ShanghaiTech University

EE 115B: Digital Circuits

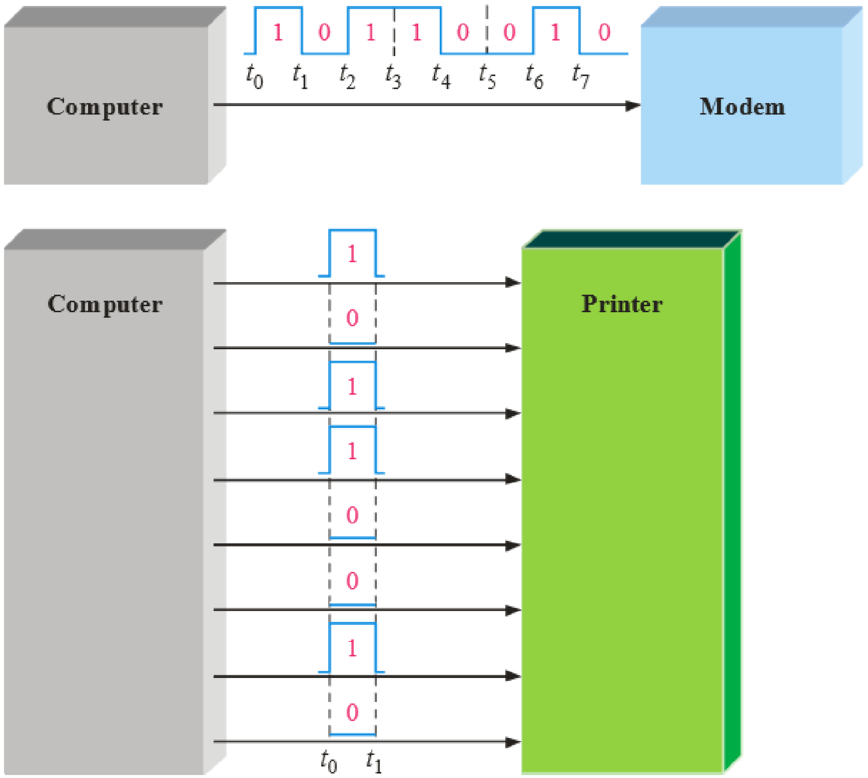
Fall 2022

Lecture 1

Hengzhao Yang
September 6, 2022

Serial and Parallel Data

Data can be transmitted by either serial transfer or parallel transfer.



Introduction to Digital Fundamentals

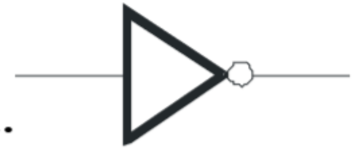
- Digital and Analog Quantities
- Binary Digits, Logic Levels and Digital Waveforms
- Basic Logic Functions
- Combinational and Sequential Logic Functions
- Programmable Logic Devices
- Fixed-Function Logic Devices
- Test and Measurement Instruments

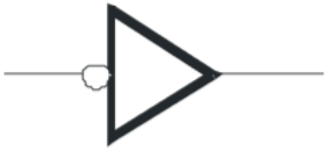
Basic Logic Functions

AND True only if *all* input conditions are true.

OR True only if *one or more* input conditions are true.

NOT Indicates the *opposite* condition.





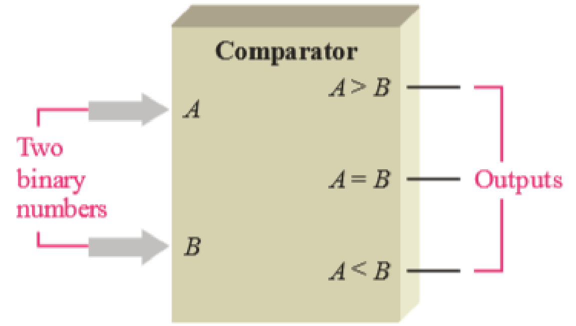
Introduction to Digital Fundamentals

- Digital and Analog Quantities
- Binary Digits, Logic Levels and Digital Waveforms
- Basic Logic Functions
- Combinational and Sequential Logic Functions
- Programmable Logic Devices
- Fixed-Function Logic Devices
- Test and Measurement Instruments

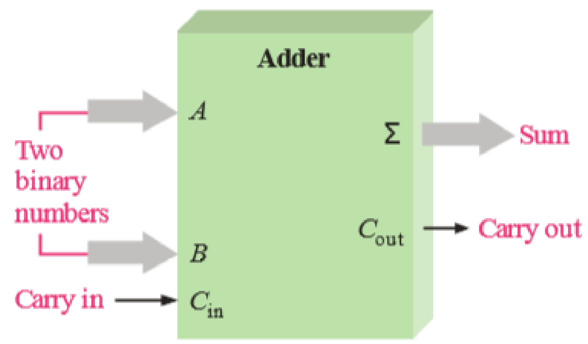
Basic System Functions

And, **or**, and **not** elements can be combined to form various logic functions. A few examples are:

The comparison function

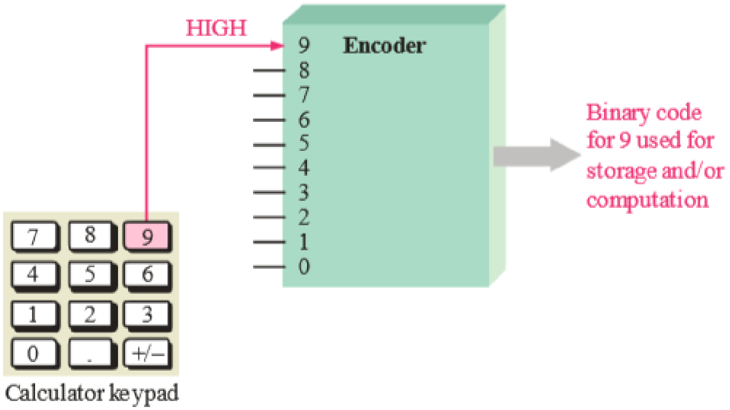


Basic arithmetic functions

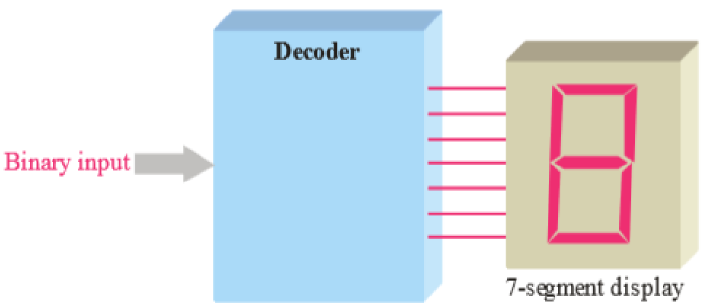


Basic System Functions

The encoding function

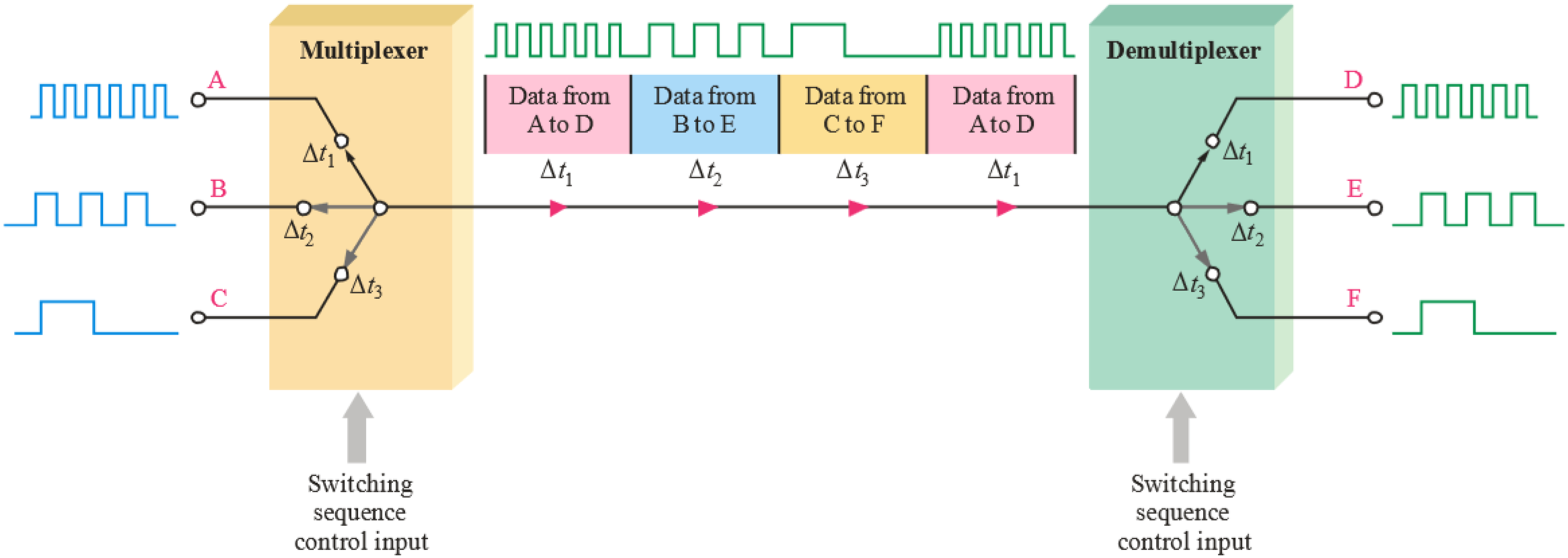


The decoding function



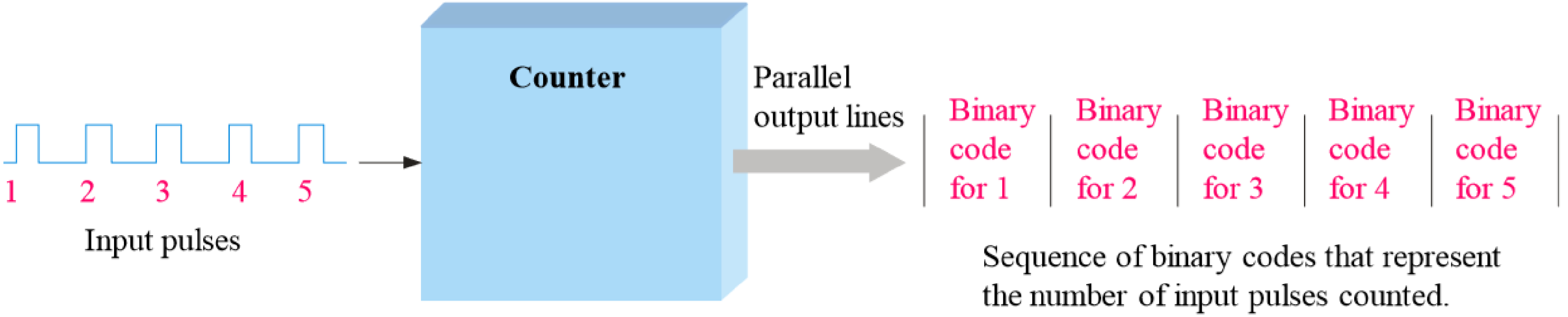
Basic System Functions

The data selection function



Basic System Functions

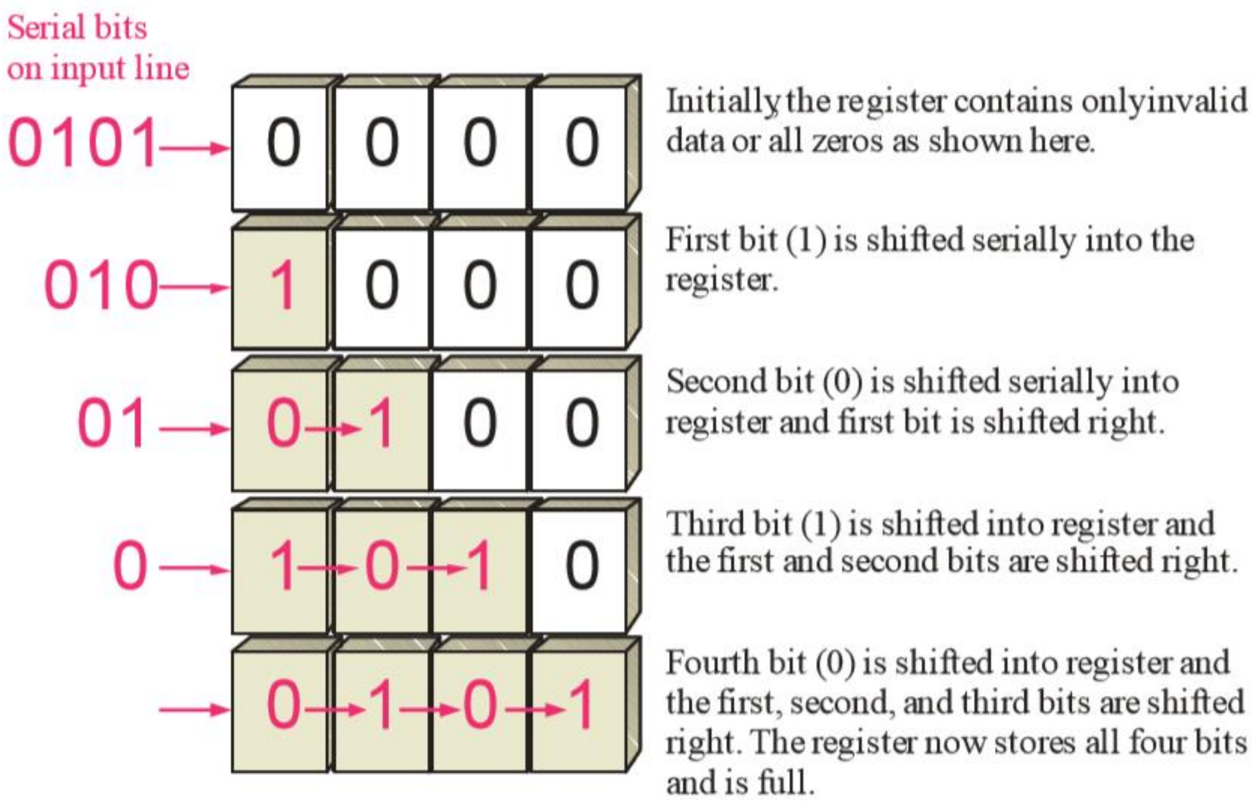
The counting function



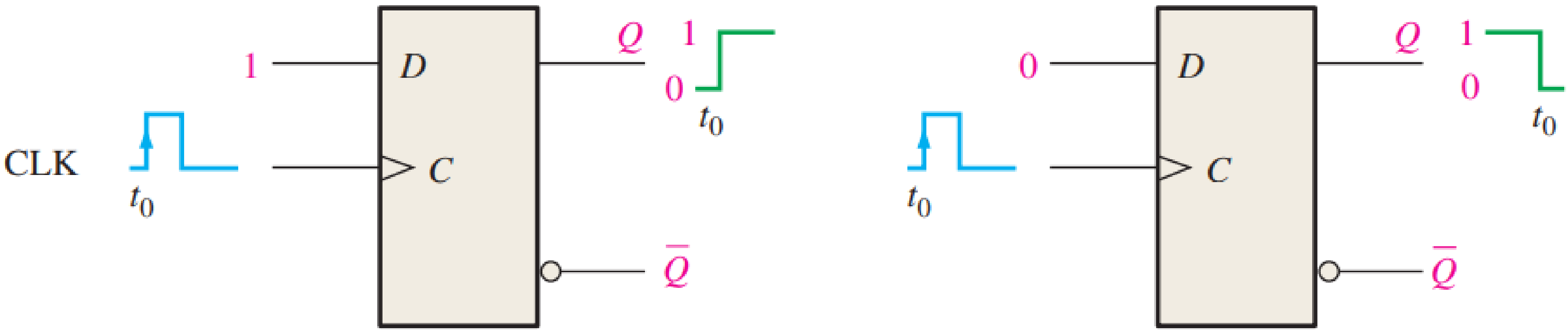
…and other functions such as code conversion and storage.

Basic System Functions

One type of storage function is the shift register, that moves and stores data each time it is clocked.



Positive Edge-Triggered D Flip-Flop



(a) $D = 1$ flip-flop SETS on positive clock edge. (If already SET, it remains SET.)

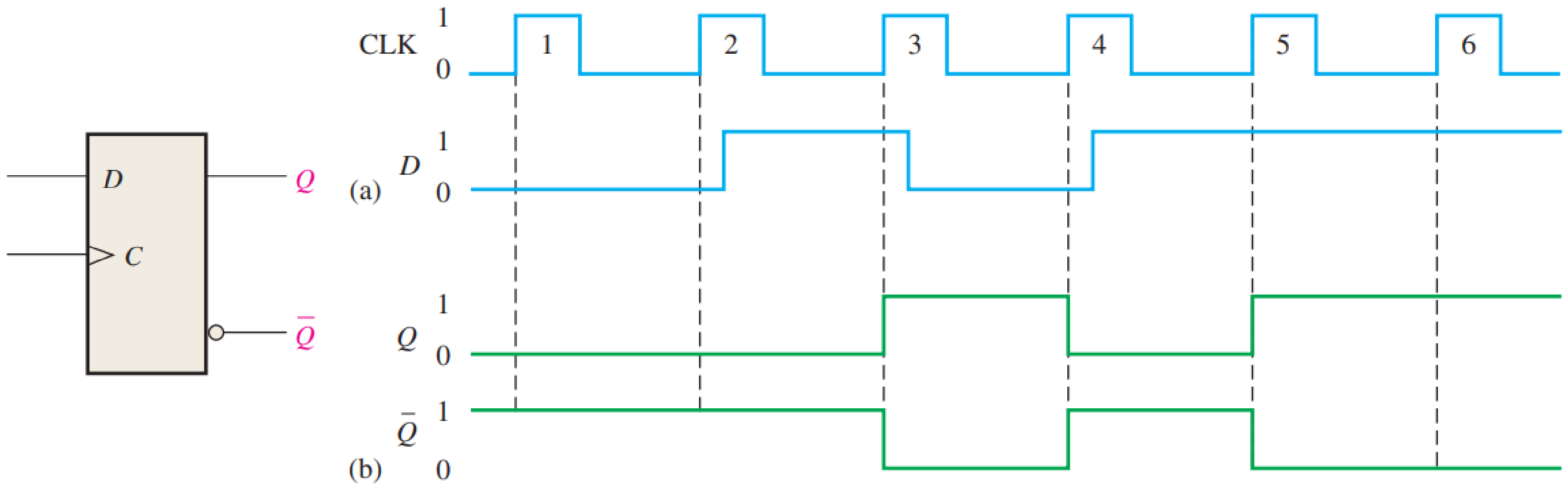
(b) $D = 0$ flip-flop RESETS on positive clock edge. (If already RESET, it remains RESET.)

Truth table for a positive edge-triggered D flip-flop.

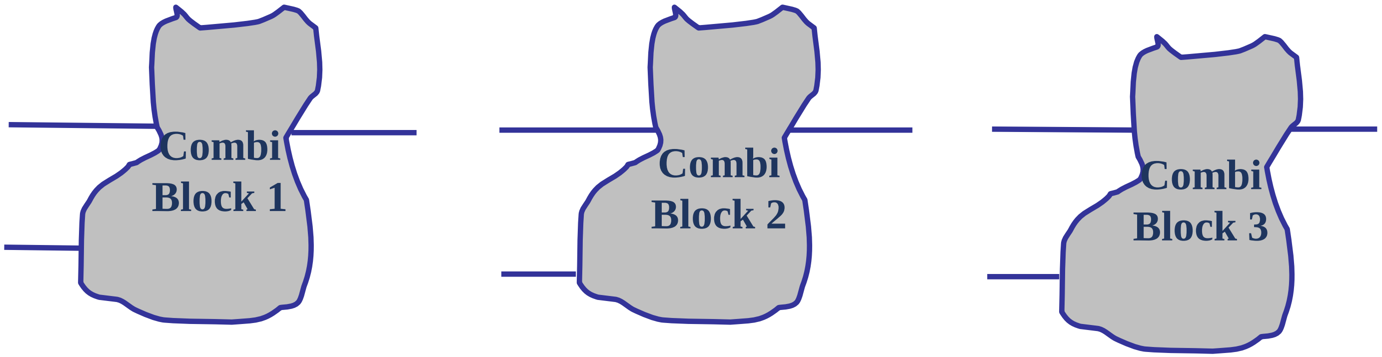
Inputs		**Outputs**		
D	**CLK**	***Q***	$\overline{Q}$	**Comments**
0	↑	0	1	RESET
1	↑	1	0	SET

↑ = clock transition LOW to HIGH

Example Waveforms of D Flip-Flop

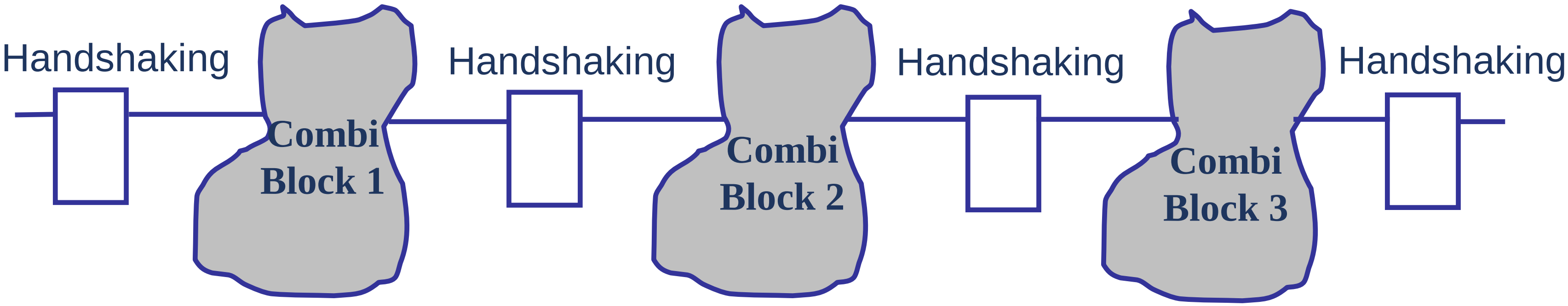


Computing with Logic Circuits



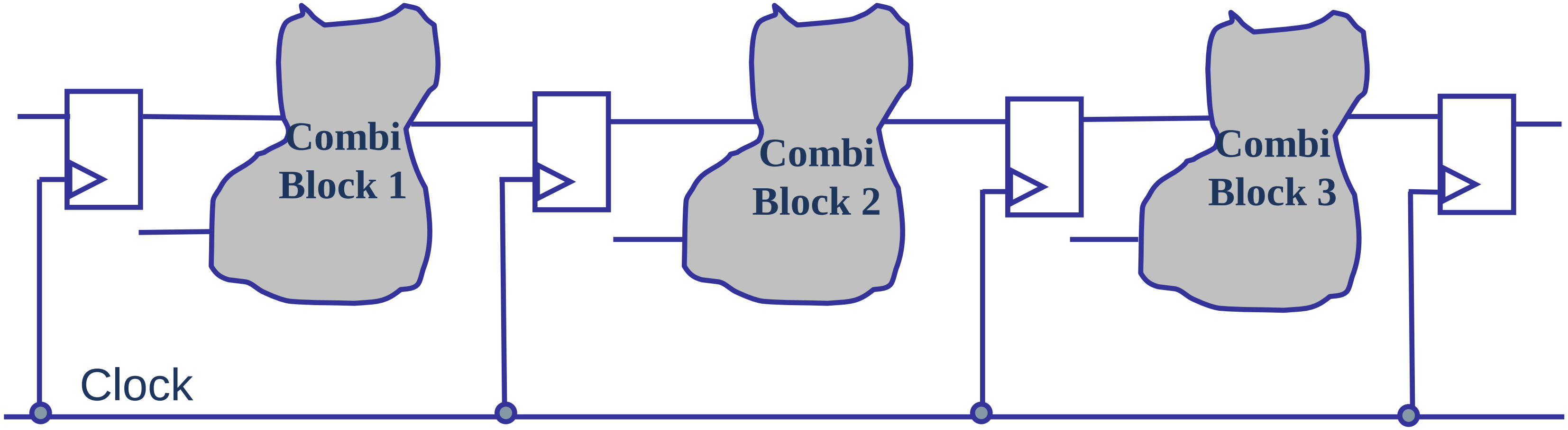
- A lot of computations in an algorithm
- Computations are done with combinatorial logic blocks.
- Results computed by combinatorial blocks should be exchanged
- **How to exchange results efficiently?!**

Asynchronous Circuits



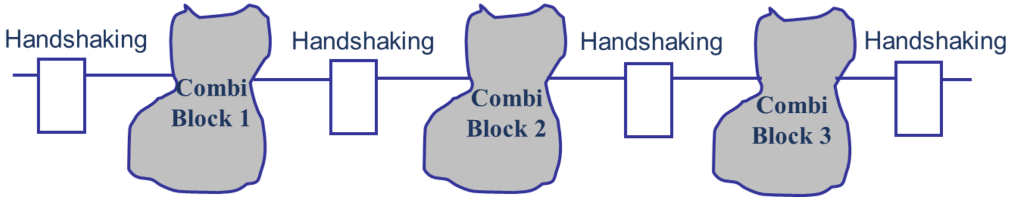
- Handshaking are used to exchange the results of computations in all combinatorial logic blocks.
- Handshaking involves stages like requesting, acknowledging, sending…
- Handshaking is only needed when there is a need for data exchange.

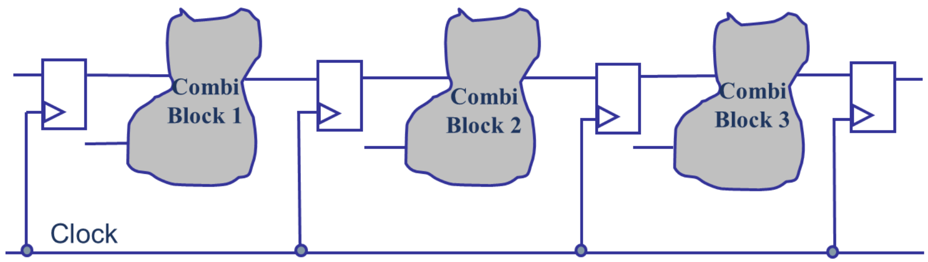
Synchronous Circuits



- Clocks are used to synchronize the start of computations in all combinatorial logic blocks.
- Clock period is determined by fining out the longest path delay of all combinatorial logic blocks.
- All combinatorial logic blocks are supposed to finish the computations of the current clock cycle before the start of the next clock cycle.

Asynchronous Versus Synchronous Circuits





- Asynchronous circuits avoid the clocks, and only communicate when necessary, potentially can achieve secure, low power and scalable computing.
- Synchronous circuits avoid the handshaking, and it communicates at a fixed pace, and support with EDA tools.
- Current industry 99% is using synchronous approach. Who knows in the future?

EE115 Analog and *Digital Circuits*

Topic 4: Number Systems, Operations and Codes

Prof. Yajun Ha

ShanghaiTech University
Shanghai, China

上海科技大学
ShanghaiTech University

Decimal Numbers (1)

The position of each digit in a weighted number system is assigned a weight based on the **base** or **radix** of the system. The radix of decimal numbers is ten, because only ten symbols (0 through 9) are used to represent any number.

The column weights of decimal numbers are powers of ten that increase from right to left beginning with $10^0 = 1$:

$\ldots 10^5\ 10^4\ 10^3\ 10^2\ 10^1\ 10^0.$

For fractional decimal numbers, the column weights are negative powers of ten that decrease from left to right:

$10^2\ 10^1\ 10^0.\ 10^{-1}\ 10^{-2}\ 10^{-3}\ 10^{-4}\ \ldots$

Decimal Numbers (2)

Decimal numbers can be expressed as the sum of the products of each digit times the column value for that digit. Thus, the number 9240 can be expressed as

$$(9 \times 10^3) + (2 \times 10^2) + (4 \times 10^1) + (0 \times 10^0)$$

or

$$9 \times 1,000 + 2 \times 100 + 4 \times 10 + 0 \times 1$$

Example Express the number 480.52 as the sum of values of each digit.

Solution

$$480.52 = (4 \times 10^2) + (8 \times 10^1) + (0 \times 10^0) + (5 \times 10^{-1}) + (2 \times 10^{-2})$$

Binary Numbers (1)

For digital systems, the binary number system is used. Binary has a radix of two and uses the digits 0 and 1 to represent quantities.

The column weights of binary numbers are powers of two that increase from right to left beginning with $2^0 = 1$:

$\ldots 2^5\ 2^4\ 2^3\ 2^2\ 2^1\ 2^0.$

For fractional binary numbers, the column weights are negative powers of two that decrease from left to right:

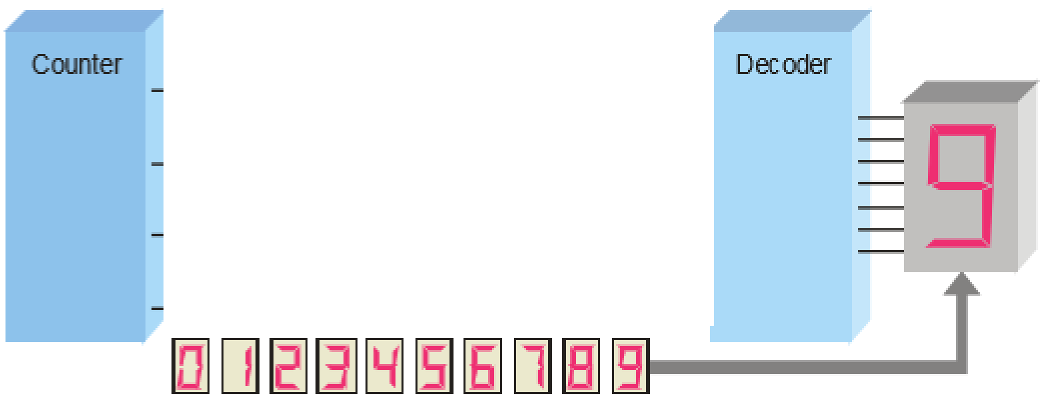
$2^2\ 2^1\ 2^0.\ 2^{-1}\ 2^{-2}\ 2^{-3}\ 2^{-4}\ \ldots$

Binary Numbers (2)

A binary counting sequence for numbers from zero to fifteen is shown.

Notice the pattern of zeros and ones in each column.

Digital counters frequently have this same pattern of digits:



Decimal Number	Binary Number
0	0 0 0 0
1	0 0 0 1
2	0 0 1 0
3	0 0 1 1
4	0 1 0 0
5	0 1 0 1
6	0 1 1 0
7	0 1 1 1
8	1 0 0 0
9	1 0 0 1
10	1 0 1 0
11	1 0 1 1
12	1 1 0 0
13	1 1 0 1
14	1 1 1 0
15	1 1 1 1