Microprocessor and Microcontroller (802681-3)

Lecture 3

Introduction to ARM Microcontrollers

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Outline

- Explain the term ARM
- Define an ARM microcontroller
  - List some popular ARM microcontroller vendors and identify the ARM microcontroller STM32F405RG
  - List some non-ARM microcontrollers
- Describe major features of STM32F405RG

What is ARM?

- ARM stands for ***Advanced RISC Machines***
  - RISC = Reduced Instruction Set Computer/Computing
- ARM was formed as ARM Holding Ltd. in 1990
  - A joint venture between Apple Computers, Acorn Computer Group, and VLSI Technology
- ARM partners ship more than 5 billion chips with ARM processors each year

What Does ARM Do?

- ARM (the company) designs processors and licenses these designs to silicon vendors
  - These designs are called *intellectual property (IP)* and this business model is called *IP licensing*
- ARM (the company) does not fabricate chips to make microcontrollers
  - Silicon vendors (designers) use the ARM processor to build their microcontrollers

Why ARM Processor?

- As of 2005, **98%** of the more than one billion mobile phones sold each year used ARM processors
- As of 2009, ARM processors accounted for approximately **90%** of all embedded 32-bit RISC processors
- In 2010 alone, **6.1 billion** ARM-based processor, representing **95%** of smartphones, **35%** of digital televisions and set-top boxes and **10%** of mobile computers
- As of 2014, over **50 billion** ARM processors have been produced

ARM Microcontrollers

- Any microcontroller that uses a 32-bit *ARM processor* is called the *ARM microcontroller*
- More than 15 silicon vendors use ARM *Cortex-M3* or *Cortex-M4* processors in their microcontroller products
  - Some of the ARM microcontroller vendors are *Atmel, ST Microelectronics, Texas Instruments (TI), Samsung, NXP, Toshiba, Fujitsu, Analog Devices, Actel, Broadcom, Dust Networks, Renesas, Cypress, Energy, Nuvoton, Ember, Freescale (previously Motorola), NXP, and Triad Semiconductor*

Other Microcontrollers

- 32-bit Microcontrollers
  - *x86 (Intel), AVR32 (Atmel/Microchip), Coldfire (Motorola/Freescale/NXP), MIPS32, PIC32 (Microchip), PowerPC (IBM & Freescale), TriCore (Infineon), SuperH, RX (Renesas)*
- 16-bit Microcontrollers
  - *MSP430 (TI), HCS12 (NXP), PIC24 (Microchip), dsPIC (Microchip), RL78 (Renesas)*
- 8-bit Microcontrollers
  - *8051 (Intel), AVR (Atmel), HCS08 (NXP), PIC16, PIC18*

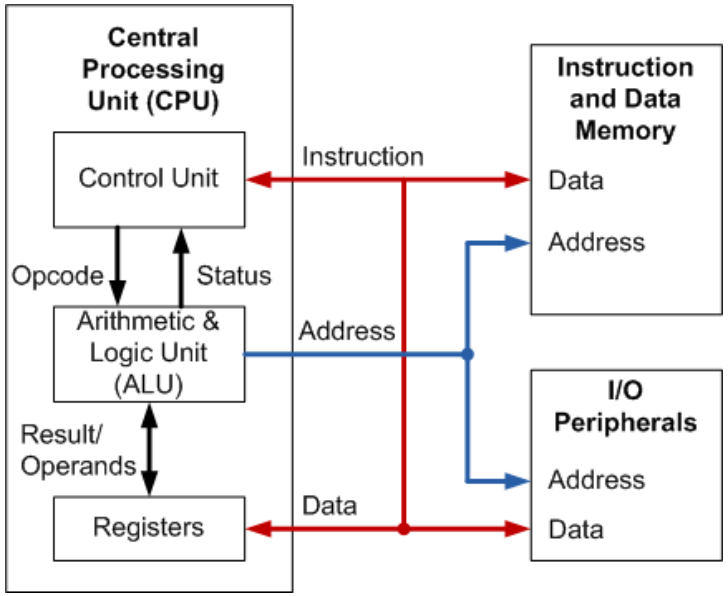
Popular ARM Processors

Architecture	Family	CORE
ARMv4T	ARM7TDMI	ARM7TDMI, ASC100, Classic ARM Processors, Embedded Cortex Processors, Application Cortex Processors
ARMv5TJ	ARM9E	ARM946, ARM968, ARM926
ARMv6	ARM11	ARM1156T2, ARM1136J, ARM176JZ, ARM11MP
ARMv7A	Cortex-A	Cortex-A5, Cortex-A8, Cortex-A9, Cortex-A15
ARMv7R	Cortex-R	Cortex-R4, Cortex-R5, Cortex-R7
ARMv7M/ME	**Cortex-M**	**Cortex-M3, Cortex-M4, SC300, Cortex-M7**
ARMv8M	Cortex-M	Cortex-M0, Cortex-M1, SC00

ARM Architecture

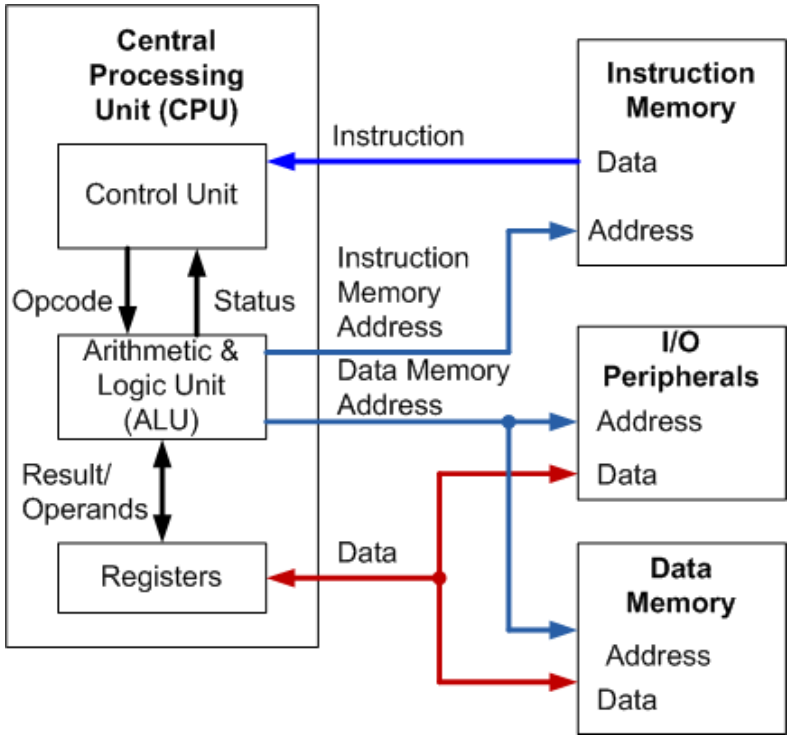
Von-Neumann

Instructions and data are stored in the same memory



Harvard

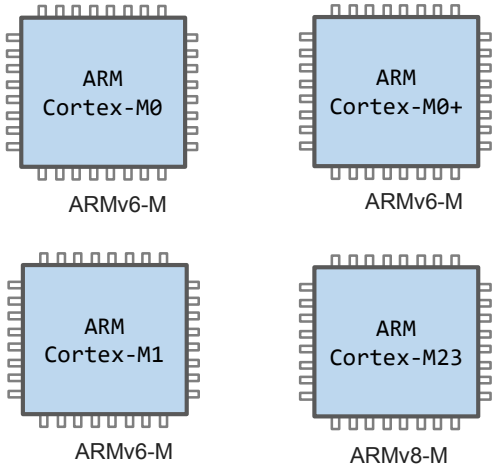
Data and instructions are stored into separate memories



ARM Cortex-M Series Family

Von-Neumann

Instructions and data are stored in the same memory



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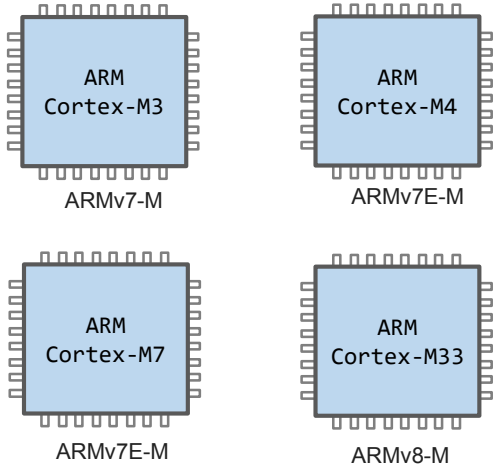
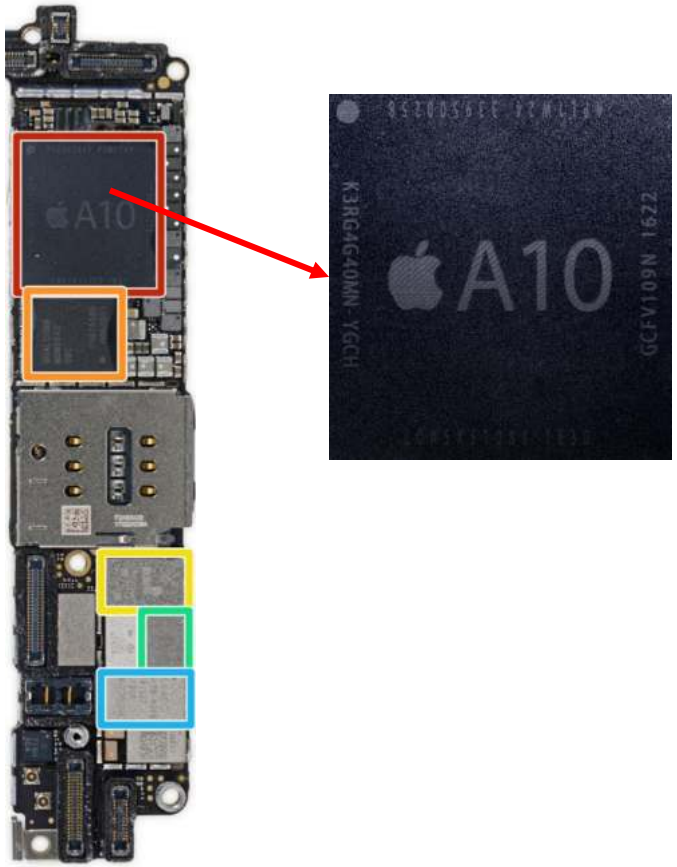


Equipment Adopting ARM Core

iPhone 7 Teardown



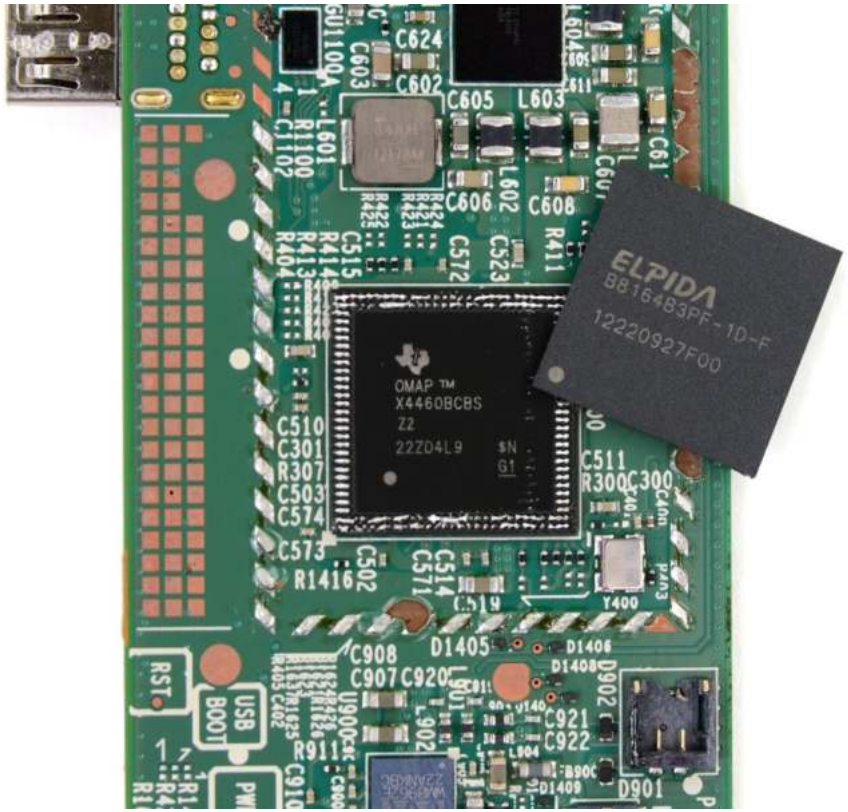
A10 processor:

- 64-bit system on chip (SoC)
- ARMv8-A core

Apple Watch

- Apple S1 Processor
  - **32-bit ARMv7-A** compatible
  - # of Cores: **1**
  - CMOS Technology: 28 nm
  - L1 cache: 32 KB data
  - L2 cache: 256 KB
  - GPU: PowerVR SGX543

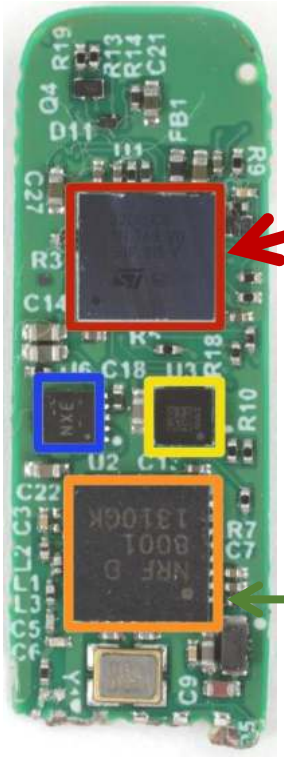
Kindle HD Fire



Texas Instruments OMAP 4460 dual-core processor

Source: http://www.ifixit.com

Fitbit Flex Teardown

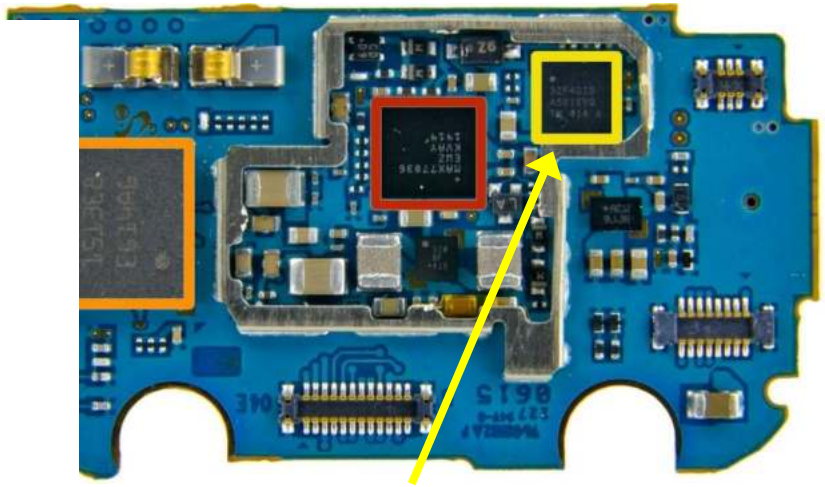


STMicroelectronics 32L151C6 Ultra Low Power ARM Cortex M3 Microcontroller

Nordic Semiconductor nRF8001 Bluetooth Low Energy Connectivity IC

Source: http://www.ifixit.com

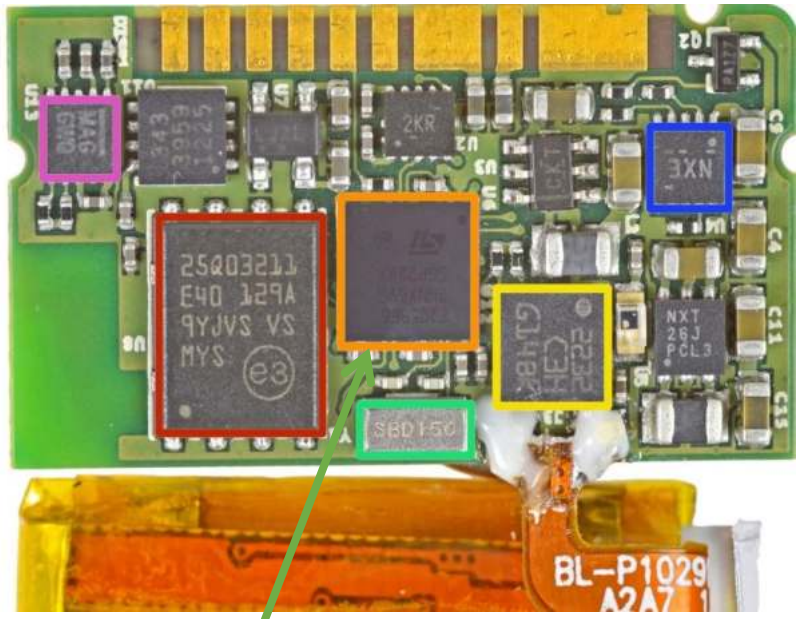
Samsung Galaxy Gear



- STMicroelectronics STM32F401B **ARM-Cortex M4** MCU with 128KB Flash

Source: http://www.ifixit.com

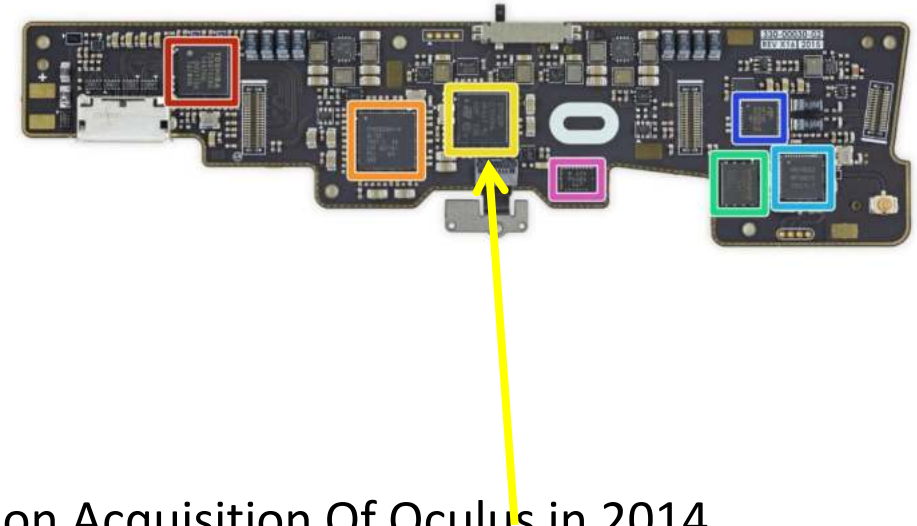
Pebble Smartwatch



- STMicroelectronics STM32F205RE **ARM Cortex-M3** MCU, with a maximum speed of 120 MHz

Source: http://www.ifixit.com

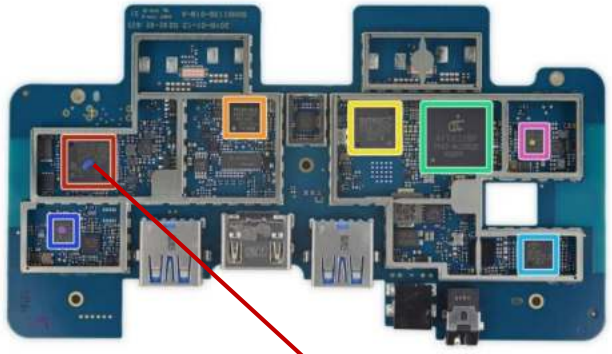
Oculus VR



- Facebook's $2 Billion Acquisition Of Oculus in 2014
- ST Microelectronics STM32F072VB **ARM Cortex-M0** 32-bit RISC Core Microcontroller

Source: http://www.ifixit.com

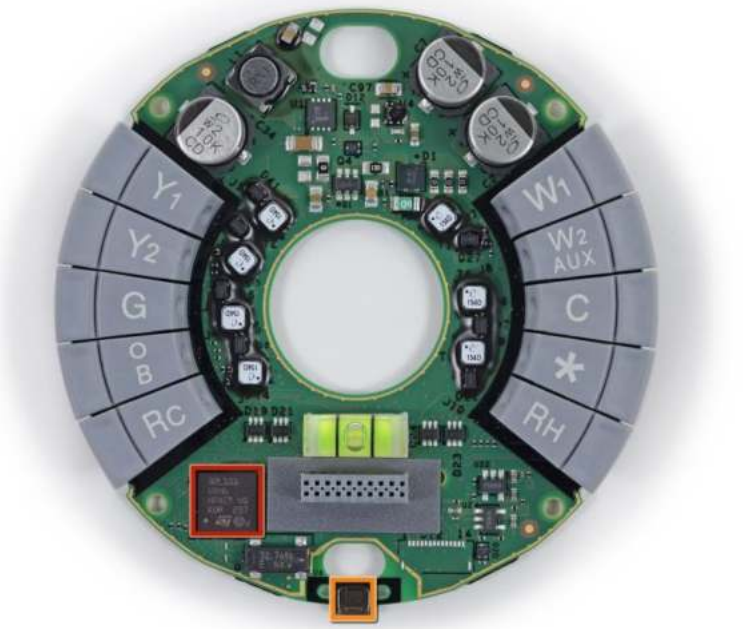
HTC Vive VR system



STMicroelectronics
32F072R8 **ARM Cortex-M0**
Microcontroller

Source: http://www.ifixit.com

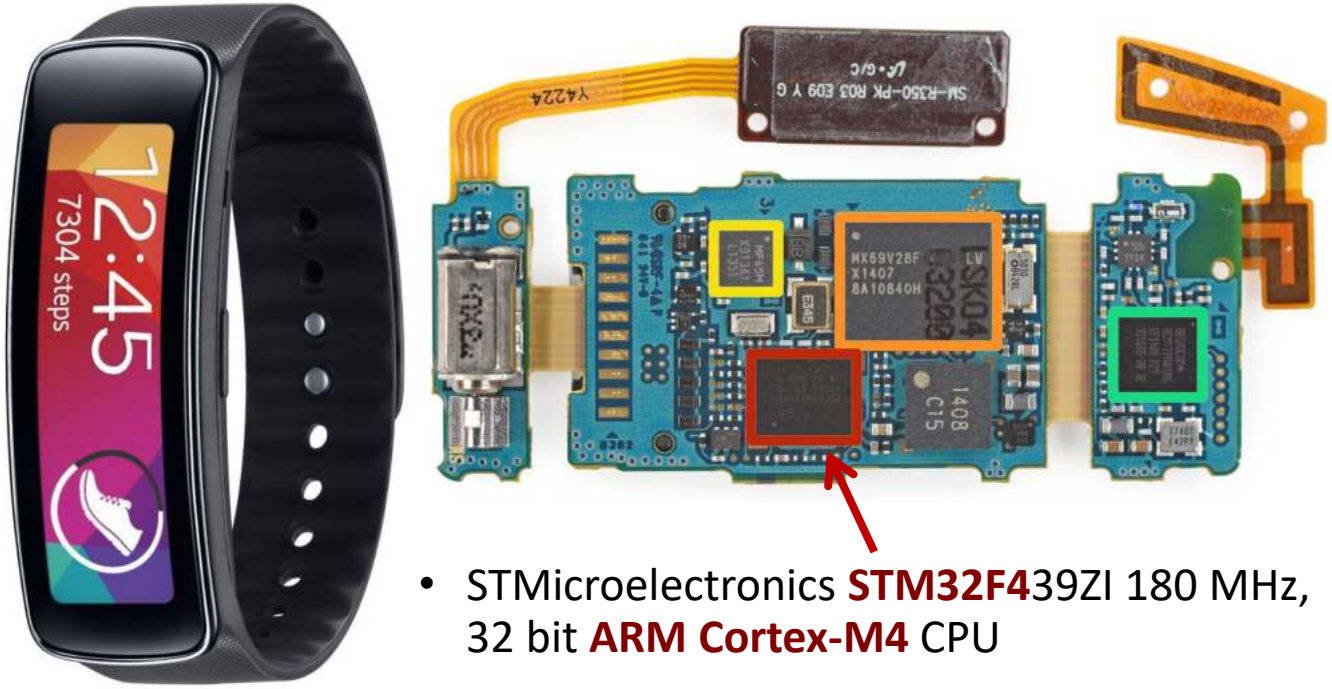
Nest Learning Thermostat-It learns what temperature you like and builds a schedule around yours



- ST Microelectronics **STM32L**151VB ultra-low-power 32 MHz ARM **Cortex-M3** MCU

Source: http://www.ifixit.com

Samsung Gear Fit Fitness Tracker



- STMicroelectronics **STM32F4**39ZI 180 MHz, 32 bit **ARM Cortex-M4** CPU

Source: http://www.ifixit.com

STM32F405RG

- In this course, we'll work with *STM32F405RG* microcontroller, manufactured by STMicroelectronics
  - Contains high performance 32-bit ARM Cortex-M4 RISC processor
  - Operates at a maximum speed of 128 MHz
  - Features 1024 Kbyte flash memory and 196 Kbyte of SRAM
  - Available in 64-pin packages called *LQFP64 (Low-profile Quad Flat Package)*

STM32F405RG Features

- **Core**
  - ARM 32-bit Cortex™-M4 CPU with FPU (Floating Point Unit) running at a maximum speed of 128 MHz
  - Adaptive Real Time Accelerator allows 0-wait state execution from Flash memory and Memory Protection Unit (MPU)
- **Memory**
  - 1024 Kbytes Flash memory
  - 192 + 4 Kbytes of SRAM including 64-Kbyte of CCM (core coupled memory) data RAM
  - Flexible static memory controller supporting Compact Flash, SRAM, PSRAM, NOR and NAND memories

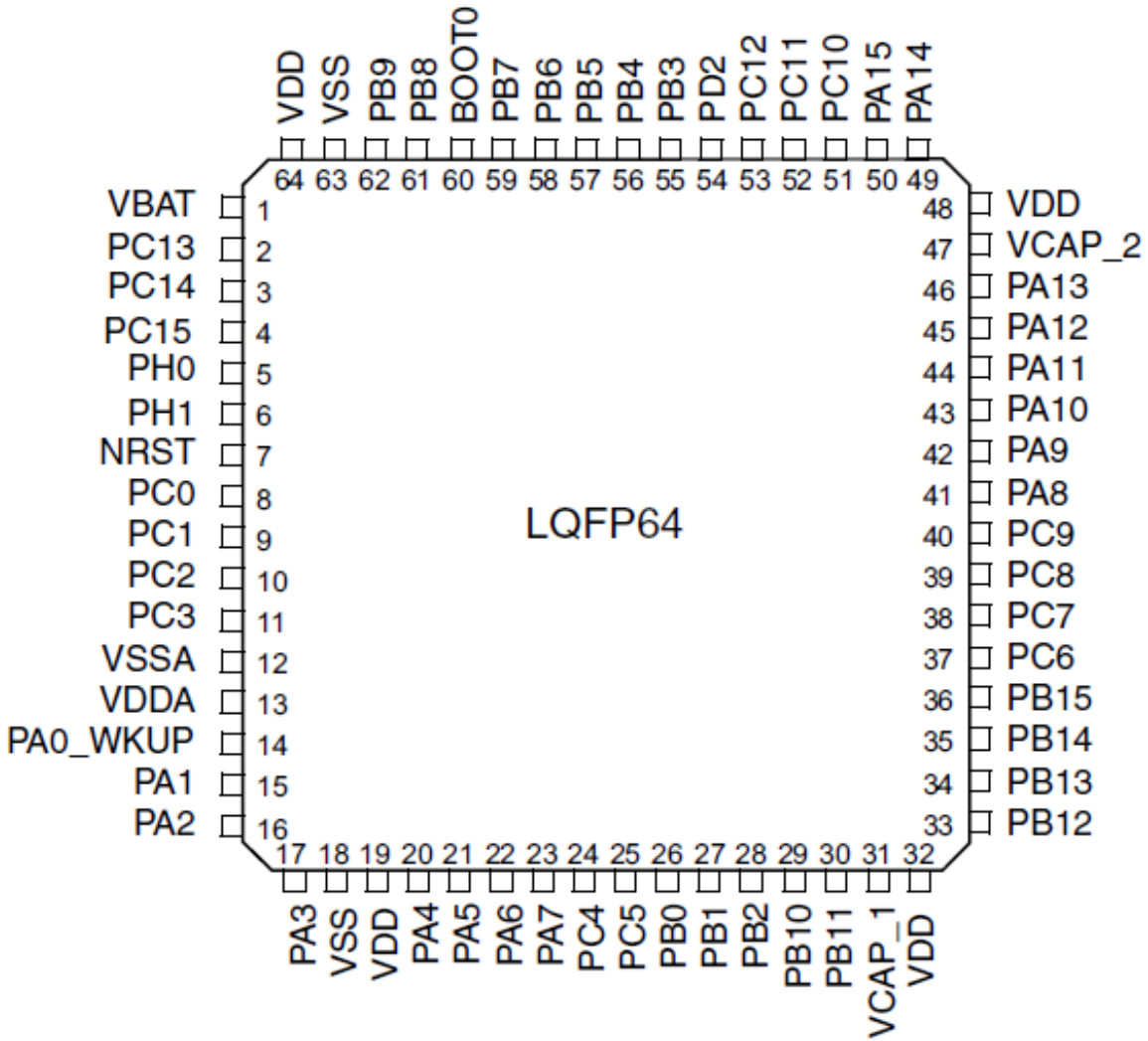
STM32F405RG Features

- **I/O Ports and Controllers**
  - 114 I/O ports with interrupt capabilities
- **Analog Interfaces**
  - Three 12-bit, 2.4 MSPS A/D converters: 24 channels and 7.2 MSPS in triple interleaved mode
  - Two 12-bit D/A converters

STM32F405RG Features

- **Serial Interfaces**
  - Three Universal Synchronous Asynchronous Receiver Transmitters (USARTs) and two Universal Asynchronous Receiver Transmitters (UARTs) with a maximum data rate of 10.5 Mbps
  - Three Inter-Integrated Circuit (I2C) interfaces, two of them with muxed full-duplex Inter-IC Sound (I2S) interface
  - Three Synchronous Peripheral Interfaces (SPIs) with a maximum data rate of 37.5 Mbps
  - Two Controller Area Network (CAN) interfaces
  - One Secure Digital Input Output (SDIO) interface

STM32F405RG Pinout



Cortex-M Architecture

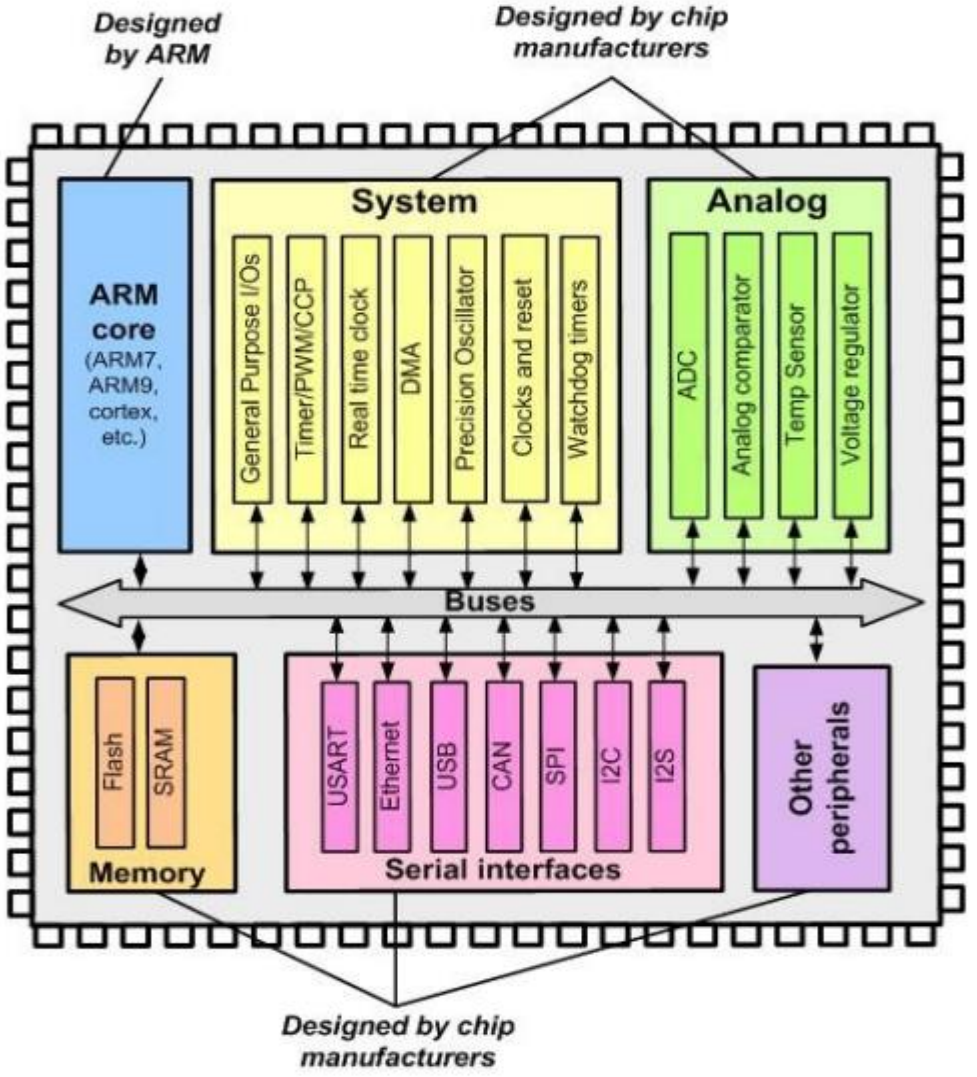
- A microcontroller integrates different subsystems in a single package.
- Typically, a microcontroller connects a microprocessor with memory and input/output interfaces to perform data exchanges and execute different tasks.

ARM Architecture Profiles

- Cortex-M profile: Processors in this profile are designed for microcontroller-based embedded systems.
- Cortex-A profile: This profile is aimed for addressing the high performance applications mainly covering the cellular market.
- Cortex-R profile: Addressing the demands of real-time applications is the main motive of this profile.

ARM Cortex-M

- The ARM Cortex-M based microcontroller architecture usually integrates the following key building blocks:
- Microprocessor core
- Nested vectored interrupt controller
- Bus system and bus matrix
- Memory and peripherals
- Debug system



References

- **Yiu, J. (2014). *The Definite Guide to ARM Cortex-M3 and Cortex-M4 Processors* (3rd Edition). Elsevier Inc. ISBN: 978-0-12-408082-9**

- **Valvano, Jonathan W. (2015). *Introduction to ARM Cortex-M Microcontrollers* (5th Edition). Jonathan W. Valvano. ISBN: 978-1-477-50899-2**