CHW 261: Logic Design

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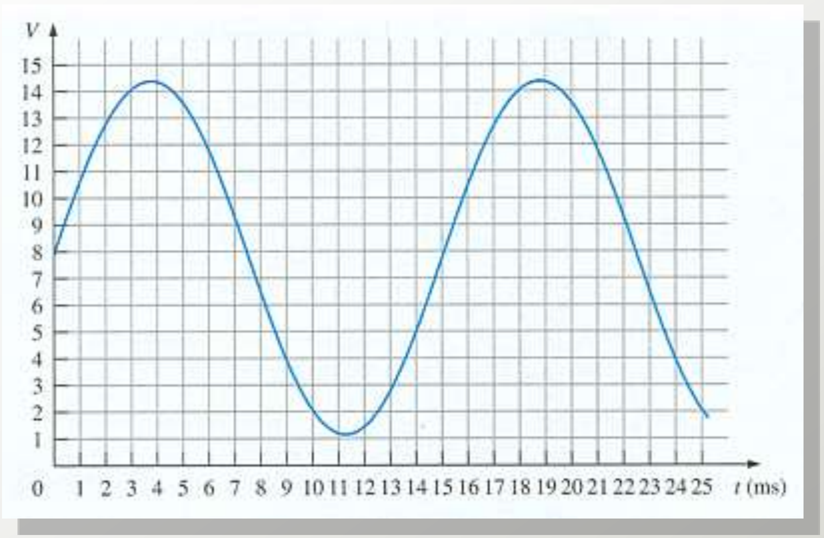
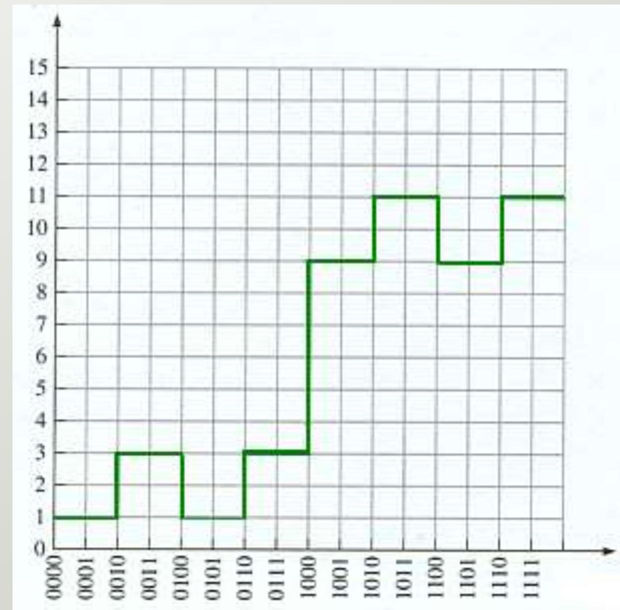
Digital Fundamentals

CHAPTER 1
Digital Concepts

Digital and Analog Quantities

Digital and Analog Quantities





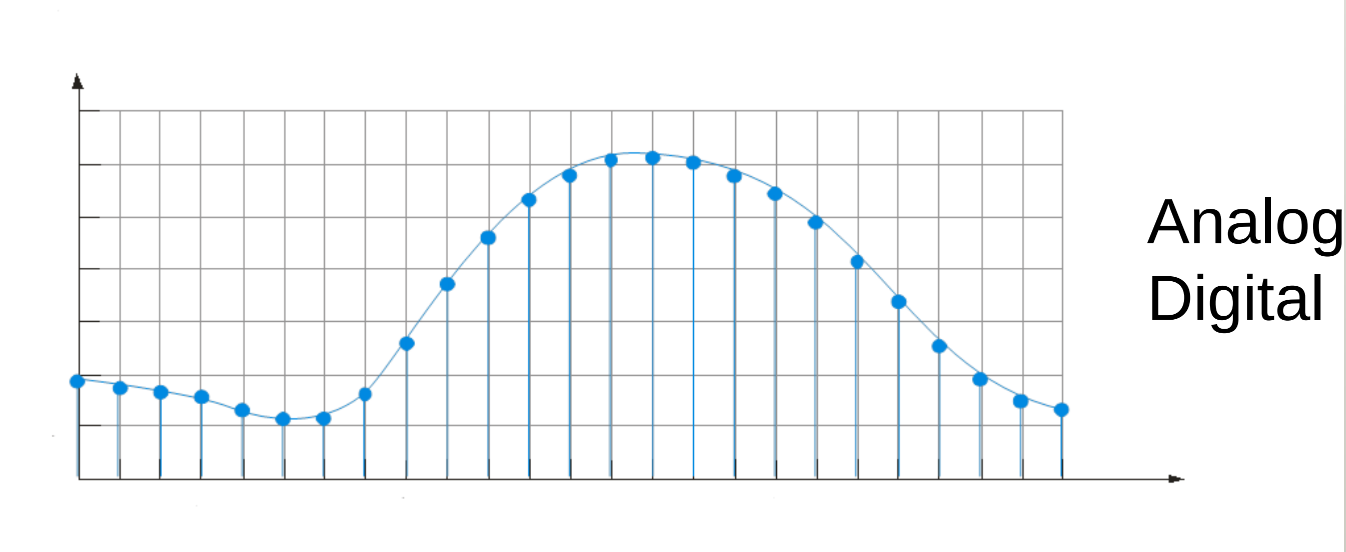
Analog quantities have continuous values

Digital quantities have discrete sets of values

Digital System (Why)

Analog vs. Digital

Most natural quantities (such as temperature, pressure, light intensity, …) are **analog** quantities that vary continuously.

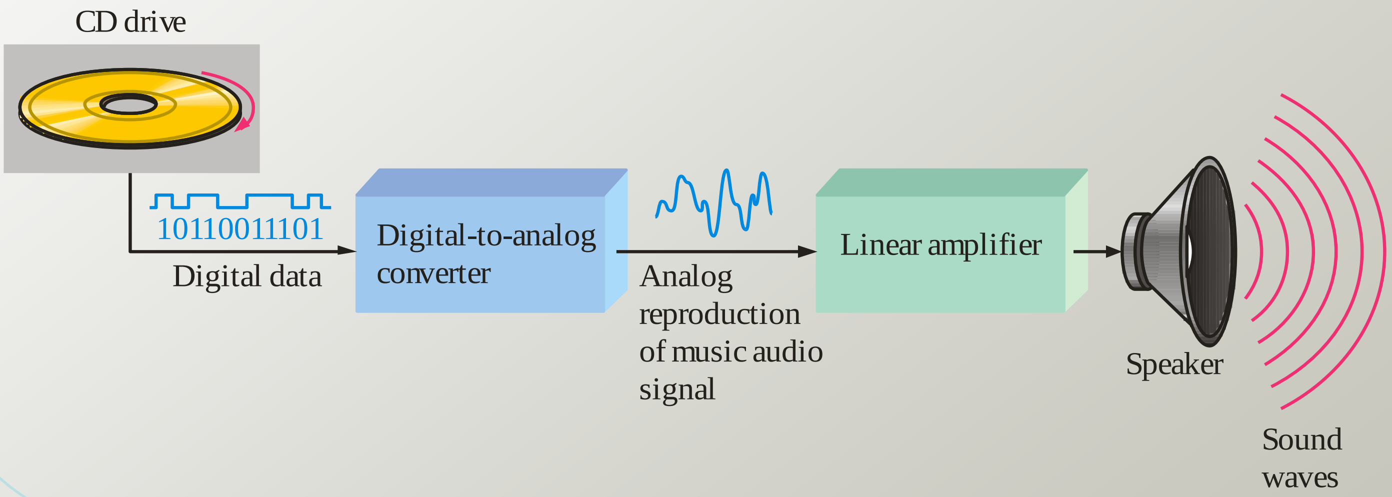


Analog = continuous
Digital = discrete

Digital systems can process, store, and transmit data more efficiently but can only assign discrete values to each point.

Digital System (Example)

- Wave Example



Digital and Analog Quantities

Types of electronic devices or instruments:

- Analog
- Digital
- Combination analog and digital

Binary Digits, Logic Levels, and Digital Waveforms

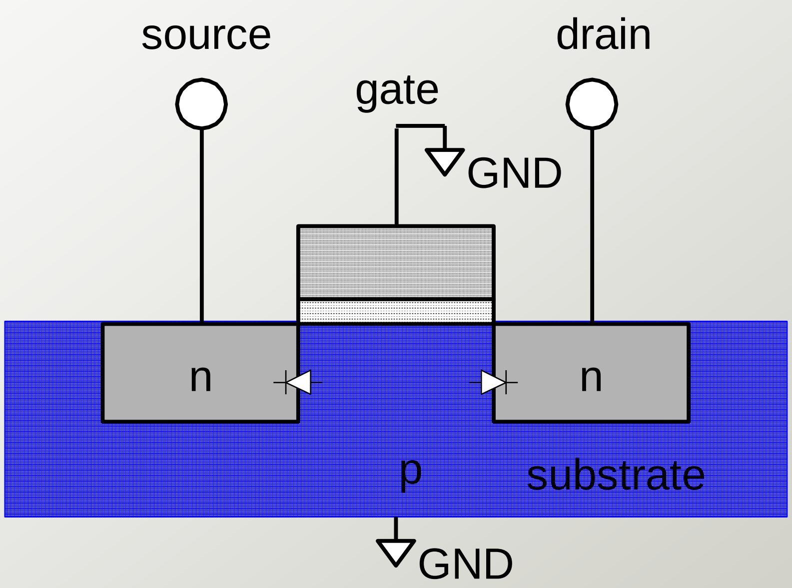
Binary Digits, Logic Levels, and Digital Waveforms

- The conventional numbering system uses ten digits: 0,1,2,3,4,5,6,7,8, and 9.
- The binary numbering system uses just two digits: **0** and **1.**
- They can also be called LOW and HIGH, where **LOW = 0** and **HIGH = 1**

Transistors: nMOS

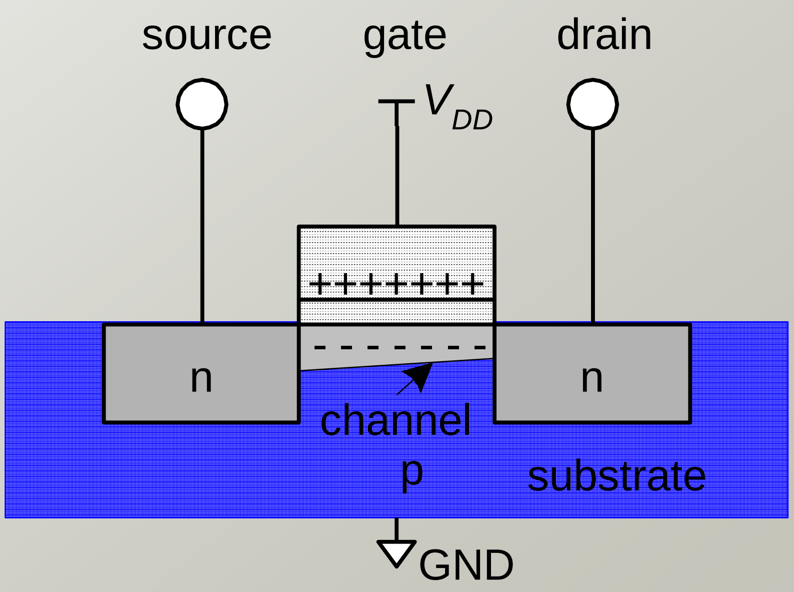
Gate = 0

OFF (no connection between source and drain)

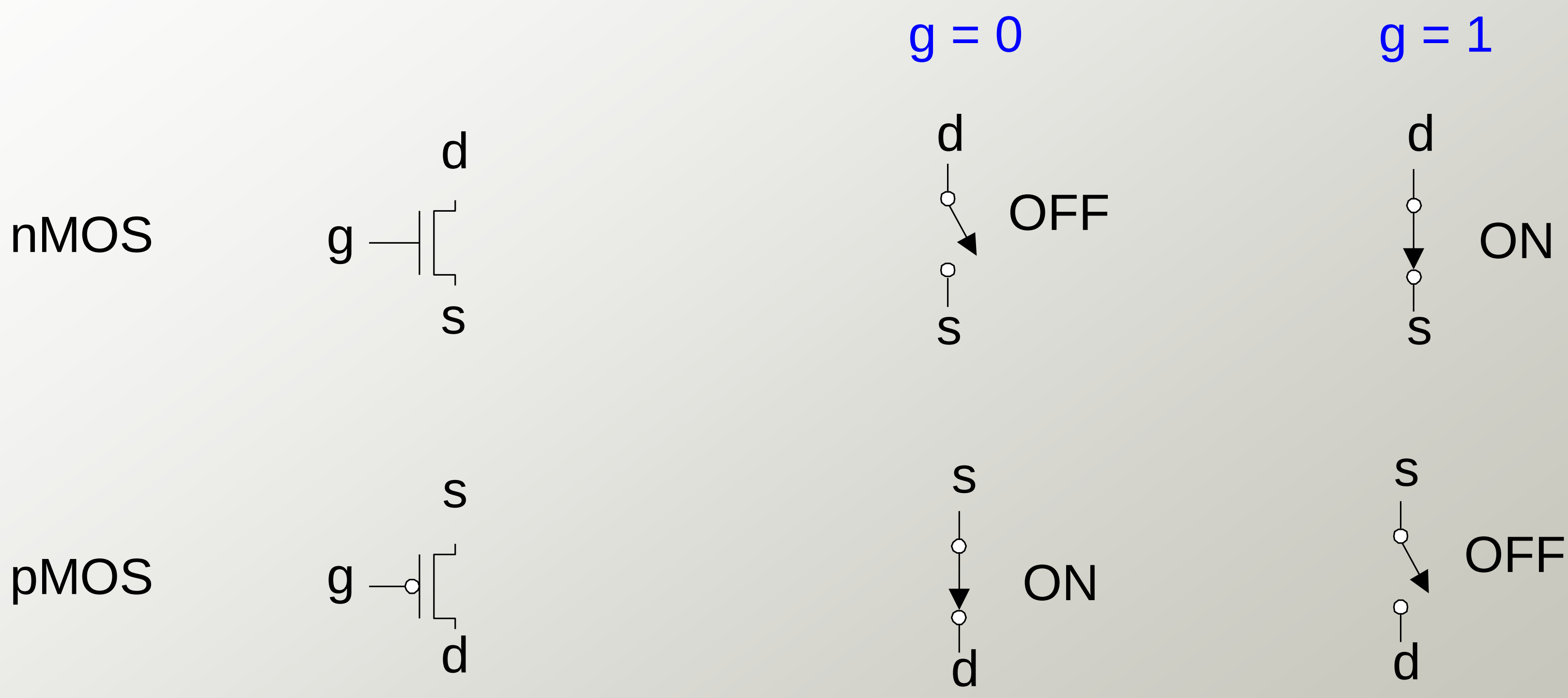


Gate = 1

ON (channel between source and drain)

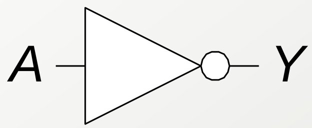


Transistor Function



CMOS Gates: NOT Gate

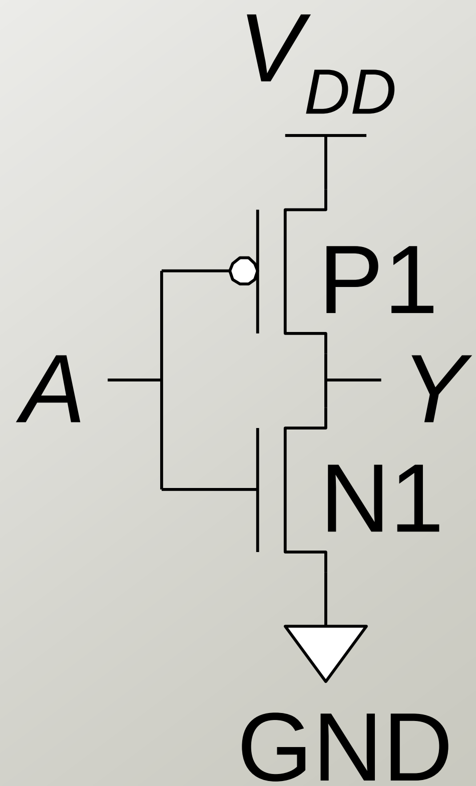
NOT



$Y = \overline{A}$

A	Y
0	1
1	0

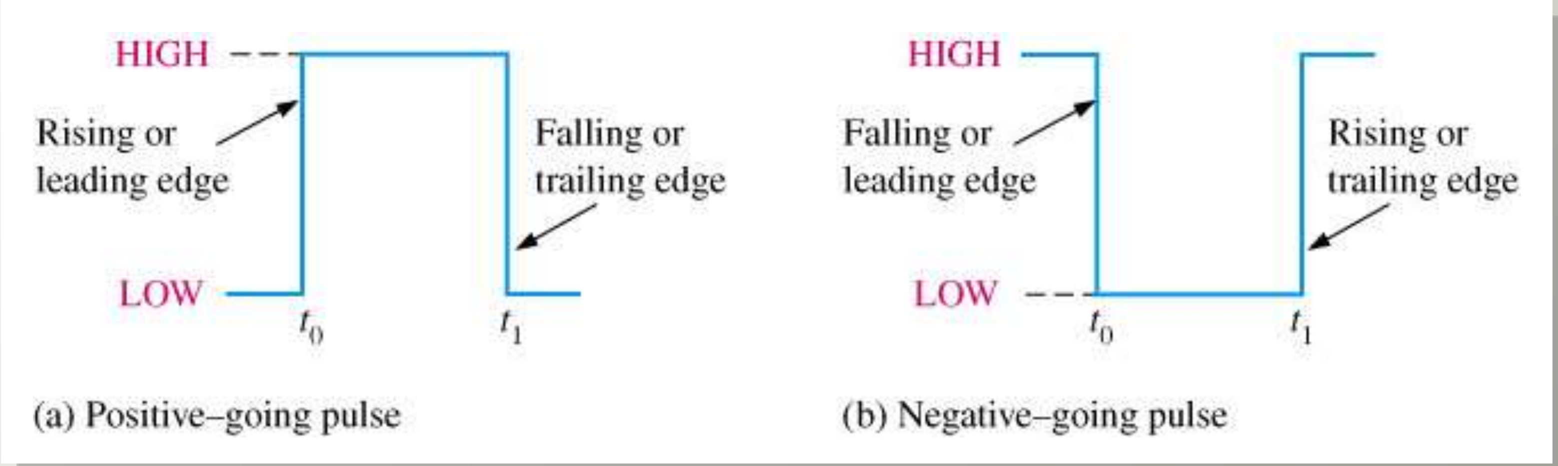
A	P1	N1	*Y*
0	ON	OFF	1
1	OFF	ON	0



Binary Digits, Logic Levels, and Digital Waveforms

The binary numbering system uses just two digits: **0** and **1.**

Binary values are also represented by voltage levels

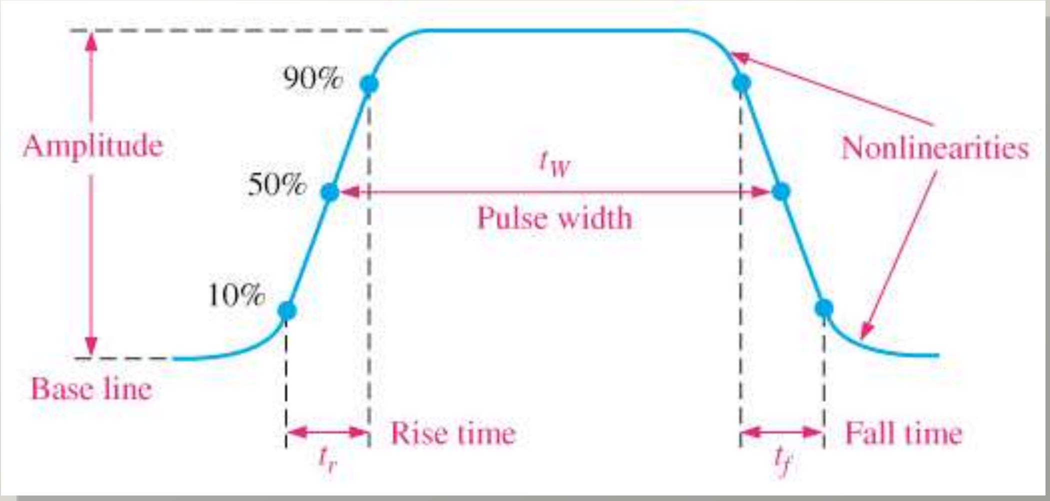


They can also be called LOW and HIGH, where **LOW = 0** and **HIGH = 1**

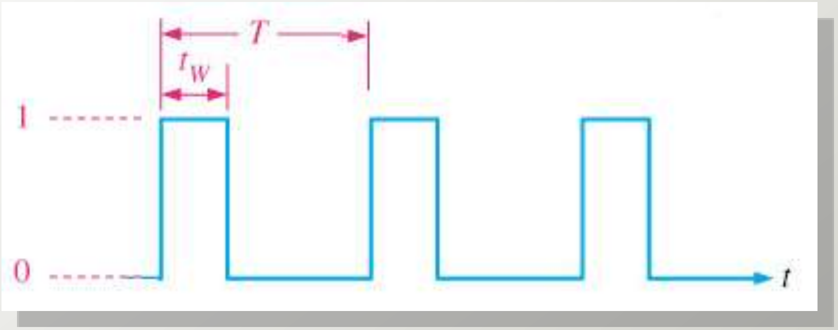
Binary Digits, Logic Levels, and Digital Waveforms

Major parts of a digital pulse

- Base line
- Amplitude
- Rise time (t_r)
- Pulse width (t_w)
- Fall time (t_f)



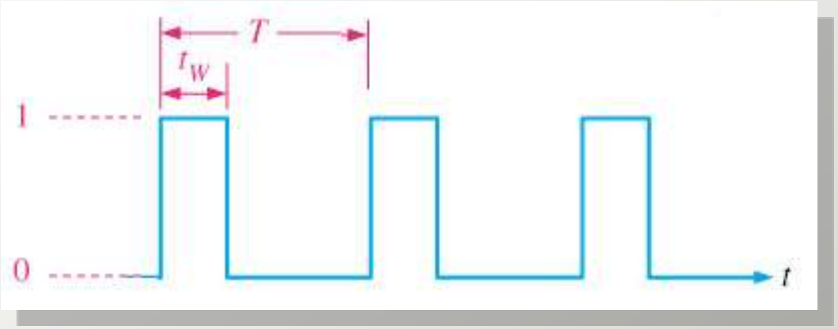
Binary Digits, Logic Levels, and Digital Waveforms



- t_w = pulse width
- T = period of the waveform
- f = frequency of the waveform

$$f = \frac{1}{T}$$

Binary Digits, Logic Levels, and Digital Waveforms



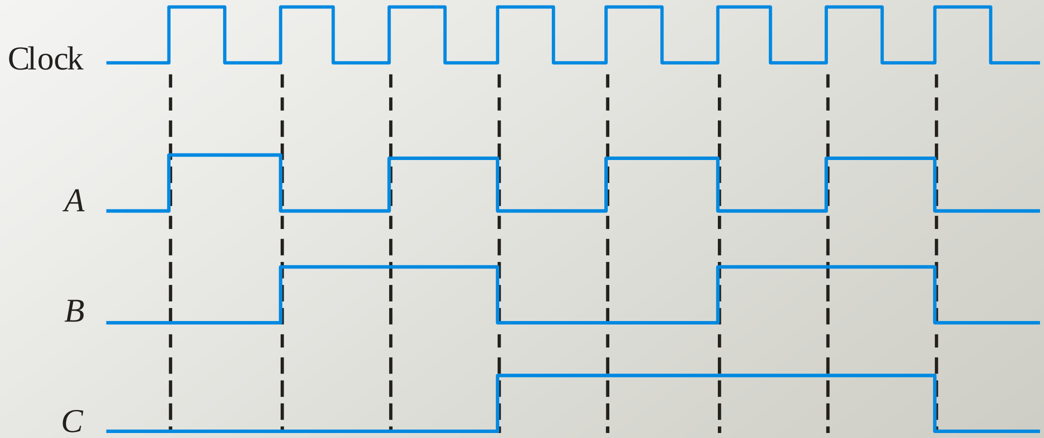
The duty cycle of a binary waveform is defined as:

$$\textbf{Duty cycle} = \left(\frac{t_W}{T}\right)100\%$$

Binary Digits, Logic Levels, and Digital Waveforms

Timing Diagrams

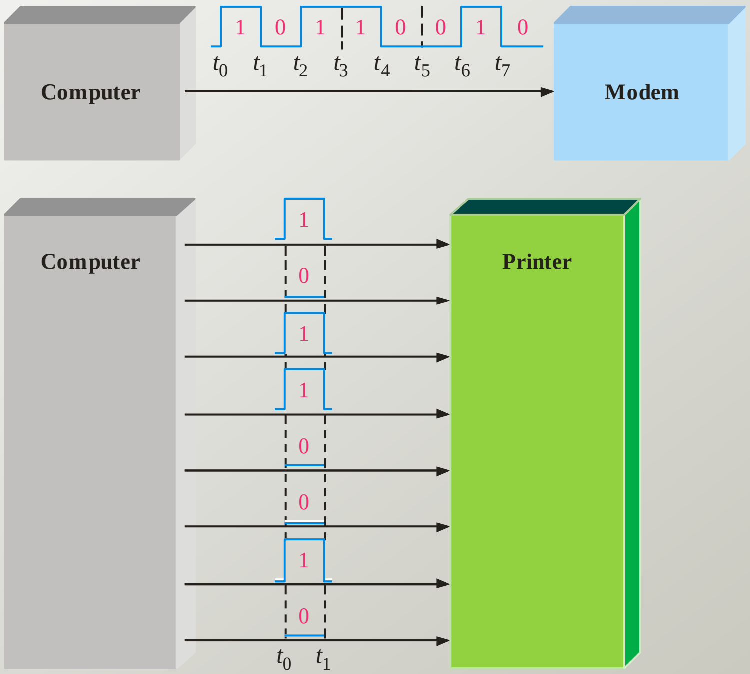
A **timing diagram** (or **waveform diagram**) is used to show the relationship between two or more digital waveforms.



Binary Digits, Logic Levels, and Digital Waveforms

Serial and Parallel Data

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



Ports on a Typical Laptop Computer

USB (Serial)

RS-232 (Serial)

PS/2 Mouse (Serial)

IEEE 1394 (Serial)

Printer (Parallel)

VGA (Analog video)

Quiz

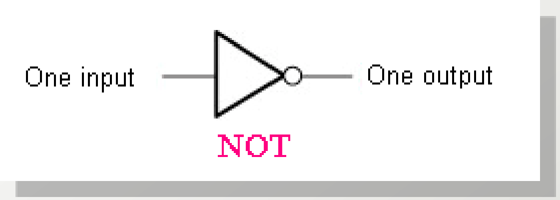
- **Question 1**: How long will it take to transmit an 8-bit binary string using **serial** transmission if the clock frequency is 100 MHz?

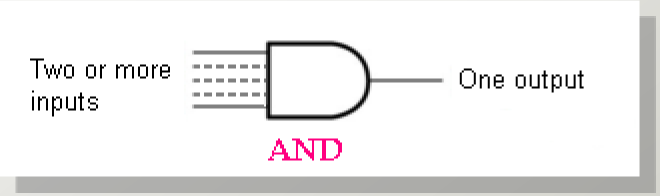
- **Question 2**: How long will it take to transmit an 8-bit binary string using **parallel** transmission if the clock frequency is 100 MHz?

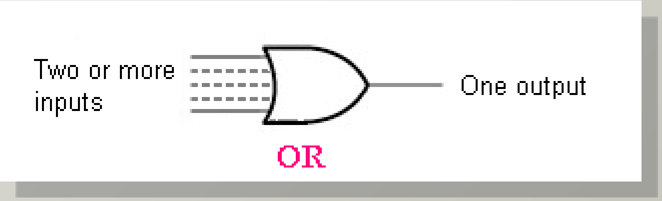
Basic Logic Operations

Basic Logic Operations

There are only three basic logic operations:

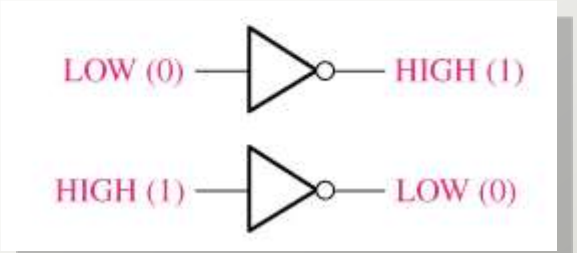






Basic Logic Operations

The NOT operation

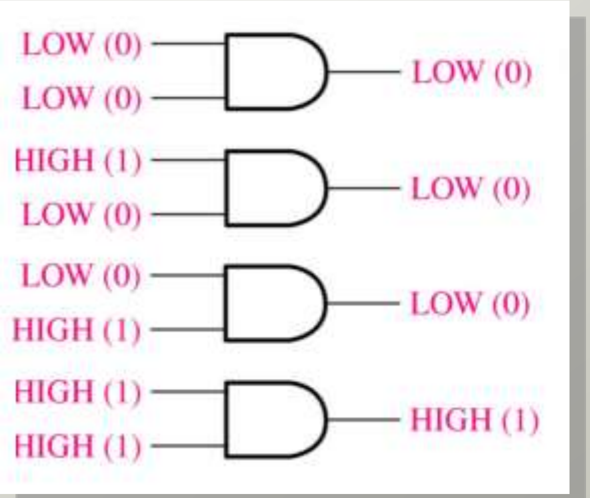


- When the input is LOW, the output is HIGH
- When the input is HIGH, the output is LOW

The output logic level is always opposite the input logic level.

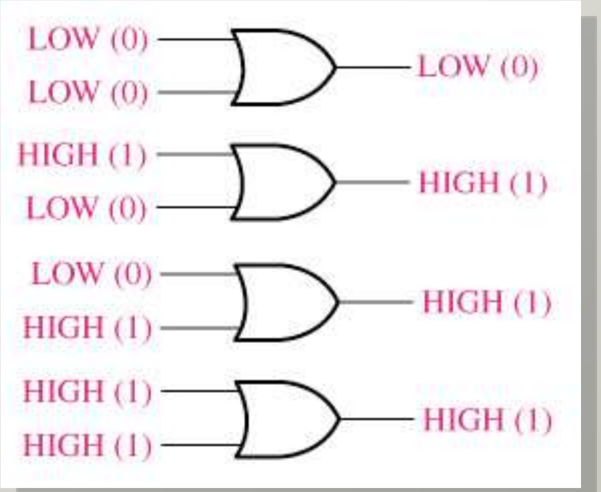
Basic Logic Operations

- The AND operation
  - When any input is LOW, the output is LOW
  - When both inputs are HIGH, the output is HIGH



Basic Logic Operations

- The OR operation
  - When any input is HIGH, the output is HIGH
  - When both inputs are LOW, the output is LOW



Overview of Basic Logic Functions

Overview of Basic Logic Functions

- Comparison function
- Arithmetic functions
- Code conversion function
- Encoding function
- Decoding function
- Data selection function
- Data storage function
- Counting function

Overview of Basic Logic Functions

Comparison function

- Compares two binary values and determines whether or not they are equal

Overview of Basic Logic Functions

Arithmetic functions

- Perform the basic arithmetic operations on two binary values:
  - Addition
  - Subtraction of two values
  - Multiplication
  - Division

Overview of Basic Logic Functions

Code conversion function

- Converts, or translates, information from one code format to another

Overview of Basic Logic Functions

Encoding function

- Converts non-binary information into a binary code

Overview of Basic Logic Functions

Decoding function

- Converts binary-coded information into a non-binary form

Overview of Basic Logic Functions

Data selection function

- Multiplexer (mux)
  - Switches digital data from any number of input sources to a single output line
- Demultiplexer (demux)
  - switches digital data from a single input to any number of output lines

Overview of Basic Logic Functions

Data storage function

- Retains binary data for a period of time
  - Flip-flops (bistable multvibrators)
  - Registers
  - Semiconductor memories
  - Magnetic-media memories
  - Optical-media memories

Overview of Basic Logic Functions

Counting function

- Generates sequences of digital pulse that represent numbers

Fixed-Function Integrated Circuits

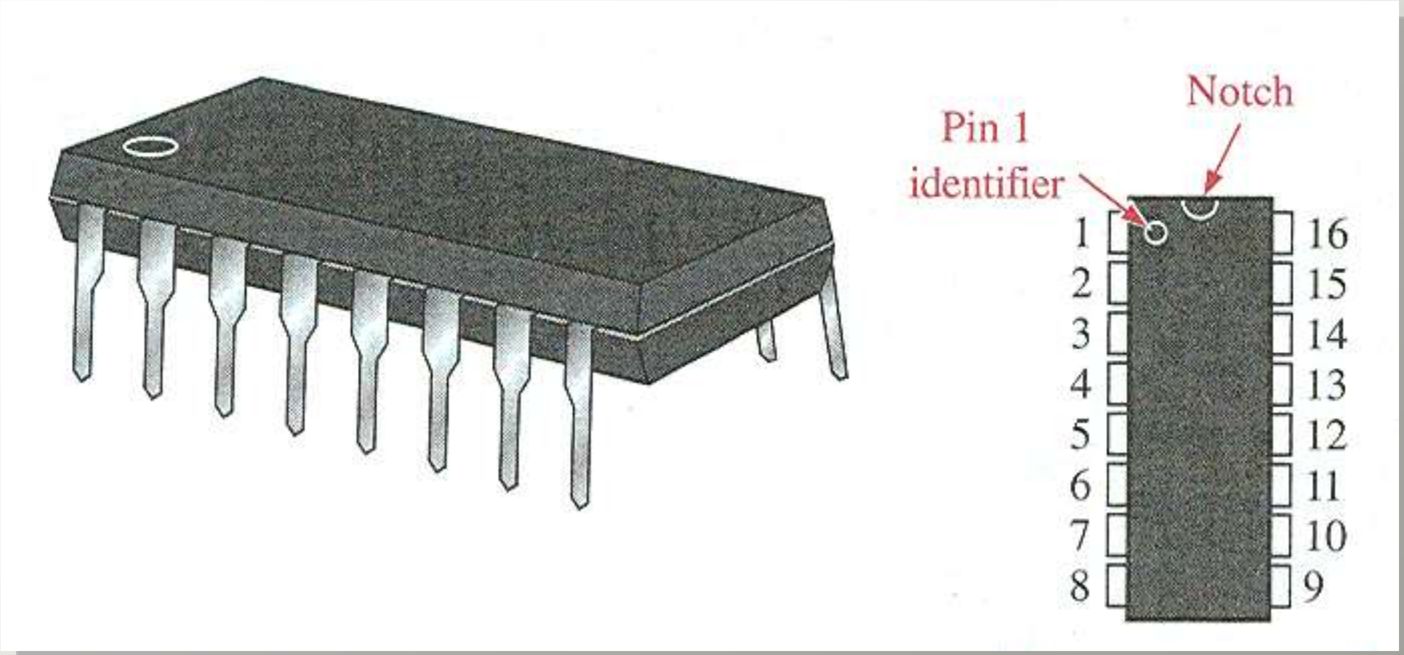
Fixed-Function Integrated Circuits

IC package styles

- Dual in-line package (DIP)
- Small-outline IC (SOIC)
- Flat pack (FP)
- Plastic-leaded chip carrier (PLCC)
- Leadless-ceramic chip carrier (LCCC)

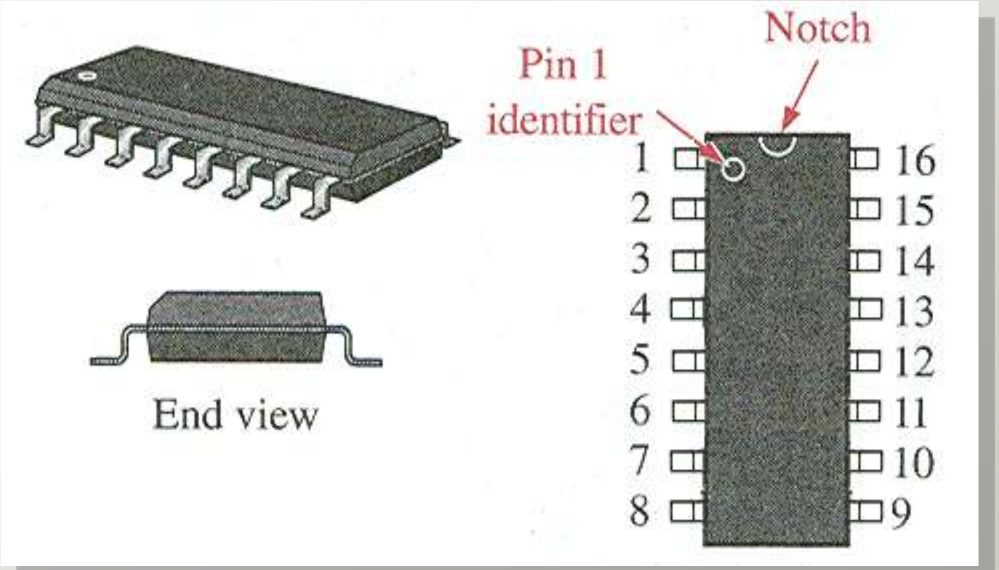
Fixed-Function Integrated Circuits

- Dual in-line package (DIP)



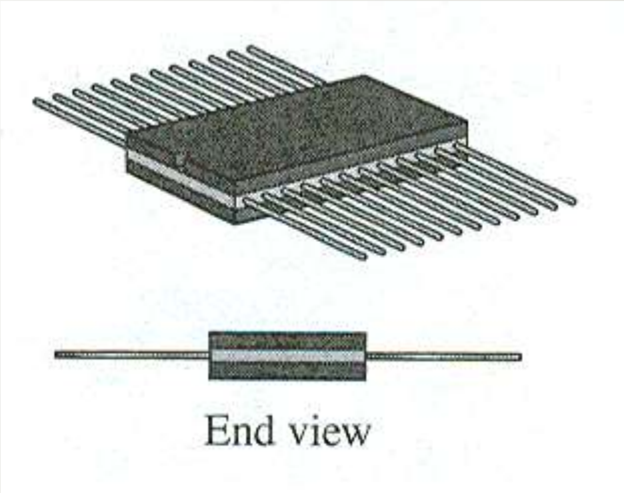
Fixed-Function Integrated Circuits

- Small-outline IC (SOIC)



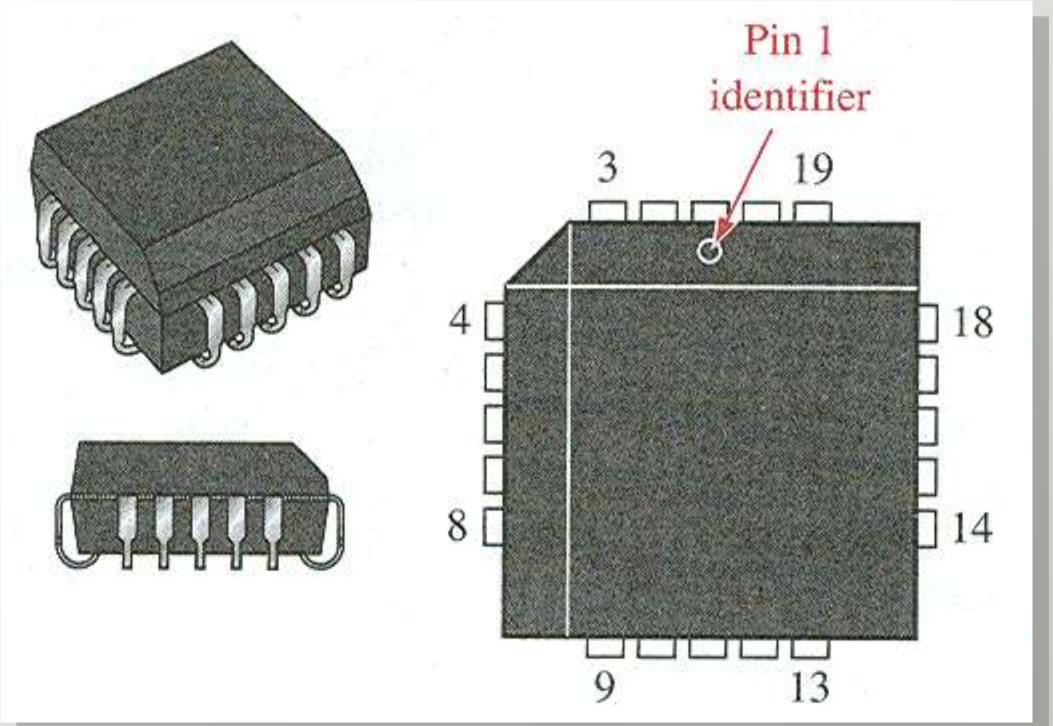
Fixed-Function Integrated Circuits

- Flat pack (FP)



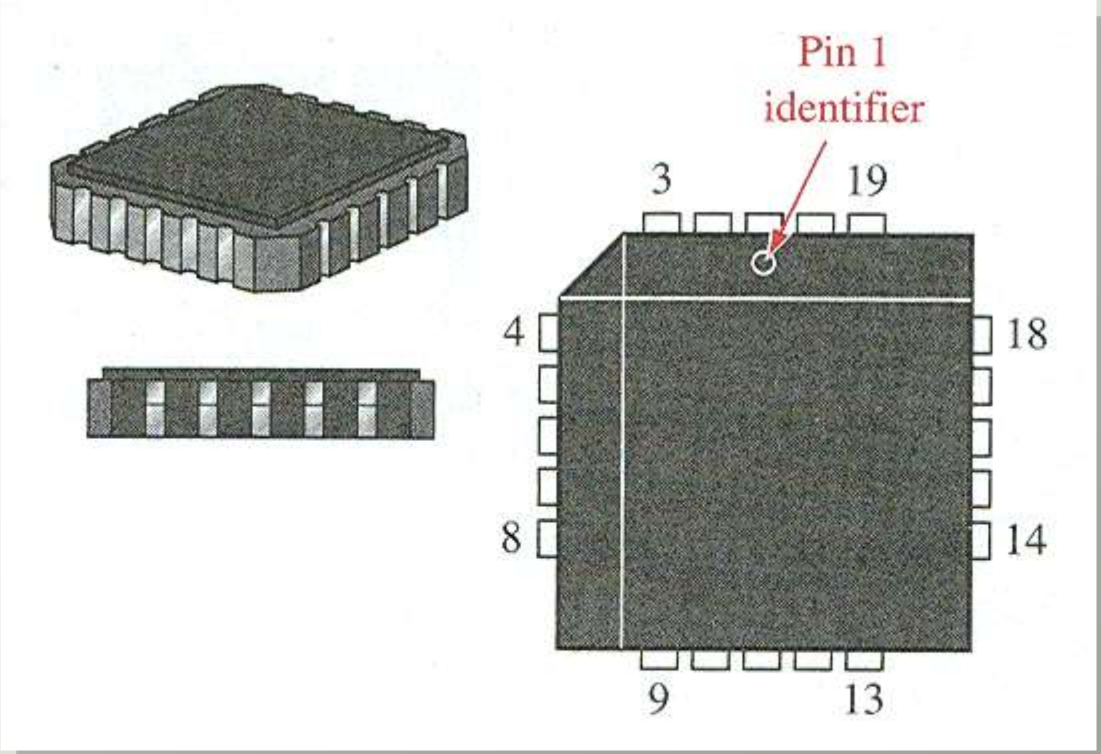
Fixed-Function Integrated Circuits

- Plastic-leaded chip carrier (PLCC)



Fixed-Function Integrated Circuits

- Leadless-ceramic chip carrier (LCCC)



Introduction to Programmable Logic

Introduction to Programmable Logic

Programmable Logic Devices (PLDs) are chips with a large number of gates that can be configured with software to perform a specific logic function. Major types of PLDs are:

SPLD (Simple PLD): the earliest type of programmable logic, used for smaller circuits with a limited number of gates.

CPLD (Complex PLD): contain multiple SPLD arrays and inter-connection arrays on a single chip.

FPGA (Field Programmable Gate Array): a more flexible arrangement than CPLDs, with much larger capacity.

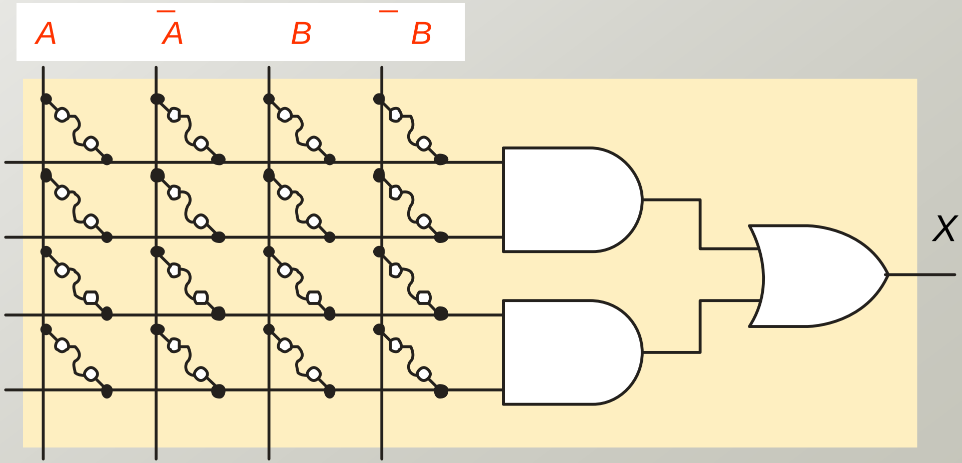
Introduction to Programmable Logic

- SPLD
  - – PAL (programmable array logic)
  - – GAL (generic array logic)
  - – PLA (programmable logic array)
  - – PROM (programmable read-only memory)

Introduction to Programmable Logic

PALs and GALs

SPLDs contain arrays of gates. Two important kinds of SPLD are **PALs** (Programmable Array Logic) and **GALs** (Generic Array Logic). A typical array consists of a matrix of conductors connected in rows and columns to AND gates.



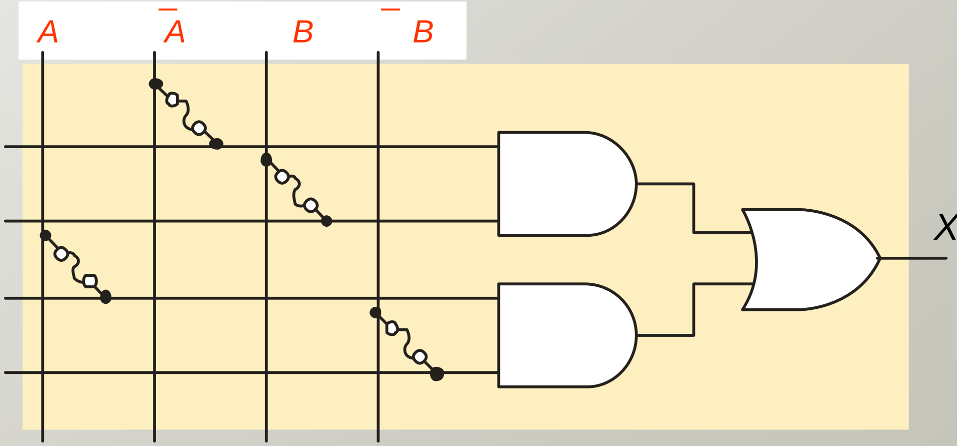
Simplified AND-OR array

Introduction to Programmable Logic

PALs

PALs are programmed with a specialized programmer that blows selected internal fuse links. After blowing the fuses, the array represents the Boolean logic expression for the desired circuit.

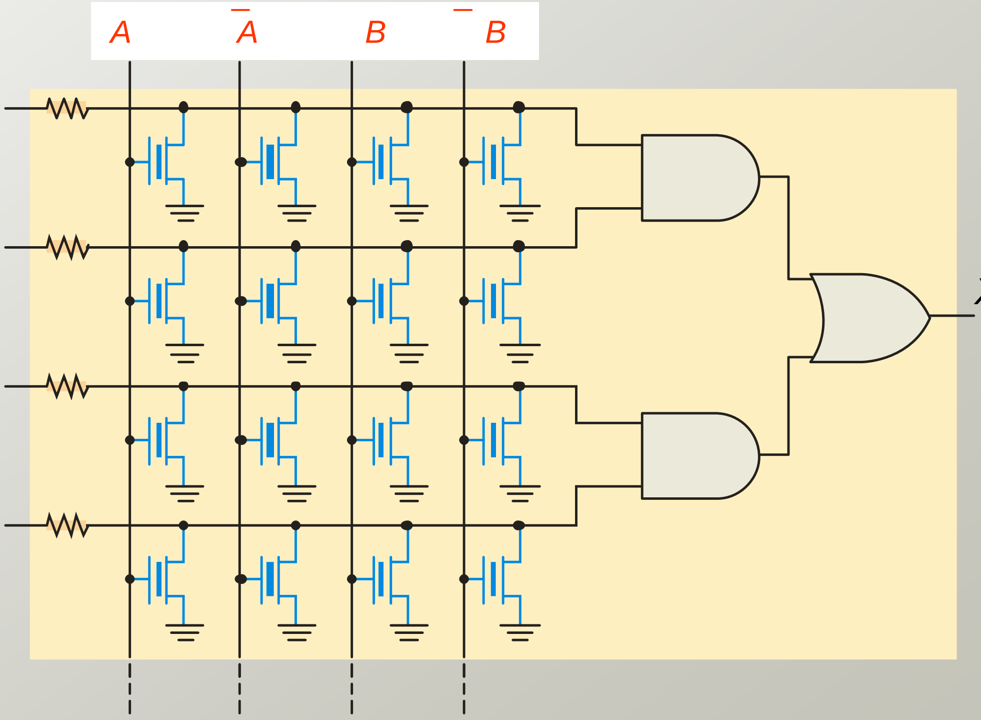
PALs have a **one-time programmable (OTP)** array, in which fuses are permanently blown, creating the product terms in an AND array.



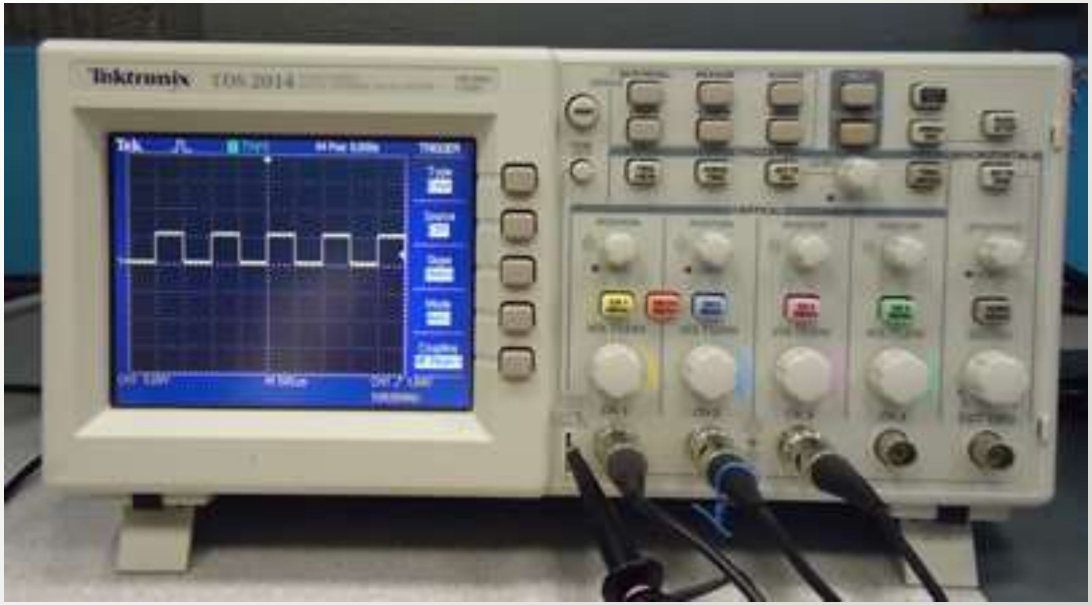
Introduction to Programmable Logic

GALs

The GAL (Generic Array Logic) is similar to a PAL but **can be reprogrammed**. For this reason, they are useful for new product development (prototyping) and for training purposes.



Test and Measurement Instruments



Analog Oscilloscope
Digital Oscilloscope

DC Power Supply

Test and Measurement Instruments

Digital Multimeter

Function Generator

Logic Probe, Pulser, and Current Probe

Home Work

- 7400 Series and 4000 Series
  - A popular series of TTL chips is the 7400 series
  - A popular series of CMOS chips is the 4000 series

Technology Magazines

- https://spectrum.ieee.org/
- https://www.technologyreview.com/