International Journal of Research in Advent Technology (E-ISSN: 2321-9637) Special Issue
1st International Conference on Advent Trends in Engineering, Science and Technology
"ICATEST 2015", 08 March 2015

An Overview of ARM Cortex-M3 Based Breakout Boards

R. R. Karhe[1], R. B. Bhamare[2]
[1] *Associate Professor, E&TC Engineering Dept. SGDCOE Jalgaon, rajeshkarhe@yahoo.com,*
[2] *PG student, E&TC Engineering Dept. SGDCOE Jalgaon, roshankumarbhamare@gmail.com,*

Abstract: The embedded system is growing rapidly with advancement in the processor architecture. The evaluation and application development on new processor architecture is done with various breakout boards. The concept of breakout board is explained in this paper. It is very difficult to select a particular breakout board from the available choices. The Cortex-M3 is one of the most efficient processor from ARM, intended for microcontroller applications. This paper gives an overview of ARM Cortex-M3 processor based breakout boards as far as proper selection and application is concerned. A list of microcontrollers based on Cortex-M3 is made and comparison of breakout boards from different manufacturers is carried out on the basis of various features and cost. Processor selection, learning outcome, precision, programming options, operating voltage, cost power supply, debug and trace, support are the important criteria's that need to be considered while selecting a breakout board.

Keywords – Breakout board, Microcontroller, ARM Cortex-M3, Application development, Programming.

1. INTRODUCTION

The economic important of embedded systems has grown exponentially as electronic components are in every day-use devices [3]. The breakout board is a well know example of this. The breakout board [1] is a hardware platform that allows hand access to densely placed pins on a microcontroller. The architectural evaluation in microprocessors for the development of microcontroller, plays an important role in the field of embedded systems. The reason for existence of breakout boards was mainly for development and evaluation of new microprocessor architectures and not for entertainment. So, unnecessary peripherals, features (like on board power supply) are left out to keep cost down. Since the boards will be used in laboratory environment they don't equipped with power supply and other enclosures.

The microcontroller breakout board is a printed circuit board contains a microcontroller unit and minimal support and logic needed to become acquainted with the advanced or new microprocessor architecture present on board and learn to program it [16]. The break boards are generally categorized according to their purpose i.e. whether the work will be evaluation type of development type. The evaluation board is sold (or given away) by the manufacturer of the microcontroller, for the purpose of engineering evaluation and sales of that microcontroller chip. It provides all the peripherals, connectors such as universal asynchronous receiver/transmitter (UART), liquid crystal display (LCD), keypad, universal serial bus (USB), Ethernet, secure digital (SD) cards and multimedia card (MMC) with high cost. With such assembly user can test any peripheral for evaluation. Evaluation systems are useful, but they will not be used for long. They have numerous outputs that will not be used later and tend to take up more space than is required. On the other side, development board or microprocessor training kits were not always produced by that microprocessor manufacturer, Many times these boards and kits were produced by third parties. Such boards are preferred by hobbyist, students, since they were earliest cheap microcomputer devices to buy. For a microcontroller based development project there are two ways to do the work, first is to design the system from the ground up and another is to use pre-built system boards for simplicity and quick project completion. A generalized block diagram of breakout board is shown in figure 1.

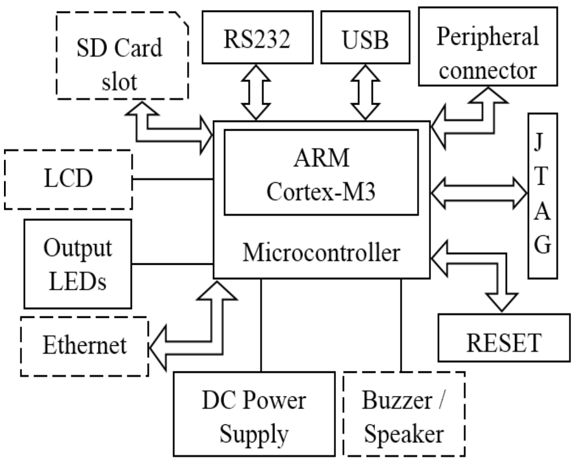

Fig. 1 : General block diagram of breakout board

The ARM based development board is a good example of breakout boards. It includes ARM core, memory components which can be configured to match the performance and bus-width of the memory in the target system, and electrically programmable devices which can be configured to emulate application specific peripherals. It can support both hardware and software development before the final application-specific hardware is available. This paper is a specific overview of ARM Cortex-M3 core based boards which can be used for development and evaluation purpose. [12]

The rest of the paper organized as follows. Section 2 contains the introduction to Cortex-M family from ARM, ARM Cortex-M3 features and the list of microcontrollers based on ARM Cortex-M3. Section 3 presents the different breakout boards. Section 4 discusses the selection criteria's for breakout boards. Section 5 concludes this paper.

2. ARM Cortex-M processor family

The different processor cores that belongs to ARM Cortex-M family [5] are shown in figure 2. The ARM processor core is the key component of most embedded systems. This core is a product of ARM Holdings plc, a British multinational semiconductor and software designing company. This is a fabless company i.e. it does not manufacture silicon. The company's original mission is to create an architecture and offer an intellectual property (IP) licensing of processor architecture to chip manufacturing companies like Intel, NVidia, Texas instruments etc. These silicon manufacturers, in turn, design microprocessors / microcontrollers around these cores and manufacture the actual silicon or chip available for commercial purchase in the market.

The ARM Cortex-M is a group of 32-bit reduced instruction set computing (RISC) processor [2] cores, intended for microcontroller use. This processor family belongs to ARM v6-M (M-microcontroller), ARMv7-M and ARMv7-EM (E-enhanced digital signal processing instructions) architecture [13] [14] [15].

It is designed for targeting low-cost applications in which processing efficiency is important with cost, power consumption, low interrupt latency, ease of use, as well as industrial control applications, including real-time control systems. The Cortex-M family is optimized for cost and power sensitive microcontroller unit (MCU) and mixed signal devices for applications such as internet of things (IoT), connectivity, smart metering, human interface devices, automotive and industrial control systems, domestic household appliances, consumer products and medical instrumentation [8] [10].

2.1 ARM Cortex-M3 processor

The chip diagram [6] for Cortex-M3 processor is shown in fig. 3. The ARM Cortex-M3 processor provides excellent performance at low gate count and has some noticeable features as listed below [6].

- Higher performance and efficiency

The processor has better balance of power consumption and design complexity. The 3-stage pipeline based on Harvard architecture allows to deliver a Dhrystone benchmark performance of 1.25 DMIPS/MHz. A Thumb-2 instruction set architecture (ISA) increases efficiency by 70% per MHz than ARM7TDMI-S [6].

- Efficient and easy application development

The Cortex-M3 processor is designed to be fast and easy to program with Thumb-2 ISA. It also allows easy 32-bit code transition, optimization for code density [7] [11].

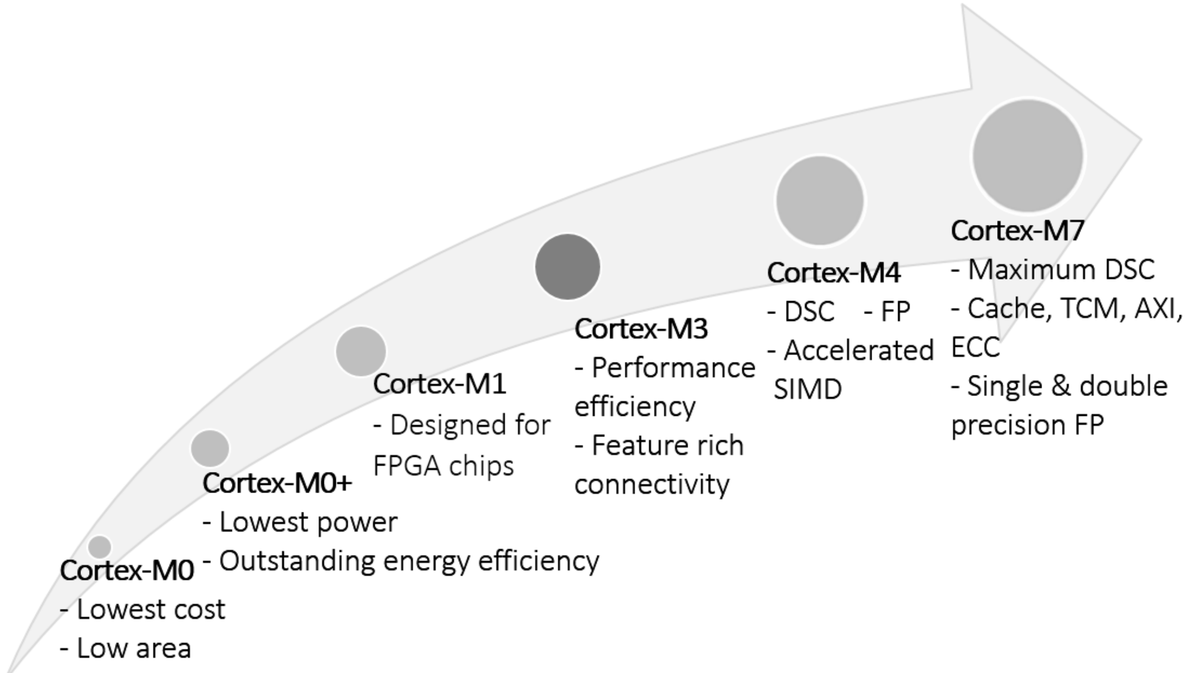

Fig. 2 : ARM Cortex-M cores

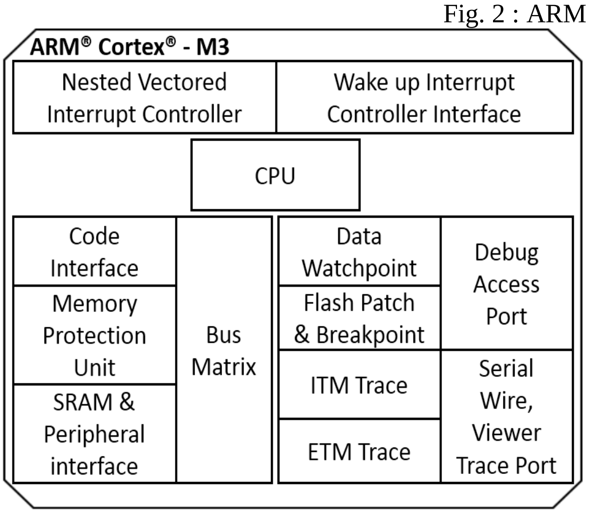

Fig. 3 ARM Cortex-M3 chip diagram

- Power sensitivity at low cost

The area of implementation and gate count directly affects chip cost and power consumption. The Cortex-M3 with 33,000 gates in central core and Thumb-2 ISA delivers a power consumption of 4.5mW with silicon footprint area of 0.30mm^2 [8] [10].

- Debug and trace

Being a smaller and complex system, the processor provides debug and trace functionality to have a high level of visibility into the system through joint test action group (JTAG) port or 2-pin serial wire debug (SWD). [8] [9]

2.2 Microcontrollers based on ARM Cortex-M3 processor

Table 1 shows a list of leading manufacturers of different microcontrollers [17] based on ARM Cortex-M3.

Table 1: List of manufacturers and their microcontrollers

Manufacturer/ Vendor	Microcontrollers
Actel Corporation	SmartFusion and SmartFusion (A2F060, A2F200, A2F500)
Analog Devices Inc.	ADuCM3xx series
Atmel Corporation	SAM3U, SAM3S, SAM3N, SAM3A, SAM3X series
Cypress Semiconductor Corporation	Programmable System-on-Chip (PSoC) 5 – CY8C5xxxx series
Spansion Inc.	FM3
Holtek Semiconductor	HT32F1251/51B/52/53
Texas Instruments Inc.	LM3S1968 (StellarisLM3S)
NXP Semiconductors	LPC1300 series, LPC1700 series, LPC1800 series
ON semiconductor	Q32M210
Silicon Laboratories Inc.	Precision32
Energy Micro AS	EFM32 (Tiny, Gecko, Leopard, Giant)
STMicroelectronics	STM32 F1, F2, L1 and W-series
Toshiba Corporation	TX03 series

3. Commonly used breakout boards

A breakout board is an embedded system, incorporating different features. Depending upon application breakout boards can generally be categorized as development and evaluation boards. The cost can also be a factor for categorizing these boards. Depending upon cost breakout boards can be differentiated as cheap (costs up to Rs. 3000), mid-range (costs from Rs. 3000 to 10000) and high-range (costs more than Rs. 10000).

Table 2 shows list of different breakout boards based on ARM Cortex-M3 processor, their manufacturer and features [18-26].

Table 2: Breakout boards and their features

Manufacturer and Board	Features [18-26]
{Sr. no. 1} Arduino Arduino Due [18]	It is based on microcontroller from Atmel (SAM3X8E). It is the first Arduino board based on a 32-bit ARM core microcontroller. It has 54 digital input/output pins (of which 12 can be used as PWM outputs), 12 analog inputs, 4 UARTs (hardware serial ports), a 84 MHz clock, an USB OTG capable connection, 2 DAC (digital to analog), 2 TWI, a power jack, an SPI header, a JTAG header, a reset button and an erase button.
{Sr. no. 2} Freetronics Ether Due [19]	It is based on 84MHz 32-bit Cortex M3 ARM processor, same as the Arduino Due. Many times more powerful than the 8-bit AVR processors of earlier Arduino models. Combined with a massive 96 kilobytes of RAM and 512 kilobytes of flash, there's tons of rooms for the most complex programs to run. Connectivity options are plentiful too - USB device and host, two i2c buses, SPI bus, CAN bus, four hardware serial ports, and a real 12-bit Digital to Analog converter for analog voltage output.
{Sr. no. 3} Elechouse TAIJIUINO Due Pro [20]	It is based on microcontroller from Atmel (SAM3X8E). It has 54 digital input/output pins (of which 12 can be used as PWM outputs), 12 analog inputs, 4 UARTs (hardware serial ports), a 84 MHz clock, an USB OTG capable connection, 2 DAC (digital to analog), 2 TWI, a power jack, an SPI header, a JTAG header, a reset button and an erase button. This board is compatible with all Arduino shields that work at 3.3V and are compliant with the 1.0 Arduino pinout.
{Sr. no. 4} LeafLabs Maple [21]	It is an Arduino-style board, using STM32 microcontroller. It was LeafLab's first product, released in 2009. It was one of the first ARM Cortex-M3 microcontroller boards that was accessible to hobbyists and engineers outside of the embedded industry. The design was modeled on the Arduino boards, with a pin-out backwards compatible with most shields and a programming environment based on the free software GCC tool chain and the Processing or Wiring or Arduino user interface. LeafLabs wrote a new open source C library (libmaple) for this board, having found the vendor supplied libraries inadequate.
{Sr. no. 5} Coridium PRO-Plus [22]	It is based on microcontroller from NXP (LPC1751), with frequency of 100MHz, programmable in a C. It has storage of 20k user code space (1600 Instructions), 5k user data, 32k flash size, 8k RAM size. It operates with 5-7V DC input and has power consumption of 350mW. The connectors present are debug connector, connections for 52 digital I/O, 4 x 12 bit analog A/Ds and programming dongle need to be purchased separately.
{Sr. no. 6} Coridium SUPER-PRO [23]	It is based on microcontroller from NXP (LPC1756) with frequency of 100 MHz, programmable in C. It has storage of 128k user code space (10,000 Instructions), 16k user data, 256k flash and 32k RAM size. It operates with 5-7V DC input and has provides 500 mA +5V. The connectors present are debug connector, connections for 52 digital I/O, 4 x 12 bit analog A/Ds, one 10bit DAC and programming dongle need to be purchased separately.
{Sr. no. 7} Bugblat Cortino [24]	It is based on STM32 series microcontroller (STM32F103), with operating frequency of 72MHz with up to 512KB of ROM and 64KB of RAM. The STM32F102 parts operate at 48MHz with up to 128KB of ROM and 16KB of RAM. And the STM32F101 parts operate at 36MHz with up to 512KB of ROM and 48KB of RAM. The Cortino series has 3 variants, Cortino-3RE, 3RB, 1R6.
{Sr. no. 8} STMicroelect	It is based on STM32F100RB microcontroller, with 128 KB Flash, 8 KB RAM in 64-pin LQFP.

ronics STMVL32DI-SCOVERY [25]	Also on-board ST-Link with selection mode switch to use the kit as a stand-alone ST-Link (with SWD connector). It is designed to be powered by USB or an external supply of 5 V or 3.3 V, can supply target application with 5 V and 3 V. It has two user LEDs (green and blue), one user push button, extension header for all QFP64 I/Os for quick connection to prototyping board or easy probing.
{Sr. no. 9} Keil MCB1343 (Evaluation board) [26]	It is based on microcontroller from NXP (LPC1343), with external clock frequency 12MHz, MCU clock of 72MHz. The storage of on-chip 8K RAM and 32K flash, 4 push buttons, 8 I/O port LEDs, analog input, 1 serial port, USB, JTAG and SWD interface and 10-pin cortex connector. It need supply of 5V DC max. 15 mA.
{Sr. no. 10} Keil MCB1700 series (Evaluation board) [26]	It is based on microcontrollers from NXP, with increased MCU clock up to 100MHz, on-chip 64K RAM and 512K flash, (16M SDRAM, 16M Nor), analog output, USB host, Ethernet, SD card interface, LCD, ETM interface, 20-pin JTAG connector, max. Current 120 mA.
{Sr. no. 11} Keil MCB9B500 (Evaluation board) [26]	It is based on microcontroller from Fujitsu and with MPU clock of 80 MHz. It has on-chip storage of 32K RAM, 512K flash, 5 push buttons, 8 I/O LEDs, USB host, JTAG, SWD and ETM interface, 10 and 20-pin connector, 5V Dc supply.
{Sr. no. 12} Keil MCBSTM32 series (Evaluation board) [26]	It is based on microcontrollers from STMicroelectronics, with external clock frequency up to 25MHz and MCU clock frequency up to 120MHz. It has on-chip storage of 128K RAM, 1M flash, external RAM up to 2M, external flash up to 8M/512M, analog I/O, 3 serial and 2 CAN ports, USB host, Ethernet, SD card interface, LCD, JTAG, ETM and SWD interface, 10 and 20-pin cortex connector, 20-pin JTAG connector, supply of 5V DC, max. Current up to 375 mA.
{Sr. no. 13} Keil MCBTMPM3xx series and MPCBTWxxxxx series (Evaluation board) [26]	It is based on microcontrollers from Toshiba, with external clock of 12MHz and MPC clock up to 64MHz. It has on-chip storage of up to 128K RAM, up to 2M flash, up to 6 push buttons, up to 5 I/O LEDs, analog input, JTAG, ETM, SWD interface, 10/20-pin cortex connector, 20-pin JTAG connector, supply of 5V DC, maximum current of 25 mA.

Figure 4 shows the cost comparison [18-26] of break boards listed in table 2.

4. Selection criteria for breakout board

The selection criteria's helps to take accurate decision based on priorities of the various engineering requirements for the application in hand. Since there are too many choices for these boards, it is difficult to decide which one is best suitable for the desired task. So, below mentioned important criteria [4] can be applied to breakout boards.

- Processor selection

The proper selection of processor depends upon purpose of use, power consumption, efficiency, documentation available, cost of MCU etc.

- Serviceability

It is the ability of board to get repaired if something goes wrong. The repairing means replacing the faulty components, updating the software if needed etc. This factor is difficult to consider as far as multilayer circuit boards with extremely complex design are concerned.

- Learning outcome

The learning expectations from board may depend upon its user. The board must offer the clear understanding of an implemented core technology.

- Precision

The board should provide good pedagogy. The selected board must be precise to perform its capable task.

- Programming options

A short term and long term use should be taken in account here. Also the environment (infield or outfield) in which board will going to be used is also important. It may be bootloader, in-system programmer (ISP), JTAG.

- Features

The features include availability of many options like onboard push buttons, light emitting diodes (LEDs), 7 segment displays, RS232 port, flash memory etc. But besides the basics, extra features like camera, LED display, liquid crystal displays (LCDs), secure digital (SD) card slot, buffer integrated circuit (IC) USB slot etc. may increase the cost of a board significantly high than its plain version.

- Operating voltage

A bulky breakout board consumes more power than its plain version. There should be good balance between board features, peripherals and its operating voltage.

- Cost

It is the most important factor. A well featured board at a reasonable cost is desired.

- Power supply

The choices available for supplying power to a board are bench top, wall wart, on board batteries, through USB connection. This decision depends on the environment in which the board will going to be used.

- Debug and trace

The debug feature is also called as on-the-fly memory access, used by halting the processor execution for some time. Whereas trace is done without halting the processor. Both these features are important for understanding of processor.

- Support

The supportive documents like user manuals, technical references should be available for easy and efficient use of board.

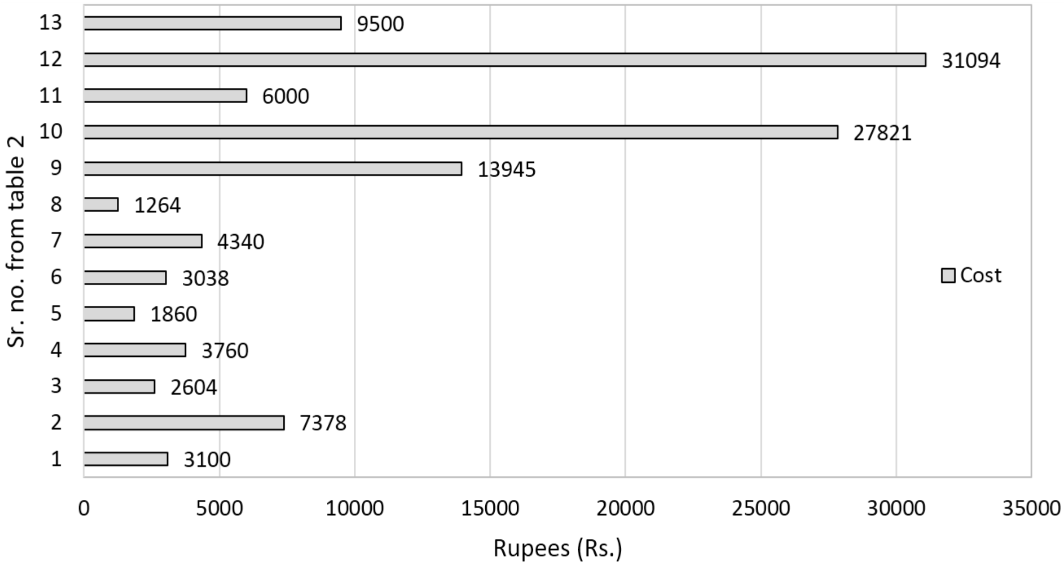

Fig. 4 Cost comparison of breakout boards

5. Conclusion

This paper presents the importance, application and comparison of breakout boards. The feature and cost comparison is useful for beginners, hobbyist who want to develop an application on ARM Cortex-M3 based hardware platform. Also various criteria to select breakout board are mentioned. The importance of particular criteria may differ from user to user and it also get affected by rapid change in technology. The proposed selection criteria's in this paper can further be expand to have more generalized view of breakout boards.

REFERENCES

[1]. Hamblen, J.O., van Bekkum, "An Embedded Systems Laboratory to Support Rapid Prototyping of Robotics and the Internet of Things", IEEE Trans. on Education, ISSN 0018-9359, Paper id - 6375774, Volume 56, Issue 1, pp. 121-128, February 2013.

[2]. Emily Blem, Jaikrishnan Menon and Karthikeyan Sankaralingam, "Power Struggles: Revisiting the RISC vs. CISC Debate on Contemporary ARM and x86 Architectures", 19th IEEE International Symposium on High

Performance Computer Architecture (HPCA), Shenzhen, Paper id – 6532302, Print ISBN 978-1-4673-5585-8, ISSN 1530-0897, pp. 1-12, 23-27 February 2013.

[3]. Pau Marti, Manel Velasco, Josep M. Fuertes, Antonio Camacho and Giorgio Buttazzo, “Design of an Embedded Control System Laboratory Experiment”, IEEE Trans. on Industrial Electronics, ISSN 0278-0046, Paper id – 5409585, Volume 57, Issue 10, pp. 3297 - 3307, October 2010.

[4]. Jeffrey Richardson, “Evaluating Development Boards for Laboratory based Embedded microcontroller Courses - A formal Evolution Matrix”, ASEE, 2008.

[5]. ARM Cortex Portfolio 2014 (http://www.arm.com/files/pdf/ARM-Cortex-Portfolio-2014.pdf)

[6]. Shyam Sadasivam, “An introduction to the ARM Cortex-M3 processor, WHITE PAPER ARM”, October 2006.

[7]. James A. Langbridge, “Professional Embedded ARM® Development”, ISBN: 978-1-118-78894-3, Wrox Publishers, Indianapolis, First edition, Pages 247, 2014.

[8]. Joseph Yiu, “The Definitive Guide to the ARM® Cortex™-M3 and Cortex™-M4 Processors”, ISBN-13: 978-0-12-408082-9, Newnes (Imprint of Elsevier Inc.), USA, Third revised edition, Pages 801, 2013.

[9]. Trevor Martin, “The Designers Guide to the Cortex-M Processor Family, A Tutorial Approach”, ISBN: 978-0-08-098296-0, Newnes (Imprint of Elsevier Inc.), USA, First edition, Pages 312, 2013.

[10]. Joseph Yiu (foreword by Paul Kimelman), “The Definitive Guide to the ARM® Cortex-M3”, ISBN: 978-0-12-382091-4, Newnes (Imprint of Elsevier Inc.), USA, Second edition, Pages 499, 2010.

[11]. Andrew Sloss, Dominic Symes and Chris Wright, “ARM® System Developer's Guide: Designing and Optimizing System Software”, ISBN: 1-55860-874-5, Morgan Kaufmann Publishers (with imprint of Elsevier Inc.), San Francisco (CA), Second edition, Pages 669, 2004.

[12]. Steve Furber, “ARM® system-on-chip architecture”, ISBN-13: 978-0201675191, Pearson Education Limited, Second edition, Pages 413, 2000.

[13]. Cortex™-M3 Devices Generic User Guide.

[14]. Cortex™-M3 Technical Reference Manual, Revision r2p1.

[15]. Stellaris® ARM® Cortex™-M3 Lab Manual.

[16]. http://en.wikipedia.org/wiki/Microprocessor_development_board

[17]. http://en.wikipedia.org/wiki/ARM_Cortex-M#Chips_4

[18]. http://arduino.cc/en/Main/ArduinoBoardDue

[19]. http://www.freetronics.com.au/products/etherdue-arduino-due-compatible-with-onboard-ethernet

[20]. http://www.elechouse.com/elechouse/images/product/Taijiuino/

[21]. http://leaflabs.com/about-maple

[22]. http://www.coridiumcorp.com/prod-specs6.html

[23]. http://www.coridiumcorp.com/prod-specs7.html

[24]. http://www.bugblat.com/products/cor.html

[25]. http://www.st.com/web/en/catalog/tools/FM116/SC959/SS1532/PF250863?sc=stm32-discovery

[26]. http://www.keil.com/arm/boards/cortexm.asp