04-061-203 วงจรดิจิตอลลอจิก 3(2-1-3)

Digital Logics and Circuits

วิชาบังคับก่อน : -

ระบบจำนวนและรหัส การแปลงฐาน การแทนเลขฐานสิบด้วยเลขฐานสองแบบไม่มีเครื่องหมาย แบบมีเครื่องหมาย การบวก ลบ คูณ หารพีชคณิตบูลีน ผังคาร์โนห์ การออกแบบ การจัดกลุ่ม ได้แก่ วงจรแปลงรหัส วงจรถอดรหัส วงจรเข้ารหัส วงจรเปรียบเทียบ วงจรมัลติเพล็กเซอร์ วงจรดีมัลติเพล็กเซอร์ วงจรบวก วงจรลบ การออกแบบวงจรลำดับ เช่น วงจรรีจิสเตอร์ วงจรชิฟท์รีจิสเตอร์ วงจรนับแบบริปเปิ้ล วงจรนับแบบซิงโครนัส

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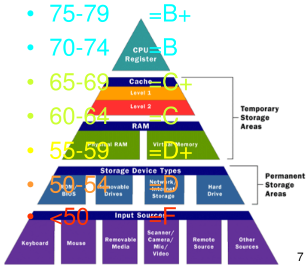
- 100
- จิตพิสัย 10
- ทฤษฎี 60
- ปฏิบัติ 30

Grade
- 80-100 = A
- 75-79 =B+
- 70-74 =B
- 65-69 =C+
- 60-64 =C
- 55-59 =D+
- 50-54 =D
- <50 =F



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Chapter 1: Introduction

Digital Logics and Circuits
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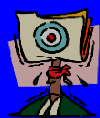
DIGITAL ELECTRONICS

- *WHAT IS A DIGITAL CIRCUIT?*
- *WHERE ARE DIGITAL CIRCUITS USED?*
- *WHY USE DIGITAL CIRCUITS?*
- *HOW DO YOU MAKE A DIGITAL SIGNAL?*
- *HOW DO YOU TEST FOR A DIGITAL SIGNAL?*



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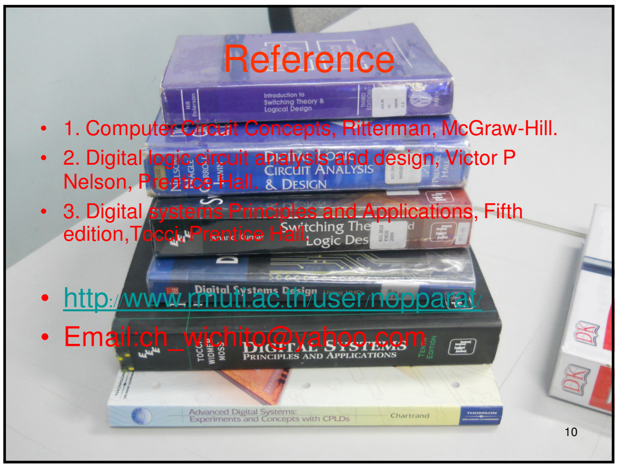

Reference

- 1. Computer Circuit Concepts, Ritterman, McGraw-Hill.
- 2. Digital logic circuit analysis and design, Victor P Nelson, Prentice Hall.
- 3. Digital systems Principles and Applications, Fifth edition, Tocci, Prentice Hall.

- http://www.rmuti.ac.th/user/nopparat
- Email:ch_wichito@yahoo.com

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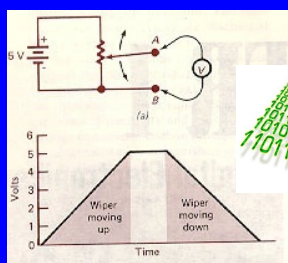
WHAT IS A DIGITAL CIRCUIT?



- **Analog output from a potentiometer.**
- **Analog signal waveform.**

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WHAT IS A DIGITAL CIRCUIT?

The word *digital* comes from the same source as the word digit and *digitus* (the Latin word for *finger*), as fingers are used for discrete counting.

A **digital** system[1] is a data technology that uses discrete (discontinuous) values. By contrast, non-digital (or analog) systems use a continuous range of values to represent information. Although digital representations are discrete, the information represented can be either discrete, such as numbers, letters or icons, or continuous, such as sounds, images, and other measurements of continuous systems.

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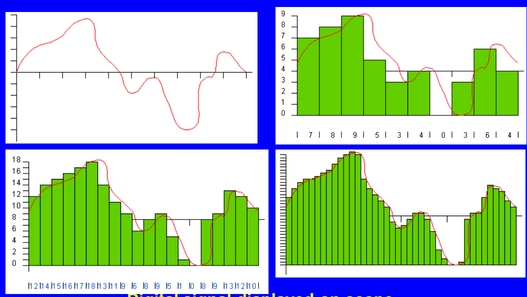
WHAT IS A DIGITAL CIRCUIT?



- Digital signal displayed on scope.
- Digital signal waveform.

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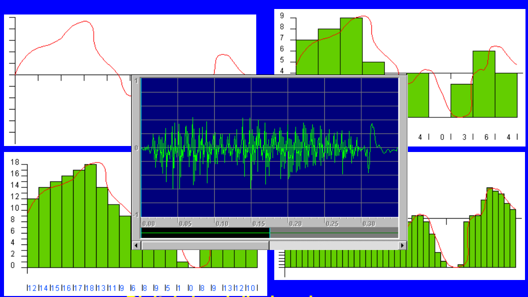
WHAT IS A DIGITAL CIRCUIT?



- Digital signal displayed on scope.
- Digital signal waveform.

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WHERE ARE DIGITAL CIRCUITS USED?

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WHY USE DIGITAL CIRCUITS?

- Analog system used to interpret float level in water tank.
- Digital system used to interpret float level in water tank.

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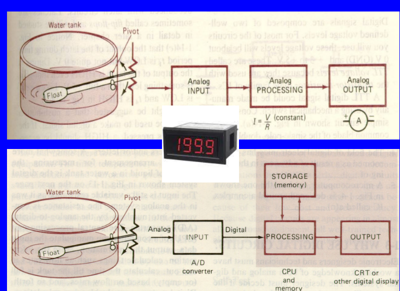
WHY USE DIGITAL CIRCUITS?



- Analog system used to interpret float level in water tank.
- Digital system used to interpret float level in water tank.

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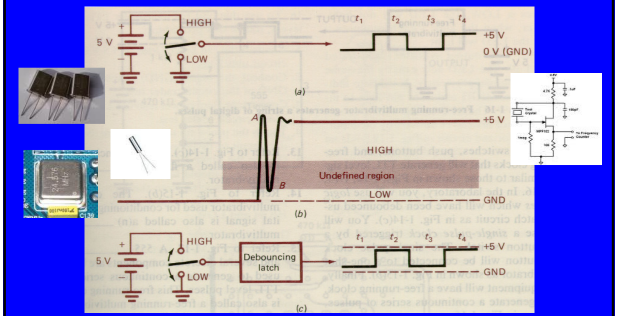
HOW DO YOU MAKE A DIGITAL SIGNAL?



- Generating a digital signal with a switch.
- Waveform of contact bounce within a mechanical switch.
- Adding a debouncing latch to a simple switch to condition the digital signal

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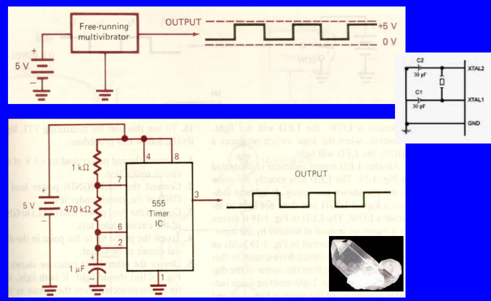
HOW DO YOU MAKE A DIGITAL SIGNAL?



- Free-running multivibrator generates a string of digital pulse.
- Schematic diagram of a free-running clock using a 555 IC.

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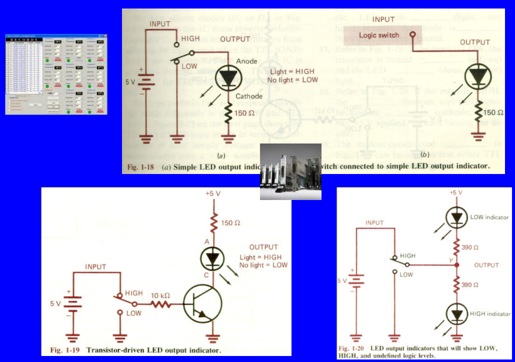
HOW DO YOU TEST FOR A DIGITAL SIGNAL?



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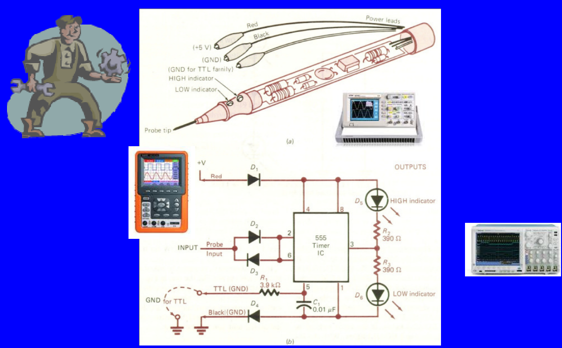
HOW DO YOU TEST FOR A DIGITAL SIGNAL?



- Schematic diagram of the logic probe project using the 555 IC.

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Advantages of Digital Techniques

- *Digital systems are easier to design.*
- *Information storage is easy.*
- *Accuracy and precision are greater.*
- *Operation can be programmed.*
- *Digital circuits are less affected by noise.*
- *More digital circuitry can be fabricated on IC chips.*
- *Computer compatibility, memory, ease of use, simplicity of design, accuracy, and stability.*

Limitation of digital circuits

- *Most "real-world" events are analog in nature.*
- *Analog processing is usually simpler and faster.*

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SUMMARY

- *Analog signals vary gradually and continuously, wh digital levels usually referred to as LOW and HIGH.*
- *Most modern electronics equipment contain both analog and digital circuitry.*
- *Logic levels are different for various digital logic families, such as TTL and CMOS.*
- *Digital circuits have become very popular because of the availability of low-cost digital ICs.*
- *Bistable, monostable, and astable multivibrators are used to generate digital signals.*
- *Logic level indicators may take the form of simple LED and resistor circuits, volt-meters, or logic probes.*

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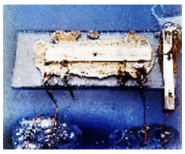
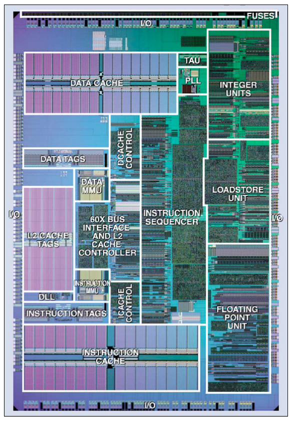
The Evolution of Computer Hardware

- When was the first IC (integrated circuit) invented?
  - In 1958 the IC was born when Jack Kilby at Texas Instruments successfully interconnected, by hand, several transistors, resistors and capacitors on a single substrate



The PowerPC 750

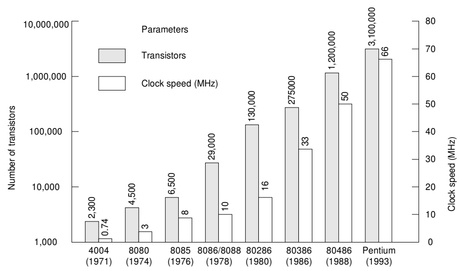


- Introduced in 1999
- 3.65M transistors
- 366 MHz clock rate
- 40 mm^2 die size
- 250nm technology

The Underlying Technologies

Year	Technology	Relative Perf./Unit Cost
1951	Vacuum Tube	1
1965	Transistor	35
1975	Integrated Circuit (IC)	900
1995	Very Large Scale IC (VLSI)	2,400,000
2005	VLSI (not a fancy name??)	6,200,000,000

History of Computing - Evolution of Intel Microprocessor



Evolution of the Intel microprocessors.

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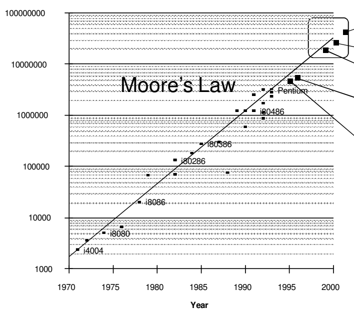
Technology Trends: Microprocessor Complexity



Itanium 2: 41 Million
Athlon (K7): 22 Million
Alpha 21264: 15 million
Pentium Pro: 5.5 million
PowerPC 620: 6.9 million
Alpha 21164: 9.3 million
Sparc Ultra: 5.2 million
2X transistors/Chip
Every 1.5 years

Called "Moore's Law"

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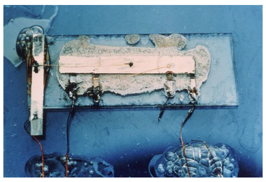
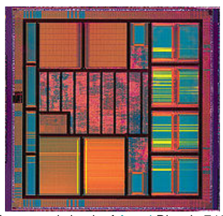


Jack Kilby's original integrated circuit



Integrated circuit of Atmel Diopsis 740 System on Chip showing memory blocks, logic and input-output pads around the periphery

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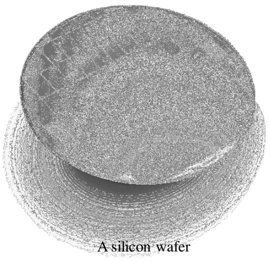
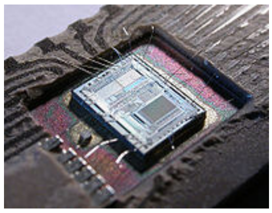
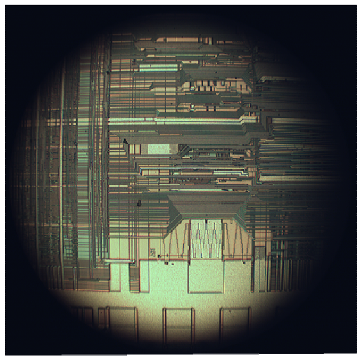




The integrated circuit from an Intel 8742, an 8-bit microcontroller that includes a CPU running at 12 MHz, 128 bytes of RAM, 2048 bytes of EPROM, and I/O in the same chip.



Upper interconnect layers on an Intel 80486DX2 microprocessor die.

Fixed-Function Integrated Circuits

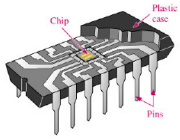


Figure 1--27 Cutaway view of one type of fixed-function IC package showing the chip mounted inside, with connection to input an output pins.

IC Packages

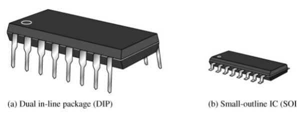


Figure 1--28 Examples of through-hole and surface-mounted devices. The DIP is larger than the SOIC with the same number of leads. This particular DIP is approximately 0.785 in. long, and the SOIC is approximately 0.385 in. long.

Digital Systems - Design Hierarchy (3)

- Transistor and physical design level: Each logic gate is implemented by a lower-level transistor circuit.
- Electronic Technologies:

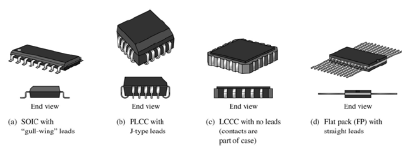


Figure 1--29 Examples of SMT package configurations.

Pin Numbering

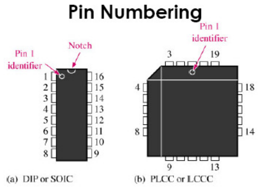
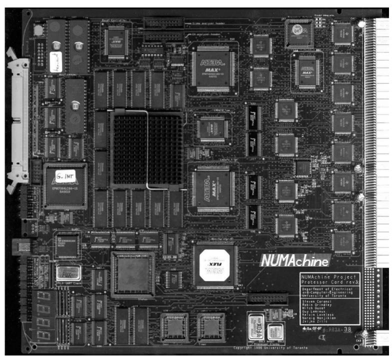


Figure 1--30 Pin numbering for two standard types of IC packages. Top views are shown.



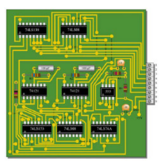
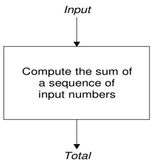


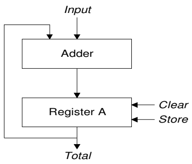
Figure 1.5 A printed circuit board

Digital Systems - Design Hierarchy (1)

- System level - Register level - Gate level - Transistor and physical design level
- System level: Black box specification.
- Register level: Collection of registers.



(a) System Level

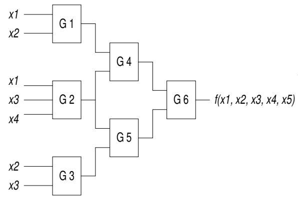


(b) Register Level

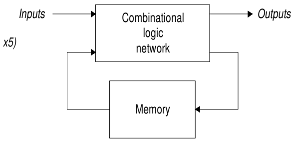
Models of a digital system that adds lists of numbers.

Digital Systems - Design Hierarchy (2)

- Gate level: Collection of logic gates.



A combinational logic circuit with six gates.



Sequential logic circuit.

Digital Systems - Design Hierarchy (3)

- Transistor and physical design level: Each logic gate is implemented by a lower-level transistor circuit.
- Electronic Technologies:

Technology (Device Type)	Power Consumption	Speed	Packaging
RTL (Bipolar junction)	High	Low	Discrete
DTL (Bipolar junction)	High	Low	Discrete, SSI
TTL (Bipolar junction)	Medium	Medium	SSI, MSI
ECL (Bipolar junction)	High	High	SSI, MSI, LSI
pMOS (MOSFET)	Medium	Low	MSI, LSI
nMOS (MOSFET)	Medium	Medium	MSI, LSI, VLSI
CMOS (MOSFET)	Low	Medium	SSI, MSI, LSI, VLSI
GaAs (MOSFET)	High	High	SSI, MSI, LSI

Generations

SSI, MSI and LSI

The first integrated circuits contained only a few transistors. Called "Small-Scale Integration" (SSI)

VLSI

The final step in the development process, starting in the 1980s and continuing through the present, was "very large-scale integration" (VLSI).

ULSI, WSI, SOC and 3D-IC

To reflect further growth of the complexity, the term **ULSI** that stands for "**Ultra-Large Scale Integration**" was proposed for chips of complexity of more than 1 million transistors.

Wafer-scale integration (WSI) is a system of building very-large integrated circuits that uses an entire silicon wafer to produce a single "super-chip".

Generations

ULSI, WSI, SOC and 3D-IC

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Wafer-scale integration (WSI) is a system of building very-large integrated circuits that uses an entire silicon wafer to produce a single "super-chip".

System-on-a-Chip (SoC or SOC) is an integrated circuit in which all the components needed for a computer or other system are included on a single chip.

Three Dimensional Integrated Circuit (3D-IC) has two or more layers of active electronic components that are integrated both vertically and horizontally into a single circuit.

IC device technologies

Integrated injection logic

Transistor–transistor logic (TTL)

Bipolar junction transistor

Emitter-coupled logic (ECL)

MOSFET

NMOS

CMOS

BiCMOS

BCDMOS

GaAs

SiGe

Mixed-signal integrated circuit

RC delay

7400 series derivative families

Bipolar

- **74** - the "standard TTL" logic family had no letters between the "74" and the specific part number.
- **74L** - Low power (compared to the original TTL logic family), very slow
- **H** - High speed (still produced but generally superseded by the S-series, used in 1970s era computers)
- **S** - Schottky (obsolete)
- **LS** - Low Power Schottky
- **AS** - Advanced Schottky
- **ALS** - Advanced Low Power Schottky
- **F** - Fast (faster than normal Schottky, similar to AS)

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TTL Speed - Power

TTL Family

	74S	74LS	74AS	74ALS	74F
Maximum Propagation delay (ns)	3	9	1.7	4	3
Power per gate (mW)	19	2	8	1.2	4
Power-Delay product (pJ)	57	18	13.6	4.8	12

(Data for a 2-input NAND Gate)

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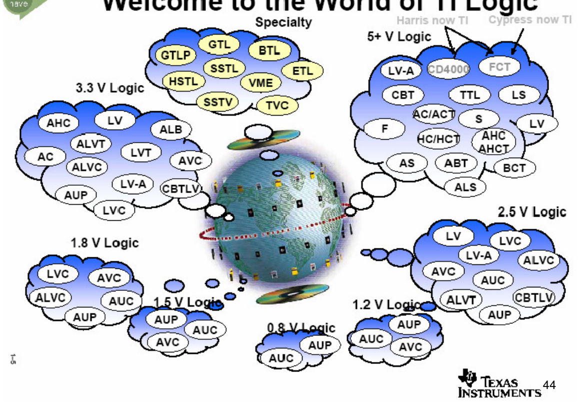
Welcome to the World of TI Logic



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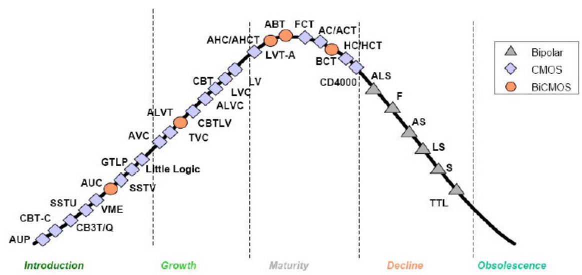
Product life cycle



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CMOS

- **C** - CMOS 4-15V operation similar to buffered 4000 (4000B) series
- **HC** - High speed CMOS, similar performance to LS, 12nS
- **HCT** - High speed, compatible logic levels to bipolar parts
- **AC** - Advanced CMOS, performance generally between S and F
- **AHC** - Advanced High-Speed CMOS, three times as fast as HC
- **ALVC** - Low voltage - 1.65 to 3.3V, tpd 2nS[7]
- **AUC** - Low voltage - 0.8 to 2.7V, tpd<1.9nS@1.8V[7]
- **FC** - Fast CMOS, performance similar to F
- **LCX** - CMOS with 3V supply and 5V tolerant inputs
- **LVC** - Low voltage - 1.65 to 3.3V and 5V tolerant inputs, tpd<5.5nS@3.3V, tpd<9nS@2.5V[7]
- **LVQ** - Low voltage - 3.3V
- **LVX** - Low voltage - 3.3V with 5V tolerant inputs
- **VHC** - Very High Speed CMOS - 'S' performance in CMOS technology and power
- **G** - Super high speeds at more than 1 GHz (Produced by Potato Semiconductor)

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BiCMOS

the integration of bipolar junction transistors and CMOS technology into a single integrated circuit device

- **BCT** - BiCMOS, TTL compatible input thresholds, used for buffers
- **ABT** - Advanced BiCMOS, TTL compatible input thresholds, faster than ACT and BCT

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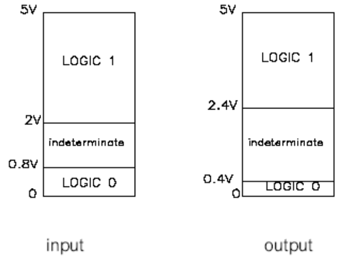

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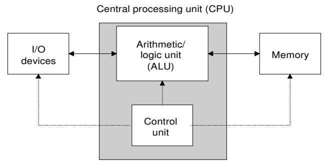
Organization of a Digital Computer - Four Major Components

- Control unit: Follows the stored list of instructions and supervises the flow of information among other components.
- Arithmetic/logic unit (ALU): Performs various operations.
- Memory unit: Stores programs, input, output, and intermediate data.
- I/O devices: Printers, monitors, keyboard, etc.



High-level organization of a digital computer.

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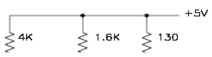

TTL Driver TTL Load	74L	74LS	74
Low-power 74LXXX	20	10	2
Low-power schottky 74LSXXX	40	20	5
Standard 74XXX	40	20	10
High-speed 74HXXX	50	25	12

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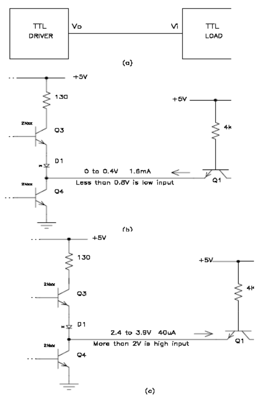

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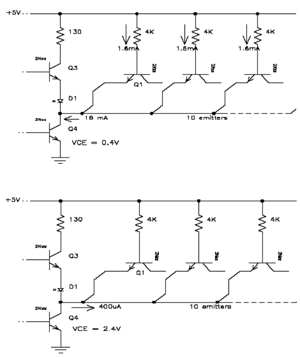

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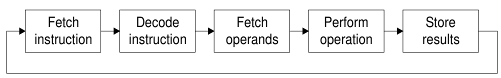
Organization of a Digital Computer - Instruction Cycle

- Fetch the next instruction into the control unit.
- Decode the instruction.
- Fetch the operands from memory or input devices.
- Perform the operation.
- Store the results in the memory (or send the results to an output device).



Instruction cycle of a stored program computer.

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Analog v.s. Digital
Definitions:

- Analog Systems: process time-varying signals that can take on any value across a continuous range of voltage, current, or other metric.
- Digital Systems: also deal with time-varying signals but they treat these signals as “NON” time-varying, which these signals are modeled as only one of two discrete values: 0 or 1 (LOW or HIGH)

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Analog v.s. Digital
Applications:

- Audio recording: magnetic tape => CD
- Automobile carburetors: “analog” mechanical leakage => microprocessor control
- Telephone system: “pure” analog system => digital conversion for routing in central office
- Traffic lights: electromechanical timers => computer control
- Movie effects: miniature clay models => computer graphics

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Why digital system is popular.

- Reproducibility of results: same input => same output
- Ease of design: no special math skills are required.
- Flexibility and functionality: logical steps in space and time
- Programmability: programmable hardware, i.e. PLD
- Speed: responded time < 10 nanosecond
- Economy: small-sized devices, e.g. IC
- Steadily advancing technology: better performance chips each year

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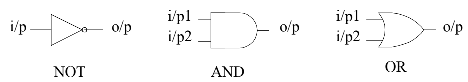
Digital Devices

- Gate: the most basic digital device, which has one or more inputs and produces an output as a function of its currents input(s).



NOT gate: output = 0 if input = 1, output = 1 if input = 0

AND gate: output = 1 if all input = 1, otherwise output = 0

OR gate: output = 0 if all input = 0, otherwise output = 1

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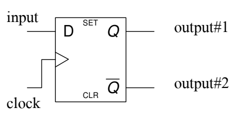
Digital Devices (Continued)

- Flip-Flop: is a device that can store its output or state, which is either 0 or 1. State can be changed by a certain pattern of “clock” input and “control” input. For example, D flip-flop:



If input = 1 and clock is set, then output#1 = 1, output#2 = 0

If input = 0 and clock is set, then output#1 = 0, output#2 = 1

Note: Details about flip-flops will be discussed in the later chapters.

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Combinational v.s. Sequential circuits

- Combinational circuit: its output depends only on the current input combination.
- Sequential circuit: output of the circuit depends on its current input and past sequence of inputs

- Gate => combinational circuit
- Flip-flop => sequential circuit

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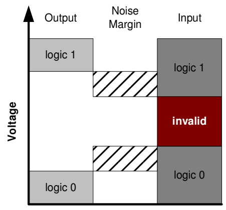
Electronics Aspects of Digital Design

Digital Abstraction: allows analog behavior to be ignored in most cases, so circuits can be modeled as if they really did process 0 and 1.



Noise margin: the difference between input and output ranges. It can prevent the real circuit from being corrupted by noise in some extend.

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Software Aspects of Digital Design

- Long before: software tools was not necessary. Only plastic template is enough.
- Now: Computer-Aided Design (CAD) tools are playing more and more important roles. It can improve the quality of designs in the sense of correctness and designer's productivity.

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Software Aspects of Digital Design (Continued)

Examples of CAD tools

- Schematic Entry: Visio
- Simulators: e.g. OrCAD
- Hardware Description Language (HDL) used to specify particular digital devices from individual function modules (e.g. NOT gate) up to large digital systems (e.g. microprocessors)
- HDL compilers, simulators, and synthesis tools

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Integrated Circuits

- Die: small sections of fabricated wafer (silicon plate).
- Integrated Circuit: or IC is a collection of one or more gates, which are fabricated on a single silicon chip. => IC = die + package
- SSI: small-scale integration => 1 – 20 gates, e.g. gates and flip-flops.
- Usually, SSI IC come in a 14-pin *dual in-line-pin* (DIP) package.

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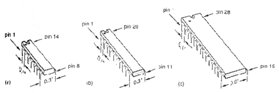
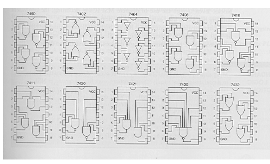
Integrated Circuits (Continued)

- Examples of 14-pin, 20-pin, and 28-pin DIP
- Pin diagrams of SSI IC in some of 7400-series family.





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Integrated Circuits (Continued)

- MSI: medium-scale integration => 20 – 200 gates, e.g. decoder, register, counter, etc.
- LSI: Large-scale integration => 200 – 200,000 gates, e.g. small memory, microprocessors, programmable logic devices, etc.
- VLSI: Very large-scale integration => over 1,000,000 transistors (not number of gates), e.g. modern memory, microprocessors, etc.
- What is the number of transistors in Pentium-III processor?

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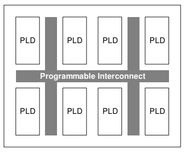
Programmable Logic Devices

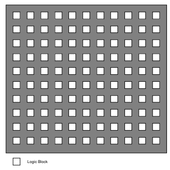
- Programmable Logic Arrays (PLAs): two-level structure of AND and OR gates
- PLA = Programmable Array Logic (PAL) devices = Programmable Logic Devices (PLDs) => MSI
- CPLD = Complex PLD => LSI – VLSI
- Field-Programmable Gate Array (FPGA)

Programmable Logic Devices (Continued)

- **CPLD**:
  - a collection of PLDs, which the interconnection between each PLD module can be specified



- **FPGA:**
  - a collection of smaller individual logic blocks, providing a large and distributed interconnection structure.



Application-Specific ICs

Advantage v.s. Disadvantage

- Application-Specific ICs or ASICs are also called semi-custom IC. They are used in particular, limited applications, e.g. microprocessors in mobile phones, MP3 decoders, etc.

Advantages:
- reducing chip count
- reducing physical size
- lower power consumption
- higher performance

Disadvantages:
- specific/small markets
- high NRE => expensive

An **application-specific integrated circuit** (ASIC) is an integrated circuit (IC) customized for a particular use, rather than intended for general-purpose use. For example, a chip designed solely to run a cell phone is an ASIC. Intermediate between ASICs and industry standard integrated circuits, like the 7400 or the 4000 series, are application specific standard products (ASSPs).