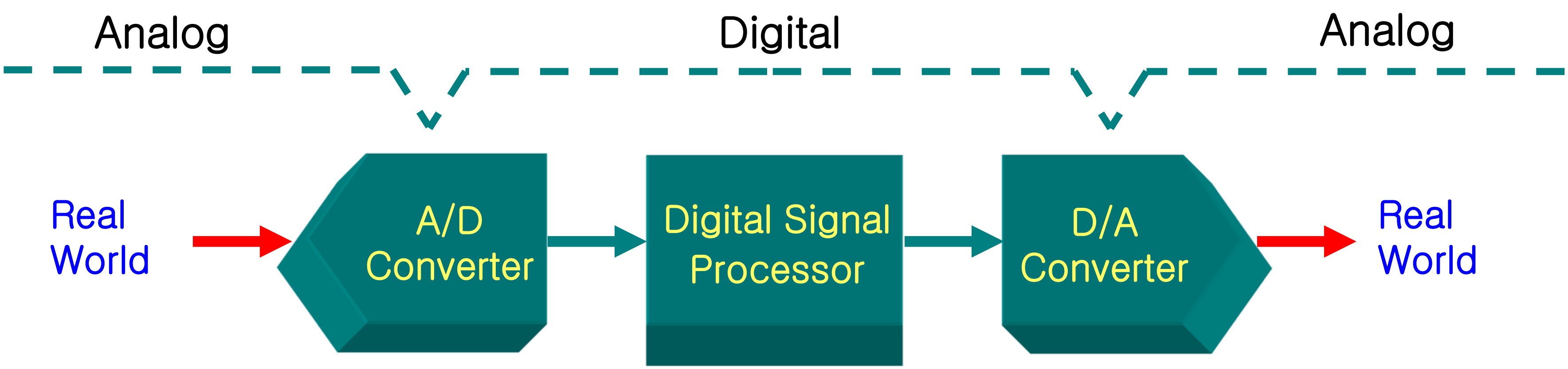
Lect. 28: Data Converters

Data Converters
- ADC: Analog to Digital Converter
- DAC: Digital to Analog Converter

Why data conversion?

- Digital is very powerful:
  Computation/Signal Processing in digital domain is much more powerful than in analog domain
- Real world is made up of analog signals



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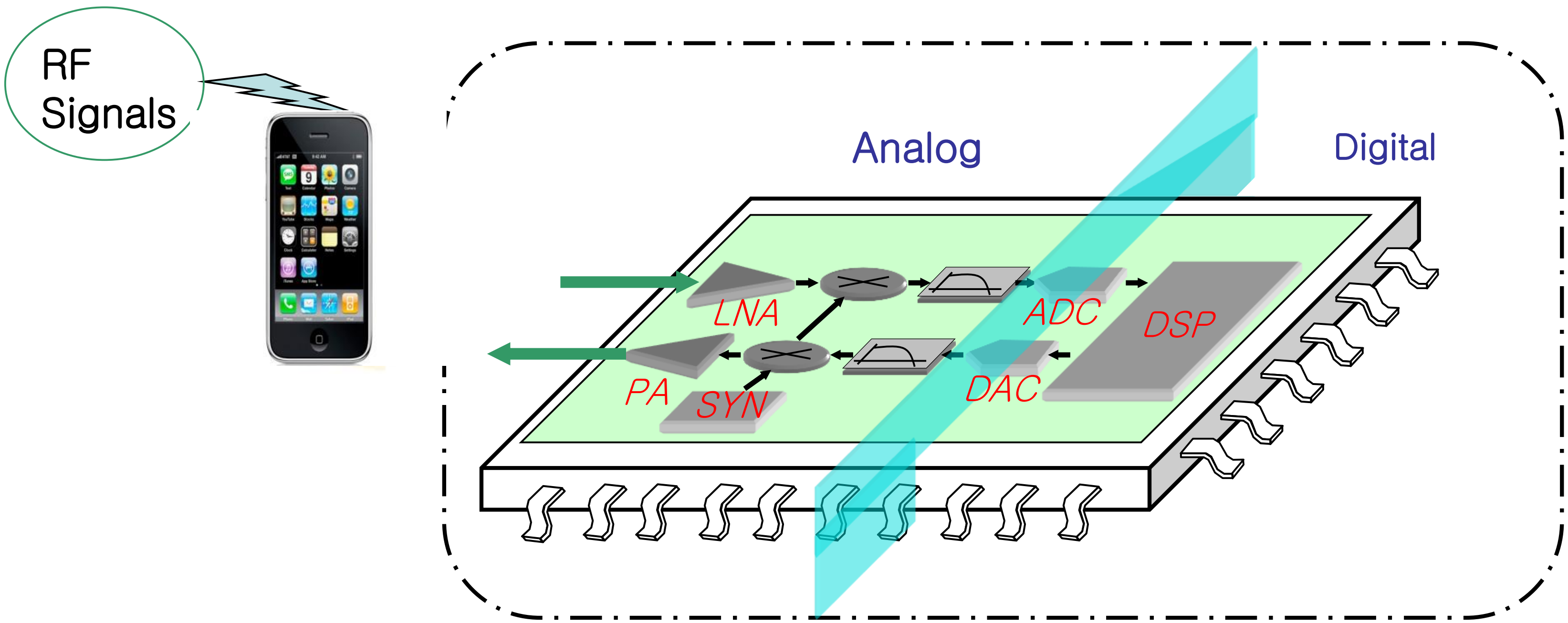
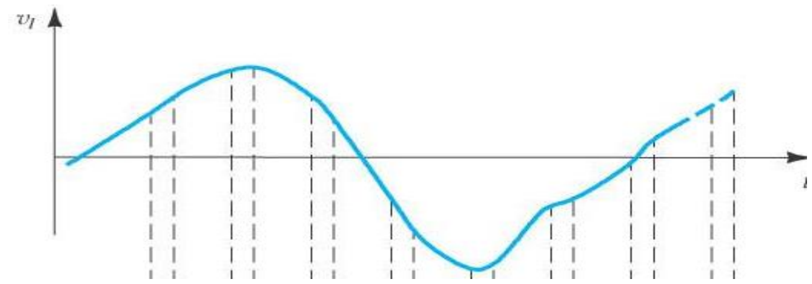
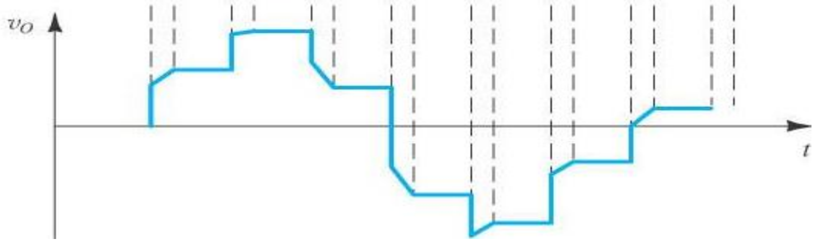


LNA: Low Noise Amplifier
PA: Power Amplifier
SYN: Frequency Synthesizer

A/D Process



Input analog signal



Sampled signal

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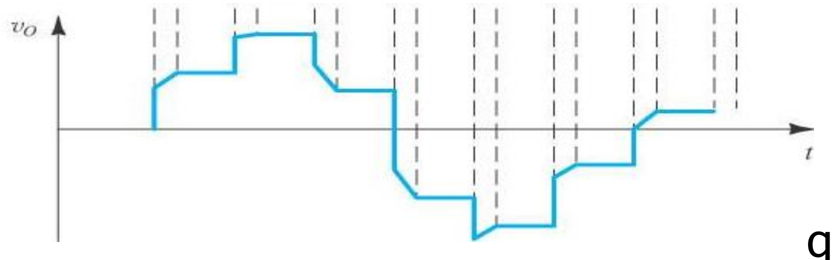
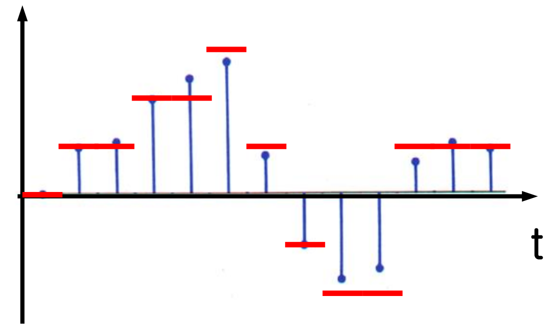
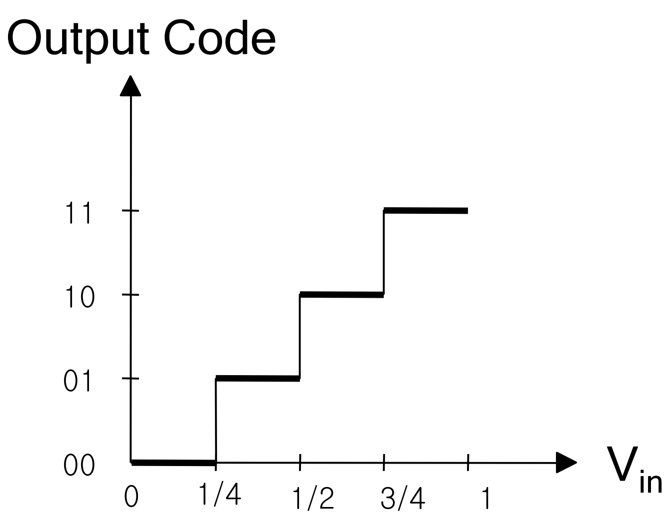


quantization





digital coding

… 01011 ….

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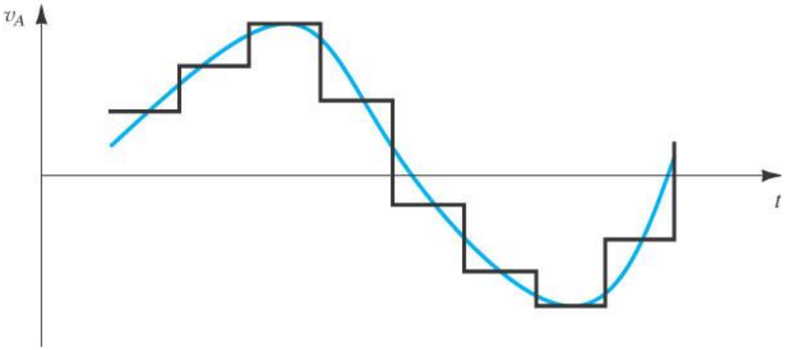
D/A Process

Digital input: …01011 ….

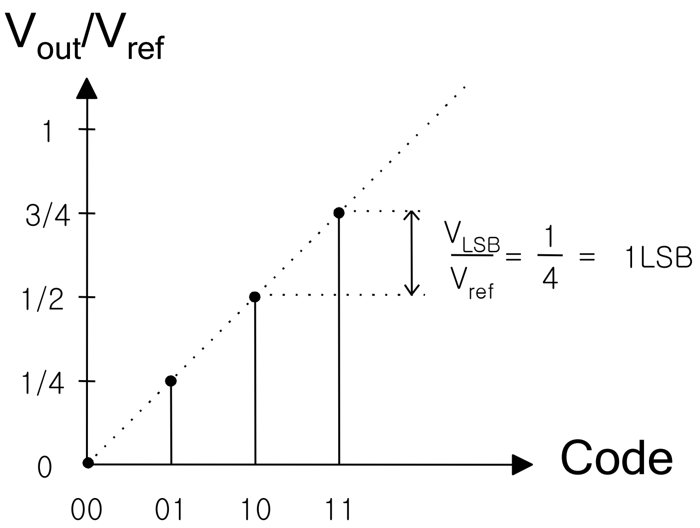


Key parameters: Resolution and bandwidth

Hardware implementation of D/A Converter

Input: $b_1 b_2 b_3 \ldots b_N$ (b_N: Least significant bit)

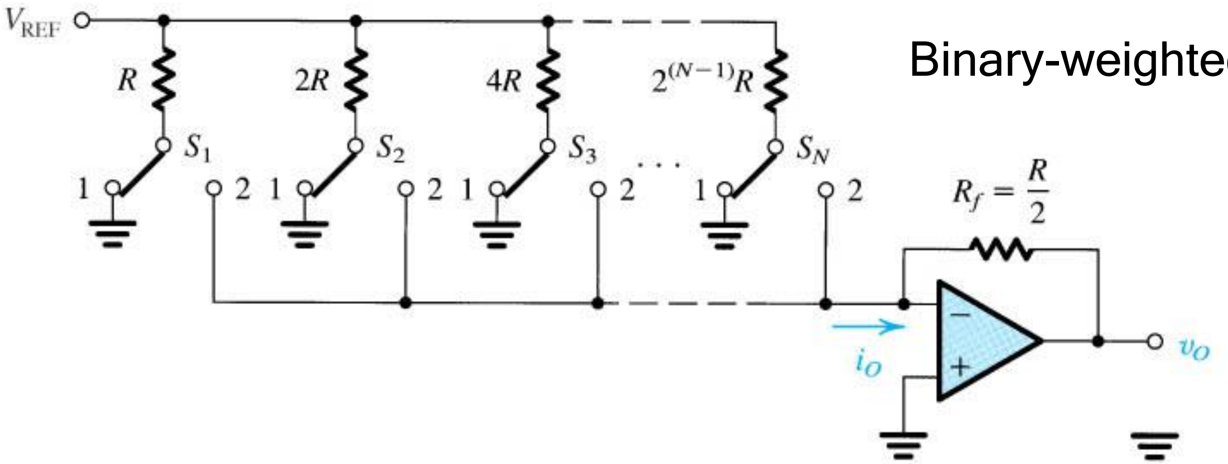
$$D = \frac{b_1}{2^1} + \frac{b_2}{2^2} + \cdot \cdot \cdot + \frac{b_N}{2^N}$$



Lect. 28: Data Converters

N-bit D/A Converter

$$D = \frac{b_1}{2^1} + \frac{b_2}{2^2} + \cdot \cdot \cdot + \frac{b_N}{2^N}$$



Binary-weighted resistors

$$i_O = \frac{V_{REF}}{R} b_1 + \frac{V_{REF}}{2R} b_2 + \cdot \cdot \cdot + \frac{V_{REF}}{2^{N-1}R} b_N = \frac{2V_{REF}}{R}\left(\frac{b_1}{2^1} + \frac{b_2}{2^2} + \cdot \cdot \cdot + \frac{b_N}{2^N}\right)$$

$$v_o = -V_{REF}\left(\frac{b_1}{2^1} + \frac{b_2}{2^2} + \cdot \cdot \cdot + \frac{b_N}{2^N}\right) = -V_{REF} D$$

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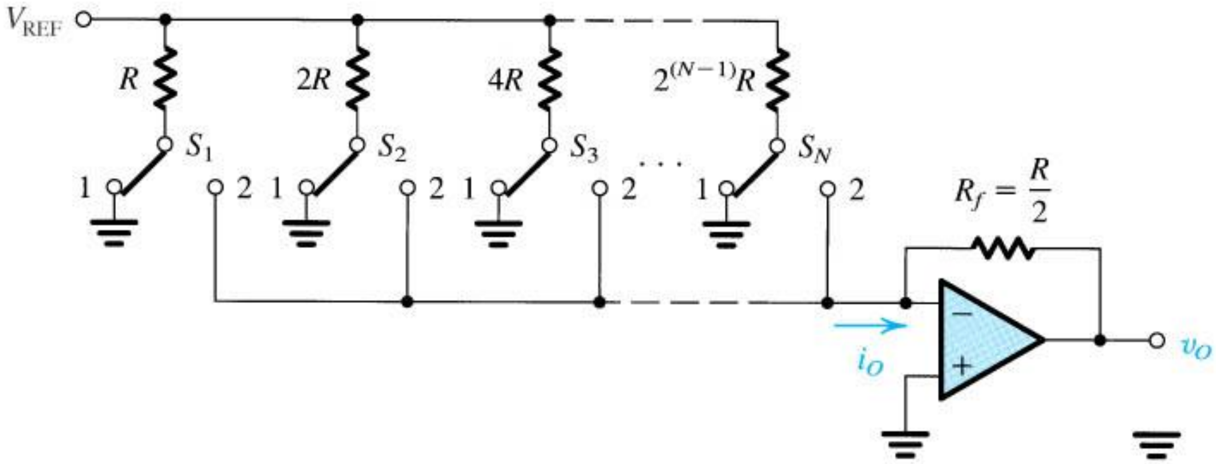
N-bit D/A Converter

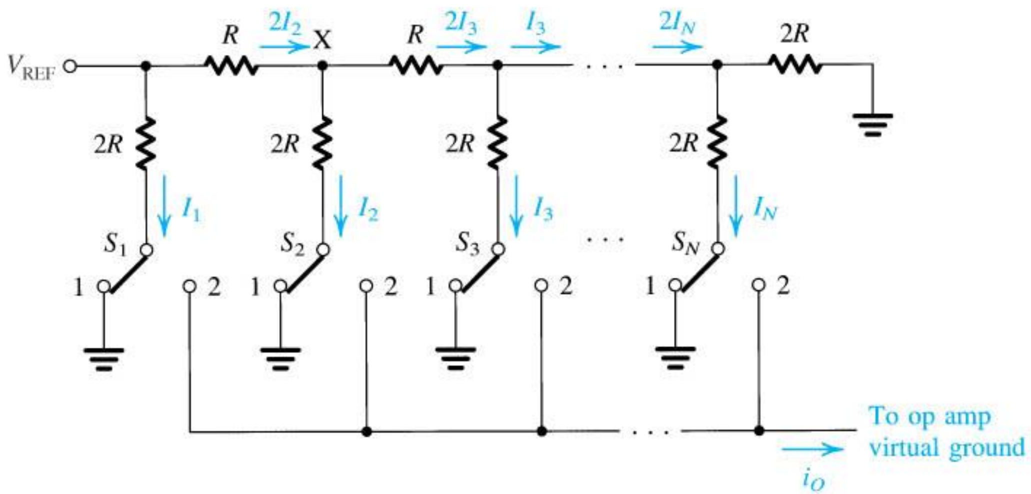


Accuracy of DAC: Precision of binary resistors

➔ With binary weighted resistors, big differences in resistance values

Lect. 28: Data Converters

D/A Converter: R-2R Ladder



$$I_1 = 2I_2 = 4I_3 = \cdots = 2^{N-1} I_N$$

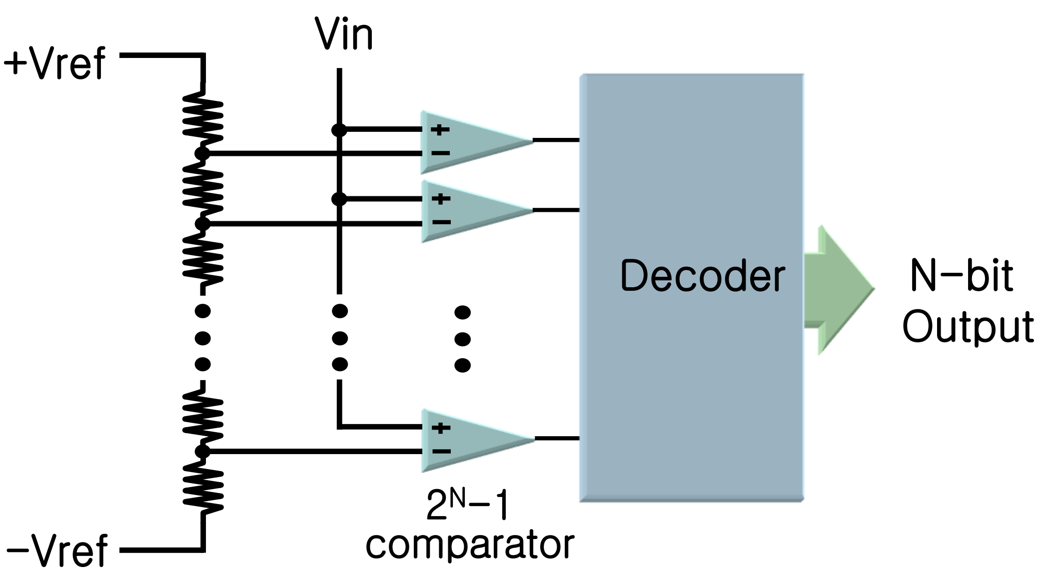
$$I_1 = \frac{V_{REF}}{2R}, I_2 = \frac{V_{REF}}{4R} \ \ldots I_N = \frac{V_{REF}}{2^N R}$$

$$i_O = \frac{V_{REF}}{R}\left(\frac{b_1}{2} + \frac{b_2}{2^2} + \ldots + \frac{b_N}{2^N}\right) = \frac{V_{REF}}{R} D$$

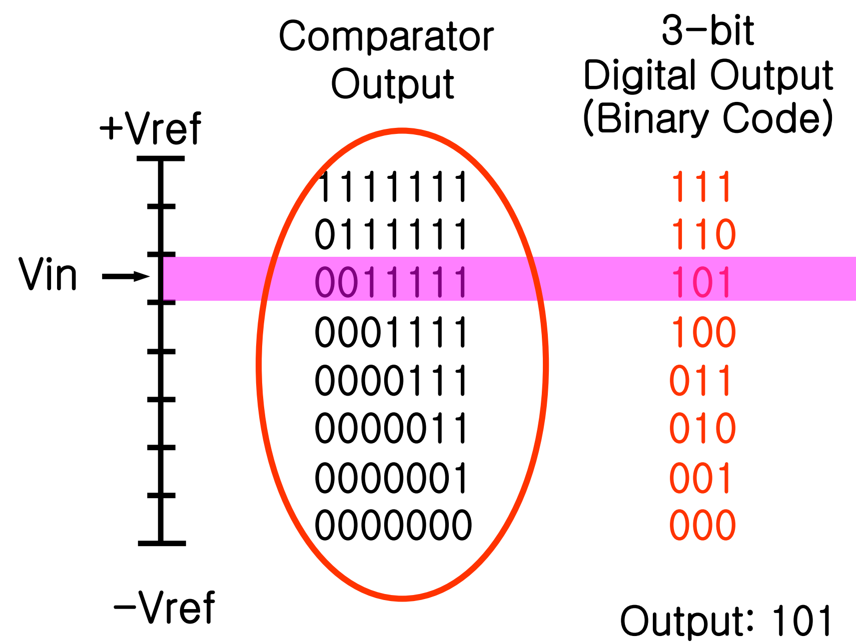
Many other techniques available.
➔ Active research area:
Resolution, bandwidth,power, manufacturability

Lect. 28: Data Converters

Flash ADC



Ex.) 3−bit Flash ADC

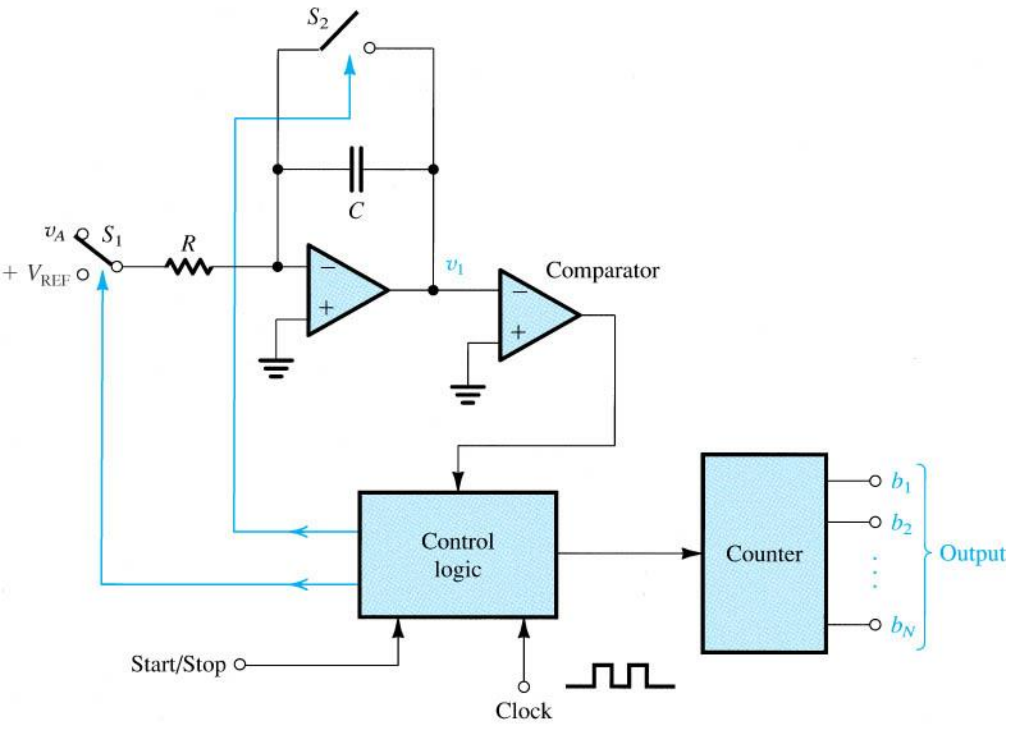


Thermometer Code

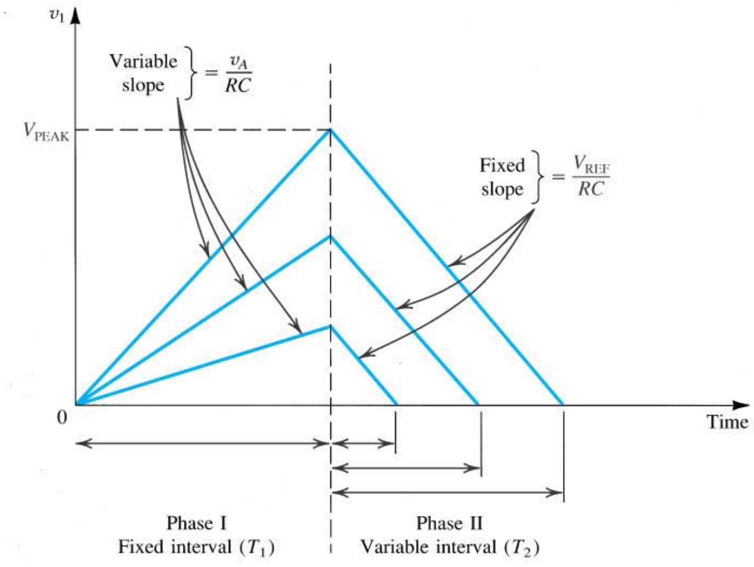
Fast because of parallel processing

R matching problem

Dual-Slope ADC



(a)



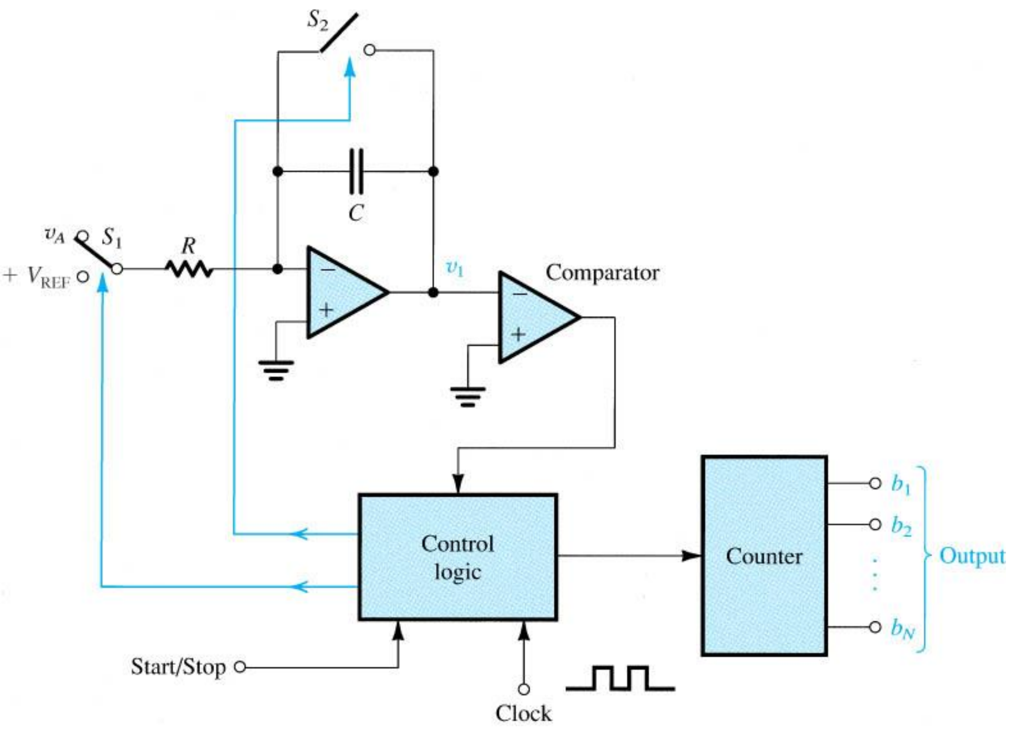
(b)

Charge up the integrator for T_1 with v_A

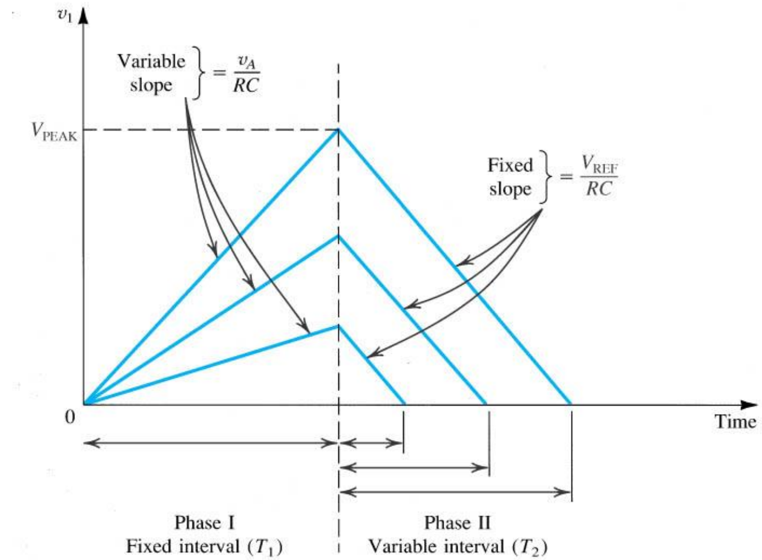
$$T_1 = \frac{V_{PEAK}}{|v_A| / RC}$$

Simultaneously count up the counter to 2^N

Dual-Slope ADC



(a)



(b)

Discharge the integrator with V_{REF}

Stop counting when v_I reaches 0 at T_2

$$T_2 = \frac{V_{PEAK}}{V_{REF} / RC} \qquad \frac{T_2}{T_1} = \frac{|v_A|}{V_{REF}}$$

High accuracy: No direct dependence on R, C

But slow

Output bit sequence is the digital bit corresponding to $\frac{|v_A|}{V_{REF}}$

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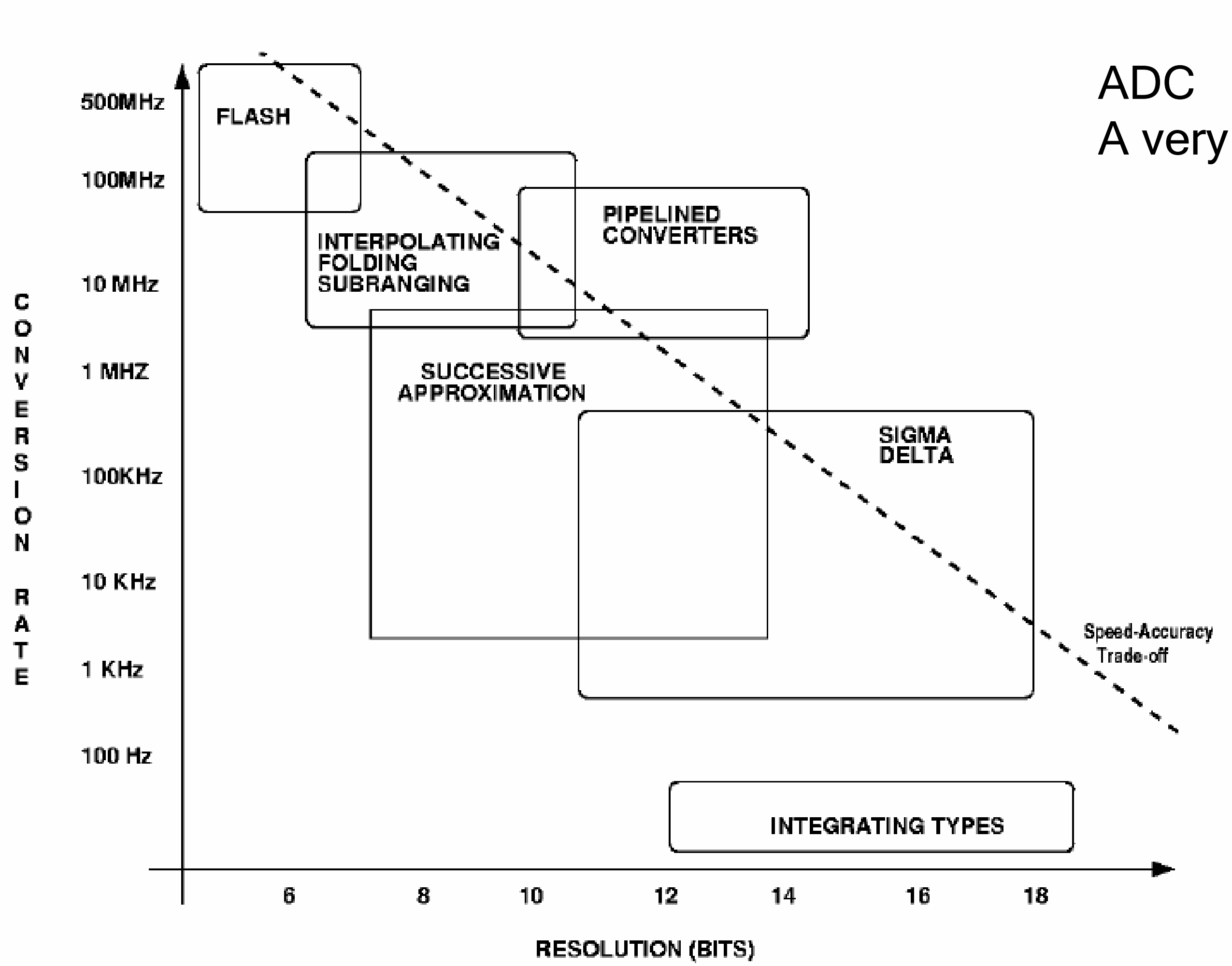

ADC

A very active research area