# Orbital Platform Revision 3 Reference Manual

Tim S., Electrical team, Flight Software team. Version 20241014. Space and Satellite Systems at UC Davis

## 1 Overview

Orbital Platform Revision 3 (OPR3) is an integrated flight system module designed for the REALOP-1 cubesat mission. It features microcontrollers and many sensors, acting as the flight computer, avionics, and forming the core of the satellite electronics system. This document is a companion to OPR3 hardware that includes technical details as well as instructions for working with OPR3.

## 2 Features

### 2.1 Processors

The Primary microcontroller (MCU) is connected to both coprocessors (Radio MCU and MGT MCU) with asynchronous UART. All three microcontrollers can be programmed via the serial wire debug (SWD) protocol and the NRST signals made available on connectors. There is an additional bidirectional UART from Primary MCU available to the user for developing, debugging, and diagnosing the satellite system.

Each MCU includes an internal temperature sensing diode that has acceptable precision but needs a calibrated offset to achieve acceptable accuracy. The temperature information can be used to supplement the dedicated high quality temperature sensors.

#### 2.1.1 Primary MCU [mcu0]

The Primary MCU [mcu0] is the most privileged microcontroller within the satellite. It is the first microcontroller to begin executing instructions after the hardware safety inhibit mechanisms are disengaged (REALOP-1 has three mechanical deployment switches and one apply/remove before flight (A/RBF) pin), and is responsible for conducting the mandated 30 minute software inhibit timer between satellite deployment and energizing of main power busses/rails.

The Primary MCU runs Flight Software (FSW) team's IntelliSat operating system/program, and has the ability to assert hardware reset to both of the two coprocessors and all sensors, and has control of all power rails besides [Vsys], which is always-on when there are no hardware inhibition and powers the main components of OPR3. Primary MCU is also connected to all diagnostic and instrumentation sensors on board the satellite, including temperature sensors and power monitor/diagnostic sensors.

The Primary MCU schedules experiments and manages all payloads and scientific equipment on board the satellite. It controls power distribution to all subsystems besides the always-on [Vsys] domain.

The Primary MCU is STM32L476ZGTx where x is "6" (standard industrial temperature range -40 °C to 85 °C) for development and engineering assembly versions, and "3" (extra extended industrial temperature range -40 °C to 125 °C) for flight candidate assembly versions. The higher temperature grade is merely a classification by ST indicating higher quality standards, but does not physically differ from any other temperature grade (identical silicon die and packaging process) and should make no difference for development purposes.

| Pin name | Signal mnemonic | MCU Pin | Description |
|---|---|---|---|
| TX | mcu02-0tx | PD5 | USART2 TX |
| RX | mcu02-0rx | PD6 | USART2 RX |

| | | | |
|---|---|---|---|
| TX | mcu01-0tx | PG9 | USART1 TX |
| RX | mcu01-0tx | PG10 | USART1 RX |
| PWM | esc-pwm | PE9 | |
| TX | esc-optx | PC4 | USART3 TX AF7 |
| RX | esc-oprx | PC5 | USART3 RX AF7 |

### 2.1.2 Radio MCU [mcu1]

The Radio MCU [mcu1] controls two AX5043 single-chip radio transceiver chips, operating on VHF and UHF bands respectively. Radio MCU has the role of managing the radio transceivers in real time, providing and accepting data as needed, as directed by the Primary MCU. Like the Magnetorquer MCU [mcu2], it is STM32L431RCT6.

The Radio MCU also controls the power supply to each of the two transceiver systems. A logical enable signal must be asserted before the corresponding radio band can be configured and used. Cycling power to transceivers will cause the radio chips to go high impedance and lose register configurations. A full hardware and software reset followed by complete programming of all registers must be performed after a power cycle to the radio system. This ability to control power can be used to conserve power budget or issue an extreme-case physical hardware reset.

While any of the radio systems are powered down, the logic signals must be asserted to a low voltage or set to high impedance, to avoid risk of inadvertent and out-of-specification delivery of power to radio transceivers through protection diodes.

| Pin name | Signal mnemonic | MCU Pin | Description |
|---|---|---|---|
| RX | mcu01-0rx | PA9 | USART1 TX AF7 |
| TX | mcu01-0tx | PA10 | USART1 RX AF7 |
| | | | |
| | | | |
| | | | |
| | | | |

### 2.1.3 Magnetorquer MCU [mcu2]

The Magnetorquer (MGT) MCU controls a three-axis magnetorquer driver and coil subsystem that can be connected to OPR3 via cable harness. It is responsible for the real time control and monitoring of each MGT coil as directed by Primary MCU. Like the Radio MCU [mcu1], it is STM32L431RCT6.

Depending on the specific need and engineering considerations of the satellite system, the MGT MCU can be bypassed and not used, in the case that Primary MCU is directly connected to a driver MCU on another circuit board via the MGT UART port and cable harnesses. The ability to choose between controlling MGT using the on board coprocessor or an off board microcontroller provides flexibility to the mission design.

| Pin name | Signal mnemonic | MCU Pin | Description |
|---|---|---|---|
| RX | mcu02-0rx | PB6 | USART1 TX AF7 |
| TX | mcu02-0tx | PB7 | USART1 RX AF7 |

| | | | |
|---|---|---|---|
| PWM1 | mgt-drv0-pwm1 | PA0 | TIM2_CH1 AF1 |
| PWM0 | mgt-drv0-pwm0 | PA1 | TIM2_CH2 AF1 |
| PWM1 | mgt-drv1-pwm1 | PB10 | TIM2_CH3 AF1 |
| PWM0 | mgt-drv1-pwm0 | PB11 | TIM2_CH4 AF1 |
| PWM0 | mgt-drv2-pwm0 | PA9 | TIM1_CH2 AF1 |
| PWM1 | mgt-drv2-pwm1 | PA8 | TIM1_CH1 AF1 |
| ISEN | mgt-drv0-isen | PC1 | |
| ISEN | mgt-drv1-isen | PC2 | |
| ISEN | mgt-drv2-isen | PC3 | |

## 2.2 Sensors

Each inertial sensor (Inertial measurement unit, IMU) and magnetometer (MAG) includes an internal temperature sensing diode that has acceptable precision but needs a calibrated offset to achieve acceptable accuracy. The temperature information can be used to supplement the dedicated high quality temperature sensors.

### 2.2.1 Inertial sensors [imu0] and [imu1]

There are two redundant ASM330 inertial sensors onboard OPR3 which each include a 3 axis gyroscope and 3 axis accelerometer within the package. The gyroscopes indicate the rate of rotation of the satellite and are used with Attitude Determination and Control Systems (ADCS) team's algorithms and on board actuators to locate and control the satellite. The gyroscopes also support science experiments like verification of the hard disk drive (HDD) reaction wheel payload.

#### 2.2.1.1 imu0 (U5)

We will be using ***SPI3 for imu0***

Pinning information for imu0 (reference designator U5)

| Pin name | Signal mnemonic | MCU Pin | Description |
|---|---|---|---|
| SDO | imu0-miso | PB4 | SPI3_MISO |
| SDI | imu0-mosi | PB5 | SPI3_MISO |
| SCK | imo0-sck | PB3 | SPI3_SCK |
| NCS | imu0-ncs | PB6 | GPIO for chip select |
| INT1 | imu0-int1 | PG15 | Interrupt for IMU events |
| INT2 | imu0-int2 | PB7 | Interrupt for IMU events |

#### 2.2.1.2 imu1 (U3)

imu1 is connected to mcu0's SPI2

Pinning information for imu1:

| Pin name | Signal mnemonic | MCU Pin | Description |
|---|---|---|---|
| MISO | imu1-miso | PB14 | SPI2_MISO |
| MOSI | imu1-mosi | PB15 | SPI2_MOSI |
| SCK | imu1-sck | PB13 | SPI2_SCK |
| CS | imu1-ncs | PB12 | SPI2_NSS (or GPIO chip select) |

| | | | |
|---|---|---|---|
| | imu1-int1 | PB10 | |
| | imu1-int2 | PB11 | |

### 2.2.2 Magnetometers [mag0] and [mag1]

There are two redundant QMC5883L 3 axis magnetometers on board OPR3. They are basically digital compasses that enable measurement of the earth's magnetic field, when not disturbed by the activity of magnetorquers or other electronic systems. The magnetometers provide an important input to ADCS software and can supplement verification of experiments like the HDD reaction wheel payload.

#### 2.2.2.1 mag0 (U8)

Pinning information for mag0:

| Pin name | Signal mnemonic | MCU Pin | Description |
|---|---|---|---|
| SDA | mag0-sda | PB9 | |
| SCL | mag0-scl | PB8 | |
| DRDY | mag0-drdy | PE0 | |

#### 2.2.2.2 mag1 (U4)

Pinning information for mag0:

| Pin name | Signal mnemonic | MCU Pin | Description |
|---|---|---|---|
| SDA | mag0-sda | PF1 | |
| SCL | mag0-scl | PF0 | |
| DRDY | mag0-drdy | PE1 | |

### 2.2.3 Temperature sensors [tmp0] and [tmp1]

There are two redundant TMP275 high accuracy temperature sensors on board OPR3. They provide scientific data and instrumentation regarding the health of the satellite.

### 2.2.4 Power monitor [pmon]

There is an INA226 voltage, current, and derived power sensor IC on board OPR3. It monitors the power input to and consumed by OPR3 as instrumentation regarding the health of the satellite.

## 2.3 Memories

Although we provide suggestions on the usage of memory peripherals on board OPR3, their usage is completely optional. We expect the flight software team to use them as they see fit. It is important to note that there are three mandatory error-corrected NAND flash devices in the form of the three microcontrollers on board OPR3. They contain pseudo-ROM code that is only accessible by the vendor, STMicroelectronics, and runs upon startup and before execution of any user code. This reduces the reliability of our electronic system, but because there are many successful missions in low earth orbit using very similar STM32 microcontrollers with the same vendor ROM limitation, we expect it to not pose a significant issue to the integrity of our mission.

### 2.3.1 NAND flash [nand]

The NAND flash is W25Q128JVS and can retain a relatively large amount of data (128 Mbit or 16 MB) in non-volatile storage. Due to the physical nature of the internal construction of flash storage cells, we believe that NAND flash is likely susceptible to radiation events due to the elevated amount of ionizing radiation in low earth orbit. Radiation events could result in a range of symptoms from individual bit flips, page erasure, whole chip erasure, or permanent damage to chip function. We intend NAND flash to be used only for

non-flight-critical data so that the mission can still continue in case of disruption to NAND flash. Examples of flight-critical data include flight software program code, calibration variables, etc. Examples of non-flight-critical data include science collected in orbit, as long as the experiments can be repeated.

### 2.3.2 Ferroelectric random access memory [fram]

The FRAM chip is MB85RS256B and can retain a relatively small amount of data (256 kbit or 32 kB) in non-volatile storage. The operating principle of FRAM in comparison to flash memory yields expectation that FRAM is more tolerant of ionizing radiation. FRAM is provisioned to store smaller but more important or less replaceable data.

## 2.4 Radio transceivers

### 2.4.1 UHF transceiver

Chip U10

| Pin mnemonic | MCU Pin | MCU Config | Description |
|---|---|---|---|
| DATA | mcu1, PC5 | | Data input/output |
| DCLK | mcu1, PC4 | | Clock output |
| SYSCLK | NC | | |
| SEL | mcu1, PA3 | gpio chip select | CS for UHF SPI1 bus |
| CLK | mcu1, PA5 | SPI1_SCK | SCLK for UHF SPI1 bus |
| MOSI | mcu1, PA7 | SPI1_MOSI | MOSI for UHF SPI1 bus |
| MISO | mcu1, PA6 | SPI1_MISO | MISO for UHF SPI1 bus |
| IRQ | mcu1, PA2 | | TX/RX interrupt |
| PWRAMP | mcu1, PA1 | | UHF power amplifier control |
| ANTSEL | mcu1, PA0 | | UHF antenna select |
| GPADC1 | mcu1, PC1 | | GPADC input |
| GPADC2 | mcu1, PC0 | | GPADC input |

### 2.4.2 VHF transceiver

Chip U15

| Pin mnemonic | MCU Pin | | Description |
|---|---|---|---|
| DATA | mcu1, PC8 | | Data input/output |
| DCLK | mcu1, PC7 | | Clock output |
| SYSCLK | NC | | |
| SEL | mcu1, PC6 | | CS for VHF SPI bus |
| CLK | mcu1, PB13 | | SCLK for VHF SPI bus |
| MOSI | mcu1, PB15 | | MOSI for VHF SPI bus |
| MISO | mcu1, PB14 | | MISO for VHF SPI bus |
| IRQ | mcu1, PB11 | | TX/RX interrupt |
| PWRAMP | mcu1, PB10 | | VHF power amplifier control |
| ANTSEL | mcu1, PB2 | | VHF antenna select |
| GPADC1 | mcu1, PB1 | | GPADC input |
| GPADC2 | mcu1, PB0 | | GPADC input |

### 2.5 Auxiliary features

#### 2.5.1 User LEDs

There are six user addressable LEDs of different colors on OPR3 to aid in development and debugging.

| LED | Connected MCU | Pin | Polarity | Color |
|---|---|---|---|---|
| D1 | mcu0 | PE2 | Push/active high | Red |
| D2 | mcu0 | PD3 | Push/active high | Green |
| D3 | mcu0 | PD1 | Push/active high | Blue |
| D4 | mcu0 | PD14 | Push/active high | White |
| D5 | mcu0 | PG11 | Push/active high | Ice Blue |
| D6 | mcu1 | PC2 | Push/active high | Yellow |

#### 2.5.2 User pushbutton [SW1]

| Signal mnemonic | MCU Pin | Description |
|---|---|---|
| SW1 | PG12 | Push button |

#### 2.5.3 Debug GPIO expansion

#### 2.5.4 Debug solder pads

## 3 Connectors

### 3.1 Connector types

### 3.2 Connector details

#### 3.2.1 Connector J0 [mgttlm]

J0 [mgttlm] is the magnetorquer telemetry connector, intended to provide current feedback from the magnetorquer coils and an I2C bus for instrumentation to the MGT MCU [mcu2].

| Pin | Signal mnemonic | Type | Direction | MCU Pin | Description |
|---|---|---|---|---|---|
| 1 | mgt-diag-ana-isen | Analog CMOS | Input | mcu2 PC0 | Analog current signal for all magnetorquer H-bridge drivers |
| 2 | GND | Power supply | | | Circuit ground |
| 3 | mgt-diag-scl | Digital CMOS | Output | mcu2 PB8 | SCL for MGT instrumentation I2C bus |
| 4 | mgt-diag-sda | Digital CMOS | Bidir. | mcu2 PB9 | SDA for MGT instrumentation I2C bus |
| 5 | GND | Power supply | | | Circuit ground |
| 6 | mgt-uart-optx | Digital CMOS | Output | mcu2 PA3 | UART TX from OPR3 to MGT |
| 7 | GND | Power supply | | | Circuit ground |
| 8 | mgt-uart-oprx | Digital CMOS | Input | mcu2 PA2 | UART RX from MGT to OPR3 |

#### 3.2.2 Connector J1 [mgt0]

| Pin | Signal mnemonic | Type | Direction | MCU Pin | Description |
|---|---|---|---|---|---|
| 1 | mgt-drv0-isen | Analog CMOS | Input | mcu2, PC1 | |

| | | | | | |
|---|---|---|---|---|---|
| 2 | mgt-drv0-pwm0 | Digital CMOS | Output | mcu2, PA1 | |
| 3 | GND | Power supply | | | Circuit ground |
| 4 | mgt-drv0-pwm1 | Digital CMOS | Output | mcu2, PA0 | |

### 3.2.3 Connector J2 [mgt1]

| Pin | Signal mnemonic | Type | Direction | MCU Pin | Description |
|---|---|---|---|---|---|
| 1 | mgt-drv1-isen | Analog CMOS | Input | mcu2, PC2 | |
| 2 | mgt-drv1-pwm0 | Digital CMOS | Output | mcu2, PB11 | |
| 3 | GND | Power supply | | | Circuit ground |
| 4 | mgt-drv1-pwm1 | Digital CMOS | Output | mcu2, PB10 | |

### 3.2.4 Connector J3 [mgt2]

| Pin | Signal mnemonic | Type | Direction | MCU Pin | Description |
|---|---|---|---|---|---|
| 1 | mgt-drv2-isen | Analog CMOS | In put | mcu2, PC3 | |
| 2 | mgt-drv2-pwm0 | Digital CMOS | Output | mcu2, PA9 | |
| 3 | GND | Power supply | | | Circuit ground |
| 4 | mgt-drv2-pwm1 | Digital CMOS | Output | mcu2, PA8 | |

### 3.2.5 Connector J4 [mgtaux]

| Pin | Signal mnemonic | Type | Direction | MCU Pin | Description |
|---|---|---|---|---|---|
| 1 | mgtaux0 | GPIO | Bidir. | mcu2, PA4 | Auxiliary GPIO connected to mcu2 |
| 2 | mgtaux1 | GPIO | Bidir. | mcu2, PA5 | Auxiliary GPIO connected to mcu2 |
| 3 | GND | Power supply | | | Circuit ground |
| 4 | mgtaux3 | GPIO | Bidir. | mcu2, PA7 | Auxiliary GPIO connected to mcu2 |
| 5 | mgtaux2 | GPIO | Bidir. | mcu2, PC4 | Auxiliary GPIO connected to mcu2 |
| 6 | GND | Power supply | | | Circuit ground |
| 7 | mgtaux4 | GPIO | Bidir. | mcu2, PB0 | Auxiliary GPIO connected to mcu2 |
| 8 | mgtaux5 | GPIO | Bidir. | mcu2, PB1 | Auxiliary GPIO connected to mcu2 |

### 3.2.6 Connector J5 [radaux0]

| Pin | Signal mnemonic | Type | Direction | MCU Pin | Description |
|---|---|---|---|---|---|
| 1 | radaux0-gp0 | GPIO | Bidir. | mcu1 PB3 | Auxiliary GPIO connected to mcu1 |
| 2 | GND | Power supply | | | Circuit ground |

| | | | | | |
|---|---|---|---|---|---|
| 3 | radaux0-gp1 | GPIO | Bidir. | mcu1, PB4 | Auxiliary GPIO connected to mcu1 |
| 4 | radaux0-gp2 | GPIO | Bidir. | mcu1, PB5 | Auxiliary GPIO connected to mcu1 |

### 3.2.7 Connector J6 [pan0]

| Pin | Signal mnemonic | Type | Direction | MCU Pin | Description |
|---|---|---|---|---|---|
| 1 | PV3V3 | Power | Output | | 3.3 V (Vsys) output through 100 ohm resistor |
| 2 | GND | Power supply | | | |
| 3 | pan0-scl | Digital CMOS | Output | mcu0, PG14 | |
| 4 | pan0-sda | Digital CMOS | Bidir. | mcu0, PG13 | |
| 5 | GND | Power supply | | GND | |
| 6 | pan0-pd0 | Analog CMOS | Input | mcu0, PC3 | |
| 7 | GND | Power supply | | | |
| 8 | pan0-pd1 | Analog CMOS | Input | mcu0, PF4 | |

### 3.2.8 Connector J7 [radaux1]

| Pin | Signal mnemonic | Type | Direction | MCU Pin | Description |
|---|---|---|---|---|---|
| 1 | radaux1-gp0 | GPIO | Bidir. | mcu1 PB6 | Auxiliary GPIO connected to mcu1 |
| 2 | GND | Power supply | | GND | Circuit ground |
| 3 | radaux1-gp1 | GPIO | Bidir. | mcu1 PB7 | Auxiliary GPIO connected to mcu1 |
| 4 | radaux1-gp2 | GPIO | Bidir. | mcu1 PB8 | Auxiliary GPIO connected to mcu1 |

### 3.2.9 Connector J8 [cam]

*Sponsored by APRL*

| Pin | Signal mnemonic | Type | Direction | MCU Pin | Description |
|---|---|---|---|---|---|
| 1 | cam-oprx | Digital CMOS | Input | mcu0, PC11 | UART RX from CAM to OPR3 |
| 2 | cam-optx | Digital CMOS | Output | mcu0, PC10 | UART TX from OPR3 to CAM |
| 3 | GND | Power supply | | | Circuit ground |
| 4 | cam-sck | Digital CMOS | Output | mcu0, PB13 | SCK for CAM SPI bus |

| Pin | Signal mnemonic | Type | Direction | MCU Pin | Description |
|---|---|---|---|---|---|
| 1 | cam-oprx | Digital CMOS | Input | mcu0, PC11 | UART RX from CAM to OPR3 |
| 5 | cam-miso | Digital CMOS | Input | mcu0, PB14 | MISO for CAM SPI bus |
| 6 | GND | Power supply | | | Circuit ground |
| 7 | cam-mosi | Digital CMOS | Output | mcu0, PB15 | MOSI for CAM SPI bus |
| 8 | cam-ncs | Digital CMOS | Output | mcu0, PB12 | nCS for CAM SPI bus |

### 3.2.10 Connector J9 [uhf-rx]

Skip - only one pin for radios!

### 3.2.11 Connector J10 [uhf-tx]

### 3.2.12 Connector J11 [vhf-rx]

### 3.2.13 Connector J12 [vhf-tx]

### 3.2.14 Connector J13 [pyro0]

| Pin | Signal mnemonic | Type | Direction | MCU Pin | Description |
|---|---|---|---|---|---|
| 1 | GND | Power supply | | | Circuit ground |
| 2 | pyro0-fire | Digital CMOS | Output | mcu0 PB2 | |
| 3 | GND | Power supply | | | Circuit ground |
| 4 | pyro0-isen | Analog CMOS | Input | mcu0 PF8 | |

### 3.2.15 Connector J14 [pyro1]

| Pin | Signal mnemonic | Type | Direction | MCU Pin | Description |
|---|---|---|---|---|---|
| 1 | GND | Power supply | | | Circuit ground |
| 2 | pyro1-fire | Digital CMOS | Output | mcu0 PF12 | |
| 3 | GND | Power supply | | | Circuit ground |
| 4 | pyro1-isen | Analog CMOS | Input | mcu0 PF5 | |

### 3.2.16 Connector J15 [pan1]

| Pin | Signal mnemonic | Type | Direction | MCU Pin | Description |
|---|---|---|---|---|---|
| 1 | PV3V3 | Power | Output | | 3.3 V (Vsys) output through 100 ohm resistor |
| 2 | GND | Power supply | | | Circuit ground |
| 3 | pan1-scl | Digital CMOS | Output | Mcu0, PF11 | |
| 4 | pan1-sda | Digital CMOS | | Mcu0, PF2 | |
| 5 | GND | Power supply | | | |

| | | | | | |
|---|---|---|---|---|---|
| 6 | pan1-pd0 | Analog CMOS | | Mcu0, PF9 | |
| 7 | GND | Power supply | | | |
| 8 | pan1-pd1 | Analog CMOS | | Mcu0, PA0 | |

### 3.2.17 Connector J16 [pan4]

| Pin | Signal mnemonic | Type | Direction | MCU Pin | Description |
|---|---|---|---|---|---|
| 1 | PV3V3 | Power supply | Output | | 3.3 V (Vsys) output through 100 ohm resistor |
| 2 | pan4-pd0 | Analog CMOS | Input | MCU0, PC0 | |
| 3 | GND | Power supply | | | |
| 4 | pan4-pd1 | Analog CMOS | Input | MCU0, PC1 | |

### 3.2.18 Connector J17 [batmon]

| Pin | Signal mnemonic | Type | Direction | MCU Pin | Description |
|---|---|---|---|---|---|
| 1 | PVBAT | Analog Power | Input | | Direct battery voltage sensing |
| 2 | batmon-sda | Digital CMOS | Bidir. | MCU0, PH0 | |
| 3 | GND | Power supply | | | |
| 4 | batmon-scl | Digital CMOS | Bidir. | MCU0, PH1 | |

### 3.2.19 Connector J18 [pan5]

| Pin | Signal mnemonic | Type | Direction | MCU Pin | Description |
|---|---|---|---|---|---|
| 1 | Net-(J18-Pin_1) | | | | |
| 2 | pan5-pd0 | Analog CMOS | Input | Mcu0 PC2 | |
| 3 | GND | Power supply | | | |
| 4 | pan5-pd1 | Analog CMOS | Input | Mcu0 PC3 | |

### 3.2.20 Connector J19 [pan2]

| Pin | Signal mnemonic | Type | Direction | MCU Pin | Description |
|---|---|---|---|---|---|
| 1 | Net-(J19-Pin_1) | | | | |
| 2 | GND | Power supply | | | |
| 3 | pan2-scl | Digital CMOS | Bidir. | mcu0 | |

| | | | | | |
|---|---|---|---|---|---|
| | | | | PG0 | |
| 4 | pan2-sda | Digital CMOS | Bidir. | MCU0, PG1 | |
| 5 | GND | Power supply | | | |
| 6 | pan2-pd0 | Analog CMOS | Input | MCU0, PA1 | |
| 7 | GND | Power supply | | | |
| 8 | pan2-pd1 | Analog CMOS | Input | MCU0, PA2 | |

### 3.2.21 Connector J20 [aux0]

| Pin | Signal mnemonic | Type | Direction | MCU Pin | Description |
|---|---|---|---|---|---|
| 1 | aux0-uart-optx | Digital CMOS | Output | MCU0, PC12 | |
| 2 | GND | Power supply | | | |
| 3 | aux0-uart-oprx | Digital CMOS | Input | MCU0, PD2 | |
| 4 | GND | Power supply | | | |

### 3.2.22 Connector J21 [esc1]

| Pin | Signal mnemonic | Type | Direction | MCU Pin | Description |
|---|---|---|---|---|---|
| 1 | GND | Power supply | | | |
| 2 | esc-pwm | Digital CMOS | Output | MCU0, PE9 | |
| 3 | GND | Power supply | | | Circuit ground |
| 4 | esc-gpio | GPIO | Bidir. | MCU0, PE7 | |

### 3.2.23 Connector J22 [esc0]

| Pin | Signal mnemonic | Type | Direction | MCU Pin | Description |
|---|---|---|---|---|---|
| 1 | GND | Power supply | | | |
| 2 | esc–optx | Digital CMOS | Output | MCU0, PC4 | |
| 3 | GND | Power supply | | | Circuit ground |
| 4 | esc-oprx | Digital CMOS | Input | MCU0, PC5 | |

### 3.2.24 Connector J23 [aux2] - mcu0

| Pin | Signal mnemonic | Type | Direction | MCU Pin | Description |
|---|---|---|---|---|---|
| 1 | aux2-gp0 | GPIO | Bidir. | PA3 | |
| 2 | aux2-gp1 | GPIO | Bidir. | PF13 | |

| | | | | | |
|---|---|---|---|---|---|
| 3 | GND | Power supply | | | Circuit ground |
| 4 | aux2-gp2 | GPIO | Bidir. | PF14 | |
| 5 | aux2-gp3 | GPIO | Bidir. | PF15 | |
| 6 | GND | Power supply | | | Circuit ground |
| 7 | aux2-gp4 | GPIO | Bidir. | PE8 | |
| 8 | aux2-gp5 | GPIO | Bidir. | PD14 | White LED |

### 3.2.24 Connector J24 [aux1] - mcu0

| Pin | Signal mnemonic | Type | Direction | MCU Pin | Description |
|---|---|---|---|---|---|
| 1 | aux1-gp0 | GPIO | Bidir. | PD8 | |
| 2 | aux1-gp1 | GPIO | Bidir. | PD9 | |
| 3 | GND | Power supply | | | Circuit ground |
| 4 | aux1-gp2 | GPIO | Bidir. | PD10 | |
| 5 | aux1-gp3 | GPIO | Bidir. | PD11 | |
| 6 | GND | Power supply | | | Circuit ground |
| 7 | aux1-gp4 | GPIO | Bidir. | PD12 | |
| 8 | aux1-gp5 | GPIO | Bidir. | PD13 | |

### 3.2.24 Connector J24 [aux1] - mcu0

| Pin | Signal mnemonic | Type | Direction | MCU Pin | Description |
|---|---|---|---|---|---|
| 1 | aux1-gp0 | GPIO | Bidir. | PD8 | |
| 2 | aux1-gp1 | GPIO | Bidir. | PD9 | |
| 3 | GND | Power supply | | | Circuit ground |
| 4 | aux1-gp2 | GPIO | Bidir. | PD10 | |
| 5 | aux1-gp3 | GPIO | Bidir. | PD11 | |
| 6 | GND | Power supply | | | Circuit ground |
| 7 | aux1-gp4 | GPIO | Bidir. | PD12 | |
| 8 | aux1-gp5 | GPIO | Bidir. | PD13 | |

### 3.2.24 Connector J28 [mcu0] - mcu0

| Pin | Signal mnemonic | Type | Direction | MCU Pin | Description |
|---|---|---|---|---|---|
| 8 | mcu0-dbgrx | GPIO | Bidir. | PG8 | LPUART1_RX |
| 7 | mcu0-dbtx | GPIO | Bidir. | PG7 | LPUART1_TX |
| 6 | GND | Power supply | | | Circuit ground |
| 5 | mcu0-nrst | GPIO | Bidir. | NRST | |
| 4 | mcu0-swdio | GPIO | Bidir. | PA13 | |
| 3 | GND | Power supply | | | Circuit ground |
| 2 | mcu0-swclk | GPIO | Bidir. | PA14 | |
| 1 | v3v3 | Power supply | | | |

# 4 Usage

## 4.1 Precautions

### 4.1.1 Electrical overstress

Absolute maximum conditions

| Parameter mnemonic | Parameter description | Min. | Typ. | Max. | Unit | Notes |
|---|---|---|---|---|---|---|
| Vin | Main power input port voltage | -0.3 | 4.2 | 5.5 | V | |
| Vsys | Main system voltage | -0.3 | 3.3 | 3.4 | V | |
| Ipin | Current through any connector pin besides main power input | -10 | | 20 | mA | |
| | | | | | | |

### 4.1.2 Mechanical damage

Avoid concentrated force or shock against individual components on the PCB, like decoupling capacitors or integrated circuits. Multilayer ceramic capacitors are highly susceptible to developing cracks and failing short. The edges and the back side of the PCB are significantly more resilient against impact.

If there are thin debug wires soldered to surface mount test pads, exercise extreme caution to avoid pulling them off, as they are very fragile.

## 4.2 Power supplies

## 4.3 Development and diagnostic access

## 4.4 Initializing the system

## 4.5 Configuring components

## 4.6 Interfacing with external modules and subsystems