EMBEDDED SYSTEMS (CMPE 30274)
ASICs, PLDs, COTs

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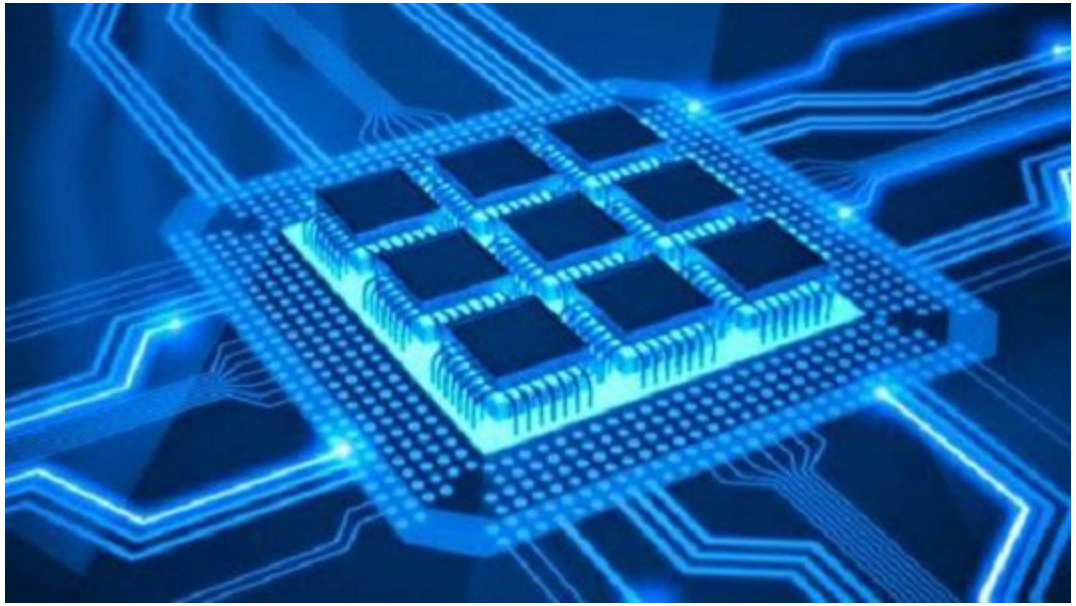
Application-Specific Integrated Circuits

Application-Specific Integrated Circuits

ASICs are integrated circuits designed for a specific application or purpose, rather than for general-purpose use.

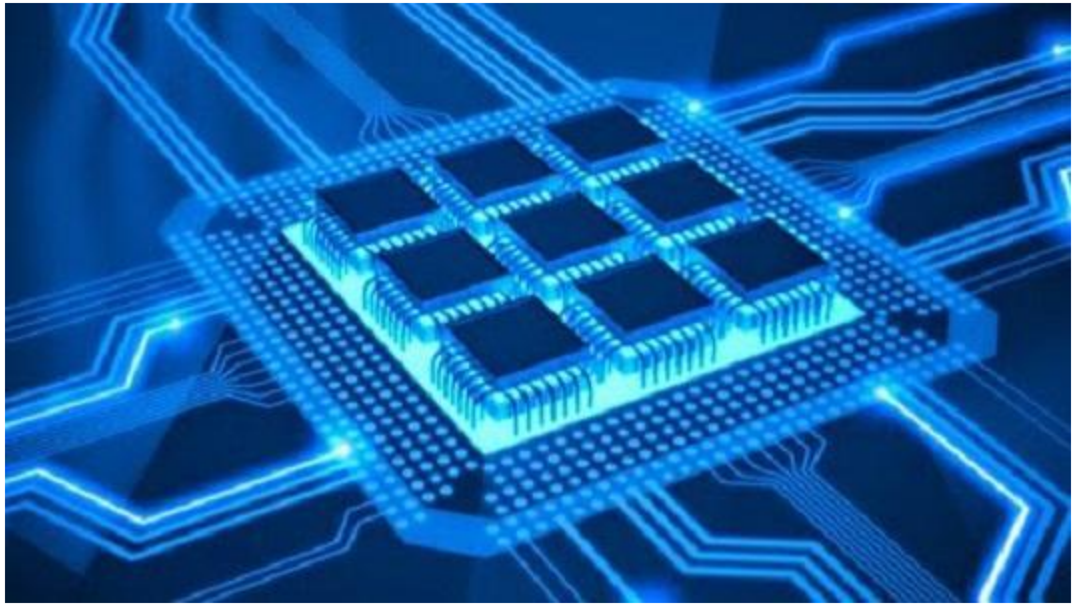
They are custom-built chips that are optimized for a particular task or function, making them highly efficient and powerful in their intended application.



Application-Specific Integrated Circuits

Applications of ASICs

- Telecommunications
- Consumer Electronics
- Automotive Applications
- Digital Signal Processing (DSP)
- Medical Devices
- Industrial Automation
- Data Centers
- Wearable Technology



Applications

Application	Example
Telecommunications	ASICs in networking equipment for data transmission and protocols
Consumer Electronics	ASICs in smartphones for video encoding/decoding
Automotive Applications	ASICs in ADAS for collision avoidance and lane-keeping assistance
Digital Signal Processing (DSP)	ASICs for audio and video processing in entertainment devices
Medical Devices	ASICs in MRI machines for real-time data processing
Industrial Automation	ASICs controlling robotic systems in manufacturing
Wearable Technology	ASICs in fitness trackers for sensor data management

Advantages of ASICs

Performance

the performance advantages of Application-Specific Integrated Circuits (ASICs) compared to more general-purpose computing devices like CPUs (Central Processing Units) and FPGAs (Field-Programmable Gate Arrays).

1. **Specific Application Design**: ASICs are created for a particular task or application. This specialization means they can be finely tuned to perform that specific task very efficiently.

2. **Optimization**: Because ASICs are tailored for specific functions, they can be optimized for maximum performance. This means they can execute tasks faster and more effectively than devices designed for multiple purposes.

3. **Reduced Overhead**: General-purpose architectures (like CPUs) have built-in flexibility to handle various tasks, which introduces some overhead (additional processing requirements). ASICs eliminate this overhead since they focus solely on their designated application.

4. **Higher Speeds and Throughput**: As a result of their specialized design and lack of overhead, ASICs can achieve much higher operational speeds and data processing rates (throughput) compared to CPUs and FPGAs.

Energy Efficiency

ASICs are tailored to the target application, enabling them to minimize power consumption and heat generation.

This is achieved through the use of custom-designed circuitry, efficient architectures, and the elimination of unnecessary components.

Cost Effectiveness

While the initial design and development costs for ASICs can be high, the per-unit manufacturing cost is often lower compared to other solutions, especially in high-volume production.

This makes ASICs cost-effective for applications with large production volumes.

Microcontrollers and ASICs

Microcontrollers

Definition: A microcontroller is a compact integrated circuit designed to govern a specific operation in an embedded system.

Components: Typically includes a processor core, memory (RAM and ROM), and peripherals (like timers, I/O ports) on a single chip.

Flexibility: Programmable; can be easily reprogrammed to perform different tasks or functions.

Use Cases: Commonly used in consumer electronics, automotive systems, industrial automation, and IoT devices.

Cost: Generally lower cost for mass production due to their general-purpose nature.

ASICs

Definition: An ASIC is a custom-designed chip tailored for a specific application or function.

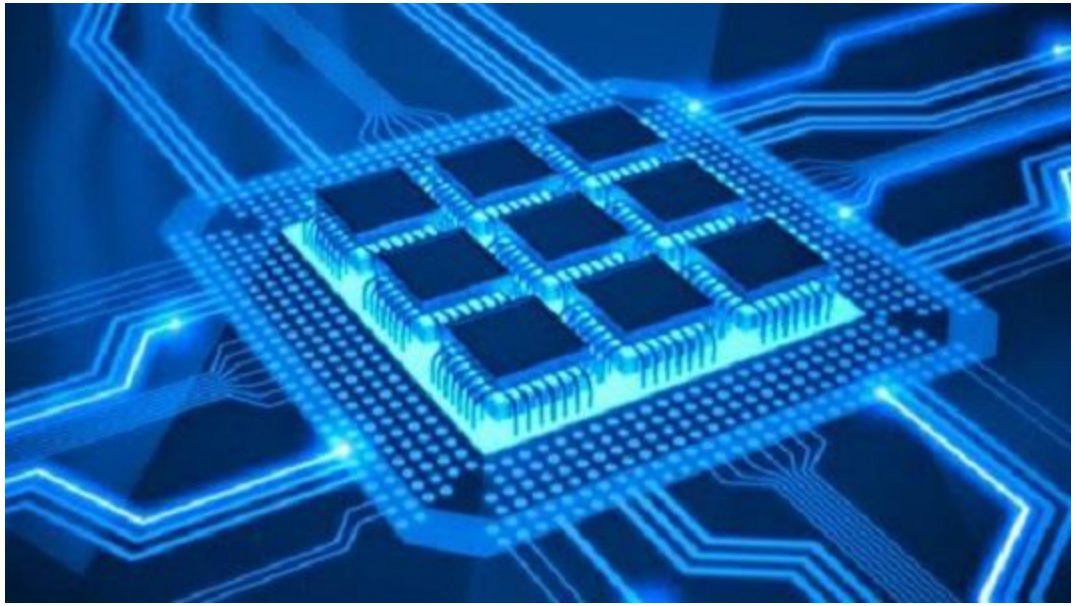
Components: Fully optimized circuit layout for particular tasks; does not include unnecessary components.

Flexibility: Not reprogrammable; designed for a specific function and cannot be changed after manufacturing.

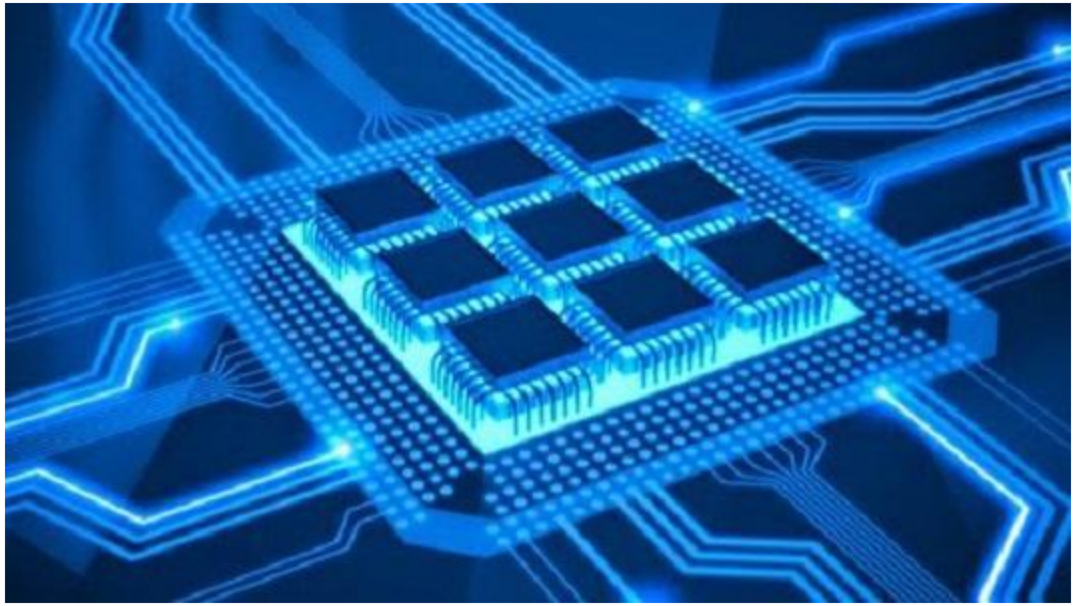
Use Cases: Used in high-performance applications such as telecommunications, networking equipment (routers and switches) and specialized computing tasks.

Cost: Higher upfront development costs due to custom design, but can be cost-effective for high-volume production.

Programmable Logic Devices (PLDs)



Programmable Logic Devices (PLDs) are a class of semiconductor devices that can be programmed or configured to perform specific logic functions. Unlike Application-Specific Integrated Circuits (ASICs), which are custom-designed for a particular application, PLDs are more general-purpose and can be reprogrammed or reconfigured to implement different logic designs.



Main types of PLDs

- Programmable Logic Array (PLA)
- Programmable Array Logic (PAL)
- Field-Programmable Gate Array (FPGA)
- Complex Programmable Logic Device (CPLD)

Main types of PLDs

PLA

Programmable Logic Array (PLA): The PLA is one of the earliest forms of PLDs, consisting of an array of AND gates and an array of OR gates that can be programmed to implement Boolean logic functions.

PAL

Programmable Array Logic (PAL): PALs are similar to PLAs, but with a more restricted architecture that is typically easier to program and has a simpler structure.

Field-Programmable Gate Array (FPGA):

Field-Programmable Gate Array (FPGA): FPGAs are the most widely used type of PLD today. They consist of an array of configurable logic blocks (CLBs) that can be interconnected and programmed to implement complex digital circuits and systems.

Complex Programmable Logic Device (CPLD):

Complex Programmable Logic Device (CPLD): CPLDs are a type of PLD that combine multiple PAL-like structures into a single integrated circuit, offering a higher level of integration and flexibility compared to individual PALs.

PLD and ASICs

PLDs are integrated circuits that can be programmed by the user to perform a wide range of functions. They offer flexibility as they can be reprogrammed to change their functionality.

Examples: A real-life example of a PLD is a FPGA used in prototyping hardware for a new product. Engineers can program the FPGA to test various configurations and functions before committing to a final ASIC design.

Key Differences

- **Flexibility**: ASICs are fixed-function, while PLDs are programmable.
- **Cost and Time**: ASICs involve higher initial costs and longer development times; PLDs are more cost-effective for lower volume applications and quicker to deploy.
- **Performance**: ASICs typically offer better performance and efficiency for specific tasks compared to PLDs.

Is PLD and PLC the same?

No

PLD and PLC

Programmable Logic Controller (PLC)

Definition: PLCs are industrial computers used for automation of manufacturing processes, control of machinery, and other industrial applications.

Functionality: They are designed to monitor inputs (like sensors), make decisions based on programmed logic, and control outputs (like actuators).

Programming: PLCs are typically programmed using ladder logic or other graphical programming languages that are user-friendly for engineers and technicians.

Applications: Commonly used in factory automation, process control, and equipment management in industries like manufacturing, food processing, and water treatment.

PLD and PLC

Programmable Logic Device (PLD)

- **Definition**: PLDs are integrated circuits that can be programmed to perform specific logic functions. They include types like FPGAs (Field-Programmable Gate Arrays) and CPLDs (Complex Programmable Logic Devices).

- **Functionality**: They are used to implement custom digital circuits and logic functions, providing flexibility in hardware design.

- **Programming**: PLDs are programmed using hardware description languages (HDLs) like VHDL or Verilog, which require knowledge of digital design.

- **Applications**: Used in various applications, including digital signal processing, telecommunications, and custom hardware design.

PLD and PLC

Differences

- **Purpose**: PLCs are for industrial control and automation, while PLDs are for implementing custom logic circuits.

- **Programming**: PLCs use user-friendly programming languages, while PLDs use HDLs for programming.

- **Applications**: PLCs are specific to industrial automation, whereas PLDs are used in a broader range of digital logic applications.

COTS

Application-Specific Integrated Circuits

COTS stands for "Commercial Off-The-Shelf".
In the context of technology and engineering, COTS refers to products or components that are commercially available and ready-made, rather than being custom-designed or built specifically for a particular application.

Most common COTS used in industrial automation:

- Programmable Logic Controllers (PLCs)
- Human-Machine Interfaces (HMIs)
- Industrial Computers and Embedded Systems
- Industrial Networking Equipment
- Sensors and Instrumentation
- Motion Control Components
- Industrial Software and Middleware

Most common COTS used in industrial automation:

Programmable Logic Controllers (PLCs):
PLCs are the backbone of industrial automation, providing the core control and logic functions for a wide range of industrial processes and equipment.

Human-Machine Interfaces (HMIs):
HMIs, such as touchscreen displays, provide the interface between the operator and the industrial control system.

Industrial Computers and Embedded Systems:
- Industrial-grade computers, single-board computers (SBCs), and embedded systems are used for advanced control, data processing, and integration tasks in industrial automation.

Most common COTS used in industrial automation:

Industrial Networking Equipment:
Industrial-grade network switches, routers, and wireless access points are used to establish reliable and secure communication networks in industrial environments.

Sensors and Instrumentation:
A wide range of COTS sensors, including temperature, pressure, flow, level, and position sensors, are used to monitor and gather data from industrial processes.

Motion Control Components:
COTS motion control products, such as servo motors, drives, and motion controllers, are integral to industrial automation systems.

well-known companies that provide common COTS

Programmable Logic Controllers (PLCs):
- Siemens
- Rockwell Automation (Allen-Bradley)
- Schneider Electric
- Mitsubishi Electric
- Omron

Human-Machine Interfaces (HMIs):
- Rockwell Automation
- Siemens
- Schneider Electric
- Beijer Electronics
- Omron

Industrial Computers and Embedded Systems:
- Advantech
- Hewlett Packard Enterprise (HPE)
- Dell

Industrial Networking Equipment:
- Cisco
- Belden

Sensors and Instrumentation:
- ABB
- Siemens
- Emerson

Motion Control Components:
- Rockwell Automation
- Siemens
- Bosch Rexroth

PLD and ASICs and Microcontroller

Feature	Commercial Off-The-Shelf	Application-Specific Integrated Circuit	Programmable Logic Device	Microcontroller
Definition	Ready-made products available for purchase	Custom-designed chips for specific applications	Devices that can be programmed to perform specific logic functions	Integrated circuits with a processor, memory, and I/O peripherals
Examples	Laptops, desktop computers, software applications	Networking Equipment (Routers and Switches)	Field-Programmable Gate Arrays, Complex Programmable Logic Devices	Arduino boards, washing machines, smart appliances

Feature	Commercial Off-The-Shelf	Application-Specific Integrated Circuit	Programmable Logic Device	Microcontroller
Cost	Generally lower due to mass production	Higher initial cost due to customization	Moderate to high, depending on complexity	Cost-effective for small-scale applications
Development Time	Quick deployment, readily available	Longer development time for design and production	Moderate; faster than Application-Specific Integrated Circuits but requires programming	Moderate; requires programming and design
Flexibility	Limited; designed for general use	Very limited; optimized for specific tasks	High; can be reprogrammed for different functions	High; can be programmed for various applications

Feature	Commercial Off-The-Shelf	Application-Specific Integrated Circuit	Programmable Logic Device	Microcontroller
Performance	Good for general tasks	High efficiency and performance for specific tasks	Good performance; depends on the implementation	Moderate; suitable for embedded systems
Market	Consumer electronics, general markets	Specialized industries (e.g., telecommunications)	Electronics design, prototyping, and specialized applications	Embedded systems, hobbyist projects