

# xyControl

0.1

Generated by Doxygen 1.8.3.1

Sun Apr 28 2013 20:42:14



# Contents

<b>1</b>	<b>Main Page</b>	<b>1</b>
<b>2</b>	<b>Module Index</b>	<b>3</b>
2.1	Modules . . . . .	3
<b>3</b>	<b>Data Structure Index</b>	<b>5</b>
3.1	Data Structures . . . . .	5
<b>4</b>	<b>File Index</b>	<b>7</b>
4.1	File List . . . . .	7
<b>5</b>	<b>Module Documentation</b>	<b>9</b>
5.1	Software . . . . .	9
5.1.1	Detailed Description . . . . .	9
5.2	System . . . . .	10
5.2.1	Detailed Description . . . . .	10
5.3	Flight . . . . .	11
5.3.1	Detailed Description . . . . .	11
5.4	Hardware . . . . .	12
5.4.1	Detailed Description . . . . .	12
5.5	Accelerometer Driver . . . . .	13
5.5.1	Detailed Description . . . . .	13
5.5.2	Macro Definition Documentation . . . . .	13
5.5.2.1	ACCREG_CTRL1 . . . . .	13
5.5.2.2	ACCREG_CTRL4 . . . . .	14
5.5.2.3	ACCREG_XL . . . . .	14
5.5.3	Enumeration Type Documentation . . . . .	14
5.5.3.1	AccRange . . . . .	14
5.5.4	Function Documentation . . . . .	14
5.5.4.1	accInit . . . . .	14
5.5.4.2	accRead . . . . .	15
5.5.4.3	accWriteRegister . . . . .	16
5.5.5	Variable Documentation . . . . .	17

5.5.5.1	accRange	17
5.6	ADC Driver	18
5.6.1	Detailed Description	18
5.6.2	Enumeration Type Documentation	18
5.6.2.1	ADCRef	18
5.6.3	Function Documentation	19
5.6.3.1	adcClose	19
5.6.3.2	adcGet	19
5.6.3.3	adcInit	19
5.6.3.4	adcReady	20
5.6.3.5	adcStart	20
5.7	Complementary-Filter	21
5.7.1	Detailed Description	21
5.7.2	Function Documentation	21
5.7.2.1	complementaryExecute	21
5.7.2.2	complementaryInit	22
5.8	Configuration	23
5.8.1	Detailed Description	25
5.8.2	Macro Definition Documentation	25
5.8.2.1	ACC_ADDRESS	25
5.8.2.2	ACCFILTERFACTOR	25
5.8.2.3	BANK0DDR	25
5.8.2.4	BANK0PIN	25
5.8.2.5	BANK0PORT	26
5.8.2.6	BANK1DDR	26
5.8.2.7	BANK1PIN	26
5.8.2.8	BANK1PORT	26
5.8.2.9	BANK2DDR	26
5.8.2.10	BANK2PIN	26
5.8.2.11	BANK2PORT	26
5.8.2.12	BATT_CHANNEL	26
5.8.2.13	BATT_MAX	27
5.8.2.14	COMPLEMENTARY_TAU	27
5.8.2.15	DT	27
5.8.2.16	GYRO_ADDRESS	27
5.8.2.17	GYROFILTERFACTOR	27
5.8.2.18	LED0DDR	27
5.8.2.19	LED0PIN	27
5.8.2.20	LED0PORT	28
5.8.2.21	LED1DDR	28

5.8.2.22	LED1PIN	28
5.8.2.23	LED1PORT	28
5.8.2.24	LED2DDR	28
5.8.2.25	LED2PIN	28
5.8.2.26	LED2PORT	28
5.8.2.27	LED3DDR	28
5.8.2.28	LED3PIN	29
5.8.2.29	LED3PORT	29
5.8.2.30	MAG_ADDRESS	29
5.8.2.31	MOTOR_BASEADDRESS	29
5.8.2.32	MOTORCOUNT	29
5.8.2.33	ORIENTATION_FILTER	29
5.8.2.34	PID_D	29
5.8.2.35	PID_FACTOR	29
5.8.2.36	PID_I	30
5.8.2.37	PID_INTMAX	30
5.8.2.38	PID_INTMIN	30
5.8.2.39	PID_OUTMAX	30
5.8.2.40	PID_OUTMIN	30
5.8.2.41	PID_P	30
5.8.2.42	Q1	30
5.8.2.43	Q2	30
5.8.2.44	Q3	31
5.8.2.45	R1	31
5.8.2.46	R2	31
5.8.2.47	RX_BUFFER_SIZE	31
5.8.2.48	SET_PITCHMINUS	31
5.8.2.49	SET_PITCHPLUS	31
5.8.2.50	SET_ROLLMINUS	31
5.8.2.51	SET_ROLLPLUS	31
5.8.2.52	SOFTWARELOWPASS	32
5.8.2.53	SPISS	32
5.8.2.54	TX_BUFFER_SIZE	32
5.9	Debug Output	33
5.9.1	Detailed Description	33
5.9.2	Macro Definition Documentation	33
5.9.2.1	assert	33
5.9.2.2	ASSERTFUNC	33
5.9.2.3	DEBUGOUT	33
5.9.2.4	debugPrint	34

5.10 Error Reporting . . . . .	35
5.10.1 Detailed Description . . . . .	35
5.10.2 Macro Definition Documentation . . . . .	35
5.10.2.1 CHECKERROR . . . . .	35
5.10.2.2 REPORTERROR . . . . .	35
5.10.3 Enumeration Type Documentation . . . . .	36
5.10.3.1 Error . . . . .	36
5.10.4 Function Documentation . . . . .	36
5.10.4.1 getErrorString . . . . .	36
5.11 Gyroscope Driver . . . . .	37
5.11.1 Detailed Description . . . . .	37
5.11.2 Macro Definition Documentation . . . . .	37
5.11.2.1 GYROREG_CTRL1 . . . . .	37
5.11.2.2 GYROREG_CTRL4 . . . . .	38
5.11.2.3 GYROREG_OUTXL . . . . .	38
5.11.3 Enumeration Type Documentation . . . . .	38
5.11.3.1 GyroRange . . . . .	38
5.11.4 Function Documentation . . . . .	38
5.11.4.1 gyroInit . . . . .	38
5.11.4.2 gyroRead . . . . .	39
5.11.4.3 gyroWriteByte . . . . .	40
5.11.5 Variable Documentation . . . . .	41
5.11.5.1 gyroRange . . . . .	41
5.12 Kalman-Filter . . . . .	42
5.12.1 Detailed Description . . . . .	42
5.12.2 Function Documentation . . . . .	42
5.12.2.1 kalmanInit . . . . .	42
5.12.2.2 kalmanInnovate . . . . .	43
5.13 Magnetometer Driver . . . . .	45
5.13.1 Detailed Description . . . . .	45
5.13.2 Macro Definition Documentation . . . . .	45
5.13.2.1 MAGREG_CRB . . . . .	45
5.13.2.2 MAGREG_MR . . . . .	46
5.13.2.3 MAGREG_XH . . . . .	46
5.13.3 Enumeration Type Documentation . . . . .	46
5.13.3.1 MagRange . . . . .	46
5.13.4 Function Documentation . . . . .	46
5.13.4.1 magInit . . . . .	46
5.13.4.2 magRead . . . . .	47
5.13.4.3 magWriteRegister . . . . .	47

5.14 Motor Controller Driver	49
5.14.1 Detailed Description	49
5.14.2 Function Documentation	49
5.14.2.1 motorInit	49
5.14.2.2 motorSet	50
5.14.2.3 motorTask	50
5.14.3 Variable Documentation	50
5.14.3.1 motorSpeed	50
5.14.3.2 motorSpeed	51
5.15 Orientation Calculation	52
5.15.1 Detailed Description	52
5.15.2 Macro Definition Documentation	53
5.15.2.1 TODEG	53
5.15.3 Function Documentation	53
5.15.3.1 orientationInit	53
5.15.3.2 orientationTask	53
5.15.3.3 zeroOrientation	54
5.15.4 Variable Documentation	54
5.15.4.1 orientation	54
5.15.4.2 orientation	55
5.15.4.3 orientationError	55
5.15.4.4 pitchData	55
5.15.4.5 rollData	55
5.16 PID-Controller	56
5.16.1 Detailed Description	57
5.16.2 Macro Definition Documentation	57
5.16.2.1 PITCH	57
5.16.2.2 ROLL	57
5.16.3 Function Documentation	57
5.16.3.1 pidExecute	57
5.16.3.2 pidInit	58
5.16.3.3 pidSet	58
5.16.3.4 pidTask	59
5.16.4 Variable Documentation	59
5.16.4.1 o_output	59
5.16.4.2 o_output	59
5.16.4.3 o_pids	59
5.16.4.4 o_pids	60
5.16.4.5 o_should	60
5.16.4.6 o_should	60

5.17	UART Library	61
5.17.1	Detailed Description	62
5.17.2	Macro Definition Documentation	62
5.17.2.1	BAUD	62
5.17.2.2	FLOWCONTROL	62
5.17.2.3	FLOWMARK	62
5.17.2.4	RX_BUFFER_SIZE	62
5.17.2.5	TX_BUFFER_SIZE	62
5.17.2.6	XOFF	63
5.17.2.7	XON	63
5.17.3	Function Documentation	63
5.17.3.1	serialAvailable	63
5.17.3.2	serialClose	63
5.17.3.3	serialGet	64
5.17.3.4	serialGetBlocking	64
5.17.3.5	serialHasChar	65
5.17.3.6	serialInit	65
5.17.3.7	serialRxBufEmpty	66
5.17.3.8	serialRxBufFull	66
5.17.3.9	serialTxBufEmpty	66
5.17.3.10	serialTxBufFull	67
5.17.3.11	serialWrite	67
5.17.3.12	serialWriteString	68
5.17.3.13	setFlow	68
5.18	Motor Speed Mixer	70
5.18.1	Detailed Description	70
5.18.2	Macro Definition Documentation	70
5.18.2.1	MAXDIFF	70
5.18.3	Function Documentation	70
5.18.3.1	setMotorSpeeds	70
5.18.3.2	setTask	71
5.18.4	Variable Documentation	71
5.18.4.1	baseSpeed	71
5.18.4.2	baseSpeed	71
5.19	SPI Driver	72
5.19.1	Detailed Description	72
5.19.2	Enumeration Type Documentation	72
5.19.2.1	SPI_MODE	72
5.19.2.2	SPI_SPEED	73
5.19.3	Function Documentation	73



5.19.3.1	spiInit	73
5.19.3.2	spiSendByte	73
5.20	Task Handler	74
5.20.1	Detailed Description	74
5.20.2	Typedef Documentation	74
5.20.2.1	Task	74
5.20.3	Function Documentation	75
5.20.3.1	addTask	75
5.20.3.2	removeTask	75
5.20.3.3	tasks	76
5.20.3.4	tasksRegistered	76
5.20.4	Variable Documentation	76
5.20.4.1	taskList	76
5.20.4.2	taskList	77
5.21	Time Keeping	78
5.21.1	Detailed Description	78
5.21.2	Macro Definition Documentation	79
5.21.2.1	OCIE	79
5.21.2.2	OCR	79
5.21.2.3	TCRA	79
5.21.2.4	TCRB	79
5.21.2.5	TIMS	79
5.21.3	Typedef Documentation	79
5.21.3.1	time_t	79
5.21.4	Function Documentation	79
5.21.4.1	getSystemTime	79
5.21.4.2	initSystemTimer	80
5.21.4.3	ISR	80
5.21.5	Variable Documentation	80
5.21.5.1	systemTime	80
5.22	I2C Driver	81
5.22.1	Detailed Description	81
5.22.2	Macro Definition Documentation	81
5.22.2.1	TWI_READ	81
5.22.2.2	TWI_WRITE	82
5.22.3	Function Documentation	82
5.22.3.1	twiInit	82
5.22.3.2	twiReadAck	82
5.22.3.3	twiReadNak	82
5.22.3.4	twiRepStart	83

5.22.3.5	twiStart	83
5.22.3.6	twiStartWait	84
5.22.3.7	twiStop	84
5.22.3.8	twiWrite	84
5.23	UART Menu	86
5.23.1	Detailed Description	86
5.23.2	Function Documentation	86
5.23.2.1	addMenuCommand	86
5.23.2.2	findEntry	87
5.23.2.3	reverseList	87
5.23.2.4	uartMenuPrintHelp	88
5.23.2.5	uartMenuRegisterHandler	88
5.23.2.6	uartMenuTask	89
5.23.3	Variable Documentation	89
5.23.3.1	uartMenu	89
5.23.3.2	unHandler	89
5.24	External Memory Interface	90
5.24.1	Detailed Description	91
5.24.2	Macro Definition Documentation	91
5.24.2.1	BANK_GENERIC	91
5.24.2.2	MEMBANKS	91
5.24.2.3	MEMSWITCH	91
5.24.2.4	MEMSWITCHBACK	91
5.24.3	Function Documentation	91
5.24.3.1	restoreState	92
5.24.3.2	saveState	92
5.24.3.3	xmemGetBank	92
5.24.3.4	xmemInit	92
5.24.3.5	xmemSetBank	93
5.24.4	Variable Documentation	93
5.24.4.1	__brkval	93
5.24.4.2	__flp	93
5.24.4.3	currentBank	94
5.24.4.4	currentBank	94
5.24.4.5	states	94
5.24.4.6	states	94
5.25	xyControl Hardware	95
5.25.1	Detailed Description	96
5.25.2	Enumeration Type Documentation	96
5.25.2.1	LED	96

5.25.2.2	LEDState	96
5.25.3	Function Documentation	96
5.25.3.1	getVoltage	96
5.25.3.2	resetSelf	97
5.25.3.3	uartinput	97
5.25.3.4	uartoutput	97
5.25.3.5	xyInit	98
5.25.3.6	xyLed	98
5.25.3.7	xyLedInternal	99
5.25.4	Variable Documentation	99
5.25.4.1	helpText	99
5.25.4.2	inFile	99
5.25.4.3	outFile	99
5.25.4.4	resetText	99
<b>6</b>	<b>Data Structure Documentation</b>	<b>101</b>
6.1	Angles Struct Reference	101
6.1.1	Detailed Description	101
6.1.2	Field Documentation	101
6.1.2.1	pitch	101
6.1.2.2	roll	101
6.1.2.3	yaw	102
6.2	Complementary Struct Reference	102
6.2.1	Detailed Description	102
6.3	Kalman Struct Reference	102
6.3.1	Detailed Description	103
6.3.2	Field Documentation	103
6.3.2.1	p33	103
6.3.2.2	x3	103
6.4	MallocState Struct Reference	103
6.4.1	Detailed Description	103
6.4.2	Field Documentation	104
6.4.2.1	end	104
6.4.2.2	fl	104
6.4.2.3	start	104
6.4.2.4	val	104
6.5	MenuEntry Struct Reference	104
6.5.1	Detailed Description	105
6.5.2	Field Documentation	105
6.5.2.1	cmd	105

6.5.2.2	f	105
6.5.2.3	helpText	105
6.5.2.4	next	105
6.6	PIDState Struct Reference	105
6.6.1	Detailed Description	106
6.6.2	Field Documentation	106
6.6.2.1	intMax	106
6.6.2.2	intMin	106
6.6.2.3	kd	106
6.6.2.4	ki	107
6.6.2.5	kp	107
6.6.2.6	last	107
6.6.2.7	lastError	107
6.6.2.8	outMax	107
6.6.2.9	outMin	107
6.6.2.10	sumError	107
6.7	TaskElement Struct Reference	108
6.7.1	Detailed Description	108
6.7.2	Field Documentation	108
6.7.2.1	next	108
6.7.2.2	task	108
6.8	Vector3f Struct Reference	108
6.8.1	Detailed Description	109
6.8.2	Field Documentation	109
6.8.2.1	x	109
6.8.2.2	y	109
6.8.2.3	z	109
<b>7</b>	<b>File Documentation</b>	<b>111</b>
7.1	include/acc.h File Reference	111
7.1.1	Detailed Description	111
7.2	include/adc.h File Reference	111
7.2.1	Detailed Description	112
7.3	include/complementary.h File Reference	112
7.3.1	Detailed Description	112
7.4	include/config.h File Reference	112
7.4.1	Detailed Description	115
7.5	include/debug.h File Reference	115
7.5.1	Detailed Description	115
7.6	include/doc.h File Reference	115

7.6.1 Detailed Description . . . . .	115
7.7 include/error.h File Reference . . . . .	116
7.7.1 Detailed Description . . . . .	116
7.8 include/gyro.h File Reference . . . . .	116
7.8.1 Detailed Description . . . . .	117
7.9 include/kalman.h File Reference . . . . .	117
7.9.1 Detailed Description . . . . .	117
7.10 include/mag.h File Reference . . . . .	117
7.10.1 Detailed Description . . . . .	118
7.11 include/motor.h File Reference . . . . .	118
7.11.1 Detailed Description . . . . .	118
7.12 include/orientation.h File Reference . . . . .	118
7.12.1 Detailed Description . . . . .	119
7.13 include/pid.h File Reference . . . . .	119
7.13.1 Detailed Description . . . . .	120
7.14 include/serial.h File Reference . . . . .	120
7.14.1 Detailed Description . . . . .	120
7.15 include/serial_device.h File Reference . . . . .	121
7.15.1 Detailed Description . . . . .	121
7.16 include/set.h File Reference . . . . .	121
7.16.1 Detailed Description . . . . .	121
7.17 include/spi.h File Reference . . . . .	121
7.17.1 Detailed Description . . . . .	122
7.18 include/tasks.h File Reference . . . . .	122
7.18.1 Detailed Description . . . . .	122
7.19 include/time.h File Reference . . . . .	122
7.19.1 Detailed Description . . . . .	123
7.20 include/twi.h File Reference . . . . .	123
7.20.1 Detailed Description . . . . .	123
7.21 include/uartMenu.h File Reference . . . . .	124
7.21.1 Detailed Description . . . . .	124
7.22 include/xmem.h File Reference . . . . .	124
7.22.1 Detailed Description . . . . .	125
7.23 include/xycontrol.h File Reference . . . . .	125
7.23.1 Detailed Description . . . . .	126
7.24 lib/acc.c File Reference . . . . .	126
7.24.1 Detailed Description . . . . .	126
7.25 lib/adc.c File Reference . . . . .	127
7.25.1 Detailed Description . . . . .	127
7.26 lib/complementary.c File Reference . . . . .	127

7.26.1 Detailed Description . . . . .	127
7.27 lib/error.c File Reference . . . . .	128
7.27.1 Detailed Description . . . . .	128
7.27.2 Variable Documentation . . . . .	128
7.27.2.1 error0 . . . . .	128
7.27.2.2 error1 . . . . .	128
7.27.2.3 error2 . . . . .	129
7.27.2.4 error3 . . . . .	129
7.27.2.5 error4 . . . . .	129
7.27.2.6 error5 . . . . .	129
7.27.2.7 errorTable . . . . .	129
7.28 lib/gyro.c File Reference . . . . .	129
7.28.1 Detailed Description . . . . .	130
7.29 lib/kalman.c File Reference . . . . .	130
7.29.1 Detailed Description . . . . .	130
7.30 lib/mag.c File Reference . . . . .	131
7.30.1 Detailed Description . . . . .	131
7.31 lib/motor.c File Reference . . . . .	131
7.31.1 Detailed Description . . . . .	132
7.32 lib/orientation.c File Reference . . . . .	132
7.32.1 Detailed Description . . . . .	133
7.33 lib/pid.c File Reference . . . . .	133
7.33.1 Detailed Description . . . . .	134
7.34 lib/serial.c File Reference . . . . .	134
7.34.1 Detailed Description . . . . .	135
7.35 lib/set.c File Reference . . . . .	135
7.35.1 Detailed Description . . . . .	135
7.36 lib/spi.c File Reference . . . . .	136
7.36.1 Detailed Description . . . . .	136
7.37 lib/tasks.c File Reference . . . . .	136
7.37.1 Detailed Description . . . . .	136
7.38 lib/time.c File Reference . . . . .	137
7.38.1 Detailed Description . . . . .	137
7.39 lib/uartMenu.c File Reference . . . . .	137
7.39.1 Detailed Description . . . . .	138
7.40 lib/xmem.c File Reference . . . . .	138
7.40.1 Detailed Description . . . . .	139
7.41 lib/xycontrol.c File Reference . . . . .	139
7.41.1 Detailed Description . . . . .	140

---

<b>8</b>	<b>Example Documentation</b>	<b>141</b>
8.1	test.c . . . . .	141
8.2	uartFlight.c . . . . .	142
	<b>Index</b>	<b>144</b>





# Chapter 1

## Main Page

xyControl is a Quadcopter Flight Controller based on Atmels Atmega2560 microcontroller. It features 512KB SR-AM on-board, using the external memory interface of this processor. Also included is a switched power supply as well as a USB connection to communicate with and program the target. All I/O pins, including 3 additional UARTs, SPI, I2C (TWI) and 16 ADC Channels, are accessible via standard 2.54mm connectors. The Board can be powered from an external stable 5V supply, USB or 7V or more, via the on-board switched power supply. All voltage sources can be selected via jumpers.

### Flight Control Software Flow

Three tasks are controlling the Quadcopter Orientation in Space.

- The Orientation Task reads the Gyroscope and Accelerometer and calculates the current Roll and Pitch angles. They are stored in the global struct "orientation".
- The PID Task is then feeding these angles into two PID controllers. Their output is then used by...
- The Set Task, which calculates the motor speeds and gives them to...
- The motor task, which sends the new values via TWI to the motor controllers.

### Supported Hardware

- Gyroscope L3GD20, code based on the [Adafruit Example](#).
- Accelerometer and Magnetometer LSM303DLHC, code based on the [Pololu Example](#).
- I got both of these Sensors on the [MinIMU-9 v2](#)
- Brushless Motor Driver [BL-Ctrl V1.2](#) with eg. the [Robbe Roxxy Outrunner 2824-34](#) Brushless Motor.
- BTM-222 Bluetooth UART Bridge ([PCB](#))

### External Memory ([xmem.h](#))

The external memory consists of a 512Kx8 SRAM, bank-switched onto the 16bit avr address space. This gives us 8 memory banks, consisting of 56KB. All memory from 0x0000 to 0x21FF is the AVR's internal memory. The memory banks are switched into 0x2200 to 0xFFFF. This gives us 8 banks with 56KB each, resulting in 448KB external RAM.

The data and bss memory sections, as well as the Stack are located in the internal RAM. The external RAM is used only for dynamically allocated memory.

## Orientation Calculation ([orientation.h](#))

Calculates the current angles of the platform, using Gyroscope and Accelerometer Data with a [Kalman](#) Filter. It is using this slightly modified [Kalman Filter Implementation](#) by Linus Helgesson.

## PC and Android Tools

You can find some PC Software in the 'tools' directory. Each one should be accompanied by it's own Readme file.

## UART-Flight Status Packet Format

```
printf("t%.2f %.2f %.2f\n", kp, ki, kd);
printf("u%.2f %.2f\n", pid_output[1], pid_output[0]); // Pitch, Roll
printf("v%i %i %i %i\n", motorSpeed[0], ..., motorSpeed[3]);
printf("w%.2f\n", orientation.pitch);
printf("x%.2f\n", orientation.roll);
printf("y%.2f\n", orientation.yaw);
printf("z%.2f\n", getVoltage());
```

## Software used

- [Peter Fleurys TWI Library](#)

## License

Peter Fleurys TWI Library ([twi.c](#) & [twi.h](#)) is released under the [GNU GPL license](#).

Everything else is released under a BSD-Style license. See the accompanying COPYING file.

## Chapter 2

# Module Index

### 2.1 Modules

Here is a list of all modules:

Software . . . . .	9
System . . . . .	10
Debug Output . . . . .	33
Error Reporting . . . . .	35
Task Handler . . . . .	74
Time Keeping . . . . .	78
UART Menu . . . . .	86
External Memory Interface . . . . .	90
xyControl Hardware . . . . .	95
Flight . . . . .	11
Complementary-Filter . . . . .	21
Kalman-Filter . . . . .	42
Orientation Calculation . . . . .	52
PID-Controller . . . . .	56
Motor Speed Mixer . . . . .	70
Hardware . . . . .	12
Accelerometer Driver . . . . .	13
ADC Driver . . . . .	18
Gyroscope Driver . . . . .	37
Magnetometer Driver . . . . .	45
Motor Controller Driver . . . . .	49
UART Library . . . . .	61
SPI Driver . . . . .	72
I2C Driver . . . . .	81
Configuration . . . . .	23



## Chapter 3

# Data Structure Index

### 3.1 Data Structures

Here are the data structures with brief descriptions:

<a href="#">Angles</a>	Can store orientation in Euler Space . . . . .	101
<a href="#">Complementary</a>	Complementary-Filter State data . . . . .	102
<a href="#">Kalman</a>	Kalman-Filter State data . . . . .	102
<a href="#">MallocState</a>	All Malloc related State . . . . .	103
<a href="#">MenuEntry</a>	Data Structure for Single-Linked-List for UART Menu . . . . .	104
<a href="#">PIDState</a>	Data Structure for a single PID Controller . . . . .	105
<a href="#">TaskElement</a>	Single-Linked Task List . . . . .	108
<a href="#">Vector3f</a>	The global 3-Dimensional Floating Point Vector . . . . .	108



## Chapter 4

# File Index

### 4.1 File List

Here is a list of all documented files with brief descriptions:

<b>test.c</b>	??
<b>uartFlight.c</b>	??
include/ <a href="#">acc.h</a>	
LSM303DLHC Accelerometer API Header	111
include/ <a href="#">adc.h</a>	
Analog-to-Digital Converter API Header	111
include/ <a href="#">complementary.h</a>	
Complementary-Filter Header	112
include/ <a href="#">config.h</a>	
Various default settings	112
include/ <a href="#">debug.h</a>	
Debug and Assert Header and Implementation	115
include/ <a href="#">doc.h</a>	
Contains Doxygen Group Definitions	115
include/ <a href="#">error.h</a>	
Global listing of different error conditions	116
include/ <a href="#">gyro.h</a>	
L3GD20 Gyroscope API Header	116
include/ <a href="#">kalman.h</a>	
Kalman-Filter Header	117
include/ <a href="#">mag.h</a>	
LSM303DLHC Magnetometer API Header	117
include/ <a href="#">motor.h</a>	
BL-Ctrl V1.2 Controller API Header	118
include/ <a href="#">orientation.h</a>	
Orientation API Header	118
include/ <a href="#">pid.h</a>	
PID Library Header	119
include/ <a href="#">serial.h</a>	
UART Library Header File	120
include/ <a href="#">serial_device.h</a>	
UART Library device-specific configuration	121
include/ <a href="#">set.h</a>	
Motor Mixer Library Header	121
include/ <a href="#">spi.h</a>	
SPI API Header	121
include/ <a href="#">tasks.h</a>	
Task API Header	122

include/ <a href="#">time.h</a>	
Time API Header . . . . .	122
include/ <a href="#">twi.h</a>	
I2C API Header . . . . .	123
include/ <a href="#">uartMenu.h</a>	
UART Menu API Header . . . . .	124
include/ <a href="#">xmem.h</a>	
XMEM API Header . . . . .	124
include/ <a href="#">xycontrol.h</a>	
XyControl API Header . . . . .	125
lib/ <a href="#">acc.c</a>	
LSM303DLHC Accelerometer API Implementation . . . . .	126
lib/ <a href="#">adc.c</a>	
Analog-to-Digital Converter API Implementation . . . . .	127
lib/ <a href="#">complementary.c</a>	
Complementary-Filter Implementation . . . . .	127
lib/ <a href="#">error.c</a>	
Global listing of different error conditions . . . . .	128
lib/ <a href="#">gyro.c</a>	
L3GD20 Gyroscope API Implementation . . . . .	129
lib/ <a href="#">kalman.c</a>	
Kalman-Filter Implementation . . . . .	130
lib/ <a href="#">mag.c</a>	
LSM303DLHC Magnetometer API Implementation . . . . .	131
lib/ <a href="#">motor.c</a>	
BL-Ctrl V1.2 Controller API Implementation . . . . .	131
lib/ <a href="#">orientation.c</a>	
Orientation API Implementation . . . . .	132
lib/ <a href="#">pid.c</a>	
PID Library Implementation . . . . .	133
lib/ <a href="#">serial.c</a>	
UART Library Implementation . . . . .	134
lib/ <a href="#">set.c</a>	
Motor Mixer Library Implementation . . . . .	135
lib/ <a href="#">spi.c</a>	
SPI API Implementation . . . . .	136
lib/ <a href="#">tasks.c</a>	
Task API Implementation . . . . .	136
lib/ <a href="#">time.c</a>	
Time API Implementation . . . . .	137
lib/ <a href="#">twi.c</a>	??
lib/ <a href="#">uartMenu.c</a>	
UART Menu API Implementation . . . . .	137
lib/ <a href="#">xmem.c</a>	
XMEM API Implementation . . . . .	138
lib/ <a href="#">xycontrol.c</a>	
XyControl API Implementation . . . . .	139



## Chapter 5

# Module Documentation

### 5.1 Software

Software Libraries.

#### Modules

- [System](#)  
*System Libraries.*
- [Flight](#)  
*Flight Control Libraries.*

#### 5.1.1 Detailed Description

Software Libraries.

## 5.2 System

System Libraries.

### Modules

- [Debug Output](#)  
*Allows debug output and assert usage.*
- [Error Reporting](#)  
*Error reporting with human readable strings.*
- [Task Handler](#)  
*System for registering different tasks that will be called regularly, one after another.*
- [Time Keeping](#)  
*Measuring Time with Millisecond Resolution.*
- [UART Menu](#)  
*Enables user interaction with an UART Menu.*
- [External Memory Interface](#)  
*Allows access to external RAM with bank-switching.*
- [xyControl Hardware](#)  
*Controls xyControl On-Board Hardware like LEDs.*

### 5.2.1 Detailed Description

System Libraries.

## 5.3 Flight

Flight Control Libraries.

### Modules

- [Complementary-Filter](#)  
*Complementary-Filter.*
- [Kalman-Filter](#)  
*Kalman-Filter from [Linus Helgesson](#)*
- [Orientation Calculation](#)  
*Calculate Orientation using the Kalman-Filter, Accelerometer and Gyroscope.*
- [PID-Controller](#)  
*Simple implementation for multiple floating-point PID Controllers.*
- [Motor Speed Mixer](#)  
*Takes the Base Speed and PID-Output and sets Motor Speed accordingly.*

### 5.3.1 Detailed Description

Flight Control Libraries.

## 5.4 Hardware

Hardware Libraries.

### Modules

- [Accelerometer Driver](#)  
*Configuring and reading an LSM303DLHC Accelerometer.*
- [ADC Driver](#)  
*Analog-to-Digital Converter Library.*
- [Gyroscope Driver](#)  
*Configuring and reading an L3GD20.*
- [Magnetometer Driver](#)  
*Configuring and reading an LSM303DLHC Magnetometer.*
- [Motor Controller Driver](#)  
*Controlling four [BL-Ctrl V1.2](#) Brushless controllers.*
- [UART Library](#)  
*UART Library enabling you to control all available UART Modules.*
- [SPI Driver](#)  
*SPI Library for AVR's built-in SPI Hardware.*
- [I2C Driver](#)  
*Using the AVR TWI/I2C Hardware.*

### 5.4.1 Detailed Description

Hardware Libraries.

## 5.5 Accelerometer Driver

Configuring and reading an LSM303DLHC Accelerometer.

### Files

- file [acc.h](#)  
*LSM303DLHC Accelerometer API Header.*
- file [acc.c](#)  
*LSM303DLHC Accelerometer API Implementation.*

### Macros

- `#define ACCREG_CTRL1 0x20`  
*Accelerometer Control Register 1.*
- `#define ACCREG_CTRL4 0x23`  
*Accelerometer Control Register 4.*
- `#define ACCREG_XL 0x28`  
*First Accelerometer Output Register.*

### Enumerations

- enum [AccRange](#) { [r2G](#), [r4G](#), [r8G](#), [r16G](#) }  
*Accelerometer Range options.*

### Functions

- [Error](#) [acclnit](#) ([AccRange](#) r)  
*Initialize the Accelerometer.*
- [Error](#) [accRead](#) ([Vector3f](#) \*v)  
*Read from the Accelerometer.*
- [Error](#) [accWriteRegister](#) (uint8\_t reg, uint8\_t val)  
*Write an Accelerometer Register.*

### Variables

- [AccRange](#) [accRange](#)  
*Stored range to scale returned values.*

#### 5.5.1 Detailed Description

Configuring and reading an LSM303DLHC Accelerometer.

#### 5.5.2 Macro Definition Documentation

##### 5.5.2.1 `#define ACCREG_CTRL1 0x20`

Accelerometer Control Register 1.

Definition at line 49 of file [acc.c](#).

Referenced by [acclnit\(\)](#).

### 5.5.2.2 #define ACCREG\_CTRL4 0x23

Accelerometer Control Register 4.

Definition at line 50 of file acc.c.

Referenced by `accInit()`.

### 5.5.2.3 #define ACCREG\_XL 0x28

First Accelerometer Output Register.

Definition at line 51 of file acc.c.

Referenced by `accRead()`.

## 5.5.3 Enumeration Type Documentation

### 5.5.3.1 enum AccRange

Accelerometer Range options.

Enumerator

***r2G*** +- 2G  
***r4G*** +- 4G  
***r8G*** +- 8G  
***r16G*** +- 16G

Definition at line 47 of file acc.h.

```

47         {
48     r2G,
49     r4G,
50     r8G,
51     r16G,
52 } AccRange;
```

## 5.5.4 Function Documentation

### 5.5.4.1 Error accInit ( AccRange r )

Initialize the Accelerometer.

Call before `accRead()`. I2C should already be initialized!

Parameters

<i>r</i>	<code>AccRange</code> to use.
----------	-------------------------------

Returns

`TWI_NO_ANSWER`, `TWI_WRITE_ERROR`, `ARGUMENT_ERROR` or `SUCCESS`.

Definition at line 76 of file acc.c.

References `accRange`, `ACCREG_CTRL1`, `ACCREG_CTRL4`, `accWriteRegister()`, `ARGUMENT_ERROR`, `r16G`, `r2G`, `r4G`, `r8G`, and `SUCCESS`.

Referenced by `orientationInit()`.

```

76         {
77         uint8_t v;
78         switch (r) {
79             case r2G:
80                 v = 0x00;
81                 break;
82             case r4G:
83                 v = 0x10;
84                 break;
85             case r8G:
86                 v = 0x20;
87                 break;
88             case r16G:
89                 v = 0x30;
90                 break;
91             default:
92                 return ARGUMENT_ERROR;
93         }
94         accRange = r;
95         Error e = accWriteRegister(ACCREG_CTRL1, 0x57); // Enable all axes,
100         100Hz
96         if (e != SUCCESS) {
97             return e;
98         }
99         e = accWriteRegister(ACCREG_CTRL4, v);
100         return e;
101     }

```

#### 5.5.4.2 Error accRead ( Vector3f \* v )

Read from the Accelerometer.

Accelerometer should already be initialized!

##### Parameters

v	Vector3f for the read values
---	------------------------------

##### Returns

TWI\_NO\_ANSWER, TWI\_WRITE\_ERROR, ARGUMENT\_ERROR or SUCCESS.

Definition at line 103 of file acc.c.

References ACC\_ADDRESS, ACCFILTERFACTOR, accRange, ACCREG\_XL, ARGUMENT\_ERROR, r16G, r2G, r4G, r8G, SUCCESS, TWI\_NO\_ANSWER, TWI\_READ, TWI\_WRITE, TWI\_WRITE\_ERROR, twiReadAck(), twiReadNak(), twiRepStart(), twiStart(), twiWrite(), Vector3f::x, Vector3f::y, and Vector3f::z.

Referenced by orientationTask().

```

103     {
104         static double accSumX = 0; /* Buffer for X Low-Pass. */
105         static double accSumY = 0; /* Buffer for Y Low-Pass. */
106         static double accSumZ = 0; /* Buffer for Z Low-Pass. */
107         static double accFilterX = 0; /* Buffer for X Low-Pass. */
108         static double accFilterY = 0; /* Buffer for Y Low-Pass. */
109         static double accFilterZ = 0; /* Buffer for Z Low-Pass. */
110
111         if (v == NULL) {
112             return ARGUMENT_ERROR;
113         }
114         if (twiStart(ACC_ADDRESS | TWI_WRITE)) {
115             return TWI_NO_ANSWER;
116         }
117         if (twiWrite(ACCREG_XL | (1 << 7))) { // Auto Increment
118             return TWI_WRITE_ERROR;
119         }
120         if (twiRepStart(ACC_ADDRESS | TWI_READ)) {
121             return TWI_NO_ANSWER;
122         }
123
124         uint8_t xl = twiReadAck();
125         uint8_t xh = twiReadAck();
126         uint8_t yl = twiReadAck();
127         uint8_t yh = twiReadAck();

```

```

128     uint8_t z1 = twiReadAck();
129     uint8_t zh = twiReadNak();
130
131     int16_t x = *(int8_t *)(&xh);
132     x *= (1 << 8);
133     x |= x1;
134
135     int16_t y = *(int8_t *)(&yh);
136     y *= (1 << 8);
137     y |= y1;
138
139     int16_t z = *(int8_t *)(&z1);
140     z *= (1 << 8);
141     z |= z1;
142
143     switch (accRange) {
144     case r2G:
145         v->x = (((double)x) * 2 / 0x8000);
146         v->y = (((double)y) * 2 / 0x8000);
147         v->z = (((double)z) * 2 / 0x8000);
148         break;
149     case r4G:
150         v->x = (((double)x) * 4 / 0x8000);
151         v->y = (((double)y) * 4 / 0x8000);
152         v->z = (((double)z) * 4 / 0x8000);
153         break;
154     case r8G:
155         v->x = (((double)x) * 8 / 0x8000);
156         v->y = (((double)y) * 8 / 0x8000);
157         v->z = (((double)z) * 8 / 0x8000);
158         break;
159     case r16G:
160         v->x = (((double)x) * 16 / 0x8000);
161         v->y = (((double)y) * 16 / 0x8000);
162         v->z = (((double)z) * 16 / 0x8000);
163         break;
164     default:
165         return ARGUMENT_ERROR;
166     }
167
168     accSumX = accSumX - accFilterX + v->x;
169     accFilterX = accSumX / ACCFILTERFACTOR;
170     v->x = accFilterX;
171
172     accSumY = accSumY - accFilterY + v->y;
173     accFilterY = accSumY / ACCFILTERFACTOR;
174     v->y = accFilterY;
175
176     accSumZ = accSumZ - accFilterZ + v->z;
177     accFilterZ = accSumZ / ACCFILTERFACTOR;
178     v->z = accFilterZ;
179
180     return SUCCESS;
181 }

```

#### 5.5.4.3 Error accWriteRegister ( uint8\_t reg, uint8\_t val )

Write an Accelerometer Register.

I2C should already be initialized!

##### Parameters

<i>reg</i>	Register Address
<i>val</i>	New Value

##### Returns

[TWI\\_NO\\_ANSWER](#), [TWI\\_WRITE\\_ERROR](#) or [SUCCESS](#).

Definition at line 62 of file acc.c.

References [TWI\\_NO\\_ANSWER](#).

Referenced by [accI2cInit\(\)](#).



```
63     if (twiStart(ACC_ADDRESS | TWI_WRITE)) {  
64         return TWI_NO_ANSWER;  
65     }  
66     if (twiWrite(reg)) {  
67         return TWI_WRITE_ERROR;  
68     }  
69     if (twiWrite(val)) {  
70         return TWI_WRITE_ERROR;  
71     }  
72     twiStop();  
73     return SUCCESS;  
74 }
```

## 5.5.5 Variable Documentation

### 5.5.5.1 AccRange accRange

Stored range to scale returned values.

Definition at line 53 of file acc.c.

Referenced by acclnit(), and accRead().

## 5.6 ADC Driver

Analog-to-Digital Converter Library.

### Files

- file [adc.h](#)  
*Analog-to-Digital Converter API Header.*
- file [adc.c](#)  
*Analog-to-Digital Converter API Implementation.*

### Enumerations

- enum [ADCRef](#) { [AREF](#), [AVCC](#), [AINT1](#), [AINT2](#) }  
*ADC Reference Voltage options.*

### Functions

- void [adclnit](#) ([ADCRef](#) ref)  
*Initialize the ADC Hardware.*
- void [adcStart](#) (uint8\_t channel)  
*Start a conversion on a given channel.*
- uint8\_t [adcReady](#) (void)  
*Check if a result is ready.*
- uint16\_t [adcGet](#) (uint8\_t next)  
*Get the conversion results.*
- void [adcClose](#) (void)  
*Disable the ADC to save energy.*

#### 5.6.1 Detailed Description

Analog-to-Digital Converter Library. With 10bit Output and selectable Reference Voltage.

#### 5.6.2 Enumeration Type Documentation

##### 5.6.2.1 enum ADCRef

ADC Reference Voltage options.

##### Enumerator

- AREF*** External Reference Voltage.  
***AVCC*** Supply Voltage.  
***AINT1*** Internal Reference 1 (1.1V)  
***AINT2*** Internal Reference 2 (2.56V)

Definition at line 45 of file [adc.h](#).

```

45         {
46     AREF,
47     AVCC,
48     AINT1,
49     AINT2
50 } ADCRef;
```

### 5.6.3 Function Documentation

#### 5.6.3.1 void adcClose ( void )

Disable the ADC to save energy.

Definition at line 107 of file adc.c.

```

107     {
108     // deactivate adc
109     ADCSRA &= ~(1 << ADSC);
110     PRRO |= (1 << PRADC);
111     ADCSRA &= ~(1 << ADEN);
112 }

```

#### 5.6.3.2 uint16\_t adcGet ( uint8\_t next )

Get the conversion results.

##### Parameters

<i>next</i>	Start next conversion if != 0
-------------	-------------------------------

##### Returns

10bit ADC value

Definition at line 96 of file adc.c.

References adcReady().

Referenced by getVoltage().

```

96     {
97     // Return measurements result
98     // Start next conversion
99     uint16_t temp = 0;
100     while (!adcReady());
101     temp = ADC;
102     if (next)
103         ADCSRA |= (1 << ADSC); // Start next conversion
104     return temp;
105 }

```

#### 5.6.3.3 void adclnit ( ADCRef ref )

Initialize the ADC Hardware.

##### Parameters

<i>ref</i>	Reference Voltage.
------------	--------------------

Definition at line 44 of file adc.c.

References AINT1, AINT2, AREF, and AVCC.

Referenced by xylnit().

```

44     {
45     // Enable ADC Module, start one conversion, wait for finish
46     PRRO &= ~(1 << PRADC); // Disable ADC Power Reduction (Enable it...)
47     switch(ref) {
48     case AVCC:
49         ADMUX = (1 << REFS0);
50         break;

```

```

51
52     case AINT1:
53         ADMUX = (1 << REFS1);
54         break;
55
56     case AINT2:
57         ADMUX = (1 << REFS1) | (1 << REFS0);
58         break;
59
60     case AREF:
61         ADMUX &= ~( (1 << REFS0) | (1 << REFS1));
62         break;
63     }
64
65     ADCSRA = (1 << ADPS2) | (1 << ADPS1) | (1 << ADPS0); // Prescaler 128
66     ADCSRB = 0;
67     ADCSRA |= (1 << ADEN) | (1 << ADSC); // Start ADC, single conversion
68 }

```

#### 5.6.3.4 uint8\_t adcReady ( void )

Check if a result is ready.

##### Returns

1 if conversion is done.

Definition at line 86 of file adc.c.

Referenced by adcGet(), and getVoltage().

```

86     {
87         // Is the measurement finished
88         if (ADCSRA & (1 << ADSC)) {
89             // ADSC bit is set
90             return 0;
91         } else {
92             return 1;
93         }
94     }

```

#### 5.6.3.5 void adcStart ( uint8\_t channel )

Start a conversion on a given channel.

##### Parameters

<i>channel</i>	Channel (0 - 15)
----------------	------------------

Definition at line 70 of file adc.c.

Referenced by getVoltage().

```

70     {
71         // Start a measurement on channel
72         if (channel > 15) {
73             channel = 0;
74         }
75         if (channel > 7) {
76             channel -= 8;
77             ADCSRB |= (1 << MUX5);
78         } else {
79             ADCSRB &= ~(1 << MUX5);
80         }
81         ADMUX &= ~0x1F; // Delete MUX0:4
82         ADMUX |= channel;
83         ADCSRA |= (1 << ADSC);
84     }

```

## 5.7 Complementary-Filter

Complementary-Filter.

### Files

- file [complementary.h](#)  
*Complementary-Filter Header.*
- file [complementary.c](#)  
*Complementary-Filter Implementation.*

### Data Structures

- struct [Complementary](#)  
*Complementary-Filter State data.*

### Functions

- void [complementaryExecute](#) ([Complementary](#) \*data, double acc, double gyro)  
*Step the [Complementary](#) Filter.*
- void [complementaryInit](#) ([Complementary](#) \*data)  
*Initialize a Complementary-State.*

#### 5.7.1 Detailed Description

Complementary-Filter. Inspired by [this presentation...](#)

#### 5.7.2 Function Documentation

##### 5.7.2.1 void complementaryExecute ( [Complementary](#) \* data, double acc, double gyro )

Step the [Complementary](#) Filter.

#### Parameters

<i>data</i>	Complementary-Filter State
<i>acc</i>	Angle from Accelerometer
<i>gyro</i>	Corresponding Gyroscope data

Definition at line 50 of file complementary.c.

References `COMPLEMENTARY_TAU`, and `getSystemTime()`.

Referenced by `orientationTask()`.

```

50                                     {
51     double dt = (getSystemTime() - data->lastExecute) / 1000.0;
52     data->angle = (data->angle + (gyro * dt)); // Gyro Integrator
53     data->angle += COMPLEMENTARY_TAU / (COMPLEMENTARY_TAU + dt); //
                    High-Pass
54     data->angle += (1 - (COMPLEMENTARY_TAU / (COMPLEMENTARY_TAU + dt))) *
                    acc; // Low-Pass
55     data->lastExecute = getSystemTime();
56 }
```

### 5.7.2.2 void complementaryInit ( Complementary \* data )

Initialize a Complementary-State.

#### Parameters

<i>data</i>	Complementary-State to be initialized
-------------	---------------------------------------

Definition at line 45 of file complementary.c.

References `getSystemTime()`.

Referenced by `orientationInit()`.

```
45                                     {  
46     data->angle = 0;  
47     data->lastExecute = getSystemTime();  
48 }
```

## 5.8 Configuration

Various default settings.

### Files

- file [config.h](#)  
*Various default settings.*

### Macros

- #define [ORIENTATION\\_FILTER](#) [FILTER\\_COMPLEMENTARY](#)  
*Filter Implementation to be used.*
- #define [COMPLEMENTARY\\_TAU](#) 0.5  
*Time Contant for Low and High Pass Filter in the [Complementary](#) Filter.*
- #define [SOFTWARELOWPASS](#) 1  
*Software Low-Pass on Gyro and ACC.*
- #define [ACCFILTERFACTOR](#) [SOFTWARELOWPASS](#)  
*Accelerometer Low Pass Factor.*
- #define [GYROFILTERFACTOR](#) [SOFTWARELOWPASS](#)  
*Gyroscope Low Pass Factor.*
- #define [PID\\_OUTMAX](#) 256  
*Maximum PID Output.*
- #define [PID\\_OUTMIN](#) -256  
*Minimum PID Output.*
- #define [PID\\_INTMAX](#) [PID\\_OUTMAX](#)  
*Maximum PID Integral Sum.*
- #define [PID\\_INTMIN](#) [PID\\_OUTMIN](#)  
*Minimal PID Integral Sum.*
- #define [PID\\_FACTOR](#) 4 / 5  
*Influence of PID in relation to Base Speed.*
- #define [DT](#) 0.01f  
*Time Constant.*
- #define [Q1](#) 5.0f  
*Q Matrix Diagonal Element 1.*
- #define [Q2](#) 100.0f  
*Q Matrix Diagonal Element 2.*
- #define [Q3](#) 0.01f  
*Q Matrix Diagonal Element 3.*
- #define [R1](#) 1000.0f  
*R Matrix Diagonal Element 1.*
- #define [R2](#) 1000.0f  
*R Matrix Diagonal Element 2.*
- #define [SET\\_ROLLPLUS](#) 1  
*Second Motor at the Right.*
- #define [SET\\_ROLLMINUS](#) 3  
*Fourth Motor at the Left.*
- #define [SET\\_PITCHPLUS](#) 0  
*First Motor at the Top.*
- #define [SET\\_PITCHMINUS](#) 2

- Third Motor at the Bottom.*

  - #define `PID_P` 5.0  
*Default PID P Constant.*
  - #define `PID_I` 0.03  
*Default PID I Constant.*
  - #define `PID_D` -13.0  
*Default PID D Constant.*
  - #define `MOTORCOUNT` 4  
*Amount of motors.*
  - #define `BATT_MAX` 15  
*Battery Voltage Reference (ADC 5V)*
  - #define `BATT_CHANNEL` 0  
*ADC Channel for Battery.*
  - #define `ACC_ADDRESS` 0x32  
*Accelerometer Address (0011001r)*
  - #define `GYRO_ADDRESS` 0xD6  
*Gyroscope Address (110101xr, x = 1)*
  - #define `MAG_ADDRESS` 0x3C  
*Magnetometer Address.*
  - #define `MOTOR_BASEADDRESS` 0x52  
*Address of first motor controller.*
  - #define `LED0PORT` PORTL  
*First LED Port.*
  - #define `LED0DDR` DDRL  
*First LED Data Direction Register.*
  - #define `LED0PIN` PL6  
*First LED Pin.*
  - #define `LED1PORT` PORTL  
*Second LED Port.*
  - #define `LED1DDR` DDRL  
*Second LED Data Direction Register.*
  - #define `LED1PIN` PL7  
*Second LED Pin.*
  - #define `LED2PORT` PORTG  
*Third LED Port.*
  - #define `LED2DDR` DDRG  
*Third LED Data Direction Register.*
  - #define `LED2PIN` PG5  
*Third LED Pin.*
  - #define `LED3PORT` PORTE  
*Fourth LED Port.*
  - #define `LED3DDR` DDRE  
*Fourth LED Data Direction Register.*
  - #define `LED3PIN` PE2  
*Fourth LED Pin.*
  - #define `BANK0PORT` PORTG  
*First Bank Selection Port.*
  - #define `BANK0DDR` DDRG  
*First Bank Selection Data Direction Register.*
  - #define `BANK0PIN` PG3  
*First Bank Selection Pin.*



- `#define BANK1PORT PORTG`  
*Second Bank Selection Port.*
- `#define BANK1DDR DDRG`  
*Second Bank Selection Data Direction Register.*
- `#define BANK1PIN PG4`  
*Second Bank Selection Pin.*
- `#define BANK2PORT PORTL`  
*Third Bank Selection Port.*
- `#define BANK2DDR DDRL`  
*Third Bank Selection Data Direction Register.*
- `#define BANK2PIN PL5`  
*Third Bank Selection Pin.*
- `#define SPISS PB0`  
*SPI Slave Select Pin.*
- `#define RX_BUFFER_SIZE 64`  
*UART Receive Buffer Size.*
- `#define TX_BUFFER_SIZE 64`  
*UART Transmit Buffer Size.*

### 5.8.1 Detailed Description

Various default settings.

### 5.8.2 Macro Definition Documentation

#### 5.8.2.1 `#define ACC_ADDRESS 0x32`

Accelerometer Address (0011001r)

Definition at line 120 of file config.h.

Referenced by `accRead()`.

#### 5.8.2.2 `#define ACCFILTERFACTOR SOFTWARELOWPASS`

Accelerometer Low Pass Factor.

Definition at line 59 of file config.h.

Referenced by `accRead()`.

#### 5.8.2.3 `#define BANK0DDR DDRG`

First Bank Selection Data Direction Register.

Definition at line 147 of file config.h.

Referenced by `xmemInit()`.

#### 5.8.2.4 `#define BANK0PIN PG3`

First Bank Selection Pin.

Definition at line 148 of file config.h.

Referenced by `xmemInit()`, and `xmemSetBank()`.

#### 5.8.2.5 `#define BANK0PORT PORTG`

First Bank Selection Port.

Definition at line 146 of file config.h.

Referenced by `xmemInit()`, and `xmemSetBank()`.

#### 5.8.2.6 `#define BANK1DDR DDRG`

Second Bank Selection Data Direction Register.

Definition at line 150 of file config.h.

Referenced by `xmemInit()`.

#### 5.8.2.7 `#define BANK1PIN PG4`

Second Bank Selection Pin.

Definition at line 151 of file config.h.

Referenced by `xmemInit()`, and `xmemSetBank()`.

#### 5.8.2.8 `#define BANK1PORT PORTG`

Second Bank Selection Port.

Definition at line 149 of file config.h.

Referenced by `xmemInit()`, and `xmemSetBank()`.

#### 5.8.2.9 `#define BANK2DDR DDRL`

Third Bank Selection Data Direction Register.

Definition at line 153 of file config.h.

Referenced by `xmemInit()`.

#### 5.8.2.10 `#define BANK2PIN PL5`

Third Bank Selection Pin.

Definition at line 154 of file config.h.

Referenced by `xmemInit()`, and `xmemSetBank()`.

#### 5.8.2.11 `#define BANK2PORT PORTL`

Third Bank Selection Port.

Definition at line 152 of file config.h.

Referenced by `xmemInit()`, and `xmemSetBank()`.

#### 5.8.2.12 `#define BATT_CHANNEL 0`

ADC Channel for Battery.

Definition at line 114 of file config.h.

Referenced by `getVoltage()`.

#### 5.8.2.13 `#define BATT_MAX 15`

Battery Voltage Reference (ADC 5V)

Definition at line 113 of file `config.h`.

Referenced by `getVoltage()`.

#### 5.8.2.14 `#define COMPLEMENTARY_TAU 0.5`

Time Constant for Low and High Pass Filter in the [Complementary](#) Filter.

In essence, time periods shorter than TAU come from gyro data, longer time periods come from the Accelerometer data. In seconds!

Definition at line 55 of file `config.h`.

Referenced by `complementaryExecute()`.

#### 5.8.2.15 `#define DT 0.01f`

Time Constant.

Definition at line 75 of file `config.h`.

Referenced by `kalmanInnovate()`.

#### 5.8.2.16 `#define GYRO_ADDRESS 0xD6`

Gyroscope Address (110101xr, x = 1)

Definition at line 121 of file `config.h`.

Referenced by `gyroRead()`.

#### 5.8.2.17 `#define GYROFILTERFACTOR SOFTWARELOWPASS`

Gyroscope Low Pass Factor.

Definition at line 60 of file `config.h`.

Referenced by `gyroRead()`.

#### 5.8.2.18 `#define LED0DDR DDRL`

First LED Data Direction Register.

Definition at line 130 of file `config.h`.

Referenced by `xyInit()`.

#### 5.8.2.19 `#define LED0PIN PL6`

First LED Pin.

Definition at line 131 of file `config.h`.

Referenced by `xyInit()`.

#### 5.8.2.20 `#define LED0PORT PORTL`

First LED Port.

Definition at line 129 of file config.h.

#### 5.8.2.21 `#define LED1DDR DDRL`

Second LED Data Direction Register.

Definition at line 133 of file config.h.

Referenced by xyInit().

#### 5.8.2.22 `#define LED1PIN PL7`

Second LED Pin.

Definition at line 134 of file config.h.

Referenced by xyInit().

#### 5.8.2.23 `#define LED1PORT PORTL`

Second LED Port.

Definition at line 132 of file config.h.

#### 5.8.2.24 `#define LED2DDR DDRG`

Third LED Data Direction Register.

Definition at line 136 of file config.h.

Referenced by xyInit().

#### 5.8.2.25 `#define LED2PIN PG5`

Third LED Pin.

Definition at line 137 of file config.h.

Referenced by xyInit().

#### 5.8.2.26 `#define LED2PORT PORTG`

Third LED Port.

Definition at line 135 of file config.h.

#### 5.8.2.27 `#define LED3DDR DDRE`

Fourth LED Data Direction Register.

Definition at line 139 of file config.h.

Referenced by xyInit().

**5.8.2.28 #define LED3PIN PE2**

Fourth LED Pin.

Definition at line 140 of file config.h.

Referenced by xyInit().

**5.8.2.29 #define LED3PORT PORTE**

Fourth LED Port.

Definition at line 138 of file config.h.

**5.8.2.30 #define MAG\_ADDRESS 0x3C**

Magnetometer Address.

Definition at line 122 of file config.h.

Referenced by magRead().

**5.8.2.31 #define MOTOR\_BASEADDRESS 0x52**

Address of first motor controller.

Definition at line 123 of file config.h.

Referenced by motorTask().

**5.8.2.32 #define MOTORCOUNT 4**

Amount of motors.

Definition at line 107 of file config.h.

Referenced by motorInit(), motorSet(), and motorTask().

**5.8.2.33 #define ORIENTATION\_FILTER FILTER\_COMPLEMENTARY**

Filter Implementation to be used.

Definition at line 48 of file config.h.

**5.8.2.34 #define PID\_D -13.0**

Default PID D Constant.

Definition at line 101 of file config.h.

Referenced by pidInit().

**5.8.2.35 #define PID\_FACTOR 4 / 5**

Influence of PID in relation to Base Speed.

Definition at line 68 of file config.h.

**5.8.2.36 #define PID\_I 0.03**

Default PID I Constant.

Definition at line 100 of file config.h.

Referenced by pidInit().

**5.8.2.37 #define PID\_INTMAX PID\_OUTMAX**

Maximum PID Integral Sum.

Definition at line 64 of file config.h.

Referenced by pidInit().

**5.8.2.38 #define PID\_INTMIN PID\_OUTMIN**

Minimal PID Integral Sum.

Definition at line 65 of file config.h.

Referenced by pidInit().

**5.8.2.39 #define PID\_OUTMAX 256**

Maximum PID Output.

Definition at line 62 of file config.h.

Referenced by pidInit().

**5.8.2.40 #define PID\_OUTMIN -256**

Minimum PID Output.

Definition at line 63 of file config.h.

Referenced by pidInit().

**5.8.2.41 #define PID\_P 5.0**

Default PID P Constant.

Definition at line 99 of file config.h.

Referenced by pidInit().

**5.8.2.42 #define Q1 5.0f**

Q Matrix Diagonal Element 1.

Definition at line 78 of file config.h.

Referenced by kalmanInnovate().

**5.8.2.43 #define Q2 100.0f**

Q Matrix Diagonal Element 2.

Definition at line 79 of file config.h.

Referenced by kalmanInnovate().

#### 5.8.2.44 `#define Q3 0.01f`

Q Matrix Diagonal Element 3.

Definition at line 80 of file config.h.

Referenced by kalmanInnovate().

#### 5.8.2.45 `#define R1 1000.0f`

R Matrix Diagonal Element 1.

Definition at line 83 of file config.h.

Referenced by kalmanInnovate().

#### 5.8.2.46 `#define R2 1000.0f`

R Matrix Diagonal Element 2.

Definition at line 84 of file config.h.

Referenced by kalmanInnovate().

#### 5.8.2.47 `#define RX_BUFFER_SIZE 64`

UART Receive Buffer Size.

Definition at line 169 of file config.h.

#### 5.8.2.48 `#define SET_PITCHMINUS 2`

Third Motor at the Bottom.

Definition at line 93 of file config.h.

#### 5.8.2.49 `#define SET_PITCHPLUS 0`

First Motor at the Top.

Definition at line 92 of file config.h.

#### 5.8.2.50 `#define SET_ROLLMINUS 3`

Fourth Motor at the Left.

Definition at line 91 of file config.h.

Referenced by setMotorSpeeds().

#### 5.8.2.51 `#define SET_ROLLPLUS 1`

Second Motor at the Right.

Definition at line 90 of file config.h.

Referenced by setMotorSpeeds().

**5.8.2.52 #define SOFTWARELOWPASS 1**

Software Low-Pass on Gyro and ACC.

Definition at line 58 of file config.h.

**5.8.2.53 #define SPISS PB0**

SPI Slave Select Pin.

Definition at line 163 of file config.h.

**5.8.2.54 #define TX\_BUFFER\_SIZE 64**

UART Transmit Buffer Size.

Definition at line 170 of file config.h.



## 5.9 Debug Output

Allows debug output and assert usage.

### Files

- file `debug.h`  
*Debug and Assert Header and Implementation.*

### Macros

- `#define DEBUGOUT(x) printf(x)`  
*Debug Output Function.*
- `#define ASSERTFUNC(x)`  
*Simple Assert Implementation.*
- `#define assert(x) ASSERTFUNC(x)`  
*Enable `assert()`*
- `#define debugPrint(ignore)`  
*Disable `debugPrint()`*

#### 5.9.1 Detailed Description

Allows debug output and assert usage. Usage: Before including this file, define `DEBUG` as the debuglevel, eg:

```
#define DEBUG 1
```

for debuglevel 1. Then use `debugPrint("Foo")` in your code. If you need to calculate stuff for your debug output, enclose it:

```
#if DEBUG >= 1
    debugPrint("Bar");
#endif
```

#### 5.9.2 Macro Definition Documentation

##### 5.9.2.1 `#define assert( x ) ASSERTFUNC(x)`

Enable `assert()`

Definition at line 88 of file `debug.h`.

##### 5.9.2.2 `#define ASSERTFUNC( x )`

Simple Assert Implementation.

Definition at line 67 of file `debug.h`.

##### 5.9.2.3 `#define DEBUGOUT( x ) printf(x)`

Debug Output Function.

Definition at line 64 of file `debug.h`.

#### 5.9.2.4 `#define debugPrint( ignore )`

Disable `debugPrint()`

Definition at line 96 of file `debug.h`.

## 5.10 Error Reporting

Error reporting with human readable strings.

### Files

- file `error.h`  
*Global listing of different error conditions.*

### Macros

- `#define CHECKERROR(x) if(x!=SUCCESS){return x;}`  
*Check an Error Code.*
- `#define REPORTERROR(x)`  
*Report an error, if it occurred.*

### Enumerations

- enum `Error` {  
    `SUCCESS = 0, TWI_NO_ANSWER, TWI_WRITE_ERROR, MALLOC_FAIL,`  
    `ERROR, ARGUMENT_ERROR` }  
*Error Conditions.*

### Functions

- `char * getErrorString (Error e)`  
*Returns a human-readable error description.*

#### 5.10.1 Detailed Description

Error reporting with human readable strings.

#### 5.10.2 Macro Definition Documentation

##### 5.10.2.1 `#define CHECKERROR( x ) if(x!=SUCCESS){return x;}`

Check an Error Code.

Return it if an error occurred.

Definition at line 56 of file `error.h`.

Referenced by `orientationInit()`, and `orientationTask()`.

##### 5.10.2.2 `#define REPORTERROR( x )`

#### Value:

```
{ \
    if (x != SUCCESS) { \
        char *s = getErrorString(x); \
        printf("Error: %s\n", s); \
        free(s); \
    } \
}
```

Report an error, if it occurred.

Using printf()

Examples:

[uartFlight.c](#).

Definition at line 59 of file error.h.

## 5.10.3 Enumeration Type Documentation

### 5.10.3.1 enum Error

Error Conditions.

Enumerator

**SUCCESS** No Error.  
**TWI\_NO\_ANSWER** No answer from TWI Slave.  
**TWI\_WRITE\_ERROR** Error while writing to TWI Slave.  
**MALLOC\_FAIL** Malloc failed.  
**ERROR** General Error.  
**ARGUMENT\_ERROR** Invalid arguments.

Definition at line 46 of file error.h.

```

46      {
47          SUCCESS = 0,
48          TWI_NO_ANSWER,
49          TWI_WRITE_ERROR,
50          MALLOC_FAIL,
51          ERROR,
52          ARGUMENT_ERROR,
53 } Error;
```

## 5.10.4 Function Documentation

### 5.10.4.1 char\* getErrorString ( Error e )

Returns a human-readable error description.

Free the string after use!

Definition at line 58 of file error.c.

References errorTable.

```

58      {
59          char *buff = (char *)malloc(strlen_P((PGM_P)pgm_read_word(&(errorTable[e]))));
60          if (buff == NULL) {
61              return NULL;
62          }
63          strcpy_P(buff, (PGM_P)pgm_read_word(&(errorTable[e])));
64          return buff;
65      }
```

## 5.11 Gyroscope Driver

Configuring and reading an L3GD20.

### Files

- file [gyro.h](#)  
*L3GD20 Gyroscope API Header.*
- file [gyro.c](#)  
*L3GD20 Gyroscope API Implementation.*

### Macros

- `#define GYROREG_CTRL1 0x20`  
*Gyroscope Control Register 1.*
- `#define GYROREG_CTRL4 0x23`  
*Gyroscope Control Register 4.*
- `#define GYROREG_OUTXL 0x28`  
*First Gyroscope Output Register.*

### Enumerations

- enum [GyroRange](#) { `r250DPS`, `r500DPS`, `r2000DPS` }  
*Gyroscope Range options.*

### Functions

- [Error gyroInit](#) ([GyroRange](#) r)  
*Initializes the Gyroscope.*
- [Error gyroRead](#) ([Vector3f](#) \*v)  
*Get a set of gyroscope data.*
- [Error gyroWriteByte](#) ([uint8\\_t](#) reg, [uint8\\_t](#) val)  
*Write a Gyroscope Register.*

### Variables

- [GyroRange gyroRange](#)  
*Stored range to scale returned values.*

#### 5.11.1 Detailed Description

Configuring and reading an L3GD20.

#### 5.11.2 Macro Definition Documentation

##### 5.11.2.1 `#define GYROREG_CTRL1 0x20`

Gyroscope Control Register 1.

Definition at line 48 of file gyro.c.

Referenced by gyroInit().

#### 5.11.2.2 #define GYROREG\_CTRL4 0x23

Gyroscope Control Register 4.

Definition at line 49 of file gyro.c.

Referenced by gyroInit().

#### 5.11.2.3 #define GYROREG\_OUTXL 0x28

First Gyroscope Output Register.

Definition at line 50 of file gyro.c.

Referenced by gyroRead().

### 5.11.3 Enumeration Type Documentation

#### 5.11.3.1 enum GyroRange

Gyroscope Range options.

Enumerator

***r250DPS*** +- 250 Degrees per Second  
***r500DPS*** +- 500 Degrees per Second  
***r2000DPS*** +- 2000 Degrees per Second

Definition at line 47 of file gyro.h.

```

47      {
48          r250DPS,
49          r500DPS,
50          r2000DPS,
51      } GyroRange;
```

### 5.11.4 Function Documentation

#### 5.11.4.1 Error gyroInit ( GyroRange r )

Initializes the Gyroscope.

I2C should already be initialized.

Parameters

<i>r</i>	<a href="#">GyroRange</a> to use
----------	----------------------------------

Returns

[TWI\\_NO\\_ANSWER](#), [TWI\\_WRITE\\_ERROR](#), [ARGUMENT\\_ERROR](#) or [SUCCESS](#)

Definition at line 75 of file gyro.c.

References [ARGUMENT\\_ERROR](#), [gyroRange](#), [GYROREG\\_CTRL1](#), [GYROREG\\_CTRL4](#), [gyroWriteByte\(\)](#), [r2000DPS](#), [r250DPS](#), [r500DPS](#), and [SUCCESS](#).

Referenced by [orientationInit\(\)](#).

```

75      {
```

```

76     uint8_t v;
77     switch (r) {
78         case r250DPS:
79             v = 0x00;
80             break;
81         case r500DPS:
82             v = 0x10;
83             break;
84         case r2000DPS:
85             v = 0x20;
86             break;
87         default:
88             return ARGUMENT_ERROR;
89     }
90     gyroRange = r;
91     Error e = gyroWriteByte(GYROREG_CTRL1, 0x0F);
92     if (e != SUCCESS) {
93         return e;
94     }
95     e = gyroWriteByte(GYROREG_CTRL4, v);
96     return e;
97 }

```

#### 5.11.4.2 Error gyroRead ( Vector3f \* v )

Get a set of gyroscope data.

[gyroInit\(\)](#) should already be called.

##### Parameters

v	Data Destination
---	------------------

##### Returns

[TWI\\_NO\\_ANSWER](#), [TWI\\_WRITE\\_ERROR](#), [ARGUMENT\\_ERROR](#) or [SUCCESS](#)

Definition at line 99 of file gyro.c.

References [ARGUMENT\\_ERROR](#), [GYRO\\_ADDRESS](#), [GYROFILTERFACTOR](#), [gyroRange](#), [GYROREG\\_OUTXL](#), [r2000DPS](#), [r250DPS](#), [r500DPS](#), [SUCCESS](#), [TWI\\_NO\\_ANSWER](#), [TWI\\_READ](#), [TWI\\_WRITE](#), [TWI\\_WRITE\\_ERROR](#), [twiReadAck\(\)](#), [twiReadNak\(\)](#), [twiRepStart\(\)](#), [twiStart\(\)](#), [twiWrite\(\)](#), [Vector3f::x](#), [Vector3f::y](#), and [Vector3f::z](#).

Referenced by [orientationTask\(\)](#).

```

99     {
100     // Simple Software Low-Pass
101     static double gyroSumX = 0, gyroSumY = 0, gyroSumZ = 0;
102     static double gyroFilterX = 0, gyroFilterY = 0, gyroFilterZ = 0;
103
104     if (v == NULL) {
105         return ARGUMENT_ERROR;
106     }
107     if (twiStart(GYRO_ADDRESS | TWI_WRITE)) {
108         return TWI_NO_ANSWER;
109     }
110     if (twiWrite(GYROREG_OUTXL | 0x80)) { // Auto Increment
111         return TWI_WRITE_ERROR;
112     }
113     if (twiRepStart(GYRO_ADDRESS | TWI_READ)) {
114         return TWI_NO_ANSWER;
115     }
116
117     uint8_t xl = twiReadAck();
118     uint8_t xh = twiReadAck();
119     uint8_t yl = twiReadAck();
120     uint8_t yh = twiReadAck();
121     uint8_t zl = twiReadAck();
122     uint8_t zh = twiReadNak();
123
124     int16_t x = *(int8_t *)(&xh);
125     x *= (1 << 8);
126     x |= xl;
127
128     int16_t y = *(int8_t *)(&yh);

```

```

129     y *= (1 << 8);
130     y |= y1;
131
132     int16_t z = *(int8_t *)(&z);
133     z *= (1 << 8);
134     z |= z1;
135
136     switch (gyroRange) {
137     case r250DPS:
138         v->x = (((double)x) * 250 / 0x8000);
139         v->y = (((double)y) * 250 / 0x8000);
140         v->z = (((double)z) * 250 / 0x8000);
141         break;
142     case r500DPS:
143         v->x = (((double)x) * 500 / 0x8000);
144         v->y = (((double)y) * 500 / 0x8000);
145         v->z = (((double)z) * 500 / 0x8000);
146         break;
147     case r2000DPS:
148         v->x = (((double)x) * 2000 / 0x8000);
149         v->y = (((double)y) * 2000 / 0x8000);
150         v->z = (((double)z) * 2000 / 0x8000);
151         break;
152     default:
153         return ARGUMENT_ERROR;
154     }
155
156     gyroSumX = gyroSumX - gyroFilterX + v->x;
157     gyroFilterX = gyroSumX / GYROFILTERFACTOR;
158     v->x = gyroFilterX;
159
160     gyroSumY = gyroSumY - gyroFilterY + v->y;
161     gyroFilterY = gyroSumY / GYROFILTERFACTOR;
162     v->y = gyroFilterY;
163
164     gyroSumZ = gyroSumZ - gyroFilterZ + v->z;
165     gyroFilterZ = gyroSumZ / GYROFILTERFACTOR;
166     v->z = gyroFilterZ;
167
168     return SUCCESS;
169 }

```

#### 5.11.4.3 Error gyroWriteByte ( uint8\_t reg, uint8\_t val )

Write a Gyroscope Register.

I2C should already be initialized!

##### Parameters

<i>reg</i>	Register Address
<i>val</i>	New Value

##### Returns

[TWI\\_NO\\_ANSWER](#), [TWI\\_WRITE\\_ERROR](#) or [SUCCESS](#).

Definition at line 61 of file gyro.c.

References [TWI\\_NO\\_ANSWER](#).

Referenced by [gyroInit\(\)](#).

```

61
62     if (twiStart(GYRO_ADDRESS | TWI_WRITE)) {
63         return TWI_NO_ANSWER;
64     }
65     if (twiWrite(reg)) {
66         return TWI_WRITE_ERROR;
67     }
68     if (twiWrite(val)) {
69         return TWI_WRITE_ERROR;
70     }
71     twiStop();
72     return SUCCESS;
73 }

```



### 5.11.5 Variable Documentation

#### 5.11.5.1 GyroRange gyroRange

Stored range to scale returned values.

Definition at line 52 of file gyro.c.

Referenced by gyroInit(), and gyroRead().

## 5.12 Kalman-Filter

Kalman-Filter from [Linus Helgesson](#)

### Files

- file [kalman.h](#)  
*Kalman-Filter Header.*
- file [kalman.c](#)  
*Kalman-Filter Implementation.*

### Data Structures

- struct [Kalman](#)  
*Kalman-Filter State data.*

### Functions

- void [kalmanInnovate](#) ([Kalman](#) \*data, double z1, double z2)  
*Step the Kalman Filter.*
- void [kalmanInit](#) ([Kalman](#) \*data)  
*Initialize a Kalman-State.*

#### 5.12.1 Detailed Description

Kalman-Filter from [Linus Helgesson](#)

#### 5.12.2 Function Documentation

##### 5.12.2.1 void kalmanInit ( Kalman \* data )

Initialize a Kalman-State.

#### Parameters

<i>data</i>	Kalman-State to be initialized
-------------	--------------------------------

Definition at line 48 of file kalman.c.

References [Kalman::p33](#), and [Kalman::x3](#).

Referenced by [orientationInit\(\)](#).

```

48                                     {
49     data->x1 = 0.0f;
50     data->x2 = 0.0f;
51     data->x3 = 0.0f;
52
53     // Init P to diagonal matrix with large values since
54     // the initial state is not known
55     data->p11 = 1000.0f;
56     data->p12 = 0.0f;
57     data->p13 = 0.0f;
58     data->p21 = 0.0f;
59     data->p22 = 1000.0f;
60     data->p23 = 0.0f;
61     data->p31 = 0.0f;
62     data->p32 = 0.0f;
63     data->p33 = 1000.0f;

```

64 }

## 5.12.2.2 void kalmanInnovate ( Kalman \* data, double z1, double z2 )

Step the [Kalman](#) Filter.

## Parameters

<i>data</i>	Kalman-Filter State
<i>z1</i>	Angle from Accelerometer
<i>z2</i>	Corresponding Gyroscope data

Definition at line 66 of file kalman.c.

References DT, Kalman::p33, Q1, Q2, Q3, R1, R2, and Kalman::x3.

Referenced by orientationTask().

```

66                                     {
67     double y1, y2;
68     double a, b, c;
69     double sDet;
70     double s11, s12, s21, s22;
71     double k11, k12, k21, k22, k31, k32;
72     double p11, p12, p13, p21, p22, p23, p31, p32, p33;
73
74     // Step 1
75     // x(k) = Fx(k-1) + Bu + w;
76     data->x1 = data->x1 + DT*data->x2 - DT*data->x3;
77     //x2 = x2;
78     //x3 = x3;
79
80     // Step 2
81     // P = FPF' + Q
82     a = data->p11 + data->p21*DT - data->p31*DT;
83     b = data->p12 + data->p22*DT - data->p32*DT;
84     c = data->p13 + data->p23*DT - data->p33*DT;
85     data->p11 = a + b*DT - c*DT + Q1;
86     data->p12 = b;
87     data->p13 = c;
88     data->p21 = data->p21 + data->p22*DT - data->p23*DT;
89     data->p22 = data->p22 + Q2;
90     //p23 = p23;
91     data->p31 = data->p31 + data->p32*DT - data->p33*DT;
92     //p32 = p32;
93     data->p33 = data->p33 + Q3;
94
95     // Step 3
96     // y = z(k) - Hx(k)
97     y1 = z1-data->x1;
98     y2 = z2-data->x2;
99
100    // Step 4
101    // S = HPT' + R
102    s11 = data->p11 + R1;
103    s12 = data->p12;
104    s21 = data->p21;
105    s22 = data->p22 + R2;
106
107    // Step 5
108    // K = PH*inv(S)
109    sDet = 1/(s11*s22 - s12*s21);
110    k11 = (data->p11*s22 - data->p12*s21)*sDet;
111    k12 = (data->p12*s11 - data->p11*s12)*sDet;
112    k21 = (data->p21*s22 - data->p22*s21)*sDet;
113    k22 = (data->p22*s11 - data->p21*s12)*sDet;
114    k31 = (data->p31*s22 - data->p32*s21)*sDet;
115    k32 = (data->p32*s11 - data->p31*s12)*sDet;
116
117    // Step 6
118    // x = x + Ky
119    data->x1 = data->x1 + k11*y1 + k12*y2;
120    data->x2 = data->x2 + k21*y1 + k22*y2;
121    data->x3 = data->x3 + k31*y1 + k32*y2;
122
123    // Step 7
124    // P = (I-KH)P
125    p11 = data->p11*(1.0f - k11) - data->p21*k12;

```

```
126     p12 = data->p12*(1.0f - k11) - data->p22*k12;  
127     p13 = data->p13*(1.0f - k11) - data->p23*k12;  
128     p21 = data->p21*(1.0f - k22) - data->p11*k21;  
129     p22 = data->p22*(1.0f - k22) - data->p12*k21;  
130     p23 = data->p23*(1.0f - k22) - data->p13*k21;  
131     p31 = data->p31 - data->p21*k32 - data->p11*k31;  
132     p32 = data->p32 - data->p22*k32 - data->p12*k31;  
133     p33 = data->p33 - data->p22*k32 - data->p13*k31;  
134     data->p11 = p11; data->p12 = p12; data->p13 = p13;  
135     data->p21 = p21; data->p22 = p22; data->p23 = p23;  
136     data->p31 = p31; data->p32 = p32; data->p33 = p33;  
137 }
```

## 5.13 Magnetometer Driver

Configuring and reading an LSM303DLHC Magnetometer.

### Files

- file [mag.h](#)  
*LSM303DLHC Magnetometer API Header.*
- file [mag.c](#)  
*LSM303DLHC Magnetometer API Implementation.*

### Macros

- `#define MAGREG_CRB 0x01`  
*Magnetometer Gain Register.*
- `#define MAGREG_MR 0x02`  
*Magnetometer Mode Register.*
- `#define MAGREG_XH 0x03`  
*First Magnetometer Output Register.*

### Enumerations

- enum [MagRange](#) {  
    [r1g3](#) = 1, [r1g9](#) = 2, [r2g5](#) = 3, [r4g0](#) = 4,  
    [r4g7](#) = 5, [r5g6](#) = 6, [r8g1](#) = 7 }  
*Magnetometer Range options.*

### Functions

- [Error magInit](#) ([MagRange](#) r)  
*Initialize the Magnetometer.*
- [Error magRead](#) ([Vector3f](#) \*v)  
*Read from the Magnetometer.*
- [Error magWriteRegister](#) (uint8\_t reg, uint8\_t val)  
*Write a Magnetometer Register.*

#### 5.13.1 Detailed Description

Configuring and reading an LSM303DLHC Magnetometer.

#### 5.13.2 Macro Definition Documentation

##### 5.13.2.1 `#define MAGREG_CRB 0x01`

Magnetometer Gain Register.

Definition at line 48 of file [mag.c](#).

Referenced by [magInit\(\)](#).

#### 5.13.2.2 `#define MAGREG_MR 0x02`

Magnetometer Mode Register.

Definition at line 49 of file mag.c.

Referenced by `magInit()`.

#### 5.13.2.3 `#define MAGREG_XH 0x03`

First Magnetometer Output Register.

Definition at line 50 of file mag.c.

Referenced by `magRead()`.

### 5.13.3 Enumeration Type Documentation

#### 5.13.3.1 `enum MagRange`

Magnetometer Range options.

Enumerator

***r1g3*** +- 1.3 Gauss

***r1g9*** +- 1.9 Gauss

***r2g5*** +- 2.5 Gauss

***r4g0*** +- 4.0 Gauss

***r4g7*** +- 4.7 Gauss

***r5g6*** +- 5.6 Gauss

***r8g1*** +- 8.1 Gauss

Definition at line 47 of file mag.h.

```

47     {
48     r1g3 = 1,
49     r1g9 = 2,
50     r2g5 = 3,
51     r4g0 = 4,
52     r4g7 = 5,
53     r5g6 = 6,
54     r8g1 = 7,
55 } MagRange;
```

### 5.13.4 Function Documentation

#### 5.13.4.1 Error `magInit ( MagRange r )`

Initialize the Magnetometer.

Call before `magRead()`. I2C should already be initialized!

Parameters

<i>r</i>	<code>MagRange</code> to use.
----------	-------------------------------

**Returns**

[TWI\\_NO\\_ANSWER](#), [TWI\\_WRITE\\_ERROR](#), [ARGUMENT\\_ERROR](#) or [SUCCESS](#).

Definition at line 73 of file mag.c.

References [ARGUMENT\\_ERROR](#), [MAGREG\\_CRB](#), [MAGREG\\_MR](#), [magWriteRegister\(\)](#), and [SUCCESS](#).

Referenced by [orientationInit\(\)](#).

```

73     {
74     if ((r <= 0) || (r >= 8)) {
75         return ARGUMENT_ERROR;
76     }
77     Error e = magWriteRegister(MAGREG_MR, 0x00); // Continuous Conversion
78     if (e != SUCCESS) {
79         return e;
80     }
81     e = magWriteRegister(MAGREG_CRB, (r << 5)); // Set Range
82     return e;
83 }
```

**5.13.4.2 Error magRead ( Vector3f \* v )**

Read from the Magnetometer.

Magnetometer should already be initialized!

**Parameters**

<b>v</b>	<a href="#">Vector3f</a> for the read values
----------	--

**Returns**

[TWI\\_NO\\_ANSWER](#), [TWI\\_WRITE\\_ERROR](#), [ARGUMENT\\_ERROR](#) or [SUCCESS](#).

Definition at line 85 of file mag.c.

References [ARGUMENT\\_ERROR](#), [MAG\\_ADDRESS](#), [MAGREG\\_XH](#), [SUCCESS](#), [TWI\\_NO\\_ANSWER](#), [TWI\\_READ](#), [TWI\\_WRITE](#), [TWI\\_WRITE\\_ERROR](#), [twiReadAck\(\)](#), [twiReadNak\(\)](#), [twiRepStart\(\)](#), [twiStart\(\)](#), [twiWrite\(\)](#), [Vector3f::x](#), [Vector3f::y](#), and [Vector3f::z](#).

```

85     {
86     if (v == NULL) {
87         return ARGUMENT_ERROR;
88     }
89     if (twiStart(MAG_ADDRESS | TWI_WRITE)) {
90         return TWI_NO_ANSWER;
91     }
92     if (twiWrite(MAGREG_XH)) {
93         return TWI_WRITE_ERROR;
94     }
95     if (twiRepStart(MAG_ADDRESS | TWI_READ)) {
96         return TWI_NO_ANSWER;
97     }
98     uint8_t xh = twiReadAck();
99     uint8_t xl = twiReadAck();
100    uint8_t zh = twiReadAck();
101    uint8_t zl = twiReadAck();
102    uint8_t yh = twiReadAck();
103    uint8_t yl = twiReadNak();
104
105    v->x = (int16_t)(xh << 8 | xl);
106    v->y = (int16_t)(yh << 8 | yl);
107    v->z = (int16_t)(zh << 8 | zl);
108    return SUCCESS;
109 }
```

**5.13.4.3 Error magWriteRegister ( uint8\_t reg, uint8\_t val )**

Write a Magnetometer Register.

I2C should already be initialized!

#### Parameters

<i>reg</i>	Register Address
<i>val</i>	New Value

#### Returns

[TWI\\_NO\\_ANSWER](#), [TWI\\_WRITE\\_ERROR](#) or [SUCCESS](#).

Definition at line 59 of file mag.c.

References [TWI\\_NO\\_ANSWER](#).

Referenced by [magInit\(\)](#).

```
59                                     {
60     if (twiStart(MAG_ADDRESS | TWI_WRITE)) {
61         return TWI_NO_ANSWER;
62     }
63     if (twiWrite(reg)) {
64         return TWI_WRITE_ERROR;
65     }
66     if (twiWrite(val)) {
67         return TWI_WRITE_ERROR;
68     }
69     twiStop();
70     return SUCCESS;
71 }
```



## 5.14 Motor Controller Driver

Controlling four **BL-Ctrl V1.2** Brushless controllers.

### Files

- file [motor.h](#)  
*BL-Ctrl V1.2 Controller API Header.*
- file [motor.c](#)  
*BL-Ctrl V1.2 Controller API Implementation.*

### Functions

- void [motorInit](#) (void)  
*Initializes the motor control library.*
- void [motorSet](#) (uint8\_t id, uint8\_t speed)  
*Set the speed of one or all motors.*
- void [motorTask](#) (void)  
*Send the values stored in [motorSpeed](#) to the Controllers.*

### Variables

- uint8\_t [motorSpeed](#) [[MOTORCOUNT](#)]  
*Speed for the four motors.*
- uint8\_t [motorSpeed](#) [[MOTORCOUNT](#)]  
*Speed for the four motors.*

#### 5.14.1 Detailed Description

Controlling four **BL-Ctrl V1.2** Brushless controllers.

#### 5.14.2 Function Documentation

##### 5.14.2.1 void motorInit ( void )

Initializes the motor control library.

Really only sets motorSpeed to zero.

Examples:

[uartFlight.c](#).

Definition at line 58 of file motor.c.

References [MOTORCOUNT](#), and [motorSpeed](#).

```

58         {
59     for (uint8_t i = 0; i < MOTORCOUNT; i++) {
60         motorSpeed[i] = 0;
61     }
62 }
```

#### 5.14.2.2 void motorSet ( uint8\_t id, uint8\_t speed )

Set the speed of one or all motors.

##### Parameters

<i>id</i>	Motor ID (0 to 3, 4 = all)
<i>speed</i>	New Speed

Definition at line 64 of file motor.c.

References MOTORCOUNT, and motorSpeed.

Referenced by setMotorSpeeds().

```

64                                     {
65     if (id < MOTORCOUNT) {
66         motorSpeed[id] = speed;
67     } else {
68         for (id = 0; id < MOTORCOUNT; id++) {
69             motorSpeed[id] = speed;
70         }
71     }
72 }
```

#### 5.14.2.3 void motorTask ( void )

Send the values stored in [motorSpeed](#) to the Controllers.

I2C already has to be initialized!

##### Examples:

[uartFlight.c](#).

Definition at line 50 of file motor.c.

References MOTOR\_BASEADDRESS, MOTORCOUNT, motorSpeed, TWI\_WRITE, twiStart(), twiStop(), and twiWrite().

```

50                                     {
51     for (uint8_t i = 0; i < MOTORCOUNT; i++) {
52         twiStart(MOTOR_BASEADDRESS + (i << 1) +
53         TWI_WRITE);
54         twiWrite(motorSpeed[i]);
55         twiStop();
56     }
```

### 5.14.3 Variable Documentation

#### 5.14.3.1 uint8\_t motorSpeed[MOTORCOUNT]

Speed for the four motors.

##### Examples:

[uartFlight.c](#).

Definition at line 48 of file motor.c.

Referenced by motorInit(), motorSet(), and motorTask().

#### 5.14.3.2 `uint8_t motorSpeed[MOTORCOUNT]`

Speed for the four motors.

Definition at line 48 of file `motor.c`.

Referenced by `motorInit()`, `motorSet()`, and `motorTask()`.

## 5.15 Orientation Calculation

Calculate Orientation using the Kalman-Filter, Accelerometer and Gyroscope.

### Files

- file [orientation.h](#)  
*Orientation API Header.*
- file [orientation.c](#)  
*Orientation API Implementation.*

### Data Structures

- struct [Angles](#)  
*Can store orientation in Euler Space.*

### Macros

- `#define TODEG(x) ((x * 180) / M_PI)`  
*Convert Radians to Degrees.*

### Functions

- [Error orientationInit](#) (void)  
*Initializes the Orientation API.*
- [Error orientationTask](#) (void)  
*Calculate the current orientation.*
- void [zeroOrientation](#) (void)  
*Sets the current orientation to zero.*

### Variables

- [Angles orientation](#)  
*Current Aircraft orientation.*
- [Angles orientation](#) = {.pitch = 0, .roll = 0, .yaw = 0}  
*Current Aircraft orientation.*
- [Angles orientationError](#) = {.pitch = 0, .roll = 0, .yaw = 0}  
*Current Aircraft orientation offset.*
- [Kalman pitchData](#)  
*Kalman-State for Pitch Angle.*
- [Kalman rollData](#)  
*Kalman-State for Roll Angle.*

#### 5.15.1 Detailed Description

Calculate Orientation using the Kalman-Filter, Accelerometer and Gyroscope.

## 5.15.2 Macro Definition Documentation

### 5.15.2.1 #define TODEG( x ) ((x \* 180) / M\_PI)

Convert Radians to Degrees.

Definition at line 55 of file orientation.c.

Referenced by orientationTask().

## 5.15.3 Function Documentation

### 5.15.3.1 Error orientationInit ( void )

Initializes the Orientation API.

Also initializes the Accelerometer, Gyroscope and Magnetometer. I2C should already be initialized!

Returns

[TWI\\_NO\\_ANSWER](#), [TWI\\_WRITE\\_ERROR](#), [ARGUMENT\\_ERROR](#) or [SUCCESS](#).

Examples:

[uartFlight.c](#).

Definition at line 73 of file orientation.c.

References [accInit\(\)](#), [CHECKERROR](#), [complementaryInit\(\)](#), [gyroInit\(\)](#), [kalmanInit\(\)](#), [magInit\(\)](#), [r1g9](#), [r250DPS](#), [r4G](#), and [SUCCESS](#).

```

73     {
74         Error e = accInit(r4G);
75         CHECKERROR(e);
76         e = gyroInit(r250DPS);
77         CHECKERROR(e);
78         e = magInit(r1g9);
79         CHECKERROR(e);
80
81         #if ORIENTATION_FILTER == FILTER_KALMAN
82             kalmanInit(&pitchData);
83             kalmanInit(&rollData);
84         #elif ORIENTATION_FILTER == FILTER_COMPLEMENTARY
85             complementaryInit(&pitchData);
86             complementaryInit(&rollData);
87         #endif
88
89         return SUCCESS;
90     }
```

### 5.15.3.2 Error orientationTask ( void )

Calculate the current orientation.

It will be stored in the global [orientation](#) Struct.

Returns

[TWI\\_NO\\_ANSWER](#), [TWI\\_WRITE\\_ERROR](#), [ARGUMENT\\_ERROR](#) or [SUCCESS](#).

Examples:

[uartFlight.c](#).

Definition at line 92 of file orientation.c.

References [accRead\(\)](#), [CHECKERROR](#), [complementaryExecute\(\)](#), [gyroRead\(\)](#), [kalmanInnovate\(\)](#), [orientation](#), [Angles::pitch](#), [Angles::roll](#), [SUCCESS](#), [TODEG](#), [Vector3f::x](#), [Vector3f::y](#), and [Vector3f::z](#).

```

92     {
93     Vector3f g, a;
94     Error e = accRead(&a); // Read Accelerometer
95     CHECKERROR(e);
96     e = gyroRead(&g); // Read Gyroscope
97     CHECKERROR(e);
98
99     // Calculate Pitch & Roll from Accelerometer Data
100    double roll = atan(a.x / hypot(a.y, a.z));
101    double pitch = atan(a.y / hypot(a.x, a.z));
102    roll = TODEG(roll);
103    pitch = TODEG(pitch); // As Degree, not radians!
104
105    // Filter Roll and Pitch with Gyroscope Data from the corresponding axis
106    #if ORIENTATION_FILTER == FILTER_KALMAN
107    kalmanInnovate(&pitchData, pitch, g.x);
108    kalmanInnovate(&rollData, roll, g.y);
109    orientation.roll = rollData.x1;
110    orientation.pitch = pitchData.x1;
111    #elif ORIENTATION_FILTER == FILTER_COMPLEMENTARY
112    complementaryExecute(&pitchData, pitch, g.x);
113    complementaryExecute(&rollData, roll, g.y);
114    orientation.roll = rollData.angle;
115    orientation.pitch = pitchData.angle;
116    #endif
117
118    // Zero Offset for angles
119    orientation.roll -= orientationError.roll;
120    orientation.pitch -= orientationError.pitch;
121
122    //orientation.roll = round(orientation.roll * 10) / 10;
123    //orientation.pitch = round(orientation.pitch * 10) / 10;
124
125    return SUCCESS;
126 }

```

### 5.15.3.3 void zeroOrientation ( void )

Sets the current orientation to zero.

Examples:

[uartFlight.c](#).

Definition at line 128 of file orientation.c.

References orientation, Angles::pitch, Angles::roll, and Angles::yaw.

```

128     {
129     orientationError.roll = orientation.roll +
orientationError.roll;
130     orientationError.pitch = orientation.pitch +
orientationError.pitch;
131     orientationError.yaw = orientation.yaw +
orientationError.yaw;
132 }

```

## 5.15.4 Variable Documentation

### 5.15.4.1 Angles orientation

Current Aircraft orientation.

Examples:

[uartFlight.c](#).

Definition at line 58 of file orientation.c.

Referenced by orientationTask(), pidTask(), and zeroOrientation().

**5.15.4.2 Angles orientation = { .pitch = 0, .roll = 0, .yaw = 0 }**

Current Aircraft orientation.

Definition at line 58 of file orientation.c.

Referenced by orientationTask(), pidTask(), and zeroOrientation().

**5.15.4.3 Angles orientationError = { .pitch = 0, .roll = 0, .yaw = 0 }**

Current Aircraft orientation offset.

Definition at line 61 of file orientation.c.

**5.15.4.4 Kalman pitchData**

Kalman-State for Pitch Angle.

Definition at line 64 of file orientation.c.

**5.15.4.5 Kalman rollData**

Kalman-State for Roll Angle.

Definition at line 65 of file orientation.c.

## 5.16 PID-Controller

Simple implementation for multiple floating-point PID Controllers.

### Files

- file [pid.h](#)  
*PID Library Header.*
- file [pid.c](#)  
*PID Library Implementation.*

### Data Structures

- struct [PIDState](#)  
*Data Structure for a single PID Controller.*

### Macros

- `#define ROLL 0`  
*Roll index for [o\\_should](#), [o\\_output](#) and [o\\_pids](#).*
- `#define PITCH 1`  
*Pitch index for [o\\_should](#), [o\\_output](#) and [o\\_pids](#).*

### Functions

- void [pidInit](#) (void)  
*Initialize Roll and Pitch PID.*
- void [pidTask](#) (void)  
*Step the Roll and Pitch PID Controllers.*
- void [pidSet](#) ([PIDState](#) \*pid, double kp, double ki, double kd, double min, double max, double iMin, double iMax)  
*Set the parameters of a PID controller.*
- double [pidExecute](#) (double should, double is, [PIDState](#) \*state)  
*Execute a single PID Control Step.*

### Variables

- double [o\\_should](#) [2]  
*Roll and Pitch target angles.*
- double [o\\_output](#) [2]  
*Roll and Pitch PID Output.*
- [PIDState](#) [o\\_pids](#) [2]  
*Roll and Pitch PID States.*
- [PIDState](#) [o\\_pids](#) [2]  
*Roll and Pitch PID States.*
- double [o\\_should](#) [2]  
*Roll and Pitch target angles.*
- double [o\\_output](#) [2]  
*Roll and Pitch PID Output.*



### 5.16.1 Detailed Description

Simple implementation for multiple floating-point PID Controllers.

### 5.16.2 Macro Definition Documentation

#### 5.16.2.1 `#define PITCH 1`

Pitch index for `o_should`, `o_output` and `o_pids`.

Examples:

`uartFlight.c`.

Definition at line 61 of file `pid.h`.

Referenced by `pidTask()`.

#### 5.16.2.2 `#define ROLL 0`

Roll index for `o_should`, `o_output` and `o_pids`.

Examples:

`uartFlight.c`.

Definition at line 60 of file `pid.h`.

Referenced by `pidTask()`.

### 5.16.3 Function Documentation

#### 5.16.3.1 `double pidExecute ( double should, double is, PIDState * state )`

Execute a single PID Control Step.

Parameters

<i>should</i>	Target value
<i>is</i>	Measured value
<i>state</i>	PID State

Returns

PID Output

Definition at line 54 of file `pid.c`.

References `getSystemTime()`, `PIDState::intMax`, `PIDState::intMin`, `PIDState::kd`, `PIDState::ki`, `PIDState::kp`, `PIDState::last`, `PIDState::lastError`, `PIDState::outMax`, `PIDState::outMin`, and `PIDState::sumError`.

Referenced by `pidTask()`.

```

54                                     {
55     time_t now = getSystemTime();
56     double timeChange = (double)(now - state->last);
57     double error = should - is;
58     double newErrorSum = state->sumError + (error * timeChange);
59     if ((newErrorSum >= state->intMin) && (newErrorSum <= state->intMax))

```

```

60     state->sumError = newErrorSum; // Prevent Integral Windup
61     double dError = (error - state->lastError) / timeChange;
62     double output = (state->kp * error) + (state->ki * state->sumError) + (state->
kd * dError);
63     state->lastError = error;
64     state->last = now;
65     if (output > state->outMax) {
66         output = state->outMax;
67     }
68     if (output < state->outMin) {
69         output = state->outMin;
70     }
71     return output;
72 }

```

### 5.16.3.2 void pidInit ( void )

Initialize Roll and Pitch PID.

Stores the PID States in [o\\_pids](#). Also resets [o\\_should](#) to zero.

Examples:

[uartFlight.c](#).

Definition at line 74 of file [pid.c](#).

References [o\\_should](#), [PID\\_D](#), [PID\\_I](#), [PID\\_INTMAX](#), [PID\\_INTMIN](#), [PID\\_OUTMAX](#), [PID\\_OUTMIN](#), [PID\\_P](#), and [pidSet\(\)](#).

```

74     {
75     for (uint8_t i = 0; i < 2; i++) {
76         pidSet(&o_pids[i], PID_P, PID_I, PID_D,
PID_OUTMIN, PID_OUTMAX, PID_INTMIN, PID_INTMAX);
77         o_should[i] = 0.0;
78     }
79 }

```

### 5.16.3.3 void pidSet ( PIDState \* pid, double kp, double ki, double kd, double min, double max, double iMin, double iMax )

Set the parameters of a PID controller.

The state variables will be reset to zero.

Parameters

<i>pid</i>	<a href="#">PIDState</a> to be changed.
<i>kp</i>	New Proportional constant.
<i>ki</i>	New Integral constant.
<i>kd</i>	New Derivative constant.
<i>min</i>	New minimum Output.
<i>max</i>	New maximum Output.
<i>iMin</i>	New minimal Integral Sum.
<i>iMax</i>	New maximal Integral Sum.

Examples:

[uartFlight.c](#).

Definition at line 81 of file [pid.c](#).

References [PIDState::intMax](#), [PIDState::intMin](#), [PIDState::kd](#), [PIDState::ki](#), [PIDState::kp](#), [PIDState::last](#), [PIDState::lastError](#), [PIDState::outMax](#), [PIDState::outMin](#), and [PIDState::sumError](#).

Referenced by [pidInit\(\)](#).

```

81
82     {
83         pid->kp = kp;
84         pid->ki = ki;
85         pid->kd = kd;
86         pid->outMin = min;
87         pid->outMax = max;
88         pid->intMin = iMin;
89         pid->intMax = iMax;
90         pid->lastError = 0;
91         pid->sumError = 0;
92         pid->last = 0;
93     }

```

#### 5.16.3.4 void pidTask ( void )

Step the Roll and Pitch PID Controllers.

Placing their output in `o_output` and reading the input from `o_should` and the global orientation `Angles`.

Examples:

[uartFlight.c](#).

Definition at line 94 of file `pid.c`.

References `o_output`, `o_should`, `orientation`, `pidExecute()`, `Angles::pitch`, `PITCH`, `Angles::roll`, and `ROLL`.

```

94     {
95         o_output[ROLL] = pidExecute(o_should[ROLL],
orientation.roll, &o_pids[ROLL]);
96         o_output[PITCH] = pidExecute(o_should[PITCH],
orientation.pitch, &o_pids[PITCH]);
97     }

```

### 5.16.4 Variable Documentation

#### 5.16.4.1 double o\_output[2]

Roll and Pitch PID Output.

Definition at line 52 of file `pid.c`.

Referenced by `pidTask()`, and `setTask()`.

#### 5.16.4.2 double o\_output[2]

Roll and Pitch PID Output.

Examples:

[uartFlight.c](#).

Definition at line 52 of file `pid.c`.

Referenced by `pidTask()`, and `setTask()`.

#### 5.16.4.3 PIDState o\_pids[2]

Roll and Pitch PID States.

Definition at line 50 of file `pid.c`.

Referenced by `setTask()`.

#### 5.16.4.4 PIDState o\_pids[2]

Roll and Pitch PID States.

Examples:

[uartFlight.c](#).

Definition at line 50 of file pid.c.

Referenced by setTask().

#### 5.16.4.5 double o\_should[2]

Roll and Pitch target angles.

Definition at line 51 of file pid.c.

Referenced by pidInit(), and pidTask().

#### 5.16.4.6 double o\_should[2]

Roll and Pitch target angles.

Examples:

[uartFlight.c](#).

Definition at line 51 of file pid.c.

Referenced by pidInit(), and pidTask().

## 5.17 UART Library

UART Library enabling you to control all available UART Modules.

### Files

- file [serial.h](#)  
*UART Library Header File.*
- file [serial\\_device.h](#)  
*UART Library device-specific configuration.*
- file [serial.c](#)  
*UART Library Implementation.*

### Macros

- `#define BAUD(baudRate, xtalCpu) ((xtalCpu)/((baudRate)*16l)-1)`  
*Calculate Baudrate Register Value.*
- `#define RX_BUFFER_SIZE 32`  
*If you define this, a '\r' (CR) will be put in front of a '\n' (LF) when sending a byte.*
- `#define TX_BUFFER_SIZE 16`  
*TX Buffer Size in Bytes (Power of 2)*
- `#define FLOWCONTROL`  
*Defining this enables incoming XON XOFF (sends XOFF if rx buff is full)*
- `#define FLOWMARK 5`  
*Space remaining to trigger xoff/xon.*
- `#define XON 0x11`  
*XON Value.*
- `#define XOFF 0x13`  
*XOFF Value.*

### Functions

- `uint8_t serialAvailable (void)`  
*Get number of available UART modules.*
- `void serialInit (uint8_t uart, uint16_t baud)`  
*Initialize the UART Hardware.*
- `void serialClose (uint8_t uart)`  
*Stop the UART Hardware.*
- `void setFlow (uint8_t uart, uint8_t on)`  
*Manually change the flow control.*
- `uint8_t serialHasChar (uint8_t uart)`  
*Check if a byte was received.*
- `uint8_t serialGet (uint8_t uart)`  
*Read a single byte.*
- `uint8_t serialGetBlocking (uint8_t uart)`  
*Wait until a character is received.*
- `uint8_t serialRxBufferFull (uint8_t uart)`  
*Check if the receive buffer is full.*
- `uint8_t serialRxBufferEmpty (uint8_t uart)`  
*Check if the receive buffer is empty.*

- void `serialWrite` (uint8\_t uart, uint8\_t data)  
*Send a byte.*
- void `serialWriteString` (uint8\_t uart, const char \*data)  
*Send a string.*
- uint8\_t `serialTxBufferFull` (uint8\_t uart)  
*Check if the transmit buffer is full.*
- uint8\_t `serialTxBufferEmpty` (uint8\_t uart)  
*Check if the transmit buffer is empty.*

### 5.17.1 Detailed Description

UART Library enabling you to control all available UART Modules. With XON/XOFF Flow Control and buffered Receiving and Transmitting.

### 5.17.2 Macro Definition Documentation

#### 5.17.2.1 `#define BAUD( baudRate, xtalCpu ) ((xtalCpu)/((baudRate)*16l)-1)`

Calculate Baudrate Register Value.

Definition at line 46 of file serial.h.

Referenced by `xyInit()`.

#### 5.17.2.2 `#define FLOWCONTROL`

Defining this enables incoming XON XOFF (sends XOFF if rx buff is full)

Definition at line 63 of file serial.c.

#### 5.17.2.3 `#define FLOWMARK 5`

Space remaining to trigger xoff/xon.

Definition at line 65 of file serial.c.

Referenced by `serialGet()`.

#### 5.17.2.4 `#define RX_BUFFER_SIZE 32`

If you define this, a '\r' (CR) will be put in front of a '\n' (LF) when sending a byte.

Binary Communication will then be impossible!RX Buffer Size in Bytes (Power of 2)

Definition at line 55 of file serial.c.

Referenced by `serialGet()`, and `serialRxBufferFull()`.

#### 5.17.2.5 `#define TX_BUFFER_SIZE 16`

TX Buffer Size in Bytes (Power of 2)

Definition at line 59 of file serial.c.

Referenced by `serialTxBufferFull()`, and `serialWrite()`.

5.17.2.6 `#define XOFF 0x13`

XOFF Value.

Definition at line 67 of file serial.c.

Referenced by `setFlow()`.

5.17.2.7 `#define XON 0x11`

XON Value.

Definition at line 66 of file serial.c.

Referenced by `serialGet()`, and `setFlow()`.

## 5.17.3 Function Documentation

5.17.3.1 `uint8_t serialAvailable ( void )`

Get number of available UART modules.

## Returns

number of modules

Definition at line 114 of file serial.c.

Referenced by `uartinput()`, `uartMenuTask()`, `uartoutput()`, and `xyInit()`.

```
114                                     {
115     return UART_COUNT;
116 }
```

5.17.3.2 `void serialClose ( uint8_t uart )`

Stop the UART Hardware.

## Parameters

<i>uart</i>	UART Module to stop
-------------	---------------------

Definition at line 149 of file serial.c.

References `serialTxBufferEmpty()`.

```
149                                     {
150     if (uart >= UART_COUNT)
151         return;
152
153     uint8_t sreg = SREG;
154     sei();
155     while (!serialTxBufferEmpty(uart));
156     while (*serialRegisters[uart][SERIALB] & (1 << serialBits[uart][SERIALUDRIE])); // Wait while Transmit
Interrupt is on
157     cli();
158     *serialRegisters[uart][SERIALB] = 0;
159     *serialRegisters[uart][SERIALC] = 0;
160     SREG = sreg;
161 }
```

### 5.17.3.3 uint8\_t serialGet ( uint8\_t uart )

Read a single byte.

#### Parameters

<i>uart</i>	UART Module to read from
-------------	--------------------------

#### Returns

Received byte or 0

Definition at line 218 of file serial.c.

References FLOWMARK, RX\_BUFFER\_SIZE, and XON.

Referenced by serialGetBlocking(), uartinput(), and uartMenuTask().

```

218                                     {
219     if (uart >= UART_COUNT)
220         return 0;
221
222     uint8_t c;
223
224     #ifdef FLOWCONTROL
225         rxBufferElements[uart]--;
226         if ((flow[uart] == 0) && (rxBufferElements[uart] <= FLOWMARK)) {
227             while (sendThisNext[uart] != 0);
228             sendThisNext[uart] = XON;
229             flow[uart] = 1;
230             if (shouldStartTransmission[uart]) {
231                 shouldStartTransmission[uart] = 0;
232                 *serialRegisters[uart][SERIALB] |= (1 << serialBits[uart][SERIALUDRIE]); // Enable Interrupt
233                 *serialRegisters[uart][SERIALA] |= (1 << serialBits[uart][SERIALUDRIE]); // Trigger Interrupt
234             }
235         }
236     #endif
237
238     if (rxRead[uart] != rxWrite[uart]) {
239         c = rxBuffer[uart][rxRead[uart]];
240         rxBuffer[uart][rxRead[uart]] = 0;
241         if (rxRead[uart] < (RX_BUFFER_SIZE - 1)) {
242             rxRead[uart]++;
243         } else {
244             rxRead[uart] = 0;
245         }
246         return c;
247     } else {
248         return 0;
249     }
250 }

```

### 5.17.3.4 uint8\_t serialGetBlocking ( uint8\_t uart )

Wait until a character is received.

#### Parameters

<i>uart</i>	UART Module to read from
-------------	--------------------------

#### Returns

Received byte

Definition at line 210 of file serial.c.

References serialGet(), and serialHasChar().

```

210                                     {

```



```

211     if (uart >= UART_COUNT)
212         return 0;
213
214     while(!SerialHasChar(uart));
215     return serialGet(uart);
216 }

```

### 5.17.3.5 uint8\_t serialHasChar ( uint8\_t uart )

Check if a byte was received.

#### Parameters

<i>uart</i>	UART Module to check
-------------	----------------------

#### Returns

1 if a byte was received, 0 if not

Definition at line 199 of file serial.c.

Referenced by serialGetBlocking(), uartinput(), and uartMenuTask().

```

199                                     {
200     if (uart >= UART_COUNT)
201         return 0;
202
203     if (rxRead[uart] != rxWrite[uart]) { // True if char available
204         return 1;
205     } else {
206         return 0;
207     }
208 }

```

### 5.17.3.6 void serialInit ( uint8\_t uart, uint16\_t baud )

Initialize the UART Hardware.

#### Parameters

<i>uart</i>	UART Module to initialize
<i>baud</i>	Baudrate. Use the <a href="#">BAUD()</a> macro!

Definition at line 118 of file serial.c.

Referenced by xylnit().

```

118                                     {
119     if (uart >= UART_COUNT)
120         return;
121
122     // Initialize state variables
123     rxRead[uart] = 0;
124     rxWrite[uart] = 0;
125     txRead[uart] = 0;
126     txWrite[uart] = 0;
127     shouldStartTransmission[uart] = 1;
128 #ifdef FLOWCONTROL
129     sendThisNext[uart] = 0;
130     flow[uart] = 1;
131     rxBufferElements[uart] = 0;
132 #endif
133
134     // Default Configuration: 8N1
135     *serialRegisters[uart][SERIALC] = (1 << serialBits[uart][SERIALUCSZ0]) | (1 << serialBits[uart][
SERIALUCSZ1]);
136
137     // Set baudrate

```

```

138 #if SERIALBAUDBIT == 8
139     *serialRegisters[uart][SERIALUBRRH] = (baud >> 8);
140     *serialRegisters[uart][SERIALUBRRL] = baud;
141 #else
142     *serialBaudRegisters[uart] = baud;
143 #endif
144
145     *serialRegisters[uart][SERIALB] = (1 << serialBits[uart][SERIALRXCIE]); // Enable Interrupts
146     *serialRegisters[uart][SERIALB] |= (1 << serialBits[uart][SERIALRXEN]) | (1 << serialBits[uart][
SERIALTXEN]); // Enable Receiver/Transmitter
147 }

```

#### 5.17.3.7 uint8\_t serialRxBufferEmpty ( uint8\_t uart )

Check if the receive buffer is empty.

##### Parameters

<i>uart</i>	UART Module to check
-------------	----------------------

##### Returns

1 if buffer is empty, 0 if not.

Definition at line 259 of file serial.c.

```

259                                     {
260     if (uart >= UART_COUNT)
261         return 0;
262
263     if (rxRead[uart] != rxWrite[uart]) {
264         return 0;
265     } else {
266         return 1;
267     }
268 }

```

#### 5.17.3.8 uint8\_t serialRxBufferFull ( uint8\_t uart )

Check if the receive buffer is full.

##### Parameters

<i>uart</i>	UART Module to check
-------------	----------------------

##### Returns

1 if buffer is full, 0 if not

Definition at line 252 of file serial.c.

References `RX_BUFFER_SIZE`.

```

252                                     {
253     if (uart >= UART_COUNT)
254         return 0;
255
256     return (((rxWrite[uart] + 1) == rxRead[uart]) || ((rxRead[uart] == 0) && ((rxWrite[uart] + 1) ==
RX_BUFFER_SIZE)));
257 }

```

#### 5.17.3.9 uint8\_t serialTxBufferEmpty ( uint8\_t uart )

Check if the transmit buffer is empty.

## Parameters

<i>uart</i>	UART Module to check
-------------	----------------------

## Returns

1 if buffer is empty, 0 if not.

Definition at line 318 of file serial.c.

Referenced by serialClose().

```

318                                     {
319     if (uart >= UART_COUNT)
320         return 0;
321
322     if (txRead[uart] != txWrite[uart]) {
323         return 0;
324     } else {
325         return 1;
326     }
327 }
```

5.17.3.10 uint8\_t serialTxBufferFull ( uint8\_t *uart* )

Check if the transmit buffer is full.

## Parameters

<i>uart</i>	UART Module to check
-------------	----------------------

## Returns

1 if buffer is full, 0 if not

Definition at line 311 of file serial.c.

References TX\_BUFFER\_SIZE.

Referenced by serialWrite().

```

311                                     {
312     if (uart >= UART_COUNT)
313         return 0;
314
315     return (((txWrite[uart] + 1) == txRead[uart]) || ((txRead[uart] == 0) && ((txWrite[uart] + 1) ==
TX_BUFFER_SIZE)));
316 }
```

5.17.3.11 void serialWrite ( uint8\_t *uart*, uint8\_t *data* )

Send a byte.

## Parameters

<i>uart</i>	UART Module to write to
<i>data</i>	Byte to send

Definition at line 274 of file serial.c.

References serialTxBufferFull(), and TX\_BUFFER\_SIZE.

Referenced by serialWriteString(), and uartoutput().

```

274                                     {
275     if (uart >= UART_COUNT)
276         return;
277
278 #ifdef SERIALINJECTCR
279     if (data == '\n') {
280         serialWrite(uart, '\r');
281     }
282 #endif
283     while (serialTxBufferFull(uart));
284
285     txBuffer[uart][txWrite[uart]] = data;
286     if (txWrite[uart] < (TX_BUFFER_SIZE - 1)) {
287         txWrite[uart]++;
288     } else {
289         txWrite[uart] = 0;
290     }
291     if (shouldStartTransmission[uart]) {
292         shouldStartTransmission[uart] = 0;
293         *serialRegisters[uart][SERIALB] |= (1 << serialBits[uart][SERIALUDRIE]); // Enable Interrupt
294         *serialRegisters[uart][SERIALA] |= (1 << serialBits[uart][SERIALUDRE]); // Trigger Interrupt
295     }
296 }

```

#### 5.17.3.12 void serialWriteString ( uint8\_t uart, const char \* data )

Send a string.

##### Parameters

<i>uart</i>	UART Module to write to
<i>data</i>	Null-Terminated String

Definition at line 298 of file serial.c.

References serialWrite().

```

298                                     {
299     if (uart >= UART_COUNT)
300         return;
301
302     if (data == 0) {
303         serialWriteString(uart, "NULL");
304     } else {
305         while (*data != '\0') {
306             serialWrite(uart, *data++);
307         }
308     }
309 }

```

#### 5.17.3.13 void setFlow ( uint8\_t uart, uint8\_t on )

Manually change the flow control.

Flow Control has to be compiled into the library!

##### Parameters

<i>uart</i>	UART Module to operate on
<i>on</i>	1 if on, 0 if off

Definition at line 164 of file serial.c.

References XOFF, and XON.

```

164                                     {
165     if (uart >= UART_COUNT)
166         return;
167 }

```

```
168     if (flow[uart] != on) {
169         if (on == 1) {
170             // Send XON
171             while (sendThisNext[uart] != 0);
172             sendThisNext[uart] = XON;
173             flow[uart] = 1;
174             if (shouldStartTransmission[uart]) {
175                 shouldStartTransmission[uart] = 0;
176                 *serialRegisters[uart][SERIALB] |= (1 << serialBits[uart][SERIALUDRIE]);
177                 *serialRegisters[uart][SERIALA] |= (1 << serialBits[uart][SERIALUDRE]); // Trigger
178             Interrupt
179             } else {
180                 // Send XOFF
181                 sendThisNext[uart] = XOFF;
182                 flow[uart] = 0;
183                 if (shouldStartTransmission[uart]) {
184                     shouldStartTransmission[uart] = 0;
185                     *serialRegisters[uart][SERIALB] |= (1 << serialBits[uart][SERIALUDRIE]);
186                     *serialRegisters[uart][SERIALA] |= (1 << serialBits[uart][SERIALUDRE]); // Trigger
187             Interrupt
188             }
189             // Wait till it's transmitted
190             while (*serialRegisters[uart][SERIALB] & (1 << serialBits[uart][SERIALUDRIE]));
191         }
192     }
```

## 5.18 Motor Speed Mixer

Takes the Base Speed and PID-Output and sets Motor Speed accordingly.

### Files

- file [set.h](#)  
*Motor Mixer Library Header.*
- file [set.c](#)  
*Motor Mixer Library Implementation.*

### Macros

- `#define MAXDIFF (baseSpeed * PID_FACTOR)`  
*Maximum Speed difference on one axis.*

### Functions

- void [setTask](#) (void)  
*Read the PID Output and Set the Motor Speeds.*
- void [setMotorSpeeds](#) (uint8\_t axis, uint8\_t \*vals)  
*Set the Motor Speeds according to the SET\_\* Motor Position Constants.*

### Variables

- uint8\_t [baseSpeed](#)  
*Motor Base Speed.*
- uint8\_t [baseSpeed](#) = 0  
*Motor Base Speed.*

#### 5.18.1 Detailed Description

Takes the Base Speed and PID-Output and sets Motor Speed accordingly.

#### 5.18.2 Macro Definition Documentation

##### 5.18.2.1 `#define MAXDIFF (baseSpeed * PID_FACTOR)`

Maximum Speed difference on one axis.

Definition at line 51 of file set.c.

Referenced by [setTask\(\)](#).

#### 5.18.3 Function Documentation

##### 5.18.3.1 `void setMotorSpeeds ( uint8_t axis, uint8_t * vals ) [inline]`

Set the Motor Speeds according to the SET\_\* Motor Position Constants.

## Parameters

<i>axis</i>	ROLL or PITCH
<i>vals</i>	Speeds for the two Motors on this axis (+, -)

Definition at line 59 of file set.c.

References motorSet(), SET\_ROLLMINUS, and SET\_ROLLPLUS.

Referenced by setTask().

```

59                                     {
60     if (axis == ROLL) {
61         motorSet (SET_ROLLPLUS, vals[0]);
62         motorSet (SET_ROLLMINUS, vals[1]);
63     } else if (axis == PITCH) {
64         motorSet (SET_PITCHPLUS, vals[0]);
65         motorSet (SET_PITCHMINUS, vals[1]);
66     }
67 }
```

## 5.18.3.2 void setTask ( void )

Read the PID Output and Set the Motor Speeds.

Examples:

[uartFlight.c](#).

Definition at line 69 of file set.c.

References baseSpeed, MAXDIFF, o\_output, o\_pids, and setMotorSpeeds().

```

69     {
70     for (uint8_t i = 0; i < 2; i++) {
71         double diff = (o_output[i] * MAXDIFF) / o_pids[i].outMax;
72         uint8_t v[2] = { baseSpeed + diff, baseSpeed - diff };
73         setMotorSpeeds(i, v);
74     }
75 }
```

## 5.18.4 Variable Documentation

## 5.18.4.1 uint8\_t baseSpeed

Motor Base Speed.

Examples:

[uartFlight.c](#).

Definition at line 53 of file set.c.

Referenced by setTask().

## 5.18.4.2 uint8\_t baseSpeed = 0

Motor Base Speed.

Definition at line 53 of file set.c.

Referenced by setTask().

## 5.19 SPI Driver

SPI Library for AVR's built-in SPI Hardware.

### Files

- file [spi.h](#)  
*SPI API Header.*
- file [spi.c](#)  
*SPI API Implementation.*

### Enumerations

- enum [SPI\\_MODE](#) { [MODE\\_0](#) = 0, [MODE\\_1](#) = 1, [MODE\\_2](#) = 2, [MODE\\_3](#) = 3 }
- SPI Mode option.*
- enum [SPI\\_SPEED](#) {  
[SPEED\\_2](#) = 4, [SPEED\\_4](#) = 0, [SPEED\\_8](#) = 5, [SPEED\\_16](#) = 1,  
[SPEED\\_32](#) = 6, [SPEED\\_64](#) = 2, [SPEED\\_128](#) = 3 }
- SPI Speed options.*

### Functions

- void [spiInit](#) ([SPI\\_MODE](#) mode, [SPI\\_SPEED](#) speed)  
*Initialize the SPI Hardware Module.*
- [uint8\\_t spiSendByte](#) ([uint8\\_t](#) d)  
*Send and Receive one byte.*

#### 5.19.1 Detailed Description

SPI Library for AVR's built-in SPI Hardware.

#### 5.19.2 Enumeration Type Documentation

##### 5.19.2.1 enum [SPI\\_MODE](#)

SPI Mode option.

##### Enumerator

- [MODE\\_0](#)** CPOL 0, CPHA 0.
- [MODE\\_1](#)** CPOL 0, CPHA 1.
- [MODE\\_2](#)** CPOL 1, CPHA 0.
- [MODE\\_3](#)** CPOL 1, CPHA 1.

Definition at line 44 of file [spi.h](#).

```

44     {
45     MODE\_0 = 0,
46     MODE\_1 = 1,
47     MODE\_2 = 2,
48     MODE\_3 = 3,
49 } SPI\_MODE;
```



## 5.19.2.2 enum SPI\_SPEED

SPI Speed options.

Enumerator

```

SPEED_2  F_CPU / 2.
SPEED_4  F_CPU / 4.
SPEED_8  F_CPU / 8.
SPEED_16 F_CPU / 16.
SPEED_32 F_CPU / 32.
SPEED_64 F_CPU / 64.
SPEED_128 F_CPU / 128.

```

Definition at line 52 of file spi.h.

```

52      {
53          SPEED_2 = 4,
54          SPEED_4 = 0,
55          SPEED_8 = 5,
56          SPEED_16 = 1,
57          SPEED_32 = 6,
58          SPEED_64 = 2,
59          SPEED_128 = 3,
60 } SPI_SPEED;

```

## 5.19.3 Function Documentation

## 5.19.3.1 void spInit ( SPI\_MODE mode, SPI\_SPEED speed )

Initialize the SPI Hardware Module.

Parameters

<i>mode</i>	SPI Mode to use
<i>speed</i>	SPI Speed to use

Referenced by xylInit().

## 5.19.3.2 uint8\_t spiSendByte ( uint8\_t d )

Send and Receive one byte.

Set the Chip Select Lines yourself!

Parameters

<i>d</i>	Data to be sent
----------	-----------------

Returns

Byte read from Bus

Definition at line 54 of file spi.c.

```

54      {
55          SPDR = d;
56          while (!(SPSR & (1 << SPIF))); // Wait for transmission
57          return SPDR;
58 }

```

## 5.20 Task Handler

System for registering different tasks that will be called regularly, one after another.

### Files

- file [tasks.h](#)  
*Task API Header.*
- file [tasks.c](#)  
*Task API Implementation.*

### Data Structures

- struct [TaskElement](#)  
*Single-Linked Task List.*

### Typedefs

- typedef void(\* [Task](#) )(void)  
*A Task has no arguments and returns nothing.*

### Functions

- uint8\_t [addTask](#) ([Task](#) func)  
*Adds another task that will be called regularly.*
- uint8\_t [removeTask](#) ([Task](#) func)  
*Removes an already registered Task.*
- void [tasks](#) (void)  
*Executes registered Tasks.*
- uint8\_t [tasksRegistered](#) (void)  
*Get the number of registered Tasks.*

### Variables

- [TaskElement](#) \* [taskList](#)  
*List of registered Tasks.*
- [TaskElement](#) \* [taskList](#) = NULL  
*List of registered Tasks.*

#### 5.20.1 Detailed Description

System for registering different tasks that will be called regularly, one after another.

#### 5.20.2 Typedef Documentation

##### 5.20.2.1 typedef void(\* Task)(void)

A Task has no arguments and returns nothing.

Definition at line 44 of file tasks.h.

### 5.20.3 Function Documentation

#### 5.20.3.1 uint8\_t addTask ( Task func )

Adds another task that will be called regularly.

##### Parameters

<i>func</i>	Task to be executed
-------------	---------------------

##### Returns

0 on success

##### Examples:

[uartFlight.c](#).

Definition at line 57 of file tasks.c.

References `BANK_GENERIC`, `MEMSWITCH`, `MEMSWITCHBACK`, `TaskElement::next`, `TaskElement::task`, and `taskList`.

Referenced by `xyInit()`.

```

57     {
58         MEMSWITCH(BANK_GENERIC);
59         TaskElement *p = (TaskElement *)malloc(sizeof(
TaskElement));
60         if (p == NULL) {
61             MEMSWITCHBACK(BANK_GENERIC);
62             return 1;
63         }
64         p->task = func;
65         p->next = taskList;
66         taskList = p;
67         MEMSWITCHBACK(BANK_GENERIC);
68         return 0;
69     }

```

#### 5.20.3.2 uint8\_t removeTask ( Task func )

Removes an already registered Task.

##### Parameters

<i>func</i>	Task to be removed
-------------	--------------------

##### Returns

0 on success

Definition at line 71 of file tasks.c.

References `BANK_GENERIC`, `MEMSWITCH`, `MEMSWITCHBACK`, `TaskElement::next`, `TaskElement::task`, and `taskList`.

```

71     {
72         MEMSWITCH(BANK_GENERIC);
73         TaskElement *p = taskList;
74         TaskElement *prev = NULL;
75         while (p != NULL) {
76             if (p->task == func) {
77                 if (prev == NULL) {
78                     taskList = p->next;
79                 } else {

```

```

80         prev->next = p->next;
81     }
82     free(p);
83     MEMSWITCHBACK(BANK_GENERIC);
84     return 0;
85 }
86 prev = p;
87 p = p->next;
88 }
89 MEMSWITCHBACK(BANK_GENERIC);
90 return 1;
91 }

```

### 5.20.3.3 void tasks ( void )

Executes registered Tasks.

Call this in your Main Loop!

Examples:

[test.c](#), and [uartFlight.c](#).

Definition at line 93 of file tasks.c.

References [BANK\\_GENERIC](#), [MEMSWITCH](#), [MEMSWITCHBACK](#), [TaskElement::next](#), [TaskElement::task](#), and [taskList](#).

```

93     {
94     MEMSWITCH(BANK_GENERIC);
95     static TaskElement *p = NULL;
96     if (p == NULL) {
97         p = taskList;
98     }
99     if (p != NULL) {
100         p->task();
101         p = p->next;
102     }
103     MEMSWITCHBACK(BANK_GENERIC);
104 }

```

### 5.20.3.4 uint8\_t tasksRegistered ( void )

Get the number of registered Tasks.

Returns

Count of registered Tasks

Definition at line 47 of file tasks.c.

References [BANK\\_GENERIC](#), [MEMSWITCH](#), [MEMSWITCHBACK](#), and [TaskElement::next](#).

```

47     {
48     uint8_t c = 0;
49     MEMSWITCH(BANK_GENERIC);
50     for (TaskElement *p = taskList; p != NULL; p = p->next) {
51         c++;
52     }
53     MEMSWITCHBACK(BANK_GENERIC);
54     return c;
55 }

```

## 5.20.4 Variable Documentation

### 5.20.4.1 TaskElement\* taskList = NULL

List of registered Tasks.

Definition at line 45 of file tasks.c.

Referenced by addTask(), removeTask(), and tasks().

#### 5.20.4.2 TaskElement\* taskList

List of registered Tasks.

Definition at line 45 of file tasks.c.

Referenced by addTask(), removeTask(), and tasks().

## 5.21 Time Keeping

Measuring Time with Millisecond Resolution.

### Files

- file [time.h](#)  
*Time API Header.*
- file [time.c](#)  
*Time API Implementation.*

### Macros

- #define [TCRA](#) TCCR2A  
*Timer 2 Control Register A.*
- #define [TCRB](#) TCCR2B  
*Timer 2 Control Register B.*
- #define [OCR](#) OCR2A  
*Timer 2 Compare Register A.*
- #define [TIMS](#) TIMSK2  
*Timer 2 Interrupt Mask.*
- #define [OCIE](#) OCIE2A  
*Timer 2 Compare Match A Interrupt Enable.*

### Typedefs

- typedef uint64\_t [time\\_t](#)  
*Timekeeping Data Type.*

### Functions

- void [initSystemTimer](#) (void)  
*Initialize the system timer.*
- [time\\_t](#) [getSystemTime](#) (void)  
*Get the System Uptime.*
- [ISR](#) (TIMER2\_COMPA\_vect)  
*Timer 2 Compare Match A Interrupt.*

### Variables

- volatile [time\\_t](#) [systemTime](#) = 0  
*Current System Uptime.*

#### 5.21.1 Detailed Description

Measuring Time with Millisecond Resolution. Uses Timer 2

Prescaler 64

Count to 250

$16000000 / 64 / 250 = 1000 \rightarrow 1$  Interrupt per millisecond

## 5.21.2 Macro Definition Documentation

### 5.21.2.1 `#define OCIE OCIE2A`

Timer 2 Compare Match A Interrupt Enable.  
Definition at line 53 of file time.c.

### 5.21.2.2 `#define OCR OCR2A`

Timer 2 Compare Register A.  
Definition at line 51 of file time.c.

### 5.21.2.3 `#define TCRA TCCR2A`

Timer 2 Control Register A.  
Definition at line 49 of file time.c.

### 5.21.2.4 `#define TCRB TCCR2B`

Timer 2 Control Register B.  
Definition at line 50 of file time.c.

### 5.21.2.5 `#define TIMS TIMSK2`

Timer 2 Interrupt Mask.  
Definition at line 52 of file time.c.

## 5.21.3 Typedef Documentation

### 5.21.3.1 `typedef uint64_t time_t`

Timekeeping Data Type.  
Overflows after 500 million years... :)  
Definition at line 53 of file time.h.

## 5.21.4 Function Documentation

### 5.21.4.1 `time_t getSystemTime ( void )`

Get the System Uptime.

#### Returns

System Uptime in Milliseconds

#### Examples:

[uartFlight.c](#).

Definition at line 68 of file time.c.

References `systemTime`.

Referenced by `complementaryExecute()`, `complementaryInit()`, and `pidExecute()`.

```
68         {
69     return systemTime;
70 }
```

#### 5.21.4.2 void initSystemTimer ( void )

Initialize the system timer.

Execution every millisecond. Uses Timer 2.

Definition at line 55 of file time.c.

Referenced by `xyInit()`.

```
55     {
56     // Timer initialization
57     TCRA |= (1 << WGM21); // CTC Mode
58     TCRB |= (1 << CS22); // Prescaler: 64
59     OCR = 250;
60     TIMS |= (1 << OCIE); // Enable compare match interrupt
61 }
```

#### 5.21.4.3 ISR ( TIMER2\_COMPA\_vect )

Timer 2 Compare Match A Interrupt.

Definition at line 64 of file time.c.

References `systemTime`.

```
64     {
65     systemTime++;
66 }
```

### 5.21.5 Variable Documentation

#### 5.21.5.1 volatile time\_t systemTime = 0

Current System Uptime.

Definition at line 47 of file time.c.

Referenced by `getSystemTime()`, and `ISR()`.



## 5.22 I2C Driver

Using the AVR TWI/I2C Hardware.

### Files

- file [twi.h](#)  
*I2C API Header.*

### Macros

- `#define TWI_READ 1`  
*I2C Read Bit.*
- `#define TWI_WRITE 0`  
*I2C Write Bit.*

### Functions

- void [twiInit](#) (void)  
*Initialize the I2C Hardware.*
- void [twiStop](#) (void)  
*Stop the I2C Hardware.*
- unsigned char [twiStart](#) (unsigned char addr)  
*Start an I2C Transfer.*
- unsigned char [twiRepStart](#) (unsigned char addr)  
*Start a repeated I2C Transfer.*
- void [twiStartWait](#) (unsigned char addr)  
*Start an I2C Transfer and poll until ready.*
- unsigned char [twiWrite](#) (unsigned char data)  
*Write to the I2C Slave.*
- unsigned char [twiReadAck](#) (void)  
*Read from the I2C Slave and request more data.*
- unsigned char [twiReadNak](#) (void)  
*Read from the I2C Slave and deny more data.*

#### 5.22.1 Detailed Description

Using the AVR TWI/I2C Hardware.

#### 5.22.2 Macro Definition Documentation

##### 5.22.2.1 `#define TWI_READ 1`

I2C Read Bit.

Definition at line 43 of file [twi.h](#).

Referenced by [accRead\(\)](#), [gyroRead\(\)](#), and [magRead\(\)](#).

### 5.22.2.2 #define TWI\_WRITE 0

I2C Write Bit.

Definition at line 44 of file twi.h.

Referenced by accRead(), gyroRead(), magRead(), and motorTask().

## 5.22.3 Function Documentation

### 5.22.3.1 void twiInit ( void )

Initialize the I2C Hardware.

Definition at line 26 of file twi.c.

Referenced by xyInit().

```

27 {
28     /* initialize TWI clock: 100 kHz clock, TWPS = 0 => prescaler = 1 */
29
30     TWSR = 0;                      /* no prescaler */
31     TWBR = ((F_CPU/SCL_CLOCK)-16)/2; /* must be > 10 for stable operation */
32
33 } /* i2c_init */

```

### 5.22.3.2 unsigned char twiReadAck ( void )

Read from the I2C Slave and request more data.

Returns

Data read

Definition at line 179 of file twi.c.

Referenced by accRead(), gyroRead(), and magRead().

```

180 {
181     TWCR = (1<<TWINT) | (1<<TWEN) | (1<<TWEA);
182     while (!(TWCR & (1<<TWINT)));
183
184     return TWDR;
185
186 } /* i2c_readAck */

```

### 5.22.3.3 unsigned char twiReadNak ( void )

Read from the I2C Slave and deny more data.

Returns

Data read

Definition at line 194 of file twi.c.

Referenced by accRead(), gyroRead(), and magRead().

```

195 {
196     TWCR = (1<<TWINT) | (1<<TWEN);
197     while (!(TWCR & (1<<TWINT)));
198
199     return TWDR;
200
201 } /* i2c_readNak */

```

5.22.3.4 unsigned char twiRepStart ( unsigned char *addr* )

Start a repeated I2C Transfer.

## Parameters

<i>addr</i>	Slave Address (with Read/Write bit)
-------------	-------------------------------------

## Returns

0 on success, 1 on error

Definition at line 127 of file twi.c.

References twiStart().

Referenced by accRead(), gyroRead(), and magRead().

```

128 {
129     return twiStart( address );
130 }
131 } /* i2c_rep_start */

```

5.22.3.5 unsigned char twiStart ( unsigned char *addr* )

Start an I2C Transfer.

## Parameters

<i>addr</i>	Slave Address (with Read/Write bit)
-------------	-------------------------------------

## Returns

0 on success, 1 on error

Definition at line 40 of file twi.c.

Referenced by accRead(), gyroRead(), magRead(), motorTask(), and twiRepStart().

```

41 {
42     uint8_t twst;
43
44     // send START condition
45     TWCR = (1<<TWINT) | (1<<TWSTA) | (1<<TWEN);
46
47     // wait until transmission completed
48     while(!(TWCR & (1<<TWINT)));
49
50     // check value of TWI Status Register. Mask prescaler bits.
51     twst = TW_STATUS & 0xF8;
52     if ( (twst != TW_START) && (twst != TW_REP_START)) return 1;
53
54     // send device address
55     TWDR = address;
56     TWCR = (1<<TWINT) | (1<<TWEN);
57
58     // wait until transmission completed and ACK/NACK has been received
59     while(!(TWCR & (1<<TWINT)));
60
61     // check value of TWI Status Register. Mask prescaler bits.
62     twst = TW_STATUS & 0xF8;
63     if ( (twst != TW_MT_SLA_ACK) && (twst != TW_MR_SLA_ACK) ) return 1;
64
65     return 0;
66 }
67 } /* i2c_start */

```

### 5.22.3.6 void twiStartWait ( unsigned char *addr* )

Start an I2C Transfer and poll until ready.

#### Parameters

<i>addr</i>	Slave Address (with Read/Write bit)
-------------	-------------------------------------

Definition at line 76 of file twi.c.

```

77 {
78     uint8_t    twst;
79
80
81     while ( 1 )
82     {
83         // send START condition
84         TWCR = (1<<TWINT) | (1<<TWSTA) | (1<<TWEN);
85
86         // wait until transmission completed
87         while(!(TWCR & (1<<TWINT)));
88
89         // check value of TWI Status Register. Mask prescaler bits.
90         twst = TW_STATUS & 0xF8;
91         if ( (twst != TW_START) && (twst != TW_REP_START)) continue;
92
93         // send device address
94         TWDR = address;
95         TWCR = (1<<TWINT) | (1<<TWEN);
96
97         // wait until transmission completed
98         while(!(TWCR & (1<<TWINT)));
99
100        // check value of TWI Status Register. Mask prescaler bits.
101        twst = TW_STATUS & 0xF8;
102        if ( (twst == TW_MT_SLA_NACK) || (twst == TW_MR_DATA_NACK) )
103        {
104            /* device busy, send stop condition to terminate write operation */
105            TWCR = (1<<TWINT) | (1<<TWEN) | (1<<TWSTO);
106
107            // wait until stop condition is executed and bus released
108            while(TWCR & (1<<TWSTO));
109
110            continue;
111        }
112        //if( twst != TW_MT_SLA_ACK) return 1;
113        break;
114    }
115
116 }/* i2c_start_wait */

```

### 5.22.3.7 void twiStop ( void )

Stop the I2C Hardware.

Definition at line 137 of file twi.c.

Referenced by motorTask().

```

138 {
139     /* send stop condition */
140     TWCR = (1<<TWINT) | (1<<TWEN) | (1<<TWSTO);
141
142     // wait until stop condition is executed and bus released
143     while(TWCR & (1<<TWSTO));
144
145 }/* i2c_stop */

```

### 5.22.3.8 unsigned char twiWrite ( unsigned char *data* )

Write to the I2C Slave.

## Parameters

<i>data</i>	Data to send
-------------	--------------

## Returns

0 on success, 1 on error

Definition at line 155 of file twi.c.

Referenced by `accRead()`, `gyroRead()`, `magRead()`, and `motorTask()`.

```
156 {
157     uint8_t    twst;
158
159     // send data to the previously addressed device
160     TWDR = data;
161     TWCR = (1<<TWINT) | (1<<TWEN);
162
163     // wait until transmission completed
164     while(!(TWCR & (1<<TWINT)));
165
166     // check value of TWI Status Register. Mask prescaler bits
167     twst = TW_STATUS & 0xF8;
168     if( twst != TW_MT_DATA_ACK) return 1;
169     return 0;
170
171 }/* i2c_write */
```

## 5.23 UART Menu

Enables user interaction with an UART Menu.

### Files

- file [uartMenu.h](#)  
*UART Menu API Header.*
- file [uartMenu.c](#)  
*UART Menu API Implementation.*

### Data Structures

- struct [MenuEntry](#)  
*Data Structure for Single-Linked-List for UART Menu.*

### Functions

- `uint8_t addMenuCommand (uint8_t cmd, PGM_P help, Task f)`  
*Add a command to the UART Menu.*
- `void uartMenuPrintHelp (void)`  
*Print all registered commands.*
- `void uartMenuRegisterHandler (void(*handler)(char))`  
*Register a Handler for unhandled menu commands.*
- `void uartMenuTask (void)`  
*Task to work the UART Menu.*
- `MenuEntry * findEntry (uint8_t cmd)`  
*Search the [uartMenu](#) Linked List.*
- `MenuEntry * reverseList (MenuEntry *root)`  
*Reverse the UART Menu List.*

### Variables

- `MenuEntry * uartMenu = NULL`  
*Single-Linked-List for commands.*
- `void(* unHandler )(char) = NULL`  
*Handler for unhandled commands.*

#### 5.23.1 Detailed Description

Enables user interaction with an UART Menu.

#### 5.23.2 Function Documentation

##### 5.23.2.1 `uint8_t addMenuCommand ( uint8_t cmd, PGM_P help, Task f )`

Add a command to the UART Menu.

#### Parameters

<i>cmd</i>	Byte that triggers command
<i>help</i>	Help Text String in Flash
<i>f</i>	Task to be executed

**Returns**

0 on success, 1 if already registered or not enough memory.

**Examples:**

[uartFlight.c](#).

Definition at line 69 of file [uartMenu.c](#).

References [BANK\\_GENERIC](#), [MenuEntry::cmd](#), [MenuEntry::f](#), [findEntry\(\)](#), [MenuEntry::helpText](#), [MenuEntry::next](#), [uartMenu](#), [xmemGetBank\(\)](#), and [xmemSetBank\(\)](#).

Referenced by [xylInit\(\)](#).

```

69                                     {
70     uint8_t lastBank = xmemGetBank();
71     xmemSetBank(BANK_GENERIC);
72     if (findEntry(cmd) != NULL) {
73         return 1;
74     } else {
75         MenuEntry *p = (MenuEntry *)malloc(sizeof(MenuEntry));
76         if (p == NULL) {
77             return 1;
78         }
79         p->cmd = cmd;
80         p->helpText = help;
81         p->f = f;
82         p->next = uartMenu;
83         uartMenu = p;
84         return 0;
85     }
86     xmemSetBank(lastBank);
87 }
```

**5.23.2.2 MenuEntry\* findEntry ( uint8\_t cmd )**

Search the [uartMenu](#) Linked List.

**Parameters**

<i>cmd</i>	Command to search for
------------	-----------------------

**Returns**

[MenuEntry](#) for command *cmd*, or NULL

Definition at line 58 of file [uartMenu.c](#).

References [MenuEntry::cmd](#), [MenuEntry::next](#), and [uartMenu](#).

Referenced by [addMenuCommand\(\)](#).

```

58                                     {
59     MenuEntry *p = uartMenu;
60     while (p != NULL) {
61         if (p->cmd == cmd) {
62             return p;
63         }
64         p = p->next;
65     }
66     return NULL;
67 }
```

**5.23.2.3 MenuEntry\* reverseList ( MenuEntry \* root )**

Reverse the UART Menu List.

**Parameters**

<i>root</i>	Root of the Single-Linked-List.
-------------	---------------------------------

**Returns**

New root of reversed list.

Definition at line 93 of file uartMenu.c.

References MenuEntry::next.

Referenced by uartMenuPrintHelp().

```

93                                     {
94     MenuEntry *new = NULL;
95     while (root != NULL) {
96         MenuEntry *next = root->next;
97         root->next = new;
98         new = root;
99         root = next;
100    }
101    return new;
102 }
```

**5.23.2.4 void uartMenuPrintHelp ( void )**

Print all registered commands.

Definition at line 104 of file uartMenu.c.

References BANK\_GENERIC, MenuEntry::cmd, MenuEntry::helpText, MenuEntry::next, reverseList(), uartMenu, xmemGetBank(), and xmemSetBank().

Referenced by xylnit().

```

104                                     {
105     static uint8_t reversed = 0;
106     uint8_t lastBank = xmemGetBank();
107     xmemSetBank(BANK_GENERIC);
108     char *buffer = (char *)malloc(35);
109     if (buffer == NULL) {
110         printf("!\n");
111         return;
112     }
113     if (!reversed) {
114         reversed = 1;
115         uartMenu = reverseList(uartMenu);
116     }
117     MenuEntry *p = uartMenu;
118     while (p != NULL) {
119         strcpy_P(buffer, p->helpText);
120         printf("%c: %s\n", p->cmd, buffer);
121         p = p->next;
122     }
123     free(buffer);
124     xmemSetBank(lastBank);
125 }
```

**5.23.2.5 void uartMenuRegisterHandler ( void(\*) (char) handler )**

Register a Handler for unhandled menu commands.

**Parameters**

<i>handler</i>	Will be called if an unknown command is received.
----------------	---

Definition at line 127 of file uartMenu.c.



References unHandler.

```

127                                     {
128     unHandler = handler;
129 }

```

#### 5.23.2.6 void uartMenuTask ( void )

Task to work the UART Menu.

Definition at line 131 of file uartMenu.c.

References BANK\_GENERIC, MenuEntry::cmd, MenuEntry::f, MenuEntry::next, serialAvailable(), serialGet(), serialHasChar(), uartMenu, unHandler, xmemGetBank(), and xmemSetBank().

Referenced by xylnit().

```

131                                     {
132     for (uint8_t i = 0; i < serialAvailable(); i++) {
133         if (serialHasChar(i)) {
134             uint8_t lastBank = xmemGetBank();
135             xmemSetBank(BANK_GENERIC);
136             uint8_t c = serialGet(i);
137             MenuEntry *p = uartMenu;
138             while (p != NULL) {
139                 if (p->cmd == c) {
140                     p->f();
141                     xmemSetBank(lastBank);
142                     return;
143                 }
144                 p = p->next;
145             }
146             if (unHandler != NULL)
147                 unHandler(c);
148             xmemSetBank(lastBank);
149         }
150     }
151 }

```

### 5.23.3 Variable Documentation

#### 5.23.3.1 MenuEntry\* uartMenu = NULL

Single-Linked-List for commands.

Definition at line 51 of file uartMenu.c.

Referenced by addMenuCommand(), findEntry(), uartMenuPrintHelp(), and uartMenuTask().

#### 5.23.3.2 void(\* unHandler)(char) = NULL

Handler for unhandled commands.

Definition at line 52 of file uartMenu.c.

Referenced by uartMenuRegisterHandler(), and uartMenuTask().

## 5.24 External Memory Interface

Allows access to external RAM with bank-switching.

### Files

- file [xmem.h](#)  
*XMEM API Header.*
- file [xmem.c](#)  
*XMEM API Implementation.*

### Data Structures

- struct [MallocState](#)  
*All Malloc related State.*

### Macros

- `#define MEMSWITCH(x) uint8_t oldMemBank=xmemGetBank();if(oldMemBank!=x)xmemSetBank(x);`  
*Switch the bank, if needed.*
- `#define MEMSWITCHBACK(x) if(oldMemBank!=x)xmemSetBank(oldMemBank);`  
*Switch back to the last bank, if needed.*
- `#define MEMBANKS 8`  
*Available Memory Banks.*
- `#define BANK_GENERIC 0`  
*Generic Memory Bank.*

### Functions

- void [xmemInit](#) (void)  
*Initialize the External Memory Interface.*
- void [xmemSetBank](#) (uint8\_t bank)  
*Switch the active memory bank.*
- uint8\_t [xmemGetBank](#) (void)  
*Get the current memory bank.*
- void [saveState](#) (uint8\_t bank)  
*Save the current malloc state.*
- void [restoreState](#) (uint8\_t bank)  
*Restore the malloc state.*

### Variables

- [MallocState](#) states [[MEMBANKS](#)]  
*MallocState for all Memory Banks.*
- uint8\_t [currentBank](#)  
*Current active Memory Bank.*
- [MallocState](#) states [[MEMBANKS](#)]  
*MallocState for all Memory Banks.*
- uint8\_t [currentBank](#) = 0

*Current active Memory Bank.*

- void \* [\\_\\_brkval](#)

*Internal Malloc Heap-End Pointer.*

- void \* [\\_\\_flp](#)

*Internal Malloc Free List Pointer (State)*

### 5.24.1 Detailed Description

Allows access to external RAM with bank-switching.

### 5.24.2 Macro Definition Documentation

#### 5.24.2.1 `#define BANK_GENERIC 0`

Generic Memory Bank.

Definition at line 55 of file xmem.h.

Referenced by `addMenuCommand()`, `addTask()`, `removeTask()`, `tasks()`, `tasksRegistered()`, `uartMenuPrintHelp()`, and `uartMenuTask()`.

#### 5.24.2.2 `#define MEMBANKS 8`

Available Memory Banks.

Definition at line 54 of file xmem.h.

Referenced by `xmemInit()`, and `xmemSetBank()`.

#### 5.24.2.3 `#define MEMSWITCH( x ) uint8_t oldMemBank=xmemGetBank();if(oldMemBank!=x)xmemSetBank(x);`

Switch the bank, if needed.

Stores the old bank in a variable `oldMemBank`.

##### Parameters

<code>x</code>	New Bank
----------------	----------

Definition at line 47 of file xmem.h.

Referenced by `addTask()`, `removeTask()`, `tasks()`, and `tasksRegistered()`.

#### 5.24.2.4 `#define MEMSWITCHBACK( x ) if(oldMemBank!=x)xmemSetBank(oldMemBank);`

Switch back to the last bank, if needed.

##### Parameters

<code>x</code>	New (current) Bank
----------------	--------------------

Definition at line 52 of file xmem.h.

Referenced by `addTask()`, `removeTask()`, `tasks()`, and `tasksRegistered()`.

### 5.24.3 Function Documentation

#### 5.24.3.1 void restoreState ( uint8\_t bank )

Restore the malloc state.

##### Parameters

<i>bank</i>	Location of state to load.
-------------	----------------------------

Definition at line 65 of file xmem.c.

References `__brkval`, `__flp`, `MallocState::end`, `MallocState::fl`, `MallocState::start`, and `MallocState::val`.

Referenced by `xmemSetBank()`.

```

65         {
66     __malloc_heap_start = states[bank].start;
67     __malloc_heap_end = states[bank].end;
68     __brkval = states[bank].val;
69     __flp = states[bank].fl;
70 }
```

#### 5.24.3.2 void saveState ( uint8\_t bank )

Save the current malloc state.

##### Parameters

<i>bank</i>	Current Bank Number
-------------	---------------------

Definition at line 55 of file xmem.c.

References `__brkval`, `__flp`, `MallocState::end`, `MallocState::fl`, `MallocState::start`, and `MallocState::val`.

Referenced by `xmemInit()`, and `xmemSetBank()`.

```

55         {
56     states[bank].start = __malloc_heap_start;
57     states[bank].end = __malloc_heap_end;
58     states[bank].val = __brkval;
59     states[bank].fl = __flp;
60 }
```

#### 5.24.3.3 uint8\_t xmemGetBank ( void )

Get the current memory bank.

##### Returns

Current Memory Bank.

Definition at line 105 of file xmem.c.

References `currentBank`.

Referenced by `addMenuCommand()`, `uartMenuPrintHelp()`, and `uartMenuTask()`.

```

105         {
106     return currentBank;
107 }
```

#### 5.24.3.4 void xmemInit ( void )

Initialize the External Memory Interface.

Definition at line 72 of file xmem.c.

References BANK0DDR, BANK0PIN, BANK0PORT, BANK1DDR, BANK1PIN, BANK1PORT, BANK2DDR, BANK2PIN, BANK2PORT, MEMBANKS, and saveState().

Referenced by xylnit().

```

72         {
73     BANK0DDR |= (1 << BANK0PIN);
74     BANK1DDR |= (1 << BANK1PIN);
75     BANK2DDR |= (1 << BANK2PIN);
76     BANK0PORT &= ~(1 << BANK0PIN);
77     BANK1PORT &= ~(1 << BANK1PIN);
78     BANK2PORT &= ~(1 << BANK2PIN);
79
80     XMCRB = 0; // Use full address space
81     XMCRA = (1 << SRW11) | (1 << SRW10); // 3 Wait cycles
82     XMCRA |= (1 << SRE); // Enable XMEM
83
84     for (uint8_t i = 0; i < MEMBANKS; i++) {
85         saveState(i);
86     }
87 }

```

#### 5.24.3.5 void xmemSetBank ( uint8\_t bank )

Switch the active memory bank.

##### Parameters

<i>bank</i>	New Memory Bank
-------------	-----------------

Definition at line 89 of file xmem.c.

References BANK0PIN, BANK0PORT, BANK1PIN, BANK1PORT, BANK2PIN, BANK2PORT, currentBank, MEMBANKS, restoreState(), and saveState().

Referenced by addMenuCommand(), uartMenuPrintHelp(), and uartMenuTask().

```

89     {
90     if (bank < MEMBANKS) {
91         saveState(currentBank);
92
93         BANK0PORT &= ~(1 << BANK0PIN);
94         BANK1PORT &= ~(1 << BANK1PIN);
95         BANK2PORT &= ~(1 << BANK2PIN);
96         BANK0PORT |= ((bank & 0x01) << BANK0PIN);
97         BANK1PORT |= (((bank & 0x02) >> 1) << BANK1PIN);
98         BANK2PORT |= (((bank & 0x04) >> 2) << BANK2PIN);
99
100         currentBank = bank;
101         restoreState(bank);
102     }
103 }

```

## 5.24.4 Variable Documentation

### 5.24.4.1 void\* \_\_brkval

Internal Malloc Heap-End Pointer.

Referenced by restoreState(), and saveState().

### 5.24.4.2 void\* \_flp

Internal Malloc Free List Pointer (State)

Referenced by restoreState(), and saveState().

#### 5.24.4.3 `uint8_t currentBank = 0`

Current active Memory Bank.

Definition at line 47 of file `xmem.c`.

Referenced by `xmemGetBank()`, and `xmemSetBank()`.

#### 5.24.4.4 `uint8_t currentBank`

Current active Memory Bank.

Definition at line 47 of file `xmem.c`.

Referenced by `xmemGetBank()`, and `xmemSetBank()`.

#### 5.24.4.5 `MallocState states[MEMBANKS]`

[MallocState](#) for all Memory Banks.

Definition at line 46 of file `xmem.c`.

#### 5.24.4.6 `MallocState states[MEMBANKS]`

[MallocState](#) for all Memory Banks.

Definition at line 46 of file `xmem.c`.

## 5.25 xyControl Hardware

Controls xyControl On-Board Hardware like LEDs.

### Files

- file [xycontrol.h](#)  
*xyControl API Header.*
- file [xycontrol.c](#)  
*xyControl API Implementation.*

### Data Structures

- struct [Vector3f](#)  
*The global 3-Dimensional Floating Point Vector.*

### Enumerations

- enum [LED](#) {  
  [LED\\_RED0](#) = 0, [LED\\_RED1](#) = 1, [LED\\_GREEN0](#) = 2, [LED\\_GREEN1](#) = 3,  
  [LED\\_ALL](#) = 4, [LED\\_BITMAP](#) = 5, [LED\\_RED](#) = 6, [LED\\_GREEN](#) = 7 }  
*Methods of addressing the LEDs.*
- enum [LEDState](#) { [LED\\_OFF](#) = 0, [LED\\_ON](#) = 1, [LED\\_TOGGLE](#) = 2 }  
*Possible states of the LEDs.*

### Functions

- void [xyInit](#) (void)  
*Initialize the xyControl Hardware.*
- void [xyLed](#) ([LED](#) l, [LEDState](#) v)  
*Set the LEDs.*
- double [getVoltage](#) (void)  
*Calculate and return the Battery Voltage.*
- void [resetSelf](#) (void)  
*Use the Watchdog to reset yourself after 15ms.*
- int [uartoutput](#) (char c, FILE \*f)  
*Method used to write to stdout and stderr.*
- int [uartinput](#) (FILE \*f)  
*Method used to read from stdin.*
- void [xyLedInternal](#) (uint8\_t v, volatile uint8\_t \*port, uint8\_t pin)  
*Internal LED Manipulation function.*

### Variables

- char PROGMEM [helpText](#) [] = "Print this Help"  
*UART Menu Help Text.*
- char PROGMEM [resetText](#) [] = "Reset MCU"  
*UART Menu Reset Text.*
- FILE [inFile](#)  
*FILE for stdin.*
- FILE [outFile](#)  
*FILE for stdout and stderr.*

### 5.25.1 Detailed Description

Controls xyControl On-Board Hardware like LEDs.

### 5.25.2 Enumeration Type Documentation

#### 5.25.2.1 enum LED

Methods of addressing the LEDs.

Enumerator

**LED\_RED0** First red LED.  
**LED\_RED1** Second red LED.  
**LED\_GREEN0** First green LED.  
**LED\_GREEN1** Second green LED.  
**LED\_ALL** All LEDs.  
**LED\_BITMAP** LEDs as Bitmap (R0, R1, G0, G1)  
**LED\_RED** Both red LEDs.  
**LED\_GREEN** Both green LEDs.

Definition at line 44 of file xycontrol.h.

```

44      {
45          LED_RED0 = 0,
46          LED_RED1 = 1,
47          LED_GREEN0 = 2,
48          LED_GREEN1 = 3,
49          LED_ALL = 4,
50          LED_BITMAP = 5,
51          LED_RED = 6,
52          LED_GREEN = 7
53 } LED;
```

#### 5.25.2.2 enum LEDState

Possible states of the LEDs.

Enumerator

**LED\_OFF** LED Off.  
**LED\_ON** LED On.  
**LED\_TOGGLE** Toggle the LED.

Definition at line 56 of file xycontrol.h.

```

56      {
57          LED_OFF = 0,
58          LED_ON = 1,
59          LED_TOGGLE = 2
60 } LEDState;
```

### 5.25.3 Function Documentation

#### 5.25.3.1 double getVoltage ( void )

Calculate and return the Battery Voltage.



**Returns**

Current Battery Voltage

**Examples:**

[uartFlight.c](#).

Definition at line 172 of file xycontrol.c.

References `adcGet()`, `adcReady()`, `adcStart()`, `BATT_CHANNEL`, and `BATT_MAX`.

```
172         {
173     adcStart(BATT_CHANNEL);
174     while(!adcReady());
175     uint16_t v = adcGet(0) * BATT_MAX;
176     return ((double)v / 1024.0);
177 }
```

**5.25.3.2 void resetSelf ( void )**

Use the Watchdog to reset yourself after 15ms.

Definition at line 179 of file xycontrol.c.

Referenced by `xyInit()`.

```
179         {
180     wdt_enable(WDTO_15MS);
181     for(;;);
182 }
```

**5.25.3.3 int uartinput ( FILE \* f )**

Method used to read from stdin.

Definition at line 81 of file xycontrol.c.

References `serialAvailable()`, `serialGet()`, and `serialHasChar()`.

Referenced by `xyInit()`.

```
81         {
82     for(;;) {
83         for (uint8_t i = 0; i < serialAvailable(); i++) {
84             if (serialHasChar(i)) {
85                 return serialGet(i);
86             }
87         }
88     }
89 }
```

**5.25.3.4 int uartoutput ( char c, FILE \* f )**

Method used to write to stdout and stderr.

Definition at line 66 of file xycontrol.c.

References `serialAvailable()`, and `serialWrite()`.

Referenced by `xyInit()`.

```
66         {
67     // Inject CR here, instead of in the serial library,
68     // so we can still do binary transfers with serialWrite()...
69     if (c == '\n') {
```

```

70         for (uint8_t i = 0; i < serialAvailable(); i++)
71             serialWrite(i, '\r');
72     }
73     if (c != '\r') {
74         for (uint8_t i = 0; i < serialAvailable(); i++)
75             serialWrite(i, c);
76     }
77     return 0;
78 }

```

### 5.25.3.5 void xyInit ( void )

Initialize the xyControl Hardware.

Initializes LEDs, Timer, UART, I2C, SPI, ADC, the UART Menu and prepares stdin and stdout.

Examples:

[test.c](#), and [uartFlight.c](#).

Definition at line 91 of file xycontrol.c.

References [adcInit\(\)](#), [addMenuCommand\(\)](#), [addTask\(\)](#), [AVCC](#), [BAUD](#), [helpText](#), [inFile](#), [initSystemTimer\(\)](#), [LED0DDR](#), [LED0PIN](#), [LED1DDR](#), [LED1PIN](#), [LED2DDR](#), [LED2PIN](#), [LED3DDR](#), [LED3PIN](#), [MODE\\_0](#), [outFile](#), [resetSelf\(\)](#), [resetText](#), [serialAvailable\(\)](#), [serialInit\(\)](#), [SPEED\\_2](#), [spiInit\(\)](#), [twiInit\(\)](#), [uartinput\(\)](#), [uartMenuPrintHelp\(\)](#), [uartMenuTask\(\)](#), [uartoutput\(\)](#), [xmemInit\(\)](#), and [xyLed\(\)](#).

```

91     {
92         xmemInit(); // Most important!
93
94         // LEDs
95         LED0DDR |= (1 << LED0PIN);
96         LED1DDR |= (1 << LED1PIN);
97         LED2DDR |= (1 << LED2PIN);
98         LED3DDR |= (1 << LED3PIN);
99         xyLed(4, 1);
100
101         initSystemTimer();
102         for (uint8_t i = 0; i < serialAvailable(); i++) {
103             serialInit(i, BAUD(38400, F_CPU));
104         }
105         twiInit();
106         spiInit(MODE_0, SPEED_2);
107         adcInit(AVCC);
108
109         addMenuCommand('q', resetText, &resetSelf);
110         addMenuCommand('h', helpText, &uartMenuPrintHelp);
111         addTask(&uartMenuTask);
112
113         // fdevopen() is using malloc, so printf in a different
114         // memory bank will not work!
115         // fdevopen(&uartoutput, NULL); // stdout & stderr
116         // fdevopen(NULL, &uartinput); // stdin
117         // Instead we have the FILE structs as static variables
118         // and assign them to stdin, stdout and stderr
119
120         fdev_setup_stream(&outFile, &uartoutput, NULL, _FDEV_SETUP_WRITE);
121         fdev_setup_stream(&inFile, NULL, &uartinput, _FDEV_SETUP_READ);
122         stdin = &inFile;
123         stdout = &outFile;
124         stderr = &outFile;
125
126         sei();
127     }

```

### 5.25.3.6 void xyLed ( LED l, LEDState v )

Set the LEDs.

Parameters

/	LEDs to set
v	New LED State

Examples:

[test.c](#), and [uartFlight.c](#).

Referenced by xyInit().

#### 5.25.3.7 void xyLedInternal ( uint8\_t v, volatile uint8\_t \* port, uint8\_t pin )

Internal LED Manipulation function.

##### Parameters

<i>v</i>	New LED State (Off, On, Toggle)
<i>port</i>	The Corresponding Output Port
<i>pin</i>	The LED Pin

Definition at line 134 of file xycontrol.c.

```

134
135     if (v == 0) {
136         *port &= ~(1 << pin);
137     } else if (v == 1) {
138         *port |= (1 << pin);
139     } else {
140         *port ^= (1 << pin);
141     }
142 }
```

## 5.25.4 Variable Documentation

### 5.25.4.1 char PROGMEM helpText[] = "Print this Help"

UART Menu Help Text.

Definition at line 59 of file xycontrol.c.

Referenced by xyInit().

### 5.25.4.2 FILE inFile

FILE for stdin.

Definition at line 62 of file xycontrol.c.

Referenced by xyInit().

### 5.25.4.3 FILE outFile

FILE for stdout and stderr.

Definition at line 63 of file xycontrol.c.

Referenced by xyInit().

### 5.25.4.4 char PROGMEM resetText[] = "Reset MCU"

UART Menu Reset Text.

Definition at line 60 of file xycontrol.c.

Referenced by xyInit().



## Chapter 6

# Data Structure Documentation

### 6.1 Angles Struct Reference

Can store orientation in Euler Space.

```
#include <orientation.h>
```

#### Data Fields

- double [pitch](#)  
*Pitch Angle in Degrees.*
- double [roll](#)  
*Roll Angle in Degrees.*
- double [yaw](#)  
*Yaw Angle in Degrees.*

#### 6.1.1 Detailed Description

Can store orientation in Euler Space.

Definition at line 48 of file orientation.h.

#### 6.1.2 Field Documentation

##### 6.1.2.1 double pitch

Pitch Angle in Degrees.

Examples:

[uartFlight.c](#).

Definition at line 49 of file orientation.h.

Referenced by `orientationTask()`, `pidTask()`, and `zeroOrientation()`.

##### 6.1.2.2 double roll

Roll Angle in Degrees.

Examples:

[uartFlight.c](#).

Definition at line 50 of file orientation.h.

Referenced by orientationTask(), pidTask(), and zeroOrientation().

#### 6.1.2.3 double yaw

Yaw Angle in Degrees.

Examples:

[uartFlight.c](#).

Definition at line 51 of file orientation.h.

Referenced by zeroOrientation().

The documentation for this struct was generated from the following file:

- include/[orientation.h](#)

## 6.2 Complementary Struct Reference

Complementary-Filter State data.

```
#include <complementary.h>
```

### 6.2.1 Detailed Description

Complementary-Filter State data.

Definition at line 46 of file complementary.h.

The documentation for this struct was generated from the following file:

- include/[complementary.h](#)

## 6.3 Kalman Struct Reference

Kalman-Filter State data.

```
#include <kalman.h>
```

### Data Fields

- double [x3](#)  
*X Vector.*
- double [p33](#)  
*P Matrix.*

### 6.3.1 Detailed Description

Kalman-Filter State data.

Definition at line 47 of file kalman.h.

### 6.3.2 Field Documentation

#### 6.3.2.1 double p33

P Matrix.

Definition at line 49 of file kalman.h.

Referenced by `kalmanInit()`, and `kalmanInnovate()`.

#### 6.3.2.2 double x3

X Vector.

Definition at line 48 of file kalman.h.

Referenced by `kalmanInit()`, and `kalmanInnovate()`.

The documentation for this struct was generated from the following file:

- `include/kalman.h`

## 6.4 MallocState Struct Reference

All Malloc related State.

```
#include <xmem.h>
```

### Data Fields

- `char * start`  
*Start of Heap.*
- `char * end`  
*End of Heap.*
- `void * val`  
*Highest Heap Point.*
- `void * fl`  
*Free List.*

### 6.4.1 Detailed Description

All Malloc related State.

The Heap is bank-switched, so this state has to be switched with the banks to allow different memory allocations on different banks.

Definition at line 62 of file xmem.h.

## 6.4.2 Field Documentation

### 6.4.2.1 char\* end

End of Heap.

Definition at line 64 of file xmem.h.

Referenced by `restoreState()`, and `saveState()`.

### 6.4.2.2 void\* fl

Free List.

Definition at line 66 of file xmem.h.

Referenced by `restoreState()`, and `saveState()`.

### 6.4.2.3 char\* start

Start of Heap.

Definition at line 63 of file xmem.h.

Referenced by `restoreState()`, and `saveState()`.

### 6.4.2.4 void\* val

Highest Heap Point.

Definition at line 65 of file xmem.h.

Referenced by `restoreState()`, and `saveState()`.

The documentation for this struct was generated from the following file:

- [include/xmem.h](#)

## 6.5 MenuEntry Struct Reference

Data Structure for Single-Linked-List for UART Menu.

```
#include <uartMenu.h>
```

### Data Fields

- [uint8\\_t cmd](#)  
*Byte that triggers the action.*
- [PGM\\_P helpText](#)  
*Text (in Flash) printed with help command.*
- [Task f](#)  
*Action that get's executed.*
- [MenuEntry \\* next](#)  
*Next [MenuEntry](#) in the linked list.*



### 6.5.1 Detailed Description

Data Structure for Single-Linked-List for UART Menu.

Stores Helptext, command and action.

Definition at line 49 of file uartMenu.h.

### 6.5.2 Field Documentation

#### 6.5.2.1 uint8\_t cmd

Byte that triggers the action.

Definition at line 50 of file uartMenu.h.

Referenced by addMenuCommand(), findEntry(), uartMenuPrintHelp(), and uartMenuTask().

#### 6.5.2.2 Task f

Action that get's executed.

Definition at line 52 of file uartMenu.h.

Referenced by addMenuCommand(), and uartMenuTask().

#### 6.5.2.3 PGM\_P helpText

Text (in Flash) printed with help command.

Definition at line 51 of file uartMenu.h.

Referenced by addMenuCommand(), and uartMenuPrintHelp().

#### 6.5.2.4 MenuEntry\* next

Next [MenuEntry](#) in the linked list.

Definition at line 53 of file uartMenu.h.

Referenced by addMenuCommand(), findEntry(), reverseList(), uartMenuPrintHelp(), and uartMenuTask().

The documentation for this struct was generated from the following file:

- include/[uartMenu.h](#)

## 6.6 PIDState Struct Reference

Data Structure for a single PID Controller.

```
#include <pid.h>
```

### Data Fields

- double [kp](#)  
*Proportional factor.*
- double [ki](#)  
*Integral factor.*

- double [kd](#)  
*Derivative factor.*
- double [outMin](#)  
*Minimum Output.*
- double [outMax](#)  
*Maximum Output.*
- double [intMin](#)  
*Minimum Integral sum.*
- double [intMax](#)  
*Maximum Integral sum.*
- double [lastError](#)  
*Derivative State.*
- double [sumError](#)  
*Integral state.*
- [time\\_t last](#)  
*Last execution time.*

### 6.6.1 Detailed Description

Data Structure for a single PID Controller.

Stores all needed constants and state variables.

Definition at line 47 of file pid.h.

### 6.6.2 Field Documentation

#### 6.6.2.1 double intMax

Maximum Integral sum.

Default is [PID\\_INTMAX](#).

Definition at line 54 of file pid.h.

Referenced by [pidExecute\(\)](#), and [pidSet\(\)](#).

#### 6.6.2.2 double intMin

Minimum Integral sum.

Default is [PID\\_INTMIN](#).

Definition at line 53 of file pid.h.

Referenced by [pidExecute\(\)](#), and [pidSet\(\)](#).

#### 6.6.2.3 double kd

Derivative factor.

Default is [PID\\_D](#).

Definition at line 50 of file pid.h.

Referenced by [pidExecute\(\)](#), and [pidSet\(\)](#).

#### 6.6.2.4 double ki

Integral factor.

Default is [PID\\_I](#).

Definition at line 49 of file pid.h.

Referenced by `pidExecute()`, and `pidSet()`.

#### 6.6.2.5 double kp

Proportional factor.

Default is [PID\\_P](#).

Definition at line 48 of file pid.h.

Referenced by `pidExecute()`, and `pidSet()`.

#### 6.6.2.6 time\_t last

Last execution time.

For dT calculation.

Definition at line 57 of file pid.h.

Referenced by `pidExecute()`, and `pidSet()`.

#### 6.6.2.7 double lastError

Derivative State.

Definition at line 55 of file pid.h.

Referenced by `pidExecute()`, and `pidSet()`.

#### 6.6.2.8 double outMax

Maximum Output.

Default is [PID\\_OUTMAX](#).

Definition at line 52 of file pid.h.

Referenced by `pidExecute()`, and `pidSet()`.

#### 6.6.2.9 double outMin

Minimum Output.

Default is [PID\\_OUTMIN](#).

Definition at line 51 of file pid.h.

Referenced by `pidExecute()`, and `pidSet()`.

#### 6.6.2.10 double sumError

Integral state.

Kept in [intMin](#), [intMax](#) Range.

Definition at line 56 of file pid.h.

Referenced by pidExecute(), and pidSet().

The documentation for this struct was generated from the following file:

- [include/pid.h](#)

## 6.7 TaskElement Struct Reference

Single-Linked Task List.

```
#include <tasks.h>
```

### Data Fields

- [Task task](#)  
*Task to be executed.*
- [TaskElement \\* next](#)  
*Next list element.*

### 6.7.1 Detailed Description

Single-Linked Task List.

Definition at line 48 of file tasks.h.

### 6.7.2 Field Documentation

#### 6.7.2.1 TaskElement\* next

Next list element.

Definition at line 50 of file tasks.h.

Referenced by addTask(), removeTask(), tasks(), and tasksRegistered().

#### 6.7.2.2 Task task

Task to be executed.

Definition at line 49 of file tasks.h.

Referenced by addTask(), removeTask(), and tasks().

The documentation for this struct was generated from the following file:

- [include/tasks.h](#)

## 6.8 Vector3f Struct Reference

The global 3-Dimensional Floating Point Vector.

```
#include <xycontrol.h>
```

## Data Fields

- double [x](#)  
*X Part.*
- double [y](#)  
*Y Part.*
- double [z](#)  
*Z Part.*

### 6.8.1 Detailed Description

The global 3-Dimensional Floating Point Vector.

Definition at line 63 of file xycontrol.h.

### 6.8.2 Field Documentation

#### 6.8.2.1 double x

X Part.

Definition at line 64 of file xycontrol.h.

Referenced by `accRead()`, `gyroRead()`, `magRead()`, and `orientationTask()`.

#### 6.8.2.2 double y

Y Part.

Definition at line 65 of file xycontrol.h.

Referenced by `accRead()`, `gyroRead()`, `magRead()`, and `orientationTask()`.

#### 6.8.2.3 double z

Z Part.

Definition at line 66 of file xycontrol.h.

Referenced by `accRead()`, `gyroRead()`, `magRead()`, and `orientationTask()`.

The documentation for this struct was generated from the following file:

- [include/xycontrol.h](#)



## Chapter 7

# File Documentation

### 7.1 include/acc.h File Reference

LSM303DLHC Accelerometer API Header.

```
#include <error.h>
#include <xycontrol.h>
```

#### Enumerations

- enum [AccRange](#) { [r2G](#), [r4G](#), [r8G](#), [r16G](#) }  
*Accelerometer Range options.*

#### Functions

- [Error accInit](#) ([AccRange](#) r)  
*Initialize the Accelerometer.*
- [Error accRead](#) ([Vector3f](#) \*v)  
*Read from the Accelerometer.*

#### 7.1.1 Detailed Description

LSM303DLHC Accelerometer API Header.

Definition in file [acc.h](#).

### 7.2 include/adc.h File Reference

Analog-to-Digital Converter API Header.

#### Enumerations

- enum [ADCRef](#) { [AREF](#), [AVCC](#), [AINT1](#), [AINT2](#) }  
*ADC Reference Voltage options.*

## Functions

- void [adclnit](#) ([ADCRef](#) ref)  
*Initialize the ADC Hardware.*
- void [adcStart](#) (uint8\_t channel)  
*Start a conversion on a given channel.*
- uint8\_t [adcReady](#) (void)  
*Check if a result is ready.*
- uint16\_t [adcGet](#) (uint8\_t next)  
*Get the conversion results.*
- void [adcClose](#) (void)  
*Disable the ADC to save energy.*

### 7.2.1 Detailed Description

Analog-to-Digital Converter API Header.

Definition in file [adc.h](#).

## 7.3 include/complementary.h File Reference

Complementary-Filter Header.

```
#include <time.h>
```

## Data Structures

- struct [Complementary](#)  
*Complementary-Filter State data.*

## Functions

- void [complementaryExecute](#) ([Complementary](#) \*data, double acc, double gyro)  
*Step the [Complementary](#) Filter.*
- void [complementaryInit](#) ([Complementary](#) \*data)  
*Initialize a Complementary-State.*

### 7.3.1 Detailed Description

Complementary-Filter Header.

Definition in file [complementary.h](#).

## 7.4 include/config.h File Reference

Various default settings.



## Macros

- #define [ORIENTATION\\_FILTER](#) FILTER\_COMPLEMENTARY  
*Filter Implementation to be used.*
- #define [COMPLEMENTARY\\_TAU](#) 0.5  
*Time Contant for Low and High Pass Filter in the [Complementary](#) Filter.*
- #define [SOFTWARELOWPASS](#) 1  
*Software Low-Pass on Gyro and ACC.*
- #define [ACCFILTERFACTOR](#) SOFTWARELOWPASS  
*Accelerometer Low Pass Factor.*
- #define [GYROFILTERFACTOR](#) SOFTWARELOWPASS  
*Gyroscope Low Pass Factor.*
- #define [PID\\_OUTMAX](#) 256  
*Maximum PID Output.*
- #define [PID\\_OUTMIN](#) -256  
*Minimum PID Output.*
- #define [PID\\_INTMAX](#) PID\_OUTMAX  
*Maximum PID Integral Sum.*
- #define [PID\\_INTMIN](#) PID\_OUTMIN  
*Minimal PID Integral Sum.*
- #define [PID\\_FACTOR](#) 4 / 5  
*Influence of PID in relation to Base Speed.*
- #define [DT](#) 0.01f  
*Time Constant.*
- #define [Q1](#) 5.0f  
*Q Matrix Diagonal Element 1.*
- #define [Q2](#) 100.0f  
*Q Matrix Diagonal Element 2.*
- #define [Q3](#) 0.01f  
*Q Matrix Diagonal Element 3.*
- #define [R1](#) 1000.0f  
*R Matrix Diagonal Element 1.*
- #define [R2](#) 1000.0f  
*R Matrix Diagonal Element 2.*
- #define [SET\\_ROLLPLUS](#) 1  
*Second Motor at the Right.*
- #define [SET\\_ROLLMINUS](#) 3  
*Fourth Motor at the Left.*
- #define [SET\\_PITCHPLUS](#) 0  
*First Motor at the Top.*
- #define [SET\\_PITCHMINUS](#) 2  
*Third Motor at the Bottom.*
- #define [PID\\_P](#) 5.0  
*Default PID P Constant.*
- #define [PID\\_I](#) 0.03  
*Default PID I Constant.*
- #define [PID\\_D](#) -13.0  
*Default PID D Constant.*
- #define [MOTORCOUNT](#) 4  
*Amount of motors.*
- #define [BATT\\_MAX](#) 15

- Battery Voltage Reference (ADC 5V)*
  - #define `BATT_CHANNEL` 0
- ADC Channel for Battery.*
  - #define `ACC_ADDRESS` 0x32
- Accelerometer Address (0011001r)*
  - #define `GYRO_ADDRESS` 0xD6
- Gyroscope Address (110101xr, x = 1)*
  - #define `MAG_ADDRESS` 0x3C
- Magnetometer Address.*
  - #define `MOTOR_BASEADDRESS` 0x52
- Address of first motor controller.*
  - #define `LED0PORT` PORTL
- First LED Port.*
  - #define `LED0DDR` DDRL
- First LED Data Direction Register.*
  - #define `LED0PIN` PL6
- First LED Pin.*
  - #define `LED1PORT` PORTL
- Second LED Port.*
  - #define `LED1DDR` DDRL
- Second LED Data Direction Register.*
  - #define `LED1PIN` PL7
- Second LED Pin.*
  - #define `LED2PORT` PORTG
- Third LED Port.*
  - #define `LED2DDR` DDRG
- Third LED Data Direction Register.*
  - #define `LED2PIN` PG5
- Third LED Pin.*
  - #define `LED3PORT` PORTE
- Fourth LED Port.*
  - #define `LED3DDR` DDRE
- Fourth LED Data Direction Register.*
  - #define `LED3PIN` PE2
- Fourth LED Pin.*
  - #define `BANK0PORT` PORTG
- First Bank Selection Port.*
  - #define `BANK0DDR` DDRG
- First Bank Selection Data Direction Register.*
  - #define `BANK0PIN` PG3
- First Bank Selection Pin.*
  - #define `BANK1PORT` PORTG
- Second Bank Selection Port.*
  - #define `BANK1DDR` DDRG
- Second Bank Selection Data Direction Register.*
  - #define `BANK1PIN` PG4
- Second Bank Selection Pin.*
  - #define `BANK2PORT` PORTL
- Third Bank Selection Port.*
  - #define `BANK2DDR` DDRL
- Third Bank Selection Data Direction Register.*

- #define [BANK2PIN](#) PL5  
*Third Bank Selection Pin.*
- #define [SPISS](#) PB0  
*SPI Slave Select Pin.*
- #define [RX\\_BUFFER\\_SIZE](#) 64  
*UART Receive Buffer Size.*
- #define [TX\\_BUFFER\\_SIZE](#) 64  
*UART Transmit Buffer Size.*

### 7.4.1 Detailed Description

Various default settings.

Definition in file [config.h](#).

## 7.5 include/debug.h File Reference

Debug and Assert Header and Implementation.

```
#include <avr/wdt.h>
#include <serial.h>
#include <stdio.h>
```

### Macros

- #define [DEBUGOUT](#)(x) printf(x)  
*Debug Output Function.*
- #define [ASSERTFUNC](#)(x)  
*Simple Assert Implementation.*
- #define [assert](#)(x) [ASSERTFUNC](#)(x)  
*Enable [assert\(\)](#)*
- #define [debugPrint](#)(ignore)  
*Disable [debugPrint\(\)](#)*

### 7.5.1 Detailed Description

Debug and Assert Header and Implementation.

Definition in file [debug.h](#).

## 7.6 include/doc.h File Reference

Contains Doxygen Group Definitions.

### 7.6.1 Detailed Description

Contains Doxygen Group Definitions.

Definition in file [doc.h](#).

## 7.7 include/error.h File Reference

Global listing of different error conditions.

### Macros

- `#define CHECKERROR(x) if(x!=SUCCESS){return x;}`  
*Check an Error Code.*
- `#define REPORTERROR(x)`  
*Report an error, if it occurred.*

### Enumerations

- `enum Error {`  
    `SUCCESS = 0, TWI_NO_ANSWER, TWI_WRITE_ERROR, MALLOC_FAIL,`  
    `ERROR, ARGUMENT_ERROR }`  
*Error Conditions.*

### Functions

- `char * getErrorString (Error e)`  
*Returns a human-readable error description.*

#### 7.7.1 Detailed Description

Global listing of different error conditions. Can be returned to signalise error or success. Also allows to print human-readable error descriptions.

Definition in file [error.h](#).

## 7.8 include/gyro.h File Reference

L3GD20 Gyroscope API Header.

```
#include <error.h>
#include <xycontrol.h>
```

### Enumerations

- `enum GyroRange { r250DPS, r500DPS, r2000DPS }`  
*Gyroscope Range options.*

### Functions

- `Error gyrolnit (GyroRange r)`  
*Initializes the Gyroscope.*
- `Error gyroRead (Vector3f *v)`  
*Get a set of gyroscope data.*

### 7.8.1 Detailed Description

L3GD20 Gyroscope API Header.

Definition in file [gyro.h](#).

## 7.9 include/kalman.h File Reference

Kalman-Filter Header.

### Data Structures

- struct [Kalman](#)  
*Kalman-Filter State data.*

### Functions

- void [kalmanInnovate](#) ([Kalman](#) \*data, double z1, double z2)  
*Step the [Kalman](#) Filter.*
- void [kalmanInit](#) ([Kalman](#) \*data)  
*Initialize a Kalman-State.*

### 7.9.1 Detailed Description

Kalman-Filter Header.

Definition in file [kalman.h](#).

## 7.10 include/mag.h File Reference

LSM303DLHC Magnetometer API Header.

```
#include <error.h>
#include <xycontrol.h>
```

### Enumerations

- enum [MagRange](#) {  
  [r1g3](#) = 1, [r1g9](#) = 2, [r2g5](#) = 3, [r4g0](#) = 4,  
  [r4g7](#) = 5, [r5g6](#) = 6, [r8g1](#) = 7 }  
*Magnetometer Range options.*

### Functions

- [Error magInit](#) ([MagRange](#) r)  
*Initialize the Magnetometer.*
- [Error magRead](#) ([Vector3f](#) \*v)  
*Read from the Magnetometer.*

### 7.10.1 Detailed Description

LSM303DLHC Magnetometer API Header.

Definition in file [mag.h](#).

## 7.11 include/motor.h File Reference

BL-Ctrl V1.2 Controller API Header.

```
#include <config.h>
```

### Functions

- void [motorInit](#) (void)  
*Initializes the motor control library.*
- void [motorSet](#) (uint8\_t id, uint8\_t speed)  
*Set the speed of one or all motors.*
- void [motorTask](#) (void)  
*Send the values stored in [motorSpeed](#) to the Controllers.*

### Variables

- uint8\_t [motorSpeed](#) [[MOTORCOUNT](#)]  
*Speed for the four motors.*

### 7.11.1 Detailed Description

BL-Ctrl V1.2 Controller API Header.

Definition in file [motor.h](#).

## 7.12 include/orientation.h File Reference

Orientation API Header.

```
#include <error.h>
```

### Data Structures

- struct [Angles](#)  
*Can store orientation in Euler Space.*

### Functions

- [Error orientationInit](#) (void)  
*Initializes the Orientation API.*
- [Error orientationTask](#) (void)  
*Calculate the current orientation.*

- void [zeroOrientation](#) (void)  
*Sets the current orientation to zero.*

## Variables

- [Angles orientation](#)  
*Current Aircraft orientation.*

### 7.12.1 Detailed Description

Orientation API Header.

Definition in file [orientation.h](#).

## 7.13 include/pid.h File Reference

PID Library Header.

## Data Structures

- struct [PIDState](#)  
*Data Structure for a single PID Controller.*

## Macros

- #define [ROLL](#) 0  
*Roll index for [o\\_should](#), [o\\_output](#) and [o\\_pids](#).*
- #define [PITCH](#) 1  
*Pitch index for [o\\_should](#), [o\\_output](#) and [o\\_pids](#).*

## Functions

- void [pidInit](#) (void)  
*Initialize Roll and Pitch PID.*
- void [pidTask](#) (void)  
*Step the Roll and Pitch PID Controllers.*
- void [pidSet](#) ([PIDState](#) \*pid, double kp, double ki, double kd, double min, double max, double iMin, double iMax)  
*Set the parameters of a PID controller.*
- double [pidExecute](#) (double should, double is, [PIDState](#) \*state)  
*Execute a single PID Control Step.*

## Variables

- double [o\\_should](#) [2]  
*Roll and Pitch target angles.*
- double [o\\_output](#) [2]  
*Roll and Pitch PID Output.*
- [PIDState](#) [o\\_pids](#) [2]  
*Roll and Pitch PID States.*

### 7.13.1 Detailed Description

PID Library Header.

Definition in file [pid.h](#).

## 7.14 include/serial.h File Reference

UART Library Header File.

### Macros

- `#define BAUD(baudRate, xtalCpu) ((xtalCpu)/((baudRate)*16l)-1)`  
*Calculate Baudrate Register Value.*

### Functions

- `uint8_t serialAvailable (void)`  
*Get number of available UART modules.*
- `void serialInit (uint8_t uart, uint16_t baud)`  
*Initialize the UART Hardware.*
- `void serialClose (uint8_t uart)`  
*Stop the UART Hardware.*
- `void setFlow (uint8_t uart, uint8_t on)`  
*Manually change the flow control.*
- `uint8_t serialHasChar (uint8_t uart)`  
*Check if a byte was received.*
- `uint8_t serialGet (uint8_t uart)`  
*Read a single byte.*
- `uint8_t serialGetBlocking (uint8_t uart)`  
*Wait until a character is received.*
- `uint8_t serialRxBufferFull (uint8_t uart)`  
*Check if the receive buffer is full.*
- `uint8_t serialRxBufferEmpty (uint8_t uart)`  
*Check if the receive buffer is empty.*
- `void serialWrite (uint8_t uart, uint8_t data)`  
*Send a byte.*
- `void serialWriteString (uint8_t uart, const char *data)`  
*Send a string.*
- `uint8_t serialTxBufferFull (uint8_t uart)`  
*Check if the transmit buffer is full.*
- `uint8_t serialTxBufferEmpty (uint8_t uart)`  
*Check if the transmit buffer is empty.*

### 7.14.1 Detailed Description

UART Library Header File.

Definition in file [serial.h](#).



## 7.15 include/serial\_device.h File Reference

UART Library device-specific configuration.

### 7.15.1 Detailed Description

UART Library device-specific configuration. Contains Register and Bit Positions for different AVR devices.

Definition in file [serial\\_device.h](#).

## 7.16 include/set.h File Reference

Motor Mixer Library Header.

### Functions

- void [setTask](#) (void)  
*Read the PID Output and Set the Motor Speeds.*

### Variables

- uint8\_t [baseSpeed](#)  
*Motor Base Speed.*

### 7.16.1 Detailed Description

Motor Mixer Library Header.

Definition in file [set.h](#).

## 7.17 include/spi.h File Reference

SPI API Header.

### Enumerations

- enum [SPI\\_MODE](#) { [MODE\\_0](#) = 0, [MODE\\_1](#) = 1, [MODE\\_2](#) = 2, [MODE\\_3](#) = 3 }  
*SPI Mode option.*
- enum [SPI\\_SPEED](#) {  
[SPEED\\_2](#) = 4, [SPEED\\_4](#) = 0, [SPEED\\_8](#) = 5, [SPEED\\_16](#) = 1,  
[SPEED\\_32](#) = 6, [SPEED\\_64](#) = 2, [SPEED\\_128](#) = 3 }  
*SPI Speed options.*

### Functions

- void [spiInit](#) ([SPI\\_MODE](#) mode, [SPI\\_SPEED](#) speed)  
*Initialize the SPI Hardware Module.*
- uint8\_t [spiSendByte](#) (uint8\_t d)  
*Send and Receive one byte.*

### 7.17.1 Detailed Description

SPI API Header.

Definition in file [spi.h](#).

## 7.18 include/tasks.h File Reference

Task API Header.

### Data Structures

- struct [TaskElement](#)  
*Single-Linked Task List.*

### Typedefs

- typedef void(\* [Task](#) )(void)  
*A Task has no arguments and returns nothing.*

### Functions

- uint8\_t [addTask](#) ([Task](#) func)  
*Adds another task that will be called regularly.*
- uint8\_t [removeTask](#) ([Task](#) func)  
*Removes an already registered Task.*
- void [tasks](#) (void)  
*Executes registered Tasks.*
- uint8\_t [tasksRegistered](#) (void)  
*Get the number of registered Tasks.*

### Variables

- [TaskElement](#) \* [taskList](#)  
*List of registered Tasks.*

### 7.18.1 Detailed Description

Task API Header.

Definition in file [tasks.h](#).

## 7.19 include/time.h File Reference

Time API Header.

### Typedefs

- typedef uint64\_t [time\\_t](#)  
*Timekeeping Data Type.*

## Functions

- void [initSystemTimer](#) (void)  
*Initialize the system timer.*
- [time\\_t](#) [getSystemTime](#) (void)  
*Get the System Uptime.*

### 7.19.1 Detailed Description

Time API Header.

Definition in file [time.h](#).

## 7.20 include/twi.h File Reference

I2C API Header.

## Macros

- #define [TWI\\_READ](#) 1  
*I2C Read Bit.*
- #define [TWI\\_WRITE](#) 0  
*I2C Write Bit.*

## Functions

- void [twiInit](#) (void)  
*Initialize the I2C Hardware.*
- void [twiStop](#) (void)  
*Stop the I2C Hardware.*
- unsigned char [twiStart](#) (unsigned char addr)  
*Start an I2C Transfer.*
- unsigned char [twiRepStart](#) (unsigned char addr)  
*Start a repeated I2C Transfer.*
- void [twiStartWait](#) (unsigned char addr)  
*Start an I2C Transfer and poll until ready.*
- unsigned char [twiWrite](#) (unsigned char data)  
*Write to the I2C Slave.*
- unsigned char [twiReadAck](#) (void)  
*Read from the I2C Slave and request more data.*
- unsigned char [twiReadNak](#) (void)  
*Read from the I2C Slave and deny more data.*

### 7.20.1 Detailed Description

I2C API Header.

Definition in file [twi.h](#).

## 7.21 include/uartMenu.h File Reference

UART Menu API Header.

```
#include <tasks.h>
```

### Data Structures

- struct [MenuEntry](#)  
*Data Structure for Single-Linked-List for UART Menu.*

### Functions

- uint8\_t [addMenuCommand](#) (uint8\_t cmd, PGM\_P help, [Task](#) f)  
*Add a command to the UART Menu.*
- void [uartMenuPrintHelp](#) (void)  
*Print all registered commands.*
- void [uartMenuRegisterHandler](#) (void(\*handler)(char))  
*Register a Handler for unhandled menu commands.*
- void [uartMenuTask](#) (void)  
*Task to work the UART Menu.*

#### 7.21.1 Detailed Description

UART Menu API Header.

Definition in file [uartMenu.h](#).

## 7.22 include/xmem.h File Reference

XMEM API Header.

### Data Structures

- struct [MallocState](#)  
*All Malloc related State.*

### Macros

- #define [MEMSWITCH](#)(x) uint8\_t oldMemBank=[xmemGetBank](#)();if(oldMemBank!=x)[xmemSetBank](#)(x);  
*Switch the bank, if needed.*
- #define [MEMSWITCHBACK](#)(x) if(oldMemBank!=x)[xmemSetBank](#)(oldMemBank);  
*Switch back to the last bank, if needed.*
- #define [MEMBANKS](#) 8  
*Available Memory Banks.*
- #define [BANK\\_GENERIC](#) 0  
*Generic Memory Bank.*

## Functions

- void [xmemInit](#) (void)  
*Initialize the External Memory Interface.*
- void [xmemSetBank](#) (uint8\_t bank)  
*Switch the active memory bank.*
- uint8\_t [xmemGetBank](#) (void)  
*Get the current memory bank.*

## Variables

- [MallocState](#) [states](#) [[MEMBANKS](#)]  
*[MallocState](#) for all Memory Banks.*
- uint8\_t [currentBank](#)  
*Current active Memory Bank.*

### 7.22.1 Detailed Description

XMEM API Header.

Definition in file [xmem.h](#).

## 7.23 include/xycontrol.h File Reference

xyControl API Header.

## Data Structures

- struct [Vector3f](#)  
*The global 3-Dimensional Floating Point Vector.*

## Enumerations

- enum [LED](#) {  
    [LED\\_RED0](#) = 0, [LED\\_RED1](#) = 1, [LED\\_GREEN0](#) = 2, [LED\\_GREEN1](#) = 3,  
    [LED\\_ALL](#) = 4, [LED\\_BITMAP](#) = 5, [LED\\_RED](#) = 6, [LED\\_GREEN](#) = 7 }  
*Methods of addressing the LEDs.*
- enum [LEDState](#) { [LED\\_OFF](#) = 0, [LED\\_ON](#) = 1, [LED\\_TOGGLE](#) = 2 }  
*Possible states of the LEDs.*

## Functions

- void [xylnit](#) (void)  
*Initialize the xyControl Hardware.*
- void [xyLed](#) ([LED](#) l, [LEDState](#) v)  
*Set the LEDs.*
- double [getVoltage](#) (void)  
*Calculate and return the Battery Voltage.*
- void [resetSelf](#) (void)  
*Use the Watchdog to reset yourself after 15ms.*

### 7.23.1 Detailed Description

xyControl API Header.

Definition in file [xycontrol.h](#).

## 7.24 lib/acc.c File Reference

LSM303DLHC Accelerometer API Implementation.

```
#include <avr/io.h>
#include <stdint.h>
#include <stdlib.h>
#include <twi.h>
#include <acc.h>
#include <error.h>
#include <config.h>
```

### Macros

- `#define ACCREG_CTRL1 0x20`  
*Accelerometer Control Register 1.*
- `#define ACCREG_CTRL4 0x23`  
*Accelerometer Control Register 4.*
- `#define ACCREG_XL 0x28`  
*First Accelerometer Output Register.*

### Functions

- `Error accWriteRegister (uint8_t reg, uint8_t val)`  
*Write an Accelerometer Register.*
- `Error accInit (AccRange r)`  
*Initialize the Accelerometer.*
- `Error accRead (Vector3f *v)`  
*Read from the Accelerometer.*

### Variables

- `AccRange accRange`  
*Stored range to scale returned values.*

### 7.24.1 Detailed Description

LSM303DLHC Accelerometer API Implementation.

Definition in file [acc.c](#).

## 7.25 lib/adc.c File Reference

Analog-to-Digital Converter API Implementation.

```
#include <avr/io.h>
#include <stdint.h>
#include <adc.h>
```

### Functions

- void [adcInit](#) ([ADCRef](#) ref)  
*Initialize the ADC Hardware.*
- void [adcStart](#) (uint8\_t channel)  
*Start a conversion on a given channel.*
- uint8\_t [adcReady](#) (void)  
*Check if a result is ready.*
- uint16\_t [adcGet](#) (uint8\_t next)  
*Get the conversion results.*
- void [adcClose](#) (void)  
*Disable the ADC to save energy.*

### 7.25.1 Detailed Description

Analog-to-Digital Converter API Implementation.

Definition in file [adc.c](#).

## 7.26 lib/complementary.c File Reference

Complementary-Filter Implementation.

```
#include <stdint.h>
#include <avr/io.h>
#include <time.h>
#include <complementary.h>
#include <config.h>
```

### Functions

- void [complementaryInit](#) ([Complementary](#) \*data)  
*Initialize a Complementary-State.*
- void [complementaryExecute](#) ([Complementary](#) \*data, double acc, double gyro)  
*Step the [Complementary](#) Filter.*

### 7.26.1 Detailed Description

Complementary-Filter Implementation.

Definition in file [complementary.c](#).

## 7.27 lib/error.c File Reference

Global listing of different error conditions.

```
#include <avr/io.h>
#include <stdint.h>
#include <stdlib.h>
#include <avr/pgmspace.h>
#include <error.h>
```

### Functions

- char \* [getErrorString](#) (Error e)  
*Returns a human-readable error description.*

### Variables

- char PROGMEM [error0](#) [] = "Success"  
*String for SUCCESS.*
- char PROGMEM [error1](#) [] = "TWI doesn't answer"  
*String for TWI\_NO\_ANSWER.*
- char PROGMEM [error2](#) [] = "TWI could not write"  
*String for TWI\_WRITE\_ERROR.*
- char PROGMEM [error3](#) [] = "Not enough memory"  
*String for MALLOC\_FAIL.*
- char PROGMEM [error4](#) [] = "General [Error](#)"  
*String for ERROR.*
- char PROGMEM [error5](#) [] = "Argument [Error](#)"  
*String for ARGUMENT\_ERROR.*
- PGM\_P PROGMEM [errorTable](#) []  
*Array of all error descriptions in Flash Memory.*

### 7.27.1 Detailed Description

Global listing of different error conditions. Can be returned to signalise error or success. Also allows to print human-readable error descriptions.

Definition in file [error.c](#).

### 7.27.2 Variable Documentation

#### 7.27.2.1 char PROGMEM [error0](#)[] = "Success"

String for SUCCESS.

Definition at line 43 of file error.c.

#### 7.27.2.2 char PROGMEM [error1](#)[] = "TWI doesn't answer"

String for TWI\_NO\_ANSWER.

Definition at line 44 of file error.c.



7.27.2.3 `char PROGMEM error2[] = "TWI could not write"`

String for TWI\_WRITE\_ERROR.

Definition at line 45 of file error.c.

7.27.2.4 `char PROGMEM error3[] = "Not enough memory"`

String for MALLOC\_FAIL.

Definition at line 46 of file error.c.

7.27.2.5 `char PROGMEM error4[] = "General Error"`

String for ERROR.

Definition at line 47 of file error.c.

7.27.2.6 `char PROGMEM error5[] = "Argument Error"`

String for ARGUMENT\_ERROR.

Definition at line 48 of file error.c.

7.27.2.7 `PGM_P PROGMEM errorTable[]`

**Initial value:**

```
= {
    error0, error1, error2, error3, error4, error5
}
```

Array of all error descriptions in Flash Memory.

Definition at line 51 of file error.c.

Referenced by `getErrorString()`.

## 7.28 lib/gyro.c File Reference

L3GD20 Gyroscope API Implementation.

```
#include <stdlib.h>
#include <stdint.h>
#include <avr/io.h>
#include <twi.h>
#include <gyro.h>
#include <error.h>
#include <config.h>
```

### Macros

- `#define GYROREG_CTRL1 0x20`  
*Gyroscope Control Register 1.*
- `#define GYROREG_CTRL4 0x23`

*Gyroscope Control Register 4.*

- `#define GYROREG_OUTXL 0x28`

*First Gyroscope Output Register.*

## Functions

- `Error gyroWriteByte` (uint8\_t reg, uint8\_t val)

*Write a Gyroscope Register.*

- `Error gyroInit` (GyroRange r)

*Initializes the Gyroscope.*

- `Error gyroRead` (Vector3f \*v)

*Get a set of gyroscope data.*

## Variables

- `GyroRange gyroRange`

*Stored range to scale returned values.*

### 7.28.1 Detailed Description

L3GD20 Gyroscope API Implementation.

Definition in file [gyro.c](#).

## 7.29 lib/kalman.c File Reference

Kalman-Filter Implementation.

```
#include <stdint.h>
#include <avr/io.h>
#include <kalman.h>
#include <config.h>
```

## Functions

- `void kalmanInit` (Kalman \*data)

*Initialize a Kalman-State.*

- `void kalmanInnovate` (Kalman \*data, double z1, double z2)

*Step the Kalman Filter.*

### 7.29.1 Detailed Description

Kalman-Filter Implementation.

Definition in file [kalman.c](#).

## 7.30 lib/mag.c File Reference

LSM303DLHC Magnetometer API Implementation.

```
#include <avr/io.h>
#include <stdint.h>
#include <stdlib.h>
#include <twi.h>
#include <mag.h>
#include <error.h>
#include <config.h>
```

### Macros

- `#define MAGREG_CRB 0x01`  
*Magnetometer Gain Register.*
- `#define MAGREG_MR 0x02`  
*Magnetometer Mode Register.*
- `#define MAGREG_XH 0x03`  
*First Magnetometer Output Register.*

### Functions

- `Error magWriteRegister (uint8_t reg, uint8_t val)`  
*Write a Magnetometer Register.*
- `Error magInit (MagRange r)`  
*Initialize the Magnetometer.*
- `Error magRead (Vector3f *v)`  
*Read from the Magnetometer.*

#### 7.30.1 Detailed Description

LSM303DLHC Magnetometer API Implementation.

Definition in file [mag.c](#).

## 7.31 lib/motor.c File Reference

BL-Ctrl V1.2 Controller API Implementation.

```
#include <stdint.h>
#include <avr/io.h>
#include <twi.h>
#include <motor.h>
#include <tasks.h>
#include <time.h>
#include <config.h>
```

## Functions

- void [motorTask](#) (void)  
*Send the values stored in [motorSpeed](#) to the Controllers.*
- void [motorInit](#) (void)  
*Initializes the motor control library.*
- void [motorSet](#) (uint8\_t id, uint8\_t speed)  
*Set the speed of one or all motors.*

## Variables

- uint8\_t [motorSpeed](#) [[MOTORCOUNT](#)]  
*Speed for the four motors.*

### 7.31.1 Detailed Description

BL-Ctrl V1.2 Controller API Implementation.

Definition in file [motor.c](#).

## 7.32 lib/orientation.c File Reference

Orientation API Implementation.

```
#include <avr/io.h>
#include <stdint.h>
#include <math.h>
#include <xycontrol.h>
#include <error.h>
#include <gyro.h>
#include <acc.h>
#include <mag.h>
#include <tasks.h>
#include <time.h>
#include <orientation.h>
#include <kalman.h>
#include <complementary.h>
#include <config.h>
```

## Macros

- #define [TODEG](#)(x) ((x \* 180) / M\_PI)  
*Convert Radians to Degrees.*

## Functions

- [Error orientationInit](#) (void)  
*Initializes the Orientation API.*
- [Error orientationTask](#) (void)  
*Calculate the current orientation.*
- void [zeroOrientation](#) (void)  
*Sets the current orientation to zero.*

## Variables

- [Angles orientation](#) = {.pitch = 0, .roll = 0, .yaw = 0}  
*Current Aircraft orientation.*
- [Angles orientationError](#) = {.pitch = 0, .roll = 0, .yaw = 0}  
*Current Aircraft orientation offset.*
- [Kalman pitchData](#)  
*Kalman-State for Pitch Angle.*
- [Kalman rollData](#)  
*Kalman-State for Roll Angle.*

### 7.32.1 Detailed Description

Orientation API Implementation.

Definition in file [orientation.c](#).

## 7.33 lib/pid.c File Reference

PID Library Implementation.

```
#include <stdint.h>
#include <avr/io.h>
#include <twi.h>
#include <motor.h>
#include <tasks.h>
#include <time.h>
#include <pid.h>
#include <orientation.h>
#include <config.h>
```

## Functions

- double [pidExecute](#) (double should, double is, [PIDState](#) \*state)  
*Execute a single PID Control Step.*
- void [pidInit](#) (void)  
*Initialize Roll and Pitch PID.*
- void [pidSet](#) ([PIDState](#) \*pid, double kp, double ki, double kd, double min, double max, double iMin, double iMax)  
*Set the parameters of a PID controller.*
- void [pidTask](#) (void)  
*Step the Roll and Pitch PID Controllers.*

## Variables

- [PIDState o\\_pids](#) [2]  
*Roll and Pitch PID States.*
- double [o\\_should](#) [2]  
*Roll and Pitch target angles.*
- double [o\\_output](#) [2]  
*Roll and Pitch PID Output.*

### 7.33.1 Detailed Description

PID Library Implementation.

Definition in file [pid.c](#).

## 7.34 lib/serial.c File Reference

UART Library Implementation.

```
#include <avr/io.h>
#include <avr/interrupt.h>
#include <stdint.h>
#include "serial.h"
#include "serial_device.h"
#include "config.h"
```

### Macros

- `#define RX_BUFFER_SIZE 32`  
*If you define this, a '\r' (CR) will be put in front of a '\n' (LF) when sending a byte.*
- `#define TX_BUFFER_SIZE 16`  
*TX Buffer Size in Bytes (Power of 2)*
- `#define FLOWCONTROL`  
*Defining this enables incoming XON XOFF (sends XOFF if rx buff is full)*
- `#define FLOWMARK 5`  
*Space remaining to trigger xoff/xon.*
- `#define XON 0x11`  
*XON Value.*
- `#define XOFF 0x13`  
*XOFF Value.*

### Functions

- `uint8_t serialAvailable` (void)  
*Get number of available UART modules.*
- `void serialInit` (uint8\_t uart, uint16\_t baud)  
*Initialize the UART Hardware.*
- `void serialClose` (uint8\_t uart)  
*Stop the UART Hardware.*
- `void setFlow` (uint8\_t uart, uint8\_t on)  
*Manually change the flow control.*
- `uint8_t serialHasChar` (uint8\_t uart)  
*Check if a byte was received.*
- `uint8_t serialGetBlocking` (uint8\_t uart)  
*Wait until a character is received.*
- `uint8_t serialGet` (uint8\_t uart)  
*Read a single byte.*
- `uint8_t serialRxBufferFull` (uint8\_t uart)  
*Check if the receive buffer is full.*
- `uint8_t serialRxBufferEmpty` (uint8\_t uart)

- Check if the receive buffer is empty.*
- void [serialWrite](#) (uint8\_t uart, uint8\_t data)  
*Send a byte.*
- void [serialWriteString](#) (uint8\_t uart, const char \*data)  
*Send a string.*
- uint8\_t [serialTxBufferFull](#) (uint8\_t uart)  
*Check if the transmit buffer is full.*
- uint8\_t [serialTxBufferEmpty](#) (uint8\_t uart)  
*Check if the transmit buffer is empty.*

### 7.34.1 Detailed Description

UART Library Implementation.

Definition in file [serial.c](#).

## 7.35 lib/set.c File Reference

Motor Mixer Library Implementation.

```
#include <stdint.h>
#include <avr/io.h>
#include <twi.h>
#include <motor.h>
#include <tasks.h>
#include <time.h>
#include <pid.h>
#include <set.h>
#include <config.h>
```

### Macros

- #define [MAXDIFF](#) ([baseSpeed](#) \* [PID\\_FACTOR](#))  
*Maximum Speed difference on one axis.*

### Functions

- void [setMotorSpeeds](#) (uint8\_t axis, uint8\_t \*vals)  
*Set the Motor Speeds according to the SET\_\* Motor Position Constants.*
- void [setTask](#) (void)  
*Read the PID Output and Set the Motor Speeds.*

### Variables

- uint8\_t [baseSpeed](#) = 0  
*Motor Base Speed.*

### 7.35.1 Detailed Description

Motor Mixer Library Implementation.

Definition in file [set.c](#).

## 7.36 lib/spi.c File Reference

SPI API Implementation.

```
#include <stdint.h>
#include <avr/io.h>
#include <spi.h>
#include <config.h>
```

### Functions

- `uint8_t spiSendByte (uint8_t d)`  
*Send and Receive one byte.*

#### 7.36.1 Detailed Description

SPI API Implementation.

Definition in file [spi.c](#).

## 7.37 lib/tasks.c File Reference

Task API Implementation.

```
#include <stdlib.h>
#include <stdint.h>
#include <xmem.h>
#include <tasks.h>
```

### Functions

- `uint8_t tasksRegistered (void)`  
*Get the number of registered Tasks.*
- `uint8_t addTask (Task func)`  
*Adds another task that will be called regularly.*
- `uint8_t removeTask (Task func)`  
*Removes an already registered Task.*
- `void tasks (void)`  
*Executes registered Tasks.*

### Variables

- `TaskElement * taskList = NULL`  
*List of registered Tasks.*

#### 7.37.1 Detailed Description

Task API Implementation.

Definition in file [tasks.c](#).



## 7.38 lib/time.c File Reference

Time API Implementation.

```
#include <stdlib.h>
#include <stdint.h>
#include <avr/io.h>
#include <avr/interrupt.h>
#include <util/atomic.h>
#include <time.h>
```

### Macros

- `#define TCRA TCCR2A`  
*Timer 2 Control Register A.*
- `#define TCRB TCCR2B`  
*Timer 2 Control Register B.*
- `#define OCR OCR2A`  
*Timer 2 Compare Register A.*
- `#define TIMS TIMSK2`  
*Timer 2 Interrupt Mask.*
- `#define OCIE OCIE2A`  
*Timer 2 Compare Match A Interrupt Enable.*

### Functions

- `void initSystemTimer (void)`  
*Initialize the system timer.*
- `ISR (TIMER2_COMPA_vect)`  
*Timer 2 Compare Match A Interrupt.*
- `time_t getSystemTime (void)`  
*Get the System Uptime.*

### Variables

- `volatile time_t systemTime = 0`  
*Current System Uptime.*

#### 7.38.1 Detailed Description

Time API Implementation.

Definition in file [time.c](#).

## 7.39 lib/uartMenu.c File Reference

UART Menu API Implementation.

```
#include <avr/io.h>
#include <stdint.h>
#include <stdlib.h>
#include <stdio.h>
#include <avr/pgmspace.h>
#include <xycontrol.h>
#include <xmem.h>
#include <tasks.h>
#include <serial.h>
#include <uartMenu.h>
```

## Functions

- [MenuEntry](#) \* [findEntry](#) (uint8\_t cmd)  
*Search the [uartMenu](#) Linked List.*
- uint8\_t [addMenuCommand](#) (uint8\_t cmd, PGM\_P help, [Task](#) f)  
*Add a command to the UART Menu.*
- [MenuEntry](#) \* [reverseList](#) ([MenuEntry](#) \*root)  
*Reverse the UART Menu List.*
- void [uartMenuPrintHelp](#) (void)  
*Print all registered commands.*
- void [uartMenuRegisterHandler](#) (void(\*handler)(char))  
*Register a Handler for unhandled menu commands.*
- void [uartMenuTask](#) (void)  
*Task to work the UART Menu.*

## Variables

- [MenuEntry](#) \* [uartMenu](#) = NULL  
*Single-Linked-List for commands.*
- void(\* [unHandler](#) )(char) = NULL  
*Handler for unhandled commands.*

### 7.39.1 Detailed Description

UART Menu API Implementation.

Definition in file [uartMenu.c](#).

## 7.40 lib/xmem.c File Reference

XMEM API Implementation.

```
#include <avr/io.h>
#include <stdint.h>
#include <stdlib.h>
#include <xmem.h>
#include <config.h>
```

## Functions

- void [saveState](#) (uint8\_t bank)  
*Save the current malloc state.*
- void [restoreState](#) (uint8\_t bank)  
*Restore the malloc state.*
- void [xmemInit](#) (void)  
*Initialize the External Memory Interface.*
- void [xmemSetBank](#) (uint8\_t bank)  
*Switch the active memory bank.*
- uint8\_t [xmemGetBank](#) (void)  
*Get the current memory bank.*

## Variables

- [MallocState](#) [states](#) [[MEMBANKS](#)]  
*MallocState for all Memory Banks.*
- uint8\_t [currentBank](#) = 0  
*Current active Memory Bank.*
- void \* [\\_\\_brkval](#)  
*Internal Malloc Heap-End Pointer.*
- void \* [\\_\\_flp](#)  
*Internal Malloc Free List Pointer (State)*

### 7.40.1 Detailed Description

XMEM API Implementation.

Definition in file [xmem.c](#).

## 7.41 lib/xycontrol.c File Reference

xyControl API Implementation.

```
#include <avr/io.h>
#include <stdint.h>
#include <stdlib.h>
#include <stdio.h>
#include <avr/interrupt.h>
#include <avr/pgmspace.h>
#include <avr/wdt.h>
#include <serial.h>
#include <spi.h>
#include <time.h>
#include <xmem.h>
#include <xycontrol.h>
#include <twi.h>
#include <adc.h>
#include <uartMenu.h>
#include <tasks.h>
#include <config.h>
```

## Functions

- int `uartoutput` (char c, FILE \*f)  
*Method used to write to stdout and stderr.*
- int `uartinput` (FILE \*f)  
*Method used to read from stdin.*
- void `xylnit` (void)  
*Initialize the xyControl Hardware.*
- void `xyLedInternal` (uint8\_t v, volatile uint8\_t \*port, uint8\_t pin)  
*Internal LED Manipulation function.*
- double `getVoltage` (void)  
*Calculate and return the Battery Voltage.*
- void `resetSelf` (void)  
*Use the Watchdog to reset yourself after 15ms.*

## Variables

- char PROGMEM `helpText` [] = "Print this Help"  
*UART Menu Help Text.*
- char PROGMEM `resetText` [] = "Reset MCU"  
*UART Menu Reset Text.*
- FILE `inFile`  
*FILE for stdin.*
- FILE `outFile`  
*FILE for stdout and stderr.*

### 7.41.1 Detailed Description

xyControl API Implementation.

Definition in file `xycontrol.c`.

## Chapter 8

# Example Documentation

### 8.1 test.c

```
/*
 * test.c
 *
 * Copyright (c) 2013, Thomas Buck <xythobuz@me.com>
 * All rights reserved.
 *
 * Redistribution and use in source and binary forms, with or without
 * modification, are permitted provided that the following conditions
 * are met:
 *
 * - Redistributions of source code must retain the above copyright notice,
 *   this list of conditions and the following disclaimer.
 *
 * - Redistributions in binary form must reproduce the above copyright
 *   notice, this list of conditions and the following disclaimer in the
 *   documentation and/or other materials provided with the distribution.
 *
 * THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS
 * "AS IS" AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED
 * TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR
 * PURPOSE ARE DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR
 * CONTRIBUTORS BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL,
 * EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO,
 * PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR
 * PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF
 * LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING
 * NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
 * SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
 */
#include <stdint.h>
#include <stdlib.h>
#include <stdio.h>
#include <avr/io.h>
#include <avr/pgmspace.h>

#include <tasks.h>
#include <error.h>
#include <xycontrol.h>
#include <time.h>
#include <uartMenu.h>
#include <serial.h>
#include <acc.h>
#include <gyro.h>
#include <mag.h>
#include <motor.h>
#include <orientation.h>
#include <pid.h>
#include <set.h>

int main(void) {
    xyInit();
    xyLed(LED_ALL, LED_ON);

    for(;;) {
        tasks();
    }

    return 0;
}
```

## 8.2 uartFlight.c

```

/*
 * uartFlight.c
 *
 * Copyright (c) 2013, Thomas Buck <xythobuz@me.com>
 * All rights reserved.
 *
 * Redistribution and use in source and binary forms, with or without
 * modification, are permitted provided that the following conditions
 * are met:
 *
 * - Redistributions of source code must retain the above copyright notice,
 *   this list of conditions and the following disclaimer.
 *
 * - Redistributions in binary form must reproduce the above copyright
 *   notice, this list of conditions and the following disclaimer in the
 *   documentation and/or other materials provided with the distribution.
 *
 * THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS
 * "AS IS" AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED
 * TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR
 * PURPOSE ARE DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR
 * CONTRIBUTORS BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL,
 * EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO,
 * PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR
 * PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF
 * LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING
 * NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
 * SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
 */
#include <stdint.h>
#include <stdlib.h>
#include <stdio.h>
#include <avr/io.h>
#include <avr/pgmspace.h>

#include <tasks.h>
#include <error.h>
#include <xycontrol.h>
#include <time.h>
#include <uartMenu.h>
#include <serial.h>
#include <acc.h>
#include <gyro.h>
#include <mag.h>
#include <motor.h>
#include <orientation.h>
#include <pid.h>
#include <set.h>

#define MAXANGLE 45
#define ANGLESTEP 10
#define MAXMOTOR 255
#define MOTORSTEP 10
#define QUADFREQ 100
#define STATUSFREQ 10

#define QUADDELAY (1000 / QUADFREQ)
#define STATUSDELAY (1000 / STATUSFREQ)

void flightTask(void);
void statusTask(void);
void controlToggle(void);
void motorToggle(void);
void motorUp(void);
void motorDown(void);
void motorForward(void);
void motorBackward(void);
void motorLeft(void);
void motorRight(void);
void parameterChange(void);

char PROGMEM motorToggleString[] = "Motor On/Off";
char PROGMEM motorUpString[] = "Up";
char PROGMEM motorDownString[] = "Down";
char PROGMEM motorLeftString[] = "Left";
char PROGMEM motorRightString[] = "Right";
char PROGMEM motorForwardString[] = "Forwards";
char PROGMEM motorBackwardString[] = "Backwards";
char PROGMEM controlToggleString[] = "Toggle PID";
char PROGMEM parameterChangeString[] = "Change PID Params";
char PROGMEM zeroString[] = "Angles to Zero";

uint8_t state = 0; // Bit 0: Motor, Bit 1: PID
uint8_t speed = 10;

```

```

int16_t targetRoll = 0;
int16_t targetPitch = 0;

uint32_t sumFlightTask = 0, sumFlightCount = 0;

int main(void) {
    xyInit();
    pidInit();
    motorInit();
    orientationInit();

    addTask(&flightTask);
    addTask(&statusTask);

    addMenuCommand('m', motorToggleString, &motorToggle);
    addMenuCommand('w', motorForwardString, &motorForward);
    addMenuCommand('a', motorLeftString, &motorLeft);
    addMenuCommand('s', motorBackwardString, &motorBackward);
    addMenuCommand('d', motorRightString, &motorRight);
    addMenuCommand('x', motorUpString, &motorUp);
    addMenuCommand('y', motorDownString, &motorDown);
    addMenuCommand('p', controlToggleString, &controlToggle);
    addMenuCommand('n', parameterChangeString, &parameterChange);
    addMenuCommand('z', zeroString, &zeroOrientation);

    xyLed(LED_RED, LED_OFF);
    xyLed(LED_GREEN, LED_ON);

    for(;;) {
        tasks();
    }

    return 0;
}

void flightTask(void) {
    static time_t last = 100; // Don't begin immediately
    if ((getSystemTime() - last) >= QUADDELAY) {
        last = getSystemTime();
        Error e = orientationTask();
        REPORTERROR(e);
        if (state & 0x02) {
            pidTask();
        } else {
            o_output[0] = o_output[1] = 0;
        }
        setTask();
        motorTask();

        uint32_t diff = getSystemTime() - last;
        if (++sumFlightCount >= QUADFREQ) {
            sumFlightCount = 1;
            sumFlightTask = diff;
        } else {
            sumFlightTask += diff;
        }
    }
}

void statusTask(void) {
    static time_t last = 100; // Don't begin immediately
    static uint32_t lastDuration = 0;
    if ((getSystemTime() - last) >= STATUSDELAY) {
        last = getSystemTime();
        printf("q%i %li\n", sumFlightTask / sumFlightCount, lastDuration);
        printf("r%.2f %.2f\n", o_pids[0].intMin, o_pids[0].intMax);
        printf("s%.2f %.2f\n", o_pids[0].outMin, o_pids[0].outMax);
        printf("t%.3f %.3f %.3f\n", o_pids[0].kp, o_pids[0].ki,
            o_pids[0].kd);
        printf("u%.2f %.2f\n", o_output[PITCH], o_output[
            ROLL]);
        printf("v%i %i %i %i\n", motorSpeed[0], motorSpeed[1],
            motorSpeed[2], motorSpeed[3]);
        printf("w%.2f\n", orientation.pitch);
        printf("x%.2f\n", orientation.roll);
        printf("y%.2f\n", orientation.yaw);
        printf("z%.2f\n", getVoltage());
        lastDuration = getSystemTime() - last;
    }
}

void controlToggle(void) {
    if (state & 0x02) {
        state &= ~0x02;
        printf("PID Off!\n");
    } else {
        state |= 0x02;
    }
}

```

```

        printf("PID On!\n");
    }
}

void motorToggle(void) {
    if (state & 0x01) {
        state &= ~0x01;
        baseSpeed = 0;
        printf("Motor Off!\n");
    } else {
        state |= 0x01;
        baseSpeed = speed = 10;
        printf("Motor On!\n");
    }
}

void motorUp(void) {
    if (speed <= (MAXMOTOR - MOTORSTEP)) {
        if (state & 0x01) {
            speed += MOTORSTEP;
            baseSpeed = speed;
            printf("Throttle up to %i\n", speed);
        }
    }
}

void motorDown(void) {
    if (speed >= MOTORSTEP) {
        if (state & 0x01) {
            speed -= MOTORSTEP;
            baseSpeed = speed;
            printf("Throttle down to %i\n", speed);
        }
    }
}

void motorForward(void) {
    if (targetPitch >= (-1 * (MAXANGLE - ANGLESTEP))) {
        targetPitch -= ANGLESTEP;
        o_should[PITCH] = targetPitch;
        printf("Pitch Forward %i\n", targetPitch);
    }
}

void motorBackward(void) {
    if (targetPitch <= (MAXANGLE - ANGLESTEP)) {
        targetPitch += ANGLESTEP;
        o_should[PITCH] = targetPitch;
        printf("Pitch Backwards %i\n", targetPitch);
    }
}

void motorLeft(void) {
    if (targetRoll <= (MAXANGLE - ANGLESTEP)) {
        targetRoll += ANGLESTEP;
        o_should[ROLL] = targetRoll;
        printf("Roll Left %i\n", targetRoll);
    }
}

void motorRight(void) {
    if (targetRoll >= (-1 * (MAXANGLE - ANGLESTEP))) {
        targetRoll -= ANGLESTEP;
        o_should[ROLL] = targetRoll;
        printf("Roll Right %i\n", targetRoll);
    }
}

void parameterChange(void) {
    double p, i, d, min, max, iMin, iMax;
    int c = scanf("%lf %lf %lf %lf %lf %lf %lf", &p, &i, &d, &min, &max, &iMin, &iMax);
    if (c == 7) {
        pidSet(&o_pids[0], p, i, d, min, max, iMin, iMax);
        pidSet(&o_pids[1], p, i, d, min, max, iMin, iMax);
    } else {
        printf("Only got %i (%lf %lf %lf %lf %lf %lf %lf)!\n", c, p, i, d, min, max, iMin, iMax);
    }
}

```



# Index

\_\_brkval  
    External Memory Interface, 93  
\_\_flp  
    External Memory Interface, 93

ADC Driver  
    AINT1, 18  
    AINT2, 18  
    AREF, 18  
    AVCC, 18  
AINT1  
    ADC Driver, 18  
AINT2  
    ADC Driver, 18  
AREF  
    ADC Driver, 18  
ARGUMENT\_ERROR  
    Error Reporting, 36  
AVCC  
    ADC Driver, 18  
ACC\_ADDRESS  
    Configuration, 25  
ACCFILTERFACTOR  
    Configuration, 25  
ACCREG\_CTRL1  
    Accelerometer Driver, 13  
ACCREG\_CTRL4  
    Accelerometer Driver, 13  
ACCREG\_XL  
    Accelerometer Driver, 14  
ADC Driver, 18  
    ADCRef, 18  
    adcClose, 19  
    adcGet, 19  
    adclnit, 19  
    adcReady, 20  
    adcStart, 20  
ADCRef  
    ADC Driver, 18  
ASSERTFUNC  
    Debug Output, 33  
adclnit  
    Accelerometer Driver, 14  
AccRange  
    Accelerometer Driver, 14  
accRange  
    Accelerometer Driver, 17  
accRead  
    Accelerometer Driver, 15  
accWriteRegister

    Accelerometer Driver, 16  
Accelerometer Driver, 13  
    ACCREG\_CTRL1, 13  
    ACCREG\_CTRL4, 13  
    ACCREG\_XL, 14  
    adclnit, 14  
    AccRange, 14  
    accRange, 17  
    accRead, 15  
    accWriteRegister, 16  
    r16G, 14  
    r2G, 14  
    r4G, 14  
    r8G, 14  
adcClose  
    ADC Driver, 19  
adcGet  
    ADC Driver, 19  
adclnit  
    ADC Driver, 19  
adcReady  
    ADC Driver, 20  
adcStart  
    ADC Driver, 20  
addMenuCommand  
    UART Menu, 86  
addTask  
    Task Handler, 75  
Angles, 101  
    pitch, 101  
    roll, 101  
    yaw, 102  
assert  
    Debug Output, 33  
  
BANK0DDR  
    Configuration, 25  
BANK0PIN  
    Configuration, 25  
BANK0PORT  
    Configuration, 25  
BANK1DDR  
    Configuration, 26  
BANK1PIN  
    Configuration, 26  
BANK1PORT  
    Configuration, 26  
BANK2DDR  
    Configuration, 26  
BANK2PIN

- Configuration, 26
- BANK2PORT
  - Configuration, 26
- BANK\_GENERIC
  - External Memory Interface, 91
- BATT\_CHANNEL
  - Configuration, 26
- BATT\_MAX
  - Configuration, 27
- BAUD
  - UART Library, 62
- baseSpeed
  - Motor Speed Mixer, 71
- CHECKERROR
  - Error Reporting, 35
- COMPLEMENTARY\_TAU
  - Configuration, 27
- cmd
  - MenuEntry, 105
- Complementary, 102
- Complementary-Filter, 21
  - complementaryExecute, 21
  - complementaryInit, 21
- complementaryExecute
  - Complementary-Filter, 21
- complementaryInit
  - Complementary-Filter, 21
- Configuration, 23
  - ACC\_ADDRESS, 25
  - ACCFILTERFACTOR, 25
  - BANK0DDR, 25
  - BANK0PIN, 25
  - BANK0PORT, 25
  - BANK1DDR, 26
  - BANK1PIN, 26
  - BANK1PORT, 26
  - BANK2DDR, 26
  - BANK2PIN, 26
  - BANK2PORT, 26
  - BATT\_CHANNEL, 26
  - BATT\_MAX, 27
  - COMPLEMENTARY\_TAU, 27
  - DT, 27
  - GYRO\_ADDRESS, 27
  - GYROFILTERFACTOR, 27
  - LED0DDR, 27
  - LED0PIN, 27
  - LED0PORT, 27
  - LED1DDR, 28
  - LED1PIN, 28
  - LED1PORT, 28
  - LED2DDR, 28
  - LED2PIN, 28
  - LED2PORT, 28
  - LED3DDR, 28
  - LED3PIN, 28
  - LED3PORT, 29
  - MAG\_ADDRESS, 29
  - MOTOR\_BASEADDRESS, 29
  - MOTORCOUNT, 29
  - ORIENTATION\_FILTER, 29
  - PID\_D, 29
  - PID\_FACTOR, 29
  - PID\_I, 29
  - PID\_INTMAX, 30
  - PID\_INTMIN, 30
  - PID\_OUTMAX, 30
  - PID\_OUTMIN, 30
  - PID\_P, 30
  - Q1, 30
  - Q2, 30
  - Q3, 31
  - R1, 31
  - R2, 31
  - RX\_BUFFER\_SIZE, 31
  - SET\_PITCHMINUS, 31
  - SET\_PITCHPLUS, 31
  - SET\_ROLLMINUS, 31
  - SET\_ROLLPLUS, 31
  - SOFTWARELOWPASS, 31
  - SPISS, 32
  - TX\_BUFFER\_SIZE, 32
- currentBank
  - External Memory Interface, 93, 94
- DEBUGOUT
  - Debug Output, 33
- DT
  - Configuration, 27
- Debug Output, 33
  - ASSERTFUNC, 33
  - assert, 33
  - DEBUGOUT, 33
  - debugPrint, 33
- debugPrint
  - Debug Output, 33
- ERROR
  - Error Reporting, 36
- end
  - MallocState, 104
- Error
  - Error Reporting, 36
- Error Reporting, 35
  - ARGUMENT\_ERROR, 36
  - CHECKERROR, 35
  - ERROR, 36
  - Error, 36
  - getErrorString, 36
  - MALLOC\_FAIL, 36
  - REPORTERROR, 35
  - SUCCESS, 36
  - TWI\_NO\_ANSWER, 36
  - TWI\_WRITE\_ERROR, 36
- error.c
  - error0, 128
  - error1, 128

- error2, [128](#)
- error3, [129](#)
- error4, [129](#)
- error5, [129](#)
- errorTable, [129](#)
- error0
  - error.c, [128](#)
- error1
  - error.c, [128](#)
- error2
  - error.c, [128](#)
- error3
  - error.c, [129](#)
- error4
  - error.c, [129](#)
- error5
  - error.c, [129](#)
- errorTable
  - error.c, [129](#)
- External Memory Interface, [90](#)
  - \_\_brkval, [93](#)
  - \_\_flp, [93](#)
  - BANK\_GENERIC, [91](#)
  - currentBank, [93](#), [94](#)
  - MEMBANKS, [91](#)
  - MEMSWITCH, [91](#)
  - MEMSWITCHBACK, [91](#)
  - restoreState, [91](#)
  - saveState, [92](#)
  - states, [94](#)
  - xmemGetBank, [92](#)
  - xmemInit, [92](#)
  - xmemSetBank, [93](#)
- f
  - MenuEntry, [105](#)
- FLOWCONTROL
  - UART Library, [62](#)
- FLOWMARK
  - UART Library, [62](#)
- findEntry
  - UART Menu, [87](#)
- fl
  - MallocState, [104](#)
- Flight, [11](#)
- GYRO\_ADDRESS
  - Configuration, [27](#)
- GYROFILTERFACTOR
  - Configuration, [27](#)
- GYROREG\_CTRL1
  - Gyroscope Driver, [37](#)
- GYROREG\_CTRL4
  - Gyroscope Driver, [37](#)
- GYROREG\_OUTXL
  - Gyroscope Driver, [38](#)
- getErrorString
  - Error Reporting, [36](#)
- getSystemTime
  - Time Keeping, [79](#)
- getVoltage
  - xyControl Hardware, [96](#)
- gyroInit
  - Gyroscope Driver, [38](#)
- GyroRange
  - Gyroscope Driver, [38](#)
- gyroRange
  - Gyroscope Driver, [41](#)
- gyroRead
  - Gyroscope Driver, [39](#)
- gyroWriteByte
  - Gyroscope Driver, [40](#)
- Gyroscope Driver, [37](#)
  - GYROREG\_CTRL1, [37](#)
  - GYROREG\_CTRL4, [37](#)
  - GYROREG\_OUTXL, [38](#)
  - gyroInit, [38](#)
  - GyroRange, [38](#)
  - gyroRange, [41](#)
  - gyroRead, [39](#)
  - gyroWriteByte, [40](#)
  - r2000DPS, [38](#)
  - r250DPS, [38](#)
  - r500DPS, [38](#)
- Hardware, [12](#)
- helpText
  - MenuEntry, [105](#)
  - xyControl Hardware, [99](#)
- I2C Driver, [81](#)
  - TWI\_READ, [81](#)
  - TWI\_WRITE, [81](#)
  - twiInit, [82](#)
  - twiReadAck, [82](#)
  - twiReadNak, [82](#)
  - twiRepStart, [82](#)
  - twiStart, [83](#)
  - twiStartWait, [83](#)
  - twiStop, [84](#)
  - twiWrite, [84](#)
- ISR
  - Time Keeping, [80](#)
- inFile
  - xyControl Hardware, [99](#)
- include/acc.h, [111](#)
- include/adc.h, [111](#)
- include/complementary.h, [112](#)
- include/config.h, [112](#)
- include/debug.h, [115](#)
- include/doc.h, [115](#)
- include/error.h, [116](#)
- include/gyro.h, [116](#)
- include/kalman.h, [117](#)
- include/mag.h, [117](#)
- include/motor.h, [118](#)
- include/orientation.h, [118](#)
- include/pid.h, [119](#)

- include/serial.h, [120](#)
- include/serial\_device.h, [121](#)
- include/set.h, [121](#)
- include/spi.h, [121](#)
- include/tasks.h, [122](#)
- include/time.h, [122](#)
- include/twi.h, [123](#)
- include/uartMenu.h, [124](#)
- include/xmem.h, [124](#)
- include/xycontrol.h, [125](#)
- initSystemTimer
  - Time Keeping, [80](#)
- intMax
  - PIDState, [106](#)
- intMin
  - PIDState, [106](#)
- Kalman, [102](#)
  - p33, [103](#)
  - x3, [103](#)
- Kalman-Filter, [42](#)
  - kalmanInit, [42](#)
  - kalmanInnovate, [43](#)
- kalmanInit
  - Kalman-Filter, [42](#)
- kalmanInnovate
  - Kalman-Filter, [43](#)
- kd
  - PIDState, [106](#)
- ki
  - PIDState, [106](#)
- kp
  - PIDState, [107](#)
- LED\_ALL
  - xyControl Hardware, [96](#)
- LED\_BITMAP
  - xyControl Hardware, [96](#)
- LED\_GREEN
  - xyControl Hardware, [96](#)
- LED\_GREEN0
  - xyControl Hardware, [96](#)
- LED\_GREEN1
  - xyControl Hardware, [96](#)
- LED\_OFF
  - xyControl Hardware, [96](#)
- LED\_ON
  - xyControl Hardware, [96](#)
- LED\_RED
  - xyControl Hardware, [96](#)
- LED\_RED0
  - xyControl Hardware, [96](#)
- LED\_RED1
  - xyControl Hardware, [96](#)
- LED\_TOGGLE
  - xyControl Hardware, [96](#)
- LED
  - xyControl Hardware, [96](#)
- LED0DDR
  - Configuration, [27](#)
- LED0PIN
  - Configuration, [27](#)
- LED0PORT
  - Configuration, [27](#)
- LED1DDR
  - Configuration, [28](#)
- LED1PIN
  - Configuration, [28](#)
- LED1PORT
  - Configuration, [28](#)
- LED2DDR
  - Configuration, [28](#)
- LED2PIN
  - Configuration, [28](#)
- LED2PORT
  - Configuration, [28](#)
- LED3DDR
  - Configuration, [28](#)
- LED3PIN
  - Configuration, [28](#)
- LED3PORT
  - Configuration, [29](#)
- LEDState
  - xyControl Hardware, [96](#)
- last
  - PIDState, [107](#)
- lastError
  - PIDState, [107](#)
- lib/acc.c, [126](#)
- lib/adc.c, [127](#)
- lib/complementary.c, [127](#)
- lib/error.c, [128](#)
- lib/gyro.c, [129](#)
- lib/kalman.c, [130](#)
- lib/mag.c, [131](#)
- lib/motor.c, [131](#)
- lib/orientation.c, [132](#)
- lib/pid.c, [133](#)
- lib/serial.c, [134](#)
- lib/set.c, [135](#)
- lib/spi.c, [136](#)
- lib/tasks.c, [136](#)
- lib/time.c, [137](#)
- lib/uartMenu.c, [137](#)
- lib/xmem.c, [138](#)
- lib/xycontrol.c, [139](#)
- MALLOC\_FAIL
  - Error Reporting, [36](#)
- MODE\_0
  - SPI Driver, [72](#)
- MODE\_1
  - SPI Driver, [72](#)
- MODE\_2
  - SPI Driver, [72](#)
- MODE\_3
  - SPI Driver, [72](#)
- MAG\_ADDRESS

- Configuration, 29
- MAGREG\_CRB
  - Magnetometer Driver, 45
- MAGREG\_MR
  - Magnetometer Driver, 45
- MAGREG\_XH
  - Magnetometer Driver, 46
- MAXDIFF
  - Motor Speed Mixer, 70
- MEMBANKS
  - External Memory Interface, 91
- MEMSWITCH
  - External Memory Interface, 91
- MEMSWITCHBACK
  - External Memory Interface, 91
- MOTOR\_BASEADDRESS
  - Configuration, 29
- MOTORCOUNT
  - Configuration, 29
- magInit
  - Magnetometer Driver, 46
- MagRange
  - Magnetometer Driver, 46
- magRead
  - Magnetometer Driver, 47
- magWriteRegister
  - Magnetometer Driver, 47
- Magnetometer Driver, 45
  - MAGREG\_CRB, 45
  - MAGREG\_MR, 45
  - MAGREG\_XH, 46
  - magInit, 46
  - MagRange, 46
  - magRead, 47
  - magWriteRegister, 47
  - r1g3, 46
  - r1g9, 46
  - r2g5, 46
  - r4g0, 46
  - r4g7, 46
  - r5g6, 46
  - r8g1, 46
- MallocState, 103
  - end, 104
  - fl, 104
  - start, 104
  - val, 104
- MenuEntry, 104
  - cmd, 105
  - f, 105
  - helpText, 105
  - next, 105
- Motor Controller Driver, 49
  - motorInit, 49
  - motorSet, 49
  - motorSpeed, 50
  - motorTask, 50
- Motor Speed Mixer, 70
  - baseSpeed, 71
  - MAXDIFF, 70
  - setMotorSpeeds, 70
  - setTask, 71
- motorInit
  - Motor Controller Driver, 49
- motorSet
  - Motor Controller Driver, 49
- motorSpeed
  - Motor Controller Driver, 50
- motorTask
  - Motor Controller Driver, 50
- next
  - MenuEntry, 105
  - TaskElement, 108
- o\_output
  - PID-Controller, 59
- o\_pids
  - PID-Controller, 59
- o\_should
  - PID-Controller, 60
- OCIE
  - Time Keeping, 79
- OCR
  - Time Keeping, 79
- ORIENTATION\_FILTER
  - Configuration, 29
- orientation
  - Orientation Calculation, 54
- Orientation Calculation, 52
  - orientation, 54
  - orientationError, 55
  - orientationInit, 53
  - orientationTask, 53
  - pitchData, 55
  - rollData, 55
  - TODEG, 53
  - zeroOrientation, 54
- orientationError
  - Orientation Calculation, 55
- orientationInit
  - Orientation Calculation, 53
- orientationTask
  - Orientation Calculation, 53
- outFile
  - xyControl Hardware, 99
- outMax
  - PIDState, 107
- outMin
  - PIDState, 107
- p33
  - Kalman, 103
- PID-Controller, 56
  - o\_output, 59
  - o\_pids, 59
  - o\_should, 60

- PITCH, [57](#)
- pidExecute, [57](#)
- pidInit, [58](#)
- pidSet, [58](#)
- pidTask, [59](#)
- ROLL, [57](#)
- PID\_D
  - Configuration, [29](#)
- PID\_FACTOR
  - Configuration, [29](#)
- PID\_I
  - Configuration, [29](#)
- PID\_INTMAX
  - Configuration, [30](#)
- PID\_INTMIN
  - Configuration, [30](#)
- PID\_OUTMAX
  - Configuration, [30](#)
- PID\_OUTMIN
  - Configuration, [30](#)
- PID\_P
  - Configuration, [30](#)
- PIDState, [105](#)
  - intMax, [106](#)
  - intMin, [106](#)
  - kd, [106](#)
  - ki, [106](#)
  - kp, [107](#)
  - last, [107](#)
  - lastError, [107](#)
  - outMax, [107](#)
  - outMin, [107](#)
  - sumError, [107](#)
- PITCH
  - PID-Controller, [57](#)
- pidExecute
  - PID-Controller, [57](#)
- pidInit
  - PID-Controller, [58](#)
- pidSet
  - PID-Controller, [58](#)
- pidTask
  - PID-Controller, [59](#)
- pitch
  - Angles, [101](#)
- pitchData
  - Orientation Calculation, [55](#)
- Q1
  - Configuration, [30](#)
- Q2
  - Configuration, [30](#)
- Q3
  - Configuration, [31](#)
- R1
  - Configuration, [31](#)
- r16G
  - Accelerometer Driver, [14](#)
- r1g3
  - Magnetometer Driver, [46](#)
- r1g9
  - Magnetometer Driver, [46](#)
- R2
  - Configuration, [31](#)
- r2000DPS
  - Gyroscope Driver, [38](#)
- r250DPS
  - Gyroscope Driver, [38](#)
- r2G
  - Accelerometer Driver, [14](#)
- r2g5
  - Magnetometer Driver, [46](#)
- r4G
  - Accelerometer Driver, [14](#)
- r4g0
  - Magnetometer Driver, [46](#)
- r4g7
  - Magnetometer Driver, [46](#)
- r500DPS
  - Gyroscope Driver, [38](#)
- r5g6
  - Magnetometer Driver, [46](#)
- r8G
  - Accelerometer Driver, [14](#)
- r8g1
  - Magnetometer Driver, [46](#)
- REPORTERROR
  - Error Reporting, [35](#)
- ROLL
  - PID-Controller, [57](#)
- RX\_BUFFER\_SIZE
  - Configuration, [31](#)
  - UART Library, [62](#)
- removeTask
  - Task Handler, [75](#)
- resetSelf
  - xyControl Hardware, [97](#)
- resetText
  - xyControl Hardware, [99](#)
- restoreState
  - External Memory Interface, [91](#)
- reverseList
  - UART Menu, [87](#)
- roll
  - Angles, [101](#)
- rollData
  - Orientation Calculation, [55](#)
- SPEED\_128
  - SPI Driver, [73](#)
- SPEED\_16
  - SPI Driver, [73](#)
- SPEED\_2
  - SPI Driver, [73](#)
- SPEED\_32
  - SPI Driver, [73](#)
- SPEED\_4

- SPI Driver, [73](#)
- SPEED\_64
  - SPI Driver, [73](#)
- SPEED\_8
  - SPI Driver, [73](#)
- SPI Driver
  - MODE\_0, [72](#)
  - MODE\_1, [72](#)
  - MODE\_2, [72](#)
  - MODE\_3, [72](#)
  - SPEED\_128, [73](#)
  - SPEED\_16, [73](#)
  - SPEED\_2, [73](#)
  - SPEED\_32, [73](#)
  - SPEED\_4, [73](#)
  - SPEED\_64, [73](#)
  - SPEED\_8, [73](#)
- SUCCESS
  - Error Reporting, [36](#)
- SET\_PITCHMINUS
  - Configuration, [31](#)
- SET\_PITCHPLUS
  - Configuration, [31](#)
- SET\_ROLLMINUS
  - Configuration, [31](#)
- SET\_ROLLPLUS
  - Configuration, [31](#)
- SOFTWARELOWPASS
  - Configuration, [31](#)
- SPI Driver, [72](#)
  - SPI\_MODE, [72](#)
  - SPI\_SPEED, [72](#)
  - spilnit, [73](#)
  - spiSendByte, [73](#)
- SPI\_MODE
  - SPI Driver, [72](#)
- SPI\_SPEED
  - SPI Driver, [72](#)
- SPISS
  - Configuration, [32](#)
- saveState
  - External Memory Interface, [92](#)
- serialAvailable
  - UART Library, [63](#)
- serialClose
  - UART Library, [63](#)
- serialGet
  - UART Library, [63](#)
- serialGetBlocking
  - UART Library, [64](#)
- serialHasChar
  - UART Library, [65](#)
- serialInit
  - UART Library, [65](#)
- serialRxBufferEmpty
  - UART Library, [66](#)
- serialRxBufferFull
  - UART Library, [66](#)
- serialTxBufferEmpty
  - UART Library, [66](#)
- serialTxBufferFull
  - UART Library, [67](#)
- serialWrite
  - UART Library, [67](#)
- serialWriteString
  - UART Library, [68](#)
- setFlow
  - UART Library, [68](#)
- setMotorSpeeds
  - Motor Speed Mixer, [70](#)
- setTask
  - Motor Speed Mixer, [71](#)
- Software, [9](#)
- spilnit
  - SPI Driver, [73](#)
- spiSendByte
  - SPI Driver, [73](#)
- start
  - MallocState, [104](#)
- states
  - External Memory Interface, [94](#)
- sumError
  - PIDState, [107](#)
- System, [10](#)
- systemTime
  - Time Keeping, [80](#)
- TWI\_NO\_ANSWER
  - Error Reporting, [36](#)
- TWI\_WRITE\_ERROR
  - Error Reporting, [36](#)
- TCRA
  - Time Keeping, [79](#)
- TCRB
  - Time Keeping, [79](#)
- TIMS
  - Time Keeping, [79](#)
- TODEG
  - Orientation Calculation, [53](#)
- TWI\_READ
  - I2C Driver, [81](#)
- TWI\_WRITE
  - I2C Driver, [81](#)
- TX\_BUFFER\_SIZE
  - Configuration, [32](#)
  - UART Library, [62](#)
- Task
  - Task Handler, [74](#)
- task
  - TaskElement, [108](#)
- Task Handler, [74](#)
  - addTask, [75](#)
  - removeTask, [75](#)
  - Task, [74](#)
  - taskList, [76, 77](#)
  - tasks, [76](#)
  - tasksRegistered, [76](#)

- TaskElement, 108
  - next, 108
  - task, 108
- taskList
  - Task Handler, 76, 77
- tasks
  - Task Handler, 76
- tasksRegistered
  - Task Handler, 76
- Time Keeping, 78
  - getSystemTime, 79
  - ISR, 80
  - initSystemTimer, 80
  - OCIE, 79
  - OCR, 79
  - systemTime, 80
  - TCRA, 79
  - TCRB, 79
  - TIMS, 79
  - time\_t, 79
- time\_t
  - Time Keeping, 79
- twiInit
  - I2C Driver, 82
- twiReadAck
  - I2C Driver, 82
- twiReadNak
  - I2C Driver, 82
- twiRepStart
  - I2C Driver, 82
- twiStart
  - I2C Driver, 83
- twiStartWait
  - I2C Driver, 83
- twiStop
  - I2C Driver, 84
- twiWrite
  - I2C Driver, 84
- UART Library, 61
  - BAUD, 62
  - FLOWCONTROL, 62
  - FLOWMARK, 62
  - RX\_BUFFER\_SIZE, 62
  - serialAvailable, 63
  - serialClose, 63
  - serialGet, 63
  - serialGetBlocking, 64
  - serialHasChar, 65
  - serialInit, 65
  - serialRxBufferEmpty, 66
  - serialRxBufferFull, 66
  - serialTxBufferEmpty, 66
  - serialTxBufferFull, 67
  - serialWrite, 67
  - serialWriteString, 68
  - setFlow, 68
  - TX\_BUFFER\_SIZE, 62
  - XOFF, 62
  - XON, 63
- UART Menu, 86
  - addMenuCommand, 86
  - findEntry, 87
  - reverseList, 87
  - uartMenu, 89
  - uartMenuPrintHelp, 88
  - uartMenuRegisterHandler, 88
  - uartMenuTask, 89
  - unHandler, 89
- uartMenu
  - UART Menu, 89
- uartMenuPrintHelp
  - UART Menu, 88
- uartMenuRegisterHandler
  - UART Menu, 88
- uartMenuTask
  - UART Menu, 89
- uartinput
  - xyControl Hardware, 97
- uartoutput
  - xyControl Hardware, 97
- unHandler
  - UART Menu, 89
- val
  - MallocState, 104
- Vector3f, 108
  - x, 109
  - y, 109
  - z, 109
- x
  - Vector3f, 109
- x3
  - Kalman, 103
- XOFF
  - UART Library, 62
- XON
  - UART Library, 63
- xmemGetBank
  - External Memory Interface, 92
- xmemInit
  - External Memory Interface, 92
- xmemSetBank
  - External Memory Interface, 93
- xyControl Hardware
  - LED\_ALL, 96
  - LED\_BITMAP, 96
  - LED\_GREEN, 96
  - LED\_GREEN0, 96
  - LED\_GREEN1, 96
  - LED\_OFF, 96
  - LED\_ON, 96
  - LED\_RED, 96
  - LED\_RED0, 96
  - LED\_RED1, 96
  - LED\_TOGGLE, 96
- xyControl Hardware, 95



- getVoltage, [96](#)
- helpText, [99](#)
- inFile, [99](#)
- LED, [96](#)
- LEDState, [96](#)
- outFile, [99](#)
- resetSelf, [97](#)
- resetText, [99](#)
- uartinput, [97](#)
- uartoutput, [97](#)
- xyInit, [98](#)
- xyLed, [98](#)
- xyLedInternal, [99](#)
- xyInit
  - xyControl Hardware, [98](#)
- xyLed
  - xyControl Hardware, [98](#)
- xyLedInternal
  - xyControl Hardware, [99](#)
- y
  - Vector3f, [109](#)
- yaw
  - Angles, [102](#)
- z
  - Vector3f, [109](#)
- zeroOrientation
  - Orientation Calculation, [54](#)