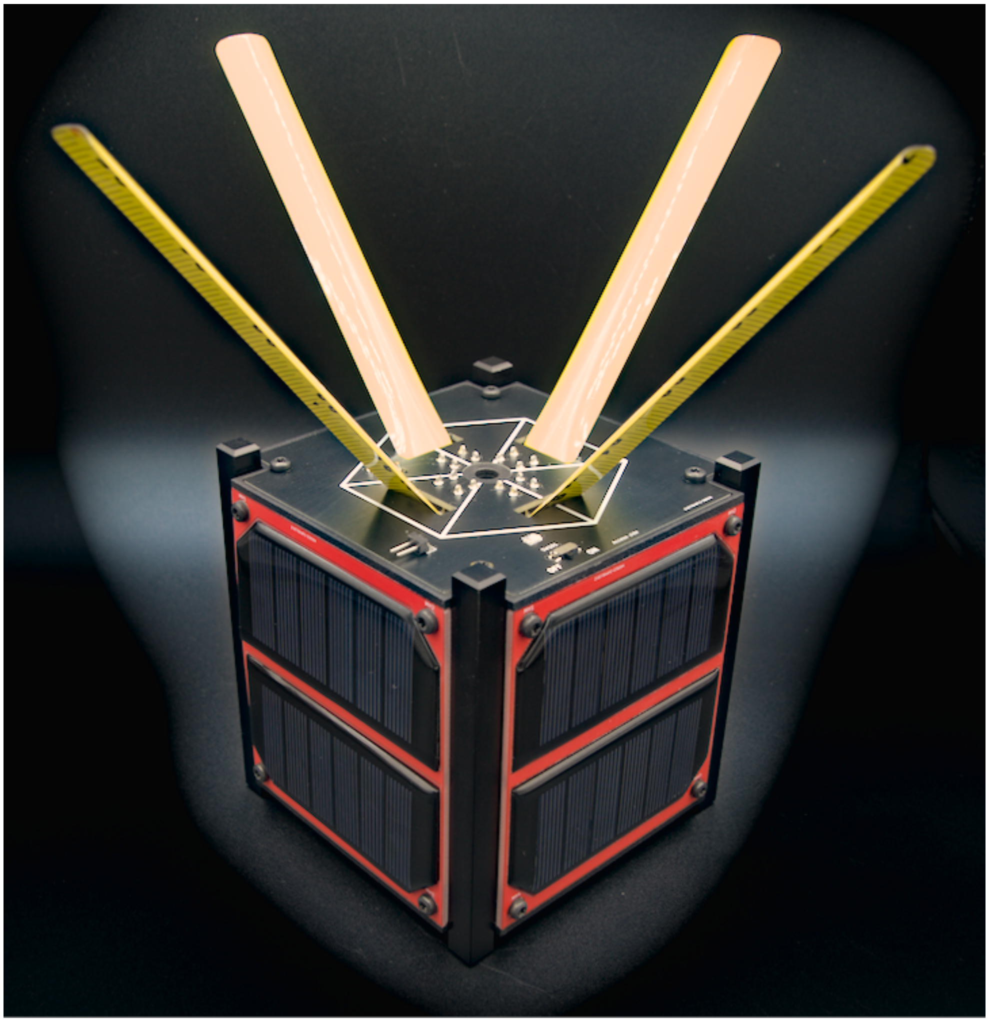


Kitsat Current Consumption

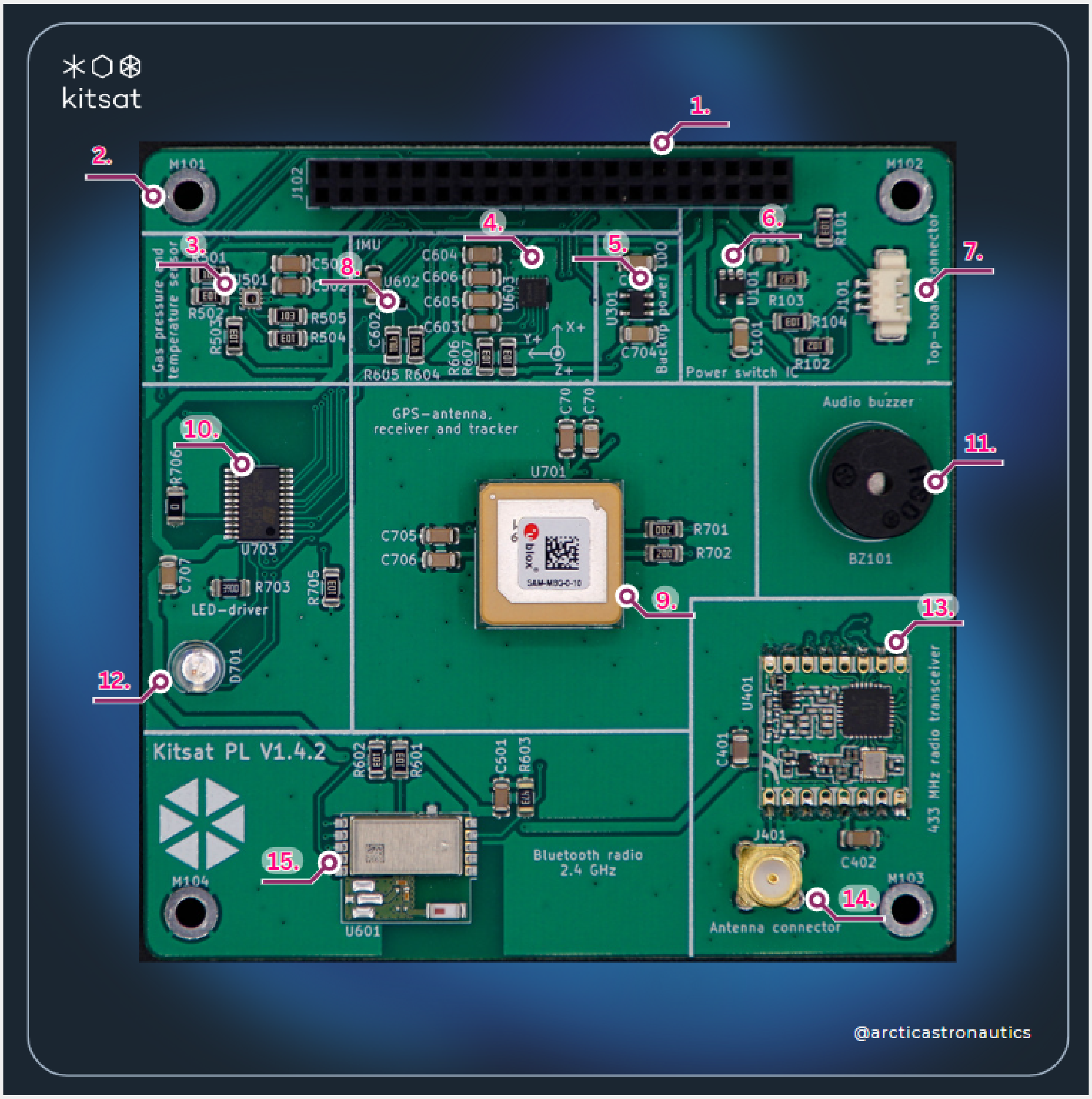
Introduction

This document details the current consumption of different components of Kitsat subsystem-by-subsystem, and explains what affects those current draws, as well as how they were measured.

This document is applicable only to the PL and EPS versions 1.4, and Nucleo-OBC.

Payload board

1	Bus conn.
2	Mounting hole
3	Barometer
4	IMU
5	GNSS LDO
6	Power switch
7	Top board conn.
8	Magnetometer
9	GNSS receiver
10	LED-driver IC
11	Buzzer
12	RGB LED
13	Main transceiver
14	Antenna conn.
15	Bluetooth radio



The current consumption of the payload board is highly dependant on the tasks being done with Kitsat. For instance, the radio mainly consumes current when the radio is being used. Next, let's look at all the PL subsystem separately to get a better understanding of the current consumption in different states.

Barometer

The barometer is BMP384, which has a very low power consumption. When operated in the standard mode, the current consumption is only maximum of 12.8 microamperes. In Kitsat, the barometer is supplied from the +3V3 line. Because of the very low consumption, sleep modes or other power saving methods are not implemented.

IMU

The accelerometer and gyroscope unit is ICM-20608-G. The current consumption in the standard mode is 1.9 mA, and again no current saving measures have been implemented. It is supplied from the +3V3 line.

GNSS LDO

This LDO is placed on the board to supply backup power to the GNSS receiver. This is the only power line active even when the Kitsat main power switch is turned off. For this reason, the LDO has been selected so that the quiescent current is very low - only 400 nA. The LDO is TI's TLV712.

Power Switch

This is a DIO7002 Power Distribution Switch IC, controlled by the small power switch in the antenna board. This controls the main power of Kitsat in parallel with the main power switch. Leakage through this IC is the main way Kitsat battery discharges when not being used, as the quiescent current is relatively high - 60 microamperes.

Magnetometer

The current consumption of the magnetometer, MMC5633NJL, varies with the number of measurements done per second, and it is approximately 13 microamperes/second / measurement. With one measurement per second, the current consumption is just 13 microamperes, and with 100, it is already 1.3 mA. It is supplied from the +3V3 line.

GNSS Receiver

The current consumption of the GNSS receiver SAM-M8Q varies somewhat depending on the operating mode. In acquisition, the current consumption is 25 mA, and drops down to 23 mA in the tracking mode. Operationally, this corresponds to looking for a fix and maintaining the fix. It seems to take 15 seconds to 2 minutes with Kitsat, depending on the environment. As mentioned before, the GNSS receiver also has a backup power line for maintaining the registers while Kitsat is shut off. This line consumes roughly 20 microamperes, and is supplied from the backup LDO. The main power line is fed from the +3V3 line.

LED Driver IC

PL board also has STP16CP05 acting as a constant current driver for the RGB LEDs. The device sinks 50 mA per active LED channel. The current consumption of the IC itself is only some microamperes, but the exact value is not reported in the datasheet and is too low to measure. Supplied by MCU from the +3V3 line.

Buzzer

The buzzer current consumption is ~50 mA when active. Supplied by MCU from the +3V3 line.

RGB LED

The buzzer current consumption is ~50 mA per channel when active. Supplied by LED Driver IC from the +3V3 line.

RFM69HCW Transceiver

Supply current in receiving mode is 16 mA. Transmission current naturally depends on the output settings, but for the default settings, it is 33 mA when transmitting. Supplied from the +3V3 line.

SPBTLE-RF0 module

Not used with the standard software, consumes 2 microamperes from the +3V3 line.

Electric Power System

1	Bus conn.
2	Solar panel conn.
3	+3V3 regulator
4	Solar panel conn.
5	ADC
6	Battery charging IC
7	Charge indicator
8	Battery holder
9	Main battery
10	Power indicator
11	Solar panel conn.
12	Main power switch
13	ADC filter capacitors
14	Instrumentation amplifier
15	RGB LED
16	Solar panel conn.

The electric power system can be hard to model well, as it is also the source of all the current consumed by the satellite in nominal operation. That being said, it also requires some power for its own operation. In the case of Kitsat, that mostly means various measurements and leakage currents. Additionally, an accurate model requires knowledge about the voltage regulation and various protection circuits, which are relatively simple in the case of Kitsat. It should be mentioned that in the standard EPS, the solar panels do not contribute to battery charging. The special flight-EPS, available for stratospheric flights, has the required MPPT circuitry to charge the batteries from the solar panels, yet the actual effect is not very significant compared to the extra consumption caused by the heater in the flight-EPS.

Solar panel connector

The connector is 3-pin PicoBlade connector. The pins are

1. Solar cell cathode (+)
2. Solar cell anode (-)
3. Frame ground

Main regulator

The regulator is LD39150, ultra low dropout regulator with 1.5 A current maximum. The output is +3V3. There is also a 1.5 A resetting fuse after the regulator.

Analog-to-digital converter

The ADC MCP3008 has a low current drain of us 100 μA. However, due to the limited input range, the battery voltage is fed through a resistor divider, which has total resistance of 20 kΩ. The leakage current naturally varies with the battery voltage, but with nominal 3.7 V it is 185 μA.

Battery charger

The battery charging controller is the MCP73831/2. This IC limits the battery charge current to 500 mA. Furthermore, the IC itself consumes around 50 to 500 μA, depending on if the charging is active or not.

Indicator LEDs

There are two indicator LEDs, one for charging, one for main power. The LED is 156120RS75300, with a 1k current limiting resistor. As the forward voltage is 2 volts, the current per LED is roughly 2 mA.

Main Battery

The battery is 18650 Keeppower Samsung 2600 mAh 5A. The battery has internal resettable protection circuits, and additionally there is a 1.5A fuse in series with the battery, as well as a diode protecting the satellite for incorrect battery orientation. Furthermore, the battery has a 100 mohm shunt resistor in series with it.

Instrumentation Amplifier

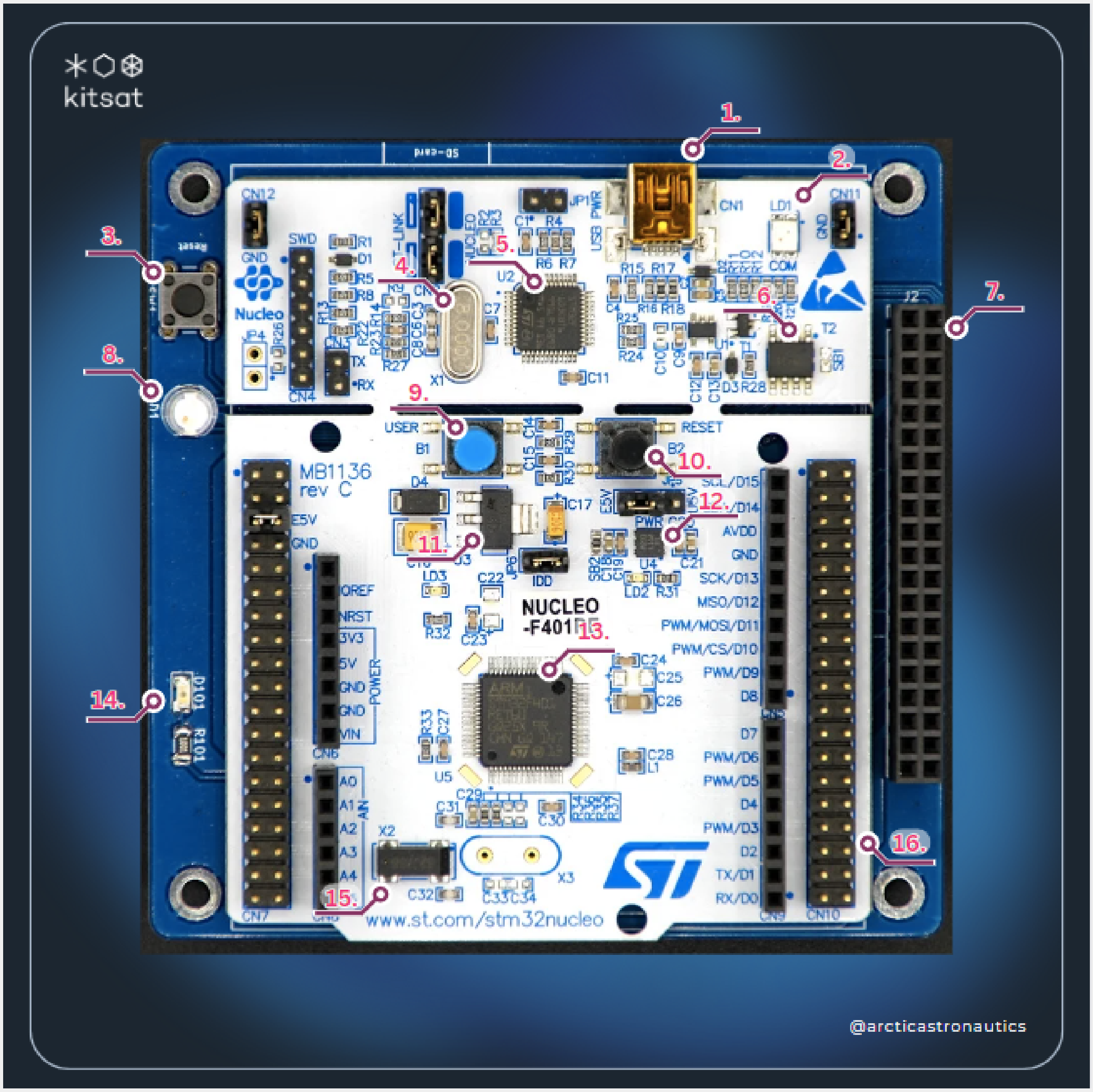
The solar panel and battery currents are measured from a shunt resistor, and amplified with INA2181 instrumentation amplifier. The amplifier requires 500 µA, which is supplied from the +3V3 line.

RGB LED

The buzzer current consumption is ~50 mA per channel when active. Supplied by LED Driver IC from the +3V3 line.

On-Board Computer

1	USB conn.
2	ST-link indicator
3	Reset button
4	ST-link crystal
5	ST-link controller
6	ST-link regulator
7	Bus connector
8	RGB LED
9	Nucleo button
10	Reset button
11	Nucleo regulator
12	Nucleo regulator
13	Main MCU
14	MCU LED
15	MCU crystal
16	Nucleo pin header



1 SD-card.

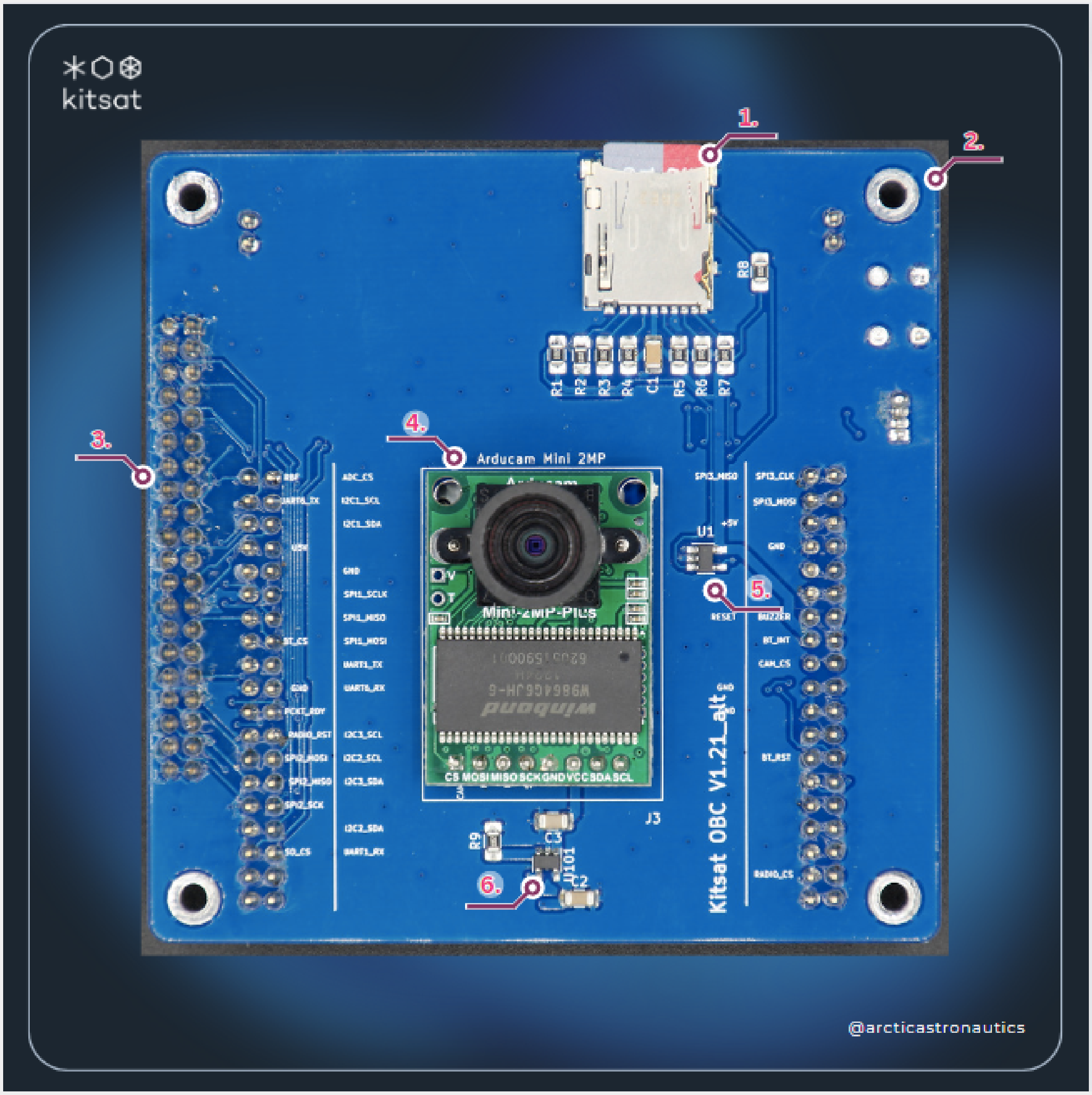
2 Mounting hole

3 Bus connector

4 Camera

5 Watchdog IC

6 Camera power switch



There are two main variants of the OBC. Ones that have been made with a Nucleo-board, and ones that have not. The reason for using Nucleo-boards as part of the OBC was originally the poor availability of STM32 MCU’s during the pandemic, but since then we have also used Nucleos in some Kitsats for the easier programmatibility offered by the ST-link on the Nucleo boards. The downside is increased cost and power consumption of the Nucleo, compared to a standalone MCU.

Nucleo

The nucleo-board is powered from the satellites +3V3 line. The USB-line is not used to directly power the OBC, but rather to charge the battery, which in turn powers on the OBC.

The current draw to power the entire nucleo-board from the +3V3 line is approximately 30 mA. Unfortunately, getting a precise figure is difficult. For more well-defined conditions, the ST-link could be disabled, which would make the power consumption in the Nucleo closer to the power consumption of the main MCU itself, which is 13.5 mA in the configuration used in Kitsat.

RGB LED

The buzzer current consumption is ~50 mA per channel when active. Supplied by LED Driver IC from the +3V3 line.

Indicator LED

The OBC board has an MCU controllable LED, used as a heartbeat LED in Kitsat software. The LED is 156120RS75300, with a 1k current limiting resistor. As the forward voltage is 2 volts, the current per LED is roughly 2 mA. As the LED is used for heartbeat indication, the duty cycle is close to 50% and the effective current consumption is 1 mA.

SD-card

The current consumption of SD-cards varies significantly between manufacturers, but Kitsat has been using SanDisk Ultra - cards for a while now. The manufacturer states that the idle current is 1.25 mA, and the average current in read/write operations is 24 mA. The peak current is stated to be max. 100 mA, however we have not seen these levels with the SPI-operation that Kitsat uses. The SD-card is supplied from the +3V3 line.

Camera

The camera, Arducam Mini 2MP Plus has a relatively high power consumption compared to other systems in Kitsat. This is why it is also fitted with a power switch, which can be used to disable the camera when not used. Kitsat automatically turns off the camera after 30 seconds of it not being used. The power switch is DIO7002, same on as one the PL board.

The current consumption is roughly 40 mA when not being used, and ~70 mA when imaging. It naturally drops to zero when the power switch is turned off.

Watchdog IC

The OBC also has a hardware-watchdog, which comes handy especially on the stratospheric flights, where environmental conditions might cause hardware-related issues in software. In this situations, the watchdog resets the OBC processor, usually enabling recovery from the problematic state. The WD IC is APX823, with supply current of only 30 μA from the +3V3 line.