

xyControl

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# Chapter 1

## Main Page

`xyControl` is a Quadcopter Flight Controller based on Atmels Atmega2560 microcontroller. It features 512KB SRAM 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.

![\[Photo 1\]](#) [\[xy1s\]](#) ![\[Photo 2\]](#) [\[xy2s\]](#) ![\[Screenshot\]](#) [\[sss\]](#)

### 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

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# Chapter 3

## Data Structure Index

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# Chapter 4

## File Index

### 4.1 File List

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# 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 AVRs 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 `acclnit()`.

### 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 `acclnit ( 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.

##### Examples:

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

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 x1 = twiReadAck();
125     uint8_t xh = twiReadAck();
126     uint8_t y1 = 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 *)(&zh);
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 `acclnit()`.

```
62                                     {
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\_KALMAN  
*Filter Implementation to be used.*
- #define [COMPLEMENTARY\\_TAU](#) 0.5  
*Time Constant 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 [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 117 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 144 of file config.h.

Referenced by `xmemInit()`.

#### 5.8.2.4 #define `BANK0PIN` `PG3`

First Bank Selection Pin.

Definition at line 145 of file config.h.

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

#### 5.8.2.5 #define BANK0PORT PORTG

First Bank Selection Port.

Definition at line 143 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 147 of file config.h.

Referenced by xmemInit().

#### 5.8.2.7 #define BANK1PIN PG4

Second Bank Selection Pin.

Definition at line 148 of file config.h.

Referenced by xmemInit(), and xmemSetBank().

#### 5.8.2.8 #define BANK1PORT PORTG

Second Bank Selection Port.

Definition at line 146 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 150 of file config.h.

Referenced by xmemInit().

#### 5.8.2.10 #define BANK2PIN PL5

Third Bank Selection Pin.

Definition at line 151 of file config.h.

Referenced by xmemInit(), and xmemSetBank().

#### 5.8.2.11 #define BANK2PORT PORTL

Third Bank Selection Port.

Definition at line 149 of file config.h.

Referenced by xmemInit(), and xmemSetBank().

#### 5.8.2.12 #define BATT\_CHANNEL 0

ADC Channel for Battery.

Definition at line 111 of file config.h.

Referenced by `getVoltage()`.

#### 5.8.2.13 `#define BATT_MAX 15`

Battery Voltage Reference (ADC 5V)

Definition at line 110 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 72 of file `config.h`.

Referenced by `kalmanInnovate()`.

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

Gyroscope Address (110101xr, x = 1)

Definition at line 118 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 127 of file `config.h`.

Referenced by `xyInit()`.

#### 5.8.2.19 `#define LED0PIN PL6`

First LED Pin.

Definition at line 128 of file `config.h`.

Referenced by `xyInit()`.

#### 5.8.2.20 `#define LED0PORT PORTL`

First LED Port.

Definition at line 126 of file config.h.

#### 5.8.2.21 `#define LED1DDR DDRL`

Second LED Data Direction Register.

Definition at line 130 of file config.h.

Referenced by `xyInit()`.

#### 5.8.2.22 `#define LED1PIN PL7`

Second LED Pin.

Definition at line 131 of file config.h.

Referenced by `xyInit()`.

#### 5.8.2.23 `#define LED1PORT PORTL`

Second LED Port.

Definition at line 129 of file config.h.

#### 5.8.2.24 `#define LED2DDR DDRG`

Third LED Data Direction Register.

Definition at line 133 of file config.h.

Referenced by `xyInit()`.

#### 5.8.2.25 `#define LED2PIN PG5`

Third LED Pin.

Definition at line 134 of file config.h.

Referenced by `xyInit()`.

#### 5.8.2.26 `#define LED2PORT PORTG`

Third LED Port.

Definition at line 132 of file config.h.

#### 5.8.2.27 `#define LED3DDR DDRE`

Fourth LED Data Direction Register.

Definition at line 136 of file config.h.

Referenced by `xyInit()`.

**5.8.2.28 #define LED3PIN PE2**

Fourth LED Pin.

Definition at line 137 of file config.h.

Referenced by xyInit().

**5.8.2.29 #define LED3PORT PORTE**

Fourth LED Port.

Definition at line 135 of file config.h.

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

Magnetometer Address.

Definition at line 119 of file config.h.

Referenced by magRead(), and magWriteRegister().

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

Address of first motor controller.

Definition at line 120 of file config.h.

Referenced by motorTask().

**5.8.2.32 #define MOTORCOUNT 4**

Amount of motors.

Definition at line 104 of file config.h.

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

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

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 98 of file config.h.

Referenced by pidInit().

**5.8.2.35 #define PID\_I 0.03**

Default PID I Constant.

Definition at line 97 of file config.h.

Referenced by pidInit().

**5.8.2.36 #define PID\_INTMAX PID\_OUTMAX**

Maximum PID Integral Sum.

Definition at line 64 of file config.h.

Referenced by pidInit().

**5.8.2.37 #define PID\_INTMIN PID\_OUTMIN**

Minimal PID Integral Sum.

Definition at line 65 of file config.h.

Referenced by pidInit().

**5.8.2.38 #define PID\_OUTMAX 256**

Maximum PID Output.

Definition at line 62 of file config.h.

Referenced by pidInit().

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

Minimum PID Output.

Definition at line 63 of file config.h.

Referenced by pidInit().

**5.8.2.40 #define PID\_P 5.0**

Default PID P Constant.

Definition at line 96 of file config.h.

Referenced by pidInit().

**5.8.2.41 #define Q1 5.0f**

Q Matrix Diagonal Element 1.

Definition at line 75 of file config.h.

Referenced by kalmanInnovate().

**5.8.2.42 #define Q2 100.0f**

Q Matrix Diagonal Element 2.

Definition at line 76 of file config.h.

Referenced by kalmanInnovate().

**5.8.2.43 #define Q3 0.01f**

Q Matrix Diagonal Element 3.

Definition at line 77 of file config.h.

Referenced by kalmanInnovate().

#### 5.8.2.44 #define R1 1000.0f

R Matrix Diagonal Element 1.

Definition at line 80 of file config.h.

Referenced by kalmanInnovate().

#### 5.8.2.45 #define R2 1000.0f

R Matrix Diagonal Element 2.

Definition at line 81 of file config.h.

Referenced by kalmanInnovate().

#### 5.8.2.46 #define RX\_BUFFER\_SIZE 64

UART Receive Buffer Size.

Definition at line 166 of file config.h.

#### 5.8.2.47 #define SET\_PITCHMINUS 2

Third Motor at the Bottom.

Definition at line 90 of file config.h.

Referenced by setMotorSpeeds().

#### 5.8.2.48 #define SET\_PITCHPLUS 0

First Motor at the Top.

Definition at line 89 of file config.h.

Referenced by setMotorSpeeds().

#### 5.8.2.49 #define SET\_ROLLMINUS 3

Fourth Motor at the Left.

Definition at line 88 of file config.h.

Referenced by setMotorSpeeds().

#### 5.8.2.50 #define SET\_ROLLPLUS 1

Second Motor at the Right.

Definition at line 87 of file config.h.

Referenced by setMotorSpeeds().

#### 5.8.2.51 #define SOFTWARELOWPASS 1

Software Low-Pass on Gyro and ACC.

Definition at line 58 of file config.h.

#### 5.8.2.52 `#define SPISS_PB0`

SPI Slave Select Pin.

Definition at line 160 of file config.h.

#### 5.8.2.53 `#define TX_BUFFER_SIZE 64`

UART Transmit Buffer Size.

Definition at line 167 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("!\%s\n", 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("!\%s\n", x)`

Debug Output Function.

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

#### 5.9.2.4 #define debugPrint( *ignore* )

Disable `debugPrint()`

Examples:

`uartFlight.c`.

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](#)

##### Examples:

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

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 |= yl;
131
132     int16_t z = *(int8_t *)(&zh);
133     z *= (1 << 8);
134     z |= zl;
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.*

### Variables

- [MagRange magRange](#)  
*Stored range to scale returned values.*

#### 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>	MagRange to use.
----------	------------------

## Returns

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

Definition at line 77 of file mag.c.

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

```

77     {
78     if ((r <= 0) || (r >= 8)) {
79         return ARGUMENT_ERROR;
80     }
81     Error e = magWriteRegister(MAGREG_MR, 0x00); // Continuous Conversion
82     if (e != SUCCESS) {
83         return e;
84     }
85     e = magWriteRegister(MAGREG_CRB, (r << 5)); // Set Range
86     magRange = r;
87     return e;
88 }

```

## 5.13.4.2 Error magRead ( Vector3f \* v )

Read from the Magnetometer.

Magnetometer should already be initialized!

## Parameters

<i>v</i>	Vector3f for the read values
----------	------------------------------

## Returns

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

## Examples:

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

Definition at line 90 of file mag.c.

References [ARGUMENT\\_ERROR](#), [MAG\\_ADDRESS](#), [magRange](#), [MAGREG\\_XH](#), [r1g3](#), [r1g9](#), [r2g5](#), [r4g0](#), [r4g7](#), [r5g6](#), [r8g1](#), [SUCCESS](#), [TWI\\_NO\\_ANSWER](#), [TWI\\_READ](#), [TWI\\_WRITE](#), [TWI\\_WRITE\\_ERROR](#), [twiReadAck\(\)](#), [twiReadNak\(\)](#), [twiRepStart\(\)](#), [twiStart\(\)](#), [twiWrite\(\)](#), [Vector3f::x](#), [Vector3f::y](#), and [Vector3f::z](#).

```

90     {
91     if (v == NULL) {
92         return ARGUMENT_ERROR;
93     }
94     if (twiStart(MAG_ADDRESS | TWI_WRITE)) {
95         return TWI_NO_ANSWER;
96     }
97     if (twiWrite(MAGREG_XH)) {
98         return TWI_WRITE_ERROR;
99     }
100    if (twiRepStart(MAG_ADDRESS | TWI_READ)) {
101        return TWI_NO_ANSWER;
102    }
103    uint8_t xh = twiReadAck();
104    uint8_t xl = twiReadAck();
105    uint8_t zh = twiReadAck();
106    uint8_t zl = twiReadAck();
107    uint8_t yh = twiReadAck();
108    uint8_t yl = twiReadNak();

```

```

109
110     int16_t x = *(int8_t *)(&xh);
111     x *= (1 << 8);
112     x |= xl;
113
114     int16_t y = *(int8_t *)(&yh);
115     y *= (1 << 8);
116     y |= yl;
117
118     int16_t z = *(int8_t *)(&zh);
119     z *= (1 << 8);
120     z |= zl;
121
122     switch (magRange) {
123     case r1g3:
124         v->x = (((double)x) * 1.3 / MAG_NORMALIZE);
125         v->y = (((double)y) * 1.3 / MAG_NORMALIZE);
126         v->z = (((double)z) * 1.3 / MAG_NORMALIZE);
127         break;
128     case r1g9:
129         v->x = (((double)x) * 1.9 / MAG_NORMALIZE);
130         v->y = (((double)y) * 1.9 / MAG_NORMALIZE);
131         v->z = (((double)z) * 1.9 / MAG_NORMALIZE);
132         break;
133     case r2g5:
134         v->x = (((double)x) * 2.5 / MAG_NORMALIZE);
135         v->y = (((double)y) * 2.5 / MAG_NORMALIZE);
136         v->z = (((double)z) * 2.5 / MAG_NORMALIZE);
137         break;
138     case r4g0:
139         v->x = (((double)x) * 4.0 / MAG_NORMALIZE);
140         v->y = (((double)y) * 4.0 / MAG_NORMALIZE);
141         v->z = (((double)z) * 4.0 / MAG_NORMALIZE);
142         break;
143     case r4g7:
144         v->x = (((double)x) * 4.7 / MAG_NORMALIZE);
145         v->y = (((double)y) * 4.7 / MAG_NORMALIZE);
146         v->z = (((double)z) * 4.7 / MAG_NORMALIZE);
147         break;
148     case r5g6:
149         v->x = (((double)x) * 5.6 / MAG_NORMALIZE);
150         v->y = (((double)y) * 5.6 / MAG_NORMALIZE);
151         v->z = (((double)z) * 5.6 / MAG_NORMALIZE);
152         break;
153     case r8g1:
154         v->x = (((double)x) * 8.1 / MAG_NORMALIZE);
155         v->y = (((double)y) * 8.1 / MAG_NORMALIZE);
156         v->z = (((double)z) * 8.1 / MAG_NORMALIZE);
157         break;
158     default:
159         return ARGUMENT_ERROR;
160     }
161
162     return SUCCESS;
163 }

```

#### 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 63 of file mag.c.

References [MAG\\_ADDRESS](#), [SUCCESS](#), [TWI\\_NO\\_ANSWER](#), [TWI\\_WRITE](#), [TWI\\_WRITE\\_ERROR](#), [twiStart\(\)](#), [twiStop\(\)](#), and [twiWrite\(\)](#).

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



```
63                                     {
64     if (twiStart(MAG_ADDRESS | TWI_WRITE)) {
65         return TWI_NO_ANSWER;
66     }
67     if (twiWrite(reg)) {
68         return TWI_WRITE_ERROR;
69     }
70     if (twiWrite(val)) {
71         return TWI_WRITE_ERROR;
72     }
73     twiStop();
74     return SUCCESS;
75 }
```

## 5.13.5 Variable Documentation

### 5.13.5.1 MagRange magRange

Stored range to scale returned values.

Definition at line 54 of file mag.c.

Referenced by magInit(), and magRead().

## 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:

[hardwareTest.c](#), and [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:

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

Definition at line 73 of file orientation.c.

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

```

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

### 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 90 of file orientation.c.

References [accRead\(\)](#), [CHECKERROR](#), [complementaryExecute\(\)](#), [ERROR](#), [getSystemTime\(\)](#), [gyroRead\(\)](#), [kalmanInnovate\(\)](#), [orientation](#), [Angles::pitch](#), [Angles::roll](#), [SUCCESS](#), [TODEG](#), [Angles::vPitch](#), [Angles::vRoll](#), [Angles::vYaw](#), [Vector3f::x](#), [xySelfReset\(\)](#), [Vector3f::y](#), [Angles::yaw](#), and [Vector3f::z](#).

```

90     {
91     Vector3f g, a;
92     Error e = accRead(&a); // Read Accelerometer
93     CHECKERROR(e);
94     e = gyroRead(&g); // Read Gyroscope
95     CHECKERROR(e);
96
97     // Calculate Pitch & Roll from Accelerometer Data
98     double roll = atan(a.x / hypot(a.y, a.z));
99     double pitch = atan(a.y / hypot(a.x, a.z));
100    roll = TODEG(roll);
101    pitch = TODEG(pitch); // As Degree, not radians!
102
103    // Filter Roll and Pitch with Gyroscope Data from the corresponding axis
104    #if ORIENTATION_FILTER == FILTER_KALMAN
105    kalmanInnovate(&pitchData, pitch, g.x);
106    kalmanInnovate(&rollData, roll, g.y);
107    orientation.roll = rollData.x1;
108    orientation.pitch = pitchData.x1;
109    #elif ORIENTATION_FILTER == FILTER_COMPLEMENTARY
110    complementaryExecute(&pitchData, pitch, g.x);
111    complementaryExecute(&rollData, roll, g.y);
112    orientation.roll = rollData.angle;
113    orientation.pitch = pitchData.angle;
114    #endif
115
116    // Zero Offset for angles
117    orientation.roll -= orientationError.roll;
118    orientation.pitch -= orientationError.pitch;
119    orientation.yaw -= orientationError.yaw;
120
121    // Store Angle Speeds
122    orientation.vRoll = g.y;
123    orientation.vPitch = g.x;
124    orientation.vYaw = g.z;
125
126    // Self-Reset if data is garbage and we just came up
127    if (getSystemTime() < 2000) {
128        if (isnan(orientation.roll) || isnan(orientation.
pitch) || isnan(orientation.yaw)) {
129            xySelfReset();
130            return ERROR;
131        }
132    }
133
134    return SUCCESS;
135 }

```

### 5.15.3.3 void zeroOrientation ( void )

Sets the current orientation to zero.

Examples:

[uartFlight.c](#).

Definition at line 137 of file orientation.c.

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

```

137     {
138     orientationError.roll = orientation.roll +
orientationError.roll;
139     orientationError.pitch = orientation.pitch +
orientationError.pitch;
140     orientationError.yaw = orientation.yaw +
orientationError.yaw;
141 }

```

## 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 [pidTarget](#), [pidOutput](#) and [pidStates](#).*
- `#define PITCH 1`  
*Pitch index for [pidTarget](#), [pidOutput](#) and [pidStates](#).*

### 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 [pidTarget](#) [2]  
*Roll and Pitch target angles.*
- double [pidOutput](#) [2]  
*Roll and Pitch PID Output.*
- [PIDState](#) [pidStates](#) [2]  
*Roll and Pitch PID States.*
- [PIDState](#) [pidStates](#) [2]  
*Roll and Pitch PID States.*
- double [pidTarget](#) [2]  
*Roll and Pitch target angles.*
- double [pidOutput](#) [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 [pidTarget](#), [pidOutput](#) and [pidStates](#).

Examples:

[uartFlight.c](#).

Definition at line 61 of file [pid.h](#).

Referenced by [pidTask\(\)](#), and [setMotorSpeeds\(\)](#).

#### 5.16.2.2 #define ROLL 0

Roll index for [pidTarget](#), [pidOutput](#) and [pidStates](#).

Examples:

[uartFlight.c](#).

Definition at line 60 of file [pid.h](#).

Referenced by [pidTask\(\)](#), and [setMotorSpeeds\(\)](#).

### 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 [pidStates](#). Also resets [pidTarget](#) to zero.

Examples:

[uartFlight.c](#).

Definition at line 74 of file pid.c.

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

```

74     {
75     for (uint8_t i = 0; i < 2; i++) {
76         pidSet(&pidStates[i], PID_P, PID_I, PID_D,
PID_OUTMIN, PID_OUTMAX, PID_INTMIN, PID_INTMAX);
77         pidTarget[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;
92 }

```

#### 5.16.3.4 void pidTask ( void )

Step the Roll and Pitch PID Controllers.

Placing their output in [pidOutput](#) and reading the input from [pidTarget](#) and the global orientation [Angles](#).

Examples:

[uartFlight.c](#).

Definition at line 94 of file [pid.c](#).

References [orientation](#), [pidExecute\(\)](#), [pidOutput](#), [pidTarget](#), [Angles::pitch](#), [PITCH](#), [Angles::roll](#), and [ROLL](#).

```

94     {
95     pidOutput[ROLL] = pidExecute(pidTarget[ROLL],
orientation.roll, &pidStates[ROLL]);
96     pidOutput[PITCH] = pidExecute(pidTarget[
PITCH], orientation.pitch, &pidStates[PITCH]);
97 }

```

### 5.16.4 Variable Documentation

#### 5.16.4.1 double pidOutput[2]

Roll and Pitch PID Output.

Definition at line 52 of file [pid.c](#).

Referenced by [pidTask\(\)](#), and [setTask\(\)](#).

#### 5.16.4.2 double pidOutput[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 pidStates[2]

Roll and Pitch PID States.

Definition at line 50 of file [pid.c](#).

#### 5.16.4.4 PIDState pidStates[2]

Roll and Pitch PID States.

Examples:

[uartFlight.c](#).

Definition at line 50 of file pid.c.

#### 5.16.4.5 double pidTarget[2]

Roll and Pitch target angles.

Definition at line 51 of file pid.c.

Referenced by pidInit(), and pidTask().

#### 5.16.4.6 double pidTarget[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 [USB](#) 0  
*First UART Name.*
- #define [BLUETOOTH](#) 1  
*Second UART Name.*
- #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 49 of file `serial.h`.

Referenced by `xyInit()`.

#### 5.17.2.2 `#define BLUETOOTH 1`

Second UART Name.

Examples:

`hardwareTest.c`.

Definition at line 46 of file `serial.h`.

#### 5.17.2.3 `#define FLOWCONTROL`

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

Definition at line 63 of file `serial.c`.

#### 5.17.2.4 `#define FLOWMARK 5`

Space remaining to trigger xoff/xon.

Definition at line 65 of file `serial.c`.

Referenced by `serialGet()`.

#### 5.17.2.5 #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().

#### 5.17.2.6 #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().

#### 5.17.2.7 #define USB 0

First UART Name.

Examples:

[hardwareTest.c](#).

Definition at line 45 of file serial.h.

#### 5.17.2.8 #define XOFF 0x13

XOFF Value.

Definition at line 67 of file serial.c.

Referenced by setFlow().

#### 5.17.2.9 #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

## Examples:

[hardwareTest.c](#).

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][SERIALUDRE]); // 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

##### Examples:

[hardwareTest.c](#).

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 #ifndef 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

## Examples:

[hardwareTest.c](#).

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 SERIALINJECTOR
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 of 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.*

### 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 Function Documentation

##### 5.18.2.1 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 57 of file set.c.

References [motorSet\(\)](#), [PITCH](#), [ROLL](#), [SET\\_PITCHMINUS](#), [SET\\_PITCHPLUS](#), [SET\\_ROLLMINUS](#), and [SET\\_ROLLPLUS](#).

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

```

57                                     {
58     if (axis == ROLL) {
59         motorSet(SET_ROLLPLUS, vals[0]);
60         motorSet(SET_ROLLMINUS, vals[1]);
61     } else if (axis == PITCH) {
62         motorSet(SET_PITCHPLUS, vals[0]);
63         motorSet(SET_PITCHMINUS, vals[1]);
64     }
65 }
```

### 5.18.2.2 void setTask ( void )

Read the PID Output and Set the Motor Speeds.

Examples:

[uartFlight.c](#).

Definition at line 67 of file set.c.

References `baseSpeed`, `pidOutput`, and `setMotorSpeeds()`.

```

67         {
68     if (baseSpeed != 0) {
69         for (uint8_t i = 0; i < 2; i++) {
70             int16_t diff = pidOutput[i];
71             // Base-Speed is always positive, diff could be negative
72             if (diff > 0) {
73                 if (diff > baseSpeed) {
74                     diff = baseSpeed; // Limit PID
75                 }
76             } else {
77                 if (diff < -baseSpeed) {
78                     diff = -baseSpeed; // Limit PID
79                 }
80             }
81             uint8_t v[2] = { baseSpeed + diff, baseSpeed - diff };
82             if (v[0] < 10)
83                 v[0] = 10; // Keep Motors running
84             if (v[1] < 10)
85                 v[1] = 10;
86             setMotorSpeeds(i, v);
87         }
88     } else {
89         // Motors stopped
90         uint8_t v[2] = {0, 0};
91         setMotorSpeeds(0, v);
92         setMotorSpeeds(1, v);
93     }
94 }

```

## 5.18.3 Variable Documentation

### 5.18.3.1 uint8\_t baseSpeed

Motor Base Speed.

Examples:

[uartFlight.c](#).

Definition at line 51 of file set.c.

Referenced by `setTask()`.

### 5.18.3.2 uint8\_t baseSpeed = 0

Motor Base Speed.

Definition at line 51 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 [spilnit](#) ([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 xylnit().

### 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:

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

Definition at line 57 of file tasks.c.

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

Referenced by `xylnit()`.

```

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:

[hardwareTest.c](#), [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:

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



Definition at line 68 of file time.c.

References systemTime.

Referenced by complementaryExecute(), complementaryInit(), orientationTask(), 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 xylnit().

```
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(), magWriteRegister(), and motorTask().

## 5.22.3 Function Documentation

## 5.22.3.1 void twiI2cInit ( void )

Initialize the I2C Hardware.

Definition at line 26 of file twi.c.

Referenced by xyI2cInit().

```

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 */

```

#### 5.2.2.3.4 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 */
```

#### 5.2.2.3.5 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(), magWriteRegister(), 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 magWriteRegister(), and 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()`, `magWriteRegister()`, 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

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

**Returns**

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

**Examples:**

[hardwareTest.c](#), and [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 `xyInit()`.

```

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 xyInit().

```

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 xyInit().

```

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.

Examples:

[hardwareTest.c](#).

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

x	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

x	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.

##### Examples:

[hardwareTest.c](#).

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 xylInit().

```

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
-------------	-----------------

##### Examples:

[hardwareTest.c](#).

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 [xySelfReset](#) (void)  
*Use the Watchdog to reset yourself after 15ms.*
- int64\_t [map](#) (int64\_t value, int64\_t oldMin, int64\_t oldMax, int64\_t newMin, int64\_t newMax)  
*Map an Integer from one range to another range.*
- 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:

[hardwareTest.c](#), and [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 int64\_t map ( int64\_t value, int64\_t oldMin, int64\_t oldMax, int64\_t newMin, int64\_t newMax )

Map an Integer from one range to another range.

##### Parameters

<i>value</i>	Integer to operate on
<i>oldMin</i>	Lower Limit of Input range
<i>oldMax</i>	Upper Limit of Input range
<i>newMin</i>	Lower Limit of Output range
<i>newMax</i>	Upper Limit of Output range

##### Returns

Value in new range

Definition at line 184 of file xycontrol.c.

```

184     {
185     return (value - oldMin) * (newMax - newMin) / (oldMax - oldMin) + newMin;
186 }

```

#### 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 `xylnit()`.

```

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 `xylnit()`.

```

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 xylnit ( void )

Initialize the xyControl Hardware.

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

Examples:

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

Definition at line 91 of file `xycontrol.c`.

References `adclnit()`, `addMenuCommand()`, `addTask()`, `AVCC`, `BAUD`, `helpText`, `inFile`, `initSystemTimer()`, `LED0DDR`, `LED0PIN`, `LED1DDR`, `LED1PIN`, `LED2DDR`, `LED2PIN`, `LED3DDR`, `LED3PIN`, `MODE_0`, `outFile`, `resetText`, `serialAvailable()`, `serialInit()`, `SPEED_2`, `spiInit()`, `twiInit()`, `uartinput()`, `uartMenuPrintHelp()`, `uartMenuTask()`, `uartoutput()`, `xmemInit()`, `xyLed()`, and `xySelfReset()`.

```

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, &xySelfReset);
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

<i>l</i>	LEDs to set
<i>v</i>	New LED State

#### Examples:

[hardwareTest.c](#), [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 }

```

### 5.25.3.8 void xySelfReset ( void )

Use the Watchdog to reset yourself after 15ms.

Definition at line 179 of file `xycontrol.c`.

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

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

## 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 xylnit().

### 5.25.4.2 FILE inFile

FILE for stdin.

Definition at line 62 of file xycontrol.c.

Referenced by xylnit().

### 5.25.4.3 FILE outFile

FILE for stdout and stderr.

Definition at line 63 of file xycontrol.c.

Referenced by xylnit().

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

UART Menu Reset Text.

Definition at line 60 of file xycontrol.c.

Referenced by xylnit().



# 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.*
- double [vPitch](#)  
*Pitch Angle Speed in Degrees per Second.*
- double [vRoll](#)  
*Roll Angle Speed in Degrees per Second.*
- double [vYaw](#)  
*Yaw Angle Speed in Degrees per Second.*

#### 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 vPitch

Pitch Angle Speed in Degrees per Second.

Examples:

[uartFlight.c](#).

Definition at line 52 of file orientation.h.

Referenced by orientationTask().

#### 6.1.2.4 double vRoll

Roll Angle Speed in Degrees per Second.

Examples:

[uartFlight.c](#).

Definition at line 53 of file orientation.h.

Referenced by orientationTask().

#### 6.1.2.5 double vYaw

Yaw Angle Speed in Degrees per Second.

Examples:

[uartFlight.c](#).

Definition at line 54 of file orientation.h.

Referenced by orientationTask().

#### 6.1.2.6 double yaw

Yaw Angle in Degrees.

Examples:

[uartFlight.c](#).

Definition at line 51 of file orientation.h.

Referenced by orientationTask(), and 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.

Examples:

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

Definition at line 63 of file xycontrol.h.

### 6.8.2 Field Documentation

#### 6.8.2.1 double x

X Part.

Examples:

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

Definition at line 64 of file xycontrol.h.

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

#### 6.8.2.2 double y

Y Part.

Examples:

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

Definition at line 65 of file xycontrol.h.

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

#### 6.8.2.3 double z

Z Part.

Examples:

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

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 acclnit](#) ([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\_KALMAN  
*Filter Implementation to be used.*
- #define **COMPLEMENTARY\_TAU** 0.5  
*Time Constant 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 **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("!\%s\n", 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 [pidTarget](#), [pidOutput](#) and [pidStates](#).*
- #define [PITCH](#) 1  
*Pitch index for [pidTarget](#), [pidOutput](#) and [pidStates](#).*

## 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 [pidTarget](#) [2]  
*Roll and Pitch target angles.*
- double [pidOutput](#) [2]  
*Roll and Pitch PID Output.*
- [PIDState](#) [pidStates](#) [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 [USB 0](#)  
*First UART Name.*
- #define [BLUETOOTH 1](#)  
*Second UART Name.*
- #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 [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 [xySelfReset](#) (void)  
*Use the Watchdog to reset yourself after 15ms.*
- int64\_t [map](#) (int64\_t value, int64\_t oldMin, int64\_t oldMax, int64\_t newMin, int64\_t newMax)  
*Map an Integer from one range to another range.*

### 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 acclnit](#) (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 [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.*

### 7.25.1 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.*

## Variables

- [MagRange magRange](#)  
*Stored range to scale returned values.*

### 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](#) [pidStates](#) [2]  
*Roll and Pitch PID States.*
- double [pidTarget](#) [2]  
*Roll and Pitch target angles.*
- double [pidOutput](#) [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>
```

### 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 [xyInit](#) (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 [xySelfReset](#) (void)  
*Use the Watchdog to reset yourself after 15ms.*
- int64\_t [map](#) (int64\_t value, int64\_t oldMin, int64\_t oldMax, int64\_t newMin, int64\_t newMax)  
*Map an Integer from one range to another range.*

### 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 hardwareTest.c

Small walk-through the inner workings of the task scheduler and other library features.

```
/*
 * hardwareTest.c
 *
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 *
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 * modification, are permitted provided that the following conditions
 * are met:
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 * 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 <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 <xmem.h>
#include <error.h>

void ledTask(void);
void printVoltage(void);
void printRaw(void);
void ramTest(void);
void bluetoothTest(void);

/*
```

```

* Strings for UART menu, stored in Flash.
*/
char PROGMEM voltageString[] = "Battery Voltage";
char PROGMEM sensorString[] = "Raw Sensor Data";
char PROGMEM ramString[] = "Test external RAM";
char PROGMEM bluetoothString[] = "Test Bluetooth Module";

int main(void) {

    /*
     * Initialize the System Timer, UART, TWI, SPI,
     * ADC and the UART menu task for user or software
     * interaction. Also enables interrupts!
     * Also, the UART will be tied to stdin, stdout and stderr.
     * This allows you to use stdio.h utilities like printf()
     */
    xyInit();
    printf("Initializing Hardware Test...\n");

    /*
     * Initialize Hardware
     */
    xyLed(LED_GREEN, LED_OFF);
    xyLed(LED_RED, LED_ON);
    motorInit();
    orientationInit();

    /*
     * Register Tasks in the Scheduler. A UART task
     * is already registered...
     */
    addTask(&ledTask); // Blink LED

    /*
     * Add commands for the UART menu
     */
    addMenuCommand('b', bluetoothString, &bluetoothTest);
    addMenuCommand('r', sensorString, &printRaw);
    addMenuCommand('t', ramString, &ramTest);
    addMenuCommand('v', voltageString, &printVoltage);

    printf("Hardware Test Initialized!\n");

    /*
     * Execute all registered tasks, forever.
     */
    for(;;) {
        tasks();
    }

    return 0;
}

void ledTask(void) {
    /*
     * Basic example of executing a task with a given frequency.
     * last contains the last time this task was executed.
     */
    static time_t last = 0;
    if ((getSystemTime() - last) > 125) { // 125ms have passed
        xyLed(LED_ALL, LED_TOGGLE); // Do something...
        last = getSystemTime(); // Store new execution time
    }
}

void printVoltage(void) {
    printf("Battery: %fV\n", getVoltage());
}

void printRaw(void) {
    Vector3f v;
    accRead(&v);
    printf("Ax: %f Ay: %f Az: %f\n", v.x, v.y, v.z);
    gyroRead(&v);
    printf("Gx: %f Gy: %f Gz: %f\n", v.x, v.y, v.z);
    magRead(&v);
    printf("Mx: %f My: %f Mz: %f\n", v.x, v.y, v.z);
}

#define CHECKSIZE 53248 // 52KB

void ramTest(void) {
    uint8_t *blocks[MEMBANKS];
    uint8_t oldBank = xmemGetBank();

    printf("Allocating Test Memory...\n");
    for (uint8_t i = 0; i < MEMBANKS; i++) {

```

```

    xmemSetBank(i);
    blocks[i] = (uint8_t *)malloc(CHECKSIZE);
    if (blocks[i] == NULL) {
        printf("  Error: Couldn't allocate %liKB in Bank %i!\n", (CHECKSIZE / 1024), i);
    } else {
        printf("  Bank %i ready!\n", i);
    }
}
printf("Filling with data...\n");
for (uint8_t i = 0; i < MEMBANKS; i++) {
    xmemSetBank(i);
    for (uint16_t j = 0; j < CHECKSIZE; j++) {
        blocks[i][j] = (j & 0xFF);
    }
    printf("  Filled Bank %i!\n", i);
}
printf("Checking data...\n");
for (uint8_t i = 0; i < MEMBANKS; i++) {
    xmemSetBank(i);
    uint8_t error = 0;
    for (uint16_t j = 0; ((j < CHECKSIZE) && (!error)); j++) {
        if (blocks[i][j] != (j & 0xFF)) {
            printf("  Error at %i in %i!\n", j, i);
            error = 1;
        }
    }
    if (!error) {
        printf("  Bank %i okay!\n", i);
    }
}
printf("Freeing memory...\n");
for (uint8_t i = 0; i < MEMBANKS; i++) {
    xmemSetBank(i);
    free(blocks[i]);
}
printf("Finished!\n");

xmemSetBank(oldBank);
}

void bluetoothTest(void) {
    printf("Please disconnect, wait 10s, then reconnect!\n");
    printf("All data will be logged, then printed after 15s.\n");
    time_t start = getSystemTime();
    while ((getSystemTime() - start) <= 15000); // Wait
    while (serialHasChar(BLUETOOTH)) { // Check
        serialWrite(USB, serialGet(BLUETOOTH));
    }
    printf("\n\nDone!\n");
}

```

## 8.2 test.c

```

/*
 * test.c
 *
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 * All rights reserved.
 *
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 * modification, are permitted provided that the following conditions
 * are met:
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 * "AS IS" AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED
 * TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR
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 * 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;
}

```

### 8.3 uartFlight.c

```

/*
 * uartFlight.c
 *
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 * All rights reserved.
 *
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 * modification, are permitted provided that the following conditions
 * are met:
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 * 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>

#define DEBUG 1

#include <debug.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);
void silent(void);
void printRaw(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";
char PROGMEM silentString[] = "Toggle Status Output";
char PROGMEM sensorString[] = "Raw Sensor Data";

#define STATE_MOTOR (1 << 0) // 1 -> Motor On
#define STATE_PID (1 << 1) // 1 -> PID enabled
#define STATE_OUTPUT (1 << 2) // 1 -> No Status Output
uint8_t state = 0;

uint8_t speed = 10;
int16_t targetRoll = 0;
int16_t targetPitch = 0;

uint32_t sumFlightTask = 0, countFlightTask = 0;

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

    debugPrint("Initialized Hardware");

    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);
    addMenuCommand('o', silentString, &silent);
    addMenuCommand('r', sensorString, &printRaw);

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

    debugPrint("Starting Tasks");

    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 & STATE_PID) {
        pidTask();
    } else {
        pidOutput[0] = pidOutput[1] = 0;
    }
    setTask();
    motorTask();

    uint32_t diff = getSystemTime() - last;
    if (++countFlightTask >= QUADFREQ) {
        countFlightTask = 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) && (!(state & STATE_OUTPUT))) {
        last = getSystemTime();
        printf("p%.2f %.2f %.2f\n", orientation.vPitch,
            orientation.vRoll, orientation.vYaw);
        printf("q%i %i\n", sumFlightTask / countFlightTask, lastDuration);
        printf("r%.2f %.2f\n", pidStates[0].intMin, pidStates[0].intMax);
        printf("s%.2f %.2f\n", pidStates[0].outMin, pidStates[0].outMax);
        printf("t%.3f %.3f %.3f\n", pidStates[0].kp, pidStates[0].ki,
            pidStates[0].kd);
        printf("u%.2f %.2f\n", pidOutput[PITCH], pidOutput[
            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 & STATE_PID) {
        state &= ~STATE_PID;
        printf("PID Off!\n");
    } else {
        state |= STATE_PID;
        printf("PID On!\n");
    }
}

void motorToggle(void) {
    if (state & STATE_MOTOR) {
        state &= ~STATE_MOTOR;
        baseSpeed = 0;
        printf("Motor Off!\n");
    } else {
        state |= STATE_MOTOR;
        baseSpeed = speed = 10;
        printf("Motor On!\n");
    }
}

void motorUp(void) {
    if (speed <= (MAXMOTOR - MOTORSTEP)) {
        if (state & STATE_MOTOR) {
            speed += MOTORSTEP;
            baseSpeed = speed;
            printf("Throttle up to %i\n", speed);
        }
    }
}

void motorDown(void) {
    if (speed >= MOTORSTEP) {
        if (state & STATE_MOTOR) {
            speed -= MOTORSTEP;
            baseSpeed = speed;
            printf("Throttle down to %i\n", speed);
        }
    }
}

```

```

void motorForward(void) {
    if (targetPitch >= (-1 * (MAXANGLE - ANGLESTEP))) {
        targetPitch -= ANGLESTEP;
        pidTarget[PITCH] = targetPitch;
        printf("Pitch Forward %i\n", targetPitch);
    }
}

void motorBackward(void) {
    if (targetPitch <= (MAXANGLE - ANGLESTEP)) {
        targetPitch += ANGLESTEP;
        pidTarget[PITCH] = targetPitch;
        printf("Pitch Backwards %i\n", targetPitch);
    }
}

void motorLeft(void) {
    if (targetRoll <= (MAXANGLE - ANGLESTEP)) {
        targetRoll += ANGLESTEP;
        pidTarget[ROLL] = targetRoll;
        printf("Roll Left %i\n", targetRoll);
    }
}

void motorRight(void) {
    if (targetRoll >= (-1 * (MAXANGLE - ANGLESTEP))) {
        targetRoll -= ANGLESTEP;
        pidTarget[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", &p, &i, &d, &min, &max, &iMin, &iMax);
    if (c == 7) {
        pidSet(&pidStates[0], p, i, d, min, max, iMin, iMax);
        pidSet(&pidStates[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);
    }
}

void silent(void) {
    if (state & STATE_OUTPUT) {
        // Currently disabled, bit set
        state &= ~STATE_OUTPUT; // Unset Bit
    } else {
        // Currently enabled
        state |= STATE_OUTPUT; // Set Bit
    }
}

void printRaw(void) {
    Vector3f v;
    accRead(&v);
    printf("Ax: %f Ay: %f Az: %f\n", v.x, v.y, v.z);
    gyroRead(&v);
    printf("Gx: %f Gy: %f Gz: %f\n", v.x, v.y, v.z);
    magRead(&v);
    printf("Mx: %f My: %f Mz: %f\n", v.x, v.y, v.z);
}

```

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