

xyControl

0.1

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Chapter 1

Main Page

xyControl is a Quadcopter Flight Controller based on Atmels Atmega2560 microcontroller. It features 64KB 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.

Known Problems

In the current PCB layout, the SD-Card holder is rotated 180 degrees. This prevents an SD-Card from being inserted!

Flight Control Software Flow

Three tasks are controlling the Quadcopter Orientation in Space.

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

Supported Hardware

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

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

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

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

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

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

PC and Android Tools

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

UART-Flight Status Packet Format

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

Software used

- [Peter Fleurys TWI Library](#)

License

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

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

Chapter 2

Module Index

2.1 Modules

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Chapter 4

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4.1 File List

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Chapter 5

Module Documentation

5.1 Software

Software Libraries.

Modules

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

5.1.1 Detailed Description

Software Libraries.

5.2 System

System Libraries.

Modules

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

5.2.1 Detailed Description

System Libraries.

5.3 Flight

Flight Control Libraries.

Modules

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

5.3.1 Detailed Description

Flight Control Libraries.

5.4 Hardware

Hardware Libraries.

Modules

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

5.4.1 Detailed Description

Hardware Libraries.

5.5 Accelerometer Driver

Configuring and reading an LSM303DLHC Accelerometer.

Files

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

Macros

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

Enumerations

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

Functions

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

Variables

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

5.5.1 Detailed Description

Configuring and reading an LSM303DLHC Accelerometer.

5.5.2 Macro Definition Documentation

5.5.2.1 `#define ACCREG_CTRL1 0x20`

Accelerometer Control Register 1.

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

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

5.5.2.2 #define ACCREG_CTRL4 0x23

Accelerometer Control Register 4.

Definition at line 50 of file acc.c.

Referenced by `accInit()`.

5.5.2.3 #define ACCREG_XL 0x28

First Accelerometer Output Register.

Definition at line 51 of file acc.c.

Referenced by `accRead()`.

5.5.3 Enumeration Type Documentation

5.5.3.1 enum AccRange

Accelerometer Range options.

Enumerator

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

Definition at line 47 of file acc.h.

```

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

5.5.4 Function Documentation

5.5.4.1 Error accInit (AccRange r)

Initialize the Accelerometer.

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

Parameters

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

Returns

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

Definition at line 76 of file acc.c.

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

Referenced by `orientationInit()`.

```

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

```

5.5.4.2 Error accRead (Vector3f * v)

Read from the Accelerometer.

Accelerometer should already be initialized!

Parameters

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

Returns

TWI_NO_ANSWER, TWI_WRITE_ERROR, ARGUMENT_ERROR or SUCCESS.

Definition at line 103 of file acc.c.

References ACC_ADDRESS, ACCFILTERFACTOR, accRange, ACCREG_XL, ARGUMENT_ERROR, r16G, r2G, r4G, r8G, SUCCESS, TWI_NO_ANSWER, TWI_READ, TWI_WRITE, TWI_WRITE_ERROR, twiReadAck(), twiReadNak(), twiRepStart(), twiStart(), twiWrite(), Vector3f::x, Vector3f::y, and Vector3f::z.

Referenced by orientationTask().

```

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

```

```

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

```

5.5.4.3 Error accWriteRegister (uint8_t reg, uint8_t val)

Write an Accelerometer Register.

I2C should already be initialized!

Parameters

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

Returns

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

Definition at line 62 of file acc.c.

References [TWI_NO_ANSWER](#).

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


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

5.5.5 Variable Documentation

5.5.5.1 AccRange accRange

Stored range to scale returned values.

Definition at line 53 of file acc.c.

Referenced by `acclnit()`, and `accRead()`.

5.6 ADC Driver

Analog-to-Digital Converter Library.

Files

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

Enumerations

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

Functions

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

5.6.1 Detailed Description

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

5.6.2 Enumeration Type Documentation

5.6.2.1 enum ADCRef

ADC Reference Voltage options.

Enumerator

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

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

```

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

5.6.3 Function Documentation

5.6.3.1 void adcClose (void)

Disable the ADC to save energy.

Definition at line 107 of file adc.c.

```

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

5.6.3.2 uint16_t adcGet (uint8_t next)

Get the conversion results.

Parameters

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

Returns

10bit ADC value

Definition at line 96 of file adc.c.

References adcReady().

Referenced by getVoltage().

```

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

5.6.3.3 void adclnit (ADCRef ref)

Initialize the ADC Hardware.

Parameters

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

Definition at line 44 of file adc.c.

References AINT1, AINT2, AREF, and AVCC.

Referenced by xylnit().

```

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

```

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

```

5.6.3.4 uint8_t adcReady (void)

Check if a result is ready.

Returns

1 if conversion is done.

Definition at line 86 of file adc.c.

Referenced by adcGet(), and getVoltage().

```

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

```

5.6.3.5 void adcStart (uint8_t channel)

Start a conversion on a given channel.

Parameters

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

Definition at line 70 of file adc.c.

Referenced by getVoltage().

```

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

```

5.7 Complementary-Filter

Complementary-Filter.

Files

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

Data Structures

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

Functions

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

5.7.1 Detailed Description

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

5.7.2 Function Documentation

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

Step the [Complementary](#) Filter.

Parameters

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

Definition at line 50 of file complementary.c.

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

Referenced by `orientationTask()`.

```

50
51     time_t dtInteger = (getSystemTime() - data->lastExecute);
52     double dt = dtInteger / 1000;
53     data->angle = (data->angle + (gyro * dt)); // Gyro Integrator
54     data->angle *= COMPLEMENTARY_TAU / (COMPLEMENTARY_TAU + dt); //
    High-Pass
55     data->angle += (1 - (COMPLEMENTARY_TAU / (COMPLEMENTARY_TAU + dt))) *
    acc; // Low-Pass
56     data->lastExecute = getSystemTime();
57 }
```

5.7.2.2 void complementaryInit (Complementary * data)

Initialize a Complementary-State.

Parameters

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

Definition at line 45 of file complementary.c.

References `getSystemTime()`.

Referenced by `orientationInit()`.

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

5.8 Configuration

Various default settings.

Files

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

Macros

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

- Third Motor at the Bottom.*

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

- `#define BANK1PORT PORTG`
Second Bank Selection Port.
- `#define BANK1DDR DDRG`
Second Bank Selection Data Direction Register.
- `#define BANK1PIN PG4`
Second Bank Selection Pin.
- `#define BANK2PORT PORTL`
Third Bank Selection Port.
- `#define BANK2DDR DDRL`
Third Bank Selection Data Direction Register.
- `#define BANK2PIN PL5`
Third Bank Selection Pin.
- `#define SPISS PB0`
SPI Slave Select Pin.
- `#define RX_BUFFER_SIZE 128`
UART Receive Buffer Size.
- `#define TX_BUFFER_SIZE 128`
UART Transmit Buffer Size.
- `#define USB 0`
FT232RL USB UART module.
- `#define BLUETOOTH 1`
Bluetooth UART module.
- `#define UART_BLUETOOTH`
UART module to use (0 to 3)

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 119 of file config.h.

Referenced by `accRead()`.

5.8.2.2 `#define ACCFILTERFACTOR SOFTWARELOWPASS`

Accelerometer Low Pass Factor.

Definition at line 58 of file config.h.

Referenced by `accRead()`.

5.8.2.3 `#define BANK0DDR DDRG`

First Bank Selection Data Direction Register.

Definition at line 146 of file config.h.

Referenced by `xmemInit()`.

5.8.2.4 `#define BANK0PIN PG3`

First Bank Selection Pin.

Definition at line 147 of file config.h.

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

5.8.2.5 `#define BANK0PORT PORTG`

First Bank Selection Port.

Definition at line 145 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 149 of file config.h.

Referenced by `xmemInit()`.

5.8.2.7 `#define BANK1PIN PG4`

Second Bank Selection Pin.

Definition at line 150 of file config.h.

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

5.8.2.8 `#define BANK1PORT PORTG`

Second Bank Selection Port.

Definition at line 148 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 152 of file config.h.

Referenced by `xmemInit()`.

5.8.2.10 `#define BANK2PIN PL5`

Third Bank Selection Pin.

Definition at line 153 of file config.h.

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

5.8.2.11 `#define BANK2PORT PORTL`

Third Bank Selection Port.

Definition at line 151 of file config.h.

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

5.8.2.12 `#define BATT_CHANNEL 0`

ADC Channel for Battery.

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

Referenced by `getVoltage()`.

5.8.2.13 `#define BATT_MAX 15`

Battery Voltage Reference (ADC 5V)

Definition at line 112 of file `config.h`.

Referenced by `getVoltage()`.

5.8.2.14 `#define BLUETOOTH 1`

Bluetooth UART module.

Definition at line 178 of file `config.h`.

5.8.2.15 `#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.

Definition at line 54 of file `config.h`.

Referenced by `complementaryExecute()`.

5.8.2.16 `#define DT 0.01f`

Time Constant.

Definition at line 74 of file `config.h`.

Referenced by `kalmanInnovate()`.

5.8.2.17 `#define GYRO_ADDRESS 0xD6`

Gyroscope Address (110101xr, x = 1)

Definition at line 120 of file `config.h`.

Referenced by `gyroRead()`.

5.8.2.18 `#define GYROFILTERFACTOR SOFTWARELOWPASS`

Gyroscope Low Pass Factor.

Definition at line 59 of file `config.h`.

Referenced by `gyroRead()`.

5.8.2.19 `#define LED0DDR DDRL`

First LED Data Direction Register.

Definition at line 129 of file config.h.

Referenced by xyInit().

5.8.2.20 `#define LED0PIN PL6`

First LED Pin.

Definition at line 130 of file config.h.

Referenced by xyInit().

5.8.2.21 `#define LED0PORT PORTL`

First LED Port.

Definition at line 128 of file config.h.

5.8.2.22 `#define LED1DDR DDRL`

Second LED Data Direction Register.

Definition at line 132 of file config.h.

Referenced by xyInit().

5.8.2.23 `#define LED1PIN PL7`

Second LED Pin.

Definition at line 133 of file config.h.

Referenced by xyInit().

5.8.2.24 `#define LED1PORT PORTL`

Second LED Port.

Definition at line 131 of file config.h.

5.8.2.25 `#define LED2DDR DDRG`

Third LED Data Direction Register.

Definition at line 135 of file config.h.

Referenced by xyInit().

5.8.2.26 `#define LED2PIN PG5`

Third LED Pin.

Definition at line 136 of file config.h.

Referenced by xyInit().

5.8.2.27 #define LED2PORT PORTG

Third LED Port.

Definition at line 134 of file config.h.

5.8.2.28 #define LED3DDR DDRE

Fourth LED Data Direction Register.

Definition at line 138 of file config.h.

Referenced by xyInit().

5.8.2.29 #define LED3PIN PE2

Fourth LED Pin.

Definition at line 139 of file config.h.

Referenced by xyInit().

5.8.2.30 #define LED3PORT PORTE

Fourth LED Port.

Definition at line 137 of file config.h.

5.8.2.31 #define MAG_ADDRESS 0x3C

Magnetometer Address.

Definition at line 121 of file config.h.

Referenced by magRead().

5.8.2.32 #define MOTOR_BASEADDRESS 0x52

Address of first motor controller.

Definition at line 122 of file config.h.

Referenced by motorTask().

5.8.2.33 #define MOTORCOUNT 4

Amount of motors.

Definition at line 106 of file config.h.

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

5.8.2.34 #define ORIENTATION_FILTER FILTER_COMPLEMENTARY

Filter Implementation to be used.

Definition at line 48 of file config.h.

5.8.2.35 #define PID_D -13.0

Default PID D Constant.

Definition at line 100 of file config.h.

Referenced by pidInit().

5.8.2.36 #define PID_FACTOR 4 / 5

Influence of PID in relation to Base Speed.

Definition at line 67 of file config.h.

5.8.2.37 #define PID_I 0.03

Default PID I Constant.

Definition at line 99 of file config.h.

Referenced by pidInit().

5.8.2.38 #define PID_INTMAX PID_OUTMAX

Maximum PID Integral Sum.

Definition at line 63 of file config.h.

Referenced by pidInit().

5.8.2.39 #define PID_INTMIN PID_OUTMIN

Minimal PID Integral Sum.

Definition at line 64 of file config.h.

Referenced by pidInit().

5.8.2.40 #define PID_OUTMAX 256

Maximum PID Output.

Definition at line 61 of file config.h.

Referenced by pidInit().

5.8.2.41 #define PID_OUTMIN -256

Minimum PID Output.

Definition at line 62 of file config.h.

Referenced by pidInit().

5.8.2.42 #define PID_P 5.0

Default PID P Constant.

Definition at line 98 of file config.h.

Referenced by pidInit().

5.8.2.43 #define Q1 5.0f

Q Matrix Diagonal Element 1.

Definition at line 77 of file config.h.

Referenced by kalmanInnovate().

5.8.2.44 #define Q2 100.0f

Q Matrix Diagonal Element 2.

Definition at line 78 of file config.h.

Referenced by kalmanInnovate().

5.8.2.45 #define Q3 0.01f

Q Matrix Diagonal Element 3.

Definition at line 79 of file config.h.

Referenced by kalmanInnovate().

5.8.2.46 #define R1 1000.0f

R Matrix Diagonal Element 1.

Definition at line 82 of file config.h.

Referenced by kalmanInnovate().

5.8.2.47 #define R2 1000.0f

R Matrix Diagonal Element 2.

Definition at line 83 of file config.h.

Referenced by kalmanInnovate().

5.8.2.48 #define RX_BUFFER_SIZE 128

UART Receive Buffer Size.

Definition at line 174 of file config.h.

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

5.8.2.49 #define SET_PITCHMINUS 2

Third Motor at the Bottom.

Definition at line 92 of file config.h.

5.8.2.50 #define SET_PITCHPLUS 0

First Motor at the Top.

Definition at line 91 of file config.h.

5.8.2.51 #define SET_ROLLMINUS 3

Fourth Motor at the Left.

Definition at line 90 of file config.h.

Referenced by setMotorSpeeds().

5.8.2.52 #define SET_ROLLPLUS 1

Second Motor at the Right.

Definition at line 89 of file config.h.

Referenced by setMotorSpeeds().

5.8.2.53 #define SOFTWARELOWPASS 1

Software Low-Pass on Gyro and ACC.

Definition at line 57 of file config.h.

5.8.2.54 #define SPISS PB0

SPI Slave Select Pin.

Definition at line 162 of file config.h.

5.8.2.55 #define TX_BUFFER_SIZE 128

UART Transmit Buffer Size.

Definition at line 175 of file config.h.

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

5.8.2.56 #define UART BLUETOOTH

UART module to use (0 to 3)

Definition at line 179 of file config.h.

5.8.2.57 #define USB 0

FT232RL USB UART module.

Definition at line 177 of file config.h.

5.9 Debug Output

Allows debug output and assert usage.

Files

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

Macros

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

5.9.1 Detailed Description

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

```
#define DEBUG 1
```

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

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

5.9.2 Macro Definition Documentation

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

Enable `assert()`

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

5.9.2.2 `#define ASSERTFUNC(x)`

Simple Assert Implementation.

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

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

Debug Output Function.

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

5.9.2.4 `#define debugPrint(ignore)`

Disable `debugPrint()`

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

5.10 Error Reporting

Error reporting with human readable strings.

Files

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

Macros

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

Enumerations

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

Functions

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

5.10.1 Detailed Description

Error reporting with human readable strings.

5.10.2 Macro Definition Documentation

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

Check an Error Code.

Return it if an error occurred.

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

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

5.10.2.2 `#define REPORTERROR(x)`

Value:

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

Report an error, if it occurred.

Using printf()

Examples:

[uartFlight.c](#).

Definition at line 59 of file error.h.

5.10.3 Enumeration Type Documentation

5.10.3.1 enum Error

Error Conditions.

Enumerator

SUCCESS No Error.
TWI_NO_ANSWER No answer from TWI Slave.
TWI_WRITE_ERROR Error while writing to TWI Slave.
MALLOC_FAIL Malloc failed.
ERROR General Error.
ARGUMENT_ERROR Invalid arguments.

Definition at line 46 of file error.h.

```

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

5.10.4 Function Documentation

5.10.4.1 char* getErrorString (Error e)

Returns a human-readable error description.

Free the string after use!

Definition at line 58 of file error.c.

References errorTable.

```

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

5.11 Gyroscope Driver

Configuring and reading an L3GD20.

Files

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

Macros

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

Enumerations

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

Functions

- [Error gyroInit](#) ([GyroRange](#) r)
Initializes the Gyroscope.
- [Error gyroRead](#) ([Vector3f](#) *v)
Get a set of gyroscope data.
- [Error gyroWriteByte](#) ([uint8_t](#) reg, [uint8_t](#) val)
Write a Gyroscope Register.

Variables

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

5.11.1 Detailed Description

Configuring and reading an L3GD20.

5.11.2 Macro Definition Documentation

5.11.2.1 `#define GYROREG_CTRL1 0x20`

Gyroscope Control Register 1.

Definition at line 48 of file gyro.c.

Referenced by gyroInit().

5.11.2.2 `#define GYROREG_CTRL4 0x23`

Gyroscope Control Register 4.

Definition at line 49 of file gyro.c.

Referenced by gyroInit().

5.11.2.3 `#define GYROREG_OUTXL 0x28`

First Gyroscope Output Register.

Definition at line 50 of file gyro.c.

Referenced by gyroRead().

5.11.3 Enumeration Type Documentation

5.11.3.1 `enum GyroRange`

Gyroscope Range options.

Enumerator

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

Definition at line 47 of file gyro.h.

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

5.11.4 Function Documentation

5.11.4.1 `Error gyroInit (GyroRange r)`

Initializes the Gyroscope.

I2C should already be initialized.

Parameters

<i>r</i>	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](#)

Definition at line 99 of file gyro.c.

References [ARGUMENT_ERROR](#), [GYRO_ADDRESS](#), [GYROFILTERFACTOR](#), [gyroRange](#), [GYROREG_OUTXL](#), [r2000DPS](#), [r250DPS](#), [r500DPS](#), [SUCCESS](#), [TWI_NO_ANSWER](#), [TWI_READ](#), [TWI_WRITE](#), [TWI_WRITE_ERROR](#), [twiReadAck\(\)](#), [twiReadNak\(\)](#), [twiRepStart\(\)](#), [twiStart\(\)](#), [twiWrite\(\)](#), [Vector3f::x](#), [Vector3f::y](#), and [Vector3f::z](#).

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

```

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

```

```

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

```

5.11.4.3 Error gyroWriteByte (uint8_t reg, uint8_t val)

Write a Gyroscope Register.

I2C should already be initialized!

Parameters

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

Returns

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

Definition at line 61 of file gyro.c.

References [TWI_NO_ANSWER](#).

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

```

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

```


5.11.5 Variable Documentation

5.11.5.1 GyroRange gyroRange

Stored range to scale returned values.

Definition at line 52 of file gyro.c.

Referenced by gyroInit(), and gyroRead().

5.12 Kalman-Filter

Kalman-Filter from [Linus Helgesson](#)

Files

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

Data Structures

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

Functions

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

5.12.1 Detailed Description

Kalman-Filter from [Linus Helgesson](#)

5.12.2 Function Documentation

5.12.2.1 void kalmanInit (Kalman * data)

Initialize a Kalman-State.

Parameters

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

Definition at line 48 of file kalman.c.

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

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

```

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

```

64 }

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

Step the [Kalman](#) Filter.

Parameters

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

Definition at line 66 of file kalman.c.

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

Referenced by orientationTask().

```

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

```

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

5.13 Magnetometer Driver

Configuring and reading an LSM303DLHC Magnetometer.

Files

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

Macros

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

Enumerations

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

Functions

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

5.13.1 Detailed Description

Configuring and reading an LSM303DLHC Magnetometer.

5.13.2 Macro Definition Documentation

5.13.2.1 `#define MAGREG_CRB 0x01`

Magnetometer Gain Register.

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

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

5.13.2.2 `#define MAGREG_MR 0x02`

Magnetometer Mode Register.

Definition at line 49 of file mag.c.

Referenced by `magInit()`.

5.13.2.3 `#define MAGREG_XH 0x03`

First Magnetometer Output Register.

Definition at line 50 of file mag.c.

Referenced by `magRead()`.

5.13.3 Enumeration Type Documentation

5.13.3.1 `enum MagRange`

Magnetometer Range options.

Enumerator

r1g3 +- 1.3 Gauss

r1g9 +- 1.9 Gauss

r2g5 +- 2.5 Gauss

r4g0 +- 4.0 Gauss

r4g7 +- 4.7 Gauss

r5g6 +- 5.6 Gauss

r8g1 +- 8.1 Gauss

Definition at line 47 of file mag.h.

```

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

5.13.4 Function Documentation

5.13.4.1 Error `magInit (MagRange r)`

Initialize the Magnetometer.

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

Parameters

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

Returns

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

Definition at line 73 of file mag.c.

References [ARGUMENT_ERROR](#), [MAGREG_CRB](#), [MAGREG_MR](#), [magWriteRegister\(\)](#), and [SUCCESS](#).

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

```

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

5.13.4.2 Error magRead (Vector3f * v)

Read from the Magnetometer.

Magnetometer should already be initialized!

Parameters

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

Returns

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

Definition at line 85 of file mag.c.

References [ARGUMENT_ERROR](#), [MAG_ADDRESS](#), [MAGREG_XH](#), [SUCCESS](#), [TWI_NO_ANSWER](#), [TWI_READ](#), [TWI_WRITE](#), [TWI_WRITE_ERROR](#), [twiReadAck\(\)](#), [twiReadNak\(\)](#), [twiRepStart\(\)](#), [twiStart\(\)](#), [twiWrite\(\)](#), [Vector3f::x](#), [Vector3f::y](#), and [Vector3f::z](#).

```

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

5.13.4.3 Error magWriteRegister (uint8_t reg, uint8_t val)

Write a Magnetometer Register.

I2C should already be initialized!

Parameters

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

Returns

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

Definition at line 59 of file mag.c.

References [TWI_NO_ANSWER](#).

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

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


5.14 Motor Controller Driver

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

Files

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

Functions

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

Variables

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

5.14.1 Detailed Description

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

5.14.2 Function Documentation

5.14.2.1 void motorInit (void)

Initializes the motor control library.

Really only sets motorSpeed to zero.

Examples:

[uartFlight.c](#).

Definition at line 58 of file motor.c.

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

```

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

5.14.2.2 void motorSet (uint8_t id, uint8_t speed)

Set the speed of one or all motors.

Parameters

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

Definition at line 64 of file motor.c.

References MOTORCOUNT, and motorSpeed.

Referenced by setMotorSpeeds().

```

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

5.14.2.3 void motorTask (void)

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

I2C already has to be initialized!

Examples:

[uartFlight.c](#).

Definition at line 50 of file motor.c.

References MOTOR_BASEADDRESS, MOTORCOUNT, motorSpeed, TWI_WRITE, twiStart(), twiStop(), and twiWrite().

```

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

5.14.3 Variable Documentation

5.14.3.1 uint8_t motorSpeed[MOTORCOUNT]

Speed for the four motors.

Examples:

[uartFlight.c](#).

Definition at line 48 of file motor.c.

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

5.14.3.2 `uint8_t motorSpeed[MOTORCOUNT]`

Speed for the four motors.

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

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

5.15 Orientation Calculation

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

Files

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

Data Structures

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

Macros

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

Functions

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

Variables

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

5.15.1 Detailed Description

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

5.15.2 Macro Definition Documentation

5.15.2.1 `#define TODEG(x) ((x * 180) / M_PI)`

Convert Radians to Degrees.

Definition at line 55 of file orientation.c.

Referenced by orientationTask().

5.15.3 Function Documentation

5.15.3.1 Error orientationInit (void)

Initializes the Orientation API.

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

Returns

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

Examples:

[uartFlight.c](#).

Definition at line 73 of file orientation.c.

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

```

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

5.15.3.2 Error orientationTask (void)

Calculate the current orientation.

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

Returns

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

Examples:

[uartFlight.c](#).

Definition at line 92 of file orientation.c.

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

```

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

```

5.15.3.3 void zeroOrientation (void)

Sets the current orientation to zero.

Examples:

[uartFlight.c](#).

Definition at line 128 of file orientation.c.

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

```

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

```

5.15.4 Variable Documentation

5.15.4.1 Angles orientation

Current Aircraft orientation.

Examples:

[uartFlight.c](#).

Definition at line 58 of file orientation.c.

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

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

Current Aircraft orientation.

Definition at line 58 of file orientation.c.

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

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

Current Aircraft orientation offset.

Definition at line 61 of file orientation.c.

5.15.4.4 Kalman pitchData

Kalman-State for Pitch Angle.

Definition at line 64 of file orientation.c.

5.15.4.5 Kalman rollData

Kalman-State for Roll Angle.

Definition at line 65 of file orientation.c.

5.16 PID-Controller

Simple implementation for multiple floating-point PID Controllers.

Files

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

Data Structures

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

Macros

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

Functions

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

Variables

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

5.16.1 Detailed Description

Simple implementation for multiple floating-point PID Controllers.

5.16.2 Macro Definition Documentation

5.16.2.1 `#define PITCH 1`

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

Examples:

`uartFlight.c`.

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

Referenced by `pidTask()`.

5.16.2.2 `#define ROLL 0`

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

Examples:

`uartFlight.c`.

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

Referenced by `pidTask()`.

5.16.3 Function Documentation

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

Execute a single PID Control Step.

Parameters

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

Returns

PID Output

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

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

Referenced by `pidTask()`.

```

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

```

```

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

```

5.16.3.2 void pidInit (void)

Initialize Roll and Pitch PID.

Stores the PID States in [o_pids](#). Also resets [o_should](#) to zero.

Examples:

[uartFlight.c](#).

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

References [o_should](#), [PID_D](#), [PID_I](#), [PID_INTMAX](#), [PID_INTMIN](#), [PID_OUTMAX](#), [PID_OUTMIN](#), [PID_P](#), and [pidSet\(\)](#).

```

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

```

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

Set the parameters of a PID controller.

The state variables will be reset to zero.

Parameters

<i>pid</i>	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 Driver

Serial Library for AVR's built-in UART Hardware.

Files

- file [serial.h](#)
UART API Header.
- file [serial.c](#)
UART API Implementation.

Macros

- `#define BAUD(baudRate, xtalCpu) ((xtalCpu)/((baudRate)*16l)-1)`
Calculate Baudrate Register Value.
- `#define XON 0x11`
XON Byte.
- `#define XOFF 0x13`
XOFF Byte.
- `#define FLOWMARK 5`
Space remaining to trigger XOFF/XON.

Functions

- void [serialInit](#) (uint16_t baud)
Initialize the UART Hardware.
- void [serialClose](#) (void)
Stop the UART Hardware.
- void [setFlow](#) (uint8_t on)
Manually change the flow control.
- uint8_t [serialHasChar](#) (void)
Check if a byte was received.
- uint8_t [serialGet](#) (void)
Read a single byte.
- uint8_t [serialGetBlocking](#) (void)
Wait until a character is received.
- uint8_t [serialRxBufferFull](#) (void)
Check if the receive buffer is full.
- uint8_t [serialRxBufferEmpty](#) (void)
Check if the receive buffer is empty.
- void [serialWrite](#) (uint8_t data)
Send a byte.
- void [serialWriteString](#) (const char *data)
Send a string.
- uint8_t [serialTxBufferFull](#) (void)
Check if the transmit buffer is full.
- uint8_t [serialTxBufferEmpty](#) (void)
Check if the transmit buffer is empty.
- [ISR](#) (SERIALRECIEVEINTERRUPT)
Receive Complete Interrupt.
- [ISR](#) (SERIALTRANSMITINTERRUPT)
Data Register Empty Interrupt.

Variables

- `uint8_t volatile rxBuffer [RX_BUFFER_SIZE]`
RX FIFO Buffer.
- `uint8_t volatile txBuffer [TX_BUFFER_SIZE]`
TX FIFO Buffer.
- `uint16_t volatile rxRead = 0`
RX FIFO Read Position.
- `uint16_t volatile rxWrite = 0`
RX FIFO Write Position.
- `uint16_t volatile txRead = 0`
TX FIFO Read Position.
- `uint16_t volatile txWrite = 0`
TX FIFO Write Position.
- `uint8_t volatile shouldStartTransmission = 1`
Should enable interrupt.

5.17.1 Detailed Description

Serial Library for AVR's built-in UART Hardware. Allows XON/XOFF Flow Control. FIFO Buffer for Receiving and Transmitting.

5.17.2 Macro Definition Documentation

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

Calculate Baudrate Register Value.

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

Referenced by `xyInit()`.

5.17.2.2 `#define FLOWMARK 5`

Space remaining to trigger XOFF/XON.

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

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

5.17.2.3 `#define XOFF 0x13`

XOFF Byte.

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

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

5.17.2.4 `#define XON 0x11`

XON Byte.

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

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

5.17.3 Function Documentation

5.17.3.1 ISR (SERIALRECIEVEINTERRUPT)

Receive Complete Interrupt.

Definition at line 107 of file serial.c.

References FLOWMARK, RX_BUFFER_SIZE, rxBuffer, rxWrite, shouldStartTransmission, and XOFF.

```

107         {
108     rxBuffer[rxWrite] = SERIALDATA;
109     if (rxWrite < (RX_BUFFER_SIZE - 1)) {
110         rxWrite++;
111     } else {
112         rxWrite = 0;
113     }
114
115 #ifndef FLOWCONTROL
116     rxBufferElements++;
117     if ((flow == 1) && (rxBufferElements >= (RX_BUFFER_SIZE -
FLOWMARK))) {
118         sendThisNext = XOFF;
119         flow = 0;
120         if (shouldStartTransmission) {
121             shouldStartTransmission = 0;
122             SERIALB |= (1 << SERIALUDRIE);
123             SERIALA |= (1 << SERIALUDRE); // Trigger Interrupt
124         }
125     }
126 #endif
127 }

```

5.17.3.2 ISR (SERIALTRANSMITINTERRUPT)

Data Register Empty Interrupt.

Definition at line 130 of file serial.c.

References shouldStartTransmission, TX_BUFFER_SIZE, txBuffer, txRead, and txWrite.

```

130         {
131 #ifndef FLOWCONTROL
132     if (sendThisNext) {
133         SERIALDATA = sendThisNext;
134         sendThisNext = 0;
135     } else {
136 #endif
137         if (txRead != txWrite) {
138             SERIALDATA = txBuffer[txRead];
139             if (txRead < (TX_BUFFER_SIZE - 1)) {
140                 txRead++;
141             } else {
142                 txRead = 0;
143             }
144         } else {
145             shouldStartTransmission = 1;
146             SERIALB &= ~(1 << SERIALUDRIE); // Disable Interrupt
147         }
148 #ifndef FLOWCONTROL
149     }
150 #endif
151 }

```

5.17.3.3 void serialClose (void)

Stop the UART Hardware.

Definition at line 164 of file serial.c.

References rxRead, rxWrite, serialTxBufferEmpty(), shouldStartTransmission, txRead, and txWrite.

```

164         {
165         uint8_t sreg = SREG;
166         sei();
167         while (!serialTxBufferEmpty());
168         while (SERIALB & (1 << SERIALUDRIE)); // Wait while Transmit Interrupt is on
169         cli();
170         SERIALB = 0;
171         SERIALC = 0;
172         rxRead = 0;
173         txRead = 0;
174         rxWrite = 0;
175         txWrite = 0;
176         shouldStartTransmission = 1;
177 #ifdef FLOWCONTROL
178         flow = 1;
179         sendThisNext = 0;
180         rxBufferElements = 0;
181 #endif
182         SREG = sreg;
183     }

```

5.17.3.4 uint8_t serialGet (void)

Read a single byte.

Returns

Received byte or 0

Definition at line 231 of file serial.c.

References FLOWMARK, RX_BUFFER_SIZE, rxBuffer, rxRead, rxWrite, shouldStartTransmission, and XON.

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

```

231         {
232         uint8_t c;
233
234 #ifdef FLOWCONTROL
235         rxBufferElements--;
236         if ((flow == 0) && (rxBufferElements <= FLOWMARK)) {
237             while (sendThisNext != 0);
238             sendThisNext = XON;
239             flow = 1;
240             if (shouldStartTransmission) {
241                 shouldStartTransmission = 0;
242                 SERIALB |= (1 << SERIALUDRIE);
243                 SERIALA |= (1 << SERIALUDRE); // Trigger Interrupt
244             }
245         }
246 #endif
247
248         if (rxRead != rxWrite) {
249             c = rxBuffer[rxRead];
250             rxBuffer[rxRead] = 0;
251             if (rxRead < (RX_BUFFER_SIZE - 1)) {
252                 rxRead++;
253             } else {
254                 rxRead = 0;
255             }
256             return c;
257         } else {
258             return 0;
259         }
260     }

```

5.17.3.5 uint8_t serialGetBlocking (void)

Wait until a character is received.

Returns

Received byte

Definition at line 226 of file serial.c.

References serialGet(), and serialHasChar().

```
226                                     {
227     while (!serialHasChar());
228     return serialGet();
229 }
```

5.17.3.6 uint8_t serialHasChar (void)

Check if a byte was received.

Returns

1 if a byte was received, 0 if not

Definition at line 218 of file serial.c.

References rxRead, and rxWrite.

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

```
218                                     {
219     if (rxRead != rxWrite) { // True if char available
220         return 1;
221     } else {
222         return 0;
223     }
224 }
```

5.17.3.7 void serialInit (uint16_t baud)

Initialize the UART Hardware.

Parameters

<i>baud</i>	Baudrate. Use the BAUD() macro!
-------------	---

Definition at line 153 of file serial.c.

Referenced by xyInit().

```
153                                     {
154     // Default: 8N1
155     SERIALC = (1 << SERIALUCSZ0) | (1 << SERIALUCSZ1);
156
157     // Set baudrate
158     SERIALUBRR = baud;
159
160     SERIALB = (1 << SERIALRXCIEN); // Enable Interrupts
161     SERIALB |= (1 << SERIALRXEN) | (1 << SERIALTXEN); // Enable Receiver/Transmitter
162 }
```

5.17.3.8 uint8_t serialRxBufferEmpty (void)

Check if the receive buffer is empty.

Returns

1 if buffer is empty, 0 if not.

Definition at line 266 of file serial.c.

References rxRead, and rxWrite.

```

266                                     {
267     if (rxRead != rxWrite) {
268         return 0;
269     } else {
270         return 1;
271     }
272 }
```

5.17.3.9 uint8_t serialRxBufferFull (void)

Check if the receive buffer is full.

Returns

1 if buffer is full, 0 if not

Definition at line 262 of file serial.c.

References RX_BUFFER_SIZE, rxRead, and rxWrite.

```

262                                     {
263     return (((rxWrite + 1) == rxRead) || ((rxRead == 0) && ((
    rxWrite + 1) == RX_BUFFER_SIZE)));
264 }
```

5.17.3.10 uint8_t serialTxBufferEmpty (void)

Check if the transmit buffer is empty.

Returns

1 if buffer is empty, 0 if not.

Definition at line 313 of file serial.c.

References txRead, and txWrite.

Referenced by serialClose().

```

313                                     {
314     if (txRead != txWrite) {
315         return 0;
316     } else {
317         return 1;
318     }
319 }
```

5.17.3.11 uint8_t serialTxBufferFull (void)

Check if the transmit buffer is full.

Returns

1 if buffer is full, 0 if not

Definition at line 309 of file serial.c.

References TX_BUFFER_SIZE, txRead, and txWrite.

Referenced by serialWrite().

```

309         {
310     return ((txWrite + 1) == txRead) || ((txRead == 0) && ((
        txWrite + 1) == TX_BUFFER_SIZE));
311 }

```

5.17.3.12 void serialWrite (uint8_t data)

Send a byte.

Parameters

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

Definition at line 278 of file serial.c.

References serialTxBufferFull(), shouldStartTransmission, TX_BUFFER_SIZE, txBuffer, and txWrite.

Referenced by serialWriteString(), and uartoutput().

```

278         {
279     #ifdef SERIALINJECTCR
280         if (data == '\n') {
281             serialWrite('\r');
282         }
283     #endif
284     while (serialTxBufferFull());
285
286     txBuffer[txWrite] = data;
287     if (txWrite < (TX_BUFFER_SIZE - 1)) {
288         txWrite++;
289     } else {
290         txWrite = 0;
291     }
292     if (shouldStartTransmission) {
293         shouldStartTransmission = 0;
294         SERIALB |= (1 << SERIALUDRIE); // Enable Interrupt
295         SERIALA |= (1 << SERIALUDRE); // Trigger Interrupt
296     }
297 }

```

5.17.3.13 void serialWriteString (const char * data)

Send a string.

Parameters

<i>data</i>	Null-Terminated String
-------------	------------------------

Definition at line 299 of file serial.c.

References serialWrite().

```

299         {
300     if (data == 0) {
301         serialWriteString("NULL");
302     } else {
303         while (*data != '\0') {
304             serialWrite(*data++);

```

```

305     }
306   }
307 }

```

5.17.3.14 void setFlow (uint8_t on)

Manually change the flow control.

Parameters

<i>on</i>	1 if on, 0 if off
-----------	-------------------

Definition at line 185 of file serial.c.

References `shouldStartTransmission`, `XOFF`, and `XON`.

```

185                                     {
186 #ifdef FLOWCONTROL
187     if (flow != on) {
188         if (on == 1) {
189             // Send XON
190             while (sendThisNext != 0);
191             sendThisNext = XON;
192             flow = 1;
193             if (shouldStartTransmission) {
194                 shouldStartTransmission = 0;
195                 SERIALB |= (1 << SERIALUDRIE);
196                 SERIALA |= (1 << SERIALUDRE); // Trigger Interrupt
197             }
198         } else {
199             // Send XOFF
200             sendThisNext = XOFF;
201             flow = 0;
202             if (shouldStartTransmission) {
203                 shouldStartTransmission = 0;
204                 SERIALB |= (1 << SERIALUDRIE);
205                 SERIALA |= (1 << SERIALUDRE); // Trigger Interrupt
206             }
207         }
208         // Wait till it's transmitted
209         while (SERIALB & (1 << SERIALUDRIE));
210     }
211 #endif
212 }

```

5.17.4 Variable Documentation

5.17.4.1 uint8_t volatile rxBuffer[RX_BUFFER_SIZE]

RX FIFO Buffer.

Definition at line 92 of file serial.c.

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

5.17.4.2 uint16_t volatile rxRead = 0

RX FIFO Read Position.

Definition at line 94 of file serial.c.

Referenced by `serialClose()`, `serialGet()`, `serialHasChar()`, `serialRxBufferEmpty()`, and `serialRxBufferFull()`.

5.17.4.3 uint16_t volatile rxWrite = 0

RX FIFO Write Position.

Definition at line 95 of file serial.c.

Referenced by ISR(), serialClose(), serialGet(), serialHasChar(), serialRxBufferEmpty(), and serialRxBufferFull().

5.17.4.4 `uint8_t volatile shouldStartTransmission = 1`

Should enable interrupt.

Definition at line 98 of file serial.c.

Referenced by ISR(), serialClose(), serialGet(), serialWrite(), and setFlow().

5.17.4.5 `uint8_t volatile txBuffer[TX_BUFFER_SIZE]`

TX FIFO Buffer.

Definition at line 93 of file serial.c.

Referenced by ISR(), and serialWrite().

5.17.4.6 `uint16_t volatile txRead = 0`

TX FIFO Read Position.

Definition at line 96 of file serial.c.

Referenced by ISR(), serialClose(), serialTxBufferEmpty(), and serialTxBufferFull().

5.17.4.7 `uint16_t volatile txWrite = 0`

TX FIFO Write Position.

Definition at line 97 of file serial.c.

Referenced by ISR(), serialClose(), serialTxBufferEmpty(), serialTxBufferFull(), and serialWrite().

5.18 Motor Speed Mixer

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

Files

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

Macros

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

Functions

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

Variables

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

5.18.1 Detailed Description

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

5.18.2 Macro Definition Documentation

5.18.2.1 `#define MAXDIFF (baseSpeed * PID_FACTOR)`

Maximum Speed difference on one axis.

Definition at line 51 of file set.c.

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

5.18.3 Function Documentation

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

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

Parameters

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

Definition at line 59 of file set.c.

References motorSet(), SET_ROLLMINUS, and SET_ROLLPLUS.

Referenced by setTask().

```

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

5.18.3.2 void setTask (void)

Read the PID Output and Set the Motor Speeds.

Examples:

[uartFlight.c](#).

Definition at line 69 of file set.c.

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

```

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

5.18.4 Variable Documentation

5.18.4.1 uint8_t baseSpeed

Motor Base Speed.

Examples:

[uartFlight.c](#).

Definition at line 53 of file set.c.

Referenced by setTask().

5.18.4.2 uint8_t baseSpeed = 0

Motor Base Speed.

Definition at line 53 of file set.c.

Referenced by setTask().

5.19 SPI Driver

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

Files

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

Enumerations

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

Functions

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

5.19.1 Detailed Description

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

5.19.2 Enumeration Type Documentation

5.19.2.1 enum [SPI_MODE](#)

SPI Mode option.

Enumerator

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

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

```

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


5.19.2.2 enum SPI_SPEED

SPI Speed options.

Enumerator

```

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

```

Definition at line 52 of file spi.h.

```

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

```

5.19.3 Function Documentation

5.19.3.1 void spInit (SPI_MODE mode, SPI_SPEED speed)

Initialize the SPI Hardware Module.

Parameters

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

Referenced by xylInit().

5.19.3.2 uint8_t spiSendByte (uint8_t d)

Send and Receive one byte.

Set the Chip Select Lines yourself!

Parameters

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

Returns

Byte read from Bus

Definition at line 54 of file spi.c.

```

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

```

5.20 Task Handler

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

Files

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

Data Structures

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

Typedefs

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

Functions

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

Variables

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

5.20.1 Detailed Description

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

5.20.2 Typedef Documentation

5.20.2.1 typedef void(* Task)(void)

A Task has no arguments and returns nothing.

Definition at line 44 of file tasks.h.

5.20.3 Function Documentation

5.20.3.1 uint8_t addTask (Task func)

Adds another task that will be called regularly.

Parameters

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

Returns

0 on success

Examples:

[uartFlight.c](#).

Definition at line 57 of file tasks.c.

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

Referenced by `xyInit()`.

```

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

```

5.20.3.2 uint8_t removeTask (Task func)

Removes an already registered Task.

Parameters

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

Returns

0 on success

Definition at line 71 of file tasks.c.

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

```

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

```

```

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

```

5.20.3.3 void tasks (void)

Executes registered Tasks.

Call this in your Main Loop!

Examples:

[uartFlight.c](#).

Definition at line 93 of file tasks.c.

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

```

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

```

5.20.3.4 uint8_t tasksRegistered (void)

Get the number of registered Tasks.

Returns

Count of registered Tasks

Definition at line 47 of file tasks.c.

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

```

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

```

5.20.4 Variable Documentation

5.20.4.1 TaskElement* taskList = NULL

List of registered Tasks.

Definition at line 45 of file tasks.c.

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

5.20.4.2 TaskElement* taskList

List of registered Tasks.

Definition at line 45 of file tasks.c.

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

5.21 Time Keeping

Measuring Time with Millisecond Resolution.

Files

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

Macros

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

Typedefs

- typedef uint64_t [time_t](#)
Timekeeping Data Type.

Functions

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

Variables

- volatile [time_t](#) [systemTime](#) = 0
Current System Uptime.

5.21.1 Detailed Description

Measuring Time with Millisecond Resolution. Uses Timer 2

Prescaler 64

Count to 250

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

5.21.2 Macro Definition Documentation

5.21.2.1 `#define OCIE OCIE2A`

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

5.21.2.2 `#define OCR OCR2A`

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

5.21.2.3 `#define TCRA TCCR2A`

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

5.21.2.4 `#define TCRB TCCR2B`

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

5.21.2.5 `#define TIMS TIMSK2`

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

5.21.3 Typedef Documentation

5.21.3.1 `typedef uint64_t time_t`

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

5.21.4 Function Documentation

5.21.4.1 `time_t getSystemTime (void)`

Get the System Uptime.

Returns

System Uptime in Milliseconds

Examples:

[uartFlight.c](#).

Definition at line 68 of file time.c.

References `systemTime`.

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

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

5.21.4.2 void initSystemTimer (void)

Initialize the system timer.

Execution every millisecond. Uses Timer 2.

Definition at line 55 of file time.c.

Referenced by `xyInit()`.

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

5.21.4.3 ISR (TIMER2_COMPA_vect)

Timer 2 Compare Match A Interrupt.

Definition at line 64 of file time.c.

References `systemTime`.

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

5.21.5 Variable Documentation

5.21.5.1 volatile time_t systemTime = 0

Current System Uptime.

Definition at line 47 of file time.c.

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

5.22 I2C Driver

Using the AVR TWI/I2C Hardware.

Files

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

Macros

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

Functions

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

5.22.1 Detailed Description

Using the AVR TWI/I2C Hardware.

5.22.2 Macro Definition Documentation

5.22.2.1 `#define TWI_READ 1`

I2C Read Bit.

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

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

5.22.2.2 #define TWI_WRITE 0

I2C Write Bit.

Definition at line 44 of file twi.h.

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

5.22.3 Function Documentation

5.22.3.1 void twiInit (void)

Initialize the I2C Hardware.

Definition at line 26 of file twi.c.

Referenced by xyInit().

```

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

```

5.22.3.2 unsigned char twiReadAck (void)

Read from the I2C Slave and request more data.

Returns

Data read

Definition at line 179 of file twi.c.

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

```

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

```

5.22.3.3 unsigned char twiReadNak (void)

Read from the I2C Slave and deny more data.

Returns

Data read

Definition at line 194 of file twi.c.

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

```

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

```

5.22.3.4 unsigned char twiRepStart (unsigned char *addr*)

Start a repeated I2C Transfer.

Parameters

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

Returns

0 on success, 1 on error

Definition at line 127 of file twi.c.

References twiStart().

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

```

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

```

5.22.3.5 unsigned char twiStart (unsigned char *addr*)

Start an I2C Transfer.

Parameters

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

Returns

0 on success, 1 on error

Definition at line 40 of file twi.c.

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

```

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

```

5.22.3.6 void twiStartWait (unsigned char *addr*)

Start an I2C Transfer and poll until ready.

Parameters

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

Definition at line 76 of file twi.c.

```

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

```

5.22.3.7 void twiStop (void)

Stop the I2C Hardware.

Definition at line 137 of file twi.c.

Referenced by motorTask().

```

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

```

5.22.3.8 unsigned char twiWrite (unsigned char *data*)

Write to the I2C Slave.

Parameters

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

Returns

0 on success, 1 on error

Definition at line 155 of file twi.c.

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

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

5.23 UART Menu

Enables user interaction with an UART Menu.

Files

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

Data Structures

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

Functions

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

Variables

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

5.23.1 Detailed Description

Enables user interaction with an UART Menu.

5.23.2 Function Documentation

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

Add a command to the UART Menu.

Parameters

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

Returns

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

Examples:

[uartFlight.c](#).

Definition at line 69 of file `uartMenu.c`.

References `BANK_GENERIC`, `MenuEntry::cmd`, `MenuEntry::f`, `findEntry()`, `MenuEntry::helpText`, `MenuEntry::next`, `uartMenu`, `xmemGetBank()`, and `xmemSetBank()`.

Referenced by `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, serialGet(), serialHasChar(), uartMenu, unHandler, xmemGetBank(), and xmemSetBank().

Referenced by xylnit().

```

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

5.23.3 Variable Documentation

5.23.3.1 MenuEntry* uartMenu = NULL

Single-Linked-List for commands.

Definition at line 51 of file uartMenu.c.

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

5.23.3.2 void(* unHandler)(char) = NULL

Handler for unhandled commands.

Definition at line 52 of file uartMenu.c.

Referenced by uartMenuRegisterHandler(), and uartMenuTask().

5.24 External Memory Interface

Allows access to external RAM with bank-switching.

Files

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

Data Structures

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

Macros

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

Functions

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

Variables

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

Current active Memory Bank.

- void * [__brkval](#)

Internal Malloc Heap-End Pointer.

- void * [__flp](#)

Internal Malloc Free List Pointer (State)

5.24.1 Detailed Description

Allows access to external RAM with bank-switching.

5.24.2 Macro Definition Documentation

5.24.2.1 #define BANK_GENERIC 0

Generic Memory Bank.

Definition at line 55 of file xmem.h.

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

5.24.2.2 #define MEMBANKS 8

Available Memory Banks.

Definition at line 54 of file xmem.h.

Referenced by xmemInit(), and xmemSetBank().

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

Switch the bank, if needed.

Stores the old bank in a variable oldMemBank.

Parameters

x	New Bank
---	----------

Definition at line 47 of file xmem.h.

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

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

Switch back to the last bank, if needed.

Parameters

x	New (current) Bank
---	--------------------

Definition at line 52 of file xmem.h.

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

5.24.3 Function Documentation

5.24.3.1 void restoreState (uint8_t bank)

Restore the malloc state.

Parameters

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

Definition at line 65 of file xmem.c.

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

Referenced by `xmemSetBank()`.

```

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

5.24.3.2 void saveState (uint8_t bank)

Save the current malloc state.

Parameters

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

Definition at line 55 of file xmem.c.

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

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

```

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

5.24.3.3 uint8_t xmemGetBank (void)

Get the current memory bank.

Returns

Current Memory Bank.

Definition at line 105 of file xmem.c.

References `currentBank`.

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

```

105     {
106     return currentBank;
107 }
```

5.24.3.4 void xmemInit (void)

Initialize the External Memory Interface.

Definition at line 72 of file xmem.c.

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

Referenced by xylnit().

```

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

```

5.24.3.5 void xmemSetBank (uint8_t bank)

Switch the active memory bank.

Parameters

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

Definition at line 89 of file xmem.c.

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

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

```

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

```

5.24.4 Variable Documentation

5.24.4.1 void* __brkval

Internal Malloc Heap-End Pointer.

Referenced by restoreState(), and saveState().

5.24.4.2 void* _flp

Internal Malloc Free List Pointer (State)

Referenced by restoreState(), and saveState().

5.24.4.3 `uint8_t currentBank = 0`

Current active Memory Bank.

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

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

5.24.4.4 `uint8_t currentBank`

Current active Memory Bank.

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

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

5.24.4.5 `MallocState states[MEMBANKS]`

[MallocState](#) for all Memory Banks.

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

5.24.4.6 `MallocState states[MEMBANKS]`

[MallocState](#) for all Memory Banks.

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

5.25 xyControl Hardware

Controls xyControl On-Board Hardware like LEDs.

Files

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

Data Structures

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

Enumerations

- enum [LED](#) {
 [LED_RED0](#) = 0, [LED_RED1](#) = 1, [LED_GREEN0](#) = 2, [LED_GREEN1](#) = 3,
 [LED_ALL](#) = 4, [LED_BITMAP](#) = 5, [LED_RED](#) = 6, [LED_GREEN](#) = 7 }
Methods of addressing the LEDs.
- enum [LEDState](#) { [LED_OFF](#) = 0, [LED_ON](#) = 1, [LED_TOGGLE](#) = 2 }
Possible states of the LEDs.

Functions

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

Variables

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

5.25.1 Detailed Description

Controls xyControl On-Board Hardware like LEDs.

5.25.2 Enumeration Type Documentation

5.25.2.1 enum LED

Methods of addressing the LEDs.

Enumerator

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

Definition at line 44 of file xycontrol.h.

```

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

5.25.2.2 enum LEDState

Possible states of the LEDs.

Enumerator

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

Definition at line 56 of file xycontrol.h.

```

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

5.25.3 Function Documentation

5.25.3.1 double getVoltage (void)

Calculate and return the Battery Voltage.

Returns

Current Battery Voltage

Examples:

[uartFlight.c](#).

Definition at line 163 of file xycontrol.c.

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

```

163         {
164     adcStart(BATT_CHANNEL);
165     while(!adcReady());
166     uint16_t v = adcGet(0) * BATT_MAX;
167     return ((double)v / 1024.0);
168 }
```

5.25.3.2 void resetSelf (void)

Use the Watchdog to reset yourself after 15ms.

Definition at line 170 of file xycontrol.c.

Referenced by `xyInit()`.

```

170         {
171     wdt_enable(WDTO_15MS);
172     for(;;);
173 }
```

5.25.3.3 int uartinput (FILE * f)

Method used to read from stdin.

Definition at line 79 of file xycontrol.c.

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

Referenced by `xyInit()`.

```

79         {
80     while (!serialHasChar());
81     return serialGet();
82 }
```

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 `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         serialWrite('\r');
71     }
72     if (c != '\r') {
73         serialWrite(c);
74     }
75     return 0;
76 }
```

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:

[uartFlight.c](#).

Definition at line 84 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`, `serialInit()`, `SPEED_2`, `spiInit()`, `twiInit()`, `uartinput()`, `uartMenuPrintHelp()`, `uartMenuTask()`, `uartoutput()`, `xmemInit()`, and `xyLed()`.

```

84     {
85         xmemInit(); // Most important!
86
87         // LEDs
88         LED0DDR |= (1 << LED0PIN);
89         LED1DDR |= (1 << LED1PIN);
90         LED2DDR |= (1 << LED2PIN);
91         LED3DDR |= (1 << LED3PIN);
92         xyLed(4, 1);
93
94         initSystemTimer();
95         serialInit(BAUD(38400, F_CPU));
96         twiInit();
97         spiInit(MODE_0, SPEED_2);
98         adcInit(AVCC);
99
100        addMenuCommand('q', resetText, &resetSelf);
101        addMenuCommand('h', helpText, &uartMenuPrintHelp);
102        addTask(&uartMenuTask);
103
104        // fdevopen() is using malloc, so printf in a different
105        // memory bank will not work!
106        // fdevopen(&uartoutput, NULL); // stdout & stderr
107        // fdevopen(NULL, &uartinput); // stdin
108        // Instead we have the FILE structs as static variables
109        // and assign them to stdin, stdout and stderr
110
111        fdev_setup_stream(&outFile, &uartoutput, NULL, _FDEV_SETUP_WRITE);
112        fdev_setup_stream(&inFile, NULL, &uartinput, _FDEV_SETUP_READ);
113        stdin = &inFile;
114        stdout = &outFile;
115        stderr = &outFile;
116
117        sei();
118    }
```

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:

[uartFlight.c](#).

Referenced by `xyInit()`.

5.25.3.7 void xyLedInternal (uint8_t v, volatile uint8_t * port, uint8_t pin)

Internal LED Manipulation function.

Parameters

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

Definition at line 125 of file xycontrol.c.

```

125                                     {
126     if (v == 0) {
127         *port &= ~(1 << pin);
128     } else if (v == 1) {
129         *port |= (1 << pin);
130     } else {
131         *port ^= (1 << pin);
132     }
133 }
```

5.25.4 Variable Documentation

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

UART Menu Help Text.

Definition at line 59 of file xycontrol.c.

Referenced by xyInit().

5.25.4.2 FILE inFile

FILE for stdin.

Definition at line 62 of file xycontrol.c.

Referenced by xyInit().

5.25.4.3 FILE outFile

FILE for stdout and stderr.

Definition at line 63 of file xycontrol.c.

Referenced by xyInit().

5.25.4.4 char PROGMEM resetText[] = "Reset MCU"

UART Menu Reset Text.

Definition at line 60 of file xycontrol.c.

Referenced by xyInit().

Chapter 6

Data Structure Documentation

6.1 Angles Struct Reference

Can store orientation in Euler Space.

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

Data Fields

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

6.1.1 Detailed Description

Can store orientation in Euler Space.

Definition at line 48 of file orientation.h.

6.1.2 Field Documentation

6.1.2.1 double pitch

Pitch Angle in Degrees.

Examples:

[uartFlight.c](#).

Definition at line 49 of file orientation.h.

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

6.1.2.2 double roll

Roll Angle in Degrees.

Examples:

[uartFlight.c](#).

Definition at line 50 of file orientation.h.

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

6.1.2.3 double yaw

Yaw Angle in Degrees.

Examples:

[uartFlight.c](#).

Definition at line 51 of file orientation.h.

Referenced by zeroOrientation().

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

- include/[orientation.h](#)

6.2 Complementary Struct Reference

Complementary-Filter State data.

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

6.2.1 Detailed Description

Complementary-Filter State data.

Definition at line 46 of file complementary.h.

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

- include/[complementary.h](#)

6.3 Kalman Struct Reference

Kalman-Filter State data.

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

Data Fields

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

6.3.1 Detailed Description

Kalman-Filter State data.

Definition at line 47 of file kalman.h.

6.3.2 Field Documentation

6.3.2.1 double p33

P Matrix.

Definition at line 49 of file kalman.h.

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

6.3.2.2 double x3

X Vector.

Definition at line 48 of file kalman.h.

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

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

- `include/kalman.h`

6.4 MallocState Struct Reference

All Malloc related State.

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

Data Fields

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

6.4.1 Detailed Description

All Malloc related State.

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

Definition at line 62 of file xmem.h.

6.4.2 Field Documentation

6.4.2.1 char* end

End of Heap.

Definition at line 64 of file xmem.h.

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

6.4.2.2 void* fl

Free List.

Definition at line 66 of file xmem.h.

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

6.4.2.3 char* start

Start of Heap.

Definition at line 63 of file xmem.h.

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

6.4.2.4 void* val

Highest Heap Point.

Definition at line 65 of file xmem.h.

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

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

- [include/xmem.h](#)

6.5 MenuEntry Struct Reference

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

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

Data Fields

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

6.5.1 Detailed Description

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

Stores Helptext, command and action.

Definition at line 49 of file uartMenu.h.

6.5.2 Field Documentation

6.5.2.1 uint8_t cmd

Byte that triggers the action.

Definition at line 50 of file uartMenu.h.

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

6.5.2.2 Task f

Action that get's executed.

Definition at line 52 of file uartMenu.h.

Referenced by addMenuCommand(), and uartMenuTask().

6.5.2.3 PGM_P helpText

Text (in Flash) printed with help command.

Definition at line 51 of file uartMenu.h.

Referenced by addMenuCommand(), and uartMenuPrintHelp().

6.5.2.4 MenuEntry* next

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

Definition at line 53 of file uartMenu.h.

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

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

- [include/uartMenu.h](#)

6.6 PIDState Struct Reference

Data Structure for a single PID Controller.

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

Data Fields

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

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

6.6.1 Detailed Description

Data Structure for a single PID Controller.

Stores all needed constants and state variables.

Definition at line 47 of file pid.h.

6.6.2 Field Documentation

6.6.2.1 double intMax

Maximum Integral sum.

Default is [PID_INTMAX](#).

Definition at line 54 of file pid.h.

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

6.6.2.2 double intMin

Minimum Integral sum.

Default is [PID_INTMIN](#).

Definition at line 53 of file pid.h.

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

6.6.2.3 double kd

Derivative factor.

Default is [PID_D](#).

Definition at line 50 of file pid.h.

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

6.6.2.4 double ki

Integral factor.

Default is [PID_I](#).

Definition at line 49 of file pid.h.

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

6.6.2.5 double kp

Proportional factor.

Default is [PID_P](#).

Definition at line 48 of file pid.h.

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

6.6.2.6 time_t last

Last execution time.

For dT calculation.

Definition at line 57 of file pid.h.

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

6.6.2.7 double lastError

Derivative State.

Definition at line 55 of file pid.h.

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

6.6.2.8 double outMax

Maximum Output.

Default is [PID_OUTMAX](#).

Definition at line 52 of file pid.h.

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

6.6.2.9 double outMin

Minimum Output.

Default is [PID_OUTMIN](#).

Definition at line 51 of file pid.h.

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

6.6.2.10 double sumError

Integral state.

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

Definition at line 56 of file pid.h.

Referenced by pidExecute(), and pidSet().

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

- [include/pid.h](#)

6.7 TaskElement Struct Reference

Single-Linked Task List.

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

Data Fields

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

6.7.1 Detailed Description

Single-Linked Task List.

Definition at line 48 of file tasks.h.

6.7.2 Field Documentation

6.7.2.1 TaskElement* next

Next list element.

Definition at line 50 of file tasks.h.

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

6.7.2.2 Task task

Task to be executed.

Definition at line 49 of file tasks.h.

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

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

- [include/tasks.h](#)

6.8 Vector3f Struct Reference

The global 3-Dimensional Floating Point Vector.

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

Data Fields

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

6.8.1 Detailed Description

The global 3-Dimensional Floating Point Vector.

Definition at line 63 of file xycontrol.h.

6.8.2 Field Documentation

6.8.2.1 double x

X Part.

Definition at line 64 of file xycontrol.h.

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

6.8.2.2 double y

Y Part.

Definition at line 65 of file xycontrol.h.

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

6.8.2.3 double z

Z Part.

Definition at line 66 of file xycontrol.h.

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

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

- [include/xycontrol.h](#)

Chapter 7

File Documentation

7.1 include/acc.h File Reference

LSM303DLHC Accelerometer API Header.

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

Enumerations

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

Functions

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

7.1.1 Detailed Description

LSM303DLHC Accelerometer API Header.

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

7.2 include/adc.h File Reference

Analog-to-Digital Converter API Header.

Enumerations

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

Functions

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

7.2.1 Detailed Description

Analog-to-Digital Converter API Header.

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

7.3 include/complementary.h File Reference

Complementary-Filter Header.

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

Data Structures

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

Functions

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

7.3.1 Detailed Description

Complementary-Filter Header.

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

7.4 include/config.h File Reference

Various default settings.

Macros

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

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

- #define [BANK2PIN](#) PL5
Third Bank Selection Pin.
- #define [SPISS](#) PB0
SPI Slave Select Pin.
- #define [RX_BUFFER_SIZE](#) 128
UART Receive Buffer Size.
- #define [TX_BUFFER_SIZE](#) 128
UART Transmit Buffer Size.
- #define [USB](#) 0
FT232RL USB UART module.
- #define [BLUETOOTH](#) 1
Bluetooth UART module.
- #define [UART BLUETOOTH](#)
UART module to use (0 to 3)

7.4.1 Detailed Description

Various default settings.

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

7.5 include/debug.h File Reference

Debug and Assert Header and Implementation.

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

Macros

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

7.5.1 Detailed Description

Debug and Assert Header and Implementation.

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

7.6 include/doc.h File Reference

Contains Doxygen Group Definitions.

7.6.1 Detailed Description

Contains Doxygen Group Definitions.

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

7.7 include/error.h File Reference

Global listing of different error conditions.

Macros

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

Enumerations

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

Functions

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

7.7.1 Detailed Description

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

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

7.8 include/gyro.h File Reference

L3GD20 Gyroscope API Header.

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

Enumerations

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

Functions

- [Error 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 API Header.

Macros

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

Functions

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

7.14.1 Detailed Description

UART API Header.

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

7.15 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.

7.15.1 Detailed Description

Motor Mixer Library Header.

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

7.16 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.

7.16.1 Detailed Description

SPI API Header.

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

7.17 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.

7.17.1 Detailed Description

Task API Header.

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

7.18 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.

7.18.1 Detailed Description

Time API Header.

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

7.19 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.

7.19.1 Detailed Description

I2C API Header.

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

7.20 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.

7.20.1 Detailed Description

UART Menu API Header.

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

7.21 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.

7.21.1 Detailed Description

XMEM API Header.

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

7.22 include/xycontrol.h File Reference

xyControl API Header.

Data Structures

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

Enumerations

- enum [LED](#) {
 [LED_RED0](#) = 0, [LED_RED1](#) = 1, [LED_GREEN0](#) = 2, [LED_GREEN1](#) = 3,
 [LED_ALL](#) = 4, [LED_BITMAP](#) = 5, [LED_RED](#) = 6, [LED_GREEN](#) = 7 }
Methods of addressing the LEDs.
- enum [LEDState](#) { [LED_OFF](#) = 0, [LED_ON](#) = 1, [LED_TOGGLE](#) = 2 }
Possible states of the LEDs.

Functions

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

7.22.1 Detailed Description

xyControl API Header.

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

7.23 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.

7.23.1 Detailed Description

LSM303DLHC Accelerometer API Implementation.

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

7.24 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.

7.24.1 Detailed Description

Analog-to-Digital Converter API Implementation.

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

7.25 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.

7.25.1 Detailed Description

Complementary-Filter Implementation.

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

7.26 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.

7.26.1 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](#).

7.26.2 Variable Documentation

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

String for SUCCESS.

Definition at line 43 of file error.c.

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

String for TWI_NO_ANSWER.

Definition at line 44 of file error.c.

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

String for TWI_WRITE_ERROR.

Definition at line 45 of file error.c.

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

String for MALLOC_FAIL.

Definition at line 46 of file error.c.

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

String for ERROR.

Definition at line 47 of file error.c.

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

String for ARGUMENT_ERROR.

Definition at line 48 of file error.c.

7.26.2.7 `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()`.

7.27 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.

7.27.1 Detailed Description

L3GD20 Gyroscope API Implementation.

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

7.28 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.

7.28.1 Detailed Description

Kalman-Filter Implementation.

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

7.29 lib/mag.c File Reference

LSM303DLHC Magnetometer API Implementation.

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

Macros

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

Functions

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

7.29.1 Detailed Description

LSM303DLHC Magnetometer API Implementation.

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

7.30 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.

7.30.1 Detailed Description

BL-Ctrl V1.2 Controller API Implementation.

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

7.31 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.

7.31.1 Detailed Description

Orientation API Implementation.

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

7.32 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.

7.32.1 Detailed Description

PID Library Implementation.

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

7.33 lib/serial.c File Reference

UART API Implementation.

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

Macros

- `#define XON 0x11`
XON Byte.
- `#define XOFF 0x13`
XOFF Byte.
- `#define FLOWMARK 5`
Space remaining to trigger XOFF/XON.

Functions

- `ISR (SERIALRECIEVEINTERRUPT)`
Receive Complete Interrupt.
- `ISR (SERIALTRANSMITINTERRUPT)`
Data Register Empty Interrupt.
- `void serialInit (uint16_t baud)`
Initialize the UART Hardware.
- `void serialClose (void)`
Stop the UART Hardware.
- `void setFlow (uint8_t on)`
Manually change the flow control.
- `uint8_t serialHasChar (void)`
Check if a byte was received.
- `uint8_t serialGetBlocking (void)`
Wait until a character is received.
- `uint8_t serialGet (void)`
Read a single byte.
- `uint8_t serialRxBufferFull (void)`
Check if the receive buffer is full.
- `uint8_t serialRxBufferEmpty (void)`
Check if the receive buffer is empty.
- `void serialWrite (uint8_t data)`
Send a byte.
- `void serialWriteString (const char *data)`

Send a string.

- uint8_t [serialTxBufferFull](#) (void)

Check if the transmit buffer is full.

- uint8_t [serialTxBufferEmpty](#) (void)

Check if the transmit buffer is empty.

Variables

- uint8_t volatile [rxBuffer](#) [RX_BUFFER_SIZE]

RX FIFO Buffer.

- uint8_t volatile [txBuffer](#) [TX_BUFFER_SIZE]

TX FIFO Buffer.

- uint16_t volatile [rxRead](#) = 0

RX FIFO Read Position.

- uint16_t volatile [rxWrite](#) = 0

RX FIFO Write Position.

- uint16_t volatile [txRead](#) = 0

TX FIFO Read Position.

- uint16_t volatile [txWrite](#) = 0

TX FIFO Write Position.

- uint8_t volatile [shouldStartTransmission](#) = 1

Should enable interrupt.

7.33.1 Detailed Description

UART API Implementation.

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

7.34 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.

7.34.1 Detailed Description

Motor Mixer Library Implementation.

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

7.35 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.

7.35.1 Detailed Description

SPI API Implementation.

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

7.36 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.

7.36.1 Detailed Description

Task API Implementation.

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

7.37 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.

7.37.1 Detailed Description

Time API Implementation.

Definition in file `time.c`.

7.38 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.

7.38.1 Detailed Description

UART Menu API Implementation.

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

7.39 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)

7.39.1 Detailed Description

XMEM API Implementation.

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

7.40 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.

7.40.1 Detailed Description

xyControl API Implementation.

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

Chapter 8

Example Documentation

8.1 uartFlight.c

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

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

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

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

```

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

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

uint8_t state = 0; // Bit 0: Motor, Bit 1: PID
uint8_t speed = 10;
int16_t targetRoll = 0;
int16_t targetPitch = 0;

uint32_t sumFlightTask = 0, sumFlightCount = 0;

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

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

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

    xyLed(LED_ALL, LED_ON);

    for(;;) {
        tasks();
    }

    return 0;
}

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

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

void statusTask(void) {
    static time_t last = 100; // Don't begin immediately
    static uint32_t lastDuration = 0;
    if ((getSystemTime() - last) >= STATUSDELAY) {

```

```

        last = getSystemTime();
        printf("q%i %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 & 0x02) {
        state &= ~0x02;
        printf("PID Off!\n");
    } else {
        state |= 0x02;
        printf("PID On!\n");
    }
}

void motorToggle(void) {
    if (state & 0x01) {
        state &= ~0x01;
        baseSpeed = 0;
        printf("Motor Off!\n");
    } else {
        state |= 0x01;
        baseSpeed = speed = 10;
        printf("Motor On!\n");
    }
}

void motorUp(void) {
    if (speed <= (MAXMOTOR - MOTORSTEP)) {
        if (state & 0x01) {
            speed += MOTORSTEP;
            baseSpeed = speed;
            printf("Throttle up to %i\n", speed);
        }
    }
}

void motorDown(void) {
    if (speed >= MOTORSTEP) {
        if (state & 0x01) {
            speed -= MOTORSTEP;
            baseSpeed = speed;
            printf("Throttle down to %i\n", speed);
        }
    }
}

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

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

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

void motorRight(void) {
    if (targetRoll >= (-1 * (MAXANGLE - ANGLESTEP))) {
        targetRoll -= ANGLESTEP;
    }
}

```

```
        o_should[ROLL] = targetRoll;
        printf("Roll Right %i\n", targetRoll);
    }
}

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


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