STM32 簡介

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術語

- ART Accelerator ™ : ST's adaptive real-time memory accelerator
- CMSIS: Cortex™ microcontroller software interface standard
- MCU: microcontroller unit
- DSC: digital signal controller
- DSP: digital signal processor
- FPU: floating point unit
- RTC: real-time clock
- MPU: memory protection unit
- FSMC: flexible static memory controller

Agenda   (1) STM32 平台資訊

(2) ARM Cortex-M 概述

(3) STM32 延伸

STM32 平台資訊

STM32F4 系列：高效數位訊號控制

Cortex-M4

ARM

Cortex
Low-Power Leadership from ARM

FPU
Single precision
Ease of use
Better code efficiency
Faster time to market
Eliminate scaling and saturation
Easier support for meta-language too

STM32 F4

MCU
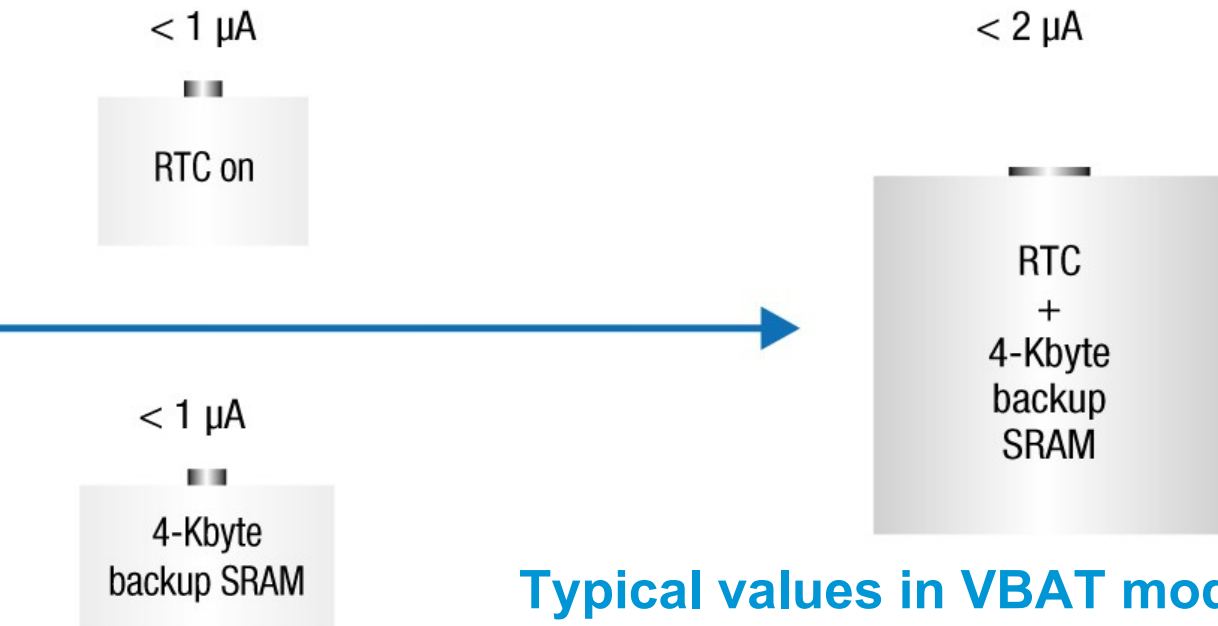Ease of use of C programming
Interrupt handling
Ultra-low power

Cortex-M4

DSP
Harvard architecture
Single-cycle MAC
Barrel shifter

< 1 µA

RTC on

< 1 µA

4-Kbyte backup SRAM

< 2 µA

RTC
+
4-Kbyte
backup
SRAM

Typical values in VBAT mode

- 230 µA/MHz, 38.6 mA at 168 MHz executing Coremark benchmark from Flash memory (with peripherals off), made possible with:
  - ST's 90 nm process allowing the CPU core to run at only 1.2 V

- ART Accelerator™ reducing the number of accesses to Flash
- Voltage scaling to optimize performance/power consumption
- VDD min down to 1.7 V
- Low-power modes with backup SRAM and RTC support

STM32F 系列產品線

Over 250 pin-to-pin compatible part numbers

STM32 F1 · STM32 F2 · STM32 F4 · STM32 L1

36 pins QFN	48 pins LQFP/QFN	48 pins LQFP/QFN	64 pins LQFP/BGA/CSP	64 pins LQFP/BGA/CSP	100 pins LQFP/BGA	100 pins LQFP/BGA	144 pins LQFP	144 pins LQFP	176 pins LQFP/UFBGA	176 pins LQFP/UFBGA
					STM32F407VG	STM32F417VG	STM32F407ZG	STM32F417ZG	STM32F407IG	STM32F…
			STM32F405RG	STM32F415RG	STM32F405VG	STM32F415VG	STM32F405ZG	STM32F415ZG		
					STM32F207VG	STM32F217VG	STM32F207ZG	STM32F217ZG	STM32F207IG	STM32F…
			STM32F205RG	STM32F215RG	STM32F205VG	STM32F215VG	STM32F205ZG	STM32F215ZG		
			STM32F101RG	STM32F103RG	STM32F101VG	STM32F103VG	STM32F101ZG	STM32F103ZG		
			STM32F205RF		STM32F205VF	STM32F207VF	STM32F205ZF	STM32F207ZF	STM32F207IF	
			STM32F101RF	STM32F103RF	STM32F101VF	STM32F103VF	STM32F101ZF	STM32F103ZF		
					STM32F407VE	STM32F417VE	STM32F407ZE	STM32F417ZE	STM32F407IE	STM32F…
					STM32F207VE	STM32F217VE	STM32F207ZE	STM32F217ZE	STM32F207IE	STM32F…
			STM32F205RE	STM32F215RE	STM32F205VE	STM32F215VE	STM32F205ZE	STM32F215ZE		
			STM32F101RE		STM32F101VE		STM32F101ZE			
			STM32F100RE	STM32F103RE	STM32F100VE	STM32F103VE	STM32F100ZE	STM32F103ZE		
				STM32L162RD[1]		STM32L162VD[1]		STM32L162ZD[1]		
			STM32L151RD[1]	STM32L152RD[1]	STM32L151VD[1]	STM32L152VD[1]	STM32L151ZD[1]	STM32L152ZD[1]		
			STM32F101RD		STM32F101VD		STM32F101ZD			
			STM32F100RD	STM32F103RD	STM32F100VD	STM32F103VD	STM32F100ZD	STM32F103ZD		
			STM32F205RC		STM32F205VC	STM32F207VC	STM32F205ZC	STM32F207ZC	STM32F207IC	
			STM32L151RC[1]	STM32L152RC[1]	STM32L151VC[1]	STM32L152VC[1]	STM32L151ZC[1]	STM32L152ZC[1]		
			STM32F105RC		STM32F105VC					
			STM32F101RC	STM32F107RC	STM32F101VC	STM32F107VC	STM32F101ZC			
			STM32F100RC	STM32F103RC	STM32F100VC	STM32F103VC	STM32F100ZC	STM32F103ZC		
			STM32F205RB		STM32F205VB					
	STM32L151CB	STM32L152CB	STM32L151RB	STM32L152RB	STM32L151VB	STM32L152VB				
			STM32F105RB	STM32F107RB	STM32F105VB					
STM32F103TB	STM32F101CB	STM32F103CB	STM32F101RB	STM32F103RB	STM32F101VB	STM32F107VB				
STM32F101TB	STM32F100CB	STM32F102CB	STM32F100RB	STM32F102RB	STM32F100VB	STM32F103VB				
	STM32L151C8	STM32L152C8	STM32L151R8	STM32L152R8	STM32L151V8	STM32L152V8				
			STM32F105R8		STM32F105V8					
STM32F103T8	STM32F101C8	STM32F103C8	STM32F101R8	STM32F103R8	STM32F101V8	STM32F103V8				
STM32F101T8	STM32F100C8	STM32F102C8	STM32F100R8	STM32F102R8	STM32F100V8					
	STM32L151C6	STM32L152C6	STM32L151R6	STM32L152R6						
STM32F103T6	STM32F101C6	STM32F103C6	STM32F101R6	STM32F103R6						
STM32F101T6	STM32F100C6	STM32F102C6	STM32F100R6	STM32F102R6						
STM32F103T4	STM32F101C4	STM32F103C4	STM32F101R4	STM32F103R4						
STM32F101T4	STM32F100C4	STM32F102C4	STM32F100R4	STM32F102R4						

Legend:
- STM32 L1
- STM32 F1
- STM32 F2
- STM32 F4

Note:
1. Available in 04/2011 for all 256- and 384-Kbyte STM32L devices

STM32F 系列產品線

4 product series

Common core peripherals and architecture:

| Communication peripherals: USART, SPI, I²C |
| Multiple general-purpose timers |
| Integrated reset and brown-out warning |
| Multiple DMA |
| 2x watchdogs Real-time clock |
| Integrated regulator PLL and clock circuit |
| External memory interface (FSMC) |
| Dual 12-bit DAC |
| Up to 3x 12-bit ADC (up to 0.41 µs) |
| Main oscillator and 32 kHz oscillator |
| Low-speed and high-speed internal RC oscillators |
| -40 to +85 °C and up to 105 °C operating temperature range |
| Low voltage 2.0 to 3.6 V or 1.65/1.7 to 3.6 V (depending on series) 5.0 V tolerant I/Os |
| Temperature sensor |

+

STM32 F4 series - High performance with DSP (STM32F405/415/407/417)

| 168 MHz Cortex-M4 with DSP and FPU | Up to 192-Kbyte SRAM | Up to 1-Mbyte Flash | 2x USB 2.0 OTG FS/HS | 3-phase MC timer | 2x CAN 2.0B | SDIO 2x I²S audio Camera IF | Ethernet IEEE 1588 | Crypto/hash processor and RNG |

STM32 F2 series - High performance (STM32F205/215/207/217)

| 120 MHz Cortex-M3 CPU | Up to 128-Kbyte SRAM | Up to 1-Mbyte Flash | 2x USB 2.0 OTG FS/HS | 3-phase MC timer | 2x CAN 2.0B | SDIO 2x I²S audio Camera IF | Ethernet IEEE 1588 | Crypto/hash processor and RNG |

STM32 F1 series - Connectivity line (STM32F105/107)

| 72 MHz Cortex-M3 CPU | Up to 64-Kbyte SRAM | Up to 256-Kbyte Flash | USB 2.0 OTG FS | 3-phase MC timer | 2x CAN 2.0B | 2x I²S audio | Ethernet IEEE 1588 |

STM32 F1 series - Performance line (STM32F103)

| 72 MHz Cortex-M3 CPU | Up to 96-Kbyte SRAM | Up to 1-Mbyte Flash | USB FS device | 3-phase MC timer | CAN 2.0B | SDIO 2x I²S |

STM32 F1 series - USB Access line (STM32F102)

| 48 MHz Cortex-M3 CPU | Up to 16-Kbyte SRAM | Up to 128-Kbyte Flash | USB FS device |

STM32 F1 series - Access line (STM32F101)

| 36 MHz Cortex-M3 CPU | Up to 80-Kbyte SRAM | Up to 1-Mbyte Flash |

STM32 F1 series - Value line (STM32F100)

| 24 MHz Cortex-M3 CPU | Up to 32-Kbyte SRAM | Up to 512-Kbyte Flash | 3-phase MC timer | CEC |

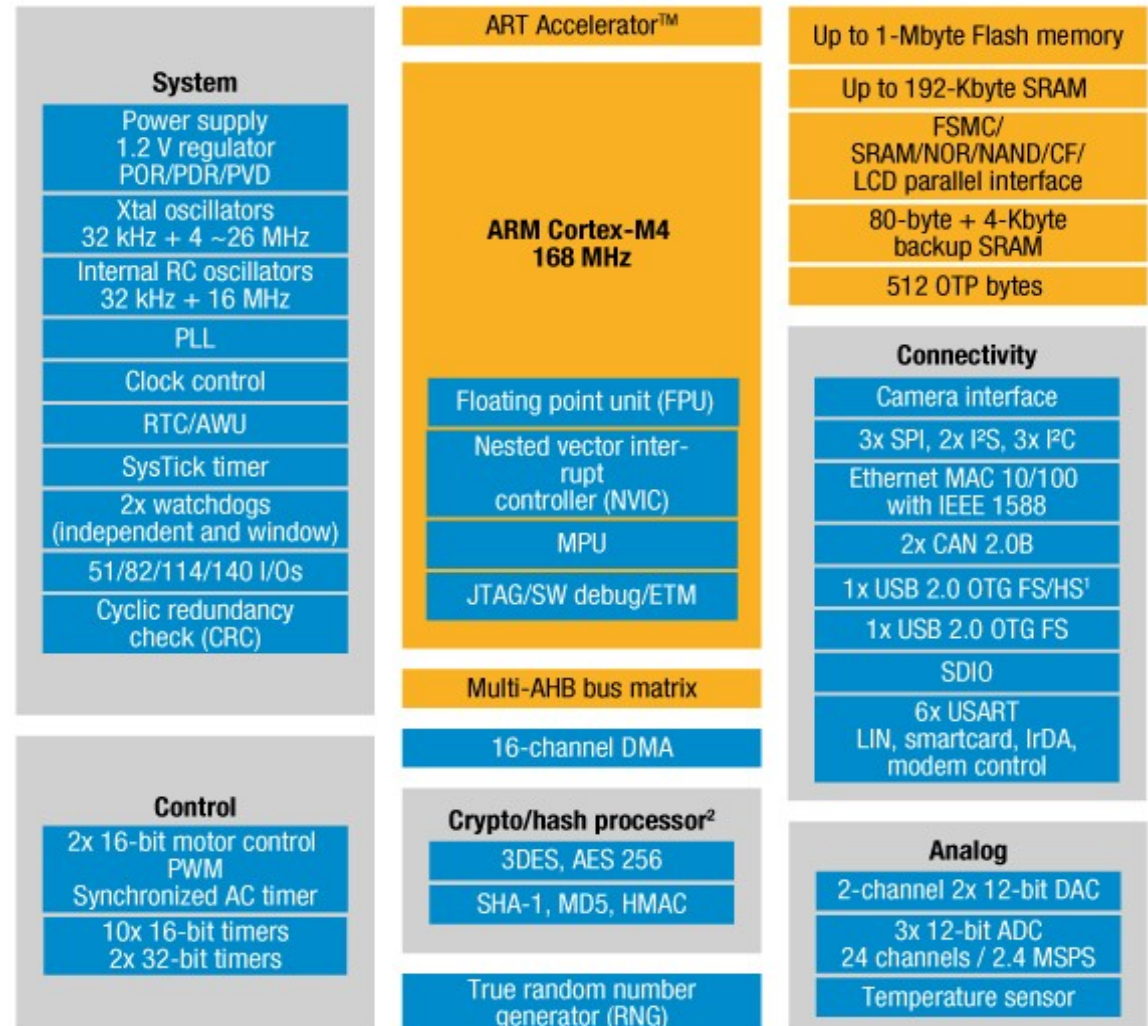**STM32 L1 series - Ultra-low-power (STM32F151/152)**

| 32 MHz Cortex-M3 CPU | Up to 48-Kbyte SRAM | Up to 384-Kbyte Flash | USB FS device | Data EEPROM up to 12 Kbytes | LCD 8x40 4x44 | Comparator | BOR MSI VScal | AES 128-bit |

STM32 F4
STM32 F2
STM32 F1
STM32 L1

STM32F4 block diagram

Feature highlight

- 168 MHz Cortex-M4 CPU
  - Floating point unit (FPU)
  - ART Accelerator TM
  - Multi-level AHB bus matrix
- 1-Mbyte Flash, 192-Kbyte SRAM
- 1.7 to 3.6 V supply
- RTC: <1 µA typ, sub second accuracy
- 2x full duplex I²S
- 3x 12-bit ADC 0.41 µs/2.4 MSPS
- 168 MHz timers

System
- Power supply 1.2 V regulator POR/PDR/PVD
- Xtal oscillators 32 kHz + 4 ~26 MHz
- Internal RC oscillators 32 kHz + 16 MHz
- PLL
- Clock control
- RTC/AWU
- SysTick timer
- 2x watchdogs (independent and window)
- 51/82/114/140 I/Os
- Cyclic redundancy check (CRC)

Control
- 2x 16-bit motor control PWM Synchronized AC timer
- 10x 16-bit timers 2x 32-bit timers

ART Accelerator™

ARM Cortex-M4 168 MHz
- Floating point unit (FPU)
- Nested vector interrupt controller (NVIC)
- MPU
- JTAG/SW debug/ETM

Multi-AHB bus matrix

16-channel DMA

Crypto/hash processor²
- 3DES, AES 256
- SHA-1, MD5, HMAC

True random number generator (RNG)

- Up to 1-Mbyte Flash memory
- Up to 192-Kbyte SRAM
- FSMC/ SRAM/NOR/NAND/CF/ LCD parallel interface
- 80-byte + 4-Kbyte backup SRAM
- 512 OTP bytes

Connectivity
- Camera interface
- 3x SPI, 2x I²S, 3x I²C
- Ethernet MAC 10/100 with IEEE 1588
- 2x CAN 2.0B
- 1x USB 2.0 OTG FS/HS[1]
- 1x USB 2.0 OTG FS
- SDIO
- 6x USART LIN, smartcard, IrDA, modem control

Analog
- 2-channel 2x 12-bit DAC
- 3x 12-bit ADC 24 channels / 2.4 MSPS
- Temperature sensor

Notes:
1. HS requires an external PHY connected to the ULPI interface
2. Crypto/hash processor on STM32F417 and STM32F415
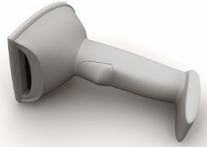
- **Points of sale/inventory management**

- **Industrial automation and solar panels**

- **Transportation**

- **Medical**

- **Building**

- **Security/fire/HVAC**

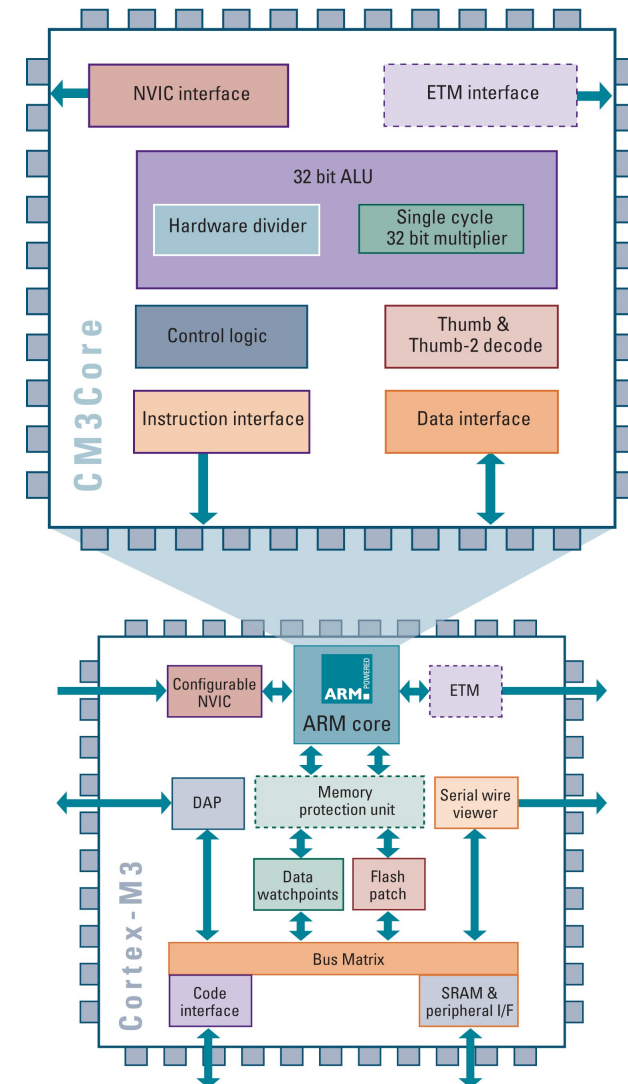- **Test and measurem**

- **Consumer**

- **Communication**
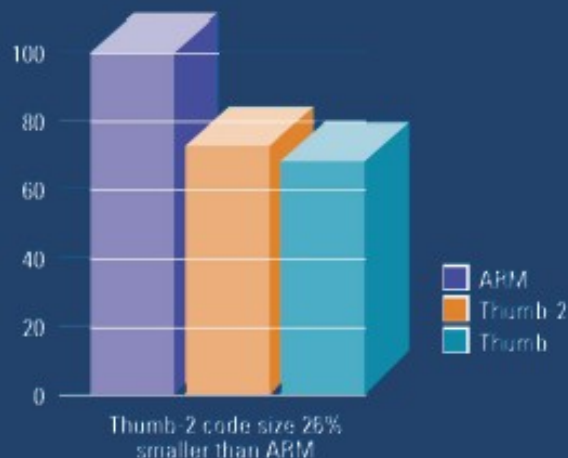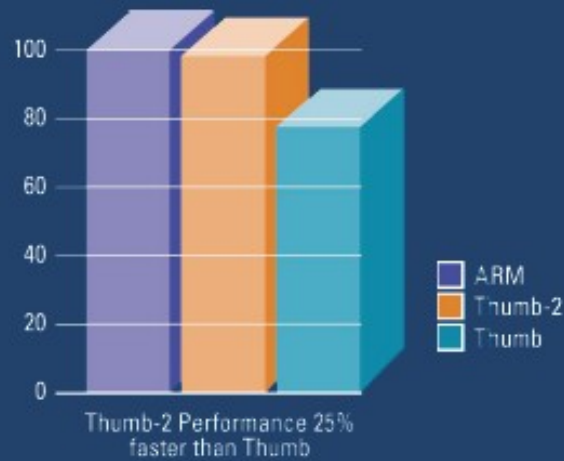
ARM Cortex-M 概述

ARM Cortex-M3

- 哈佛架構
- 具有分支預測功能的三級 pipeline
- 指令集： Thumb-2
- 具備硬體除法與單週期乘法的 ALU
- Cortex-M3
  – NVIC
  – MPU (optional)
  – ETM (optional)

EEMBC Analysis – Code Size

Thumb-2 code size 26% smaller than ARM

EEMBC Analysis - Performance

Thumb-2 Performance 25% faster than Thumb

- 2004 年推出 ARMv7 架构，应用在 Cortex™ 处理器家族
- Cortex 处理器分为三种
  - A 系列，适用于复杂操作系统和应用程序
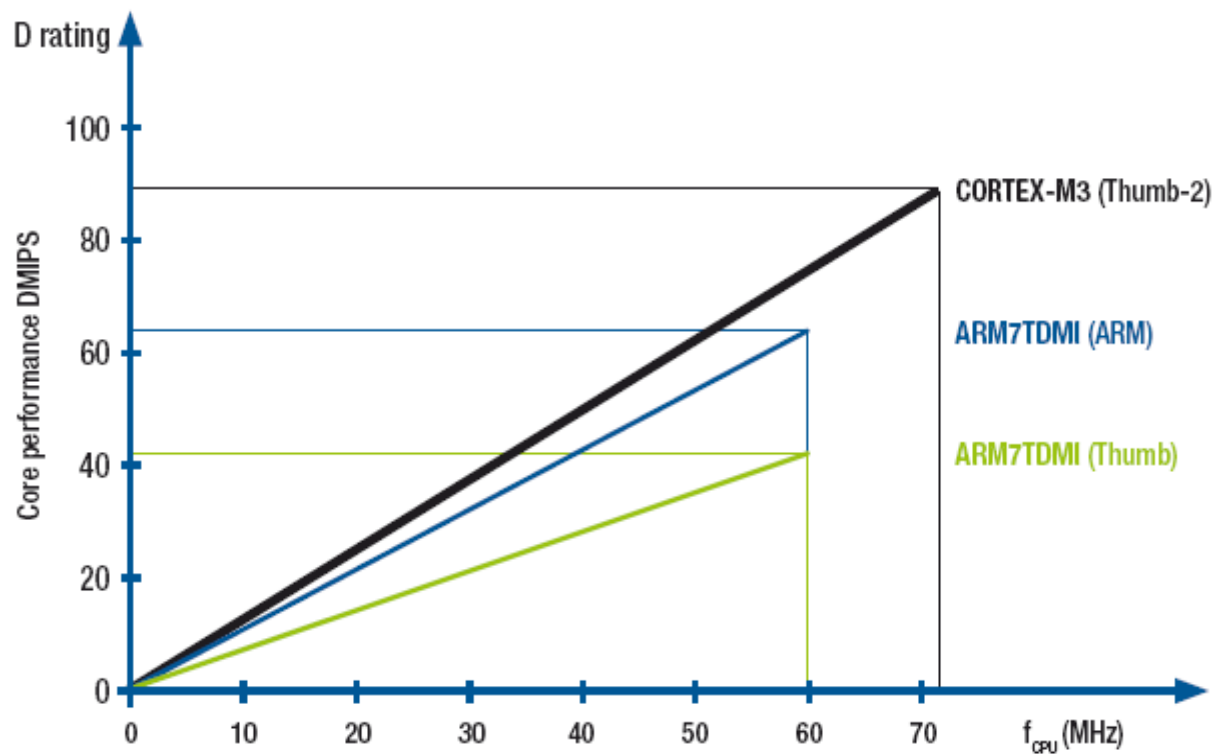 - R 系列，适用于嵌入式实时系统
  - M 系列，适用于对成本敏感的深嵌入式领域

- ARMv7-A（应用程序）
  - 内存控制器 (MMU)，支持虚拟存储器
  - 满足多任务操作系统的需要

- ARMv7-R（实时系统）
  - 内存保护单元 (MPU)
  - 低延迟，可预测性实时需要
  - 支持原有嵌入式系统的升级

- ARMv7-M（微控制器）
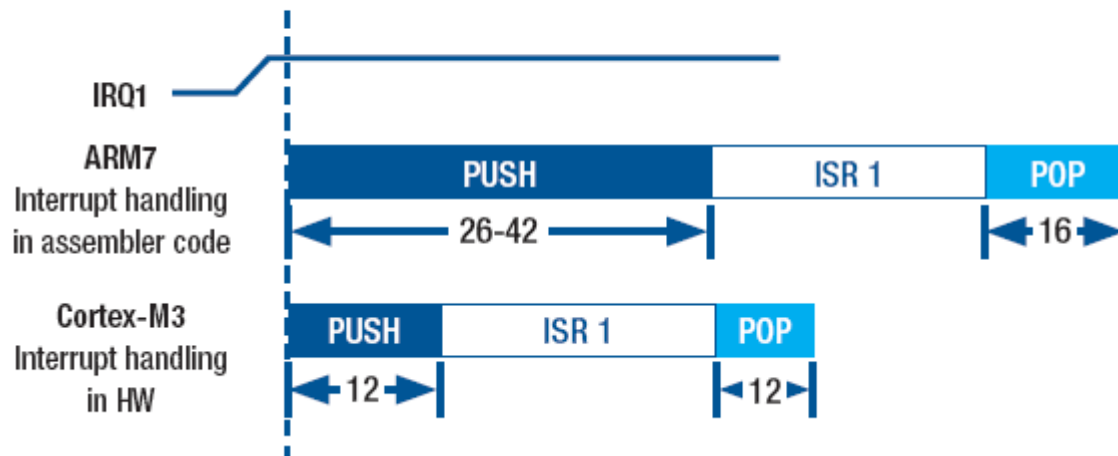 - 最少的门数目
  - "深"嵌入式 (Deeply embedded)
  - 可与 ARMv7-R 紧密协作

- 哈佛结构
  - 指令总线和数据总线分离，允许并行地取指和数据存储

- 1.25DMIPS/MHz ， 0.19mW/MHz

- Thumb-2 指令集拥有 32 位的性能和 16 位的代码密度

- 单周期乘法和硬件除法

- Cortex-M3 核内部集成了嵌入式高速中断控制器：
  - 低中断响应时间，最低可达 6 个 CPU 周期（内部中断）
  - 从低功耗模式被唤醒也只需 6 个 CPU 周期

- 相比于 ARM7TDMI ， Cortex-M3 内核要快 35% 且减少了 45% 的代码

D rating

Core performance DMIPS

100
80
60
40
20
0

0 10 20 30 40 50 60 70 f_{CPU} (MHz)

CORTEX-M3 (Thumb-2)

ARM7TDMI (ARM)

ARM7TDMI (Thumb)

Cortex-M3 interrupt versus ARM7TDMI

IRQ1

ARM7
Interrupt handling
in assembler code

PUSH | ISR 1 | POP

26-42 | 16

Cortex-M3
Interrupt handling
in HW

PUSH | ISR 1 | POP

12 | 12

ARM Cortex-M3

- 三级流水线
  - 取指，解码和执行

- 单信号周期乘法

Source	Destination	Cycles
16b x 16b	32b	1
32b x 16b	32b	1
32b x 32b	32b	1
32b x 32b	64b	3-7*

- 硬件除法
  - UDIV & SDIV
  - 指令执行需要 2 到 12 周期，取决与被除数与除数
  - 两者越相近指令完成越快
  - 指令可以被中断（丢弃 / 重启）

ARM Cortex-M3 vs. ARM7

	ARM7TDMI-S	Cortex-M3
体系结构	v4T	v7M
指令集	ARM (32-bit) & Thumb (16-bit)	Thumb-2 (Merged 32/16-bit)
DMIPS/MHz	0.74 Thumb / 0.93 ARM	1.25 Thumb-2
流水线	3-Stage	3-Stage + Branch Speculation
中断	FIQ / IRQ	**NMI, SysTick and up to 240 interrupts. Integrated NVIC Interrupt Controller up to 1-255 Priorities**
中断响应时间	**24-42 Cycles (Depending on LSM)**	12 Cycles (6 when Tail Chaining)
存储器印射	Undefined	Architecture Defined
系统状态	PSR. 6 modes. 20 Banked regs	xPSR. 2 modes. Stacked regs (1 bank)
睡眠模式	No	Three

- **Cortex-M3 附加的特性**
  - 简化了跟踪调试接口的管脚，从 9 脚减少到 2 或 3 脚
  - 硬件中断处理不需要汇编代码
  - 综合的原子位操作改进了数据存储
  - 扩展的数据观测点 & Flash 保护技术
  - 嵌入式的睡眠控制和掉电模式
  - 可选择的小型的存储器保护单元 (MPU) 和 嵌入式跟踪宏单元 (ETM)

Register

R0		R8		• R0 – R12
R1		R9		• General Purpose
R2		R10		• R13
R3		R11		• Stack Pointer
R4		R12		• R14
R5		R13 (SP)		• Link Register
R6		R14 (LR)		• R15
R7		R15 (PC)		• Program Counter

PSR	PRIMASK
	FAULTMASK
CONTROL	BASEPRI

- CM3 has a fixed memory map

- Easy to port software

- 4GB Address Space

- STM32

Peripherals
SRAM
Flash
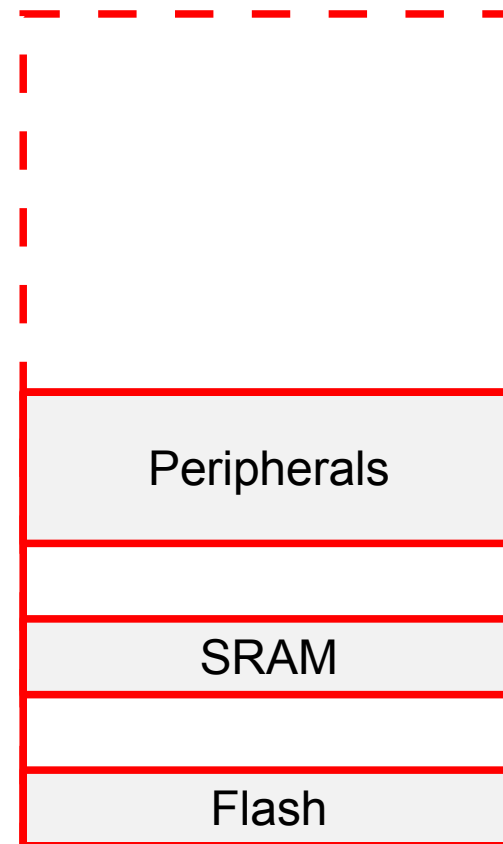
- SP from address 0x0
- PC from address 0x4
- Address is mapped to Flash

| Reset Vec. |
| Initial SP |

0x0004

0x0000
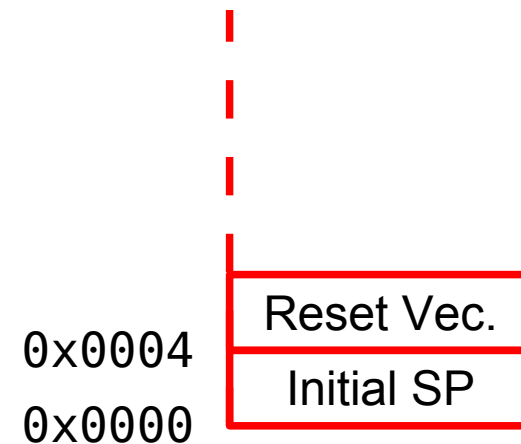
STM32 延伸

- ART
- 6502 sumulator
- Quake

- ART_work 是 ART 板在 PC 上的配套软件，修改至 Arduino IDE （ ART 是使用 STM32F407VG 芯片，兼容 Arduino 接口核心小板）

- ART_work 携带 ARM embedded 版本的 GNU GCC ，并采用 STM32 DFU 作为下载方式。从而能够使用一条 USB 线把程序下载和 RT-Thread 里的 shell 操作都搞定

- ART 的创新有几点：
  - 兼容 Arduino ，不仅是 Arduino 硬件接口，也兼容 Arduino 软件语法，源文件。 ART_work 的 examples 都未经修改，直接引用 Arduino 的例程

  - 使用实时多任务的 RT-Thread 操作系统，也相应的获得其中的功能特性：虚拟文件系统（默认加载只读文件系统、 FAT 文件系统），pthreads 库等

  - Arduino 程序编译形成单独可执行的程序。这个是在 ARM Cortex-M3/M4 上未使用 MMU 而实现的一种伪进程技术；依赖于这种方式，把多个 Arduino 程序进行并行化，形成多任务目的

- http://www.rt-thread.org/phpbbforum/viewtopic.php?f=27&t=1752

6502 simulator!

- https://plus.google.com/106353937620710166166/posts/eZ6AgpxHVug

- After a few optimizations, and actually compiling with -O3 instead of -Os, the simulator is effectively doing a 17.8 MHz 6502.

- more benchmarking in the meantime-- with the more intensive instructions, the sim slows down to about 3MHz. Boo. On the other hand, EhBasic has been added to the mix, and a bug with the BMI instruction was fixed.

- https://plus.google.com/106353937620710166166/posts/eZ6AgpxHVug
- https://plus.google.com/photos/103257746843984378946/albums/5714631288595384433/5714591873201494850

- STM32 F4 series, High-performance Cortex™-M4 MCU, STMicroelectronics
- Embedded Programming with the GNU Toolchain, Vijay Kumar B.

http://0xlab.org