

PROJECT:

LoRa Comms Payload: Electrical Ground Support Equipment

PART OF THE MASTER'S THESIS:

"Development of a LoRa-based communications payload for CubeSat"

MASTER'S DEGREE IN ELECTRONIC SYSTEMS ENGINEERING
 POLYTECHNIC UNIVERSITY OF VALENCIA
 ACADEMIC COURSE 2023/2024

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SUPERVISORS:

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DEPARTMENT OF ELECTRONIC ENGINEERING

Vicente Enrique Boria Esbert

DEPARTMENT OF COMMUNICATIONS



DEVELOPED IN PROUD COLLABORATION WITH:

UNIVERSITAT
POLITECNICA
DE VALÈNCIAGENERACIÓN
ESPONTÁNEA— TELECOM
UPV VLCDEPARTAMENTO
DE INGENIERÍA
ELECTRÓNICAiTEAM
Instituto de Telecomunicaciones
y Aplicaciones MultimediaMICROWAVE
APPLICATIONS
GROUP

A

A

B

B

C

C

D

D

Notes:

This project consists of an Electrical Ground Support Equipment board. It is used to program, power and test the payload. It contains a microcontroller symmetrical to the carrier, a PCI-104 bus interface to emulate communication with an OBC, and an RF sink with a LoRa transceiver and variable attenuators, simulating propagation losses.

Title: **Cover and block diagram**

Prj: Estigia Comms Payload - EGSE

Date: 2024-08-11 13:29:29 Last modified: 2024-08-11

Size: A4 Sheet 1 of 12

File: 1_cover.SchDoc

Author: Juan Del Pino Mena

Approved: *

Prj. revision: 0.4

Variant: [No Variations]

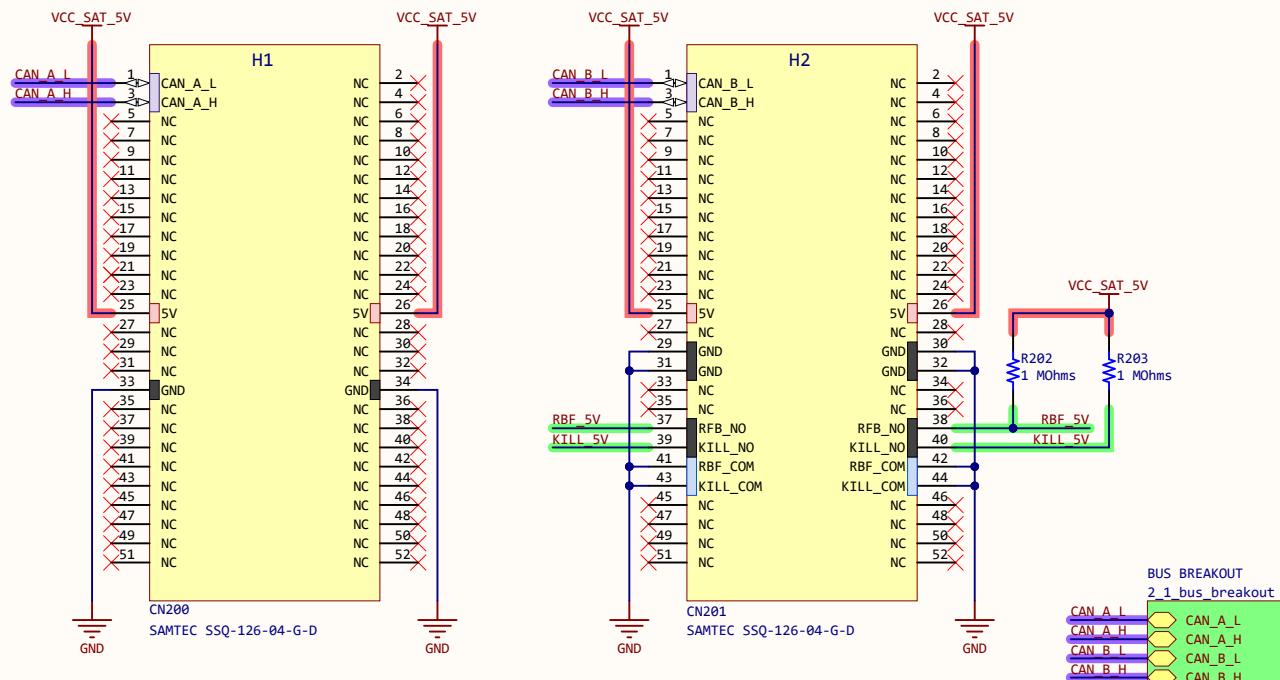
Altium version: 24.3.1.35

License: --

Git Hash: 167b6dbce7c06eaf0d7dd3dfce0f5bce47e45ecb [Locally Modified]

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CubeSat Bus PCI-104 connectors

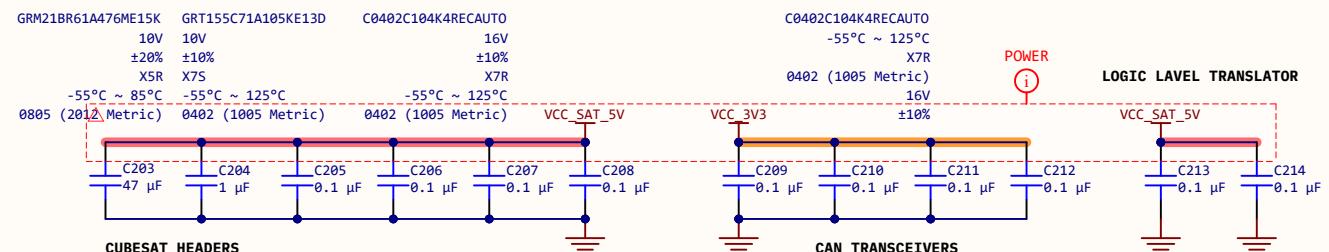


KILL: Global killswitch (NORMAL_OP=1, SHUTDOWN=0)

RBF: Remove Before Flight switch (NORMAL_OP=1, SHUTDOWN=0)

KILL_COM, RFB_COM: The respective switch common voltage

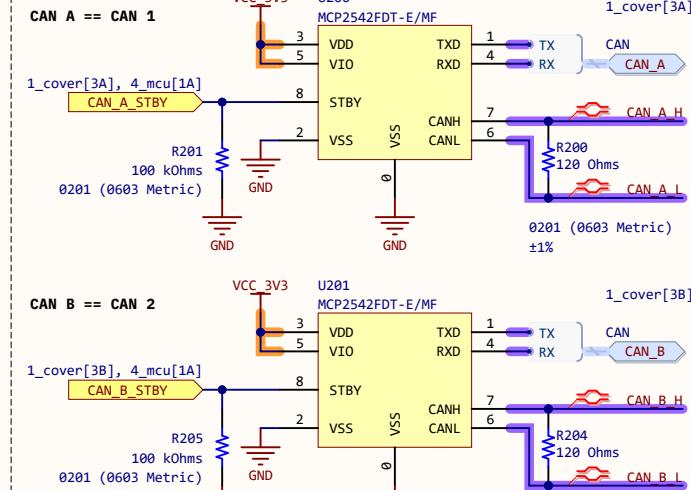
Decoupling capacitors



Notes:

- [1] LibreCube Board Spec. https://librecube.gitlab.io/standards/board_specification/ (04-2024)
- [2] LibreCube SpaceCAN Spec. <https://librecube.gitlab.io/standards/spacecan/> (04-2024)
- [3] LibreCube PCI104 pinout spreadsheet <https://docs.google.com/spreadsheets/d/1N1JiXR-5huo--XefjsvC9CI1hi59xMNs0TzhUcuixQ0> (04-2024)
- [4] Microchip Inc. MCP2542FD/4FD MCP2542WFD/4WFDS datasheet, DS20005514C, 2020

CAN transceivers



Title: CubeSat Bus interface

Prj: Estigia Comms Payload - EGSE

Date: 2024-08-11 13:29:30

Size: A4

File: 2_cubesat_bus.SchDoc

Author: Juan Del Pino Mena

Approved: *

Prj. revision: 0.4

Variant: [No Variations]

Altium version: 24.3.1.35

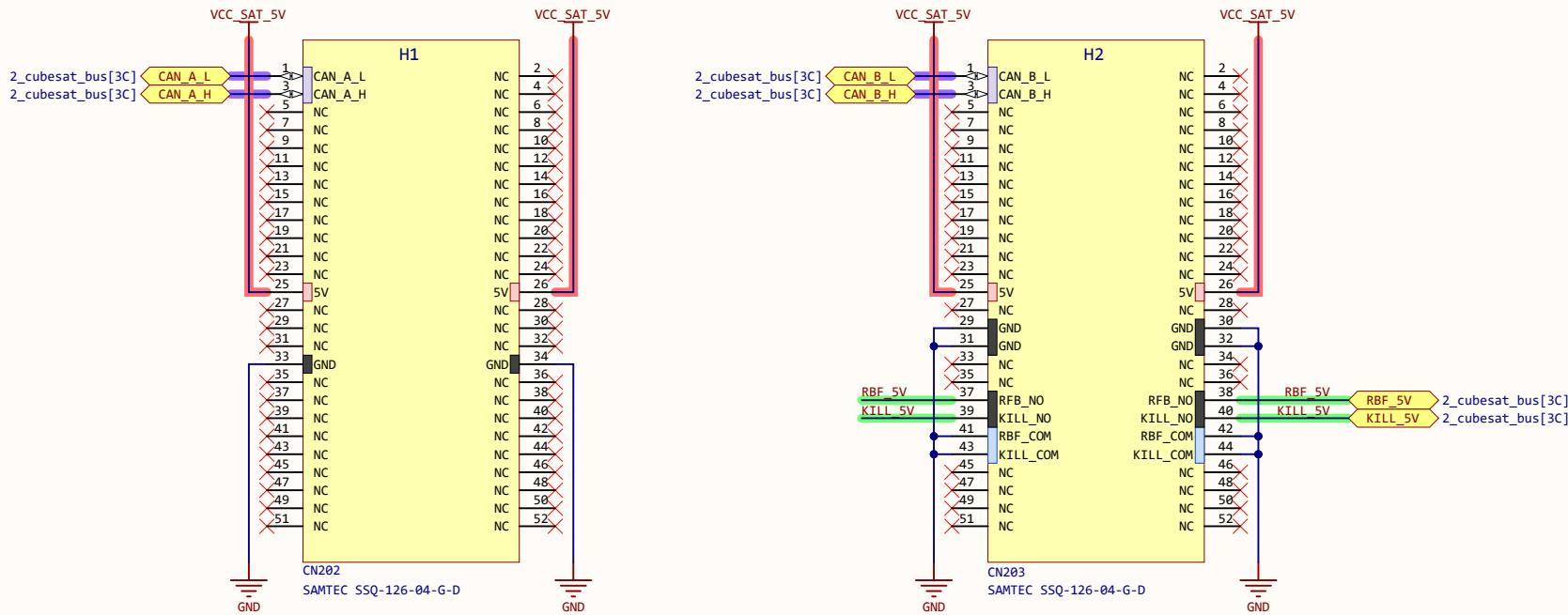
License: --

Git Hash: 167b6dbce7c06eaf0d7dd3dfce0f5bce47e45ecb [Locally Modified]

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A

A

B

B

C

C

Notes:

Title: **CubeSat Bus Breakout**

Prj: Estigia Comms Payload - EGSE

Date: 2024-08-11 13:29:30 Last modified: 2024-08-11

Size: A4 Sheet 3 of 12

File: 2_1_bus_breakout.SchDoc

Author: Juan Del Pino Mena

Approved: *

Prj. revision: 0.4

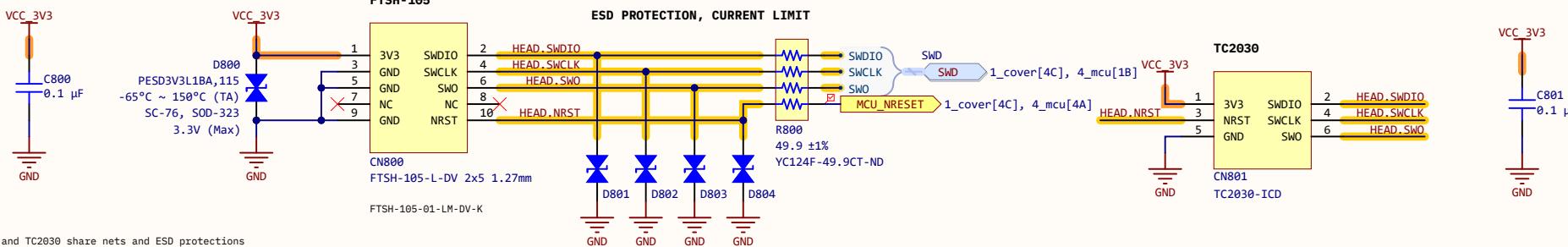
Variant: [No Variations]

Altium version: 24.3.1.35

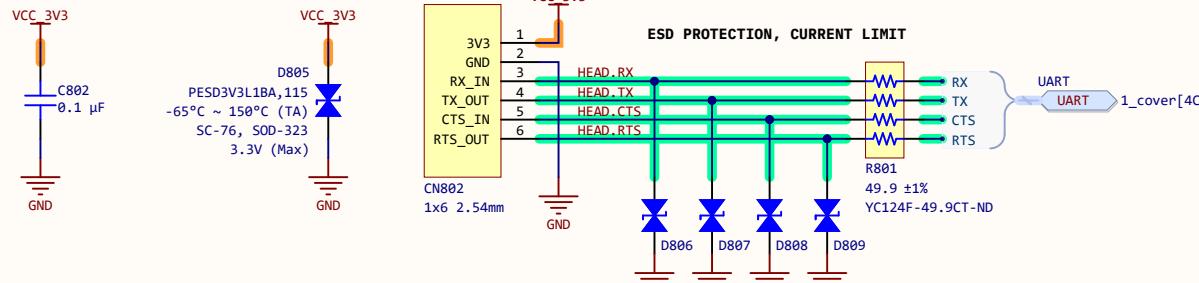
License: --

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SWD

FTSH-105 and TC2030 share nets and ESD protections
(there are 2 possibilities for the same SWD interface!)

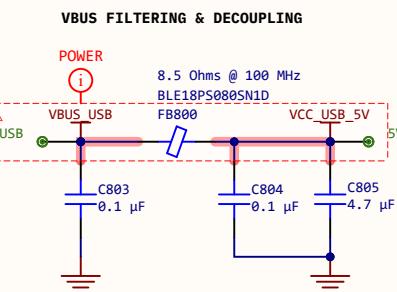
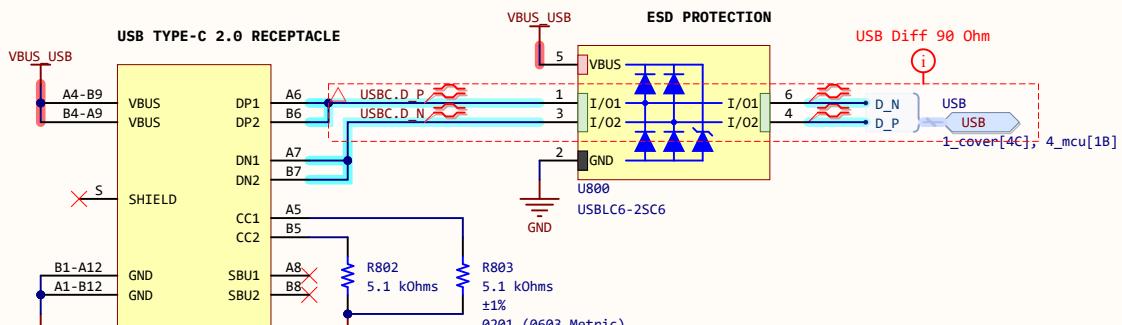
UART

CAUTION: UART SIGNALS ALREADY CROSSED!
Compatible serial adapter pinout:
1:3V3, 2:GND, 3:TXD, 4:RXD, 5:RTS, 6:CTS

USB

USB-C 2.0 interface. Pull down resistors on CC pins make the connector behave electrically as an USB type B device only, which sinks up to 15 W (5V, 3A max).

This USB is used for both power and comms

**Notes:**

- Miscellaneous connectors: Debug, UART, USB. With ESD protections.
- [1] STMicroelectronics Inc. STLINK-V3MINIE debugger/programmer User Manual, UM2910, Rev 3, 04-2024
- [2] Tag-connect, ARM-CTX (20-pin ARM to TC2030) adapter for SWD datasheet.
- [3] Tag-connect, TC2030-ICD datasheet, Rev B, 05-2019
- [4] STMicroelectronics Inc. AN4879, Rev 6,

Title: Ports

Prj: Estigia Comms Payload - EGSE

Date: 2024-08-11 13:29:30 Last modified: 2024-08-11

Size: A4 Sheet 4 of 12

File: 3_ports.SchDoc

Author: Juan Del Pino Mena
Approved: *

Prj. revision: 0.4

Variant: [No Variations]

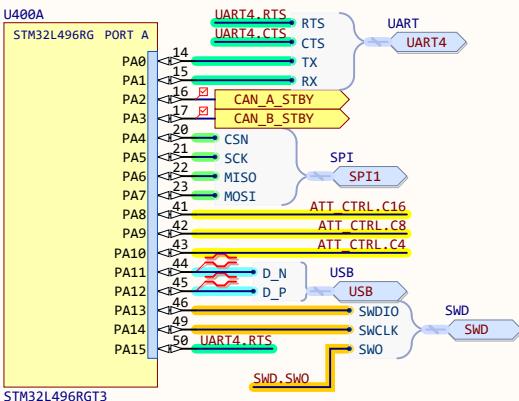
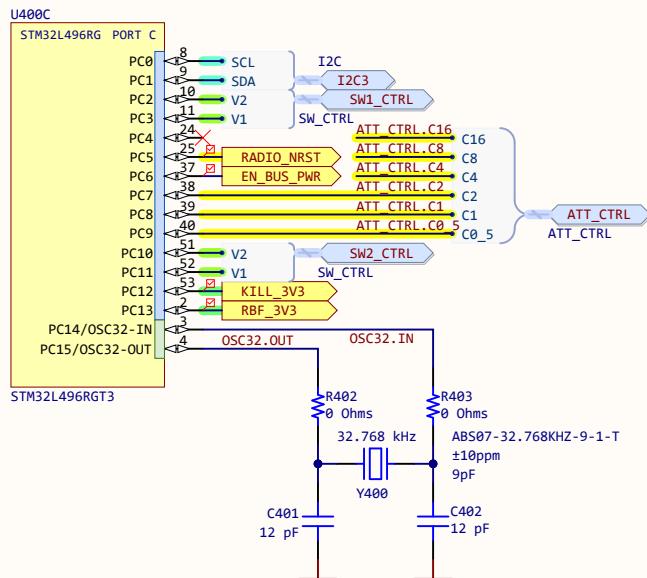
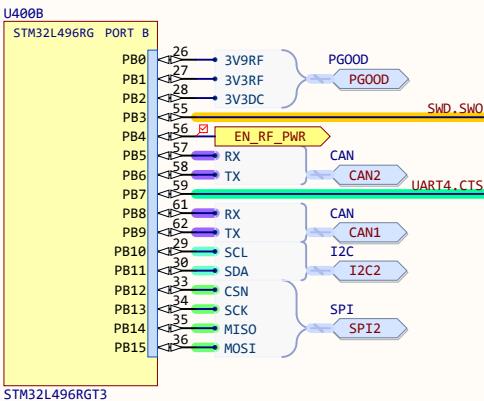
Altium version: 24.3.1.35

License: --

Git Hash: 167b6dbce7c06eaf0d7dd3dfce0f5bcbe47e45ecb [Locally Modified]

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I/O Ports**PORT A****PORT C****PORT B**

CAN A = CAN 1

CAN B = CAN 2

Altium warns about "net connection problems" when a bi-directional pin is connected to a input or output port. Ignore warning.

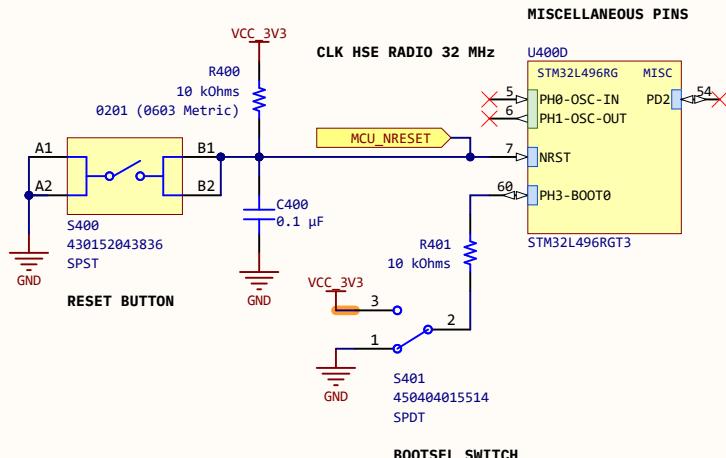
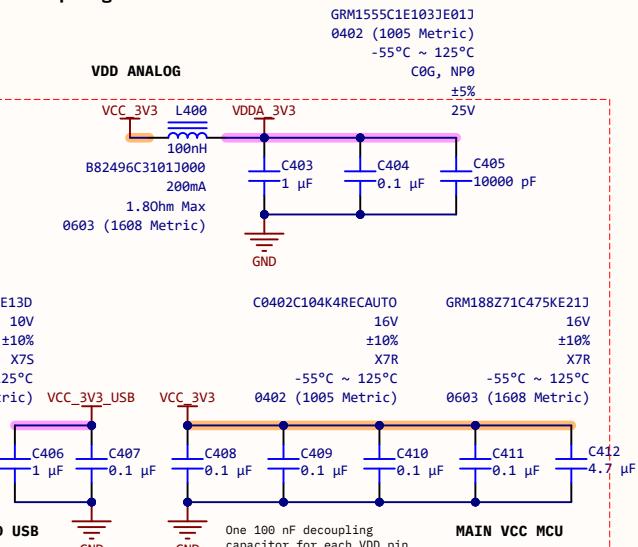
Many interfaces are defined and made available into the sheet symbol, so this sheet can be re-used easily between designs. Some peripherals are used both by the Carrier and EGSE, whereas others are only used in one of them.

Notes:

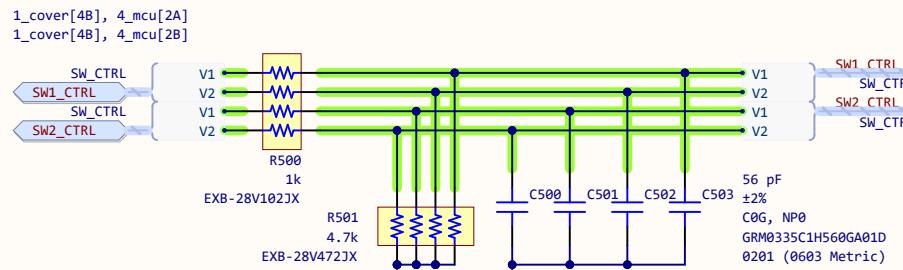
[1] STMicroelectronics Inc. STM32L496xx Datasheet, DS11585, Rev 17, 11-2022

[2] STMicroelectronics Inc. Getting started with STM32L4/L4+ hardware dev., AN4555, Rev 9, 11-2022

[3] STMicroelectronics Inc. Oscillator design guide for STM32 MCUs, AN2687, Rev 19, 04-2023

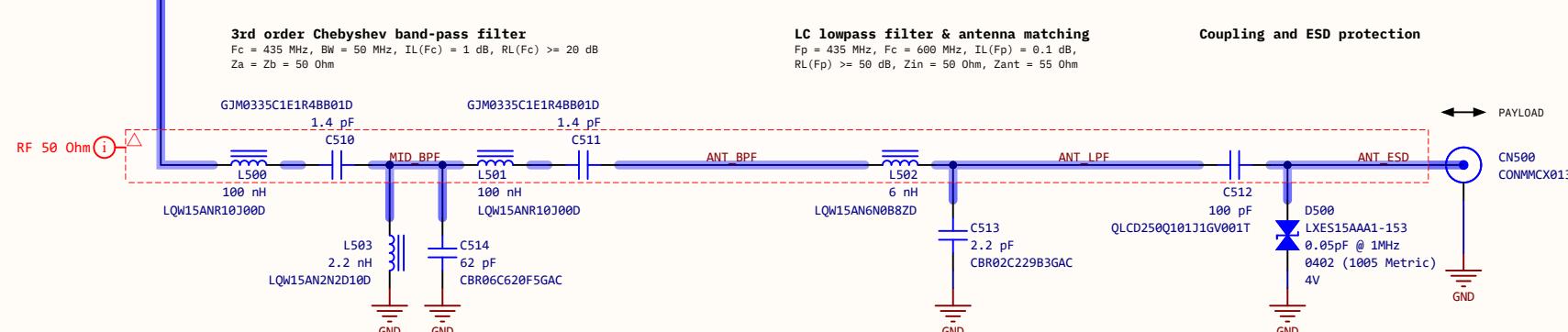
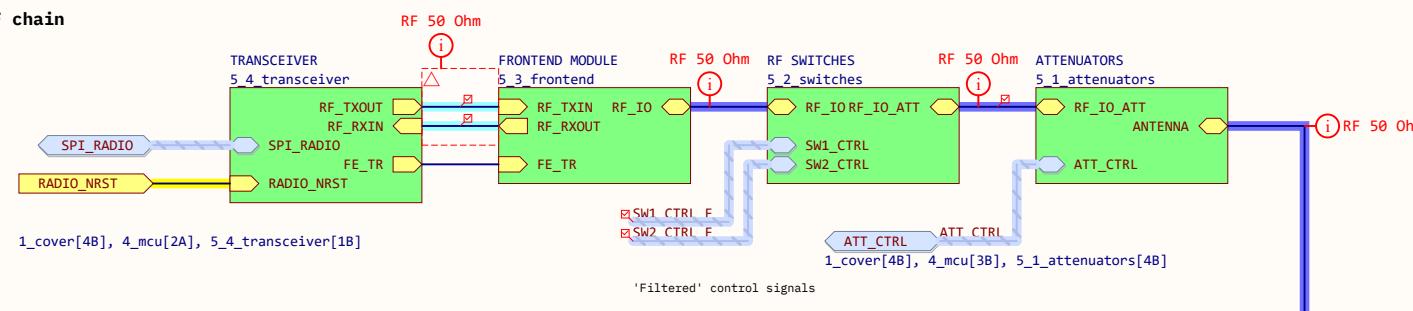
Title: Microcontroller**Prj: Estigia Comms Payload - EGSE****Date: 2024-08-11 13:29:31** **Last modified: 2024-08-11****Size: A4** **Sheet 5 of 12****File: 4_mcu.SchDoc****Reset button and boot selection dip switch****Filtering & decoupling****POWER**

Filtering of control signals



Voltage divider needed because SKY13373-460LF logic only supports 1.6 to 3.0 V

RF chain



Notes:

Title: **RF path and LoRa transceiver**

Author: Juan Del Pino Mena

Approved: *

Prj. revision: 0.4

Varient: [No Variations]

Date: 2024-08-11 13:29:31 Last modified: 2024-08-11

Altium version: 24.3.1.35

Size: A4 Sheet 6 of 12

File: 5_rf_path.SchDoc

Author: Juan Del Pino Mena

Approved: *

Prj. revision: 0.4

Varient: [No Variations]

Date: 2024-08-11 13:29:31 Last modified: 2024-08-11

Altium version: 24.3.1.35

Size: A4 Sheet 6 of 12

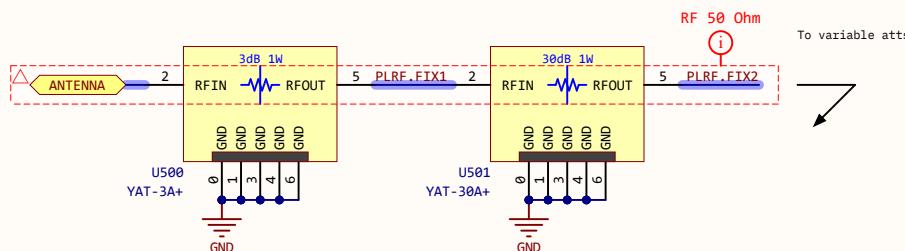
File: 5_rf_path.SchDoc

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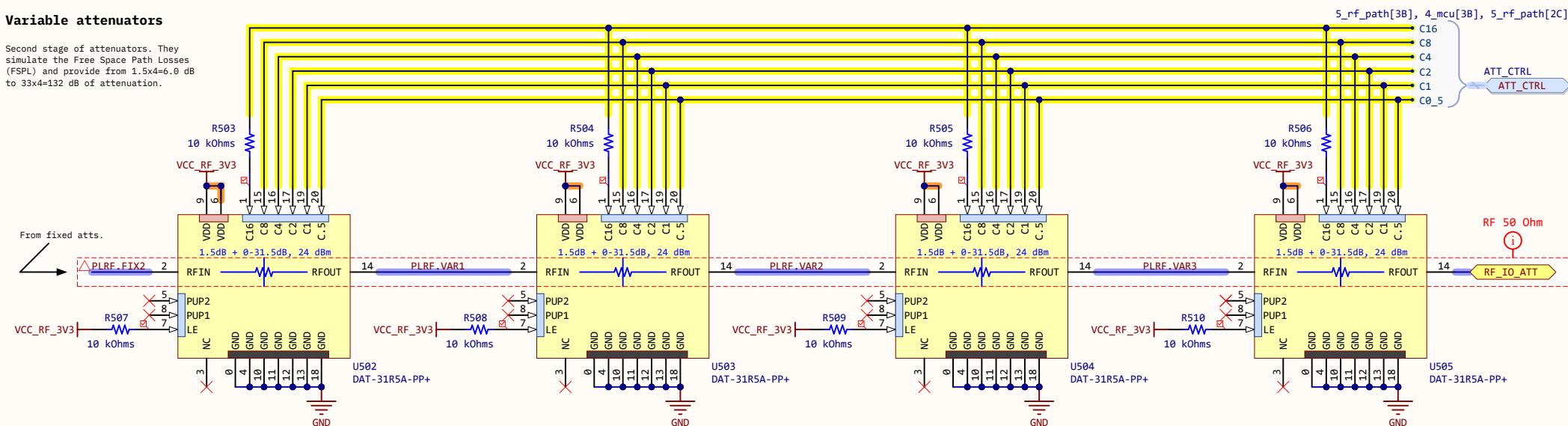
Fixed attenuators

First stage of attenuators. They dissipate the most power in the chain (up to 2W), and protect the RF ICs limiting the input RF power to a safe level.

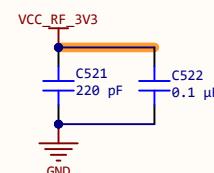
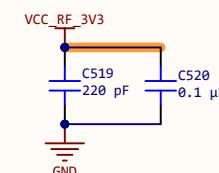
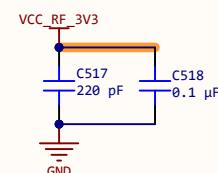
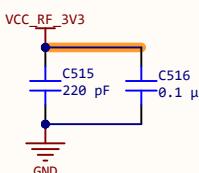


Variable attenuators

Second stage of attenuators. They simulate the Free Space Path Losses (FSPL) and provide from 1.5x4=6.0 dB to 33x4=132 dB of attenuation.



Decoupling caps



Notes:

- [1] Mini-Circuits Inc. YAT-30A+ datasheet, ECO-011434, REV. A, 01-2022
- [2] Mini-Circuits Inc. YAT-3A+ datasheet, ECO-011434, REV. A, 01-2022
- [3] Mini-Circuits Inc. DAT-31R5A-PP+ datasheet, M164761, REV. C, 05-2020

Title: RF Attenuators

Prj: Estigia Comms Payload - EGSE

Date: 2024-08-11 13:29:31 Last modified: 2024-08-11

Size: A4 Sheet 7 of 12

File: 5_1_attenuators.SchDoc

Author: Juan Del Pino Mena

Approved: *

Prj. revision: 0.4

Variant: [No Variations]

Altium version: 24.3.1.35

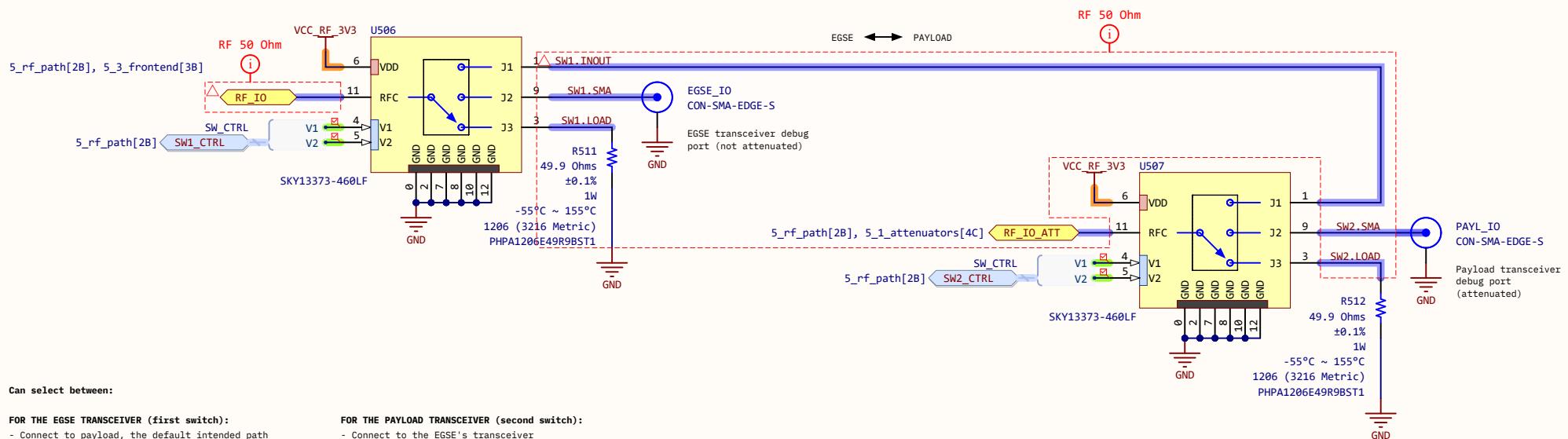
License: --

Git Hash: 167b6dbce7c06eaf0d7dd3dfce0f5bce47e45ecb [Locally Modified]

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RF path selection switches



Can select between:

FOR THE EGSE TRANSCEIVER (first switch):

- Connect to payload, the default intended path through the attenuators to the payload's transceiver
- Connect to a SMA connector, rendering the transceiver output available for an antenna, an analyzer, etc.
- Connect to 50-ohm load, to sink the rf signal if not used.
- Connect to 50-ohm load, to sink the rf signal if not used.
- MMX to payload, general-purpose SMA, 50-ohm load

Decoupling capacitors



Notes:
 [1] Skyworks Inc. SKY13373-460LF Datasheet, 2012640, 05-2016

Title: RF Switches

Prj: Estigia Comms Payload - EGSE

Date: 2024-08-11 13:29:32 **Last modified: 2024-08-11**

Size: A4 **Sheet 8 of 12**

File: 5_2_switches.SchDoc

Author: Juan Del Pino Mena

Approved: *

Prj. revision: 0.4

Variant: [No Variations]

Altium version: 24.3.1.35

License: --

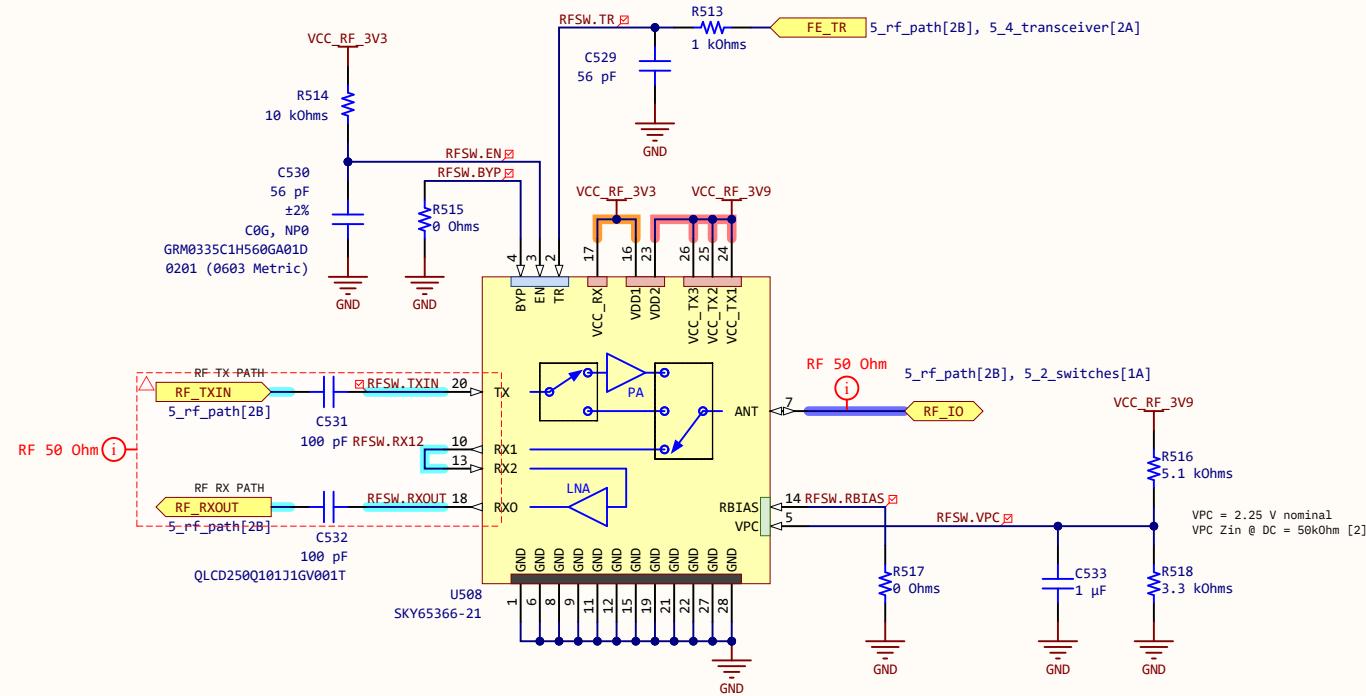
Git Hash: 167b6dbce7c06eaf0d7dd3dfce0f5bce47e45ecb [Locally Modified]

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RF Front-End module (Switch + LNA + PA)

Front-end module always enabled, never bypassed.



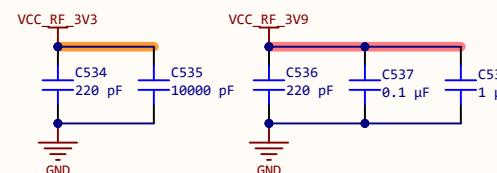
A

A

B

B

Decoupling capacitors



Notes:

[1] Semtech Inc. SX1302 Corecell Reference Design with SX1250 RF Front-Ends, PCB_E539V01A, 01-2020
[2] Skyworks Inc. SKY65366-21 400 MHz Tx/Rx Front-End Module, 203146E, 10-2020

Title: **RF Front-end module**

Prj: Estigia Comms Payload - EGSE

Date: 2024-08-11 13:29:32 Last modified: 2024-08-11

Size: A4 Sheet 9 of 12

File: 5_3_frontend.SchDoc

Author: Juan Del Pino Mena
Approved: *

Prj. revision: 0.4

Variant: [No Variations]

Altium version: 24.3.1.35

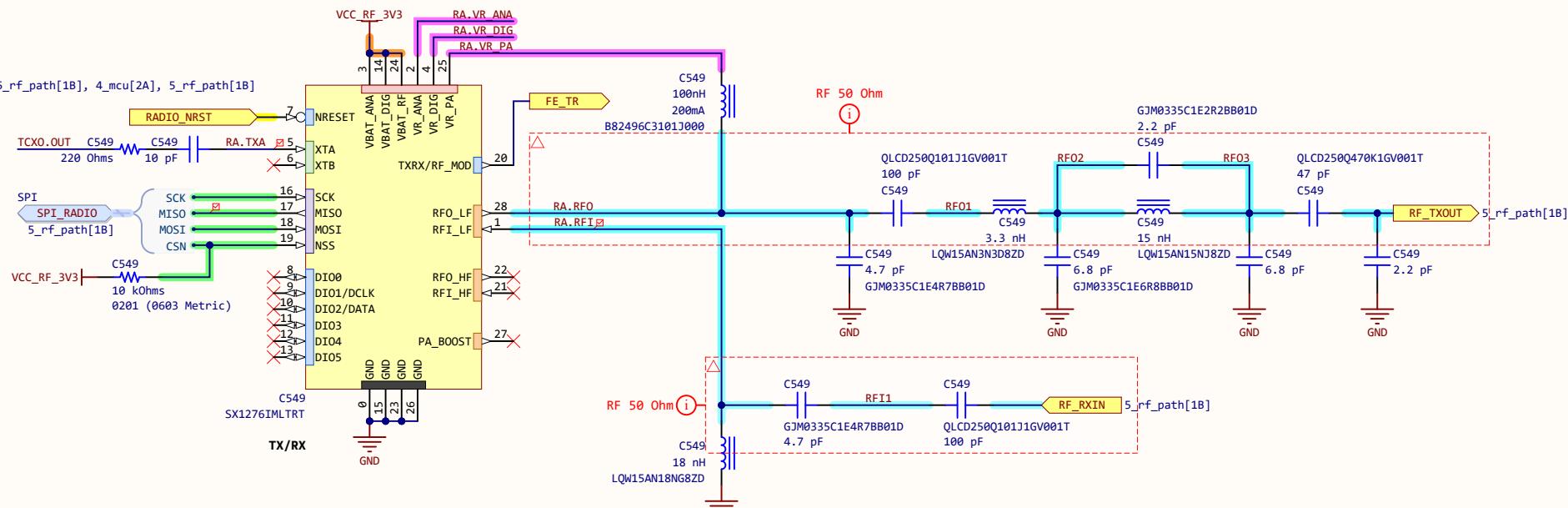
License: --

Git Hash: 167b6dbce7c06eaf0d7dd3dfce0f5bce47e45ecb [Locally Modified]

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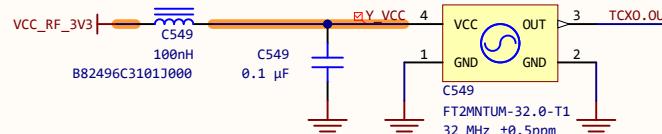


LoRa Node Transceiver

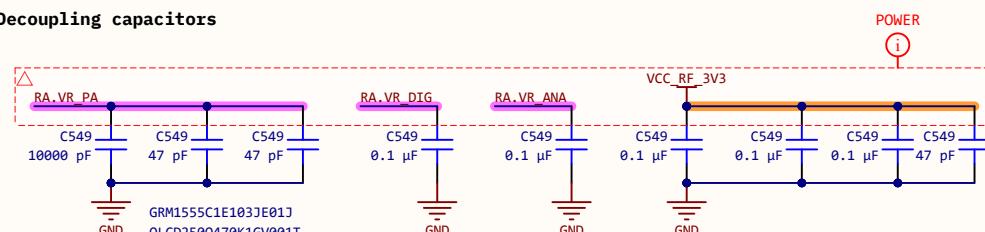


Xtal oscillator

Clipped-sine output TCXO are required, $V_{out_pp} \leq 1.2$ V. Recommended a GPS-precision TCXO (0.5 ppm). A TCXO should be connected to pin XTA through a 220-ohm res and a 10 pF DC-cut cap to reduce the amplitude [4]. Pin XTB should be left open [1].



Decoupling capacitors



Notes:

- [1] Semtech Inc. SX127x datasheet, Rev 7, 05-2020
- [2] Semtech Inc. SX127x reference design overview, AN1200.19, 12-2014
- [3] Semtech Inc. SX1276 433/915 MHz reference design SX1276MB1LAS, PCB_E311V02A, v1a, 02-2015

Title: **LoRa node transceiver**

Prj: Estigia Comms Payload - EGSE

Date: 2024-08-11 13:29:32 Last modified: 2024-08-11

Size: A4 Sheet 10 of 12

File: 5_4_transceiver.SchDoc

Author: Juan Del Pino Mena

Approved: *

Prj. revision: 0.4

Variant: [No Variations]

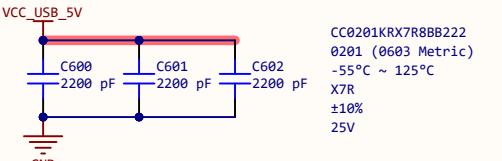
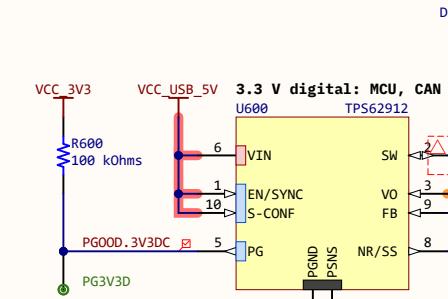
Altium version: 24.3.1.35

License: --

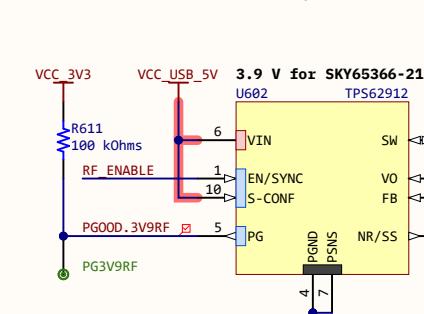
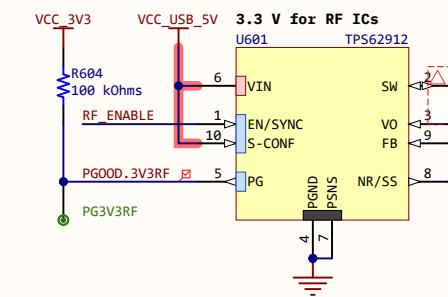
Git Hash: 167b6dbce7c06eaf0d7dd3dfce0f5bce47e45ecb [Locally Modified]

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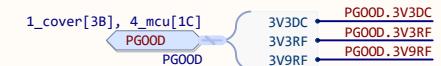


Decoupling capacitors**Low noise DC/DC converters**

EN/SYNC pin: Open-drain, pull-down (500k, 100k pull-up to 1V2 (instead of 5VIN) to avoid unwanted power-up



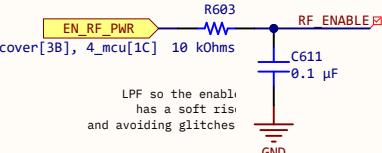
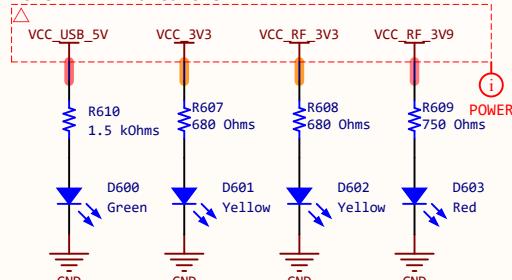
S-CONF to VIN:
Fsw = 2.2 MHz
Spread-Spectrum OFF
Output Discharge OFF
Sync OFF



CAUTION! Power good signals are working in the digital 3V3 rail

A

A

Enable RF supply**Power LED indicators**

The TPS62912 PG pin is in high Z when V(FB) >= 95%, and driven low when V(FB) <= 90%. The open-drain pin requires a pullup. The PG signal is used for sequencing of multiple rails by connecting to the EN pin of other converters [1].

To ensure control of all digital IOs during the power-up/down of the SX1302 and avoid an inrush current, the 1.2 V rail shall be enabled before 3.3 V at start-up [2].

Notes:

Power supply based on low-noise DC/DC converters.

[1] Texas Instruments Inc. TPS62912/3 datasheet, SLVSPFPB, 03-2021

[2] Semtech Inc. Errata Note Corecell PCB #e539v0le Reference Design, Rev 1.0, 03-2020

Title: Power management

Prj: Estigia Comms Payload - EGSE

Date: 2024-08-11 13:29:32 Last modified: 2024-08-11

Size: A4 Sheet 11 of 12

File: 6_power_dcdc.SchDoc

Author: Juan Del Pino Mena

Approved: *

Prj. revision: 0.4

Variant: [No Variations]

Altium version: 24.3.1.35

License: --

Git Hash: 167b6dbce7c06eaf0d7dd3dfce0f5bce47e45ecb [Locally Modified]

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Voltage, current and power monitor

Power measurement excludes EGSE's own consumption. It only monitors the payload's.

A

R_SHUNT selection (early power budget estimation)

Carrier power consumption: 0.33 W (max)
LoRa SoM power consumption: 4.62 W (tx); 0.58 W (rx)

Expected total power consumption: [0.9 W, 5 W]
Thus, at $V_{cc} = 5$ V : current consumption: [0.18 A, 1 A]

Account for an instantaneous peak current consumption of double the maximum: $I_{peak} = 2$ A

For minimum voltage drop, $V_{sense} = 20.48$ mV (INA232 cfg)

$R_{shunt} < V_{sense} / I_{peak} = 10.24$ mOhm

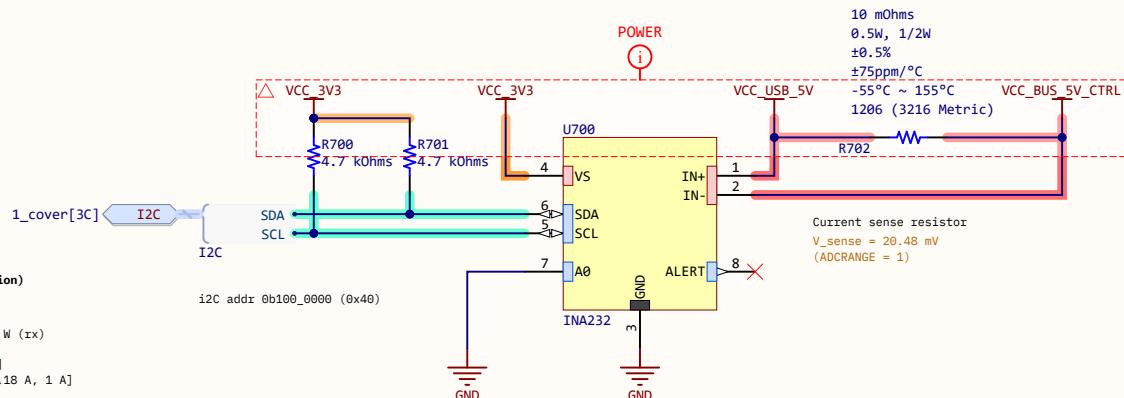
Power dissipated on R_{shunt} : 42 mW

$R_{shunt} = 10$ mOhm, tolerance <=0.5 %, power >= 0.1 W

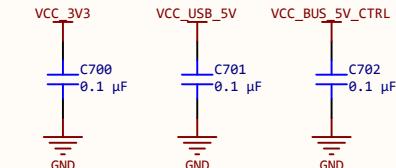
Load power switch

Notes:

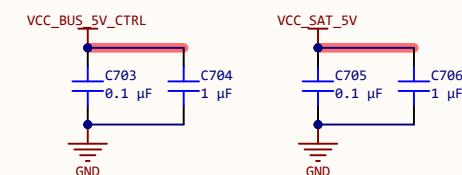
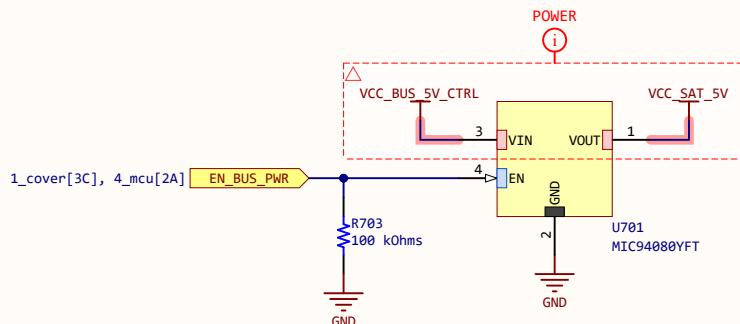
- [1] Texas Instruments Inc. INA232 datasheet, SBOSAA2, 12-2022
- [2] Semtech Inc. Errata Note Corecell PCB #e539v01e Reference Design, Rev 1.0, 03-2020
- [3] Microchip Inc. MIC94080/1/2/3/4/5 datasheet, DS20006118A, 2019



Decoupling capacitors



C



Title: **Bus power control & monitoring**

Prj: Estigia Comms Payload - EGSE

Date: 2024-08-11 13:29:33 Last modified: 2024-08-11

Size: A4 Sheet 12 of 12

File: 7_power_prot_mon.SchDoc

Author: Juan Del Pino Mena
Approved: *

Prj. revision: 0.4

Variant: [No Variations]

Altium version: 24.3.1.35

License: --

Git Hash: 167b6dbce7c06eaf0d7dd3dfce0f5bce47e45ecb [Locally Modified]

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