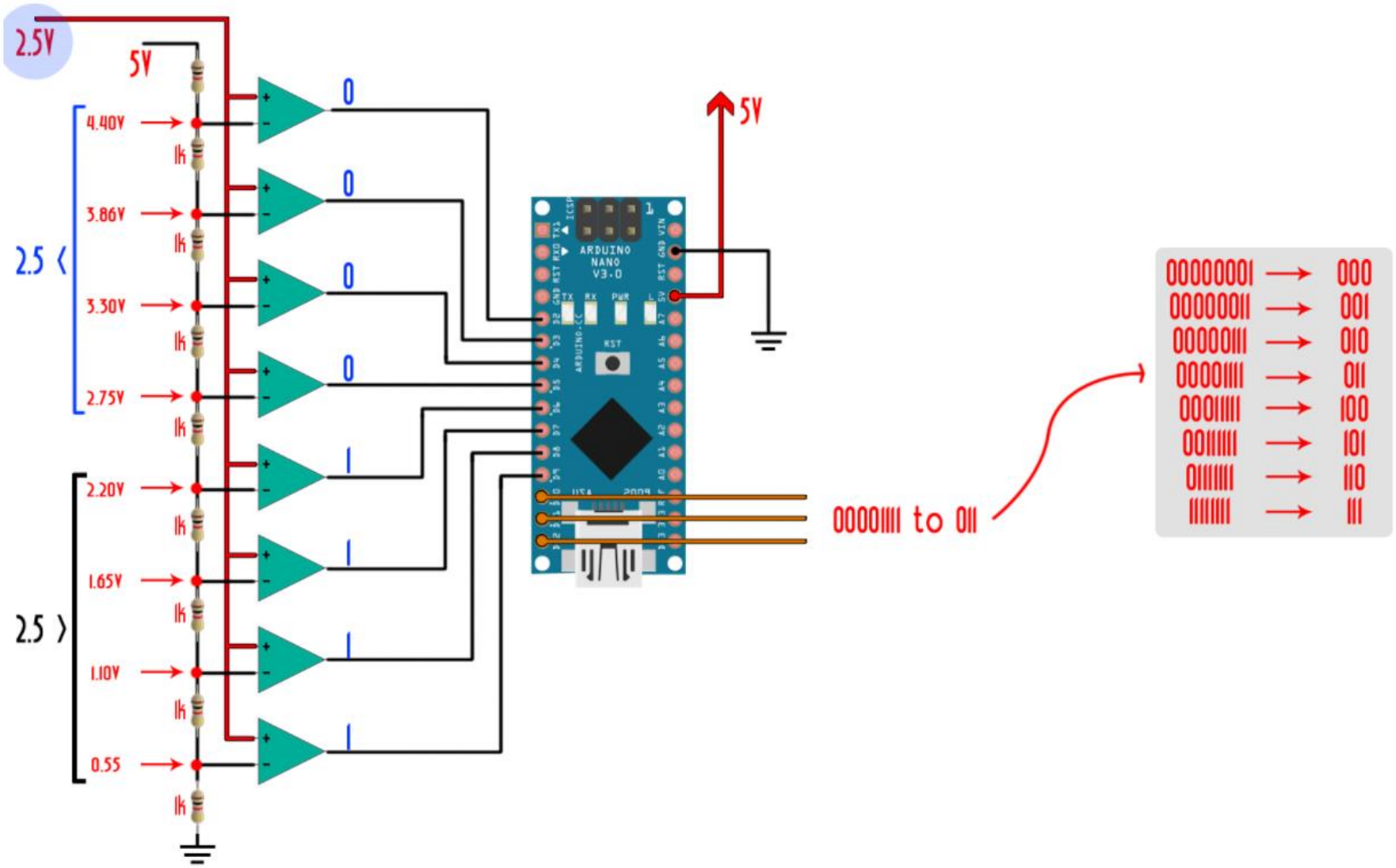
No.	Y3	Y2	Y1	Y0	D2	D1	D0
0	0	0	0	0	0	0	0
1	0	0	0	1	0	0	1
2	0	0	1	1	0	1	0
3	0	1	1	1	0	1	1
4	1	1	1	1	1	0	0
5	1	X	X	X	1	0	0
6	1	X	X	X	1	0	0
7	1	X	X	X	1	0	0







Flash ADC applied Arduino decoder



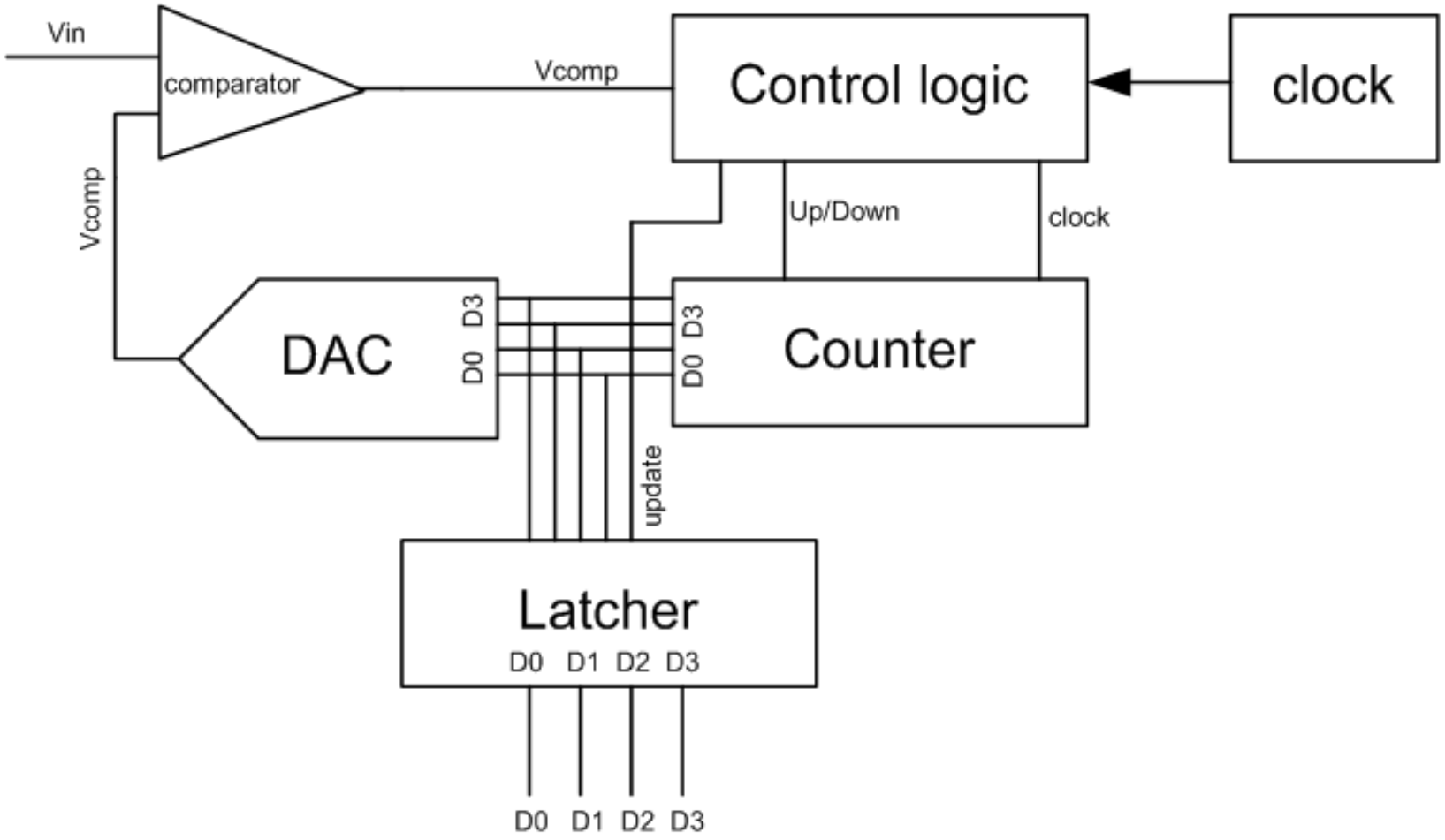
ADC: SUCCESSIVE APPROXIMATION REGISTER (SAR)

Successive Approximation Register

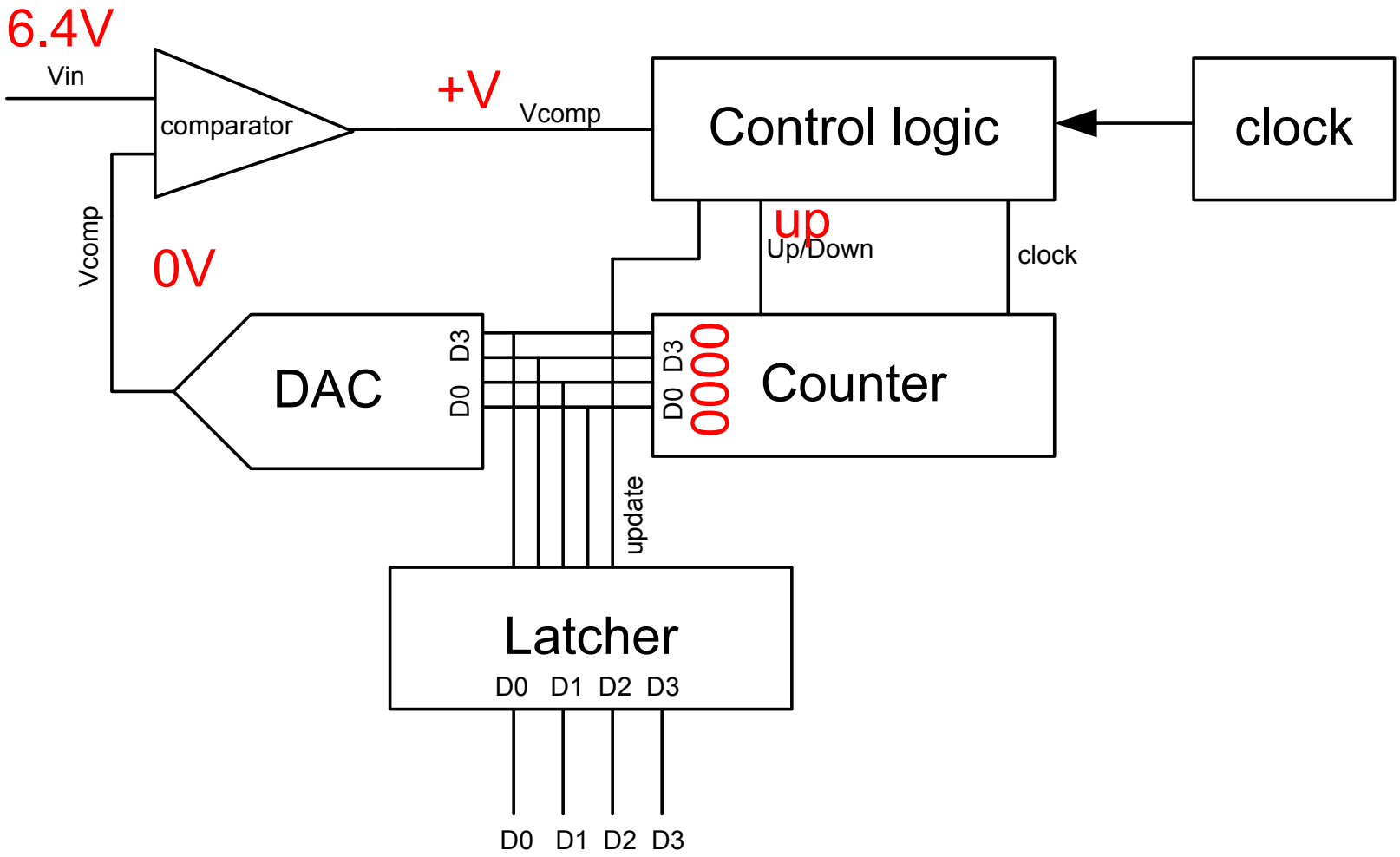
Key features

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

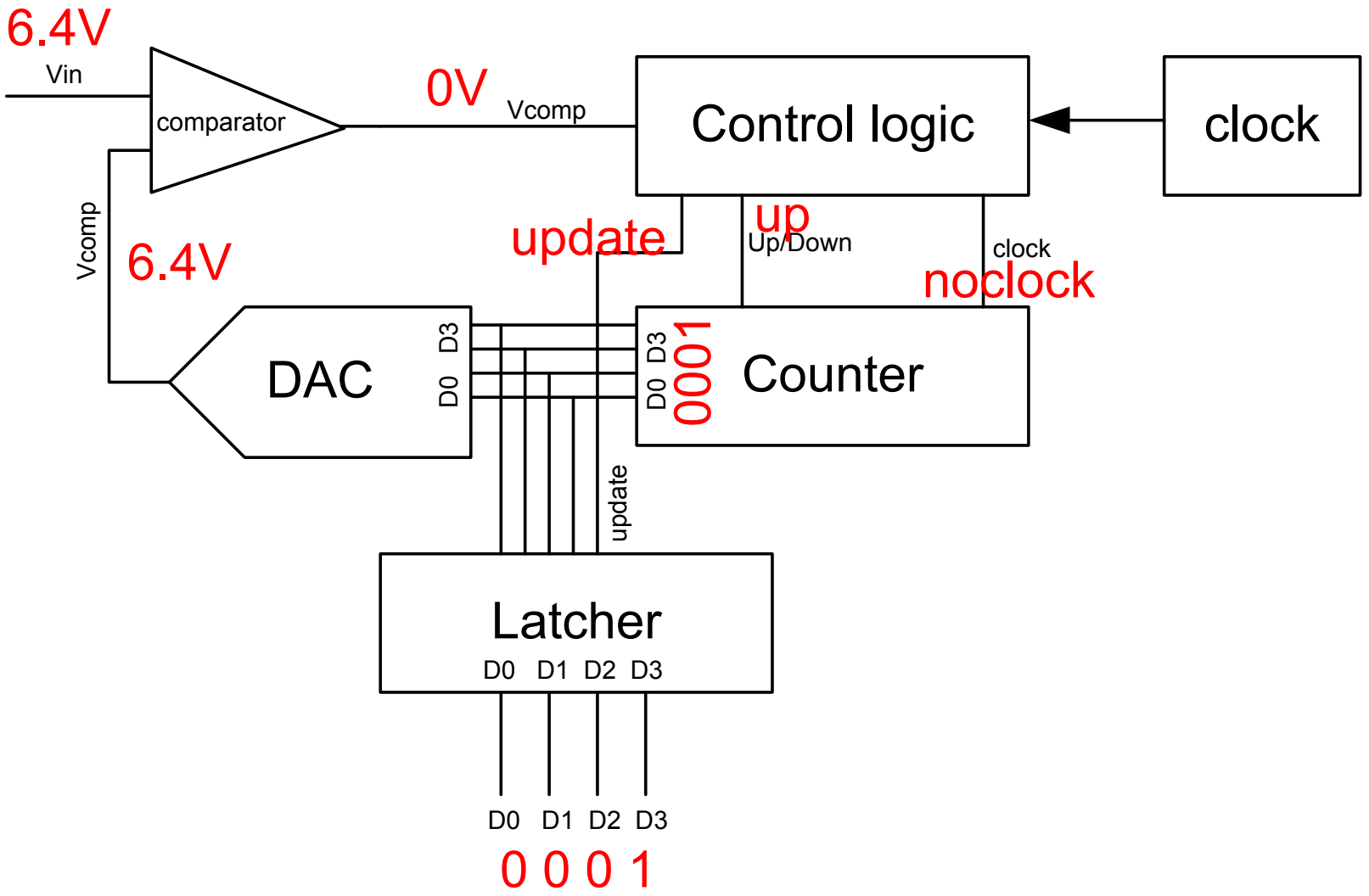
SAR-ADC


Vin
comparator
Vcomp
Control logic
clock
Vcomp
Up/Down
clock
DAC
D3
D0
D0 D3
Counter
update
Latcher
D0 D1 D2 D3
D0 D1 D2 D3

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