

xyControl

0.1

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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

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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 AVR's built-in SPI Hardware.
- [I2C Driver](#)
Using the AVR TWI/I2C Hardware.

5.4.1 Detailed Description

Hardware Libraries.

5.5 Accelerometer Driver

Configuring and reading an LSM303DLHC Accelerometer.

Files

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

Macros

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

Enumerations

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

Functions

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

Variables

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

5.5.1 Detailed Description

Configuring and reading an LSM303DLHC Accelerometer.

5.5.2 Macro Definition Documentation

5.5.2.1 `#define ACCREG_CTRL1 0x20`

Accelerometer Control Register 1.

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

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

5.5.2.2 #define ACCREG_CTRL4 0x23

Accelerometer Control Register 4.

Definition at line 50 of file acc.c.

Referenced by `accInit()`.

5.5.2.3 #define ACCREG_XL 0x28

First Accelerometer Output Register.

Definition at line 51 of file acc.c.

Referenced by `accRead()`.

5.5.3 Enumeration Type Documentation

5.5.3.1 enum AccRange

Accelerometer Range options.

Enumerator

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

Definition at line 47 of file acc.h.

```

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

5.5.4 Function Documentation

5.5.4.1 Error accInit (AccRange r)

Initialize the Accelerometer.

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

Parameters

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

Returns

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

Definition at line 76 of file acc.c.

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

Referenced by `orientationInit()`.

```

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

```

5.5.4.2 Error accRead (Vector3f * v)

Read from the Accelerometer.

Accelerometer should already be initialized!

Parameters

v	Vector3f for the read values
---	--

Returns

[TWI_NO_ANSWER](#), [TWI_WRITE_ERROR](#), [ARGUMENT_ERROR](#) or [SUCCESS](#).

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 Contant for Low and High Pass Filter in the [Complementary](#) Filter.
- #define [SOFTWARELOWPASS](#) 1
Software Low-Pass on Gyro and ACC.
- #define [ACCFILTERFACTOR](#) SOFTWARELOWPASS
Accelerometer Low Pass Factor.
- #define [GYROFILTERFACTOR](#) SOFTWARELOWPASS
Gyroscope Low Pass Factor.
- #define [PID_OUTMAX](#) 256
Maximum PID Output.
- #define [PID_OUTMIN](#) -256
Minimum PID Output.
- #define [PID_INTMAX](#) PID_OUTMAX
Maximum PID Integral Sum.
- #define [PID_INTMIN](#) PID_OUTMIN
Minimal PID Integral Sum.
- #define [PID_FACTOR](#) 4 / 5
Influence of PID in relation to Base Speed.
- #define [DT](#) 0.01f
Time Constant.
- #define [Q1](#) 5.0f
Q Matrix Diagonal Element 1.
- #define [Q2](#) 100.0f
Q Matrix Diagonal Element 2.
- #define [Q3](#) 0.01f
Q Matrix Diagonal Element 3.
- #define [R1](#) 1000.0f
R Matrix Diagonal Element 1.
- #define [R2](#) 1000.0f
R Matrix Diagonal Element 2.
- #define [SET_ROLLPLUS](#) 1
Second Motor at the Right.
- #define [SET_ROLLMINUS](#) 3
Fourth Motor at the Left.
- #define [SET_PITCHPLUS](#) 0
First Motor at the Top.
- #define [SET_PITCHMINUS](#) 2

- Third Motor at the Bottom.*

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

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

5.8.1 Detailed Description

Various default settings.

5.8.2 Macro Definition Documentation

5.8.2.1 `#define ACC_ADDRESS 0x32`

Accelerometer Address (0011001r)

Definition at line 120 of file config.h.

Referenced by `accRead()`.

5.8.2.2 `#define ACCFILTERFACTOR SOFTWARELOWPASS`

Accelerometer Low Pass Factor.

Definition at line 59 of file config.h.

Referenced by `accRead()`.

5.8.2.3 `#define BANK0DDR DDRG`

First Bank Selection Data Direction Register.

Definition at line 147 of file config.h.

Referenced by `xmemInit()`.

5.8.2.4 `#define BANK0PIN PG3`

First Bank Selection Pin.

Definition at line 148 of file config.h.

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

5.8.2.5 `#define BANK0PORT PORTG`

First Bank Selection Port.

Definition at line 146 of file config.h.

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

5.8.2.6 `#define BANK1DDR DDRG`

Second Bank Selection Data Direction Register.

Definition at line 150 of file config.h.

Referenced by `xmemInit()`.

5.8.2.7 `#define BANK1PIN PG4`

Second Bank Selection Pin.

Definition at line 151 of file config.h.

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

5.8.2.8 `#define BANK1PORT PORTG`

Second Bank Selection Port.

Definition at line 149 of file config.h.

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

5.8.2.9 `#define BANK2DDR DDRL`

Third Bank Selection Data Direction Register.

Definition at line 153 of file config.h.

Referenced by `xmemInit()`.

5.8.2.10 `#define BANK2PIN PL5`

Third Bank Selection Pin.

Definition at line 154 of file config.h.

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

5.8.2.11 `#define BANK2PORT PORTL`

Third Bank Selection Port.

Definition at line 152 of file config.h.

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

5.8.2.12 `#define BATT_CHANNEL 0`

ADC Channel for Battery.

Definition at line 114 of file config.h.

Referenced by `getVoltage()`.

5.8.2.13 `#define BATT_MAX 15`

Battery Voltage Reference (ADC 5V)

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

Referenced by `getVoltage()`.

5.8.2.14 `#define COMPLEMENTARY_TAU 0.5`

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

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

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

Referenced by `complementaryExecute()`.

5.8.2.15 `#define DT 0.01f`

Time Constant.

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

Referenced by `kalmanInnovate()`.

5.8.2.16 `#define GYRO_ADDRESS 0xD6`

Gyroscope Address (110101xr, x = 1)

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

Referenced by `gyroRead()`.

5.8.2.17 `#define GYROFILTERFACTOR SOFTWARELOWPASS`

Gyroscope Low Pass Factor.

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

Referenced by `gyroRead()`.

5.8.2.18 `#define LED0DDR DDRL`

First LED Data Direction Register.

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

Referenced by `xyInit()`.

5.8.2.19 `#define LED0PIN PL6`

First LED Pin.

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

Referenced by `xyInit()`.

5.8.2.20 `#define LED0PORT PORTL`

First LED Port.

Definition at line 129 of file config.h.

5.8.2.21 `#define LED1DDR DDRL`

Second LED Data Direction Register.

Definition at line 133 of file config.h.

Referenced by xyInit().

5.8.2.22 `#define LED1PIN PL7`

Second LED Pin.

Definition at line 134 of file config.h.

Referenced by xyInit().

5.8.2.23 `#define LED1PORT PORTL`

Second LED Port.

Definition at line 132 of file config.h.

5.8.2.24 `#define LED2DDR DDRG`

Third LED Data Direction Register.

Definition at line 136 of file config.h.

Referenced by xyInit().

5.8.2.25 `#define LED2PIN PG5`

Third LED Pin.

Definition at line 137 of file config.h.

Referenced by xyInit().

5.8.2.26 `#define LED2PORT PORTG`

Third LED Port.

Definition at line 135 of file config.h.

5.8.2.27 `#define LED3DDR DDRE`

Fourth LED Data Direction Register.

Definition at line 139 of file config.h.

Referenced by xyInit().

5.8.2.28 #define LED3PIN PE2

Fourth LED Pin.

Definition at line 140 of file config.h.

Referenced by xyInit().

5.8.2.29 #define LED3PORT PORTE

Fourth LED Port.

Definition at line 138 of file config.h.

5.8.2.30 #define MAG_ADDRESS 0x3C

Magnetometer Address.

Definition at line 122 of file config.h.

Referenced by magRead(), and magWriteRegister().

5.8.2.31 #define MOTOR_BASEADDRESS 0x52

Address of first motor controller.

Definition at line 123 of file config.h.

Referenced by motorTask().

5.8.2.32 #define MOTORCOUNT 4

Amount of motors.

Definition at line 107 of file config.h.

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

5.8.2.33 #define ORIENTATION_FILTER FILTER_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 101 of file config.h.

Referenced by pidInit().

5.8.2.35 #define PID_FACTOR 4 / 5

Influence of PID in relation to Base Speed.

Definition at line 68 of file config.h.

5.8.2.36 #define PID_I 0.03

Default PID I Constant.

Definition at line 100 of file config.h.

Referenced by pidInit().

5.8.2.37 #define PID_INTMAX PID_OUTMAX

Maximum PID Integral Sum.

Definition at line 64 of file config.h.

Referenced by pidInit().

5.8.2.38 #define PID_INTMIN PID_OUTMIN

Minimal PID Integral Sum.

Definition at line 65 of file config.h.

Referenced by pidInit().

5.8.2.39 #define PID_OUTMAX 256

Maximum PID Output.

Definition at line 62 of file config.h.

Referenced by pidInit().

5.8.2.40 #define PID_OUTMIN -256

Minimum PID Output.

Definition at line 63 of file config.h.

Referenced by pidInit().

5.8.2.41 #define PID_P 5.0

Default PID P Constant.

Definition at line 99 of file config.h.

Referenced by pidInit().

5.8.2.42 #define Q1 5.0f

Q Matrix Diagonal Element 1.

Definition at line 78 of file config.h.

Referenced by kalmanInnovate().

5.8.2.43 #define Q2 100.0f

Q Matrix Diagonal Element 2.

Definition at line 79 of file config.h.

Referenced by kalmanInnovate().

5.8.2.44 `#define Q3 0.01f`

Q Matrix Diagonal Element 3.

Definition at line 80 of file config.h.

Referenced by kalmanInnovate().

5.8.2.45 `#define R1 1000.0f`

R Matrix Diagonal Element 1.

Definition at line 83 of file config.h.

Referenced by kalmanInnovate().

5.8.2.46 `#define R2 1000.0f`

R Matrix Diagonal Element 2.

Definition at line 84 of file config.h.

Referenced by kalmanInnovate().

5.8.2.47 `#define RX_BUFFER_SIZE 64`

UART Receive Buffer Size.

Definition at line 169 of file config.h.

5.8.2.48 `#define SET_PITCHMINUS 2`

Third Motor at the Bottom.

Definition at line 93 of file config.h.

5.8.2.49 `#define SET_PITCHPLUS 0`

First Motor at the Top.

Definition at line 92 of file config.h.

5.8.2.50 `#define SET_ROLLMINUS 3`

Fourth Motor at the Left.

Definition at line 91 of file config.h.

Referenced by setMotorSpeeds().

5.8.2.51 `#define SET_ROLLPLUS 1`

Second Motor at the Right.

Definition at line 90 of file config.h.

Referenced by setMotorSpeeds().

5.8.2.52 #define SOFTWARELOWPASS 1

Software Low-Pass on Gyro and ACC.

Definition at line 58 of file config.h.

5.8.2.53 #define SPISS PB0

SPI Slave Select Pin.

Definition at line 163 of file config.h.

5.8.2.54 #define TX_BUFFER_SIZE 64

UART Transmit Buffer Size.

Definition at line 170 of file config.h.

5.9 Debug Output

Allows debug output and assert usage.

Files

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

Macros

- `#define DEBUGOUT(x) printf("!\%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>	GyroRange 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 *)(&z);
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 [accInit\(\)](#), [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\(\)](#), [gyroRead\(\)](#), [kalmanInnovate\(\)](#), [orientation](#), [Angles::pitch](#), [Angles::roll](#), [SUCCESS](#), [TODEG](#), [Vector3f::x](#), [Vector3f::y](#), and [Vector3f::z](#).

```

90     {
91         Vector3f g, a, m;
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
120         return SUCCESS;
121     }

```

5.15.3.3 void zeroOrientation (void)

Sets the current orientation to zero.

Examples:

[uartFlight.c](#).

Definition at line 123 of file orientation.c.

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

```

123     {
124         orientationError.roll = orientation.roll +
orientationError.roll;
125         orientationError.pitch = orientation.pitch +
orientationError.pitch;
126         orientationError.yaw = orientation.yaw +
orientationError.yaw;
127     }

```

5.15.4 Variable Documentation

5.15.4.1 Angles orientation

Current Aircraft orientation.

Examples:

[uartFlight.c](#).

Definition at line 58 of file orientation.c.

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

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

Current Aircraft orientation.

Definition at line 58 of file orientation.c.

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

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

Current Aircraft orientation offset.

Definition at line 61 of file orientation.c.

5.15.4.4 **Kalman pitchData**

Kalman-State for Pitch Angle.

Definition at line 64 of file orientation.c.

5.15.4.5 **Kalman rollData**

Kalman-State for Roll Angle.

Definition at line 65 of file orientation.c.

5.16 PID-Controller

Simple implementation for multiple floating-point PID Controllers.

Files

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

Data Structures

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

Macros

- `#define ROLL 0`
Roll index for [o_should](#), [o_output](#) and [o_pids](#).
- `#define PITCH 1`
Pitch index for [o_should](#), [o_output](#) and [o_pids](#).

Functions

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

Variables

- double [o_should](#) [2]
Roll and Pitch target angles.
- double [o_output](#) [2]
Roll and Pitch PID Output.
- [PIDState](#) [o_pids](#) [2]
Roll and Pitch PID States.
- [PIDState](#) [o_pids](#) [2]
Roll and Pitch PID States.
- double [o_should](#) [2]
Roll and Pitch target angles.
- double [o_output](#) [2]
Roll and Pitch PID Output.

5.16.1 Detailed Description

Simple implementation for multiple floating-point PID Controllers.

5.16.2 Macro Definition Documentation

5.16.2.1 `#define PITCH 1`

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

Examples:

`uartFlight.c`.

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

Referenced by `pidTask()`.

5.16.2.2 `#define ROLL 0`

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

Examples:

`uartFlight.c`.

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

Referenced by `pidTask()`.

5.16.3 Function Documentation

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

Execute a single PID Control Step.

Parameters

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

Returns

PID Output

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

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

Referenced by `pidTask()`.

```

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

```

```

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

```

5.16.3.2 void pidInit (void)

Initialize Roll and Pitch PID.

Stores the PID States in `o_pids`. Also resets `o_should` to zero.

Examples:

[uartFlight.c](#).

Definition at line 74 of file pid.c.

References `o_should`, `PID_D`, `PID_I`, `PID_INTMAX`, `PID_INTMIN`, `PID_OUTMAX`, `PID_OUTMIN`, `PID_P`, and `pidSet()`.

```

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

```

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

Set the parameters of a PID controller.

The state variables will be reset to zero.

Parameters

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

Examples:

[uartFlight.c](#).

Definition at line 81 of file pid.c.

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

Referenced by `pidInit()`.

```

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

```

5.16.3.4 void pidTask (void)

Step the Roll and Pitch PID Controllers.

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

Examples:

[uartFlight.c](#).

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

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

```

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

```

5.16.4 Variable Documentation

5.16.4.1 double o_output[2]

Roll and Pitch PID Output.

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

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

5.16.4.2 double o_output[2]

Roll and Pitch PID Output.

Examples:

[uartFlight.c](#).

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

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

5.16.4.3 PIDState o_pids[2]

Roll and Pitch PID States.

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

Referenced by `setTask()`.

5.16.4.4 PIDState o_pids[2]

Roll and Pitch PID States.

Examples:

[uartFlight.c](#).

Definition at line 50 of file pid.c.

Referenced by setTask().

5.16.4.5 double o_should[2]

Roll and Pitch target angles.

Definition at line 51 of file pid.c.

Referenced by pidInit(), and pidTask().

5.16.4.6 double o_should[2]

Roll and Pitch target angles.

Examples:

[uartFlight.c](#).

Definition at line 51 of file pid.c.

Referenced by pidInit(), and pidTask().

5.17 UART Library

UART Library enabling you to control all available UART Modules.

Files

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

Macros

- `#define 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][SERIALUDRIE]); // Trigger Interrupt
234         }
235     }
236     #endif
237
238     if (rxRead[uart] != rxWrite[uart]) {
```

```

239         c = rxBuffer[uart][rxRead[uart]];
240         rxBuffer[uart][rxRead[uart]] = 0;
241         if (rxRead[uart] < (RX_BUFFER_SIZE - 1)) {
242             rxRead[uart]++;
243         } else {
244             rxRead[uart] = 0;
245         }
246         return c;
247     } else {
248         return 0;
249     }
250 }

```

5.17.3.4 uint8_t serialGetBlocking (uint8_t uart)

Wait until a character is received.

Parameters

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

Returns

Received byte

Definition at line 210 of file serial.c.

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

```

210                                     {
211         if (uart >= UART_COUNT)
212             return 0;
213
214         while(!serialHasChar(uart));
215         return serialGet(uart);
216 }

```

5.17.3.5 uint8_t serialHasChar (uint8_t uart)

Check if a byte was received.

Parameters

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

Returns

1 if a byte was received, 0 if not

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 BAUD() macro!

Definition at line 118 of file serial.c.

Referenced by xylnit().

```

118                                     {
119     if (uart >= UART_COUNT)
120         return;
121
122     // Initialize state variables
123     rxRead[uart] = 0;
124     rxWrite[uart] = 0;
125     txRead[uart] = 0;
126     txWrite[uart] = 0;
127     shouldStartTransmission[uart] = 1;
128 #ifdef FLOWCONTROL
129     sendThisNext[uart] = 0;
130     flow[uart] = 1;
131     rxBufferElements[uart] = 0;
132 #endif
133
134     // Default Configuration: 8N1
135     *serialRegisters[uart][SERIALC] = (1 << serialBits[uart][SERIALUCSZ0]) | (1 << serialBits[uart][
SERIALUCSZ1]);
136
137     // Set baudrate
138 #if SERIALBAUDBIT == 8
139     *serialRegisters[uart][SERIALUBRRH] = (baud >> 8);
140     *serialRegisters[uart][SERIALUBRRL] = baud;
141 #else
142     *serialBaudRegisters[uart] = baud;
143 #endif
144
145     *serialRegisters[uart][SERIALB] = (1 << serialBits[uart][SERIALRXCIE]); // Enable Interrupts
146     *serialRegisters[uart][SERIALB] |= (1 << serialBits[uart][SERIALRXEN]) | (1 << serialBits[uart][
SERIALTXEN]); // Enable Receiver/Transmitter
147 }

```

5.17.3.7 uint8_t serialRxBufferEmpty (uint8_t uart)

Check if the receive buffer is empty.

Parameters

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

Returns

1 if buffer is empty, 0 if not.

Definition at line 259 of file serial.c.

```

259                                     {
260     if (uart >= UART_COUNT)
261         return 0;
262
263     if (rxRead[uart] != rxWrite[uart]) {

```

```

264         return 0;
265     } else {
266         return 1;
267     }
268 }

```

5.17.3.8 uint8_t serialRxBufferFull (uint8_t uart)

Check if the receive buffer is full.

Parameters

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

Returns

1 if buffer is full, 0 if not

Definition at line 252 of file serial.c.

References `RX_BUFFER_SIZE`.

```

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

```

5.17.3.9 uint8_t serialTxBufferEmpty (uint8_t uart)

Check if the transmit buffer is empty.

Parameters

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

Returns

1 if buffer is empty, 0 if not.

Definition at line 318 of file serial.c.

Referenced by `serialClose()`.

```

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

```

5.17.3.10 uint8_t serialTxBufferFull (uint8_t uart)

Check if the transmit buffer is full.

Parameters

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

Returns

1 if buffer is full, 0 if not

Definition at line 311 of file serial.c.

References TX_BUFFER_SIZE.

Referenced by serialWrite().

```

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

5.17.3.11 void serialWrite (uint8_t *uart*, uint8_t *data*)

Send a byte.

Parameters

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

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             }
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             }
188         }
189         // Wait till it's transmitted
190         while (*serialRegisters[uart][SERIALB] & (1 << serialBits[uart][SERIALUDRIE]));
191     }
192 }
```

5.18 Motor Speed Mixer

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

Files

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

Macros

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

Functions

- void [setTask](#) (void)
Read the PID Output and Set the Motor Speeds.
- void [setMotorSpeeds](#) (uint8_t axis, uint8_t *vals)
Set the Motor Speeds according to the SET_ Motor Position Constants.*

Variables

- uint8_t [baseSpeed](#)
Motor Base Speed.
- uint8_t [baseSpeed](#) = 0
Motor Base Speed.

5.18.1 Detailed Description

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

5.18.2 Macro Definition Documentation

5.18.2.1 `#define MAXDIFF (baseSpeed * PID_FACTOR)`

Maximum Speed difference on one axis.

Definition at line 51 of file [set.c](#).

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

5.18.3 Function Documentation

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

Set the Motor Speeds according to the SET_* Motor Position Constants.

Parameters

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

Definition at line 59 of file set.c.

References motorSet(), SET_ROLLMINUS, and SET_ROLLPLUS.

Referenced by setTask().

```

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

5.18.3.2 void setTask (void)

Read the PID Output and Set the Motor Speeds.

Examples:

[uartFlight.c](#).

Definition at line 69 of file set.c.

References baseSpeed, MAXDIFF, o_output, o_pids, and setMotorSpeeds().

```

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

5.18.4 Variable Documentation**5.18.4.1 uint8_t baseSpeed**

Motor Base Speed.

Examples:

[uartFlight.c](#).

Definition at line 53 of file set.c.

Referenced by setTask().

5.18.4.2 uint8_t baseSpeed = 0

Motor Base Speed.

Definition at line 53 of file set.c.

Referenced by setTask().

5.19 SPI Driver

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

Files

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

Enumerations

- enum [SPI_MODE](#) { [MODE_0](#) = 0, [MODE_1](#) = 1, [MODE_2](#) = 2, [MODE_3](#) = 3 }
- SPI Mode option.*
- enum [SPI_SPEED](#) {
[SPEED_2](#) = 4, [SPEED_4](#) = 0, [SPEED_8](#) = 5, [SPEED_16](#) = 1,
[SPEED_32](#) = 6, [SPEED_64](#) = 2, [SPEED_128](#) = 3 }
- SPI Speed options.*

Functions

- void [spiInit](#) ([SPI_MODE](#) mode, [SPI_SPEED](#) speed)
Initialize the SPI Hardware Module.
- uint8_t [spiSendByte](#) (uint8_t d)
Send and Receive one byte.

5.19.1 Detailed Description

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

5.19.2 Enumeration Type Documentation

5.19.2.1 enum SPI_MODE

SPI Mode option.

Enumerator

- [MODE_0](#)** CPOL 0, CPHA 0.
- [MODE_1](#)** CPOL 0, CPHA 1.
- [MODE_2](#)** CPOL 1, CPHA 0.
- [MODE_3](#)** CPOL 1, CPHA 1.

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

```

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

5.19.2.2 enum SPI_SPEED

SPI Speed options.

Enumerator

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

Definition at line 52 of file spi.h.

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

5.19.3 Function Documentation

5.19.3.1 void spInit (SPI_MODE mode, SPI_SPEED speed)

Initialize the SPI Hardware Module.

Parameters

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

Referenced by xylInit().

5.19.3.2 uint8_t spiSendByte (uint8_t d)

Send and Receive one byte.

Set the Chip Select Lines yourself!

Parameters

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

Returns

Byte read from Bus

Definition at line 54 of file spi.c.

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

5.20 Task Handler

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

Files

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

Data Structures

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

Typedefs

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

Functions

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

Variables

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

5.20.1 Detailed Description

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

5.20.2 Typedef Documentation

5.20.2.1 typedef void(* Task)(void)

A Task has no arguments and returns nothing.

Definition at line 44 of file tasks.h.

5.20.3 Function Documentation

5.20.3.1 uint8_t addTask (Task func)

Adds another task that will be called regularly.

Parameters

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

Returns

0 on success

Examples:

[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 `xyInit()`.

```

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

```

5.20.3.2 uint8_t removeTask (Task func)

Removes an already registered Task.

Parameters

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

Returns

0 on success

Definition at line 71 of file tasks.c.

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

```

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

```

```

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

```

5.20.3.3 void tasks (void)

Executes registered Tasks.

Call this in your Main Loop!

Examples:

[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()`, and `pidExecute()`.

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

5.21.4.2 void initSystemTimer (void)

Initialize the system timer.

Execution every millisecond. Uses Timer 2.

Definition at line 55 of file time.c.

Referenced by `xyInit()`.

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

5.21.4.3 ISR (TIMER2_COMPA_vect)

Timer 2 Compare Match A Interrupt.

Definition at line 64 of file time.c.

References `systemTime`.

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

5.21.5 Variable Documentation

5.21.5.1 volatile time_t systemTime = 0

Current System Uptime.

Definition at line 47 of file time.c.

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

5.22 I2C Driver

Using the AVR TWI/I2C Hardware.

Files

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

Macros

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

Functions

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

5.22.1 Detailed Description

Using the AVR TWI/I2C Hardware.

5.22.2 Macro Definition Documentation

5.22.2.1 `#define TWI_READ 1`

I2C Read Bit.

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

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

5.22.2.2 #define TWI_WRITE 0

I2C Write Bit.

Definition at line 44 of file twi.h.

Referenced by accRead(), gyroRead(), magRead(), 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 */

```

5.22.3.4 unsigned char twiRepStart (unsigned char *addr*)

Start a repeated I2C Transfer.

Parameters

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

Returns

0 on success, 1 on error

Definition at line 127 of file twi.c.

References twiStart().

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

```

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

```

5.22.3.5 unsigned char twiStart (unsigned char *addr*)

Start an I2C Transfer.

Parameters

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

Returns

0 on success, 1 on error

Definition at line 40 of file twi.c.

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

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

Returns

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

Examples:

[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 xylnit().

```

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

```

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

Register a Handler for unhandled menu commands.

Parameters

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

Definition at line 127 of file uartMenu.c.

References unHandler.

```

127                                     {
128     unHandler = handler;
129 }
```

5.23.2.6 void uartMenuTask (void)

Task to work the UART Menu.

Definition at line 131 of file uartMenu.c.

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

Referenced by xylnit().

```

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

5.23.3 Variable Documentation

5.23.3.1 MenuEntry* uartMenu = NULL

Single-Linked-List for commands.

Definition at line 51 of file uartMenu.c.

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

5.23.3.2 void(* unHandler)(char) = NULL

Handler for unhandled commands.

Definition at line 52 of file uartMenu.c.

Referenced by uartMenuRegisterHandler(), and uartMenuTask().

5.24 External Memory Interface

Allows access to external RAM with bank-switching.

Files

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

Data Structures

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

Macros

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

Functions

- void [xmemInit](#) (void)
Initialize the External Memory Interface.
- void [xmemSetBank](#) (uint8_t bank)
Switch the active memory bank.
- uint8_t [xmemGetBank](#) (void)
Get the current memory bank.
- void [saveState](#) (uint8_t bank)
Save the current malloc state.
- void [restoreState](#) (uint8_t bank)
Restore the malloc state.

Variables

- [MallocState](#) states [[MEMBANKS](#)]
MallocState for all Memory Banks.
- uint8_t [currentBank](#)
Current active Memory Bank.
- [MallocState](#) states [[MEMBANKS](#)]
MallocState for all Memory Banks.
- uint8_t [currentBank](#) = 0

Current active Memory Bank.

- void * [__brkval](#)

Internal Malloc Heap-End Pointer.

- void * [__flp](#)

Internal Malloc Free List Pointer (State)

5.24.1 Detailed Description

Allows access to external RAM with bank-switching.

5.24.2 Macro Definition Documentation

5.24.2.1 `#define BANK_GENERIC 0`

Generic Memory Bank.

Definition at line 55 of file xmem.h.

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

5.24.2.2 `#define MEMBANKS 8`

Available Memory Banks.

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

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

Definition at line 47 of file xmem.h.

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

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

Switch back to the last bank, if needed.

Parameters

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

Definition at line 52 of file xmem.h.

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

5.24.3 Function Documentation

5.24.3.1 `void restoreState (uint8_t bank)`

Restore the malloc state.

Parameters

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

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

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

Referenced by `xmemSetBank()`.

```

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

5.24.3.2 `void saveState (uint8_t bank)`

Save the current malloc state.

Parameters

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

Definition at line 55 of file `xmem.c`.

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

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

```

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

5.24.3.3 `uint8_t xmemGetBank (void)`

Get the current memory bank.

Returns

Current Memory Bank.

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 xyInit().

```

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 [resetSelf](#) (void)
Use the Watchdog to reset yourself after 15ms.
- int [uartoutput](#) (char c, FILE *f)
Method used to write to stdout and stderr.
- int [uartinput](#) (FILE *f)
Method used to read from stdin.
- void [xyLedInternal](#) (uint8_t v, volatile uint8_t *port, uint8_t pin)
Internal LED Manipulation function.

Variables

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

5.25.1 Detailed Description

Controls xyControl On-Board Hardware like LEDs.

5.25.2 Enumeration Type Documentation

5.25.2.1 enum LED

Methods of addressing the LEDs.

Enumerator

LED_RED0 First red LED.
LED_RED1 Second red LED.
LED_GREEN0 First green LED.
LED_GREEN1 Second green LED.
LED_ALL All LEDs.
LED_BITMAP LEDs as Bitmap (R0, R1, G0, G1)
LED_RED Both red LEDs.
LED_GREEN Both green LEDs.

Definition at line 44 of file xycontrol.h.

```

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

5.25.2.2 enum LEDState

Possible states of the LEDs.

Enumerator

LED_OFF LED Off.
LED_ON LED On.
LED_TOGGLE Toggle the LED.

Definition at line 56 of file xycontrol.h.

```

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

5.25.3 Function Documentation

5.25.3.1 double getVoltage (void)

Calculate and return the Battery Voltage.

Returns

Current Battery Voltage

Examples:

[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 void resetSelf (void)

Use the Watchdog to reset yourself after 15ms.

Definition at line 179 of file xycontrol.c.

Referenced by `xyInit()`.

```

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

5.25.3.3 int uartinput (FILE * f)

Method used to read from stdin.

Definition at line 81 of file xycontrol.c.

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

Referenced by `xyInit()`.

```

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

5.25.3.4 int uartoutput (char c, FILE * f)

Method used to write to stdout and stderr.

Definition at line 66 of file xycontrol.c.

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

Referenced by `xyInit()`.

```

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

```

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

```

5.25.3.5 void xyInit (void)

Initialize the xyControl Hardware.

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

Examples:

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

Definition at line 91 of file xycontrol.c.

References [adcInit\(\)](#), [addMenuCommand\(\)](#), [addTask\(\)](#), [AVCC](#), [BAUD](#), [helpText](#), [inFile](#), [initSystemTimer\(\)](#), [LED0DDR](#), [LED0PIN](#), [LED1DDR](#), [LED1PIN](#), [LED2DDR](#), [LED2PIN](#), [LED3DDR](#), [LED3PIN](#), [MODE_0](#), [outFile](#), [resetSelf\(\)](#), [resetText](#), [serialAvailable\(\)](#), [serialInit\(\)](#), [SPEED_2](#), [spiInit\(\)](#), [twiInit\(\)](#), [uartinput\(\)](#), [uartMenuPrintHelp\(\)](#), [uartMenuTask\(\)](#), [uartoutput\(\)](#), [xmemInit\(\)](#), and [xyLed\(\)](#).

```

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

```

5.25.3.6 void xyLed (LED l, LEDState v)

Set the LEDs.

Parameters

<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

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

Definition at line 134 of file `xycontrol.c`.

```

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

5.25.4 Variable Documentation

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

UART Menu Help Text.

Definition at line 59 of file `xycontrol.c`.

Referenced by `xyInit()`.

5.25.4.2 FILE inFile

FILE for stdin.

Definition at line 62 of file `xycontrol.c`.

Referenced by `xyInit()`.

5.25.4.3 FILE outFile

FILE for stdout and stderr.

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

Referenced by `xyInit()`.

5.25.4.4 char PROGMEM resetText[] = "Reset MCU"

UART Menu Reset Text.

Definition at line 60 of file `xycontrol.c`.

Referenced by `xyInit()`.

Chapter 6

Data Structure Documentation

6.1 Angles Struct Reference

Can store orientation in Euler Space.

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

Data Fields

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

6.1.1 Detailed Description

Can store orientation in Euler Space.

Definition at line 48 of file orientation.h.

6.1.2 Field Documentation

6.1.2.1 double pitch

Pitch Angle in Degrees.

Examples:

[uartFlight.c](#).

Definition at line 49 of file orientation.h.

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

6.1.2.2 double roll

Roll Angle in Degrees.

Examples:

[uartFlight.c](#).

Definition at line 50 of file orientation.h.

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

6.1.2.3 double yaw

Yaw Angle in Degrees.

Examples:

[uartFlight.c](#).

Definition at line 51 of file orientation.h.

Referenced by zeroOrientation().

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

- include/[orientation.h](#)

6.2 Complementary Struct Reference

Complementary-Filter State data.

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

6.2.1 Detailed Description

Complementary-Filter State data.

Definition at line 46 of file complementary.h.

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

- include/[complementary.h](#)

6.3 Kalman Struct Reference

Kalman-Filter State data.

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

Data Fields

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

6.3.1 Detailed Description

Kalman-Filter State data.

Definition at line 47 of file kalman.h.

6.3.2 Field Documentation

6.3.2.1 double p33

P Matrix.

Definition at line 49 of file kalman.h.

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

6.3.2.2 double x3

X Vector.

Definition at line 48 of file kalman.h.

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

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

- `include/kalman.h`

6.4 MallocState Struct Reference

All Malloc related State.

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

Data Fields

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

6.4.1 Detailed Description

All Malloc related State.

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

Definition at line 62 of file xmem.h.

6.4.2 Field Documentation

6.4.2.1 char* end

End of Heap.

Definition at line 64 of file xmem.h.

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

6.4.2.2 void* fl

Free List.

Definition at line 66 of file xmem.h.

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

6.4.2.3 char* start

Start of Heap.

Definition at line 63 of file xmem.h.

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

6.4.2.4 void* val

Highest Heap Point.

Definition at line 65 of file xmem.h.

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

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

- [include/xmem.h](#)

6.5 MenuEntry Struct Reference

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

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

Data Fields

- [uint8_t cmd](#)
Byte that triggers the action.
- [PGM_P helpText](#)
Text (in Flash) printed with help command.
- [Task f](#)
Action that get's executed.
- [MenuEntry * next](#)
Next [MenuEntry](#) in the linked list.

6.5.1 Detailed Description

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

Stores Helptext, command and action.

Definition at line 49 of file uartMenu.h.

6.5.2 Field Documentation

6.5.2.1 uint8_t cmd

Byte that triggers the action.

Definition at line 50 of file uartMenu.h.

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

6.5.2.2 Task f

Action that get's executed.

Definition at line 52 of file uartMenu.h.

Referenced by addMenuCommand(), and uartMenuTask().

6.5.2.3 PGM_P helpText

Text (in Flash) printed with help command.

Definition at line 51 of file uartMenu.h.

Referenced by addMenuCommand(), and uartMenuPrintHelp().

6.5.2.4 MenuEntry* next

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

Definition at line 53 of file uartMenu.h.

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

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

- [include/uartMenu.h](#)

6.6 PIDState Struct Reference

Data Structure for a single PID Controller.

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

Data Fields

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

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

6.6.1 Detailed Description

Data Structure for a single PID Controller.

Stores all needed constants and state variables.

Definition at line 47 of file pid.h.

6.6.2 Field Documentation

6.6.2.1 double intMax

Maximum Integral sum.

Default is [PID_INTMAX](#).

Definition at line 54 of file pid.h.

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

6.6.2.2 double intMin

Minimum Integral sum.

Default is [PID_INTMIN](#).

Definition at line 53 of file pid.h.

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

6.6.2.3 double kd

Derivative factor.

Default is [PID_D](#).

Definition at line 50 of file pid.h.

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

6.6.2.4 double ki

Integral factor.

Default is [PID_I](#).

Definition at line 49 of file pid.h.

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

6.6.2.5 double kp

Proportional factor.

Default is [PID_P](#).

Definition at line 48 of file pid.h.

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

6.6.2.6 time_t last

Last execution time.

For dT calculation.

Definition at line 57 of file pid.h.

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

6.6.2.7 double lastError

Derivative State.

Definition at line 55 of file pid.h.

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

6.6.2.8 double outMax

Maximum Output.

Default is [PID_OUTMAX](#).

Definition at line 52 of file pid.h.

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

6.6.2.9 double outMin

Minimum Output.

Default is [PID_OUTMIN](#).

Definition at line 51 of file pid.h.

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

6.6.2.10 double sumError

Integral state.

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

Definition at line 56 of file pid.h.

Referenced by pidExecute(), and pidSet().

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

- [include/pid.h](#)

6.7 TaskElement Struct Reference

Single-Linked Task List.

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

Data Fields

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

6.7.1 Detailed Description

Single-Linked Task List.

Definition at line 48 of file tasks.h.

6.7.2 Field Documentation

6.7.2.1 TaskElement* next

Next list element.

Definition at line 50 of file tasks.h.

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

6.7.2.2 Task task

Task to be executed.

Definition at line 49 of file tasks.h.

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

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

- [include/tasks.h](#)

6.8 Vector3f Struct Reference

The global 3-Dimensional Floating Point Vector.

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

Data Fields

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

6.8.1 Detailed Description

The global 3-Dimensional Floating Point Vector.

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

7.1.1 Detailed Description

LSM303DLHC Accelerometer API Header.

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

7.2 include/adc.h File Reference

Analog-to-Digital Converter API Header.

Enumerations

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

Functions

- void [adclnit](#) ([ADCRef](#) ref)
Initialize the ADC Hardware.
- void [adcStart](#) (uint8_t channel)
Start a conversion on a given channel.
- uint8_t [adcReady](#) (void)
Check if a result is ready.
- uint16_t [adcGet](#) (uint8_t next)
Get the conversion results.
- void [adcClose](#) (void)
Disable the ADC to save energy.

7.2.1 Detailed Description

Analog-to-Digital Converter API Header.

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

7.3 include/complementary.h File Reference

Complementary-Filter Header.

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

Data Structures

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

Functions

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

7.3.1 Detailed Description

Complementary-Filter Header.

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

7.4 include/config.h File Reference

Various default settings.

Macros

- #define [ORIENTATION_FILTER](#) FILTER_KALMAN
Filter Implementation to be used.
- #define [COMPLEMENTARY_TAU](#) 0.5
Time Contant for Low and High Pass Filter in the [Complementary](#) Filter.
- #define [SOFTWARELOWPASS](#) 1
Software Low-Pass on Gyro and ACC.
- #define [ACCFILTERFACTOR](#) SOFTWARELOWPASS
Accelerometer Low Pass Factor.
- #define [GYROFILTERFACTOR](#) SOFTWARELOWPASS
Gyroscope Low Pass Factor.
- #define [PID_OUTMAX](#) 256
Maximum PID Output.
- #define [PID_OUTMIN](#) -256
Minimum PID Output.
- #define [PID_INTMAX](#) PID_OUTMAX
Maximum PID Integral Sum.
- #define [PID_INTMIN](#) PID_OUTMIN
Minimal PID Integral Sum.
- #define [PID_FACTOR](#) 4 / 5
Influence of PID in relation to Base Speed.
- #define [DT](#) 0.01f
Time Constant.
- #define [Q1](#) 5.0f
Q Matrix Diagonal Element 1.
- #define [Q2](#) 100.0f
Q Matrix Diagonal Element 2.
- #define [Q3](#) 0.01f
Q Matrix Diagonal Element 3.
- #define [R1](#) 1000.0f
R Matrix Diagonal Element 1.
- #define [R2](#) 1000.0f
R Matrix Diagonal Element 2.
- #define [SET_ROLLPLUS](#) 1
Second Motor at the Right.
- #define [SET_ROLLMINUS](#) 3
Fourth Motor at the Left.
- #define [SET_PITCHPLUS](#) 0
First Motor at the Top.
- #define [SET_PITCHMINUS](#) 2
Third Motor at the Bottom.
- #define [PID_P](#) 5.0
Default PID P Constant.
- #define [PID_I](#) 0.03
Default PID I Constant.
- #define [PID_D](#) -13.0
Default PID D Constant.
- #define [MOTORCOUNT](#) 4
Amount of motors.
- #define [BATT_MAX](#) 15

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

- #define [BANK2PIN](#) PL5
Third Bank Selection Pin.
- #define [SPISS](#) PB0
SPI Slave Select Pin.
- #define [RX_BUFFER_SIZE](#) 64
UART Receive Buffer Size.
- #define [TX_BUFFER_SIZE](#) 64
UART Transmit Buffer Size.

7.4.1 Detailed Description

Various default settings.

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

7.5 include/debug.h File Reference

Debug and Assert Header and Implementation.

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

Macros

- #define [DEBUGOUT](#)(x) printf("!\%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 gyroInit (GyroRange r)`
Initializes the Gyroscope.
- `Error gyroRead (Vector3f *v)`
Get a set of gyroscope data.

7.8.1 Detailed Description

L3GD20 Gyroscope API Header.

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

7.9 include/kalman.h File Reference

Kalman-Filter Header.

Data Structures

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

Functions

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

7.9.1 Detailed Description

Kalman-Filter Header.

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

7.10 include/mag.h File Reference

LSM303DLHC Magnetometer API Header.

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

Enumerations

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

Functions

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

7.10.1 Detailed Description

LSM303DLHC Magnetometer API Header.

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

7.11 include/motor.h File Reference

BL-Ctrl V1.2 Controller API Header.

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

Functions

- void [motorInit](#) (void)
Initializes the motor control library.
- void [motorSet](#) (uint8_t id, uint8_t speed)
Set the speed of one or all motors.
- void [motorTask](#) (void)
Send the values stored in [motorSpeed](#) to the Controllers.

Variables

- uint8_t [motorSpeed](#) [[MOTORCOUNT](#)]
Speed for the four motors.

7.11.1 Detailed Description

BL-Ctrl V1.2 Controller API Header.

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

7.12 include/orientation.h File Reference

Orientation API Header.

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

Data Structures

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

Functions

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

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

Variables

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

7.12.1 Detailed Description

Orientation API Header.

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

7.13 include/pid.h File Reference

PID Library Header.

Data Structures

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

Macros

- #define [ROLL](#) 0
Roll index for [o_should](#), [o_output](#) and [o_pids](#).
- #define [PITCH](#) 1
Pitch index for [o_should](#), [o_output](#) and [o_pids](#).

Functions

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

Variables

- double [o_should](#) [2]
Roll and Pitch target angles.
- double [o_output](#) [2]
Roll and Pitch PID Output.
- [PIDState](#) [o_pids](#) [2]
Roll and Pitch PID States.

7.13.1 Detailed Description

PID Library Header.

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

7.14 include/serial.h File Reference

UART Library Header File.

Macros

- `#define 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 [resetSelf](#) (void)
Use the Watchdog to reset yourself after 15ms.

7.23.1 Detailed Description

xyControl API Header.

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

7.24 lib/acc.c File Reference

LSM303DLHC Accelerometer API Implementation.

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

Macros

- #define [ACCREG_CTRL1](#) 0x20
Accelerometer Control Register 1.
- #define [ACCREG_CTRL4](#) 0x23
Accelerometer Control Register 4.
- #define [ACCREG_XL](#) 0x28
First Accelerometer Output Register.

Functions

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

Variables

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

7.24.1 Detailed Description

LSM303DLHC Accelerometer API Implementation.

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

7.25 lib/adc.c File Reference

Analog-to-Digital Converter API Implementation.

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

Functions

- void [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 o_pids](#) [2]
Roll and Pitch PID States.
- double [o_should](#) [2]
Roll and Pitch target angles.
- double [o_output](#) [2]
Roll and Pitch PID Output.

7.33.1 Detailed Description

PID Library Implementation.

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

7.34 lib/serial.c File Reference

UART Library Implementation.

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

Macros

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

Functions

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

- Check if the receive buffer is empty.*
- void [serialWrite](#) (uint8_t uart, uint8_t data)
Send a byte.
- void [serialWriteString](#) (uint8_t uart, const char *data)
Send a string.
- uint8_t [serialTxBufferFull](#) (uint8_t uart)
Check if the transmit buffer is full.
- uint8_t [serialTxBufferEmpty](#) (uint8_t uart)
Check if the transmit buffer is empty.

7.34.1 Detailed Description

UART Library Implementation.

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

7.35 lib/set.c File Reference

Motor Mixer Library Implementation.

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

Macros

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

Functions

- void [setMotorSpeeds](#) (uint8_t axis, uint8_t *vals)
Set the Motor Speeds according to the SET_ Motor Position Constants.*
- void [setTask](#) (void)
Read the PID Output and Set the Motor Speeds.

Variables

- uint8_t [baseSpeed](#) = 0
Motor Base Speed.

7.35.1 Detailed Description

Motor Mixer Library Implementation.

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

7.36 lib/spi.c File Reference

SPI API Implementation.

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

Functions

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

7.36.1 Detailed Description

SPI API Implementation.

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

7.37 lib/tasks.c File Reference

Task API Implementation.

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

Functions

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

Variables

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

7.37.1 Detailed Description

Task API Implementation.

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

7.38 lib/time.c File Reference

Time API Implementation.

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

Macros

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

Functions

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

Variables

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

7.38.1 Detailed Description

Time API Implementation.

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

7.39 lib/uartMenu.c File Reference

UART Menu API Implementation.

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

Functions

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

Variables

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

7.39.1 Detailed Description

UART Menu API Implementation.

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

7.40 lib/xmem.c File Reference

XMEM API Implementation.

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

Functions

- void [saveState](#) (uint8_t bank)
Save the current malloc state.
- void [restoreState](#) (uint8_t bank)
Restore the malloc state.
- void [xmemInit](#) (void)
Initialize the External Memory Interface.
- void [xmemSetBank](#) (uint8_t bank)
Switch the active memory bank.
- uint8_t [xmemGetBank](#) (void)
Get the current memory bank.

Variables

- [MallocState](#) [states](#) [[MEMBANKS](#)]
MallocState for all Memory Banks.
- uint8_t [currentBank](#) = 0
Current active Memory Bank.
- void * [__brkval](#)
Internal Malloc Heap-End Pointer.
- void * [__flp](#)
Internal Malloc Free List Pointer (State)

7.40.1 Detailed Description

XMEM API Implementation.

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

7.41 lib/xycontrol.c File Reference

xyControl API Implementation.

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

Functions

- int `uartoutput` (char c, FILE *f)
Method used to write to stdout and stderr.
- int `uartinput` (FILE *f)
Method used to read from stdin.
- void `xylnit` (void)
Initialize the xyControl Hardware.
- void `xyLedInternal` (uint8_t v, volatile uint8_t *port, uint8_t pin)
Internal LED Manipulation function.
- double `getVoltage` (void)
Calculate and return the Battery Voltage.
- void `resetSelf` (void)
Use the Watchdog to reset yourself after 15ms.

Variables

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

7.41.1 Detailed Description

xyControl API Implementation.

Definition in file `xycontrol.c`.

Chapter 8

Example Documentation

8.1 hardwareTest.c

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

```
/*
 * hardwareTest.c
 *
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 * modification, are permitted provided that the following conditions
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 * 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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 *
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 * 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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 * 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, sumFlightCount = 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 & 0x02) {
            pidTask();
        } else {
            o_output[0] = o_output[1] = 0;
        }
        setTask();
        motorTask();

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

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

void controlToggle(void) {
    if (state & 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;
        o_should[PITCH] = targetPitch;
        printf("Pitch Forward %i\n", targetPitch);
    }
}

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

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

void motorRight(void) {
    if (targetRoll >= (-1 * (MAXANGLE - ANGLESTEP))) {
        targetRoll -= ANGLESTEP;
        o_should[ROLL] = targetRoll;
        printf("Roll Right %i\n", targetRoll);
    }
}

void parameterChange(void) {
    double p, i, d, min, max, iMin, iMax;
    int c = scanf("%lf %lf %lf %lf %lf %lf %lf", &p, &i, &d, &min, &max, &iMin, &iMax);
    if (c == 7) {
        pidSet(&o_pids[0], p, i, d, min, max, iMin, iMax);
        pidSet(&o_pids[1], p, i, d, min, max, iMin, iMax);
    } else {
        printf("Only got %i (%lf %lf %lf %lf %lf %lf %lf)!\n", c, p, i, d, min, max, iMin, iMax);
    }
}

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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