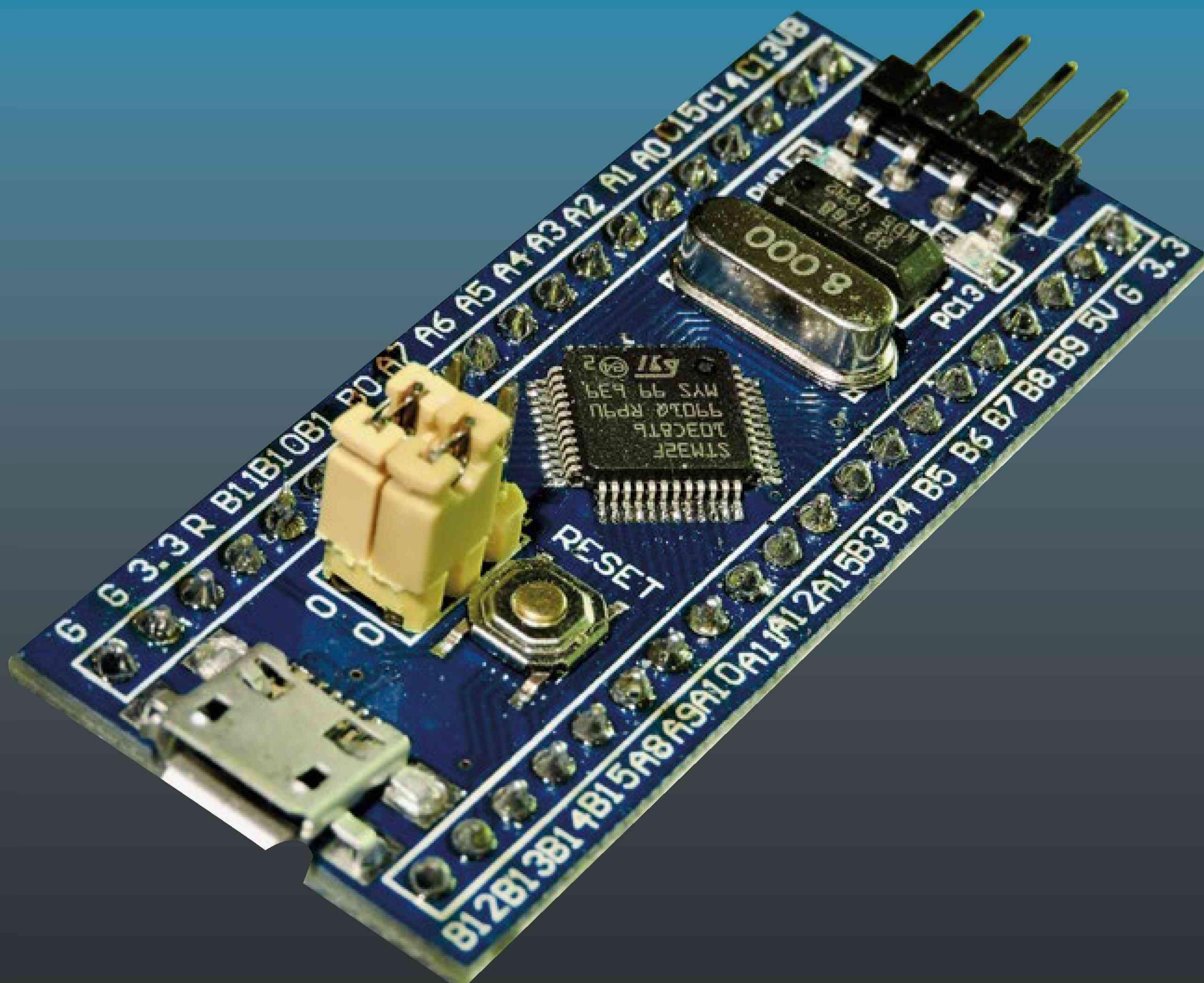


TECHNOLOGY IN ACTION™



# Beginning STM32



# Developing with FreeRTOS, libopencm3 and GCC

# Warren Gay

# Apress®

# **Beginning STM32**

**Developing with FreeRTOS,  
libopencm3 and GCC**

**Warren Gay**

**Apress®**

## ***Beginning STM32: Developing with FreeRTOS, libopencm3 and GCC***

Warren Gay

St. Catharines, Ontario, Canada

ISBN-13 (pbk): 978-1-4842-3623-9

<https://doi.org/10.1007/978-1-4842-3624-6>

ISBN-13 (electronic): 978-1-4842-3624-6

Library of Congress Control Number: 2018945101

Copyright © 2018 by Warren Gay

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

Trademarked names, logos, and images may appear in this book. Rather than use a trademark symbol with every occurrence of a trademarked name, logo, or image we use the names, logos, and images only in an editorial fashion and to the benefit of the trademark owner, with no intention of infringement of the trademark.

The use in this publication of trade names, trademarks, service marks, and similar terms, even if they are not identified as such, is not to be taken as an expression of opinion as to whether or not they are subject to proprietary rights.

While the advice and information in this book are believed to be true and accurate at the date of publication, neither the authors nor the editors nor the publisher can accept any legal responsibility for any errors or omissions that may be made. The publisher makes no warranty, express or implied, with respect to the material contained herein.

Managing Director, Apress Media LLC: Welmoed Spahr

Acquisitions Editor: Aaron Black

Development Editor: James Markham

Coordinating Editor: Jessica Vakili

Cover designed by eStudioCalamar

Cover image designed by Freepik ([www.freepik.com](http://www.freepik.com))

Distributed to the book trade worldwide by Springer Science+Business Media New York, 233 Spring Street, 6th Floor, New York, NY 10013. Phone 1-800-SPRINGER, fax (201) 348-4505, email [orders-ny@springer-sbm.com](mailto:orders-ny@springer-sbm.com), or visit [www.springeronline.com](http://www.springeronline.com). Apress Media, LLC is a California LLC and the sole member (owner) is Springer Science + Business Media Finance Inc (SSBM Finance Inc). SSBM Finance Inc is a **Delaware** corporation.

For information on translations, please email [rights@apress.com](mailto:rights@apress.com) or visit <http://www.apress.com/rights-permissions>.

Apress titles may be purchased in bulk for academic, corporate, or promotional use. eBook versions and licenses are also available for most titles. For more information, reference our Print and eBook Bulk Sales web page at <http://www.apress.com/bulk-sales>.

Any source code or other supplementary material referenced by the author in this book is available to readers on GitHub via the book's product page, located at [www.apress.com/978-1-4842-3623-9](http://www.apress.com/978-1-4842-3623-9). For more detailed information, please visit <http://www.apress.com/source-code>.

Printed on acid-free paper

*For Jackie*

# Table of Contents

<b>About the Author .....</b>	<b>xix</b>
<b>About the Technical Reviewer .....</b>	<b>xxi</b>
<b>Chapter 1: Introduction.....</b>	<b>1</b>
STM32F103C8T6.....	2
FreeRTOS .....	5
libopencm3 .....	5
No Arduino .....	6
No IDE .....	6
Development Framework.....	7
Assumptions About You.....	7
What You Need .....	8
ST-Link V2 Programming Unit.....	8
Breadboard.....	9
DuPont (Jumper) Wires.....	10
0.1 uF Bypass Capacitors .....	11
USB TTL Serial Adapter.....	12
Power Supply .....	14
Small Stuff.....	15
Summary.....	16
<b>Chapter 2: Software Setup.....</b>	<b>17</b>
Directory Conventions Used.....	17
Operating Software .....	17

## TABLE OF CONTENTS

<b>Book Software.....</b>	<b>18</b>
libopencm3.....	18
FreeRTOS.....	19
~/stm32f103c8t6/rtos/Project.mk.....	19
<b>ARM Cross Compiler .....</b>	<b>20</b>
<b>Build the Software .....</b>	<b>23</b>
<b>ST-Link Tool.....</b>	<b>24</b>
<b>Summary.....</b>	<b>25</b>
<b>Chapter 3: Power Up and Blink.....</b>	<b>27</b>
Power.....	27
+3.3V Regulator.....	29
USB Power/+5V.....	30
+3.3V Supply .....	30
One Power Source Rule.....	31
Ground .....	32
Reset.....	32
Showtime.....	32
ST-Link V2 .....	34
st-flash Utility.....	36
Read STM32 .....	36
Write Image .....	37
Erase Flash.....	38
Summary.....	38
Bibliography .....	38
<b>Chapter 4: GPIO.....</b>	<b>39</b>
Building miniblink .....	39
Flashing miniblink.....	40
miniblink.c Source Code .....	41
GPIO API .....	44
GPIO Configuration .....	46

## TABLE OF CONTENTS

Ducks in a Row .....	51
GPIO Inputs .....	51
Digital Output, Push/Pull.....	52
Digital Output, Open Drain .....	53
GPIO Characteristics .....	53
Input Voltage Thresholds .....	55
Output-Voltage Thresholds .....	55
Programmed Delays.....	56
The Problem with Programmed Delay.....	57
Summary.....	58
<b>Chapter 5: FreeRTOS .....</b>	<b>59</b>
FreeRTOS Facilities .....	59
Tasking .....	60
Message Queues .....	60
Semaphores and Mutexes .....	61
Timers.....	61
Event Groups .....	62
The blinky2 Program.....	62
Build and Test blinky2 .....	66
Execution .....	66
FreeRTOSConfig.h .....	67
FreeRTOS Naming Convention .....	69
FreeRTOS Macros .....	70
Summary.....	71
<b>Chapter 6: USART.....</b>	<b>73</b>
USART/UART Peripheral .....	73
Asynchronous Data.....	74
USB Serial Adapters .....	74
Hookup .....	76
Project uart .....	77

## TABLE OF CONTENTS

Project .....	81
Project uart2 .....	85
USART API .....	90
Include Files .....	92
Clocks .....	92
Configuration .....	92
DMA .....	93
Interrupts .....	93
Input/Output/Status .....	93
Ducks-in-a-Row .....	93
FreeRTOS .....	94
Tasks .....	94
Queues .....	95
Summary .....	96
<b>Chapter 7: USB Serial .....</b>	<b>97</b>
Blue Pill USB Issue .....	97
Introduction to USB .....	99
Pipes and Endpoints .....	99
USB Serial Device .....	101
Linux USB Serial Device .....	101
MacOS USB Serial Device .....	102
Windows USB Serial Device .....	103
USB GPIO .....	103
Demo Source Code .....	104
cdcacm_set_config() .....	105
cdc_control_request() .....	106
cdcacm_data_rx_cb() .....	107
USB Task .....	108
USB Receiving .....	110
USB Sending .....	110

## TABLE OF CONTENTS

USB Serial Demo.....	111
Summary.....	113
Bibliography .....	114
<b>Chapter 8: SPI Flash .....</b>	<b>115</b>
Introducing W25QXX .....	115
Serial Peripheral Interface Bus .....	115
Chip Select .....	117
Wiring and Voltages.....	117
SPI Circuit .....	118
Hardware /NSS Control.....	118
STM32 SPI Configuration .....	120
SPI Clock Rate .....	124
SPI Clock Modes.....	125
Endianess and Word Length.....	127
SPI I/O .....	128
Read SR1 .....	128
Waiting for Ready .....	129
Read Manufacturer ID.....	130
Writing Flash .....	131
Flash Erase.....	133
Reading Flash.....	136
Demonstration.....	137
Running the Demo .....	139
Manufacturer ID.....	144
Power Down .....	144
Summary .....	145
Bibliography .....	145

## TABLE OF CONTENTS

<b>Chapter 9: Code Overlays .....</b>	<b>147</b>
The Linker Challenge .....	147
MEMORY Section .....	149
Entry .....	151
Sections.....	151
PROVIDE.....	154
Relocation.....	154
Defining Overlays.....	155
Overlay Code .....	157
Overlay Stubs .....	159
Overlay Manager .....	159
VMA and Load Addresses .....	160
Linker Symbols in Code.....	161
Overlay Manager Function.....	162
Overlay Stubs .....	164
Demonstration.....	165
Extracting Overlays.....	166
Upload Overlays to W25Q32 .....	167
Overlay Demo Continued .....	171
Code Change Trap.....	173
Summary.....	173
Bibliography .....	174
<b>Chapter 10: Real-Time Clock (RTC).....</b>	<b>175</b>
Demonstration Projects.....	175
RTC Using One Interrupt.....	175
RTC Configuration.....	176
Interrupt and Setup .....	178
Interrupt Service Routine .....	179
Task Notification.....	181
Mutexes.....	183