

A step-by-step guide to the most complete ARM Cortex-M platform, using a free and powerful development environment based on Eclipse and GCC

## **Mastering STM32**

A step-by-step guide to the most complete ARM Cortex-M platform, using a free and powerful development environment based on Eclipse and GCC

### Carmine Noviello

This book is for sale at http://leanpub.com/mastering-stm32

This version was published on 2018-01-03



This is a Leanpub book. Leanpub empowers authors and publishers with the Lean Publishing process. Lean Publishing is the act of publishing an in-progress ebook using lightweight tools and many iterations to get reader feedback, pivot until you have the right book and build traction once you do.

© 2015 - 2018 Carmine Noviello

## **Tweet This Book!**

Please help Carmine Noviello by spreading the word about this book on Twitter!

The suggested hashtag for this book is #MasteringSTM32.

Find out what other people are saying about the book by clicking on this link to search for this hashtag on Twitter:

#MasteringSTM32

# **Contents**

Pro	eface			. i
			te the Book?	
			ok For?	
	Ho	w to Integrat	te This Book?	. iii
	Ho	w Is the Book	k Organized?	. iv
			ns	
	Book Sup	pport		. viii
			hor	
			·	
	Credits			. ix
Ac	knowledg	gments		. X
T	T 4	. 14: .		
I	intr	oauctio	on	. 1
1.	Introduc	otion to STM:	32 MCU Portfolio	. 2
1.			to ARM Based Processors	
	1.1		and Cortex-M Based Processors	
	1,1,	1.1.1.1	Core Registers	
		1.1.1.2	Memory Map	
		1.1.1.3	Bit-Banding	
		1.1.1.4	Thumb-2 and Memory Alignment	
		1.1.1.5	Pipeline	
		1.1.1.6	Interrupts and Exceptions Handling	
		1.1.1.7	SysTimer	
		1.1.1.8	Power Modes	
		1.1.1.9	CMSIS	
		1.1.1.10	Effective Implementation of Cortex-M Features in the STM32	
		1.1.1.10	Portfolio	
	1.2 Iı	ntroduction to	to STM32 Microcontrollers	
			ages of the STM32 Portfolio	

		1.2.2	And its Drawbacks
	1.3	A Qu	nick Look at the STM32 Subfamilies
		1.3.1	F0 26
		1.3.2	F1 27
		1.3.3	F2 28
		1.3.4	F3 30
		1.3.5	F4 32
		1.3.6	F7 33
		1.3.7	H7
		1.3.8	L0
		1.3.9	L1
		1.3.10	L4
		1.3.11	L4+ 40
		1.3.12	W and J STM32 MCUs
		1.3.13	How to Select the Right MCU for You?
	1.4	The l	Nucleo Development Board
			•
2.	Setti	ng-Up t	he Tool-Chain
	2.1	Why	Choose Eclipse/GCC as Tool-Chain for STM32
		2.1.1	Two Words About Eclipse 53
		2.1.2	and GCC
	2.2	Wind	dows - Installing the Tool-Chain
		2.2.1	Windows - Eclipse Installation
		2.2.2	Windows - Eclipse Plug-Ins Installation
		2.2.3	Windows - GCC ARM Embedded Installation 63
		2.2.4	Windows – Build Tools Installation
		2.2.5	Windows - OpenOCD Installation
		2.2.6	Windows – ST Tools and Drivers Installation
			2.2.6.1 Windows – ST-LINK Firmware Upgrade 65
	2.3	Linu	x - Installing the Tool-Chain
		2.3.1	Linux - Install i386 Run-Time Libraries on a 64-bit Ubuntu 67
		2.3.2	Linux - Java Installation
		2.3.3	Linux - Eclipse Installation
		2.3.4	Linux - Eclipse Plug-Ins Installation
		2.3.5	Linux - GCC ARM Embedded Installation
		2.3.6	Linux - Nucleo Drivers Installation
			2.3.6.1 Linux – ST-LINK Firmware Upgrade
		2.3.7	Linux – OpenOCD Installation
		2.3.8	Linux - ST Tools Installation
	2.4		- Installing the Tool-Chain
		2.4.1	Mac - Eclipse Installation
		2.4.2	Mac - Eclipse Plug-Ins Installation
		2.4.3	Mac - GCC ARM Embedded Installation

		2.4.4	Mac - Nucleo Drivers Installation
			2.4.4.1 Mac – ST-LINK Firmware Upgrade
		2.4.5	Mac – OpenOCD Installation
		2.4.6	Mac - ST Tools Installation
3.	Hell	o, Nucl	eo!
	3.1	Get	in Touch With the Eclipse IDE
	3.2		te a Project
	3.3	Con	necting the Nucleo to the PC
	3.4	Flasl	ning the Nucleo using STM32CubeProgrammer
	3.5		erstanding the Generated Code
4.	STM	i32Cube	eMX Tool
	4.1		oduction to CubeMX Tool
		4.1.1	Pinout View
			4.1.1.1 Chip View
			4.1.1.2 IP Tree Pane
		4.1.2	Clock View
		4.1.3	Configuration View
		4.1.4	Power Consumption Calculator View
	4.2		ect Generation
		4.2.1	Generate C Project with CubeMX
			4.2.1.1 Understanding Generated Code
		4.2.2	Create Eclipse Project
		4.2.3	Importing Generated Files Into the Eclipse Project Manually 129
		4.2.4	Importing Files Generated With CubeMX Into the Eclipse Project Automat-
			ically
	4.3	Und	erstanding Generated Application Code
		4.3.1	Add Something Useful to the Firmware
	4.4		rnloading Book Source Code Examples
5.	Intro	oductio	n to Debugging
	5.1	Gett	ing Started With OpenOCD
	0.1	5.1.1	Launching OpenOCD
		0,1,1	5.1.1.1 Launching OpenOCD on Windows
			5.1.1.2 Launching OpenOCD on Linux and MacOS X
		5.1.2	Connecting to the OpenOCD Telnet Console
		5.1.3	Configuring Eclipse
		5.1.4	Debugging in Eclipse
	5.2		4 Semihosting
	3.2	5.2.1	Enable Semihosting on a New Project
		5.2.1	5.2.1.1 Using Semihosting With C Standard Library
		5.2.2	Enable Semihosting on an Existing Project
		J. L. L	- made commoding on an matching ridged

		5.2.3 5.2.4	Semihosting Drawbacks	
II	Ι	Divir	ng into the HAL	'5
6.	GPI		gement	
	6.1	STM	32 Peripherals Mapping and HAL <i>Handlers</i>	76
	6.2	GPIC	Os Configuration	31
		6.2.1	GPIO Mode	33
		6.2.2	GPIO Alternate Function	35
		6.2.3	Understanding GPIO Speed	36
	6.3	Driv	ing a GPIO	<del>)</del> 0
	6.4	De-i	nitialize a GPIO	}0
7.	Inte	rrupts N	Management	)2
	7.1	NVI	C Controller	€
		7.1.1	Vector Table in STM32	€3
	7.2	Enab	oling Interrupts	€7
		7.2.1	External Lines and NVIC	€7
		7.2.2	Enabling Interrupts With CubeMX	)1
	7.3	Inter	rupt Lifecycle	)3
	7.4		rupt Priority Levels	
		7.4.1	Cortex-M0/0+	)7
		7.4.2	Cortex-M3/4/7	12
		7.4.3	Setting Interrupt Priority in CubeMX	
	7.5	Inter	rupt Re-Entrancy	
	7.6		k All Interrupts at Once or an a Priority Basis	
8.	Univ	ersal A	synchronous Serial Communications	24
	8.1	Intro	oduction to UARTs and USARTs	24
	8.2	UAR	T Initialization	28
		8.2.1	UART Configuration Using CubeMX	35
	8.3	UAR	T Communication in <i>Polling Mode</i>	36
		8.3.1	Installing a Serial Console in Windows	<del>1</del> 0
		8.3.2	Installing a Serial Console in Linux and MacOS X	43
	8.4	UAR	T Communication in <i>Interrupt Mode</i>	44
		8.4.1	UART Related Interrupts	<del>4</del> 5
	8.5		r Management	
	8.6		Retargeting	
9.	DM	A Mana	gement	58
	9.1	Intro	duction to DMA	58

		9.1.1	The Need of a DMA and the Role of the Internal Buses
		9.1.2	The DMA Controller
			9.1.2.1 The DMA Implementation in F0/F1/F3/L1 MCUs 265
			9.1.2.2 The DMA Implementation in F2/F4/F7 MCUs 267
			9.1.2.3 The DMA Implementation in L0/L4 MCUs
	9.2	HAL_I	DMA Module
		9.2.1	DMA_HandleTypeDef in F0/F1/F3/L0/L1/L4 HALs
		9.2.2	DMA_HandleTypeDef in F2/F4/F7 HALs
		9.2.3	DMA_HandleTypeDef in L0/L4 HALs
		9.2.4	How to Perform Transfers in Polling Mode
		9.2.5	How to Perform Transfers in Interrupt Mode
		9.2.6	How to Perform <i>Peripheral-To-Peripheral</i> Transfers
		9.2.7	Using the HAL_UART Module With DMA Mode Transfers
		9.2.8	Miscellaneous Functions From HAL_DMA and HAL_DMA_Ex Modules 280
	9.3	Using	g CubeMX to Configure DMA Requests
	9.4	Corre	ect Memory Allocation of DMA Buffers
	9.5	A Ca	se Study: The DMA <i>Memory-To-Memory</i> Transfer Performance Analysis 289
10.			
	10.1	Cloc	k Distribution
		10.1.1	
			10.1.1.1 The Multispeed Internal RC Oscillator in STM32L Families 300
		10.1.2	Configuring Clock Tree Using CubeMX
		10.1.3	Clock Source Options in Nucleo Boards
			10.1.3.1 OSC Clock Supply
			10.1.3.2 OSC 32kHz Clock Supply
	10.2	Over	view of the HAL_RCC Module
		10.2.1	Compute the Clock Frequency at Run-Time
		10.2.2	Enabling the Master Clock Output
		10.2.3	Enabling the Clock Security System
	10.3	HSI (	Calibration
11.			
	11.1		duction to Timers
		11.1.1	Timer Categories in an STM32 MCU
		11.1.2	Effective Availability of Timers in the STM32 Portfolio
	11.2		e Timers
		11.2.1	Using Timers in Interrupt Mode
			11.2.1.1 Time Base Generation in Advanced Timers
		11.2.2	Using Timers in Polling Mode
		11.2.3	Using Timers in DMA Mode
		11.2.4	Stopping a Timer
		11.2.5	Using CubeMX to Configure a <i>Basic Timer</i>

	11.3	Gene	ral Purpo	se Timers	326
		11.3.1	Time Ba	se Generator With External Clock Sources	326
			11.3.1.1	External Clock Mode 2	328
			11.3.1.2	External Clock Mode 1	332
			11.3.1.3	Using CubeMX to Configure the Source Clock of a General	
				Purpose Timer	337
		11.3.2	Master/S	Slave Synchronization Modes	338
			11.3.2.1	Enable Trigger-Related Interrupts	343
			11.3.2.2	Using CubeMX to Configure the Master/Slave Synchronization .	343
		11.3.3	Generate	e Timer-Related Events by Software	
		11.3.4	Counting	g Modes	346
		11.3.5	Input Ca	pture Mode	347
			11.3.5.1	Using CubeMX to Configure the Input Capture Mode	354
		11.3.6	Output (	Compare Mode	355
			11.3.6.1	Using CubeMX to Configure the Output Compare Mode	360
		11.3.7	Pulse-W	idth Generation	360
			11.3.7.1	Generating a Sinusoidal Wave Using PWM	364
			11.3.7.2	Using CubeMX to Configure the PWM Mode	369
		11.3.8	One Puls	se Mode	
			11.3.8.1	Using CubeMX to Configure the OPM Mode	
		11.3.9		Mode	
			11.3.9.1	Using CubeMX to Configure the <i>Encoder Mode</i>	
		11.3.10		atures Available in <i>General Purpose</i> and <i>Advanced</i> Timers	
				Hall Sensor Mode	379
			11.3.10.2	Combined Three-Phase PWM Mode and Other Motor-Control	
				Related Features	
				Break Input and Locking of Timer Registers	
				Preloading of Auto-Reload Register	
				ng and Timers	
	11.4				
				ther Timer as System Timebase Source	
	11.5	A Ca	se Study:	How to Precisely Measure Microseconds With STM32 MCUs	384
12	Anal	იσ-Tი-I	Digital Co	onversion	390
12.	12.1			SAR ADC	
	12.2			le	
		12.2.1		ion Modes	
			12.2.1.1	Single-Channel, Single Conversion Mode	
			12.2.1.2	Scan Single Conversion Mode	
			12.2.1.3	Single-Channel, Continuous Conversion Mode	
			12.2.1.4	Scan Continuous Conversion Mode	
			12.2.1.5	Injected Conversion Mode	
			12.2.1.6	Dual Modes	

		12.2.2	Channel Selection	<b>£</b> 01
		12.2.3	ADC Resolution and Conversion Speed	<u> </u>
		12.2.4	A/D Conversions in Polling Mode	<u> 1</u> 02
		12.2.5	A/D Conversions in Interrupt Mode	<del>1</del> 06
		12.2.6	A/D Conversions in DMA Mode	<u> 1</u> 07
			12.2.6.1 Convert Multiple Times the Same Channel in DMA Mode 4	<b>£1</b> 1
			12.2.6.2 Multiple and not Continuous Conversions in DMA Mode 4	<b>£1</b> 1
			12.2.6.3 Continuous Conversions in DMA Mode	<b>£1</b> 1
		12.2.7	Errors Management	<b>£1</b> 1
		12.2.8	Timer-Driven Conversions	£12
		12.2.9	Conversions Driven by External Events	í15
		12.2.10	ADC Calibration	í16
	12.3	Using	g CubeMX to Configure ADC Peripheral	£16
13.	Digit	tal-To-A	Analog Conversion	19
	13.1	Intro	duction to the DAC Peripheral	<u> </u>
	13.2	HAL_[	DAC Module	<u> </u>
		13.2.1	Driving the DAC Manually	<b>í</b> 23
		13.2.2	Driving the DAC in DMA Mode Using a Timer	í25
		13.2.3	Triangular Wave Generation	£29
		13.2.4	Noise Wave Generation	<del>1</del> 3(
14.	I <sup>2</sup> C			132
	14.1	Intro	duction to the I <sup>2</sup> C specification	<u> 1</u> 32
		14.1.1	The I <sup>2</sup> C Protocol	<u> </u>
			14.1.1.1 START and STOP Condition	<u> 1</u> 35
			14.1.1.2 Byte Format	í35
			14.1.1.3 Address Frame	<u> </u>
			14.1.1.4 Acknowledge (ACK) and Not Acknowledge (NACK) 4	í36
			14.1.1.5 Data Frames	<u> 1</u> 37
			14.1.1.6 Combined Transactions	<u> 1</u> 37
			14.1.1.7 Clock Stretching	£38
		14.1.2	Availability of I <sup>2</sup> C Peripherals in STM32 MCUs	£39
	14.2		I2C Module	
		14.2.1	Using the I <sup>2</sup> C Peripheral in <i>Master Mode</i>	<b>44</b> 3
			14.2.1.1 I/O MEM Operations	<b>£</b> 51
			14.2.1.2 Combined Transactions	
			14.2.1.3 A Note About the Clock Configuration in STM32F0/L0/L4 families 4	
		14.2.2	Using the I <sup>2</sup> C Peripheral in <i>Slave Mode</i>	
	14.3	Using	g CubeMX to Configure the I $^2$ C Peripheral	<b>i</b> 61
15.	SPI			163
				163

		15.1.1 Clock Polarity and Phase	
		15.1.2 Slave Select Signal Management	
		15.1.3 SPI <i>TI Mode</i>	
		15.1.4 Availability of SPI Peripherals in STM32 MCUs	69
	15.2	HAL_SPI Module	7(
		15.2.1 Exchanging Messages Using SPI Peripheral	72
		15.2.2 Maximum Transmission Frequency Reachable using the CubeHAL 4	74
	15.3	Using CubeMX to Configure SPI Peripheral	ŀ74
16.	Cycl	ic Redundancy Check	75
	16.1	Introduction to CRC Computing	75
		16.1.1 CRC Calculation in STM32F1/F2/F4/L1 MCUs	78
		16.1.2 CRC Peripheral in STM32F0/F3/F7/L0/L4 MCUs	8(
	16.2	HAL_CRC Module	81
17.	IWD	OG and WWDG Timers	85
	17.1	The Independent Watchdog Timer	8.
		17.1.1 Using the CubeHAL to Program IWDG Timer	
	17.2	The System Window Watchdog Timer	87
		17.2.1 Using the CubeHAL to Program WWDG Timer	
	17.3	Detecting a System Reset Caused by a Watchdog Timer	
	17.4	Freezing Watchdog Timers During a Debug Session	
	17.5	Selecting the Right Watchdog Timer for Your Application	
18.	Real-	-Time Clock	93
	18.1	Introduction to the RTC Peripheral	9:
	18.2	HAL_RTC Module	9:
		18.2.1 Setting and Retrieving the Current Date/Time	96
		18.2.1.1 Correct Way to Read Date/Time Values	98
		18.2.2 Configuring Alarms	0(
		18.2.3 Periodic Wakeup Unit	
		18.2.4 Timestamp Generation and Tamper Detection	03
		18.2.5 RTC Calibration	04
		18.2.5.1 RTC Coarse Calibration	0
		18.2.5.2 RTC Smooth Calibration	05
		18.2.5.3 Reference Clock Detection	06
	18.3	Using the Backup SRAM	07
II	<b>I</b> .	Advanced topics50	80
19.	Pow	er Management	09
			:nc

	19.2	How Cortex-M MCUs Handle Run and Sleep Modes	0
		19.2.1 Entering/exiting sleep modes	3
		19.2.1.1 Sleep-On-Exit	5
		19.2.2 Sleep Modes in Cortex-M Based MCUs	6
	19.3	Power Management in STM32F Microcontrollers	6
		19.3.1 Power Sources	7
		19.3.2 Power Modes	8
		19.3.2.1 Run Mode	8
		19.3.2.1.1 Dynamic Voltage Scaling in STM32F4/F7 MCUs 51	9
		19.3.2.1.2 Over/Under-Drive Mode in STM32F4/F7 MCUs 52	0
		19.3.2.2 Sleep Mode	0
		19.3.2.3 Stop Mode	1
		19.3.2.4 Standby Mode	2
		19.3.2.5 Low-Power Modes Example	2
		19.3.3 An Important Warning for STM32F1 Microcontrollers 52	7
	19.4	Power Management in STM32L Microcontrollers	8
		19.4.1 Power Sources	8
		19.4.2 Power Modes	0
		19.4.2.1 Run Modes	0
		19.4.2.2 Sleep Modes	2
		19.4.2.2.1 Batch Acquisition Mode	3
		19.4.2.3 Stop Modes	3
		19.4.2.4 Standby Modes	4
		19.4.2.5 Shutdown Mode	
		19.4.3 Power Modes Transitions	6
		19.4.4 Low-Power Peripherals	
		19.4.4.1 LPUART	
		19.4.4.2 LPTIM	
	19.5	Power Supply Supervisors	
	19.6	Debugging in Low-Power Modes	
	19.7	Using the CubeMX Power Consumption Calculator	
	19.8	A Case Study: Using Watchdog Timers With Low-Power Modes 54	0
20	Mam	omy lovovit	1
20.	20.1	ory layout	
	20.1	· · ·	
	20.2	20.1.1 Understanding Compilation and Linking Processes	
	20.2	The Really Minimal STM32 Application	
		20.2.1 ELF Binary File Inspection	
		20.2.2 . data and .bss Sections Initialization	
		20.2.3 .rodata Section	
		20.2.4 Stack and Heap Regions	
		20.2.5 Checking the Size of Heap and Stack at Compile-Time	5

		20.2.6	Differences With the Tool-Chain Script Files	566
	20.3	How	to Use the CCM Memory	568
		20.3.1		
	20.4	How	to Use the MPU in Cortex-M0+/3/4/7 Based STM32 MCUs	
		20.4.1		
21.	Flasl		ory Management	
	21.1	Intro	duction to STM32 Flash Memory	582
	21.2	The I	HAL_FLASH Module	586
		21.2.1	Flash Memory Unlocking	586
		21.2.2	Flash Memory Erasing	586
		21.2.3	Flash Memory Programming	588
		21.2.4	Flash Read Access During Programming and Erasing	589
	21.3	Optio	on Bytes	
		21.3.1	Flash Memory Read Protection	591
	21.4	Optio	onal OTP and True-EEPROM Memories	593
	21.5	Flash	n Read Latency and the ART™ Accelerator	
		21.5.1	The Role of the TCM Memories in STM32F7 MCUs	597
			21.5.1.1 How to Access Flash Memory Through the TCM Interface	603
			21.5.1.2 Using CubeMX to Configure Flash Memory Interface	604
22.	Boot	ing Pro	ocess	606
	22.1	The	Cortex-M Unified Memory Layout and the Booting Process	606
		22.1.1	Software <i>Physical Remap</i>	607
		22.1.2	Vector Table Relocation	608
		22.1.3	Running the Firmware From SRAM Using the GNU MCU Eclipse Toolchain	610
	22.2	Integ	grated Bootloader	611
		22.2.1	Starting the Bootloader From the On-Board Firmware	613
		22.2.2	The Booting Sequence in the GNU MCU Eclipse Tool-chain	614
	22.3	Deve	eloping a Custom Bootloader	617
		22.3.1	Vector Table Relocation in STM32F0 Microcontrollers	628
		22.3.2	How to Use the flasher.py Tool	631
23.	Runi	ning Fre	eeRTOS	633
	23.1	Unde	erstanding the Concepts Underlying an RTOS	634
	23.2	Intro	duction to FreeRTOS and CMSIS-RTOS Wrapper	640
		23.2.1	The FreeRTOS Source Tree	
			23.2.1.1 How to Import FreeRTOS Manually	642
			•	643
			23.2.1.3 How to Enable FPU Support in Cortex-M4F and Cortex-M7 Cores	645
	23.3	Thre	ad Management	
		23.3.1	Thread States	
		23.3.2	Thread Priorities and Scheduling Policies	

		23.3.3	Voluntary Release of the Control
		23.3.4	The <i>idle</i> Thread
	23.4	Mem	ory Allocation and Management
		23.4.1	Dynamic Memory Allocation Model
			23.4.1.1 heap_1.c
			23.4.1.2 heap_2.c
			23.4.1.3 heap_3.c
			23.4.1.4 heap_4.c
			23.4.1.5 heap_5.c
			23.4.1.6 How to Use malloc() and Related C Functions With FreeRTOS . 658
			23.4.1.7 FreeRTOS Heap Definition
		23.4.2	Static Memory Allocation Model
			23.4.2.1 <i>idle</i> Thread Allocation With Static Memory Allocation Model 660
		23.4.3	Memory Pools
		23.4.4	Stack Overflow Detection
	23.5	Sync	hronization Primitives
		23.5.1	Message Queues
		23.5.2	Semaphores
		23.5.3	Thread Signals
	23.6	Reso	urces Management and Mutual Exclusion
		23.6.1	Mutexes
			23.6.1.1 The Priority Inversion Problem 673
			23.6.1.2 Recursive Mutexes
		23.6.2	Critical Sections
		23.6.3	Interrupt Management With an RTOS 670
			23.6.3.1 FreeRTOS API and Interrupt Priorities 677
	23.7	Softv	vare Timers
		23.7.1	How FreeRTOS Manages Timers
	23.8	A Ca	se Study: Low-Power Management With an RTOS
		23.8.1	The <i>idle</i> Thread Hook
		23.8.2	The Tickless Mode in FreeRTOS
			23.8.2.1 A Schema for the <i>tickless</i> Mode
			23.8.2.2 A Custom tickless Mode Policy
	23.9	Debu	gging Features
		23.9.1	configASSERT() Macro
		23.9.2	Run-Time Statistics and Thread State Information
	23.10	Alter	natives to FreeRTOS
		23.10.1	ChibiOS
		23.10.2	Contiki OS
		23.10.3	OpenRTOS
24.			ebugging Techniques
	24.1	Unde	erstanding Cortex-M Fault-Related Exceptions

		24.1.1	8	
			tion	704
			24.1.1.1 How the GNU MCU Eclipse Tool-chain Handles Fault-Related	
			Exceptions	709
			24.1.1.2 How to Interpret the Content of the LR Register on Exception	
			Entrance	
		24.1.2	Fault Exceptions and Faults Analysis	
			24.1.2.1 Memory Management Exception	
			24.1.2.2 Bus Fault Exception	
			24.1.2.3 Usage Fault Exception	
			24.1.2.4 Hard Fault Exception	
			24.1.2.5 Enabling Optional Fault Handlers	
			24.1.2.6 Fault Analysis in Cortex-M0/0+ Based Processors	
	24.2	_	ose Advanced Debugging Features	
		24.2.1	1	
			24.2.1.1 Memory Monitors	
		24.2.2	Watchpoints	
		24.2.3	Instruction Stepping Mode	
		24.2.4	Keil Packs and Peripheral Registers View	
		24.2.5	Core Registers View	
	24.3		agging Aids From the CubeHAL	
	24.4		rnal Debuggers	
		24.4.1	Using SEGGER J-Link for ST-LINK Debugger	
		24.4.2	Using the ITM Interface and SWV Tracing	
	24.5		Studio	
	24.6	Debu	agging two Nucleo Boards Simultaneously	/34
25.	FAT	-	tem	
	25.1		oduction to FatFs Library	
		25.1.1	Using CubeMX to Include FatFs Library in Your Projects	
			25.1.1.1 The Generic Disk Interface API	
			25.1.1.2 The Implementation of a Driver to Access SD Cards in SPI Mode	
		25.1.2	Relevant FatFs Structures and Functions	
			25.1.2.1 Mounting a Filesystem	
			25.1.2.2 Opening a File	
				744
				745
		25.1.3	How to Configure the FatFs Library	748
26.	Deve	elop IoT	[ Applications	<b>′5</b> 1
	26.1		tions Offered by STM to Develop IoT Applications	
	26.2	The '	W5500 Ethernet Controller	754
		26.2.1	How to Use the W5500 Shield and the ioLibrary_Driver Module	758

		26.2.1.1 Configuring the SPI Interface	
		26.2.1.2 Configuring the Socket Buffers and the Network Interface	
	26.2.2	Socket APIs	
		26.2.2.1 Handling Sockets in TCP Mode	
		26.2.2.2 Handling Sockets in UDP Mode	766
	26.2.3	I/O Retargeting to a TCP/IP Socket	
	26.2.4	Setting up an HTTP Server	769
		26.2.4.1 A Web-Based Oscilloscope	772
27.		rted With a New Design	
	27.1 Hard	dware Design	
	27.1.1	PCB Layer Stack-Up	
	27.1.2	MCU Package	
	27.1.3	Decoupling of Power-Supply Pins	
	27.1.4	Clocks	
	27.1.5	Filtering of RESET Pin	
	27.1.6	Debug Port	
	27.1.7	Boot Mode	
	27.1.8	Pay attention to "pin-to-pin" Compatibility	
	27.1.9	And to Selecting the Right Peripherals	
		The Role of CubeMX During the Board Design Stage	
		Board Layout Strategies	
		ware Design	
	27.2.1	Generating the binary image for production	799
٨	nn an di	<del></del>	
A	ppenar	<b>X</b>	802
A.		us HAL functions and STM32 features	
		reset from the firmware	
	STM32 96-b	it Unique CPU ID	803
В. ′		ting guide	
		Eclipse Installation Issues	
		ted issue	
	_	e cannot locate the compiler	
	_	e continuously breaks at every instruction during debug session	
		ep-by-step debugging is really slow	
		rmware works only under a debug session	
	STM32 relat		
		dicrocontroller does not boot correctly	
	It is N	ot Possibile to Flash or to Debug the MCU	810

C. Nucleo pin-out												. 81	2
Nucleo-F446RE						 						. 81	13
Arduino compatible headers						 						. 81	13
Morpho headers						 						. 81	13
Nucleo-F411RE						 						. 81	14
Arduino compatible headers						 						. 81	14
Morpho headers						 						. 81	14
Nucleo-F410RB						 						. 81	15
Arduino compatible headers						 						. 81	15
Morpho headers						 						. 81	15
Nucleo-F401RE						 						. 81	16
Arduino compatible headers						 						. 81	16
Morpho headers						 						. 81	16
Nucleo-F334R8						 						. 81	17
Arduino compatible headers						 						. 81	۱7
Morpho headers						 						. 81	17
Nucleo-F303RE						 						. 81	18
Arduino compatible headers						 						. 81	18
Morpho headers						 						. 81	18
Nucleo-F302R8						 						. 81	19
Arduino compatible headers						 						. 81	19
Morpho headers						 						. 81	19
Nucleo-F103RB						 						. 82	20
Arduino compatible headers						 						. 82	20
Morpho headers						 						. 82	20
Nucleo-F091RC						 						. 82	21
Arduino compatible headers						 						. 82	21
Morpho headers												. 82	21
Nucleo-F072RB												. 82	22
Arduino compatible headers						 						. 82	22
Morpho headers												. 82	22
Nucleo-F070RB						 						. 82	23
Arduino compatible headers						 						. 82	23
Morpho headers													23
Nucleo-F030R8													24
Arduino compatible headers						 						. 82	24
Morpho headers												. 82	24
Nucleo-L476RG						 						. 82	25
Arduino compatible headers						 						. 82	25
Morpho headers													
Nucleo-L152RE													
Arduino compatible headers						 						. 82	26

Morpho headers	. 826
Nucleo-L073R8	. 827
Arduino compatible headers	. 827
Morpho headers	. 827
Nucleo-L053R8	. 828
Arduino compatible headers	. 828
Morpho headers	. 828
D. STM32 packages	
LFBGA	
LQFP	
TFBGA	
TSSOP	
UFBGA	
UFQFPN	
VFQFP	
WLCSP	. 831
E. History of this book	022
Release 0.1 - October 2015	
Release 0.2 - October 28th, 2015	
Release 0.2.1 - October 31th, 2015	
Release 0.2.2 - November 1st, 2015	
Release 0.3 - November 12th, 2015	
Release 0.4 - December 4th, 2015	
Release 0.5 - December 19th, 2015	
Release 0.6 - January 18th, 2016	
Release 0.6.1 - January 20th, 2016	
Release 0.6.2 - January 30th, 2016	
Release 0.7 - February 8th, 2016	
Release 0.8 - February 18th, 2016	
Release 0.8.1 - February 23th, 2016	
Release 0.9 - March 27th, 2016	
Release 0.9.1 - March 28th, 2016	
Release 0.10 - April 26th, 2016	. 837
Release 0.11 - May 27th, 2016	. 837
Release 0.11.1 - June 3rd, 2016	. 838
Release 0.11.2 - June 24th, 2016	. 838
Release 0.12 - July 4th, 2016	. 838
Release 0.13 - July 18th, 2016	. 839
Release 0.14 - August 12th, 2016	
Release 0.15 - September 13th, 2016	. 839
Release 0.16 - October 3th, 2016	

Release 0.17 - October 24th, 2016	340
Release 0.18 - November 15th, 2016	340
Release 0.19 - November 29th, 2016	341
Release 0.20 - December 28th, 2016	341
Release 0.21 - January 29th, 2017	341
Release 0.22 - May 2nd, 2017	341
Release 0.23 - July 20th, 2017	342
Release 0.24 - December 11th, 2017	342
Release 0.25 - January 3rd, 2018	342