
Hardware Integration Manual

Bolder Flight Systems

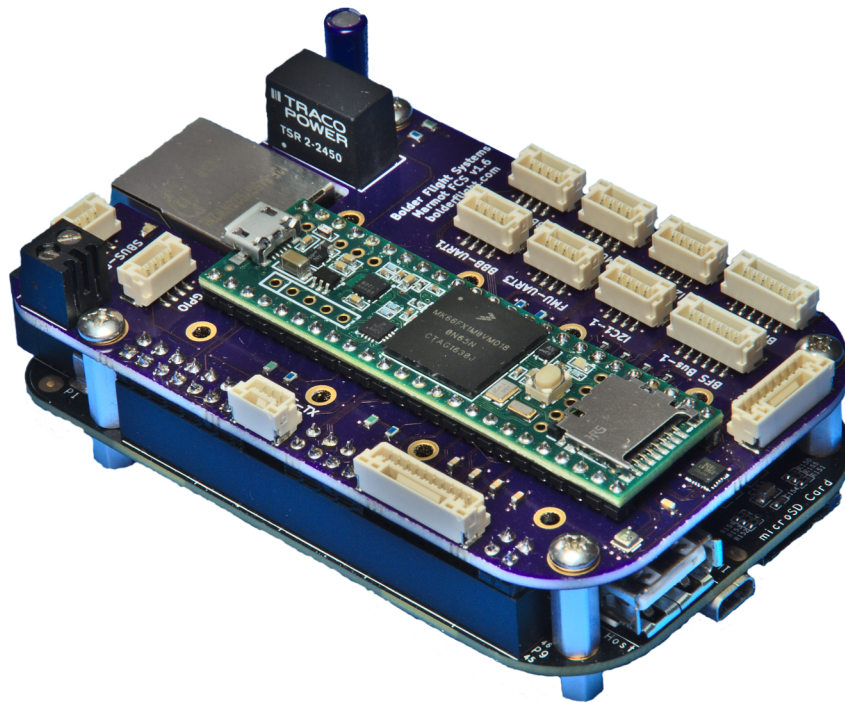


Table of Contents

Revision History.....	3
Flight Control System Overview.....	4
Purpose.....	6
Marmot Flight Management Unit.....	7
Overview.....	7
Specifications.....	8
Mounting.....	8
Location.....	8
Orientation.....	8
Power.....	9
Connections.....	9
Schematic.....	10
Raven Sensor and Actuator Node.....	11
Overview.....	11
Specifications.....	11
Mounting.....	11
Location.....	12
Power.....	12
Connections.....	12
Schematic.....	13
Swift Air Data.....	14
Overview.....	14
Specifications.....	14
Mounting.....	14
Location.....	14
Orientation.....	15
Power.....	15
Connections.....	15
PWM, SBUS, and Analog Breakout Boards.....	16
Overview.....	16
Mounting.....	16
Connections.....	16
VectorNav Breakout Boards.....	17
Overview.....	17
Mounting.....	17
Power.....	17
Connections.....	17
Connectors.....	18
Overview.....	18
Specifications.....	18



Revision History

Revision Date	Number	Description
2018-09-05	1.0	Initial release



Flight Control System Overview

Our flight control system is designed to be extremely low-latency, deterministic, and highly scalable. At the core of the flight control system is the Marmot Flight Management Unit (FMU). From a hardware standpoint, the Marmot FMU consists of:

- A Teensy 3.6 Cortex M4 microcontroller capable of a 240 MHz CPU frequency with a single precision hardware floating point unit.
- Voltage regulation with a +6.5V to +36V input range providing clean 5V output up to 2A capacity.
- MPU-9250 nine axis inertial measurement unit.
- BME-280 pressure, temperature, and humidity sensor.
- SBUS input for sensing up to 16 channels of pilot input from an SBUS capable receiver.
- SBUS output for actuating up to 16 SBUS capable servos.
- PWM output for actuating up to 8 PWM capable servos.
- One I2C and one SPI bus for connecting external sensors, such as the Swift Air Data sensor or VectorNav inertial measurement units and systems.
- Four UARTS, two from the Teensy 3.6 microcontroller and two from the BeagleBone Black, for connecting external sensors such as GNSS receivers or radio modems.
- Two GPIO's, which can be configured for PWM output, digital I/O, or analog input up to +3.3V.
- Bolder Flight Systems expansion bus.
- Measurement of input, regulated, SBUS, and PWM voltages.

The FMU is intended to integrate with a BeagleBone Black using a high speed UART port capable of transferring data at rates up to 1.5 Mbaud. The FMU provides regulated 5V power to the BeagleBone Black. Two digital pins are shared between FMU and BeagleBone Black for triggering interrupts.

Additional sensing and actuation can be added by integrating Raven Sensor and Actuator Nodes (Nodes) over the Bolder Flight Systems expansion bus (BFS Bus). An unlimited number of Nodes can be added; the BFS Bus provides regulated power, high bandwidth data transfer up to 245 kB/s, and two digital lines for synchronization. Pulses on the digital lines can be used to synchronize data collection, actuator commands, and keep a synchronized clock across the network of FMU and Nodes. We consider this capability critical for research and development environments where sensing and actuation requirements often change dramatically from one research program to the next.



Each node consists of:

- A Teensy 3.6 Cortex M4 microcontroller capable of a 240 MHz CPU frequency with a single precision hardware floating point unit.
- SBUS input for sensing up to 16 channels of pilot input from an SBUS capable receiver.
- SBUS output for actuating up to 16 SBUS capable servos.
- PWM output for actuating up to 8 PWM capable servos.
- Two I2C buses for connecting external sensors, such as the Swift Air Data sensor.
- Two UARTS, for connecting external sensors such as GNSS receivers or radio modems.
- Eight analog inputs up to +3.3V.
- Four digital I/O.
- Measurement of SBUS, and PWM voltages.

PWM, SBUS, and Analog boards breakout the PWM, SBUS, and Analog pins from JST-GH connectors to convenient 0.1" (2.54 mm) spaced headers. A VectorNav VN-100 / VN-200 breakout enables easy integration of VectorNav VN-100 or VN-200 inertial measurement units and systems to the FMU.

Functional block diagrams of a couple example layouts are given below.

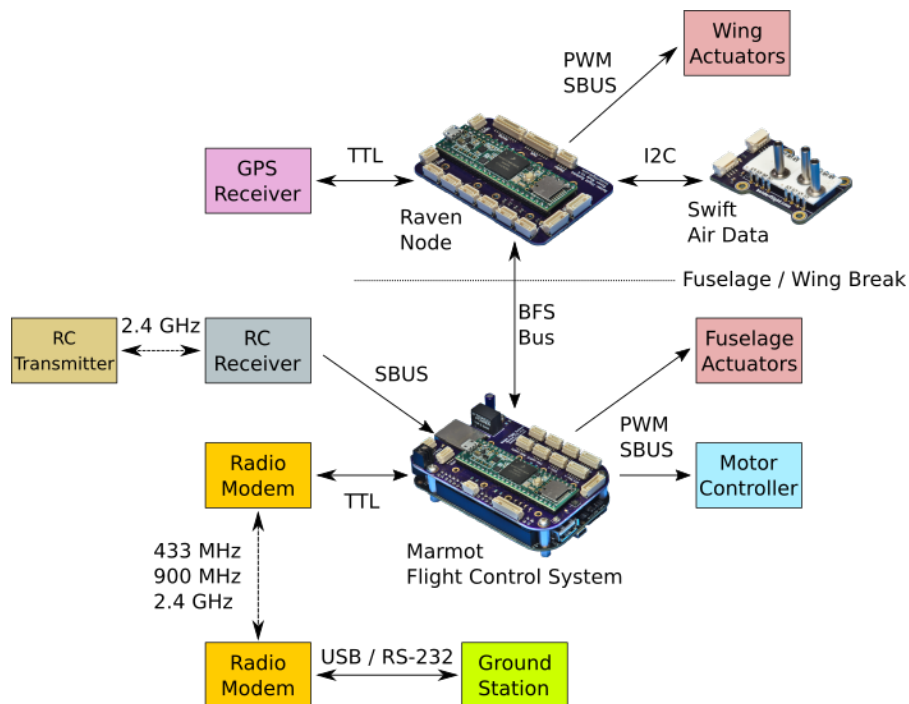


Figure 1: A simple aircraft integration

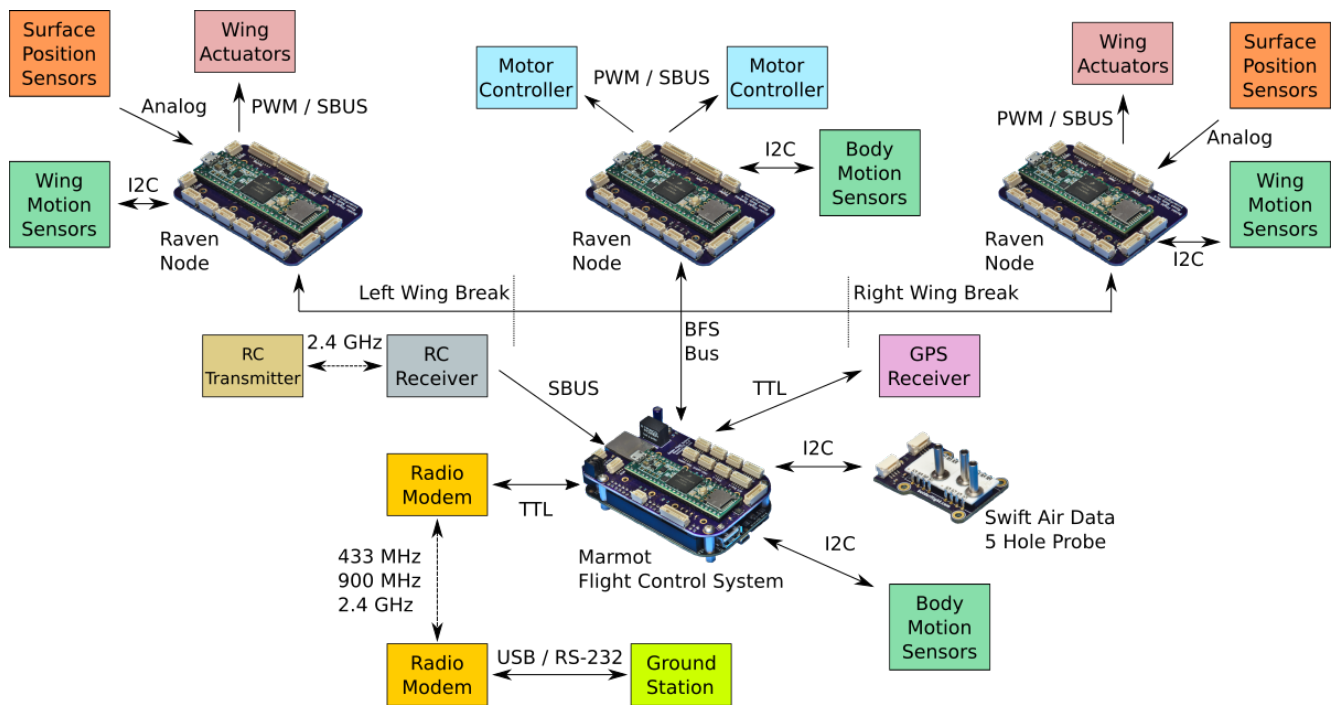


Figure 2: A complex aircraft integration

Purpose

The purpose of this manual is to provide:

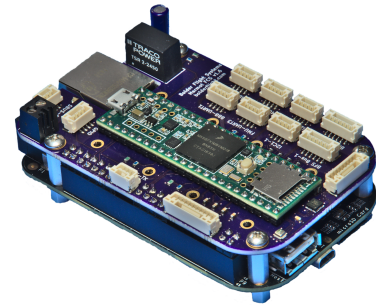
- Hardware technical specifications for flight control system components.
- Guidance on mounting, orientation, and location of flight control system components.
- Power input requirements.
- Technical specifications for all buses.

Marmot Flight Management Unit

Overview

At the core of the flight control system is the Marmot Flight Management Unit (FMU). From a hardware standpoint, the Marmot FMU consists of:

- A Teensy 3.6 Cortex M4 microcontroller capable of a 240 MHz CPU frequency with a single precision hardware floating point unit.
- Voltage regulation with a +6.5V to +36V input range providing clean 5V output up to 2A capacity.
- MPU-9250 nine axis inertial measurement unit.
- BME-280 pressure, temperature, and humidity sensor.
- SBUS input for sensing up to 16 channels of pilot input from an SBUS capable receiver.
- SBUS output for actuating up to 16 SBUS capable servos.
- PWM output for actuating up to 8 PWM capable servos.
- One I2C and one SPI bus for connecting external sensors, such as the Swift Air Data sensor or VectorNav inertial measurement units and systems.
- Four UARTS, two from the Teensy 3.6 microcontroller and two from the BeagleBone Black, for connecting external sensors such as GNSS receivers or radio modems.
- Two GPIO's, which can be configured for PWM output, digital I/O, or analog input up to +3.3V.
- Bolder Flight Systems expansion bus.
- Measurement of input, regulated, SBUS, and PWM voltages.



The FMU is intended to integrate with a BeagleBone Black using a high speed UART port capable of transferring data at rates up to 1.5 Mbaud. The FMU provides regulated 5V power to the BeagleBone Black. Two digital pins are shared between FMU and BeagleBone Black for triggering interrupts.



Specifications

- Voltage Input: +6.5V to +36V
- Current Draw (with BeagleBone Black): 350 mA
- Size (with BeagleBone Black): 55 mm x 89 mm x 30.5 mm
- Weight (with BeagleBone Black): 75 g

Mounting

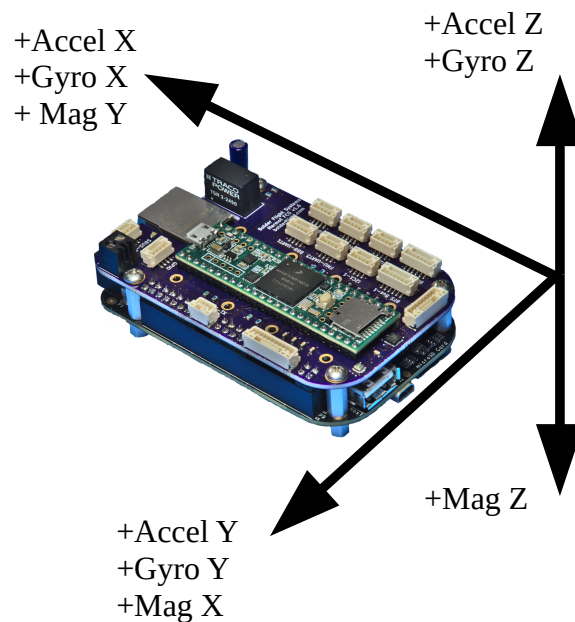
Four 4-40 mounting holes are provided and aligned with the BeagleBone Black mounting holes. We recommend a 7/16 inch length standoff between the BeagleBone Black and FMU and a 3/16 inch length standoff between the BeagleBone Black and the aircraft structure.

Location

The FMU should be mounted near the aircraft center of gravity.

Orientation

Relative to the FMU, the MPU-9250 orientation is depicted below. If you use the Bolder Flight Systems MPU-9250 library, the accelerometer and gyroscope are transformed to align with the magnetometer axis system.



Power

Power input is provided via a screw terminal, labeled PWR, capable of accepting 16-28 AWG wire. +6.5V to +36V input voltage is acceptable; typically this would be provided by the UAS motor battery if it is between a 2S and 6S battery pack, otherwise, this power would need to be provided by a regulator or separate avionics battery.

Regulated 5V power, up to 2A, is provided by the FMU to the BeagleBone Black, BFS Bus Nodes, and integrated sensors. Regulated power from the FMU is not intended to be used by SBUS or PWM servos and this must be provided separately.

Input, regulated, PWM, and SBUS voltages are brought to analog inputs for monitoring and recording these voltage levels. Voltage dividers are used to scale the voltages to acceptable analog input ranges, please see the schematic for details.

Connections

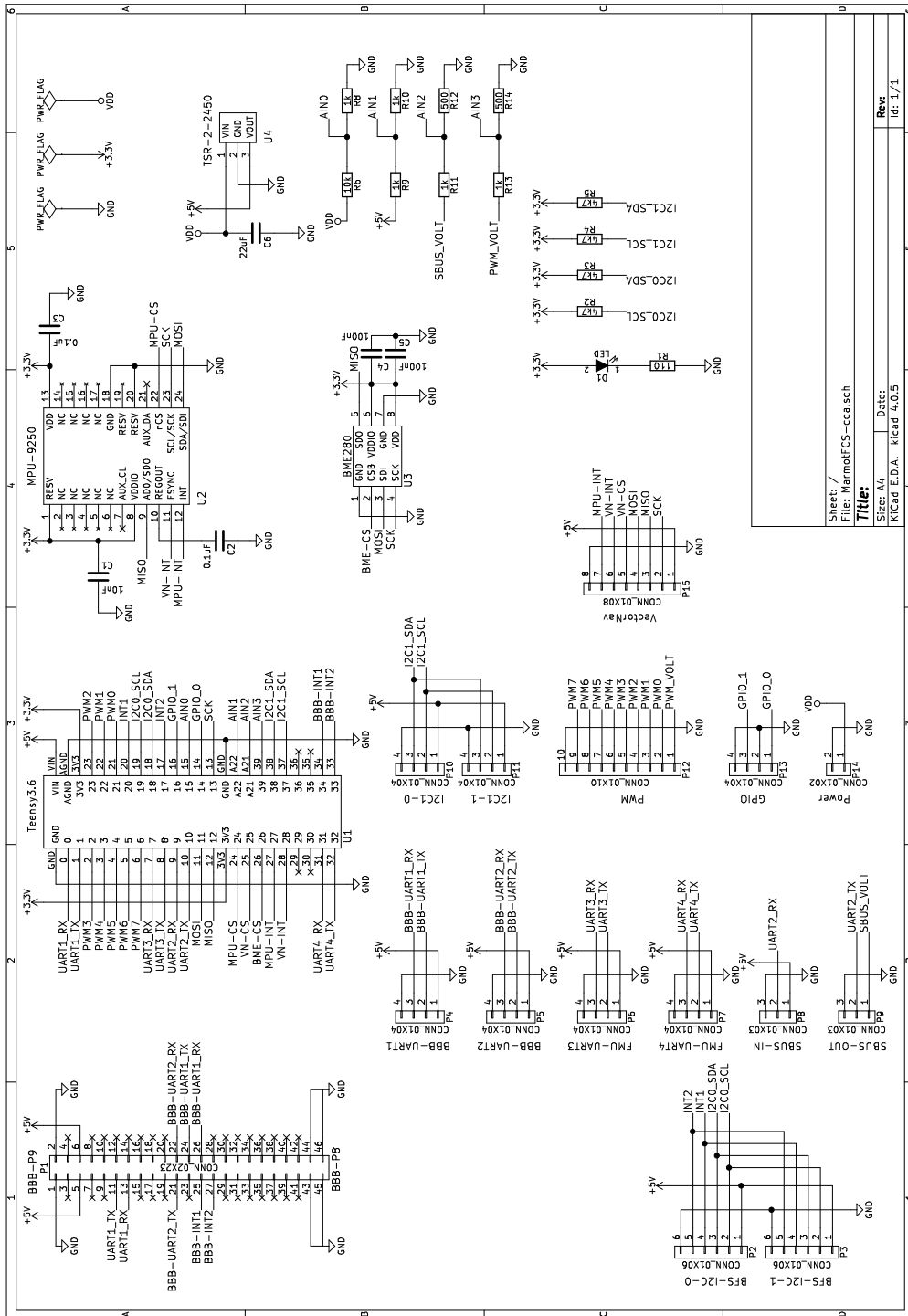
The following connections are available on the FMU:

- SBUS input for sensing up to 16 channels of pilot input from an SBUS capable receiver.
- SBUS output for actuating up to 16 SBUS capable servos.
- PWM output for actuating up to 8 PWM capable servos.
- One I2C and one SPI bus for connecting external sensors, such as the Swift Air Data sensor or VectorNav inertial measurement units and systems.
- Four UARTS, two from the Teensy 3.6 microcontroller and two from the BeagleBone Black, for connecting external sensors such as GNSS receivers or radio modems.
- Two GPIO's, which can be configured for PWM output, digital I/O, or analog input up to +3.3V.
- Bolder Flight Systems expansion bus (BFS Bus).

Reference the Connectors section for details.



Schematic



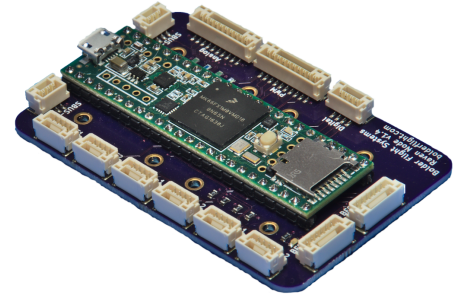
Sheet: /	File: MarmotCS-cca.sch
Title:	
Size: A4	Date:
KiCad E.D.A. kicad 4.0.5	Rev: Id: 1/1



Raven Sensor and Actuator Node

Overview

Additional sensing and actuation can be added by integrating Raven Sensor and Actuator Nodes (Nodes) over the Bolder Flight Systems expansion bus (BFS Bus). An unlimited number of Nodes can be added; the BFS Bus provides regulated power, high bandwidth data transfer up to 245 kB/s, and two digital lines for synchronization. Each node consists of:



- A Teensy 3.6 Cortex M4 microcontroller capable of a 240 MHz CPU frequency with a single precision hardware floating point unit.
- SBUS input for sensing up to 16 channels of pilot input from an SBUS capable receiver.
- SBUS output for actuating up to 16 SBUS capable servos.
- PWM output for actuating up to 8 PWM capable servos.
- Two I2C buses for connecting external sensors, such as the Swift Air Data sensor.
- Two UARTS, for connecting external sensors such as GNSS receivers or radio modems.
- Eight analog inputs up to +3.3V.
- Four digital I/O.
- Bolder Flight Systems expansion bus.
- Measurement of SBUS, and PWM voltages.

Specifications

- Voltage Input: +3.6V to +6V
- Current Draw: 125 mA
- Size: 45 mm x 70 mm x 8.5 mm
- Weight: 20 g

Mounting

Eight 2-56 mounting holes are provided and there is no minimum standoff length.



Location

Nodes should be located conveniently for sensing and actuation while minimizing BFS Bus lengths. On UAS with removable wings, this is typically in the wing root to minimize the wiring crossing the wing break, which can often be resolved to only the BFS Bus and actuator power and ground.

Power

Power is provided by the BFS Bus from the FMU. For situations where the Node is not powered by the FMU, the BFS Bus may be used to power the Node using a voltage input from +3.6V to +6V.

Connections

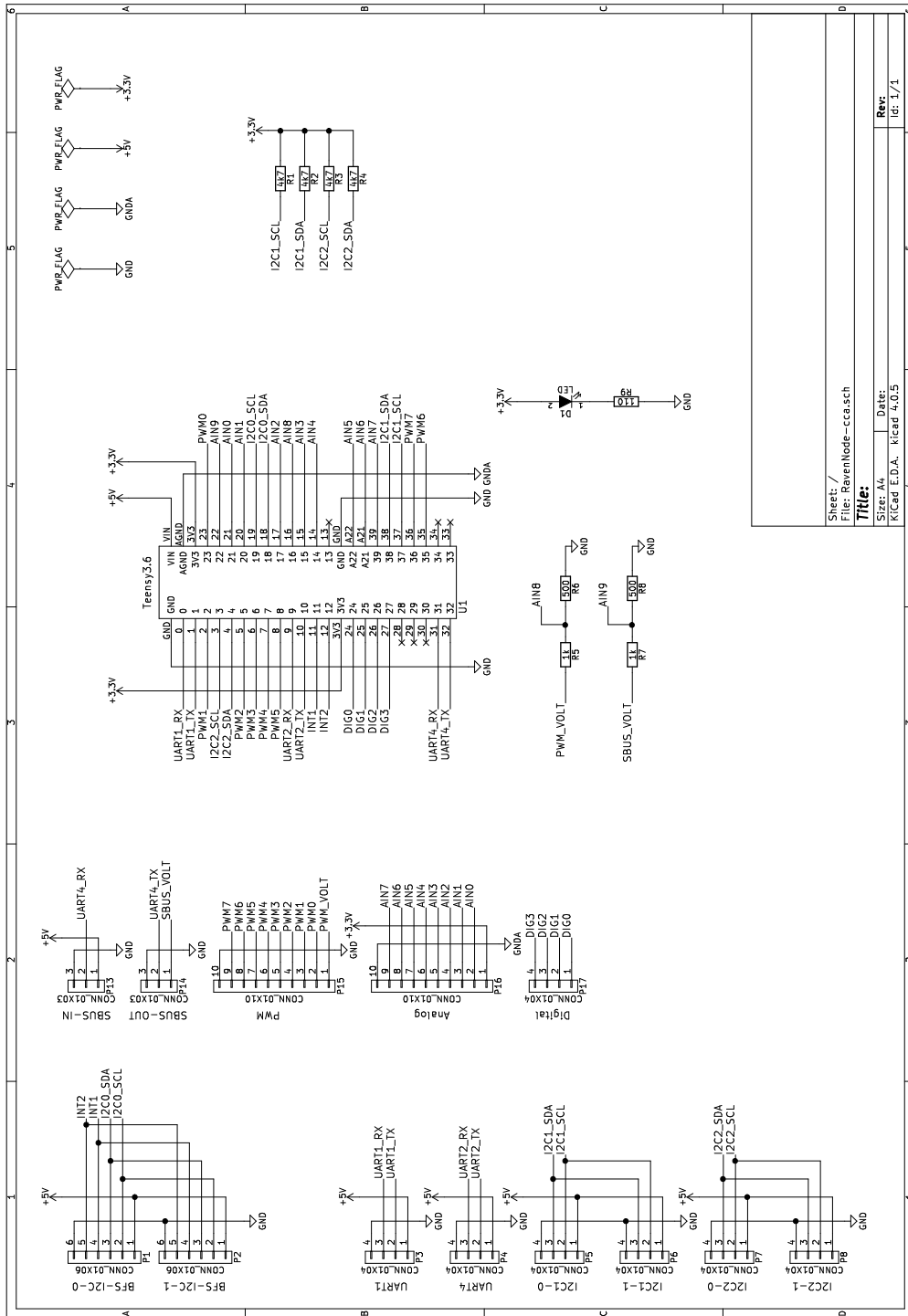
The following connections are available on the Node:

- SBUS input for sensing up to 16 channels of pilot input from an SBUS capable receiver.
- SBUS output for actuating up to 16 SBUS capable servos.
- PWM output for actuating up to 8 PWM capable servos.
- Two I2C buses for connecting external sensors, such as the Swift Air Data sensor.
- Two UARTS, for connecting external sensors such as GNSS receivers or radio modems.
- Eight analog inputs up to +3.3V.
- Four digital I/O.
- Bolder Flight Systems expansion bus (BFS Bus).

Reference the Connectors section for details.



Schematic



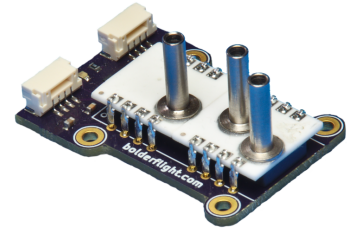
Sheet: /
 File: RavenNode-Cca.sch
Title:
 Size: A4
 Date: 4/05
 KICad E.D.A. kicad 4.0.5
Rev:
 Id: 1/1



Swift Air Data

Overview

The Swift Air Data sensor provides high accuracy measurements of static and differential pressure in a convenient package that integrates easily with Bolder Flight Systems components.



- Calibrated and temperature compensated static and differential pressure with digital output over I2C.
- Small overall error within a temperature range of -25C to +85C.
- 14 bit resolution.
- Libraries available to initialize the sensor and collect pressure data at rates of up to 2 kHz.

Specifications

- Voltage Input: +3.32V to +6V
- Current Draw: 20 mA
- Size: 28 mm x 40 mm x 18.5 mm
- Weight: 10 g

Mounting

Four 2-56 mounting holes are provided and there is no minimum standoff length.

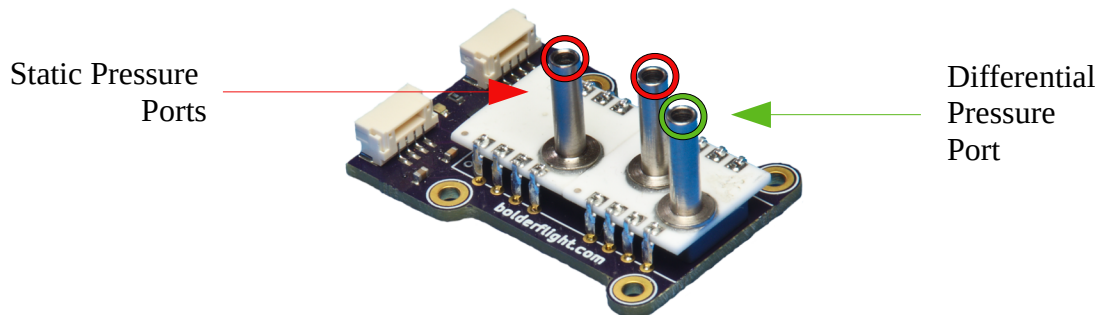
Location

The Swift Air Data sensor should be located near the UAS air data boom to minimize pneumatic delay. Air data booms should be located far outside of the propeller diameter to minimize motor influence and the boom length should be at least 1.5 times the wing chord to reduce upwash. If the air data boom is located off center-line, the data should be corrected back to the aircraft center of gravity.



Orientation

The Swift Air Data sensor contains both static and differential sensors, pneumatic connections are depicted below.



Custom I2C addresses can be selected for the pressure transducers when ordering; typically the static pressure sensor is given the lower numbered address. The default I2C address for the static pressure sensor is 0x10 with a range of 70000 Pa – 120000 Pa. The default I2C address for the differential pressure transducer is 0x11 with a range of 0 Pa – 2000 Pa; however, transducers with ranges of 0 Pa – 500 Pa and 0 Pa – 1000 Pa are available on request.

Power

Power is supplied via the I2C interface from the FMU or Node. Nominally, +5V is the input voltage level; however, a range of +3.32V to +6V is acceptable.

Connections

I2C interfaces are used and two I2C connectors are present to enable daisy chaining devices connected to the bus. Please refer to the Connectors section for a detailed pinout.

PWM, SBUS, and Analog Breakout Boards

Overview

PWM, SBUS, and Analog breakout boards breakout the JST-GH connectors to convenient 0.1” (2.54 mm) spaced headers. These boards fit eight channels of signals and provide bused power and ground as well. Connector orientation is labeled on the board and matches RC servo wire ordering, enabling standard servo connectors to be used. Two of the SBUS breakout boards can be daisy chained to enable up to 16 channels of SBUS output.

For the PWM and SBUS breakout boards, power must be provided for the servos, either via one of the actuator channels or via the provided screw terminals. Actuator voltage is measured, up to +9.9V. Breakout boards are designed to handle 12A of current draw from the servos.

For the analog breakout board, +3.3V is supplied to enable the easy integration of potentiometers.

Mounting

Four 2-56 mounting holes are provided on each board in a pattern matching mounting holes on the FMU and Node. If mounting the breakout board to an FMU or Node, a minimum standoff length of 5/16” is recommended.

Connections

Please refer to the Connectors section for a detailed pinout of the PWM, SBUS, and analog connectors.



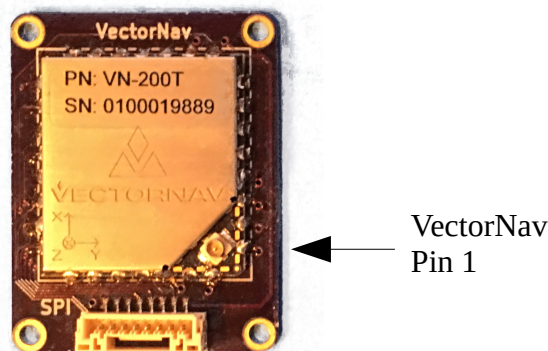
VectorNav Breakout Boards

Overview

A breakout board is available to enable integration of VectorNav VN-100 or VN-200 inertial measurement units and systems. These breakout boards work with the VectorNav surface mounted units and interface the VectorNav with the FMU over SPI.

Mounting

If you are soldering the VectorNav unit to the breakout board, the orientation is shown below.



Four 2-56 mounting holes are provided to mount the VectorNav breakout board to the FMU. 5/16” length standoffs are recommended between the VectorNav breakout board and the FMU.

Power

Power is supplied via the SPI interface from the FMU. Nominally, +5V is the input voltage level; however, a range of +3.2V to +5.5V is acceptable.

Connections

An SPI interface is used, please refer to the Connectors section for a detailed pinout. Note the *Interrupt Out* pin brings the VectorNav generated interrupt to the FMU microcontroller and the MPU-9250 FSYNC pin. The *Interrupt In* pin brings the MPU-9250 generated interrupt to the VectorNav SYNC_IN pin. This setup enables either IMU to drive interrupts on the FMU and data synchronization between the inertial measurement units.



Connectors

Overview

JST-GH connectors are used for all Bolder Flight Systems components, incorporating signals as well as regulated voltage. Connector requirements are below:

- Connector type: JST-GH
- Cable: 26 AWG, insulation outer diameter 0.76 to 1.0 mm. We recommend EcoWire 6711 by Alpha Wire.
- Power voltage: +5V
- Signal voltage: +3.3V (typical, see specifications)

Specifications

Details for each connector is below, please use caution and ensure specified voltage levels are met, higher voltage levels may damage components:

UART Specification			
Pin	Color	Signal	Voltage
1	Red	VCC	+5V
2	White	TX	+3.3V
3	Blue	RX	+3.3V
4	Black	GND	GND

I2C Specification			
Pin	Color	Signal	Voltage
1	Red	VCC	+5V
2	Slate	SCL	+3.3V
3	Violet	SDA	+3.3V
4	Black	GND	GND



CAN Specification			
Pin	Color	Signal	Voltage
1	Red	VCC	+5V
2	Orange	CAN H	+3.3V
3	Brown	CAN L	+3.3V
4	Black	GND	GND

SPI Specification			
Pin	Color	Signal	Voltage
1	Red	VCC	+5V
2	Slate	SCK	+3.3V
3	Blue	MISO	+3.3V
4	Violet	MOSI	+3.3V
5	White	CS	+3.3V
6	Orange	Interrupt Out	+3.3V
7	Brown	Interrupt In	+3.3V
8	Black	GND	GND

SBUS RX Specification			
Pin	Color	Signal	Voltage
1	Red	VCC	+5V
2	White	RX	+3.3V
3	Black	GND	GND

SBUS TX Specification			
Pin	Color	Signal	Voltage
1	Red	Vmeas	Measure up to +9.9V
2	Orange	TX	+3.3V
3	Black	GND	GND



PWM Specification			
Pin	Color	Signal	Voltage
1	Red	Vmeas	Measure up to +9.9V
2	White	Actuator 0	+3.3V
3	Blue	Actuator 1	+3.3V
4	Slate	Actuator 2	+3.3V
5	Violet	Actuator 3	+3.3V
6	Orange	Actuator 4	+3.3V
7	Brown	Actuator 5	+3.3V
8	White	Actuator 6	+3.3V
9	Violet	Actuator 7	+3.3V
10	Black	GND	GND

Analog Specification			
Pin	Color	Signal	Voltage
1	Red	VCC	+3.3V
2	Slate	Analog 0	+3.3V
3	Blue	Analog 1	+3.3V
4	Violet	Analog 2	+3.3V
5	White	Analog 3	+3.3V
6	Brown	Analog 4	+3.3V
7	Orange	Analog 5	+3.3V
8	Blue	Analog 6	+3.3V
9	Slate	Analog 7	+3.3V
10	Black	GND	GND



GPIO Specification			
Pin	Color	Signal	Voltage
1	White	GPIO 0	+3.3V
2	Black	GND	GND
3	Violet	GPIO 1	+3.3V
4	Black	GND	GND

Digital Specification			
Pin	Color	Signal	Voltage
1	White	Digital 0	+3.3V
2	Orange	Digital 1	+3.3V
3	Blue	Digital 2	+3.3V
4	Brown	Digital 3	+3.3V

BFS Bus Specification			
Pin	Color	Signal	Voltage
1	Red	VCC	+5V
2	Slate	SCL	+3.3V
3	Violet	SDA	+3.3V
4	Blue	Interrupt 1	+3.3V
5	White	Interrupt 2	+3.3V
6	Black	GND	GND

