

Discovering the STM32 Microcontroller

Geoffrey Brown
©2012

June 5, 2016

This work is covered by the Creative Commons Attribution-NonCommercial-ShareAlike 3.0 Unported (CC BY-NC-SA 3.0) license.
<http://creativecommons.org/licenses/by-nc-sa/3.0/>



Contents

List of Exercises	7
Foreword	11
1 Getting Started	13
1.1 Required Hardware	16
STM32 VL Discovery	16
Asynchronous Serial	19
SPI	20
I2C	21
Time Based	22
Analog	23
Power Supply	24
Prototyping Materials	25
Test Equipment	25
1.2 Software Installation	26
GNU Tool chain	27
STM32 Firmware Library	27
Code Template	28
GDB Server	29
1.3 Key References	30
2 Introduction to the STM32 F1	31
2.1 Cortex-M3	34
2.2 STM32 F1	38
3 Skeleton Program	47
Demo Program	48
Make Scripts	50
STM32 Memory Model and Boot Sequence	52

CONTENTS

4	STM32 Configuration	57
4.1	Clock Distribution	61
4.2	I/O Pins	63
4.3	Alternative Functions	65
4.4	Remapping	65
4.5	Pin Assignments For Examples and Exercises	66
4.6	Peripheral Configuration	68
5	Asynchronous Serial Communication	71
5.1	STM32 Polling Implementation	76
5.2	Initialization	78
6	SPI	85
6.1	Protocol	85
6.2	STM32 SPI Peripheral	87
6.3	Testing the SPI Interface	90
6.4	EEPROM Interface	92
7	SPI : LCD Display	97
7.1	Color LCD Module	97
7.2	Copyright Information	108
7.3	Initialization Commands (Remainder)	108
8	SD Memory Cards	111
8.1	FatFs Organization	114
8.2	SD Driver	115
8.3	FatFs Copyright	122
9	I²C – Wii Nunchuk	123
9.1	I ² C Protocol	124
9.2	Wii Nunchuk	126
9.3	STM32 I ² C Interface	131
10	Timers	139
10.1	PWM Output	142
	7735 Backlight	142
10.2	Input Capture	146
11	Interrupts	151
11.1	Cortex-M3 Exception Model	155
11.2	Enabling Interrupts and Setting Their Priority	159

CONTENTS

11.3	NVIC Configuration	159
11.4	Example: Timer Interrupts	160
11.5	Example: Interrupt Driven Serial Communications	161
	Interrupt-Safe Queues	165
	Hardware Flow Control	167
11.6	External Interrupts	171
12	DMA: Direct Memory Access	179
12.1	STM32 DMA Architecture	181
12.2	SPI DMA Support	182
13	DAC : Digital Analog Converter	189
	Warning:	190
13.1	Example DMA Driven DAC	194
14	ADC : Analog Digital Converter	201
14.1	About Successive Approximation ADCs	202
15	NewLib	209
15.1	Hello World	210
15.2	Building newlib	215
16	Real-Time Operating Systems	217
16.1	Threads	219
16.2	FreeRTOS Configuration	224
16.3	Synchronization	225
16.4	Interrupt Handlers	227
16.5	SPI	230
16.6	FatFS	232
16.7	FreeRTOS API	233
16.8	Discussion	234
17	Next Steps	235
17.1	Processors	236
17.2	Sensors	238
	Position/Inertial Measurement	238
	Environmental Sensors	238
	Motion and Force Sensors	239
	ID – Barcode/RFID	239
	Proximity	239
17.3	Communication	239

CONTENTS

17.4 Discussion	239
Attributions	242
Bibliography	243

List of exercises

Exercise 3.1 <i>GDB on STM32</i>	50
Exercise 4.1 <i>Blinking Lights</i>	60
Exercise 4.2 <i>Blinking Lights with Pushbutton</i>	65
Exercise 4.3 <i>Configuration without Standard Peripheral Library</i>	68
Exercise 5.1 <i>Testing the USB/UART Interface</i>	73
Exercise 5.2 <i>Hello World!</i>	80
Exercise 5.3 <i>Echo</i>	84
Exercise 6.1 <i>SPI Loopback</i>	91
Exercise 6.2 <i>Write and Test an EEPROM Module</i>	96
Exercise 7.1 <i>Complete Interface Code</i>	101
Exercise 7.2 <i>Display Text</i>	102
Exercise 7.3 <i>Graphics</i>	103
Exercise 8.1 <i>FAT File System</i>	118
Exercise 9.1 <i>Reading Wii Nunchuk</i>	130
Exercise 10.1 <i>Ramping LED</i>	144
Exercise 10.2 <i>Hobby Servo Control</i>	144
Exercise 10.3 <i>Ultrasonic Sensor</i>	149
Exercise 11.1 <i>Timer Interrupt – Blinking LED</i>	161
Exercise 11.2 <i>Interrupt Driven Serial Communciations</i>	170
Exercise 11.3 <i>External Interrupt</i>	173
Exercise 12.1 <i>SPI DMA module</i>	185
Exercise 12.2 <i>Display BMP Images from Fat File System</i>	185
Exercise 13.1 <i>Waveform Generator</i>	190
Exercise 13.2 <i>Application Software Driven Conversion</i>	191
Exercise 13.3 <i>Interrupt Driven Conversion</i>	192
Exercise 13.4 <i>Audio Player</i>	195
Exercise 14.1 <i>Continuous Sampling</i>	205
Exercise 14.2 <i>Timer Driven Conversion</i>	207
Exercise 14.3 <i>Voice Recorder</i>	208

CONTENTS

Exercise 15.1 <i>Hello World</i>	213
Exercise 16.1 <i>RTOS – Blinking Lights</i>	225
Exercise 16.2 <i>Multiple Threads</i>	227
Exercise 16.3 <i>Multithreaded Queues</i>	228
Exercise 16.4 <i>Multithreaded SPI</i>	232
Exercise 16.5 <i>Multithreaded FatFS</i>	232

Acknowledgment

I have had a lot of help from various people in the Indiana University School of Informatics in developing these materials. Most notably, Caleb Hess developed the protoboard that we use in our lab, and he, along with Bryce Himebaugh made significant contributions to the development of the various experiments. Tracey Theriault provided many of the photographs.

I am grateful to ST Microelectronics for the many donations that allowed us to develop this laboratory. I particularly wish to thank Andrew Dostie who always responded quickly to any request that I made.

STM32 F1, STM32 F2, STM32 F3, STM32 F4, STM32 L1, Discovery Kit, Cortex, ARM and others are trademarks and are the property of their owners.

