

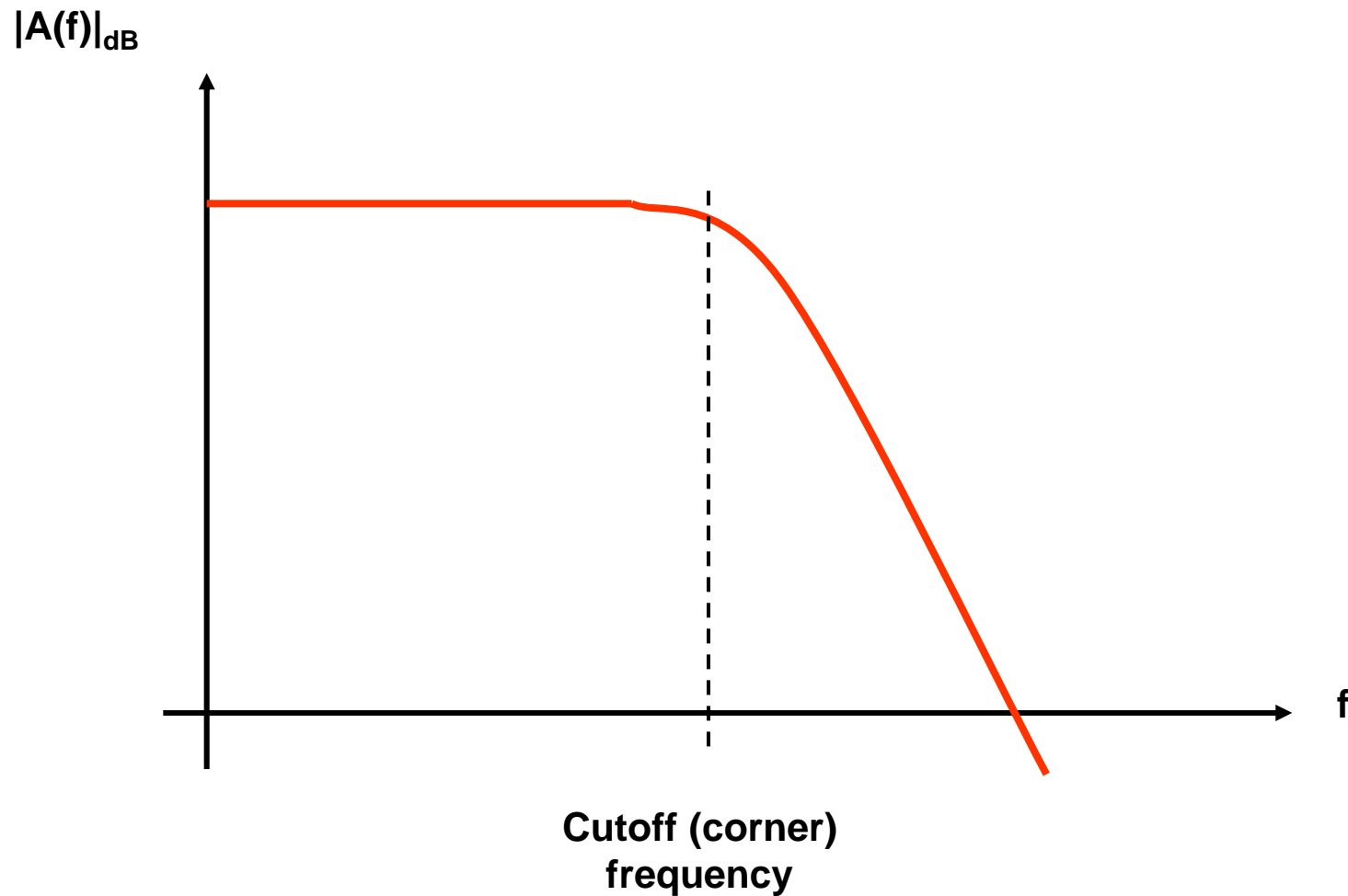
# Design IV

## E232 Fall 07

Class 7

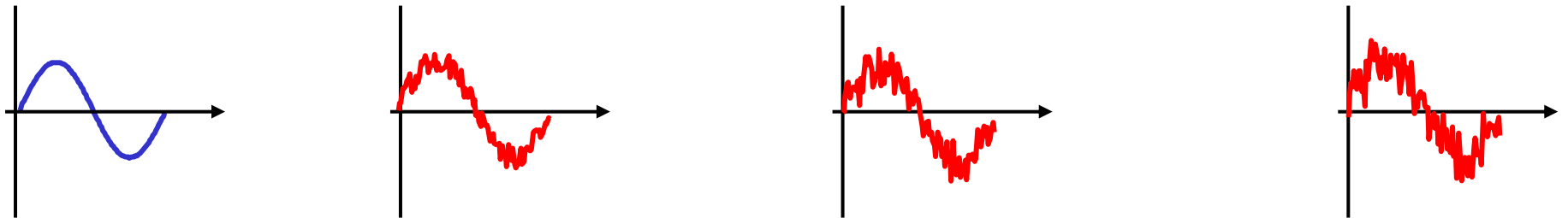
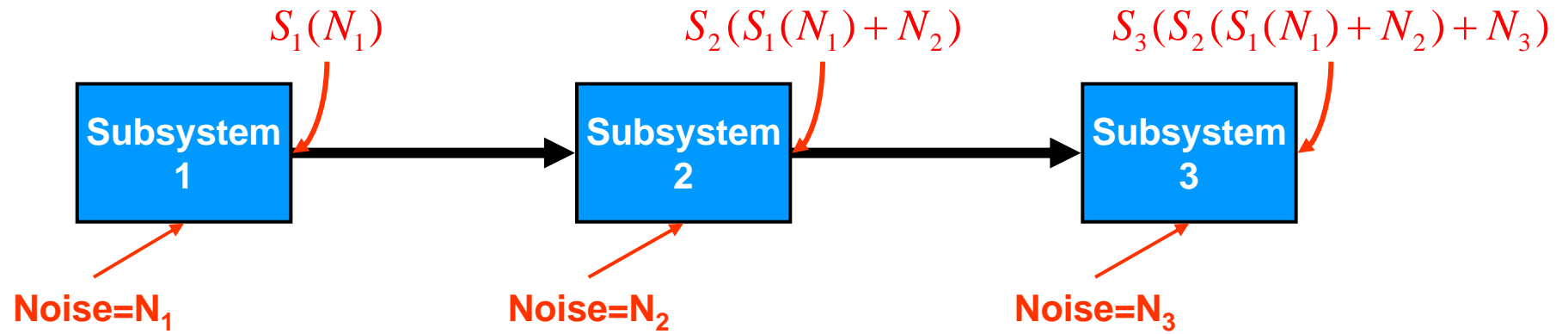
Bruce McNair  
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# Example Low-Pass Filter Design (like HW2 – Problem 3.18)



# Transmission Systems

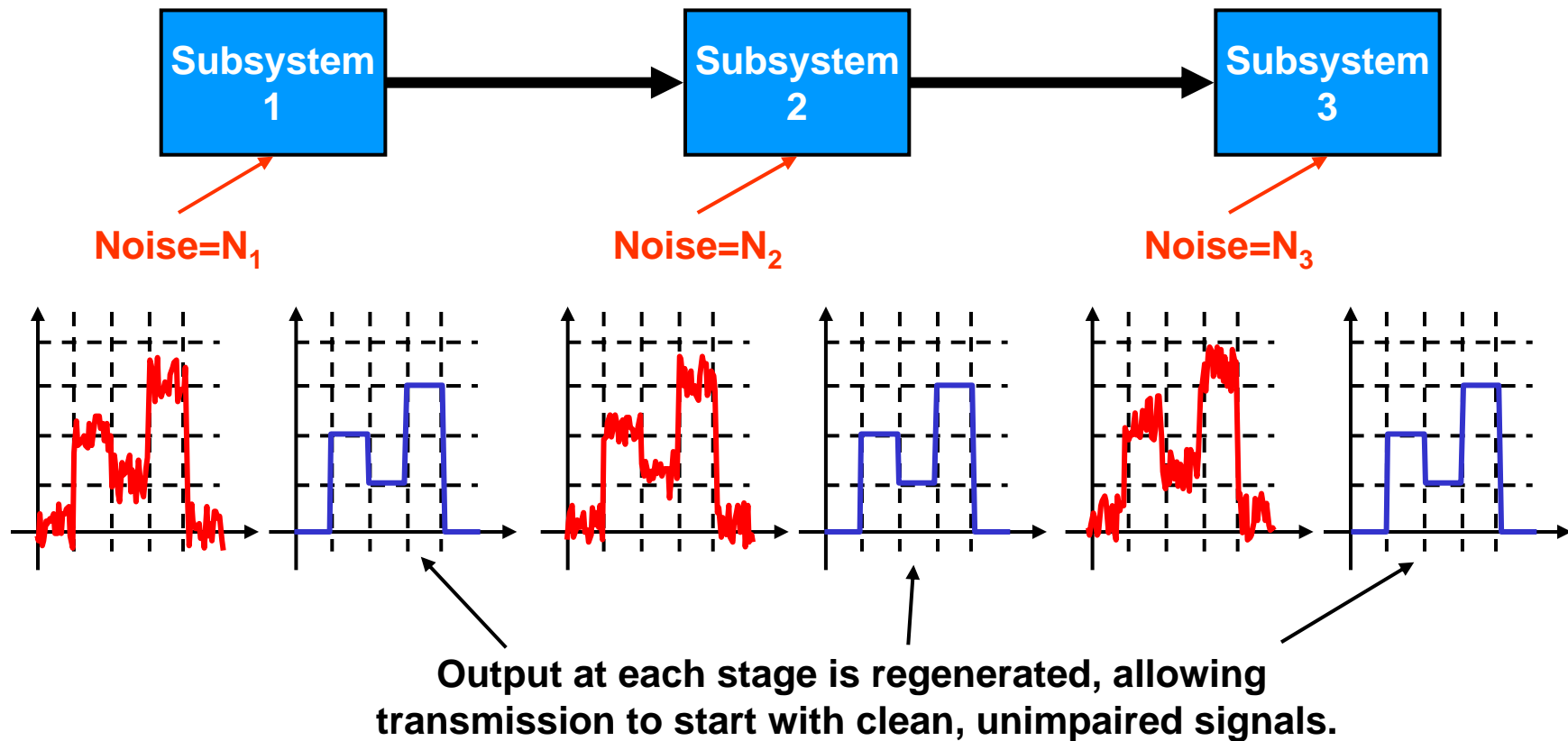
- Analog signal transmission



**Noise from each stage combines with input noise and cannot be removed**

# Transmission Systems

- Digital signal transmission



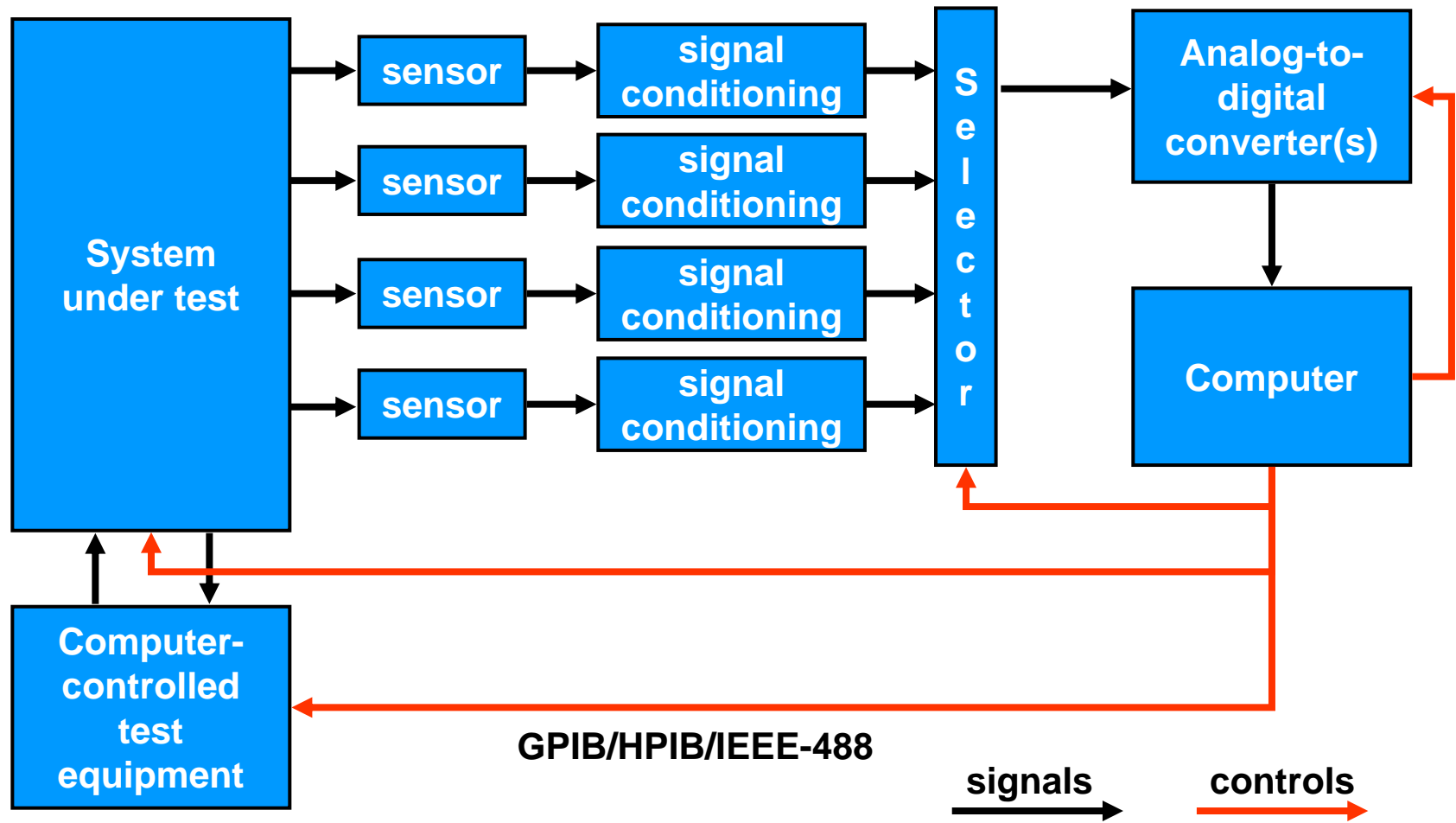
**Signals change at established points in time, with specific allowed levels**

# Today's topics

- Computerized Data Acquisition
  - Architecture
  - Components
  - Signal representation
  - A/D conversion

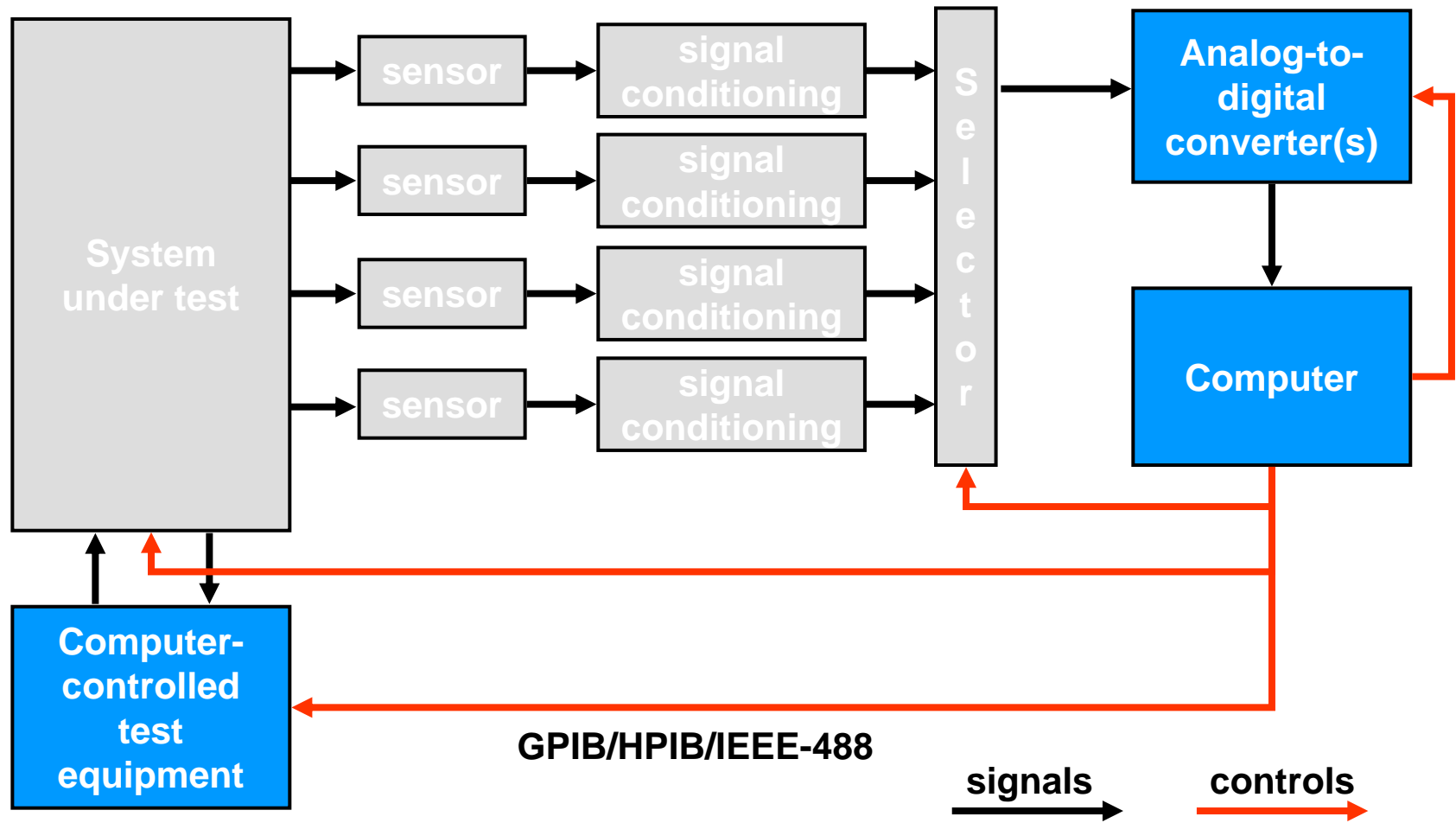
# Computerized Data Acquisition

- Measurement system architecture



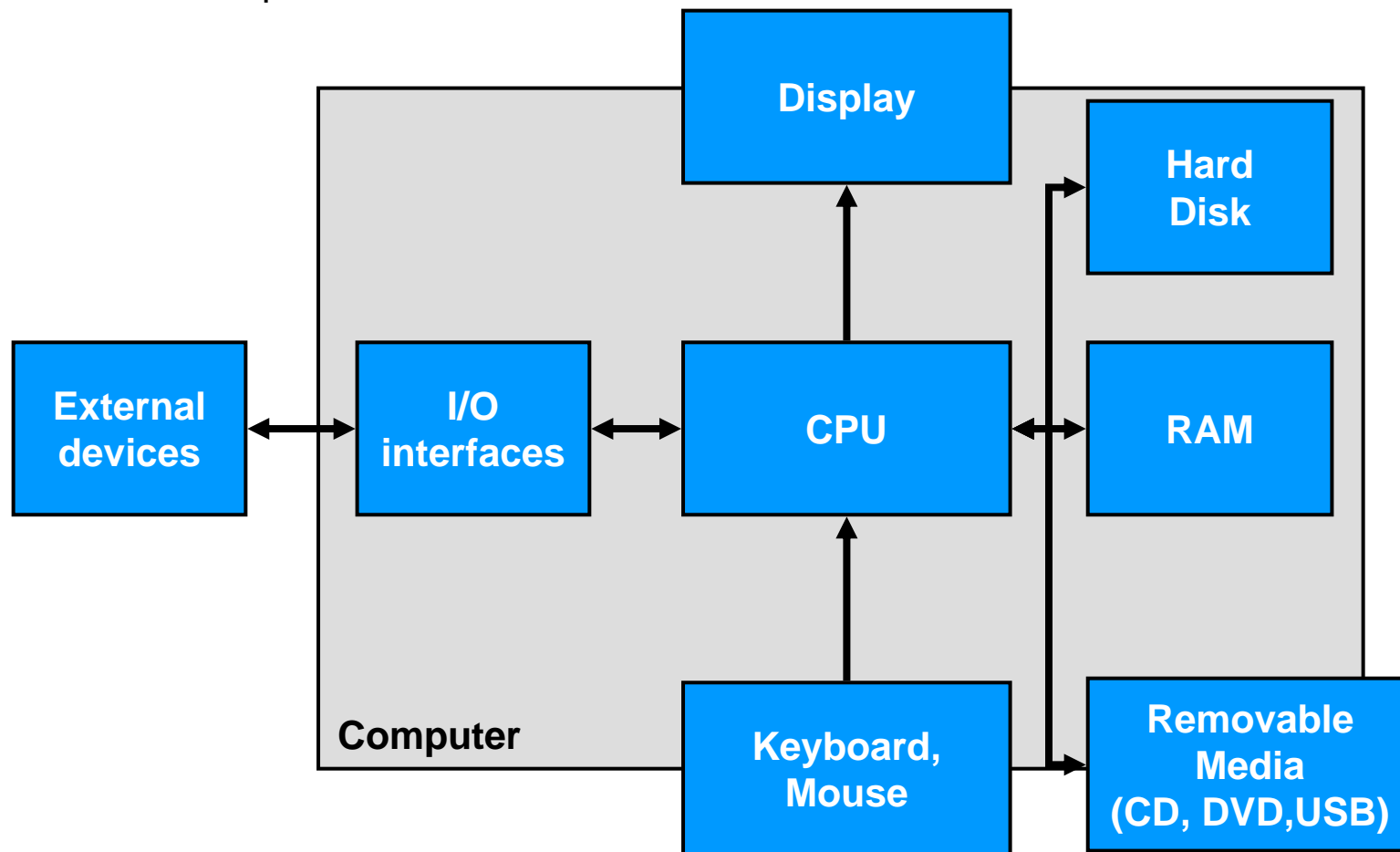
# Computerized Data Acquisition

- Measurement system architecture



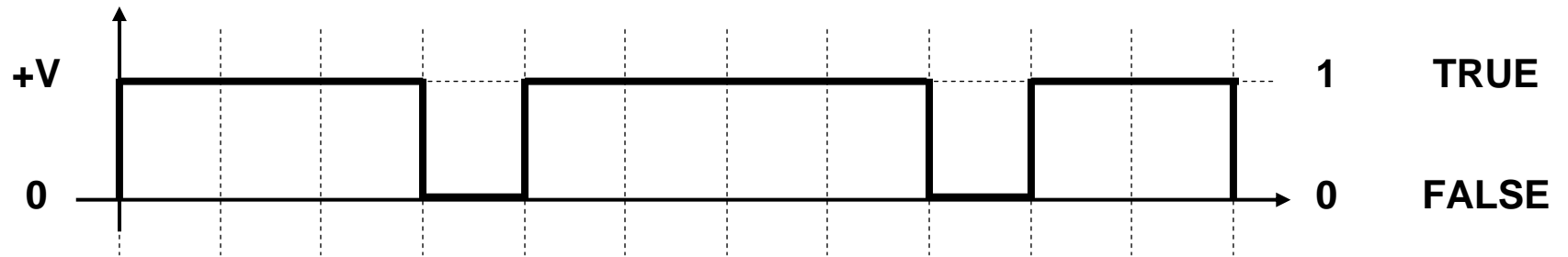
# Computerized Data Acquisition

- Components



# Computerized Data Acquisition

- Signal representation



**All information is represented by a series of 1's and 0's  
using Base-2 arithmetic**

# Computerized Data Acquisition

- Signal representation

**In Base-10 arithmetic:**

$$849_{10} = (8 \times 10^2) + (4 \times 10^1) + (9 \times 10^0)$$

# Computerized Data Acquisition

- Signal representation

**In Base-10 arithmetic:**

$$849_{10} = (8 \times 10^2) + (4 \times 10^1) + (9 \times 10^0)$$

**In Base-2 arithmetic:**

$$\begin{aligned} 849_{10} = 1101010001_2 = & \\ & (1 \times 2^9) + (1 \times 2^8) + (0 \times 2^7) + (1 \times 2^6) + (0 \times 2^5) + \\ & (1 \times 2^4) + (0 \times 2^3) + (0 \times 2^2) + (0 \times 2^1) + (1 \times 2^0) = \\ & 512 + 256 + 64 + 16 + 1 \end{aligned}$$

# Computerized Data Acquisition

- Converting Base-10 to Base-2:

- First, recognize powers of 2:

1

2

4

8

16

**$2^{10} \sim 1000$**

32

**$2^{20} \sim 1,000,000$**

64

128

**$2^{30} \sim 1,000,000,000$**

256

512

1024

2048

4096

8192

16384

32768

65536

131072

262144

524288

1048576

2097152

# Computerized Data Acquisition

- Converting Base-10 to Base-2:
  - Successive integer division by 2, noting remainder

**Remainder:**

<b>2)849</b>	
<b>2)424</b>	<b>-&gt; 1</b>
<b>2)212</b>	<b>-&gt; 0</b>
<b>2)106</b>	<b>-&gt; 0</b>
<b>2)53</b>	<b>-&gt; 0</b>
<b>2)26</b>	<b>-&gt; 1</b>
<b>2)13</b>	<b>-&gt; 0</b>
<b>2)6</b>	<b>-&gt; 1</b>
<b>2)3</b>	<b>-&gt; 0</b>
<b>2)1</b>	<b>-&gt; 1</b>
<b>0</b>	<b>-&gt; 1</b>

**-> 1101010001**

# Computerized Data Acquisition

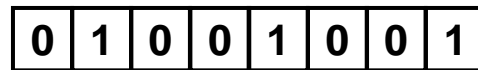
- Converting Base-2 to Base-10:
  - Successive doubling with addition of bits

$$\begin{aligned} & 1001001_2 = \\ & 2^6 + 2^3 + 2^0 = \\ & (((1 \times 2) + 0) \times 2) + 0) \times 2) + 1) \times 2) + 0) \times 2) + 0) \times 2) + 1 = 73_{10} \end{aligned}$$

# Computerized Data Acquisition

- Representing binary numbers

$73_{10}$ :



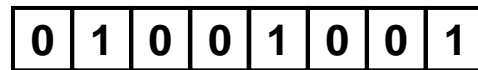
**MSB**

**LSB**

# Computerized Data Acquisition

- Representing binary numbers

$73_{10}$ :



**MSB**

**LSB**

- Representing negative numbers – 2's complement:

$-73_{10}$ :



**MSB**

**LSB**

# Computerized Data Acquisition

- Representing binary numbers

$73_{10}$ :

0	1	0	0	1	0	0	1
---	---	---	---	---	---	---	---

**MSB**

**LSB**

- Representing negative numbers – 2's complement:

$-73_{10}$ :

**Sign**

1	0	1	1	0	1	1	1
---	---	---	---	---	---	---	---

**MSB**

**LSB**

	<b>01001001</b>
<b>Invert bits</b>	<b>10110110</b>
<b>Add 1</b>	<b>00000001</b>
	<b>10110111</b>

# Computerized Data Acquisition

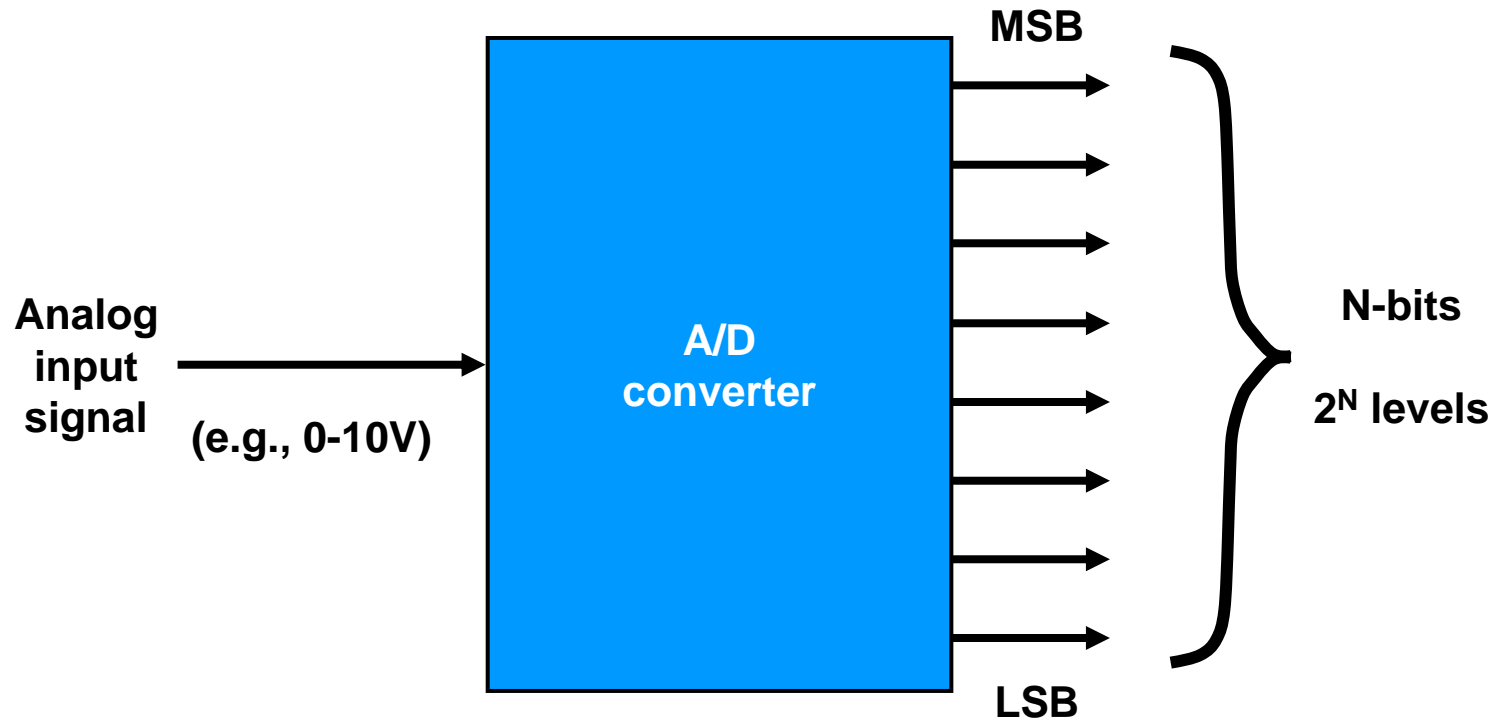
- Arithmetic with 2's complement

$10_{10}$	00001010
$+23_{10}$	00010111
-----	-----
$33_{10}$	00100001
$-17_{10}$	11101111
-----	-----
$16_{10}$	X00010000

**2's complement numbers can be added (subtraction by adding negative numbers) continually, as long as final result can fit in word size.**

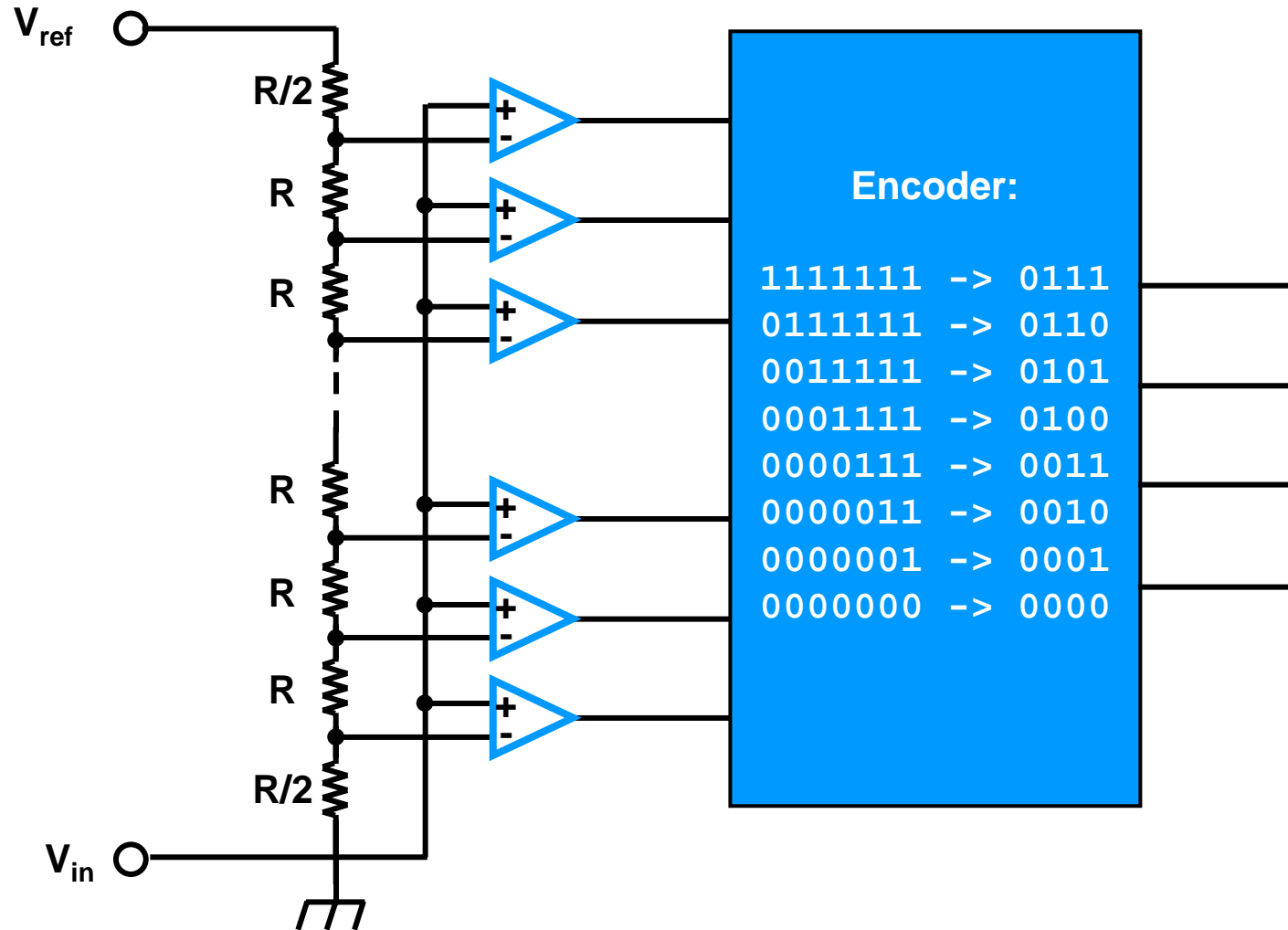
# Computerized Data Acquisition

- Analog-to-digital converters



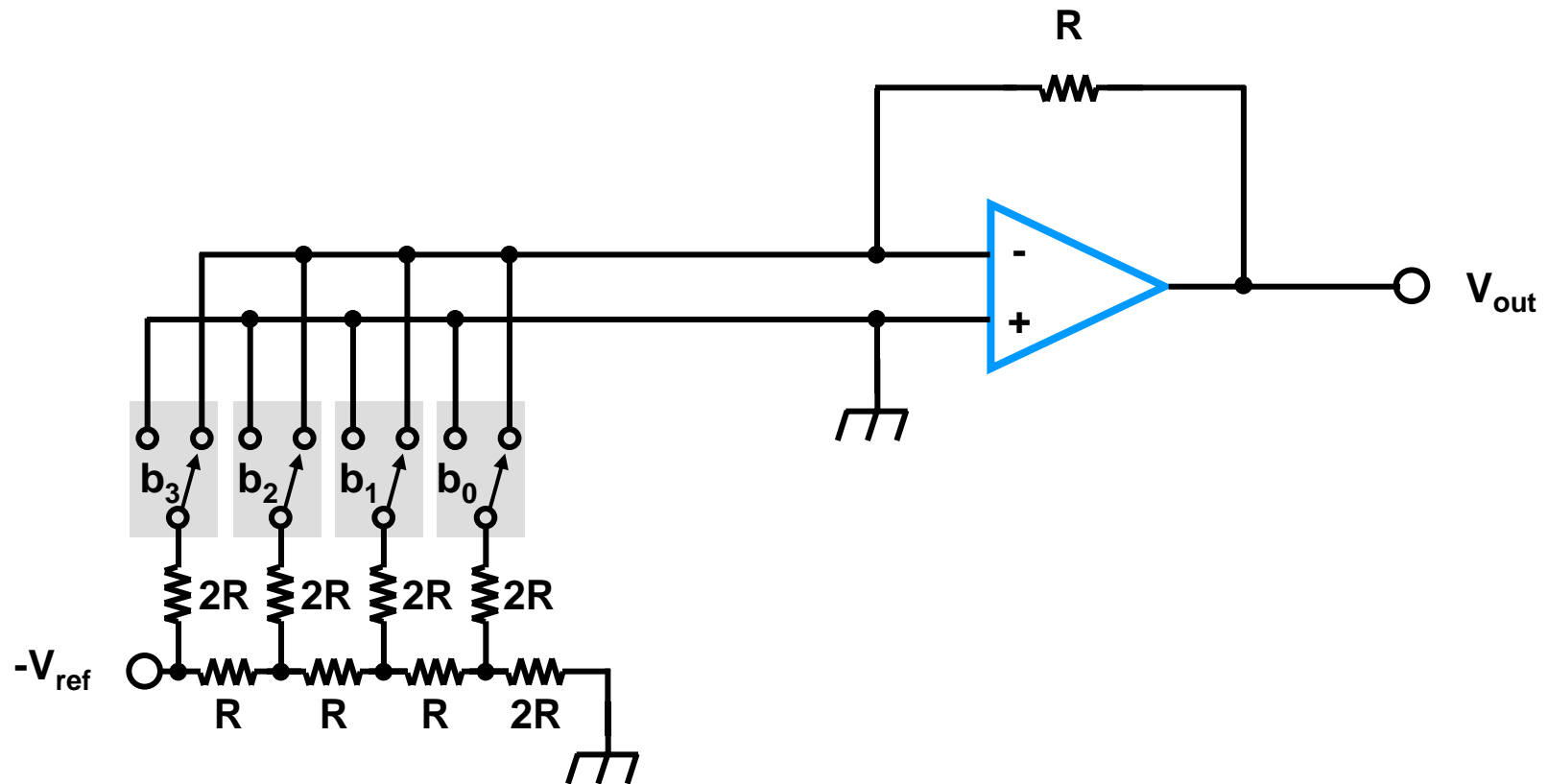
# Computerized Data Acquisition

- Analog-to-digital converters – Parallel/Flash A/D



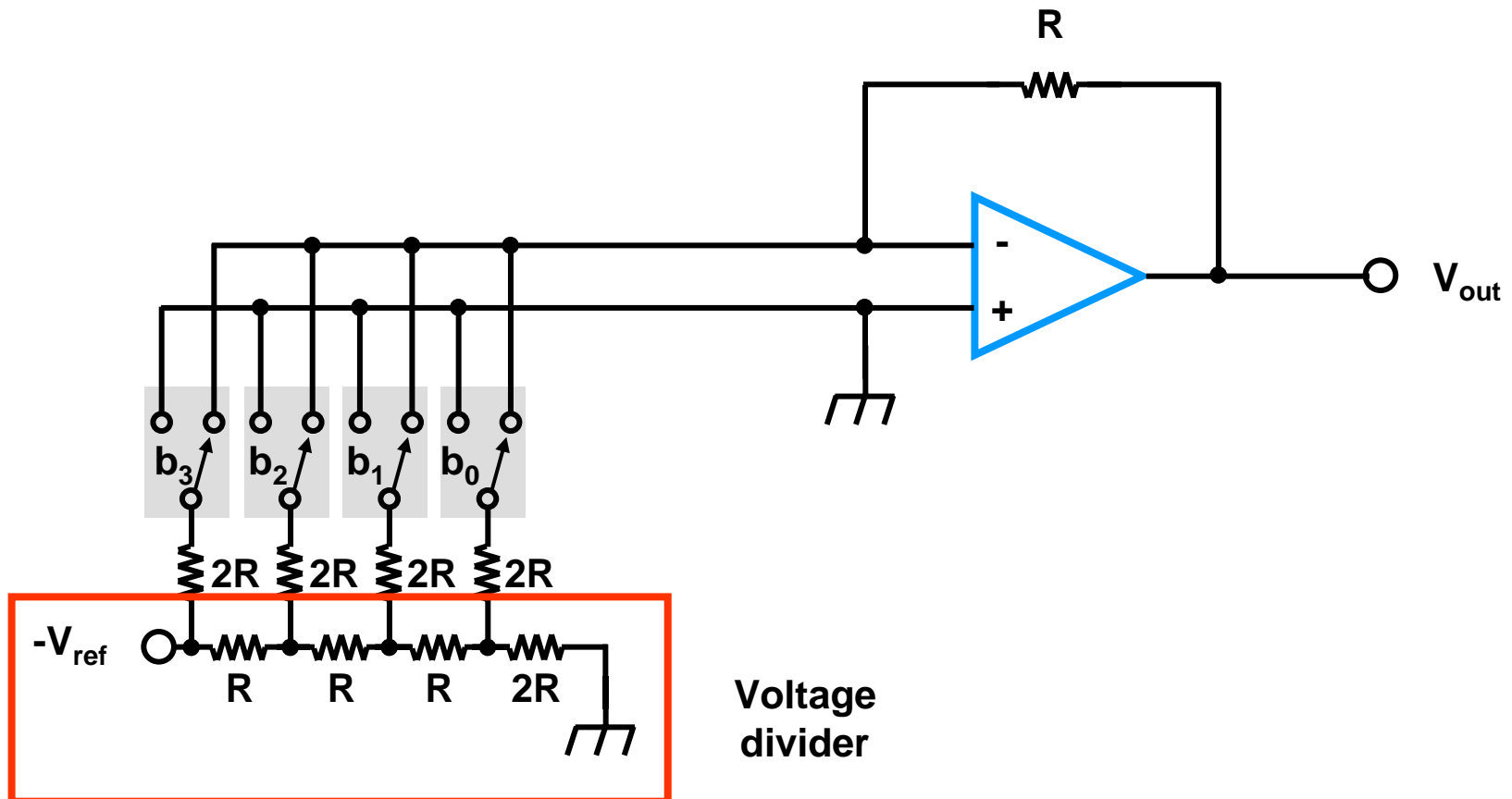
# Computerized Data Acquisition

- Digital-to-analog converters



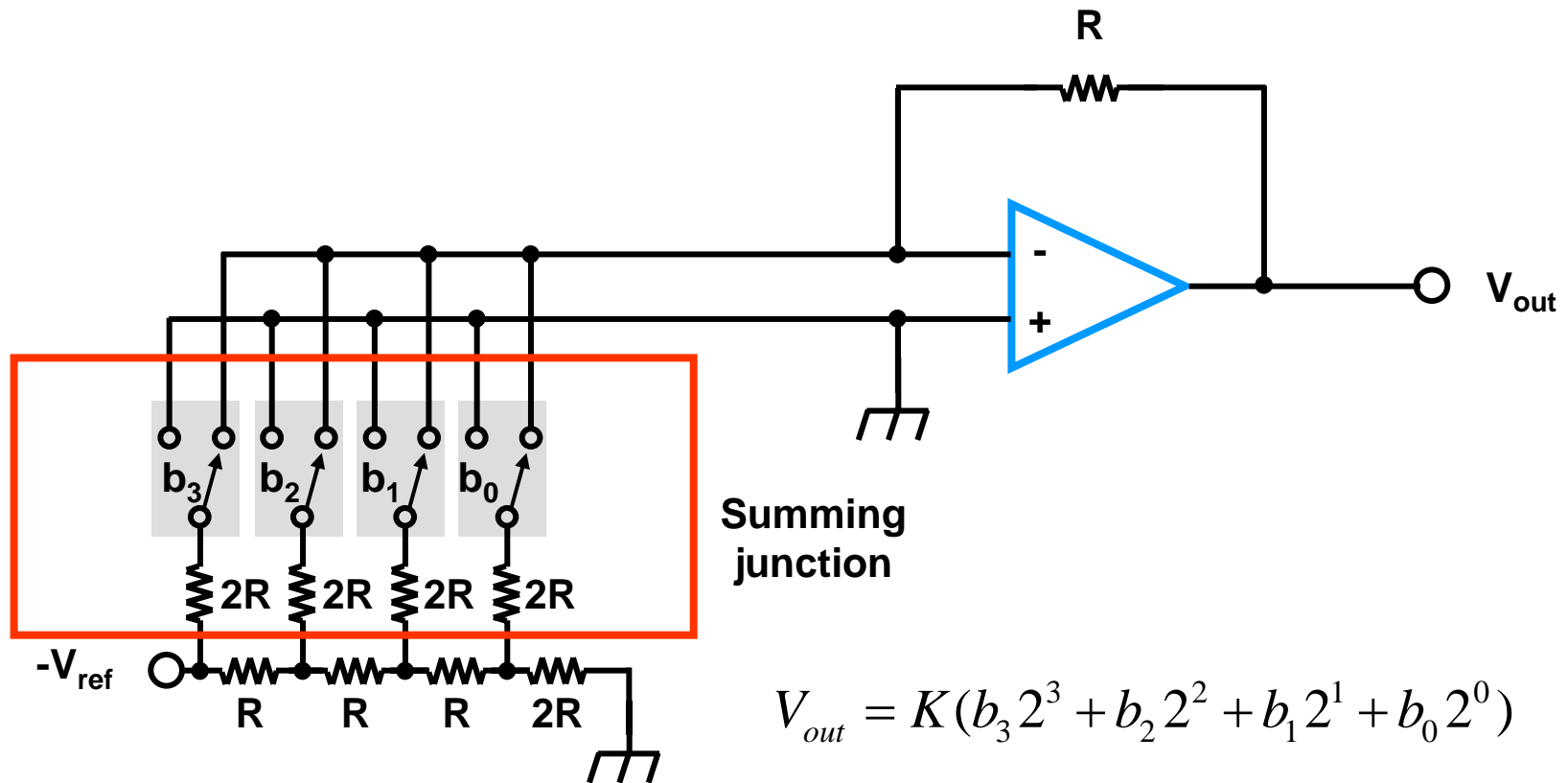
# Computerized Data Acquisition

- Digital-to-analog converters



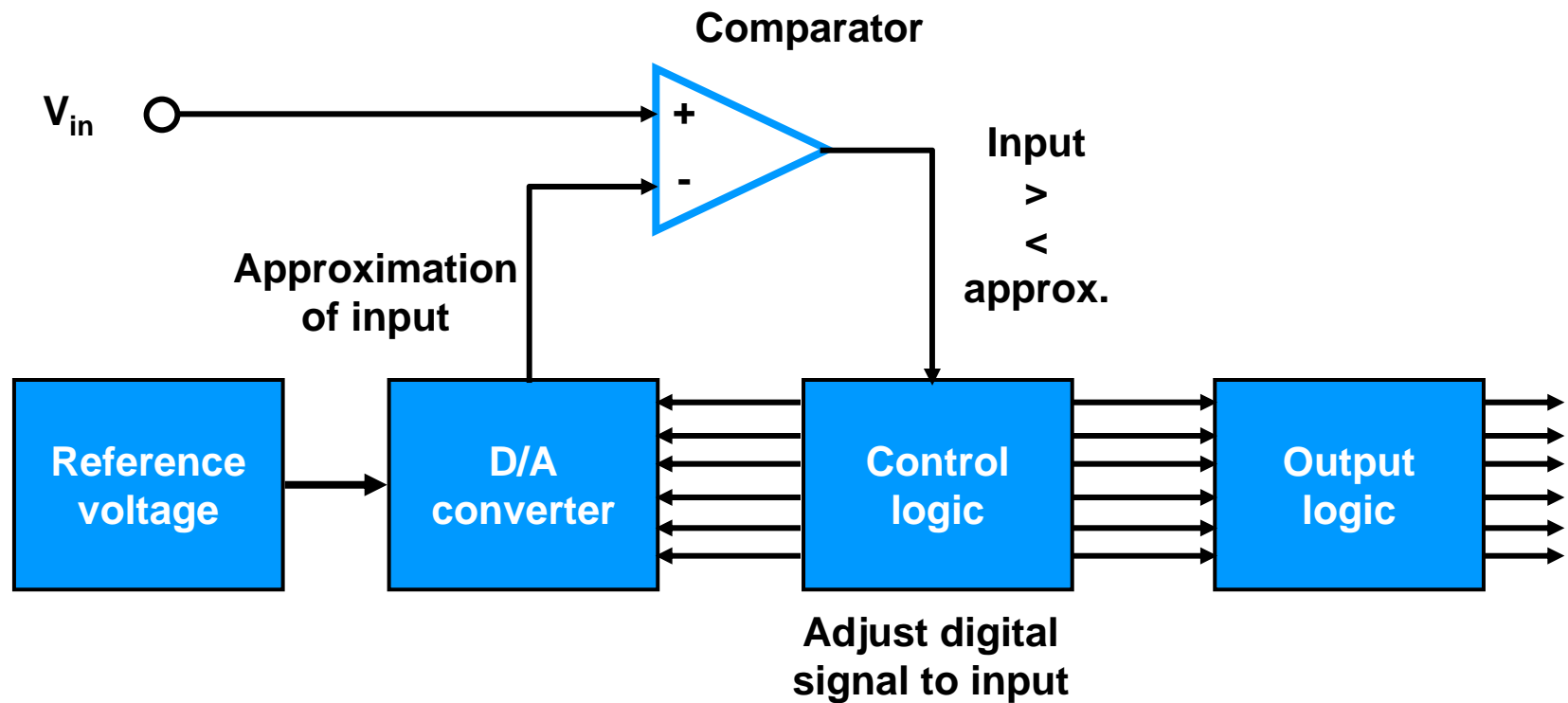
# Computerized Data Acquisition

- Digital-to-analog converters



# Computerized Data Acquisition

- Successive approximation A/D converter



# Next topics

- Computerized Data Acquisition
  - Sampling
  - Quantization effects
  - Fourier Transform and frequency domain analysis