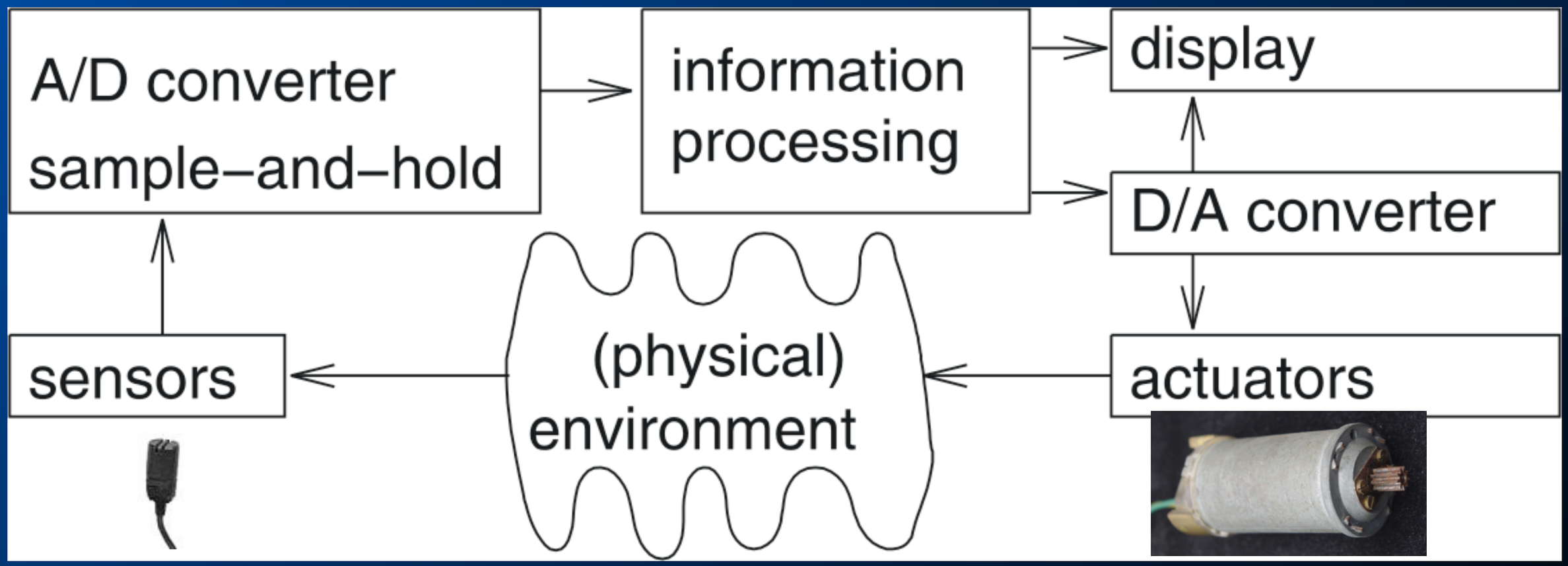
Embedded Microprocessor

Embedded System Hardware

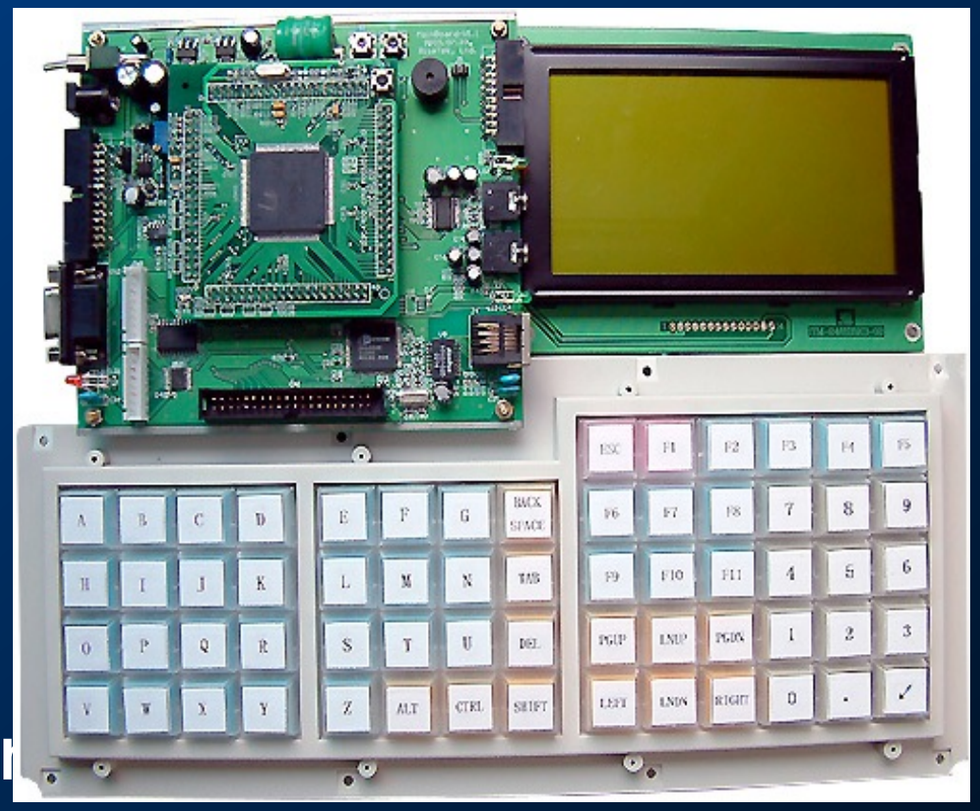
- Embedded system hardware is frequently used in a loop (***"hardware in a loop"***):



☞ cyber-physical systems

Hardware platform architecture

- Contains several elements:
  - CPU;
  - bus;
  - memory;
  - I/O devices: networking, sensor
- How big/fast much each one be?



Popular Microcontroller

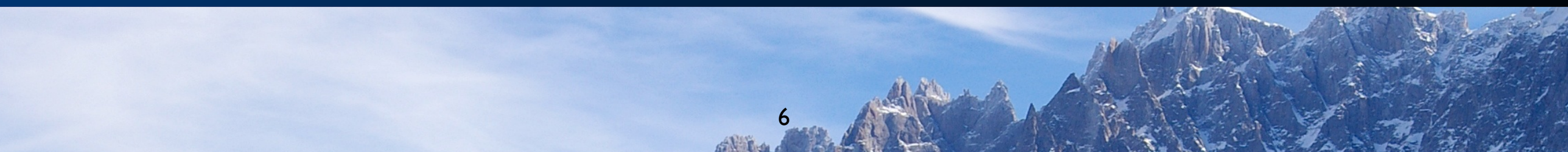
- ARM
- MIPS
  - 美国计算机协会（ACM）宣布 John L. Hennessy 和 David A. Patterson 荣获 2017 年图灵奖。
  - “无互锁流水级的微处理器”(Microprocessor without interlocked piped stages)
- PowerPC
- X86

von Neumann architecture

- Memory holds data, instructions.
- Central processing unit (CPU) fetches instructions from memory.
  - Separate CPU and memory distinguishes programmable computer.
- CPU registers help out: program counter (PC), instruction register (IR), general-purpose registers, etc.

Harvard

- Harvard can't use self-modifying code.
- Harvard allows two simultaneous memory fetches.
- Most DSPs use Harvard architecture for streaming data:
  - greater memory bandwidth;
  - more predictable bandwidth.



RISC vs. CISC

- Complex instruction set computer (CISC):
  - many addressing modes;
  - many operations.
- Reduced instruction set computer (RISC):
  - load/store;
  - pipelinable instructions.

RISC与CISC的主要特征对比

比较内容	CISC	RISC
指令系统	复杂，庞大	简单，精简
指令数目	一般>200	一般<100
指令格式	一般>4	一般<4
寻址方式	一般>4	一般<4
指令字长	不固定	等长
访存指令	不加限制	只有LOAD/STORE指令
指令使用频率	相差很大	相差不大
指令执行时间	相差很大	绝大多数在一个周期内完成
优化编译实现	很难	较容易

RISC-V

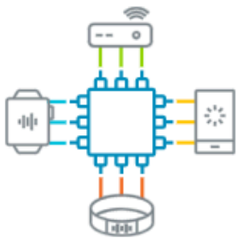
- 简单、完全开源并且免费
- 将基准指令和扩展指令分开，可以通过扩展指令做定制化的模块和扩展。
  - RISC-V的基准指令确定后将不会再有变化，这是RISC-V稳定性的重要保障。
- 32、64、128位指令集

RISC-V微处理器的兼容性

- 2015年非盈利性组织RISC-V基金会（RISC-V Foundation）成立

设计系统芯片之前需要考虑的五件事

- 成本
- 生态系统
- 碎片化风险
- 安全性
- 设计保证



Processor IP

Technology for the Widest Range of Devices—from Sensors to Servers

Arm is the world's leading technology provider of silicon IP and custom SoCs at the heart of billions of devices. Our portfolio of products enable partners to get-to-market faster.

Explore IP Products >

IoT Products

Technology that Removes the Complexities of IoT

Arm removes the complexities of IoT with a complete IoT products and pre-integrated subsystems that enable customers and partners to rapidly design and deploy flexible IoT solutions.

Explore IoT Products >

微处理器架构类型

	von Neumann	Harvard
CISC	X86，Motorola 68000	SHARC(DSP)
RISC	ARM7, SPARC, MIPS, PowerPC	ARM9，PIC

Programming model

- Programming model: registers visible to the programmer.
- Some registers are not visible (IR).

嵌入式微处理器的分类

- 嵌入式微处理器种类繁多，按位数可分为4位、8位、16位、32位和64位。

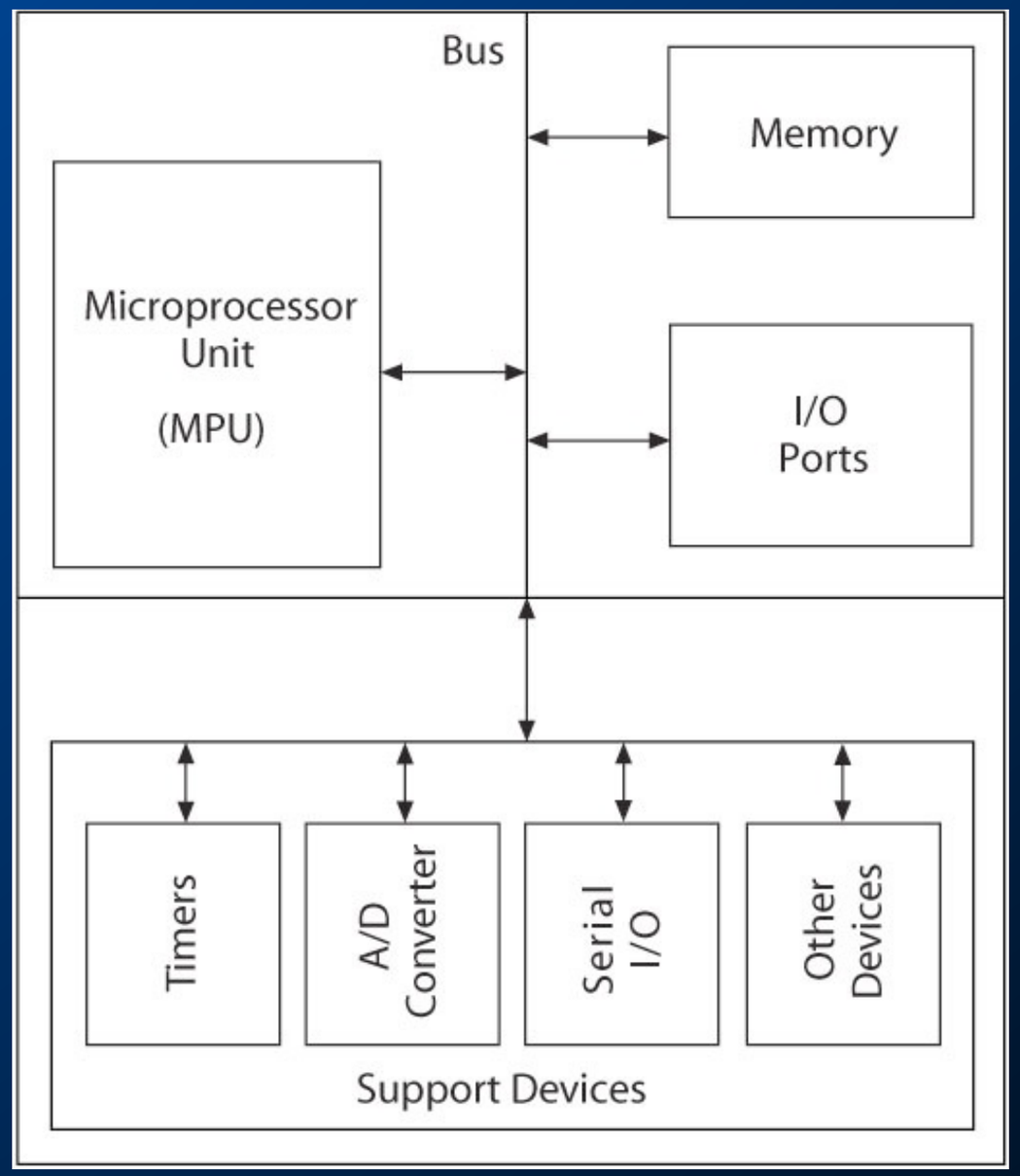
- 根据功能不同，嵌入式微处理器分为四种：
  - 嵌入式微处理单元（MPU）
  - 嵌入式微控制器（MCU）
  - 嵌入式DSP处理器
  - 嵌入式SoC

嵌入式微处理单元（MPU）

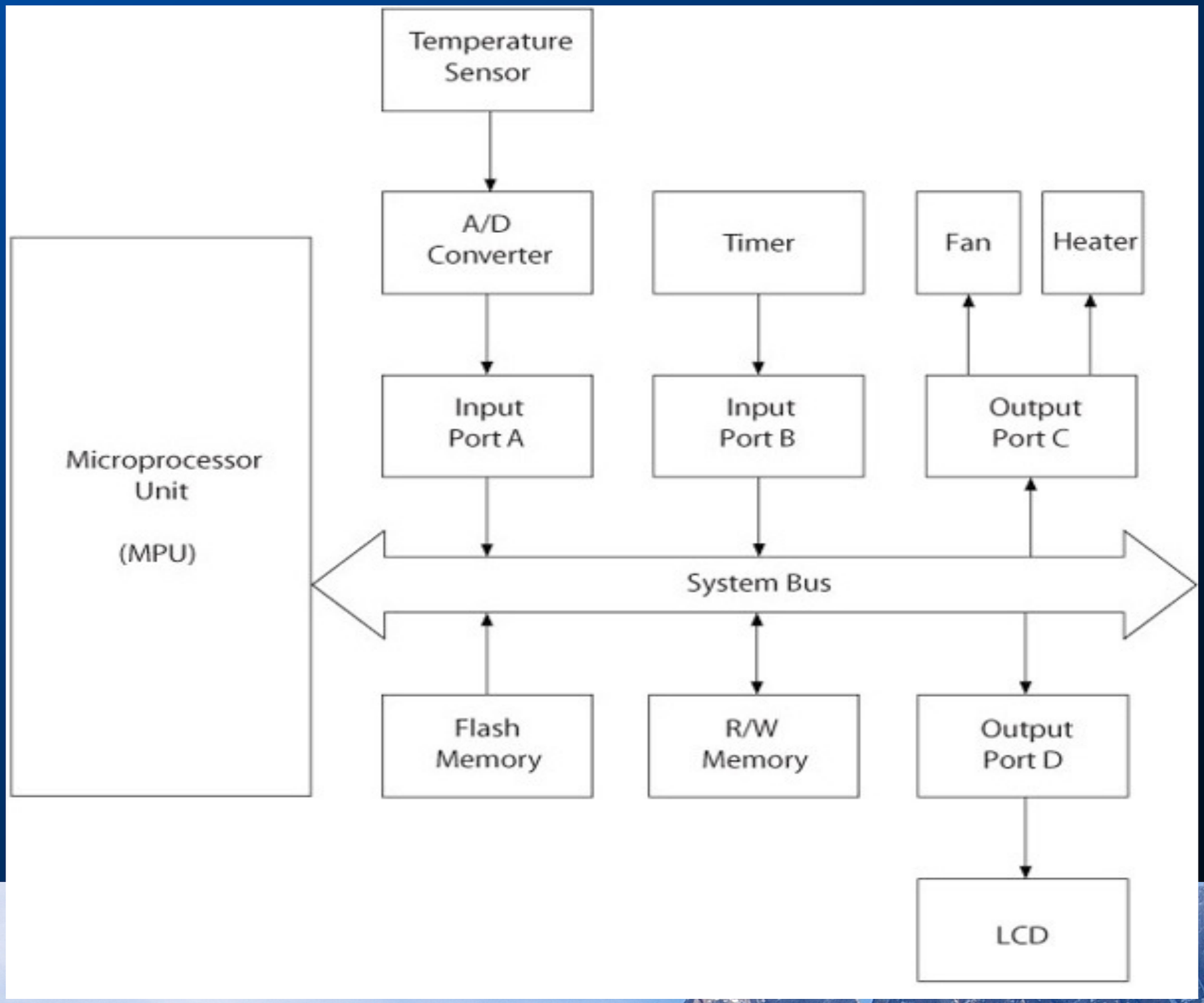
- 嵌入式微处理器就是和通用计算机的处理器对应的CPU。
  - 功能和微处理器基本一样,是具有32位以上的处理器,具有较高的性能.
  - 具有体积小,功耗少,成本低,可靠性高的特点.
  - 有的可提供工业级应用.

- 流行的嵌入式微处理器:
  - ARM(ARM公司): Cortex-A8/A9/A15/A75/A76/A77/A78
  - Power
  - MIPS(MIPS公司)

Block Diagram



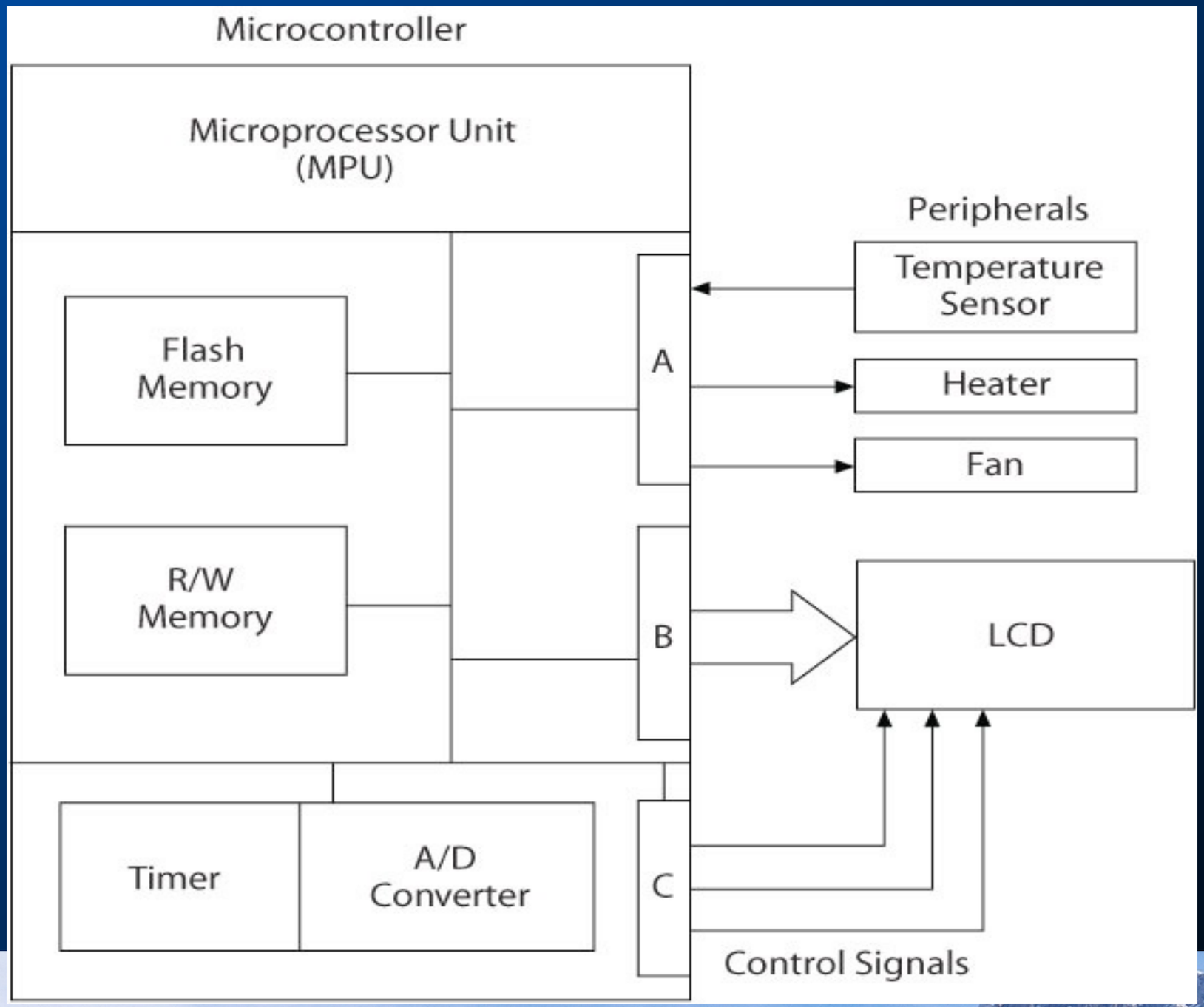
MPU-Based Time and Temperature System



嵌入式微控制器（MCU）

- 嵌入式微控制器就是将整个计算机系统的主要硬件集成到一块芯片中,芯片内部集成ROM/EPROM, RAM, 总线, 总线逻辑, 定时/计数器, Watchdog, I/O, 串行口等各种必要功能和外设.
- 特点：
  - 一个系列的微控制器具有多种衍生产品;
  - 单片化,体积大大减小,功耗和成本降低,可靠性提高;
  - 是目前嵌入式工业的主流,约占嵌入式系统50%的份额;
  - 多是8位和16位处理器
- 流行的嵌入式微控制器
  - 通用系列:8051,Coldfire的MC683xx（32位）， Cortex-M0/3/4/7/M33/M35P
  - 半通用系列:支持I2C,CAN BUS及众多专用MCU和兼容系列

MCU-Based Time and Temperature System



NXP i.MX RT系列跨界处理器

嵌入式DSP

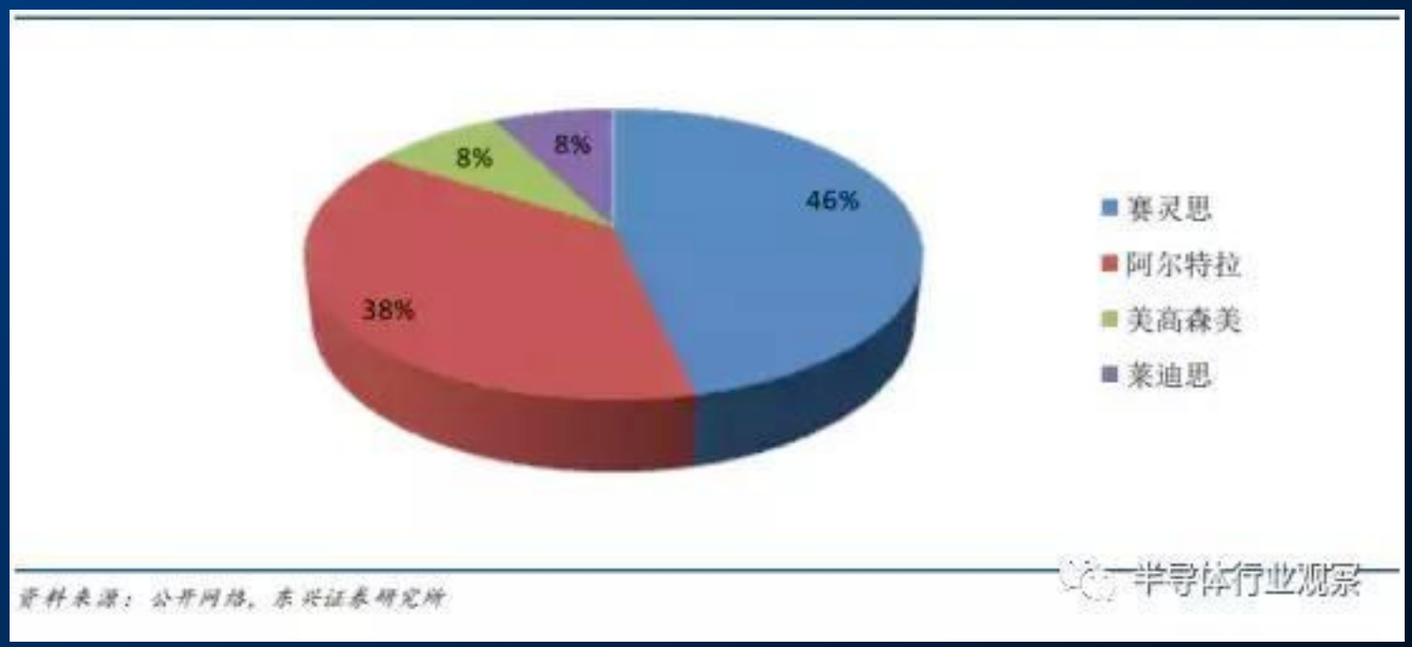
- 嵌入式DSP是专门用于信号处理方面的处理器，其在系统结构和指令算法方面进行了特殊设计，具有很高的编译效率和指令执行速度。
- 应用领域：
  - 数字滤波
  - 频谱分析
  - FFT
- 流行的嵌入式DSP
  - 德州仪器（TI），c6000 与 c5000
  - 模拟器件公司（ADI）
  - 摩托罗拉（Motorola） 公司

嵌入式SoC

- 嵌入式SoC是追求产品系统最大包容的集成器件。绝大多数系统构件都在一个系统芯片内部。
- 特点：
  - 结构简洁
  - 体积小、功耗小
  - 可靠性高
  - 设计生产效率高
- 流行的SoC
  - 高通骁龙（Snapdragon）
  - 海思

FPGA

- 现场可编程门阵列
- 赛灵思、阿尔特拉（被英特尔收购）



DSP与FPGA

DSP	FPGA
通用的信号处理器，用软件实现数据处理	用硬件实现数据处理
DSP成本低，算法灵活，功能性强	FPGA的实时性好，成本较高
适合于控制功能复杂且含有大量计算任务的工程应用。	适合于控制功能算法简单且含有大量重复计算的工程使用
对较低速的事件串联执行， 但是处理前可能会有些时延	不能处理多事件， 因为每个事件都有专用的硬件， 但是采用这种专用硬件实现的每个事件的方式可以使各个事件同时执行；

TI Embedded Processing Portfolio

TI Embedded Processors

Microcontrollers (MCUs)

16-bit ultra-low power MCUs

MSP430™

Up to 25 MHz

Flash
1 KB to 256 KB
Analog I/O, ADC
LCD, USB, RF

Measurement, Sensing, General Purpose

$0.25 to $9.00

32-bit real-time MCUs

C2000™
Delfino™
Piccolo™

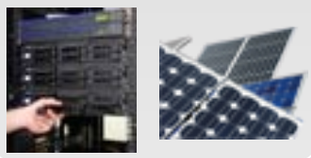
40MHz to 300 MHz

Flash, RAM
16 KB to 512 KB

PWM, ADC, CAN, SPI, I²C

Motor Control, Digital Power, Lighting, Ren. Enrgy

$1.50 to $20.00



ARM®-Based Processors

32-bit ARM Cortex™-M3 MCUs

Stellaris®
ARM® Cortex™-M3

Up to 100 MHz

Flash
8 KB to 256 KB

USB, ENET
MAC+PHY CAN,
ADC, PWM, SPI

Connectivity, Security, Motion Control, HMI, Industrial Automation

$1.00 to $8.00

ARM Cortex-A8 MPUs

Sitara™
ARM® Cortex™-A8
& ARM9

300MHz to >1GHz

Cache,
RAM, ROM
USB, CAN,
PCIe, EMAC

Industrial computing, POS & portable data terminals

$5.00 to $20.00

Digital Signal Processors (DSPs)

DSP DSP+ARM

C6000™
DaVinci™
video processors
OMAP™
300MHz to >1Ghz
+Accelerator

Cache
RAM, ROM

USB, ENET,
PCIe, SATA, SPI

Floating/Fixed Point

Video, Audio, Voice, Security, Conferencing

$5.00 to $200.00

Multi-core DSP

C6000™

24.000 MMACS

Cache
RAM, ROM

SRIO, EMAC
DMA, PCIe

Telecom test & meas, media gateways, base stations

$40 to $200.00

Ultra Low power DSP

C5000™

Up to 300 MHz
+Accelerator

Up to 320KB RAM
Up to 128KB ROM
USB, ADC
McBSP, SPI, I²C

Audio, Voice

Medical, Biometrics

$3.00 to $10.00

Cortex-A

Highest Performance

Supreme performance at optimal power

Example use cases:

Automotive

Industrial

Medical

Modem

Storage

Cortex-R

Real-Time Processing

Reliable mission-critical performance

Example use cases:

Automotive

Cameras

Industrial

Medical

Cortex-M

Lowest Power, Lower Cost

Powering the most energy efficient embedded devices

Example use cases:

Automotive

Energy grid

Medical

Secure embedded applications

Smart cards

Smart devices

Sensor fusion

Wearables

Machine Learning

Efficiency Uplift for All Devices

Project Trillium for unmatched versatility and scalability

Example use cases:

Artificial intelligence

Augmented reality

Edge computing

Neural network frameworks

Object detection

Virtual reality

SecurCore

Tamper Resistant

Powerful solutions for security applications

Example use cases:

Advanced payment systems

Electronic passports

SIM

Smart cards

嵌入式微处理器的特点

- 基础是通用微处理器
- 与通用微处理器相比的区别：
  - 体积小、重量轻、可靠性高
  - 功耗低
  - 成本低：片上存储、引脚与封装、代码密度
  - 工作温度、抗电磁干扰、可靠性等方面增强

ARM Ltd

- Founded in November 1990
  - Spun out of Acorn Computers
- Designs the ARM range of RISC processor cores
- Licenses ARM core designs to semiconductor partners who fabricate and sell to their customers.
  - ARM does not fabricate silicon itself
- Also develop technologies to assist with the design-in of the ARM architecture
  - Software tools, boards, debug hardware, application software, bus architectures, peripherals etc

Connect with an Arm Partner

Silicon Partners

Our network of silicon partners delivers Arm-based systems on chip (SoCs) optimized for targeted market opportunities.

OEMs & ODMs

We have teamed up with OEMs and ODMs to provide meaningful input and feedback on new designs and sometimes license our technology directly.

System Integrators

Our wide range of system integrators can provide faster turnaround for products that meet your specifications.

Software

Arm's ecosystem of software partners provide customers a wide range of products to get to market faster than the competition.

Hardware/Boards

Arm development boards are the ideal platform for accelerating the development and reducing the risk of new SoC designs. Arm single board computers help customers save time and hassle by getting to production sooner and with less manufacturing overhead.

Service Providers

Our service provider partners serve Arm customers from concept and development through to ongoing support.

Development Tools

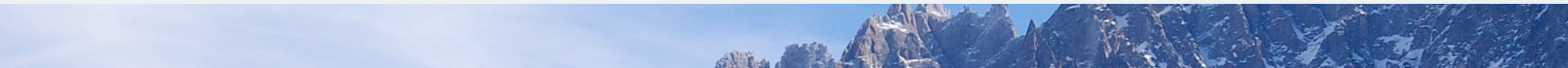
Created by experts in the Arm architecture, partners in development solutions are designed to accelerate engineering from SoC design through to software application development.

Training Partners

Experienced technology trainers write and deliver training information on a wide range of Arm technology topics in an approachable format.

Distributors

Arm has partnered with distributors and agents globally (Americas, APAC and EMEA) to provide access to our technology through partner products.



ARM Powered Products

ARM处理器的分类

- 结构体系版本（Architecture）
  - ARM v4T
  - ARM v5TE
  - ARM v6
  - ARM Cortex (v7 ， v8)
- 按应用特征分类
  - 应用处理器
    - Application Processor
  - 实时控制处理器
    - Real-time Controller
  - 微控制器
    - Micro-controller
- SecurCore

- Processor Family
  - ARM7
  - ARM9
  - ARM10
  - ARM11
  - ARM Cortex

Highest performance
Optimized for rich operating systems

Fast response
Optimized for high-performance, hard real-time applications

Smallest/lowest power
Optimized for discrete processing and microcontroller

Tamper resistant
Optimized for security applications

ARM Architecture

- Typical RISC architecture:
  - Large uniform register file
  - Load/store architecture
  - Simple addressing modes
  - Uniform and fixed-length instruction fields

ARM Architecture (2)

- Enhancements:
  - Each instruction controls the ALU and shifter
  - Auto-increment and auto-decrement addressing modes
  - Multiple Load/Store
  - Conditional execution

ARM Architecture (3)

- Results:
  - High performance
  - Low code size
  - Low power consumption
  - Low silicon area

Pipeline Organization

- Increases speed – most instructions executed in single cycle
- Versions:
  - 3-stage (ARM7TDMI and earlier)
  - 5-stage (ARMS, ARM9TDMI)
  - 6-stage (ARM10TDMI)

Pipeline Organization (2)

- Pipeline flushed and refilled on branch, causing execution to slow down
- Special features in instruction set eliminate small jumps in code to obtain the best flow through pipeline

Meltdown & Spectre

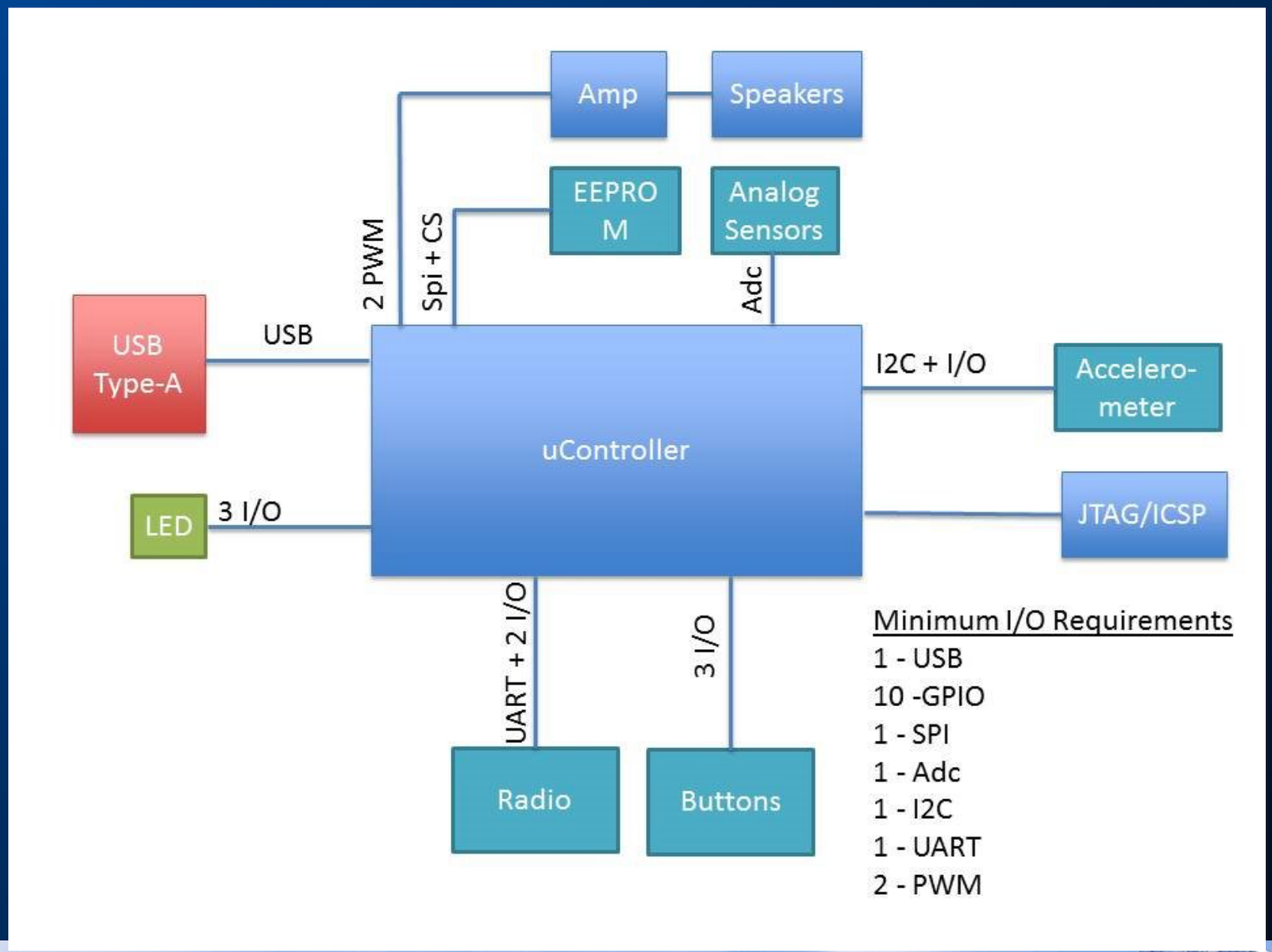
- 近20年的Intel，AMD，Qualcomm厂家和其它ARM的处理器受到影响；
- 因为此次CPU漏洞的特殊性，包括Linux, Windows, OSX等在内的操作系统平台参与了修复；
- Firefox, Chrome, Edge等浏览器也发布了相关的安全公告和缓解方案；
-

Criteria for Selecting microcontroller

- meeting the computing needs of the task efficiently and cost effectively
  - speed, the amount of ROM and RAM, the number of I/O ports and timers, size, packaging, power consumption
  - easy to upgrade
  - cost per unit
- availability of software development tools
  - assemblers, debuggers, C compilers, emulator, simulator, technical support
- wide availability and reliable sources of the microcontrollers.

10 Steps to Selecting a Microcontroller

- Step 1: Make a list of required hardware interfaces



jacobbeningo
https://community.arm.com/iot/embedded/b/embedded-blog/posts/10-steps-to-selecting-a-microcontroller
https://community.arm.com/cn/f/discussions/4097/thread

10 Steps to Selecting a Microcontroller (cont'd)

- Step 2: Examine the software architecture
- Step 3: Select the architecture
- Step 4: Identify Memory Needs
- Step 5: Start searching for microcontrollers
- Step 6: Examine Costs and Power Constraints
- Step 7: Check part availability
- Step 8: Select a development kit
- Step 9: Investigate compilers and tools
- Step 10: Start Experimenting

References

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- https://www.arm.com/
- https://github.com/Eugnis/spectre-attack
- https://spectreattack.com/

Thank you!