UNIVERSITY OF ALBERTA

UAARG Autopilot Embedded System Board - Falcon I User Guide

Jorge Marin

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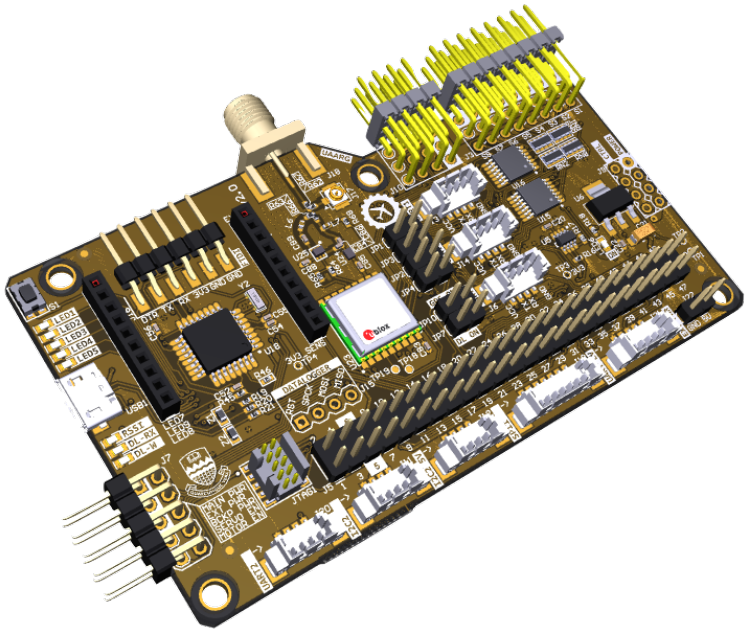


Introduction

This user guide introduces the University of Alberta Aerial Robotics Group (UAARG) Autopilot Embedded System Board as part of the *Falcon I* project, and describes the use and development capabilities for Unmanned Aerial Vehicle (UAV) applications.

Scope

This guide provides details on the UAARG Autopilot system. It is made up of four main sections:

- Section 1 - describes the UAARG Autopilot main features.
- Section 2 - provides instructions to power up the UAARG Autopilot board.
- Section 3 - provides an overview of the UAARG Autopilot board.
- Section 4 - describes the UAARG Autopilot board components.

Related Items

- STMicroelectronics STM32F405 Datasheet

Contents

1 Specifications

Table 1.1: Board Specifications.

Characteristic	Specifications
Temperature: - Operating - Storage	 0°C to +70°C -40°C to +85°C
Relative Humidity	0 to 90% (non-condensing)
RoHS status	Compliant

1.1 Electrostatic Warning

Warning: ESD-Sensitive Electronic Equipment!

The board system must not be subject to high electrostatic potentials.

It is strongly recommended to use a grounding strap or similar ESD protective device when handling the board in hostile ESD environments (for example, places with synthetic carpets). Avoid touching the component pins or any other metallic element on the board.

1.2 Power Supply Warning

Warning: Hardware Power Supply Limitation

Power supply must be 5VDC. Using a power adapter greater than 5VDC may damage the board.

Warning: Hardware Power Budget

Using the USB port as the main power source (max. 500 mA) is acceptable when using the on-board peripherals only.

When connecting external peripherals or add-on boards, it is recommended the use of an external power source connected to the J9 POWER header (can provide up to 1A on the 3.3V node).

2 Power Up

Several power source options are available to power up the UAARG Autopilot board.

The board can be:

- USB-powered through the Micro USB connector (USB1 connector).
- Powered through an external 5V source connected via the J9 POWER header. The external power source must be able to supply 200mA just for the board to work with the basic configuration. Additional peripherals or boards connected might require more supply current.
- Powered through an external 5V source connected via the J5 expansion header - pins 1 and 2. Same conditions as above.

Warning: The UAARG Autopilot board runs at 3.3V. The maximum voltage that the I/O pins can tolerate is 3.3V. Providing higher voltages (e.g. 5V) to an I/O pin could damage the board.

2.1 Power Up the Board

Take the board and connect 5V and GND through the J9 POWER header (check pinout information for J9 to see what pins to use).

Table 2.1: Electrical Characteristics.

Electrical Parameter	**Values**
Input Voltage	5VDC
Max DC 3.3V Current Available	1A
I/O Voltage	3.3V only

2.2 Programming

The UAARG Autopilot board is fully compatible with the Lisa MX from 1 Bit Square, and therefore can be programmed using the same external programmer. This programmer is called "*Black Magic Probe*", and connects directly to the UAARG Autopilot board through the JTAG port. Connect the other end to a free USB port of your PC using a mini-USB to USB cable.

Open PaparazziUAV, and configure and program the board using the same source files used with the Lisa MX.

3 Hardware Introduction

3.1 Introduction

The UAARG Autopilot board is a fully-featured development platform for UAV applications. It integrates all major components needed for UAV autopilot control.

3.2 Equipment List

The UAARG Autopilot board is built around the integration of a Cortex®-M4-based microcontroller with floating-point unit, 3-axis accelerometer, gyroscope, and magnetometer, barometer, GPS unit, secondary microcontroller with SD card for data-logging, 8 PWM outputs for motors/servos and expansion headers and connectors.

3.3 Board Features

Table 3.1: Board Specifications.

Characteristics	**Specifications**
PCB characteristics	90 x 52 x 11mm (4-layers)
Microcontroller	STM32F405VGT6 - 168MHz 32-bit ARM® Cortex® M4 MCU with 192KB RAM, 1024KB Flash, and floating point unit (FPU)
USB	One Micro-USB
10 DOF IMU	3 axis accelerometer 3 axis gyroscope 3 axis magnetometer barometer
Remote Control	Two TTL UART ports for remote control receivers
Telemetry	One socket for XBee radio
GPS	One uBlox MAX-7Q GPS unit The GPS on-board circuitry includes: - SAW filter - Optional LNA - Selectable uFL or SMA connector for GPS antenna
Debug Port	One JTAG interface connector
PWM Outputs	Eight PWM outputs for motors/servos
Data-logger	Secondary MCU and micro-SD card socket for telemetry data-logging
Expansion Connectors	- One high speed SPI interface for high speed hardware expansion - Two I2C interfaces for actuators and sensors - One CAN interface (with onboard transceiver) for actuators and sensors - Three General Purpose IO pins - Three analog inputs - One TTL UART port with adjustable level shifter - One 48-pin header with access to multiple MCU pins
Board Supply Voltage	5V from USB or J9 POWER header On-board power regulation to 3.3V is performed by a LDO linear voltage regulator
User Interface	Bind button Eight indicator LEDs for status check

4 Board Components

4.1 Board Overview

The UAARG Autopilot board integrates several peripherals and interface connectors, as shown in Figures 4.1 and 4.2.

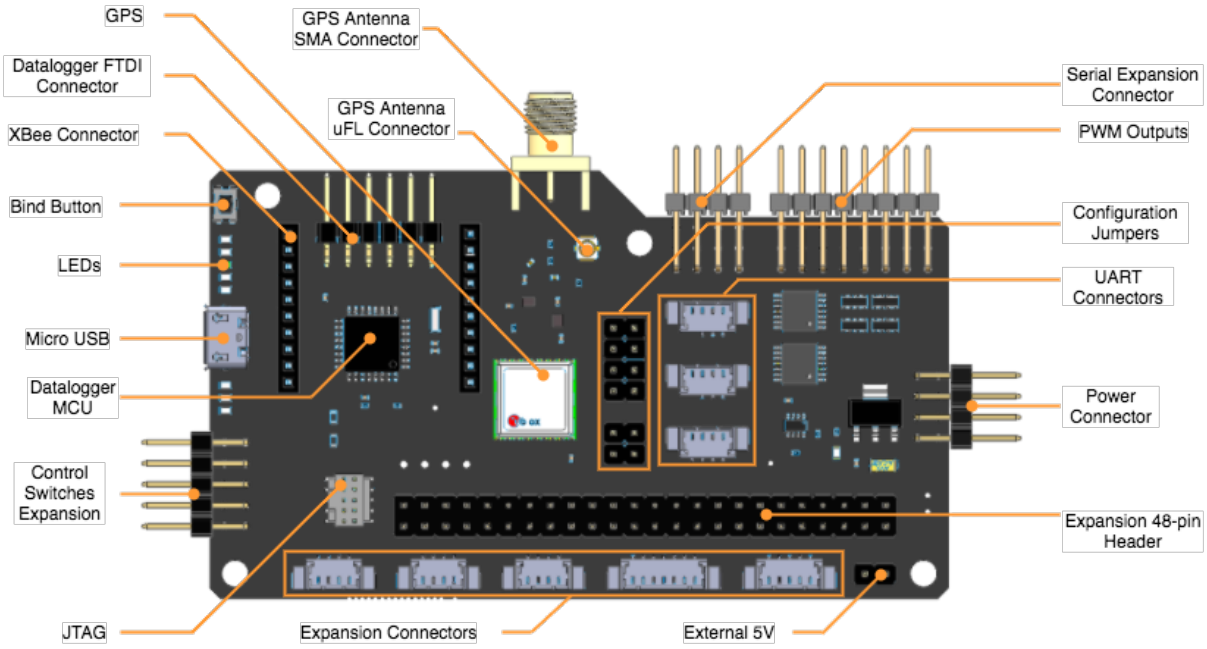


Figure 4.1: UAARG Autopilot Board Overview (Top).

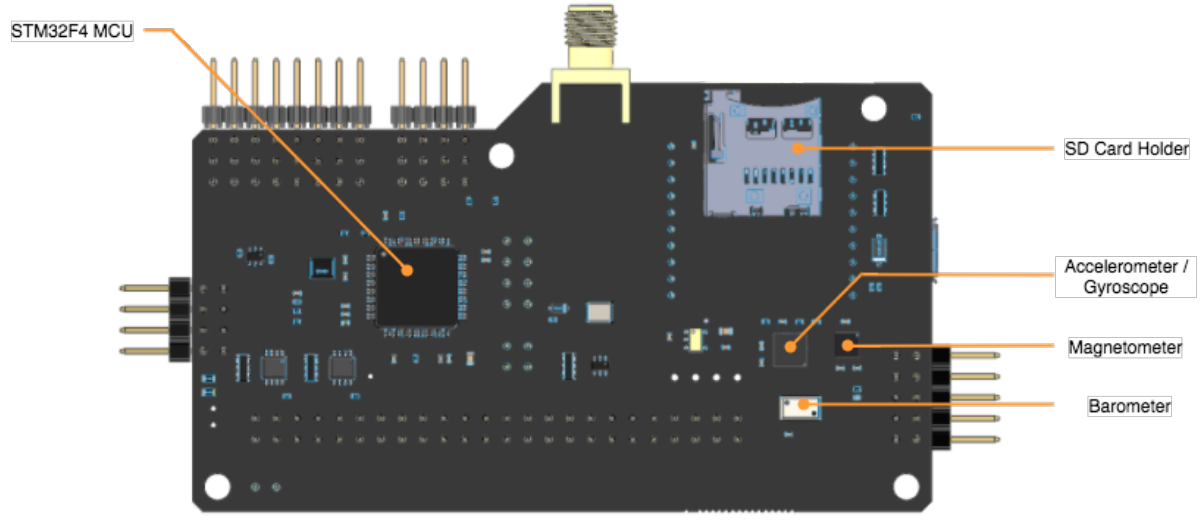


Figure 4.2: UAARG Autopilot Board Overview (Bottom).

The UAARG Autopilot board is equipped with the following interface connectors:

- J3: PWM outputs for motors/servos
- J5: Expansion 48-pin header with access to power, GPIO, and communication ports
- J6: UART3 port (connected to GPS)
- J7: Control switches connector
- J9: Main power supply
- J10: Expansion connector with two UART ports (UART1 and UART5) for RC receivers and one I2C port (I2C1)
- J11: I2C 3.3V port (I2C2)
- J12: I2C 5V port (I2C2)
- J13: UART1 port (for RC receiver)
- J14: UART5 port (for RC receiver)
- J15: ISP connector for data-logger MCU
- J16: FTDI connector for data-logger MCU
- J17: uFL connector for GPS antenna
- J18: SMA connector for GPS antenna
- J19: SPI port
- J20: UART2 port (connected to XBee)
- J21: UART port with voltage level converter
- J22: Secondary 5V supply for external system
- JTAG1: JTAG 10-pin connector
- USB1: micro-USB connector
- EX1, EX2: Female sockets for XBee
- Various test points located throughout the board

4.2 Function Blocks

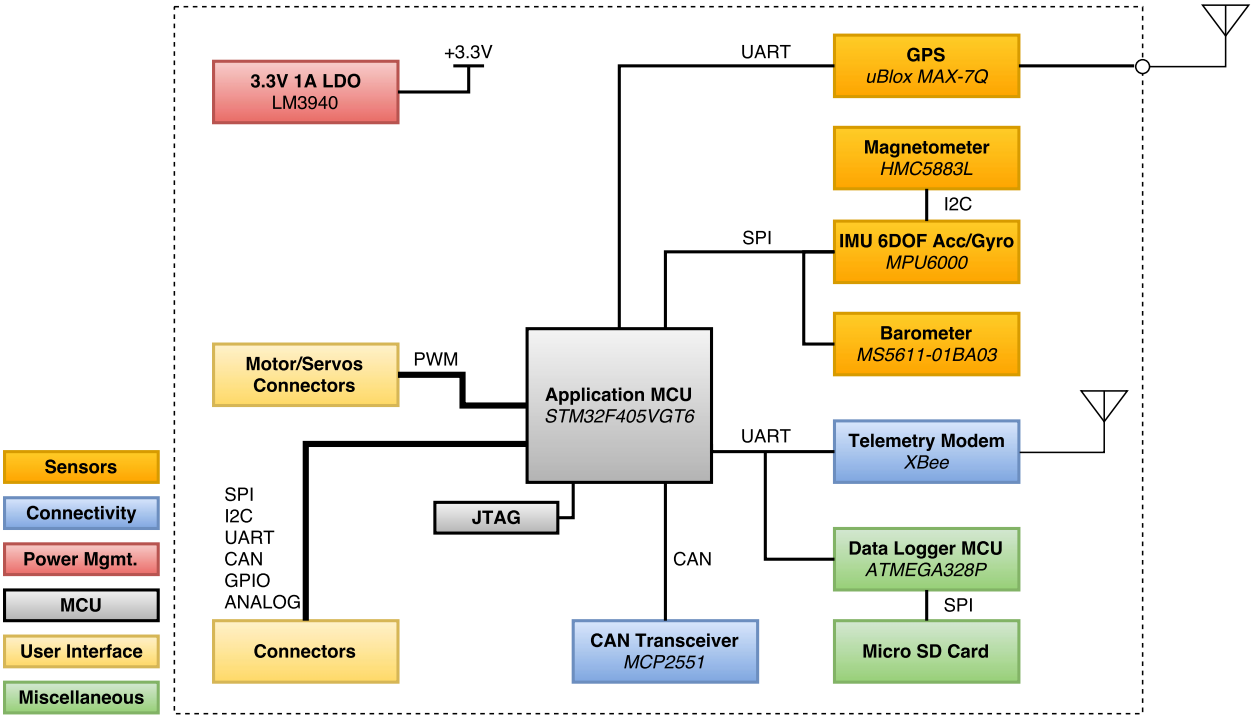


Figure 4.3: UAARG Autopilot Board Block Diagram.

4.2.1 Microcontroller Unit (MCU)

The UAARG Autopilot board is built around the STM32F405VGT6, a 32-bit ARM® Cortex® M4 microcontroller running at 168MHz with 192KB RAM, 1024KB Flash, and a floating point unit (FPU). The microcontroller includes CAN, I2C, I2S, SPI and UART communication interfaces, 82 I/O and 10 Timers in a LQFP-100 package.

4.2.2 Power Supply

The on-board power supply is split into two 3.3V Low Drop-Out (LDO) voltage regulators. One of the voltage regulators (LP2992AIM5-3.3) supplies power to the IMU only, so as to avoid noise in the sensors, white the other (LM3940IMPX-3.3) supplies power to the rest of the board.

4.2.3 Inertial Measurement Unit (IMU)

The boards features a 10 Degrees-of-Freedom (DOF) Inertial Measurement Unit (IMU) comprised by a 3-axis accelerometer and 3-axis gyroscope (MPU6000), a 3-axis magnetometer (HMC5883L) and a barometer (MS5611-01BA03).

The accelerometer/gyroscope and the barometer are connected via SPI interface with the MCU, and the magnetometer is connected to the accelerometer/gyroscope via I2C interface.

The accelerometer/gyroscope acts as a master with the magnetometer, pulling the data and saving it locally, allowing the MCU to extract all three sensors data directly from the MPU6000.

4.2.4 GPS

The board includes a uBlox MAX-7Q GPS module with a super-capacitor for hot start and antenna matching circuitry. The GPS works in the 1575.42Mhz band. The antenna circuitry includes a SAW filter and a optional Low Noise Amplifier (LNA) that can be enabled/disabled by means of on-board 0ohm resistors as jumper. The board also includes a uFL and a SMA connector for GPS antenna. The connectors can also be selected using 0ohm resistors as jumper.

The default setup includes the SMA connector selected and the LNA disabled, so as to use an active antenna. The use of the on-board LNA is advised only when using passive antennas, since active antennas already have an LNA.

The GPS communication interface is serial and is connected to the MCU using the UART3 port. The board also features jumpers for powering on/off the GPS and connecting/disconnecting the GPS from the UART3 port, in case and external GPS is used. Details on these jumper can be found on section 4.2.10.

4.2.5 XBee

The board includes a set of female headers for connecting an XBee RF transceiver module for telemetry. It is important to connect the XBee with the right orientation. Figure 4.4 shows an example of an XBee module with SMA connector plugged into the UAARG Autopilot board. The XBee communication interface is serial and is connected to the MCU using the UART2 port.

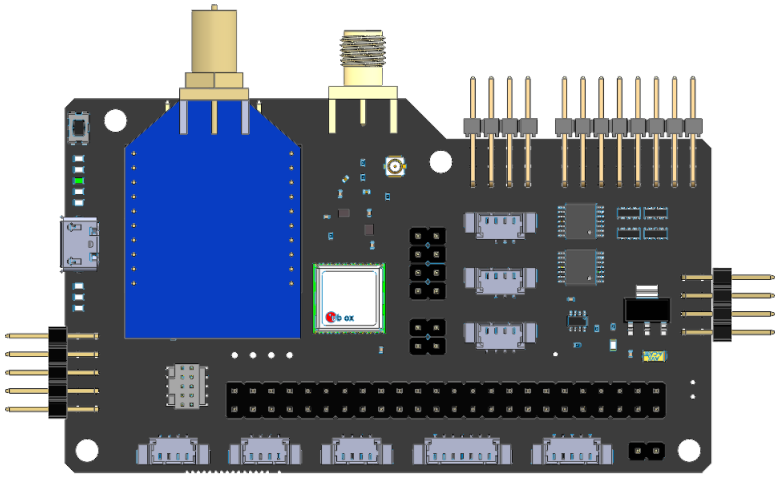


Figure 4.4: UAARG Autopilot Board Overview with XBee connected.

4.2.6 Data-Logger

A secondary MCU based on an Atmel AVR 8-bits 16Mhz ATMEGA328P takes care of listening to the telemetry serial port (UART2) and saving the data in a micro-SD card that can be connected using the micro-SD card holder located in the bottom of the board. The MCU uses a modified version of the "OpenLog" firmware that was officially adapted by paparazziUAV to work with their system. Once the data-logging firmware is running there is no need to change any settings, as it starts running and saving data automatically after power up.

The board includes a jumper for powering on/off the data-logger. Details on this jumper can be found on section 4.2.10.

4.2.7 CAN Transceiver

The board features a Microchip MCP2551 CAN transceiver supporting 1M/s operation. The CANH and CANL pins are accessible through connector J5. Details on this connector can be found on section 4.2.9.

4.2.8 Motor/Servo Outputs (PWM)

The UAARG autopilot board has eight PWM outputs that can be used to control motors and servos. Outputs run through tristate buffers and each signal can be enabled/disabled using one of two user control signals. This functionality is intended for using external kill-switches for motor and servo signals.

PWM outputs and control signals are accessible through connectors J3 and J7 respectively. Details on these connectors can be found on section 4.2.9

4.2.9 Connectors

J3 Header

Figure 4.5 shows the location and pinout of the motor/servo headers. There are eight 3-pin headers, each one with GND, Power and PWM output. The Power pins are all tied together and have 4.8-5.5V range. When an Electronic Speed Controller (ESC) is connected, the power coming from it is used to power the servos.

Each of the 8 PWM outputs can be assigned to one of the two user control switches (as a motor or as a servo), as explained in 4.2.8. This is done via solder jumpers SB6-SB13. Details on these jumpers can be found on section 4.2.10.

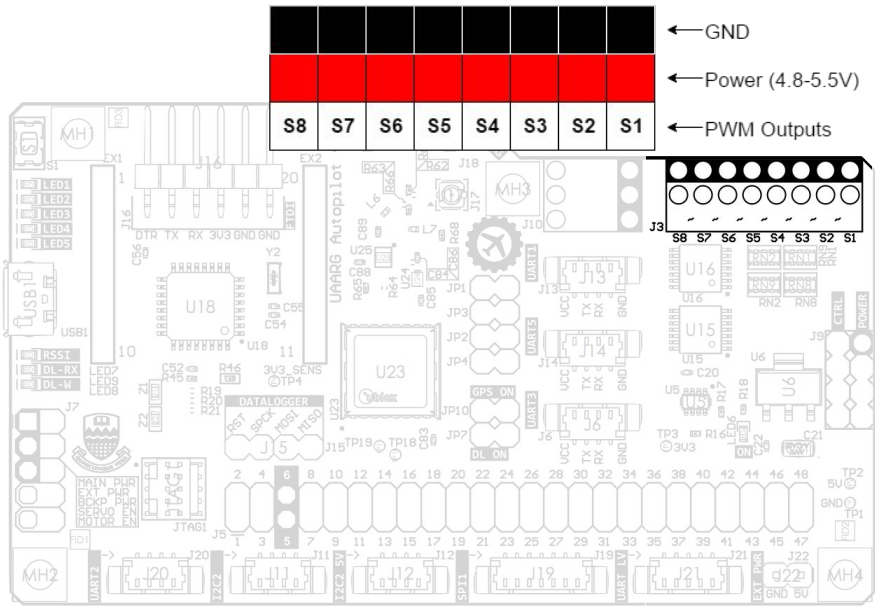


Figure 4.5: J3 Header Pinout.

J5 Header

Figure 4.6 shows the location and pinout of the 48-pin expansion header that can used to access communication ports, GPIO, Analog inputs, etc.

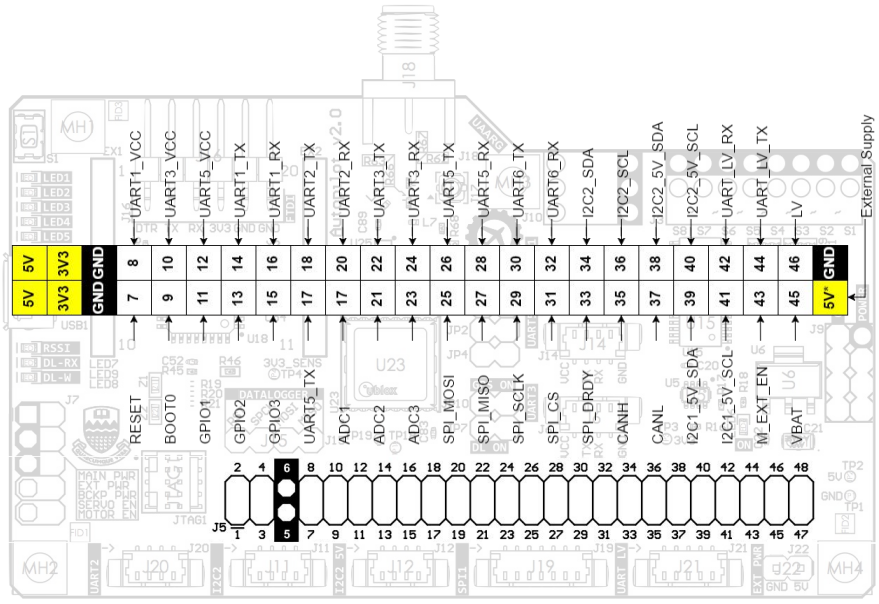


Figure 4.6: J5 Header Pinout.

J6 Header

Figure 4.7 shows the location and pinout of the pico-blade connector for UART3. This serial port can be used to connect an external GPS module. If an external GPS module is used, the on-board GPS module can be disconnected from power using jumper JP10 and the TX and RX lines can be disconnected from the MCU using jumpers JP2 and JP4. Details on these jumpers can be found on section 4.2.10.

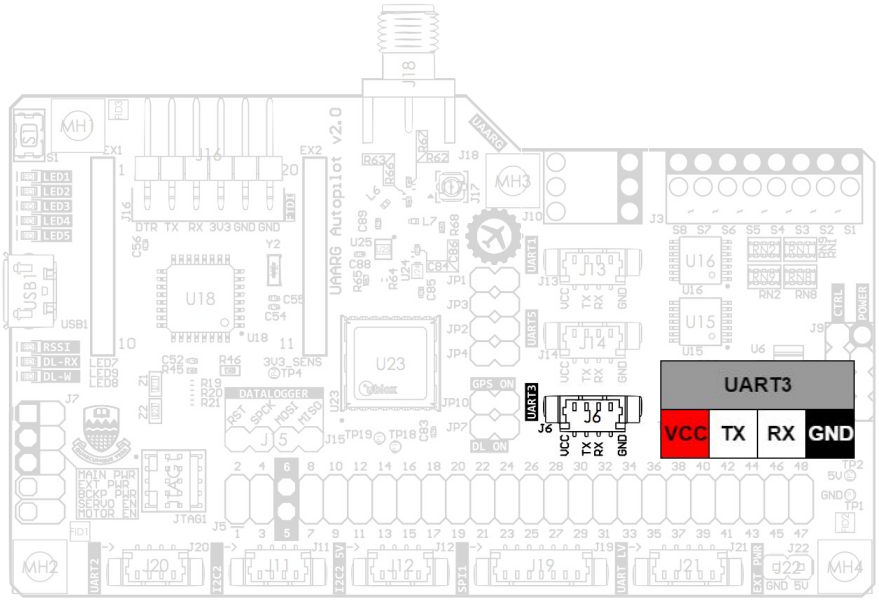


Figure 4.7: J6 Header Pinout.

J7 Header

Figure 4.8 shows the location and pinout of the user control switches. This header can also be used with jumper, but is primarily intended to be used with SPST toggle switches, each one connected between pins 1-2, 3-4, 5-6, 7-8, and 9-10.

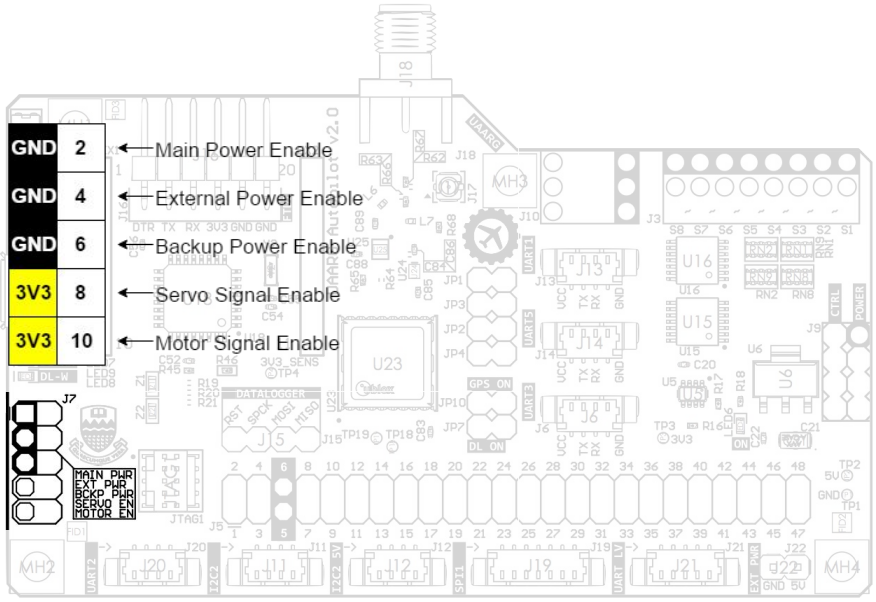


Figure 4.8: J7 Header Pinout.

From top to bottom, the first three pairs are used for enabling/disabling the main power supply, external power supply and backup power supply respectively. When the switch (or jumper) in on, those pins are shorted to GND and power is off for the corresponding function. The last two pairs are used for enabling/disabling the servo and motor signals respectively. When the switch (or jumper) in on, those pins are shorted to 3.3V, and the servo/motor signals are disabled (PWM signal disabled and output pulled-down to GND). Jumper SB6-SB13 are used to select which PWM outputs are assigned to motors and servos. Details on these jumpers can be found on section 4.2.10.

J9 Header

Figure 4.9 shows the location and pinout of the power header. This header is used for powering the board, and also carries external and backup power supplies as well as power enable signals. Table 4.1 shows a description of each pin of this header.

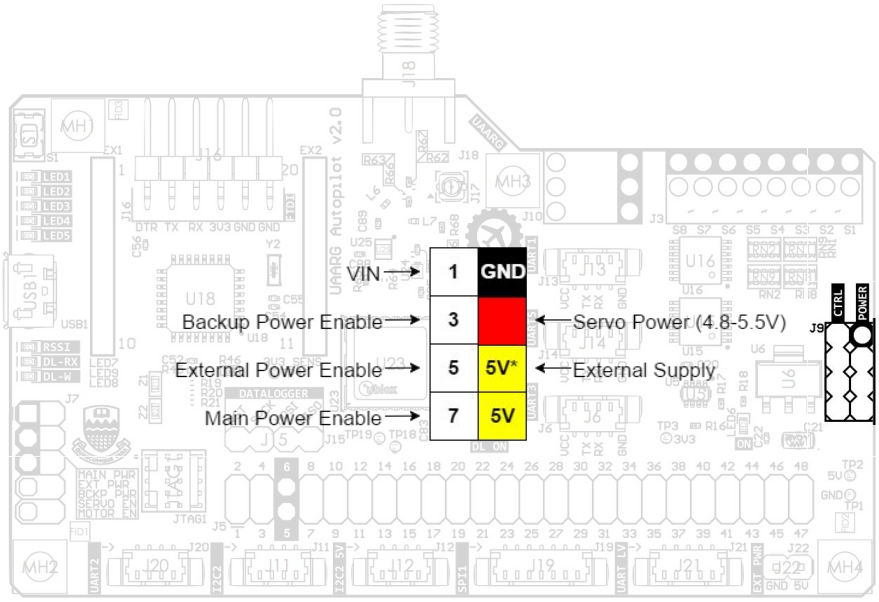


Figure 4.9: J9 Header Pinout.

Table 4.1: J9 Header Pinout Description.

Pin	Signal	Description
1	VIN	Battery voltage for voltage measurement
2	GND	Ground
3	Backup Power Enable	Enable signal for backup power
4	Servo Power	Backup power for servos
5	External Power Enable	Enable signal for external power
6	External Supply	External power (5V) for secondary system
7	Main Power Enable	Enable signal for main power
8	5V	Main power (5V)

J10 Header

Header J10 includes 3 communication ports: 1 x I2C and 2 x UART.

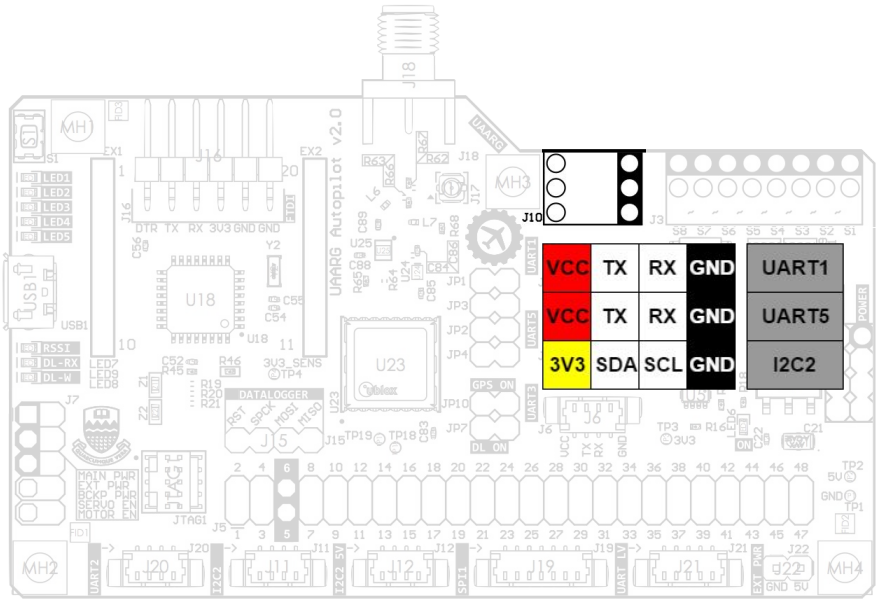


Figure 4.10: J10 Header Pinout.

J11 Header

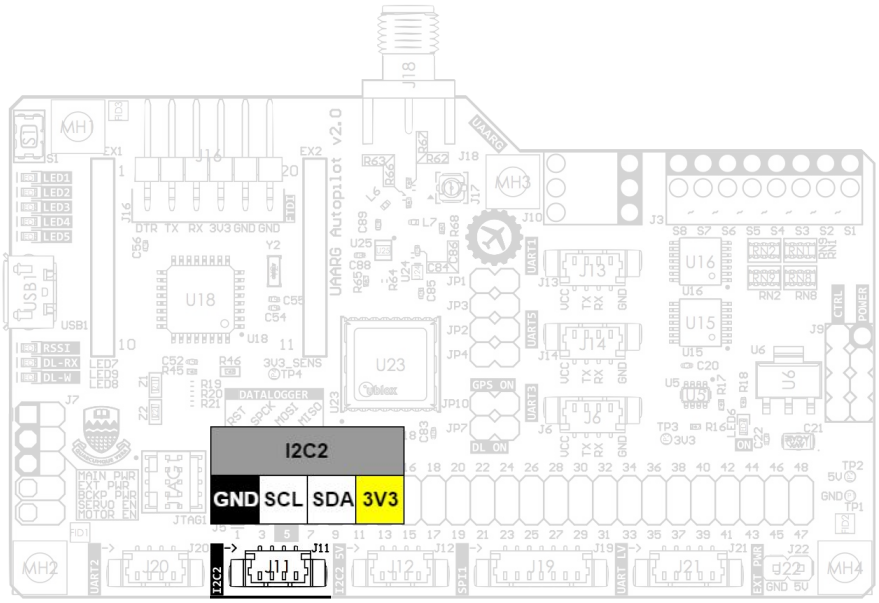


Figure 4.11: J11 Header Pinout.

J12 Header

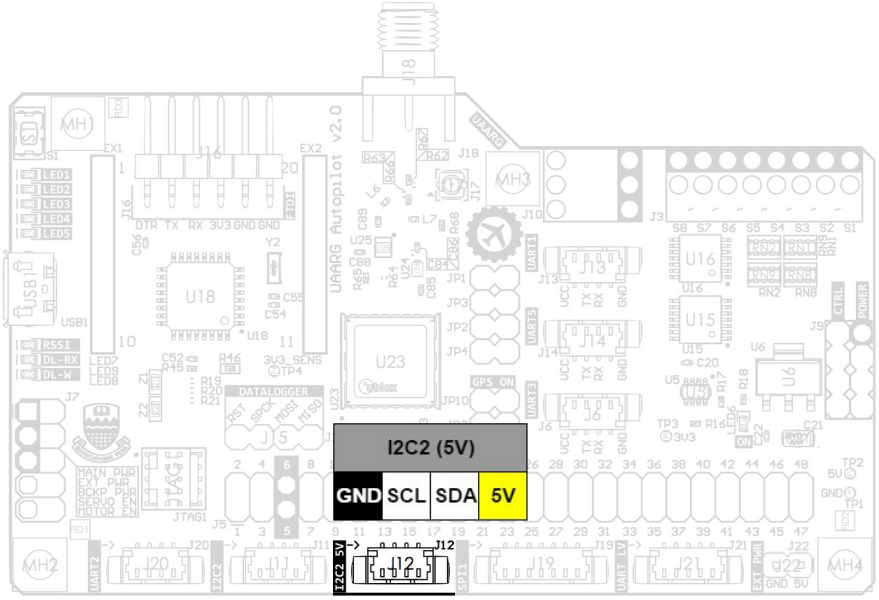


Figure 4.12: J12 Header Pinout.

J13 Header

Figure 4.13 shows the location and pinout of the pico-blade connector for UART1. This serial port is used to connect an RC receiver.

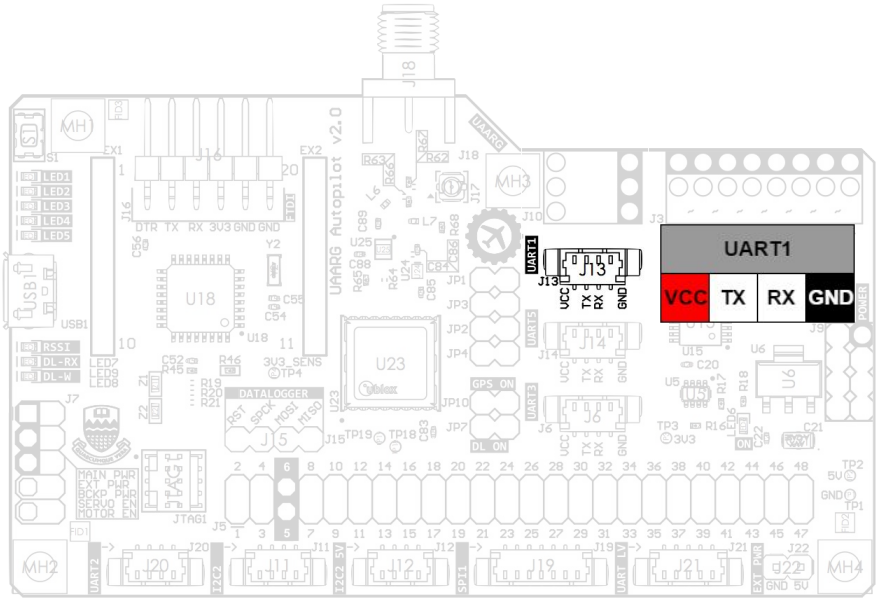


Figure 4.13: J13 Header Pinout.

J14 Header

Figure 4.14 shows the location and pinout of the pico-blade connector for UART5. This serial port is used to connect an RC receiver.

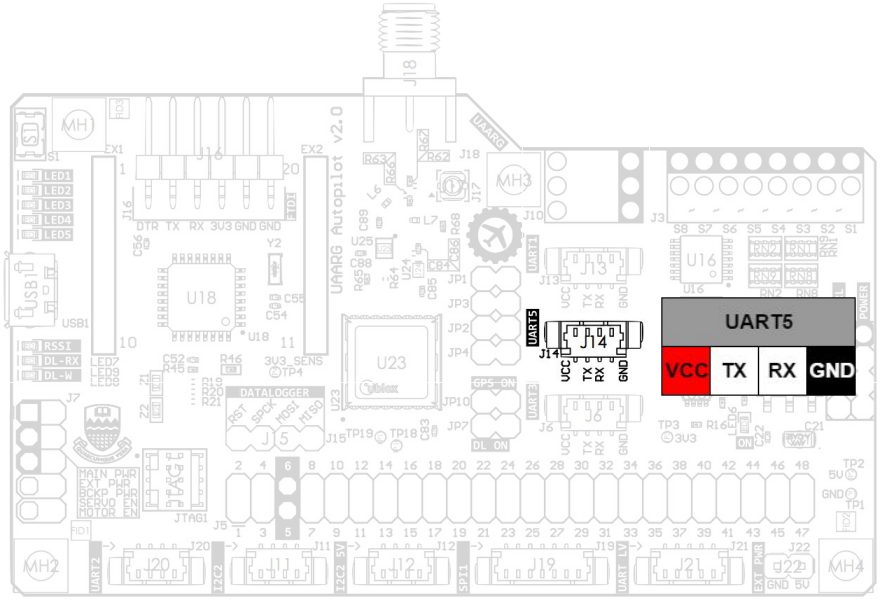


Figure 4.14: J14 Header Pinout.

J15 Header

Figure 4.15 shows the location and pinout of the ISP connector used for programming the data-logger MCU ATMEGA328P.

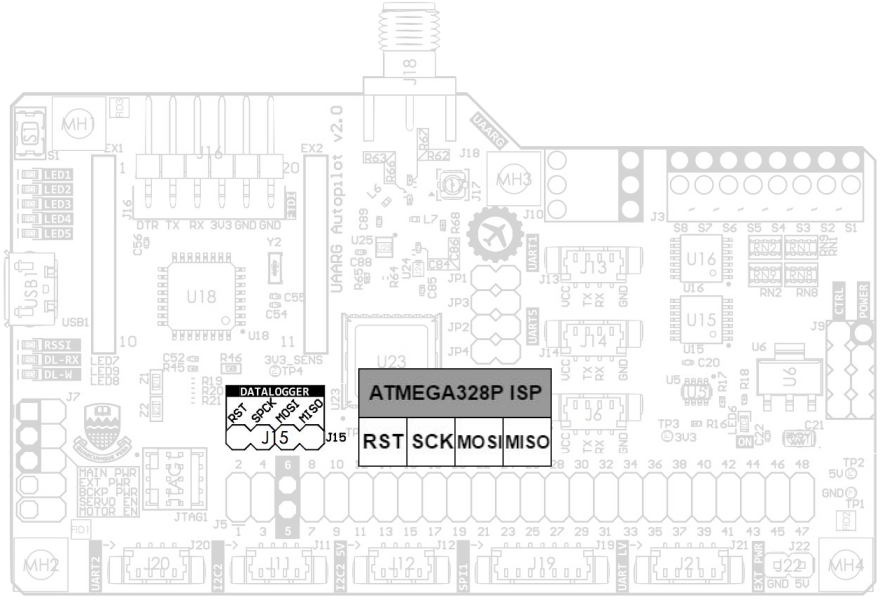


Figure 4.15: J15 Header Pinout.

J16 Header

Figure 4.16 shows the location and pinout of the FTDI connector used for communicating with the data-logger MCU ATMEGA328P.

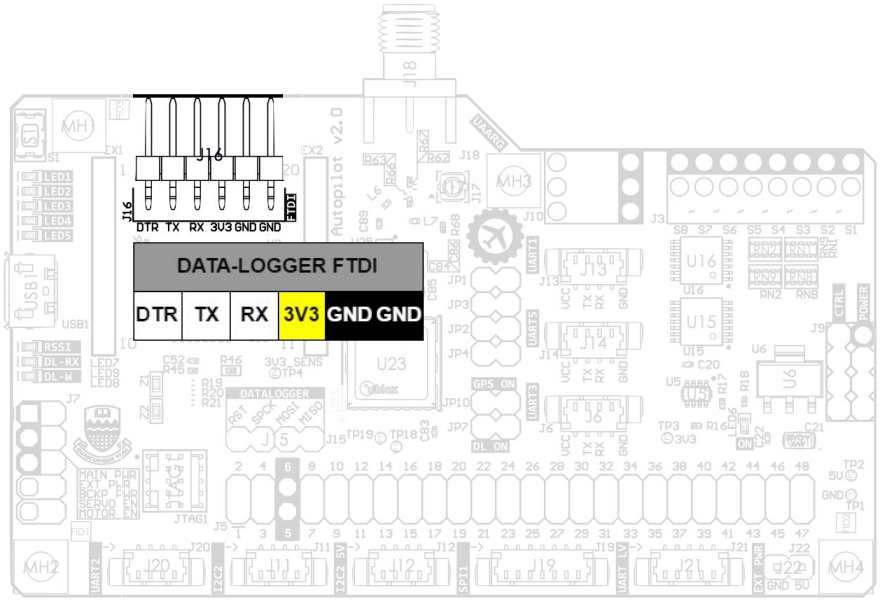


Figure 4.16: J16 Header Pinout.

J17 Header

Figure 4.17 shows the location of the uFL connector for the GPS antenna. This connector can be enabled setting the jumper resistor R62 instead of R67.

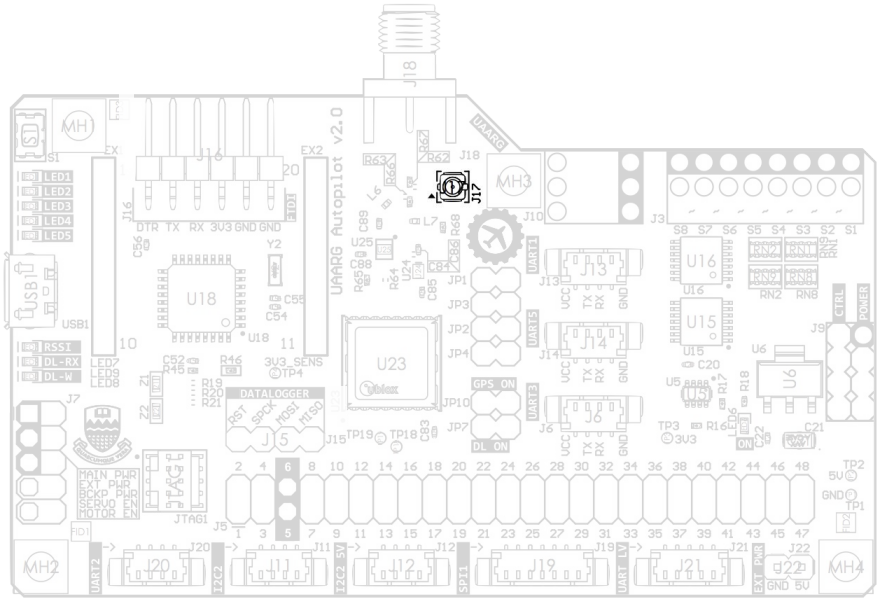


Figure 4.17: J17 Header Pinout.

J18 Header

Figure 4.18 shows the location of the SMA connector for the GPS antenna. This connector can be enabled setting the jumper resistor R67 instead of R62.

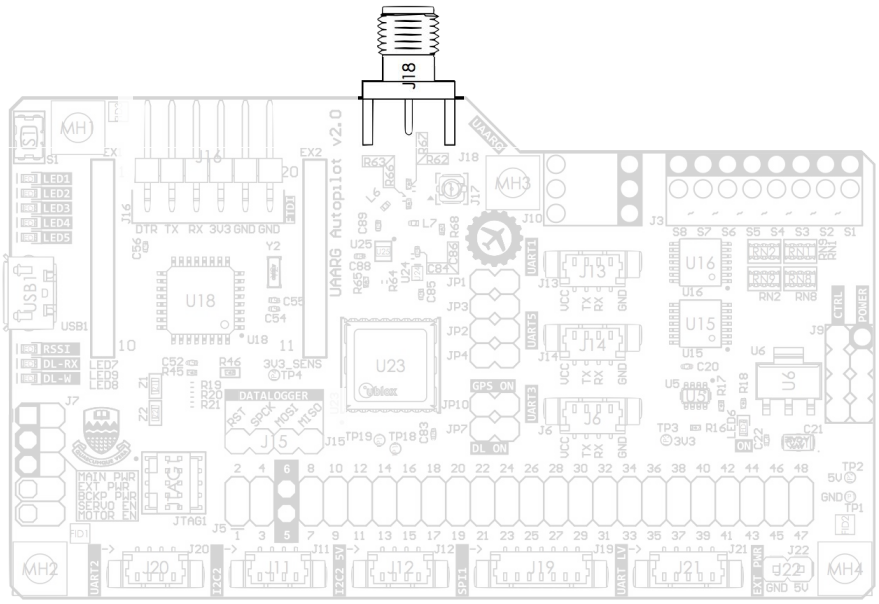


Figure 4.18: J18 Header Pinout.

J19 Header

Figure 4.19 shows the location and pinout of the SPI interface connector.

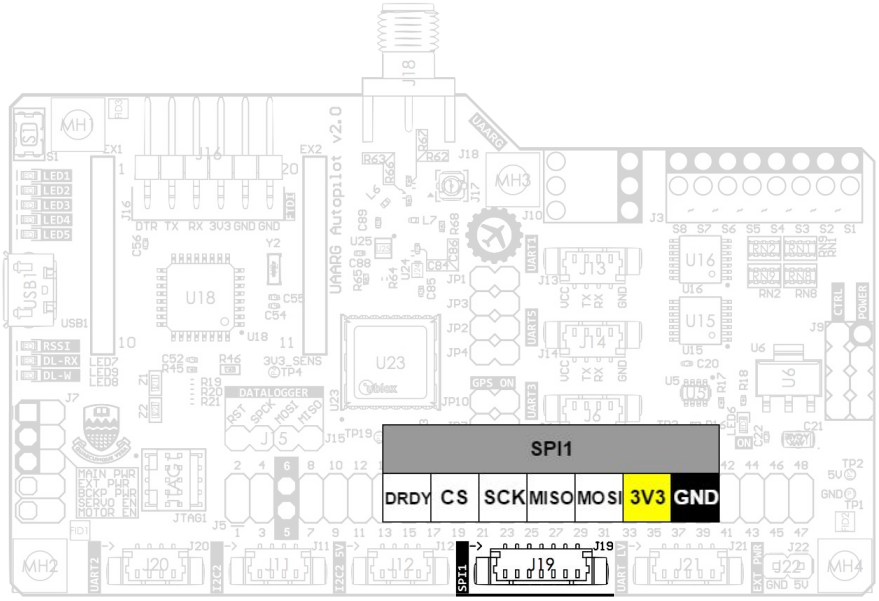


Figure 4.19: J19 Header Pinout.

J20 Header

Figure 4.20 shows the location and pinout of the UART2 connector. This serial port is connected to the XBee module used for telemetry. If an external telemetry module is used, it can be connected to this port while leaving the XBee sockets empty.

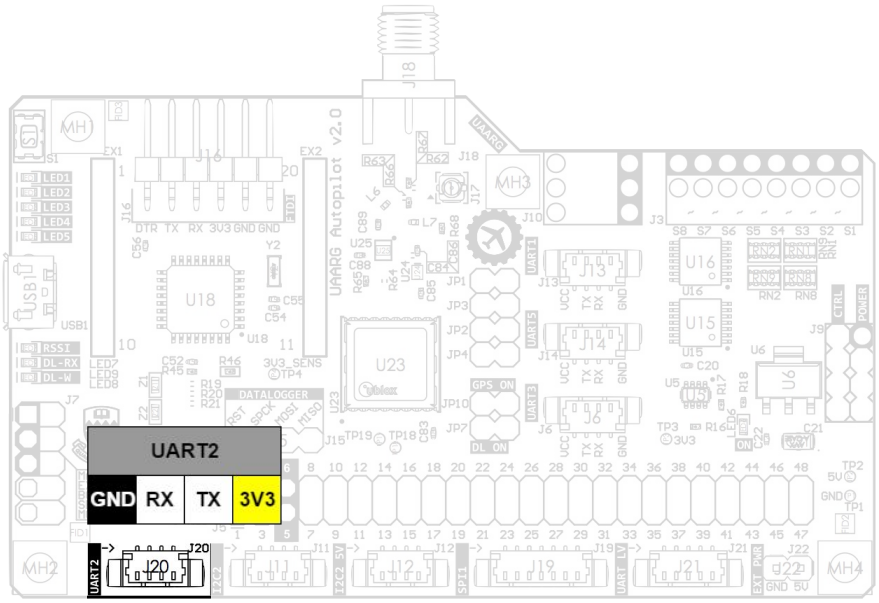


Figure 4.20: J20 Header Pinout.

J21 Header

Figure 4.21 shows the location and pinout of the UART_LV connector. This UART port has a voltage level shifter and can be used for communication with an external system that uses a different voltage level (e.g. ODROID Linux mini-PC using 1.8V logic).

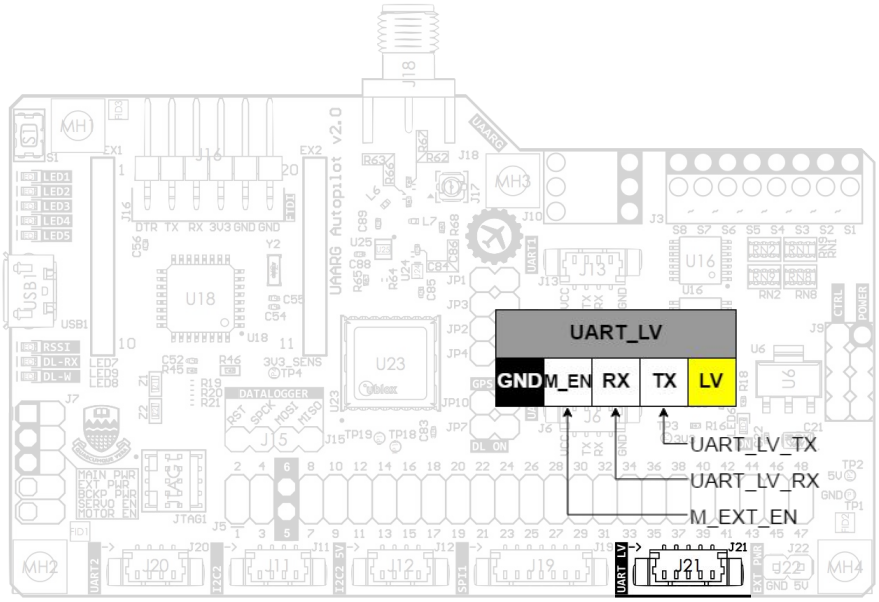


Figure 4.21: J21 Header Pinout.

This serial port can be connected to UART2 (currently used for the XBee telemetry module) in case the secondary system only wants to listen to telemetry information; or it can be connected to UART6, which can be used as a dedicated serial link. This change can be done using SB1 and SB2 solder jumpers. Details on these jumpers can be found on section 4.2.10.

J22 Header

Figure 4.22 shows the location and pinout of the External Power connector. This connector provides power to an external system. Power comes from pin 6 in header J9.

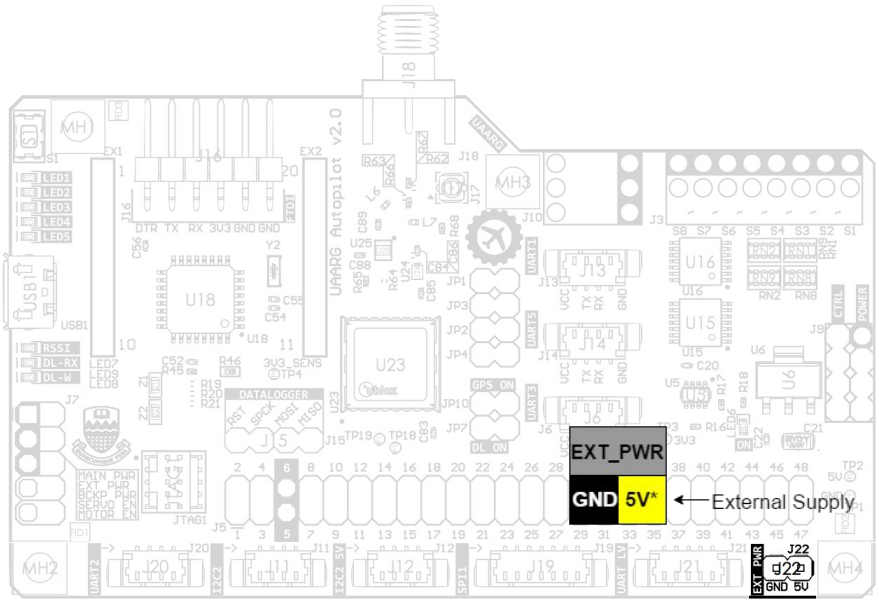


Figure 4.22: J22 Header Pinout.

JTAG1 Header

Figure 4.23 shows the location of the JTAG connector used for programming the STM32F4 MCU.

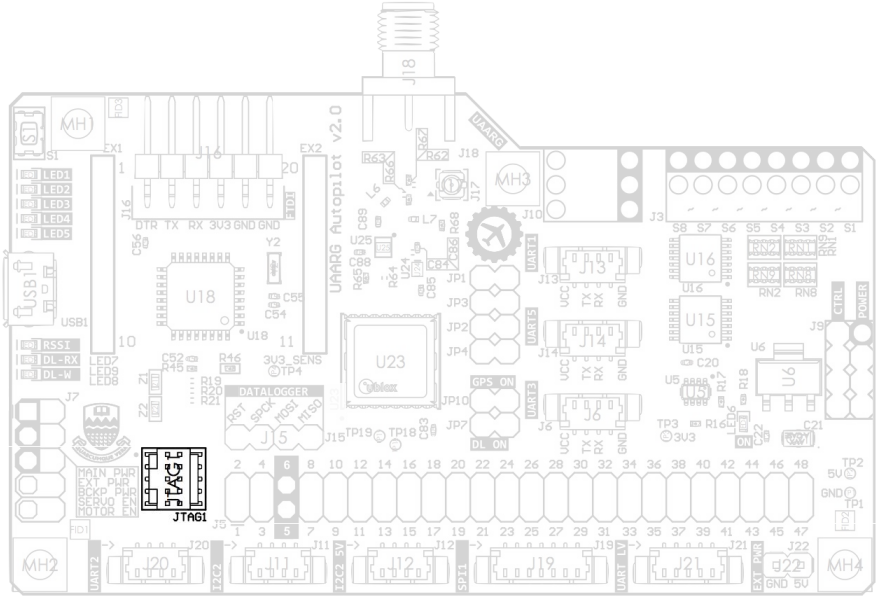


Figure 4.23: JTAG1 Header Pinout.

USB1 Header

Figure 4.24 shows the location of the micro-USB connector.

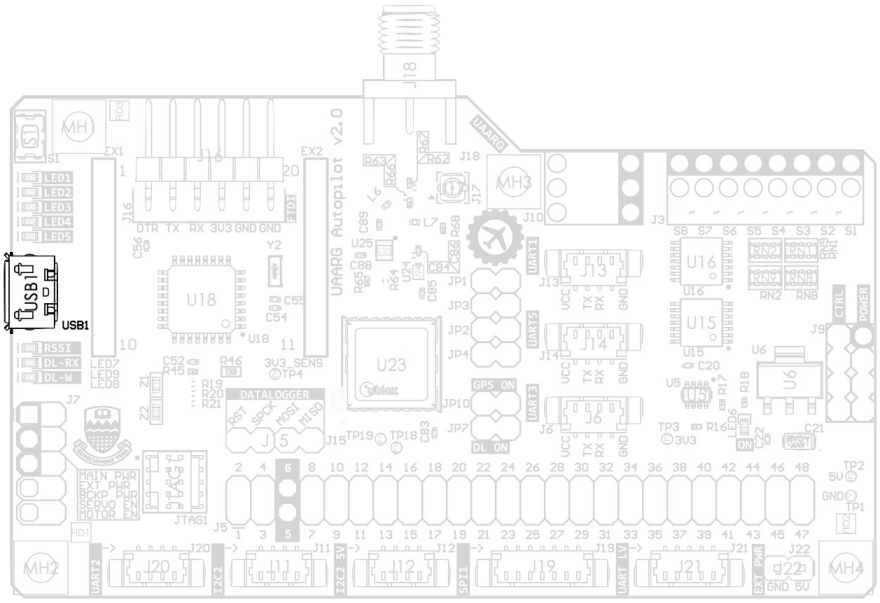


Figure 4.24: USB1 Header Pinout.

EX1, EX2 Headers

Figure 4.25 shows the location of the XBee socket connectors used for plugging the XBee module. Refer to section 4.2.5 for correct orientation of the XBee module.

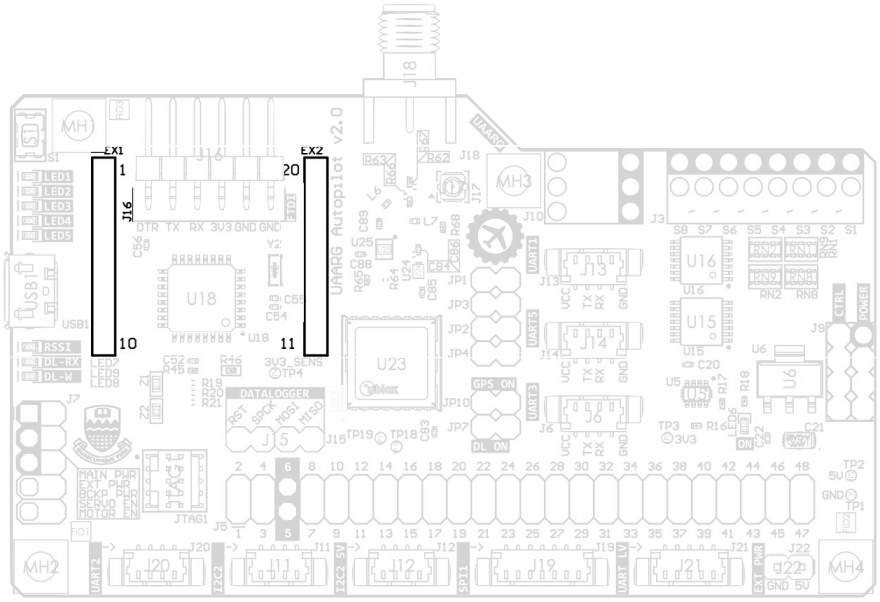


Figure 4.25: EX1, EX2 Headers Pinout.

4.2.10 Jumpers

Solder Jumper SB1-SB13

Figure 4.26 shows the location of the solder jumpers SB1 to SB13 on the bottom side of the UAARG Autopilot board, and Figure 4.27 shows the three sub-groups of solder jumpers. All solder jumpers have the same 3-pad footprint, where the middle pad is the common pin and the two side pads are the options. To make a connection, place a solder bridge between the middle pad and one of the side pads. Some jumpers come already with a default connection by means of a small exposed track (no solder mask) joining the middle pad with one of the side pads. If the default option is no desired, the track needs to be cut so as to disconnect the pads.

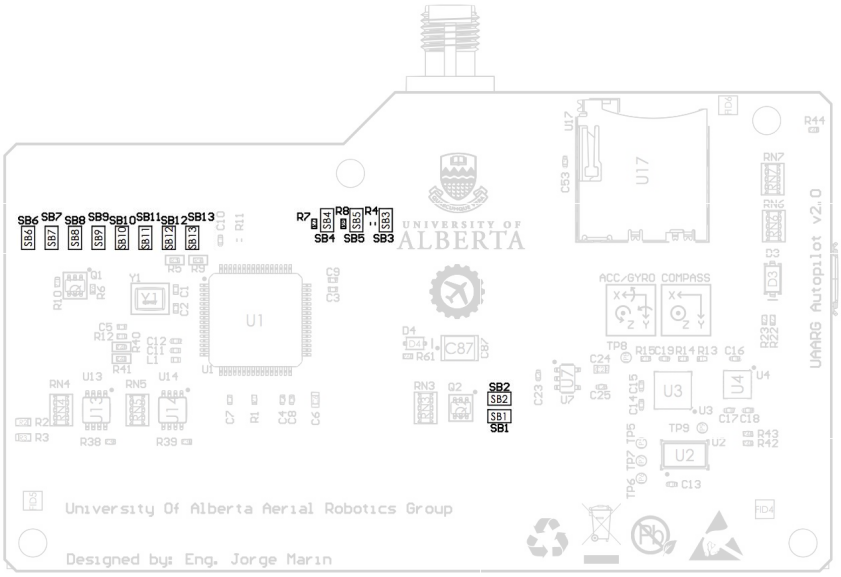
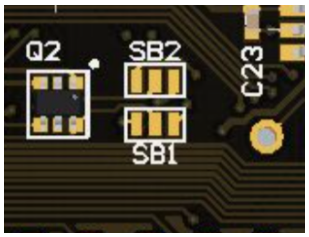
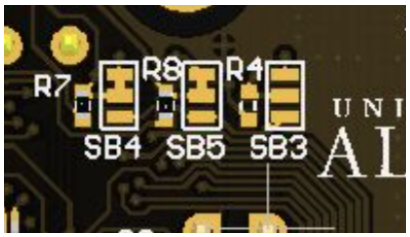


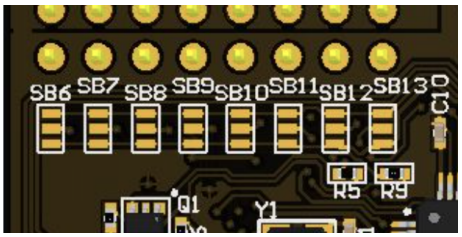
Figure 4.26: Location of all solder jumpers.



(a) Solder jumpers SB1-SB2.



(b) Solder jumpers SB3-SB5.



(c) Solder jumpers SB6-SB13.

Figure 4.27: Solder jumper sub-groups.

Table 4.2 shows the description for each solder jumper and the two options. The location reference for the options (Left, Right, Top, Bottom) is based on the orientation of the jumpers shown in Figure 4.27.

Table 4.2: Solder jumpers descriptions.

SB	Option 1	Option 2	Description
1	(Left) UART6_TX	(Right) UART2_TX	Selects UART (Low Voltage) port (TX pin)
2	(Left) UART2_RX	(Right) UART6_RX	Selects UART (Low Voltage) port (RX pin)
3	(Top) 3.3V	(Bottom) 5V	UART3 Power Rail
4	(Top) 3.3V	(Bottom) 5V	UART1 Power Rail
5	(Top) 3.3V	(Bottom) 5V	UART5 Power Rail
6	(Top) Servo Group	(Bottom) Motor Group	PWM signal enable/disable (Output 1)
7	(Top) Servo Group	(Bottom) Motor Group	PWM signal enable/disable (Output 2)
8	(Top) Servo Group	(Bottom) Motor Group	PWM signal enable/disable (Output 3)
9	(Top) Servo Group	(Bottom) Motor Group	PWM signal enable/disable (Output 4)
10	(Top) Servo Group	(Bottom) Motor Group	PWM signal enable/disable (Output 5)
11	(Top) Servo Group	(Bottom) Motor Group	PWM signal enable/disable (Output 6)
12	(Top) Servo Group	(Bottom) Motor Group	PWM signal enable/disable (Output 7)
13	(Top) Servo Group	(Bottom) Motor Group	PWM signal enable/disable (Output 8)

GPS Signal Jumpers

Figure 4.28 shows the location of the jumpers used for configuring the GPS signal circuitry. There are three GPS signal setup jumpers used for configuring the signal path. Each jumper consists of an 0402 capacitor/resistor that can be soldered vertically or horizontally. The orientation of these components defines the route of the signal. Table 4.3 shows the description for each setup based on these jumpers.

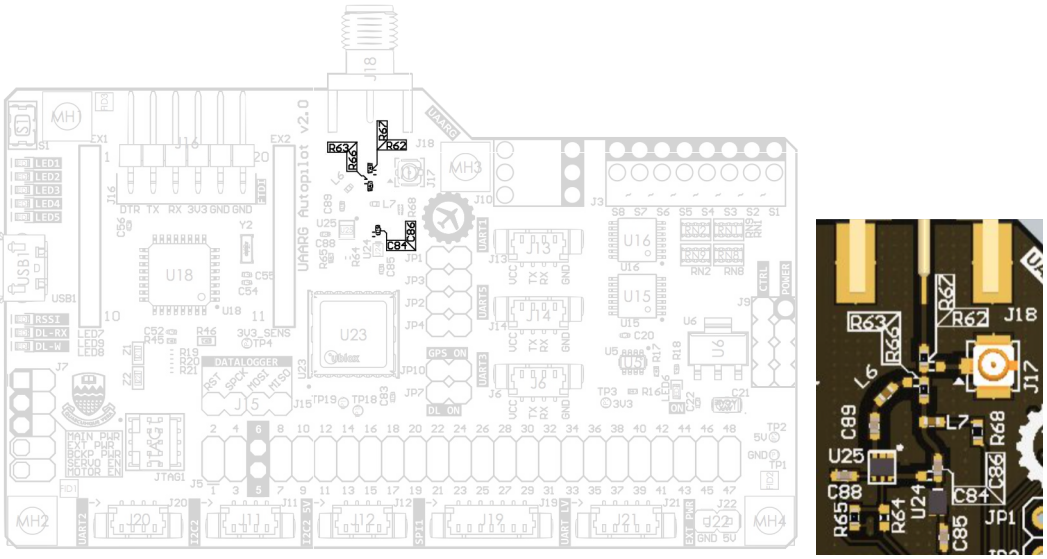


Figure 4.28: Location of GPS signal jumpers.

Table 4.3: GPS signal jumpers descriptions.

Setup	Description
C84 On and R63 On	On-board LNA enabled
C86 On and R66 On	On-board LNA disabled
R62 On	uFL antenna connector enabled
R67 On	SMS antenna connector enabled

GPS and Data-logger Power Jumpers

Figure 4.29 shows the location of the two power jumpers. When JP7 is closed the data-logger is powered and when JP10 in closed the GPS is powered.

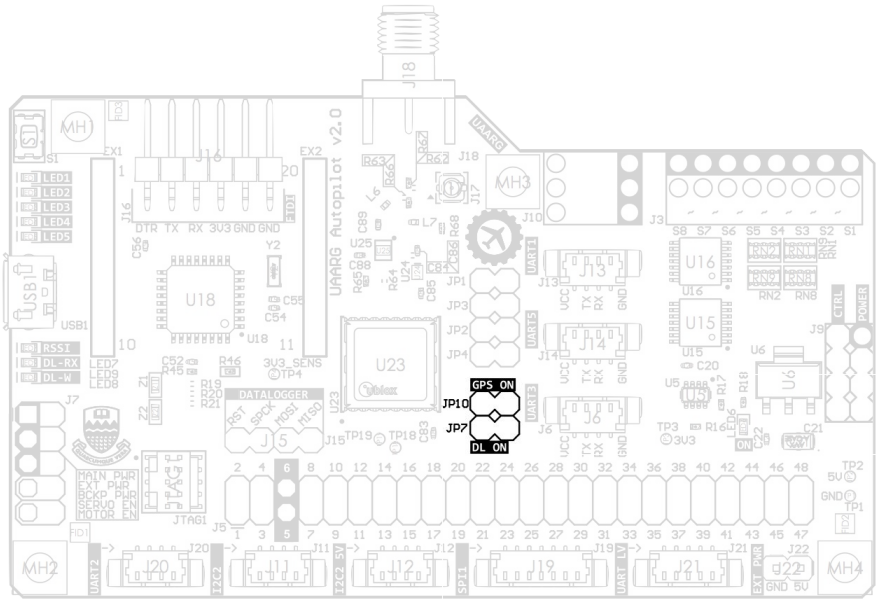


Figure 4.29: Location of power jumpers.

GPS Serial Jumpers

Figure 4.30 shows the location of the GPS serial jumpers. These jumpers form a "T" connection for the UART3 port between the on-board GPS module, MCU and J6 header. JP1 and JP3 connect the RX and TX lines respectively of the on-board GPS module to header J6. JP2 and JP4 connect the TX and RX lines respectively of the MCU to header J6.

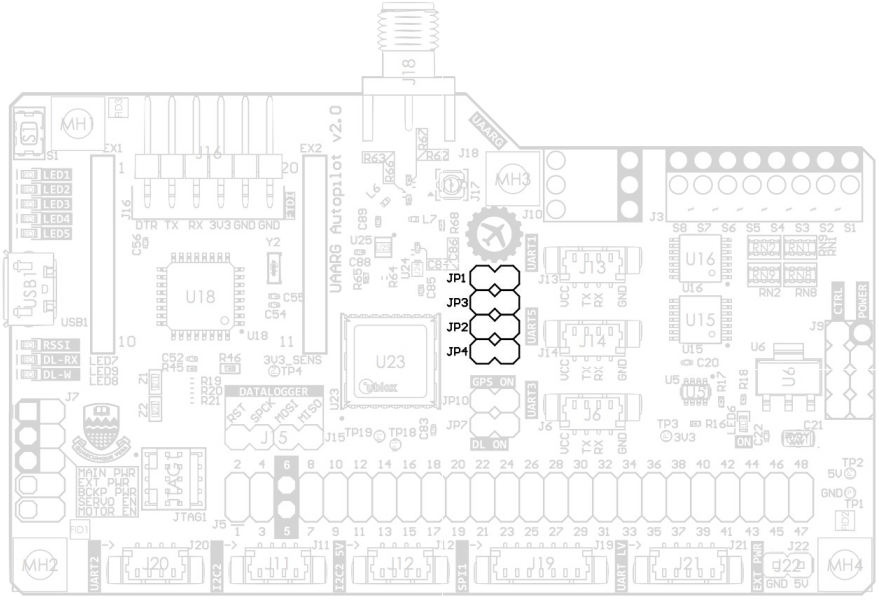


Figure 4.30: Location of GPS serial jumpers.

During normal operation (using the on-board GPS), all 4 jumpers are closed. There are other two cases:

1. JP1 and JP3 can be left open for using an external GPS module connected directly to J6.
2. JP2 and JP4 can be left open for talking directly to the GPM module from an external system through J6. An example of this is connecting to the GPS from a PC in order to configure it.

4.3 UAARG Autopilot Board Schematics

This section contains the following schematics:

- Index
- UAARG Autopilot
- Connectors
- MCU
- IMU
- GPS
- CAN, JTAG, LDO, USB
- Telemetry, I2C
- Switches, UI
- Data Logger
- Power
- Main Power
- Backup Power
- Notes
- Documentation
- Revision History

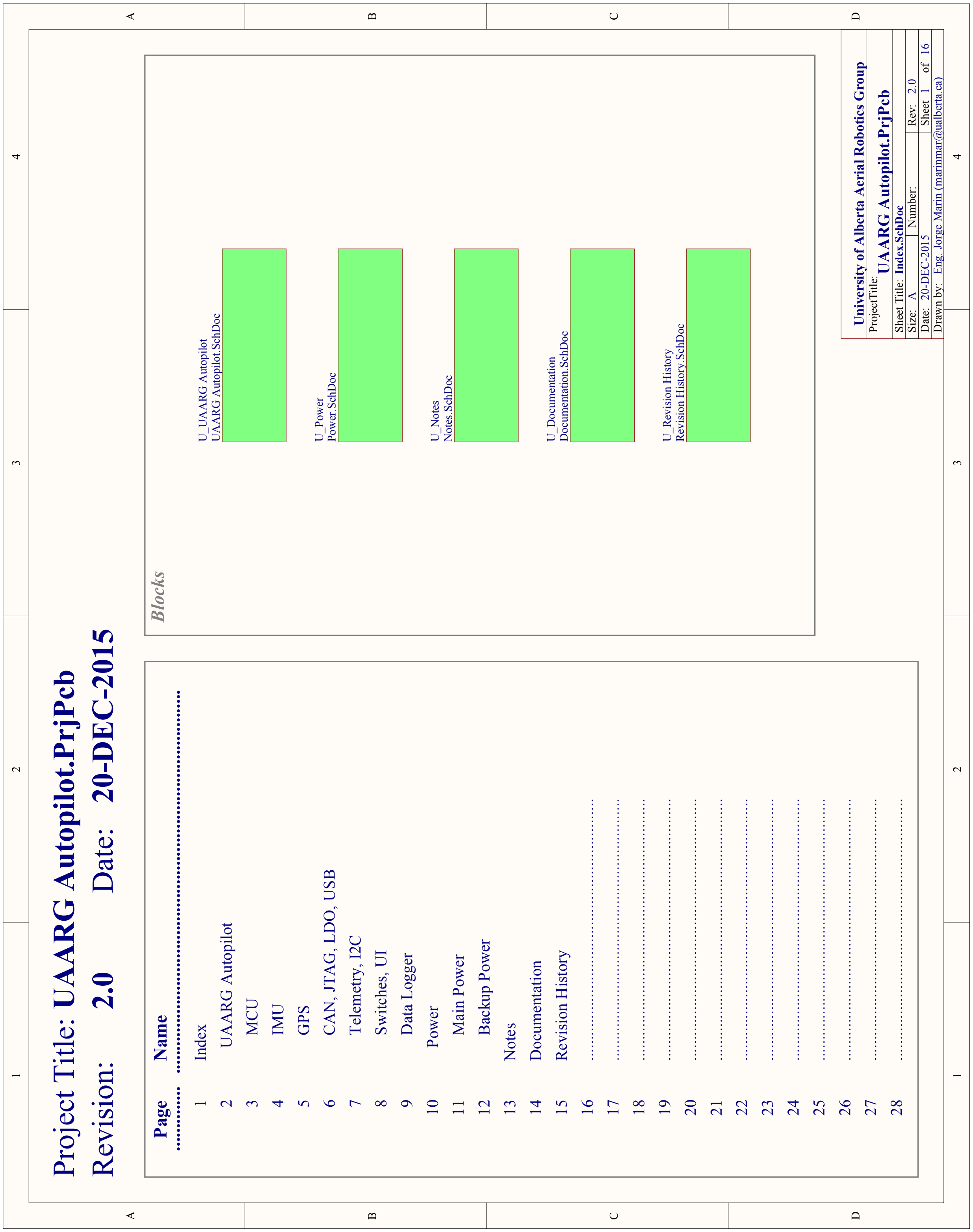


Figure 4.31: Index.

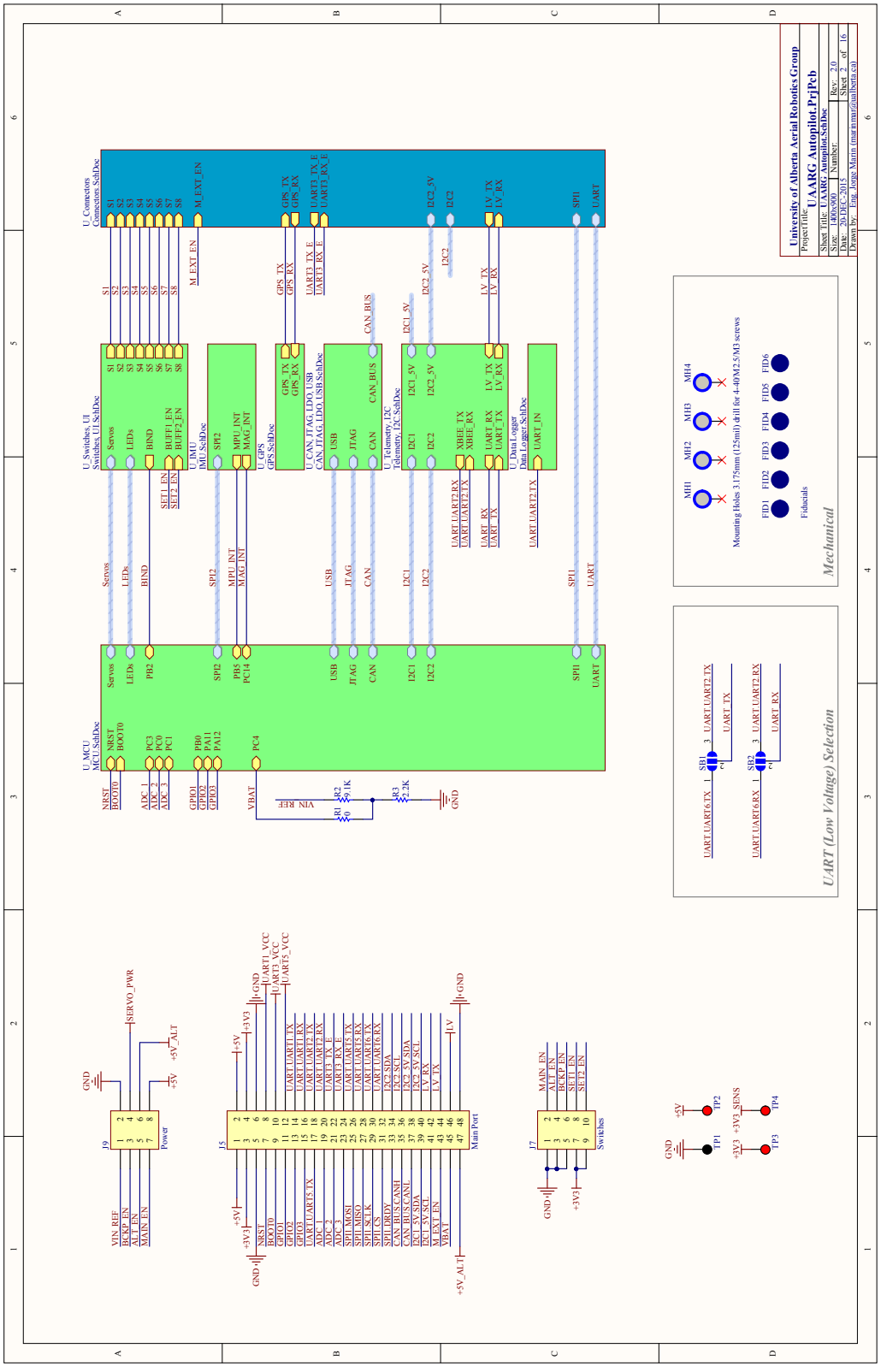


Figure 4.32: UAARG Autopilot.

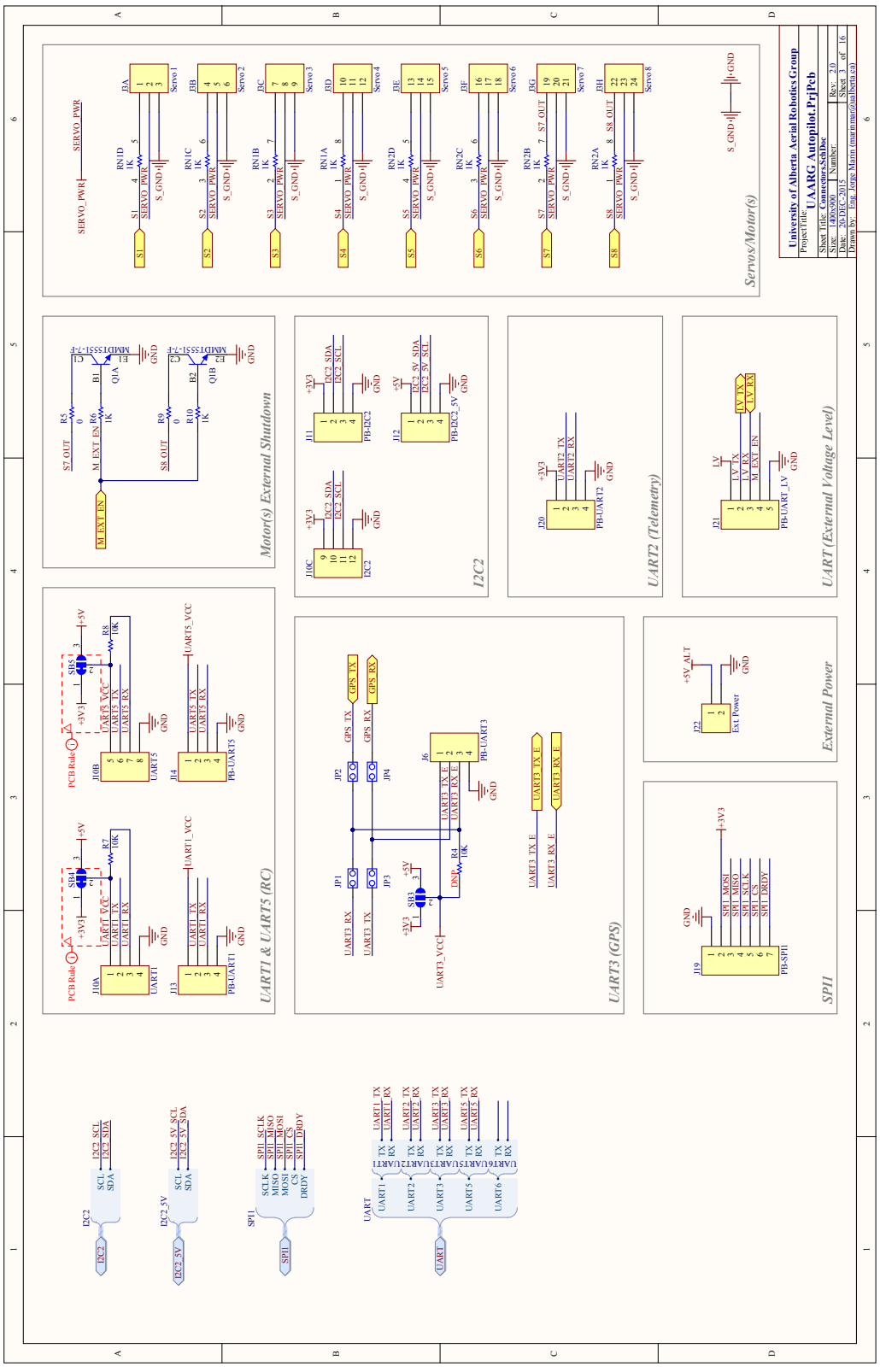


Figure 4.33: Connectors.

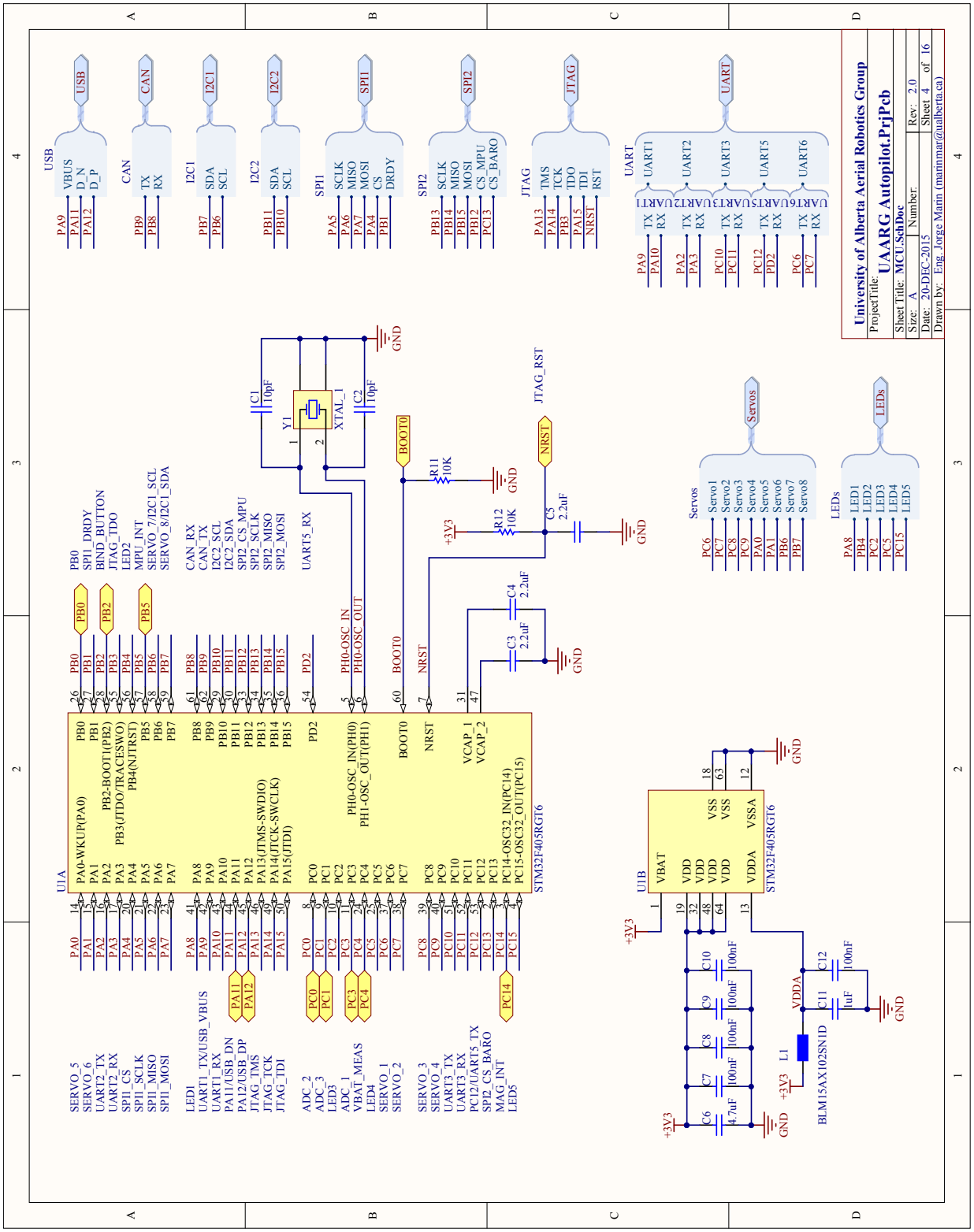


Figure 4.34: MCU.

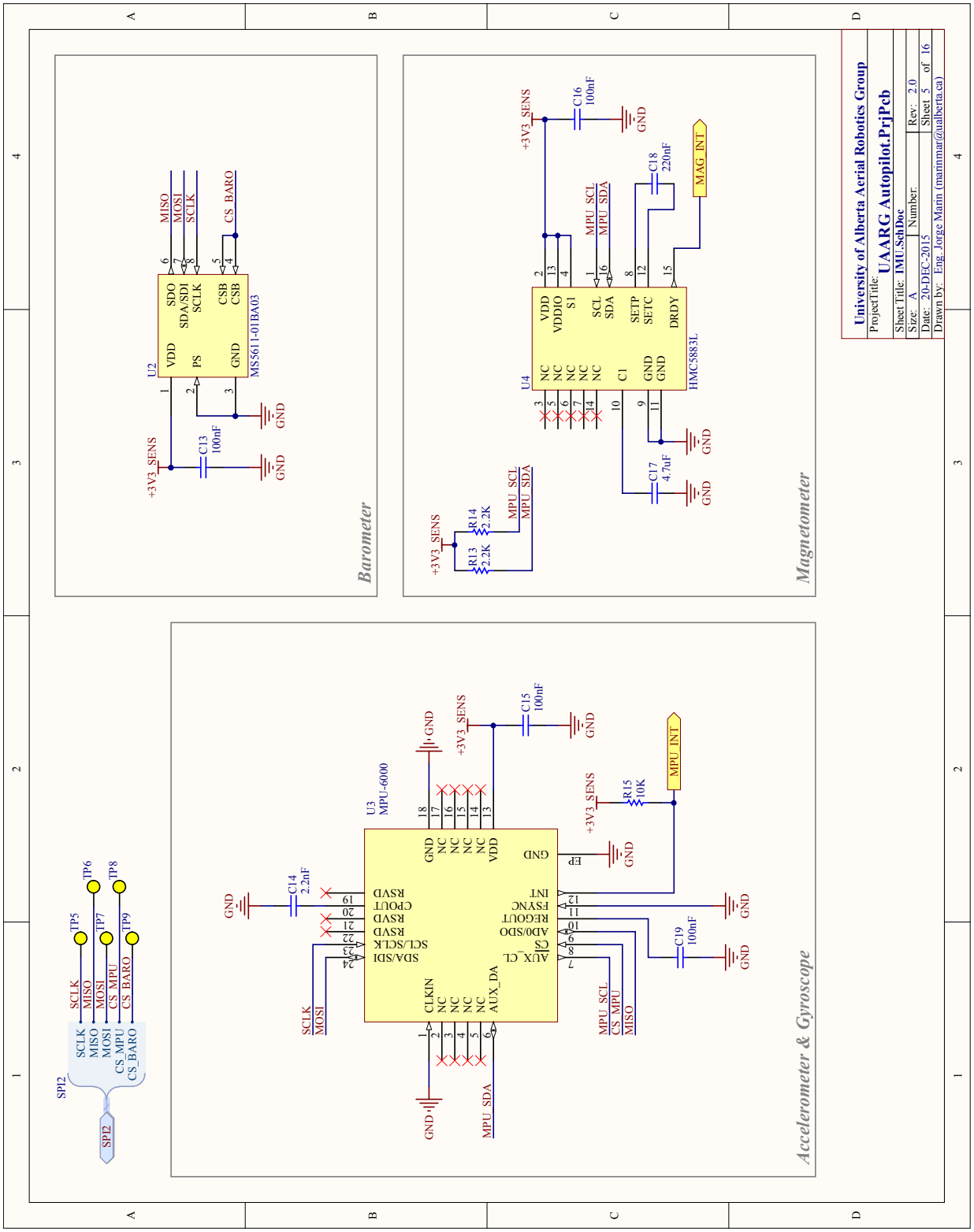


Figure 4.35: IMU.

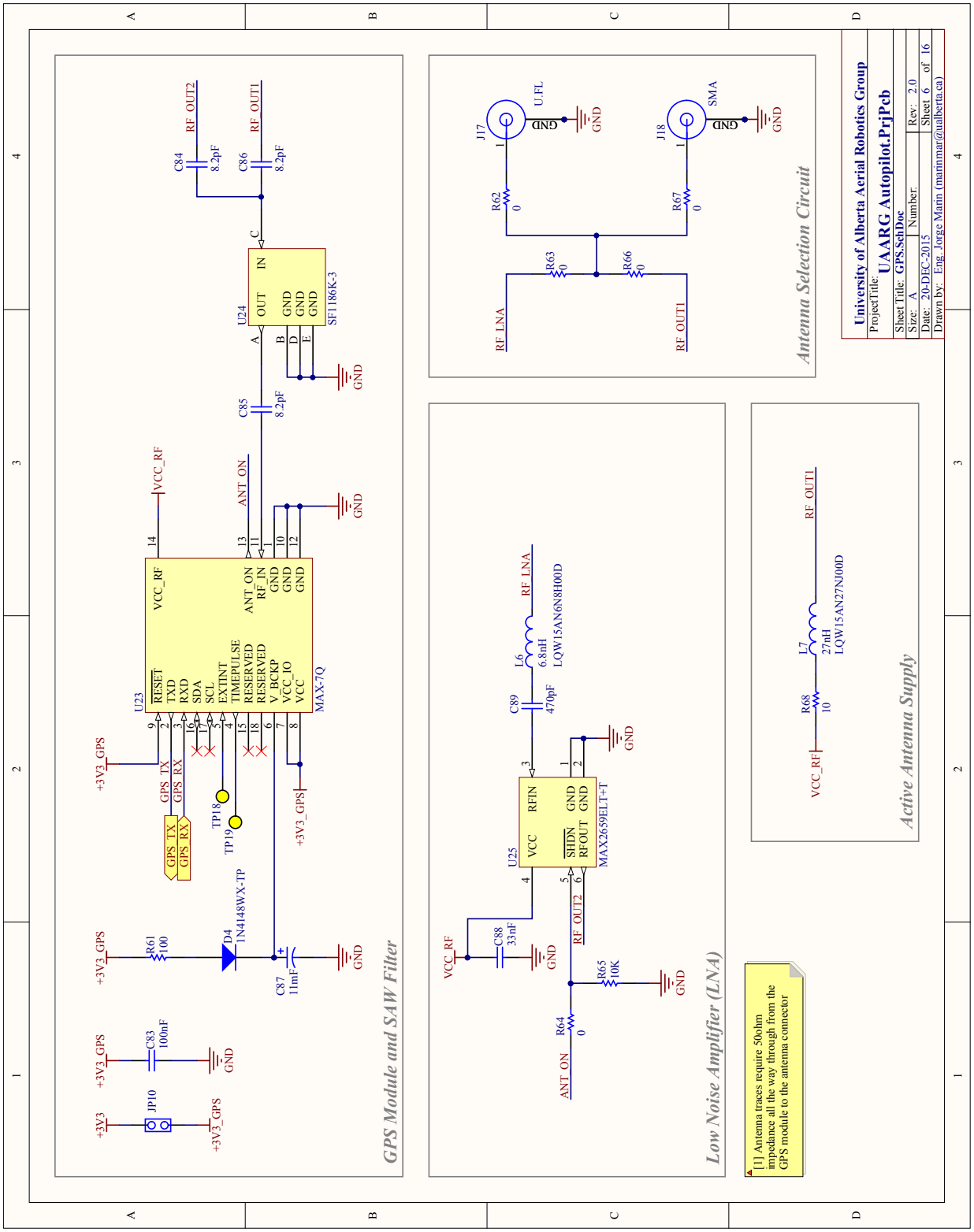


Figure 4.36: GPS.

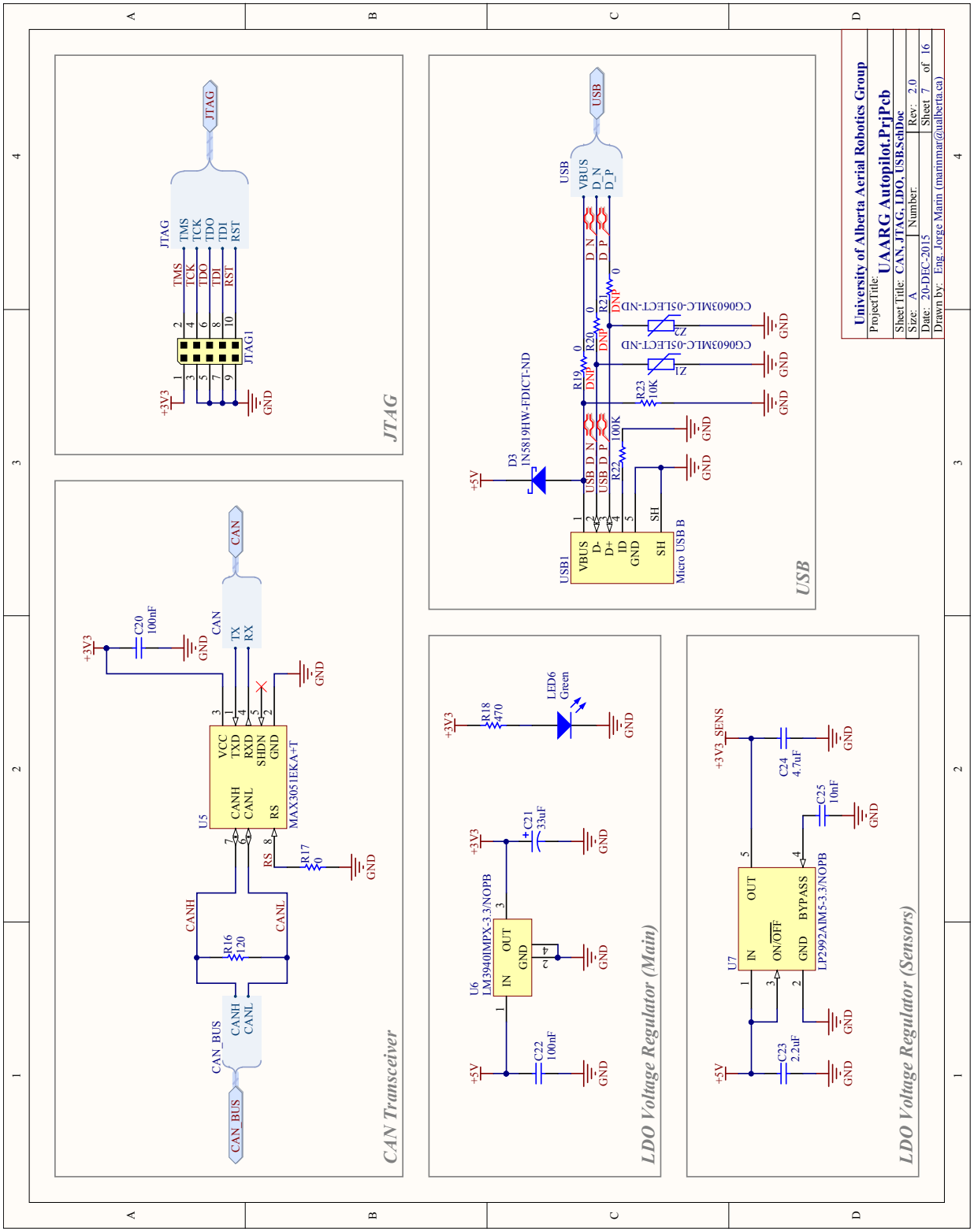


Figure 4.37: CAN, JTAG, LDO, USB.

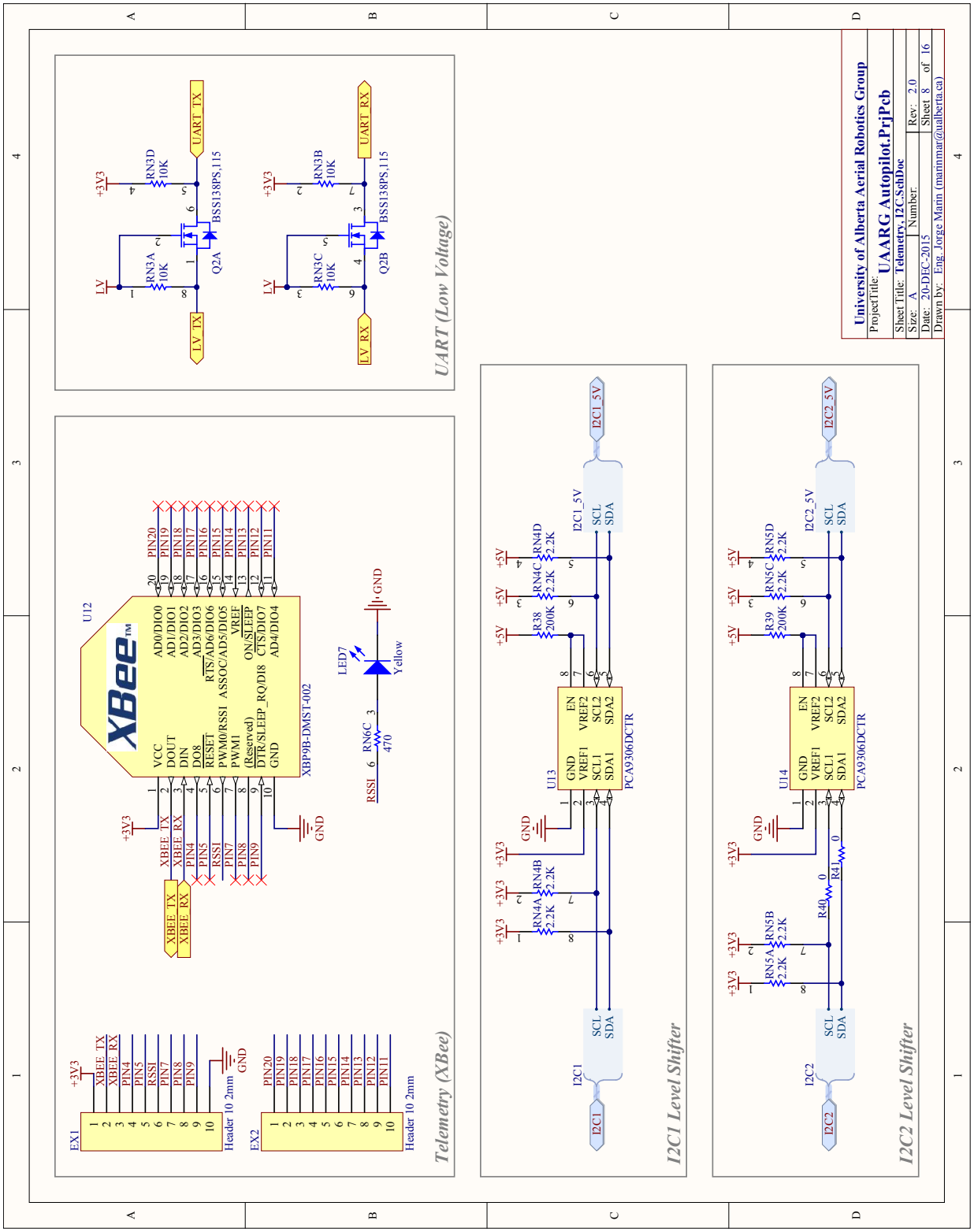


Figure 4.38: Telemetry, I2C.

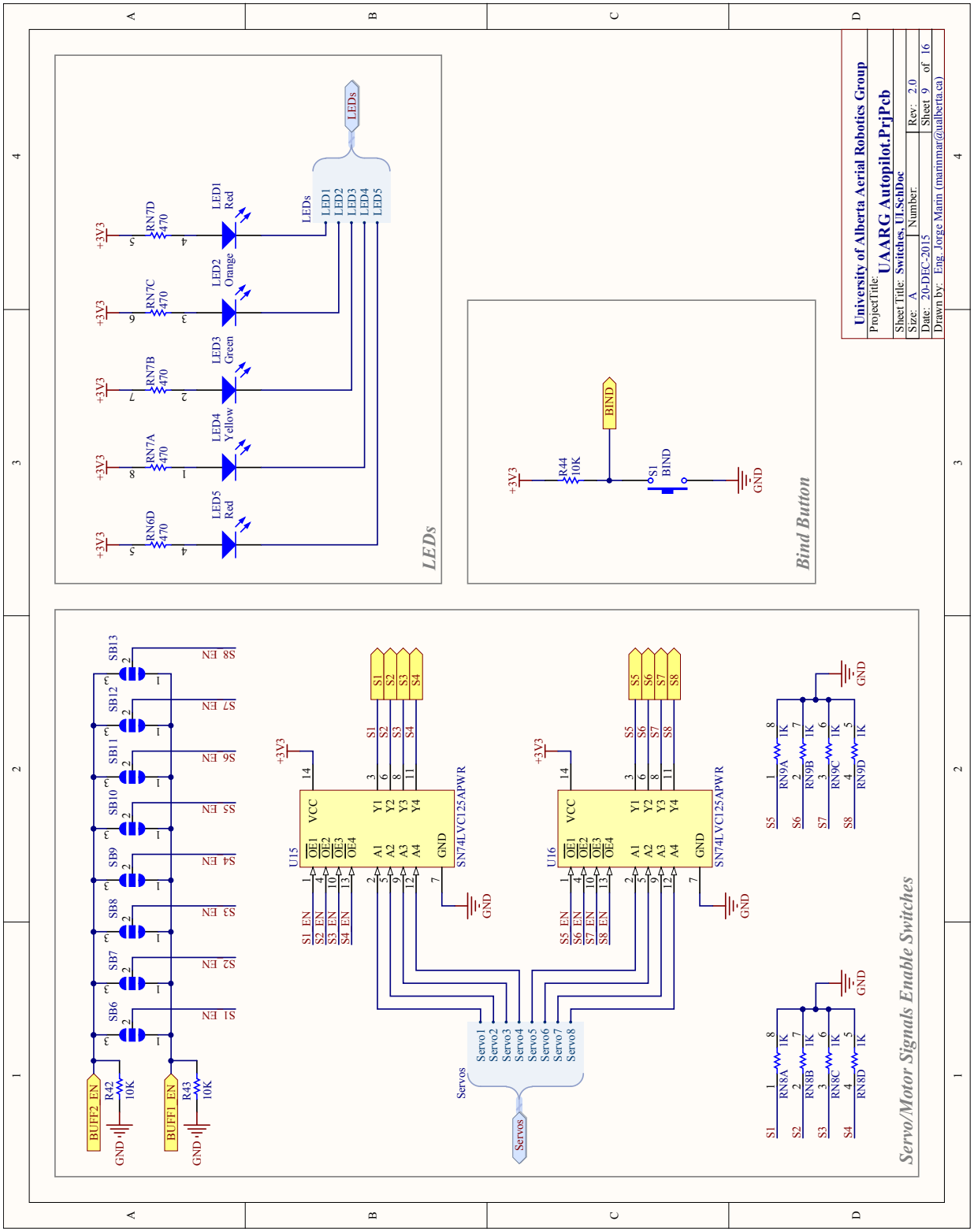


Figure 4.39: Switches, UI.

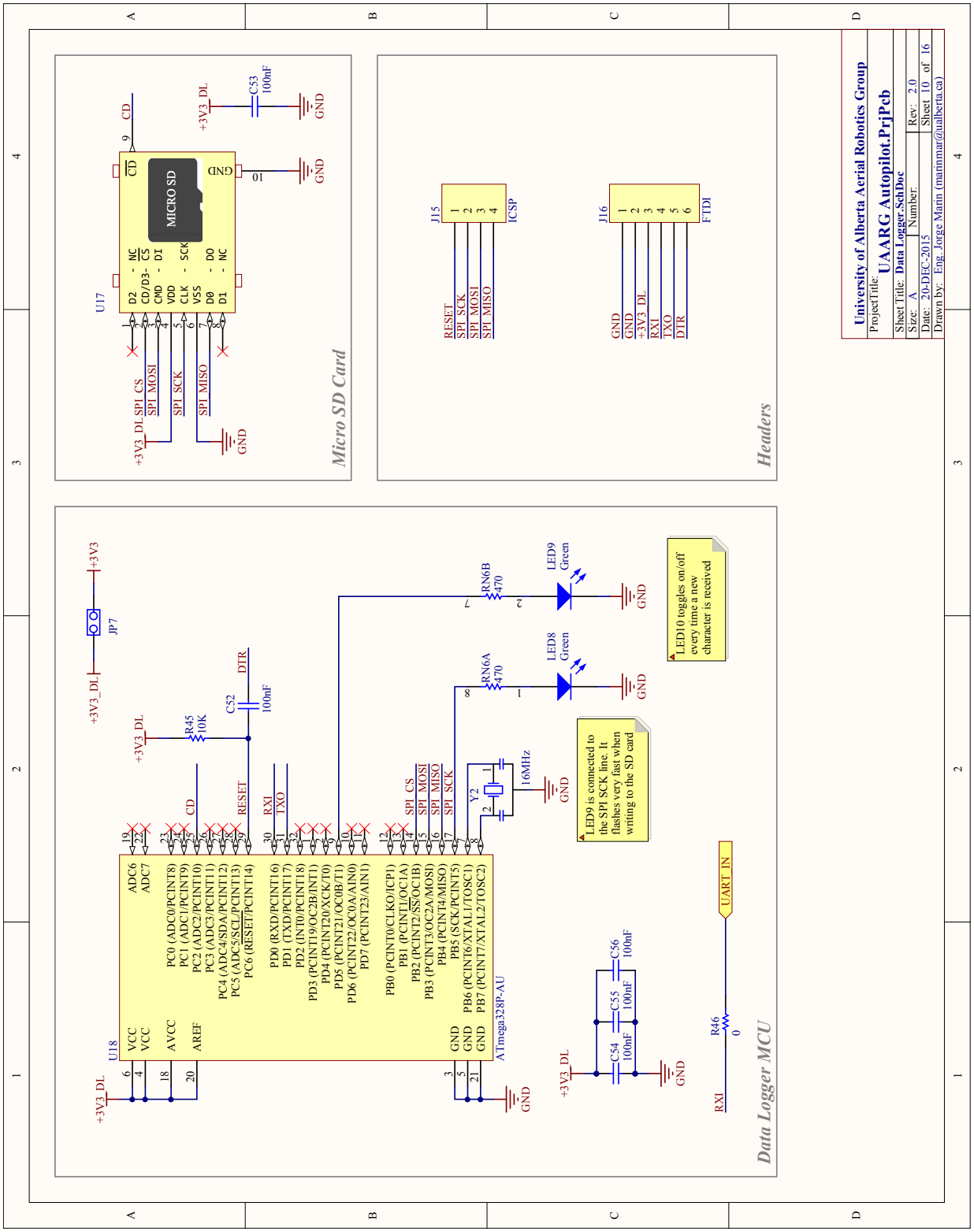


Figure 4.40: Data Logger.

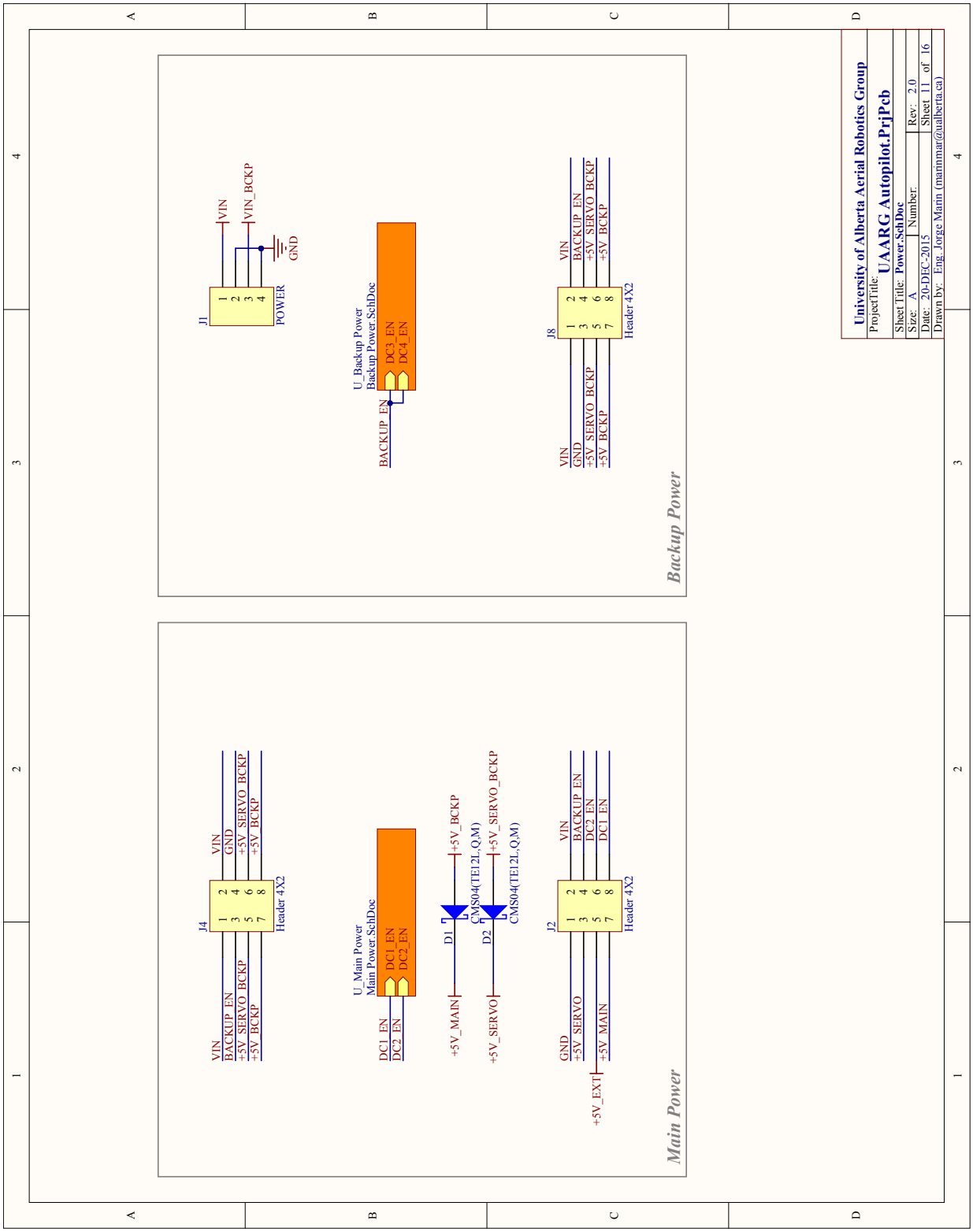


Figure 4.41: Power.

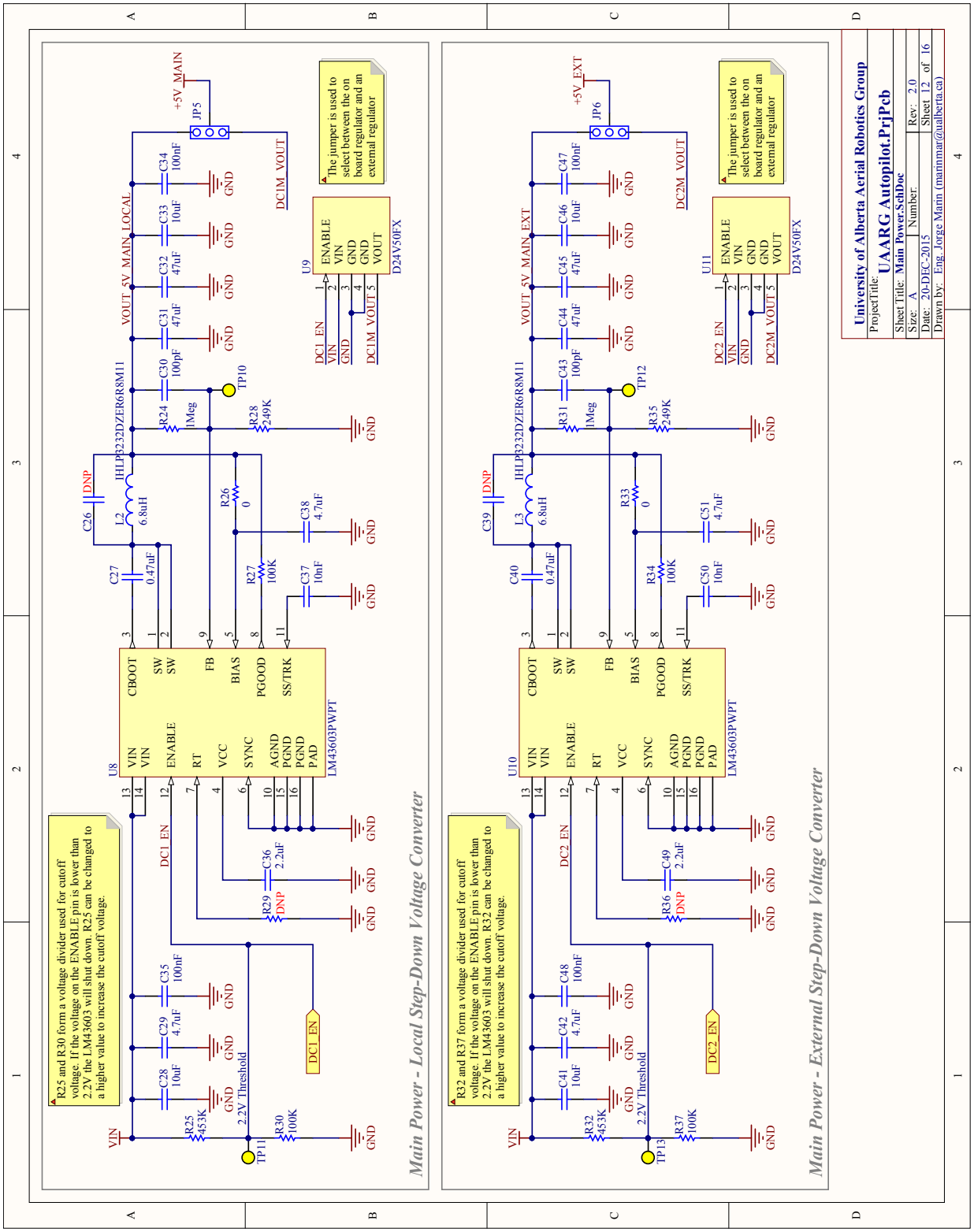


Figure 4.42: Main Power.

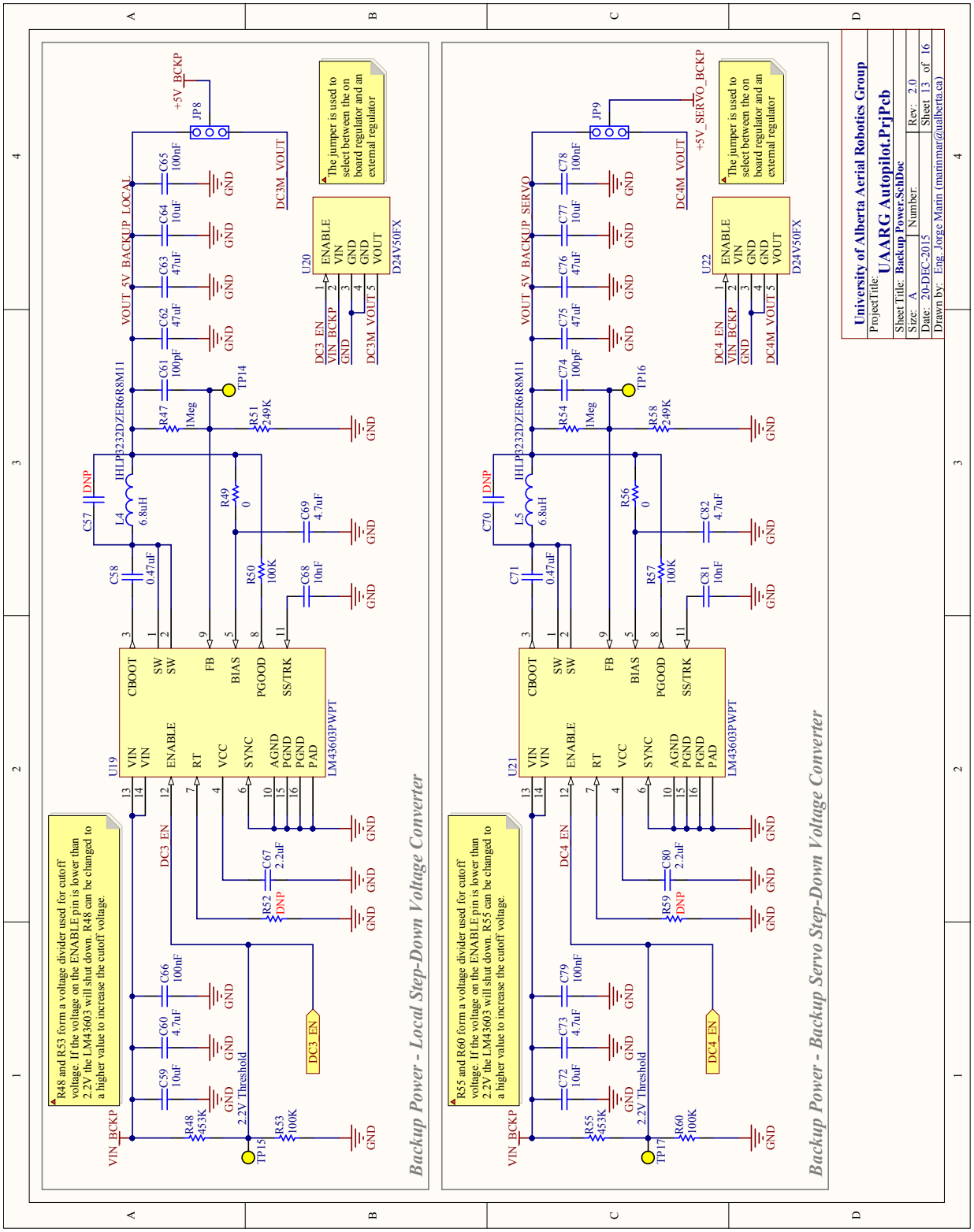


Figure 4.43: Backup Power.

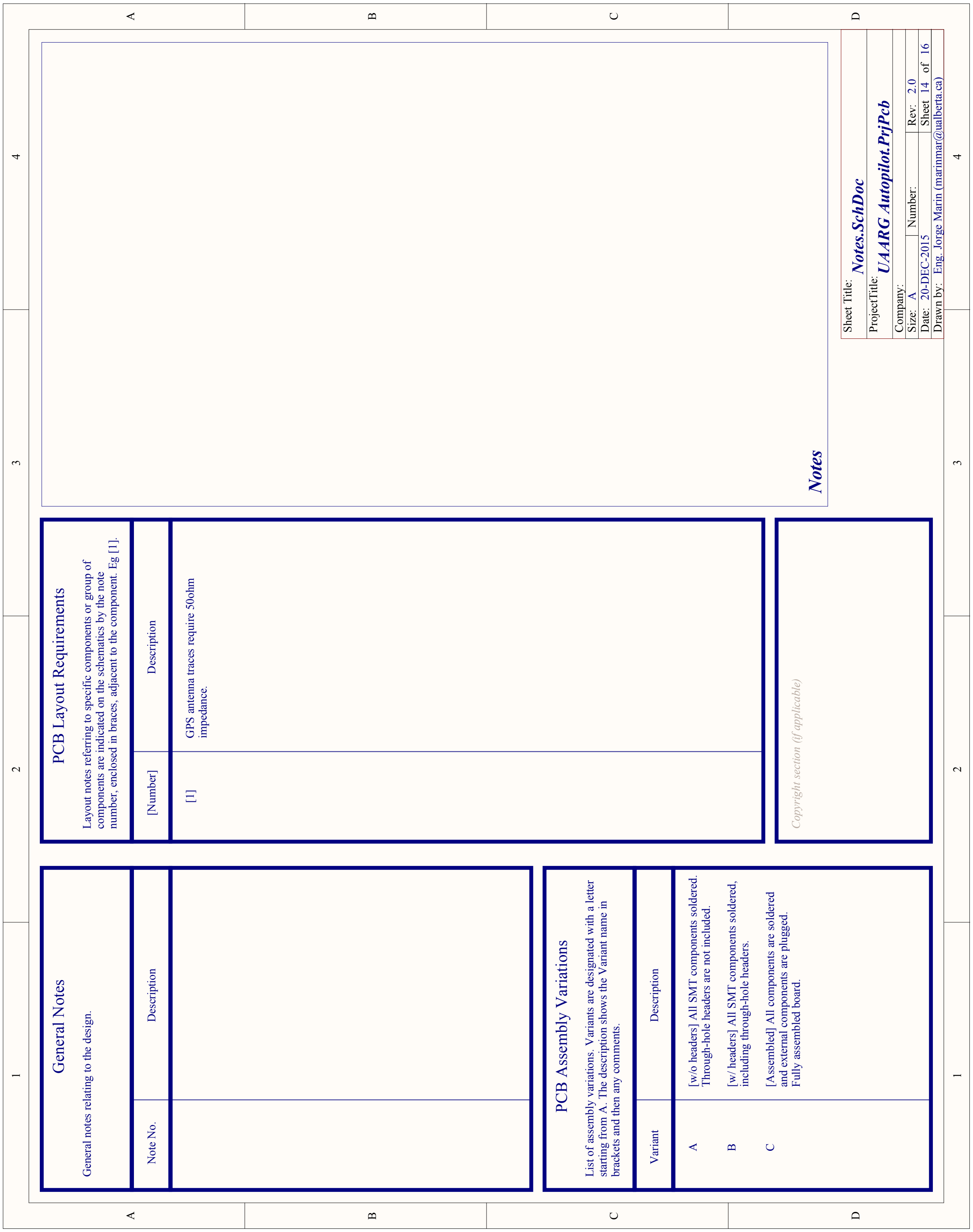
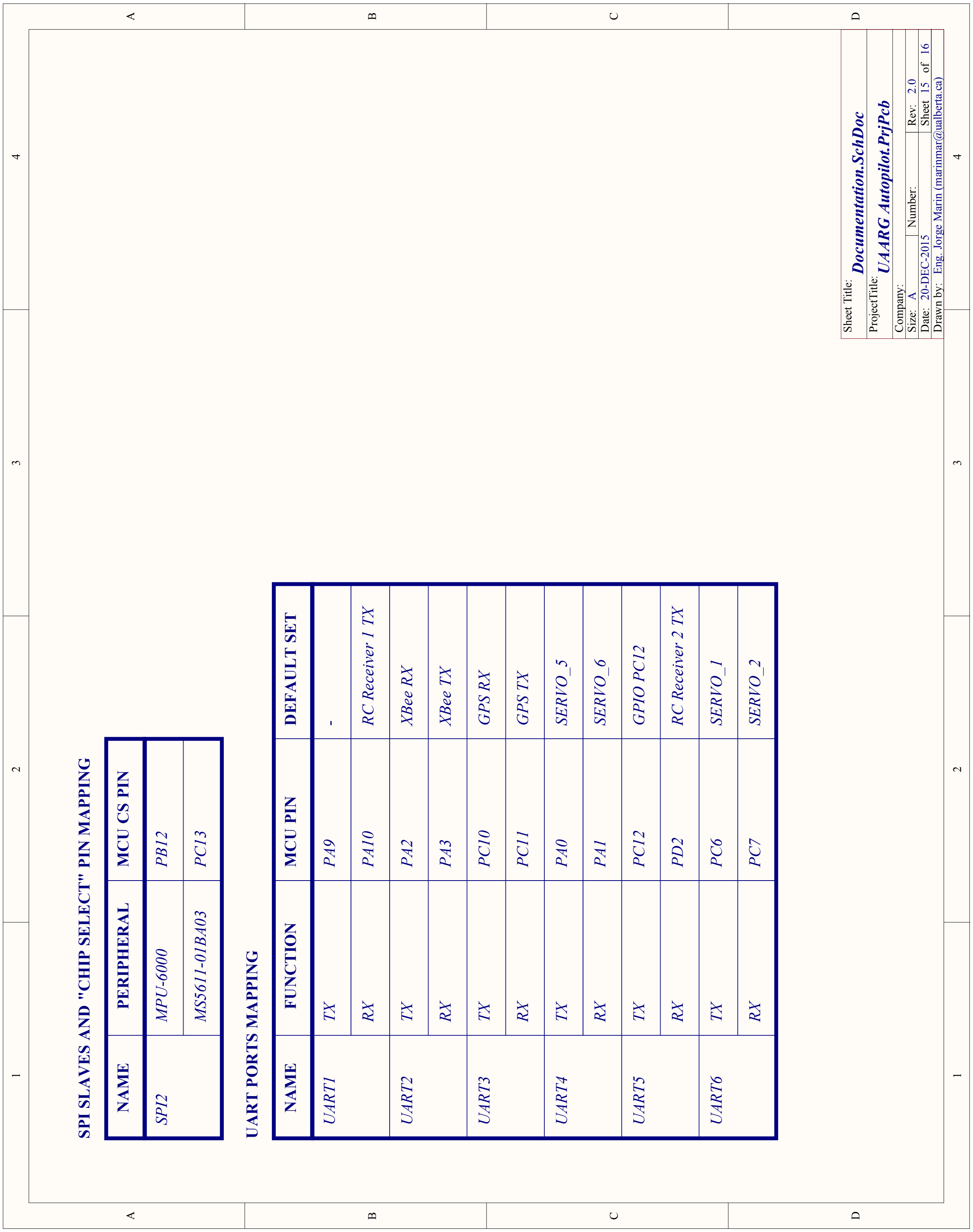


Figure 4.44: Notes.



SPI SLAVES AND "CHIP SELECT" PIN MAPPING

NAME	PERIPHERAL	MCU CS PIN
SPI2	MPU-6000	PB12
	MS5611-01BA03	PC13

UART PORTS MAPPING

NAME	FUNCTION	MCU PIN	DEFAULT SET
UART1	TX	PA9	-
	RX	PA10	RC Receiver 1 TX
UART2	TX	PA2	XBee RX
	RX	PA3	XBee TX
UART3	TX	PC10	GPS RX
	RX	PC11	GPS TX
UART4	TX	PA0	SERVO_5
	RX	PA1	SERVO_6
UART5	TX	PC12	GPIO PC12
	RX	PD2	RC Receiver 2 TX
UART6	TX	PC6	SERVO_1
	RX	PC7	SERVO_2

Figure 4.45: Documentation.

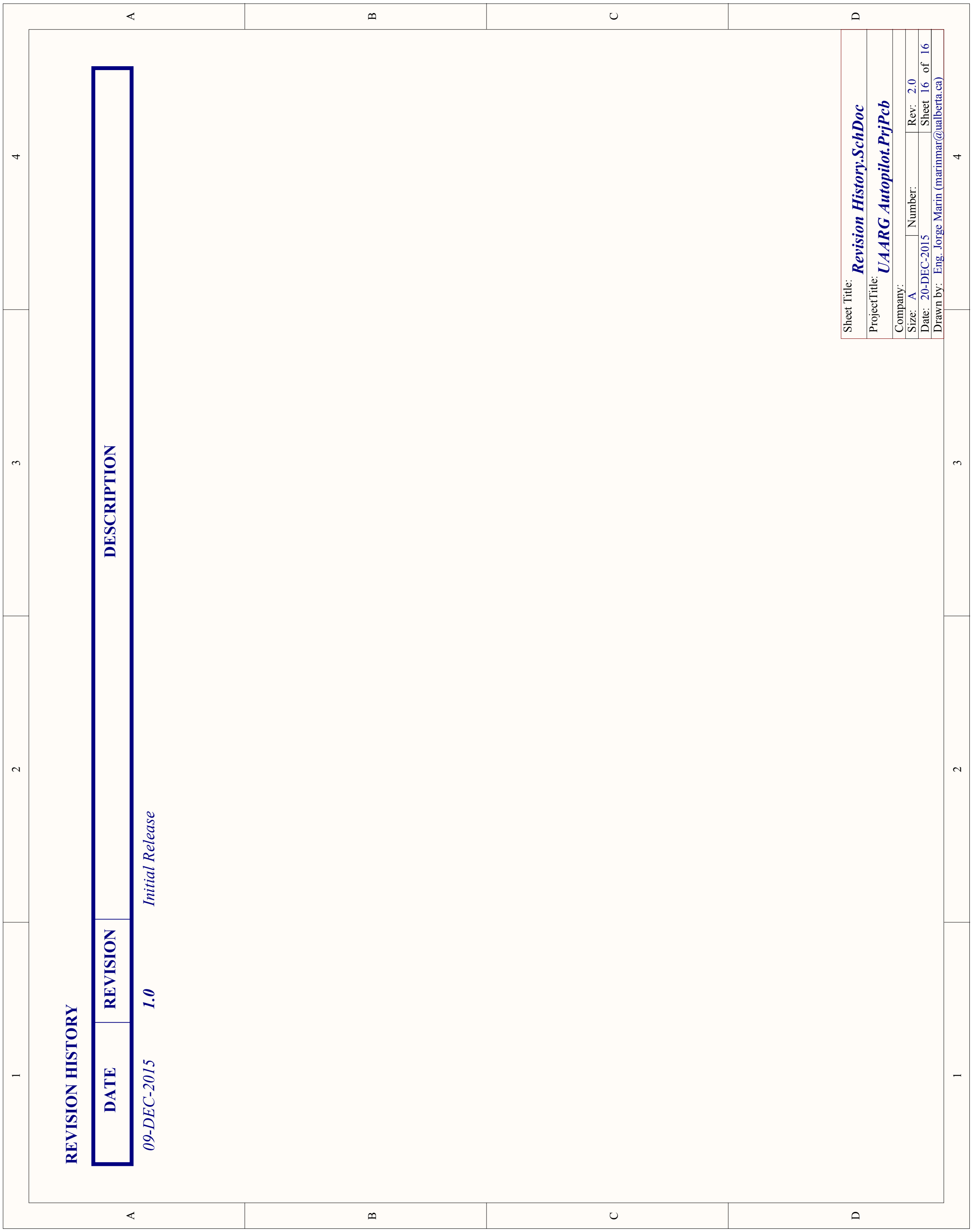


Figure 4.46: Revision History.

5 Revision History

Table 5.1: UAARG Autopilot Board User Guide Revision History.

Rev.	**Date**	**Changes**
1.0	04-Aug-2016	First issue.