
Nucleo Boards Programming with the STM32CubeIDE

Hands-on in more than 50 projects



Dogan Ibrahim

● This is an Elektor Publication. Elektor is the media brand of
Elektor International Media B.V.
PO Box 11, NL-6114-ZG Susteren, The Netherlands
Phone: +31 46 4389444

● All rights reserved. No part of this book may be reproduced in any material form, including photocopying, or storing in any medium by electronic means and whether or not transiently or incidentally to some other use of this publication, without the written permission of the copyright holder except in accordance with the provisions of the Copyright Designs and Patents Act 1988 or under the terms of a licence issued by the Copyright Licensing Agency Ltd., 90 Tottenham Court Road, London, England W1P 9HE. Applications for the copyright holder's permission to reproduce any part of the publication should be addressed to the publishers.

● **Acknowledgements**

The following figures and pictures in this book, numbered: 1.1, 1.5, 1.6, 1.7, 1.9, 2.2, 2.3, 2.9, 2.10 through 2.20, 2.22 through 2.32, 4.1, 4.2, 6.1, 14.1, 15.1 through 15.10, 16.2, and 16.7 are taken from these STMicroelectronics sources:

- UM1724 User Manual, STM32 Nucleo-64 Boards (DocID025833 Rev 14);
- RM0351 Reference Manual STM32L4x5 and STM32L4x6 advanced ARM®-based 32-bit MCUs (DocID024597 Rev 5).

The pictures of Nucleo Expansion Boards in Chapter 16 of the book are taken from the following STMicroelectronics Internet source:

<http://www.st.com/en/evaluation-tools/stm32-nucleo-expansion-boards.html?querycriteria=productId=SC1971>.

All the above figures/pictures are used with the written permission of:

© STMicroelectronics. Used with permission.

The author would like to thank to Michael Markowitz of the STMicroelectronics for giving permission to reproduce the above pictures/figures, as well as for providing sample Nucleo expansion boards for use in the projects contained in the book. The author is also grateful to Elektor International Media for editing and publishing the book.

● The author and publisher have used their best efforts in ensuring the correctness of the information contained in this book. They do not assume, and hereby disclaim, any liability to any party for any loss or damage caused by errors or omissions in this book, whether such errors or omissions result from negligence, accident or any other caus

● British Library Cataloguing in Publication Data

A catalogue record for this book is available from the British Library

● **ISBN 978-3-89576-416-5** Print

ISBN 978-3-89576-416-6 eBook

ISBN 978-3-89576-416-7 ePub

● © Copyright 2020: Elektor International Media B.V.

Prepress Production: D-Vision, Julian van den Berg

Elektor is part of EIM, the world's leading source of essential technical information and electronics products for pro engineers, electronics designers, and the companies seeking to engage them. Each day, our international team develops and delivers high-quality content - via a variety of media channels (including magazines, video, digital media, and social media) in several languages - relating to electronics design and DIY electronics. **www.elektormagazine.com**

PREFACE	11
CHAPTER 1 • STM32 Nucleo Development Boards	12
1.1 Overview	12
1.2 STM32 Nucleo development boards	12
1.2.1 STM32 processor family numbering	13
1.2.2 Nucleo-32 development boards	15
1.2.3 Nucleo-64 development boards	16
1.2.4 Nucleo-144 development boards	17
1.3 The Nucleo-L476RG development board	18
1.3.1 Two-part board	18
1.3.2 The power supply	21
1.3.3 The LEDs	22
1.3.4 Pushbutton switches	22
1.3.5 Jumper JP6	22
1.3.6 The ST-LINK/V2-1	22
1.3.7 Input-Output connectors	23
1.3.8 The demo software	24
1.4 Summary	25
CHAPTER 2 • STM32 Nucleo Processor Architecture	26
2.1 Overview	26
2.2 Arm processors	26
2.2.1 Cortex-M	28
2.2.2 Cortex-R	28
2.2.3 Cortex-A	29
2.2.4 Cortex-M processor comparison	29
2.2.5 Processor performance measurement	29
2.2.6 Cortex-M compatibility	30
2.2.7 Choice of an STM32 processor	30
2.3 The STM32L476RGT6 microcontroller	30
2.3.1 Basic features of the STM32L476RGT6	31
2.3.2 Internal block diagram	31
2.3.3 General purpose inputs and outputs (GPIOs)	34

2.3.4 Electrical characteristics	42
2.3.5 The power supply	43
2.3.6 Low power modes	44
2.3.7 The clock circuit.	45
2.3.8 Analogue to digital converter (ADC)	48
2.3.9 Digital to analogue converter (DAC)	48
2.3.10 Timers	49
2.3.11 Interrupts	49
2.4 Summary	55
CHAPTER 3 • STM32 Nucleo Software Development Tools (Toolchains)	56
3.1 Overview	56
3.2 Integrated development environments supporting the Nucleo boards.	56
3.3 Embedded Workbench for Arm (EWARM)	56
3.3.1 Installing the EWARM	57
3.4 Arm Mbed.	58
3.5 MDK-ARM	60
3.6 TrueSTUDIO	61
3.7 System Workbench for STM32 (SW4STM32)	62
3.8 STM32CubeIDE	64
3.9 Summary	66
CHAPTER 4 • Example Project — Using the Mbed	67
4.1 Overview	67
4.2 Using the ARM Mbed	67
4.3 Summary	71
CHAPTER 5 • STM32CubeIDE Nucleo-L476 Projects	72
5.1 Overview	72
5.1.1 STM32cubeIDE GPIO library	72
5.2 Project 1: Lighthouse flashing LED.	75
5.3 Project 2: Alternately Flashing LEDs.	89
5.4 Project 3: ‘Moving’ LEDs.	95
5.5 Project 4: Binary Up Counter with LEDs	101
5.6 Project 5: Random Flashing LEDs	106

5.7 Project 6: Pushbutton and LED	110
5.8 Project 7: Control of Multiple LEDs by 2 Buttons	115
5.9 Project 8: LED Dice	123
5.10 Project 9: 7-Segment LED Counter	132
5.11 Project 10: Two-Digit Multiplexed 7-Segment LED	140
5.12 Project 11: External interrupt to control an LED	148
5.13 Project 12: Two-digit Interrupt-Driven 7-Segment Event Counter	157
5.14 Project 13: Four-Digit 7-Segment LED Display.	163
5.15 Project 14: Interrupt-Based Up/Down Counter with Four-Digit 7-Segment LED Display	170
5.16 Project 15: Multiple External Interrupts Sharing the Same Interrupt Line	180
5.17 Summary	186
CHAPTER 6 • Timers.	187
6.1 Overview	187
6.2 STM32 timers	187
6.3 Setting a timer	189
6.4 Project 1: Timer Interrupt to Flash LED Every Second	190
6.5 Project 2: 4-Digit 7-Segment LED Up Counter with Timer Interrupts	195
6.6 Summary	204
CHAPTER 7 • LCD Displays	205
7.1 Overview	205
7.2 Project 1: Using parallel LCDs – Displaying Text	205
7.3 Project 2: Using LCDs – Simple Up Counter	221
7.4 Summary	225
CHAPTER 8 • Using the Analogue to Digital Converters	226
8.1 Overview	226
8.2 The STM32 ADC conversion modes	226
8.3 Project 1: Analogue Voltmeter (polling ADC).	228
8.4 Project 2: ADC with Multiple Inputs (polling ADC)	237
8.5 Project 3: Single-input ADC with Conversion Interrupt.	246
8.6 Project 4: Analogue Temperature Sensor	251
8.7 Project 5: ON-OFF Temperature Controller	258

8.8 Project 6: Multiple-input ADC with DMA	266
8.9 Timer-driven ADC	276
8.10 External-driven ADC.	276
8.11 ADC calibration	276
8.12 Summary	276
CHAPTER 9 • Using the Digital-to-Analogue Converters	277
9.1 Overview	277
9.2 Project 1: Sawtooth Waveform Generator with Manual DAC Driving.	277
9.3 Project 2: Squarewave Generator with Manual DAC Driving	285
9.4 Project 3: Sinewave Generator with Manual DAC Driving	286
9.5 Project 4: Arbitrary Waveform Generator with Manual DAC Driving	287
9.6 Project 5: Arbitrary Waveform Generator with timer-based DMA	289
9.7 Hardware waveform generation.	296
9.8 Project 6: Hardware-based Triangular Waveform Generation.	298
9.9 Noise signal generation	303
9.10 Summary	304
CHAPTER 10 • Pulsewidth Modulation (PWM)	305
10.1 Overview	305
10.2 Basic theory of pulsewidth modulation	305
10.3 Operation of the PWM	306
10.4 Project 1: Mosquito Repeller	308
10.5 Project 2: Continuously Variable Duty Cycle	316
10.6 Project 3: Multiple PWM Waveforms	318
10.7 Project 4: Potentiometer-controlled Duty Cycle Control of PWM Waveform.	325
10.8 Summary	333
CHAPTER 11 • Serial Communication.	334
11.1 Overview	334
11.2 UART ports of the Nucleo-L476RG development board	336
11.3 Serial communication program on a PC	337
11.4 Project 1: Displaying Text on the PC.	340
11.5 Project 2: Simple Up Counter	345
11.6 Project 3: Times Table	351

11.7 Project 4: Practising Elementary Multiplication	358
11.8 Project 5: Displaying Ambient Temperature on the PC Screen	362
11.9 Project 6: Communicating with Arduino (Displaying Temperature)	369
11.10 UART in interrupt mode	376
11.11 Project 7: Communicating with Arduino – UART Interrupt Mode.	376
11.12 Using UART in DMA mode	382
11.13 Summary	382
CHAPTER 12 • The I²C Bus Interface	383
12.1 Overview	383
12.2 The I ² C Bus.	383
12.3 STM32L476RG I ² C ports	384
12.4 Project 1: Port Expander.	385
12.5 Project 2: EEPROM memory	395
12.6 Project 3: TMP102 Temperature Sensor Chip Reading	405
12.7 Summary	414
CHAPTER 13 • SPI Bus Projects	415
13.1 Overview	415
13.2 Nucleo-L476RG SPI pins	416
13.3 Project 1: Port Expander.	417
13.4 Summary	427
CHAPTER 14 • Program Debugging	428
14.1 Overview	428
14.2 Project 1: Simple Debug.	428
14.3 Project 2: Debugging the GPIO	432
14.4 Project 3: Displaying Characters in Debug Window	433
14.5 Project 4: Using ‘printf’ to Display Data in Debug Window	436
14.6 Project 5: Using the ST-Link Virtual COM Port	438
14.7 Summary	438
CHAPTER 15 • STM32L4 MCU Power Management	439
15.1 Overview	439
15.2 Low power modes	439
15.3 Power modes transitions.	444

15.4 Low power peripherals	445
15.5 Debugging in low-power modes.	445
15.6 Measuring Nucleo current consumption	445
15.7 Project 1: Sleep Mode Example	445
15.8 Project 2: Stop Mode Example.	449
15.9 Project 3: Standby Mode Example	451
15.10 Summary	452
CHAPTER 16 • Using the Expansion Boards	453
16.1 Overview	453
16.2 Industrial Digital Output Expansion Board (X-NUCLEO-OUT01A1)	453
16.3 Project 1: Flashing an LED	456
16.4 Brushed DC Motor Driver Expansion Board (X-NUCLEO-IHM13A1)	459
16.5 Motion MEMS and Environmental Sensor Expansion Board (X-NUCLEO-IKS01A2)	461
16.6 Project 2: Reading the Temperature from the X-NUCLEO-IKS01A2 Expansion Board	464
16.7 Project 3: Using the X-CUBE-MEMS1 Library	478
16.8 Wi-Fi Expansion Board (X-NUCLEO-IDW01M1).	481
APPENDIX • FreeRTOS For the STM32 MCU	484
A.1 Overview	484
A.2 Multitasking kernel advantages	484
A.3 The need for an RTOS	485
A.4 The FreeRTOS	485
A.5 FreeRTOS project with the STM32MCubeIDE	486
Index	494