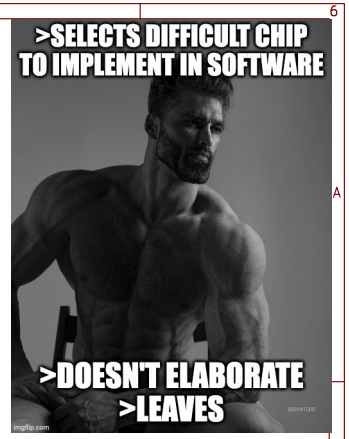
Groundstation Block Diagram

Summary: board carrying a 433 MHz radio front-end and transceiver module built around an nRF52840 for software control + Bluetooth LE support



Connectors
File: connectors.kicad_sch
USB_D+
USB_D-
UART1_TX
UART1_RX
UART2_TX
UART2_RX

LEDs
File: leds.kicad_sch
LED_1
LED_2
PWR_3V9A
PWR_3V3A

Accelerometer
File: accelerometer.kicad_sch
IMU_CS
IMU_SPC
IMU_SDI
IMU_SDO
IMU_INT1
IMU_INT2
PWR_3V3A

Input Power
File: input-power.kicad_sch

Digital Rails
File: digital-rails.kicad_sch

Analog Rails
File: analog-rails.kicad_sch
PWR_3V3A
PWR_3V9A

DO NOT EXCEED POWER RATING OF RF IC

J2
MM8430-2610RB3
GND

J1
MM8430-2610RB3
GND

RF Front-End
File: rf-front-end.kicad_sch
PWR_3V9A
RFFE_VPC
RFFE_RXD
RFFE_TR
RFFE_EN
RFFE_BYP
RFFE_TX

Radio Transceiver
File: radio-transceiver.kicad_sch
XCVR_RX
XCVR_TXD
XCVR_nRESET
XCVR_GPIO0
XCVR_SOD
XCVR_nCS
XCVR_GPIO2
XCVR_SCLK
XCVR_GPIO3
XCVR_SI

MCU
File: mcu.kicad_sch
MCU_D+
MCU_D-
UART1_TX
UART1_RX
UART2_TX
UART2_RX
XCVR_GPIO0
XCVR_GPIO2
XCVR_GPIO3
XCVR_nRESET
RFFE_TR
RFFE_EN
RFFE_BYP
LED_1
LED_2
IMU_INT1
IMU_INT2
IMU_CSD
COMPASS_CSD
XCVR_nCSD
DAC_CSD
SPI1_SCKD
SPI1_MOSID
SPI1_MISO
DISP_RSTD
DISP_CSD
SPI2_SCKD
SPI2_MOSID
SPI2_MISO

Compass
File: compass.kicad_sch
PWR_3V3A
COMPASS_CS
COMPASS_SPC
COMPASS_SDI
COMPASS_SDO

Display
File: display.kicad_sch
DISP_RST
DISP_CS
DISP_SCLK
DISP_SID
DISP_SOD

DAC
File: dac.kicad_sch
DAC_CS
DAC_SCK
DAC_SDI
PWR_3V3A
DAC_VOUT

Critical length around 91 mm on 4.5 dielectric board

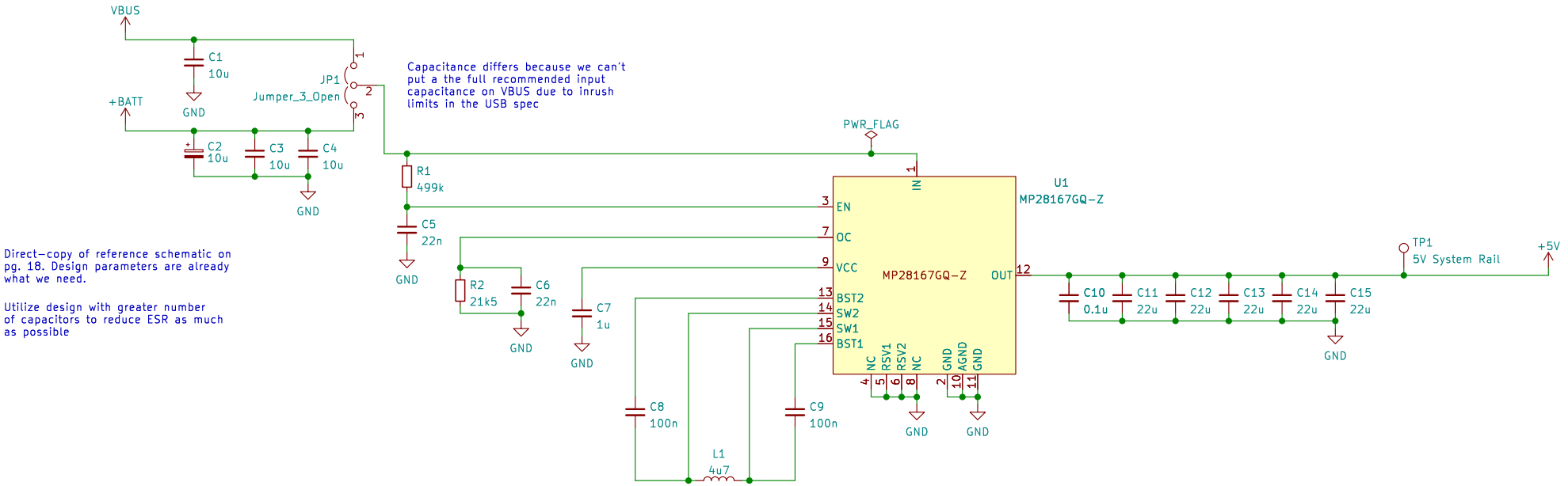
Trace widths (JLC3313 4-layer prepreg):
- CPW+GND 50 ohm: 0.202114 mm (GND 0.2 mm clearance)
- Microstrip 50 ohm: 0.146812 mm
- Diff pair 90 ohm: 0.159 mm, 0.2 mm spacing

TODO: Parasitic simulation

Groundstation		
AerospaceNU **Designer: Johnny Cao** Sheet: File: groundstation-v2.kicad_sch		
Size: A4	Date: 2022-10-30	**Rev: v2**
KiCad E.D.A. kicad 7.0.2-0		Page 1 of 13

Design requirements:
- 2S–5S Battery + USB input
- Provide 3A of current in case of maximum power draw from downstream regulators
- 5V to provide enough headroom for up to 1.1V dropout from 3.9V LDO

5V Buck–boost
VIN = 2.8–22V
VOUT = 5V
IMAX = 3A
Frequency = 500 kHz



Direct–copy of reference schematic on pg. 18. Design parameters are already what we need.

Utilize design with greater number of capacitors to reduce ESR as much as possible

Groundstation

AerospaceNU
Designer: Johnny Cao
Sheet: Input Power
File: input–power.kicad_sch

Size: A4	Date: 2022–10–30	**Rev: v2**
KiCad E.D.A. kicad 7.0.2–0		Page 2 of 13

Design requirements:
- BLE capability
- USB interface
- 2x UART
- Connectivity with other board blocks
- SWD

Utilize "Reg0 DC/DC and LDO Mode Disabled" power scheme on pg. 42 since regulated +3V3 is <3.6V

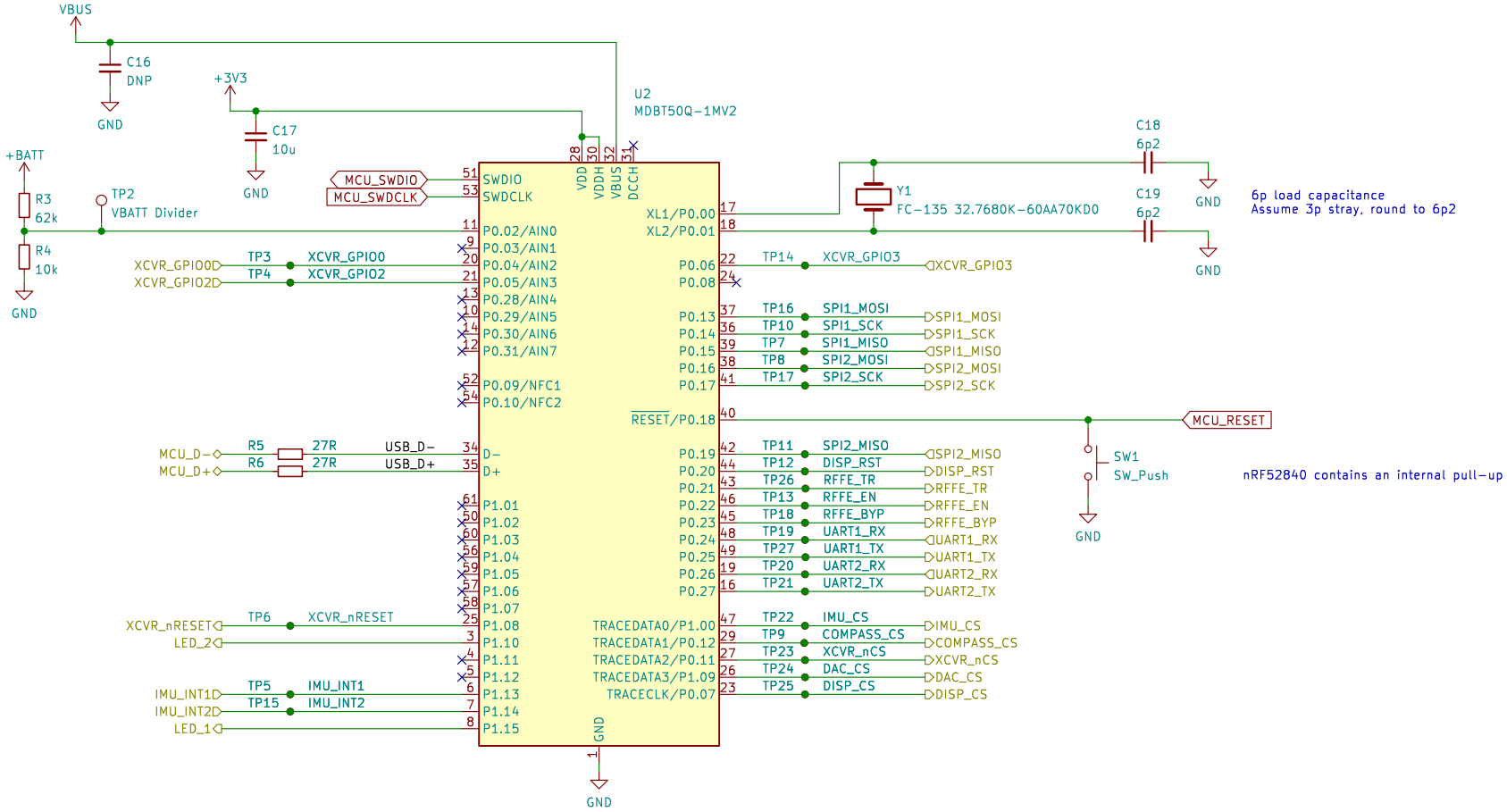
USB standard limits the downstream capacitance for inrush reasons, we have the full 10u on the VBUS at the buck-boost so DNP a capacitor here just in case we need to adjust the capacitance distribution near the respective power/MCU chips

Utilize decoupling strategy from pg. 42

0.1388 divider ratio to allow 5S battery to be measured at 3.0 reference voltage

Pinout strategy:
Avoid low frequency pins as much as possible even for regular GPIO, the only ones attached to those pins are the IMU interrupts on the NFC pins since we are not using NFC so it shouldn't matter

P1.10 and P1.15 are low drive only but we limit LED current to avoid high current draw and place them there for Adafruit Arduino Core compatibility



Groundstation

AerospaceNU
Designer: Johnny Cao
Sheet: MCU
File: mcu.kicad_sch

Size: A4	Date: 2022-10-30	**Rev: v2**
KiCad E.D.A. kicad 7.0.2-0		Page 3 of 13

RFFE Requirements:
- Range extender for transceiver module
- 30 dBm TX power
- 15 dB gain LNA
- 30 dBm RX power
- 433 MHz ISM-band

PWR_3V9AD
C21 1u
C22 1n
C24 220p
GND
+3V3
C23 10n
C25 220p
GND

Follow datasheet pg. 8 for decoupling strategy

U3
SKY65366-21

SKY65366
VDD1 16
VCC_RX 17
VDD2 23
VCC_TX1 24
VCC_TX2 25
VCC_TX3 26
TR 2
EN 3
BYP 4
VPC 5
RX2 13
RBIAS 14
TX 20
ANT 7
RX1 10
RXO 18
GND 1,6,8,9,11,12,15,19,21,22,27,28
PAD 29

RFFE_TRD
RFFE_END
RFFE_BYPD
RFFE_VPCD
C20 1u
GND
Place cap close to RFFE

R7 0R
GND
Undocumented bias resistor (leave 0R per pg. 8)

50 ohm

RFFE_TXD
50 ohm
Do not exceed 13 dBm input power on TX pin (pg. 4)

Intermediate RF filter stage
Do not perform RX-only filtering since we have the filtering on ANT as well as downstream

RFFE_RX
50 ohm

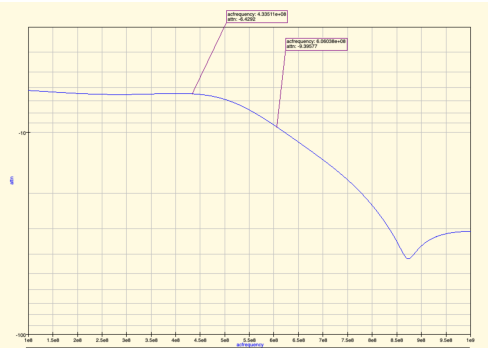
Antenna LPF
Take design from datasheet pg. 8
C27 3p
L2 12n
C26 6p8
C28 6p8
GND GND
580 MHz HPBW into the RFFE across the entire input chain

6 dB attenuation across input chain at 433 MHz

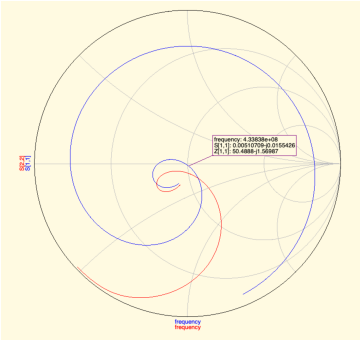
Impedance match tune
L3 12n
C29 DNP
C30 5p1
GND GND
SMA sees input impedance at 50.07-j1.52

J3
Conn_Coaxial
GND
Do not exceed 33 dBm input power on ANT pin (pg. 4)

Attenuation measured at ANT



Impedance measured at antenna port



Groundstation

AerospaceNU
Designer: Johnny Cao
Sheet: RF Front-End
File: rf-front-end.kicad_sch

Size: A4	Date: 2022-10-30	**Rev: v2**
KiCad E.D.A. kicad 7.0.2-0		Page 4 of 13

Transceiver Requirements:
- 433 MHz ISM-band
- Do not blow up RFFE (see RFFE max power)

Reference documents:
- SWRR122 - 420-470 MHz reference design from TI (CC1200)
- SWRR110 - 915 MHz to SKY65313 reference design from TI (CC1120)

+3V0

C35 47n, C36 47n, C38 47n, C40 47n, C43 47n, C45 47n, C46 47n, C47 47n, C48 47n

GND

47n decoupling per power pin (ref. SWRR122 schematic)

U5 CC1200

XCVR_nRESET	2	RESET	
	5	DVDD	
	12	DVDD	
	1	VDD_GUARD	
XCVR_nCSD	11	CS	
XCVR_SCLK	8	SCLK	
XCVR_SI	7	SI	
	13	AVDD_IF	
XCVR_SO	9	SO(GPIO1)	
	15	AVDD_RF	
	25	AVDD_PFD_CHP	
XCVR_GPIO0	10	GPIO0	
	28	AVDD_XOSC	
XCVR_GPIO2	4	GPIO2	
	22	AVDD_SYNTH1	
XCVR_GPIO3	3	GPIO3	
	27	AVDD_SYNTH2	
	30	XOSC_Q1	
	6	DCPL	
	31	XOSC_Q2	
	21	DCPL_VCO	
	32	EXT_XOSC	
	26	DCPL_PFD_CHP	
	29	DCPL_XOSC	
	14	RBIAS	
LNA_P	19	LNA_P	
LNA_N	20	LNA_N	
	23	LPF0	
	18	TRX_SW	
	24	LPF1	
	17	PA	
	33	GND_EP	

+3V0

C32 100n

GND

U4 ECS-TXO-32CSMV-400-BN-TR

TCXO: VDD (4), OUT (3), GND (1), GND (2)

Utilize TCXO - connect to EXT_XOSC (pg. 20), tie Q1 to GND and float Q2 (pg. 6).

Decoupling + DC cap value ref. SWRR122 BOM

C39 22p

GND

56k bias (ref. SWRR122 schematic)

R9 56k

GND

1.5n loop filter (ref. SWRR122 schematic)

C41 1.5n

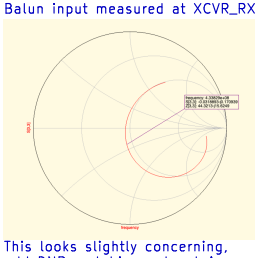
GND

Decoupling cap values ref. SWRR122

C49 47n, C52 47n, C54 10n, C56 220n

GND

Balun input measured at XCVR_RX



This looks slightly concerning, add DNP matching network in front just in case

LNA input impedance is 100+j60 at 433 MHz (pg. 10)

LC balun design ref. SWRR122

Some conflicting info about whether the 15n L should be there - based on SWRR110 and impedance simulation I think it should be, but TI employees believe the un side of the balun is already 50R - place 0R if this is the case

No connect TRX_SW since MCU controls RX mode, also don't need to worry about impedance match and see SWRR110

Balun

L9 56n

C50 5.1p, L7 27n, C55 5.1p, L10 27n

GND GND

L6 15n

PA bias (ref. SWRR122 schematic)

+3V0

C31 10n, C33 100p, C34 56p, R8 18

GND

L4 56n

Impedance match tune

L11 0R

XCVR_RX

50 ohm

C86 DNP, C87 DNP

GND GND

10 dBm max input (pg. 7)
DC-blocking cap in RFFE

C37 39p

PA impedance match

L5 22n

C42 3p3, C44 6p2

GND GND

Impedance match + DC block is around 55.6+j21.4 @ 433 MHz

50 ohm

FL1 B39431B3710U410

IN (2), OUT (5), GND GND GND GND (1, 3, 4, 6)

GND

10 dBm max input (pg. 9)
Center freq = 433.92 MHz

50 ohm

Impedance match tune

L8 0R

C51 DNP, C53 DNP

GND GND

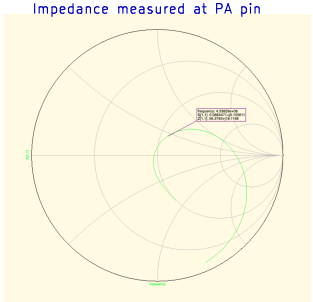
XCVR_TX

50 ohm

PA load impedance must be 55+j25 at 433 MHz (pg. 13)

DC-blocking cap value taken from SWRR122

Impedance measured at PA pin



Groundstation

AerospaceNU
Designer: Johnny Cao

Sheet: Radio Transceiver
File: radio-transceiver.kicad_sch

Size: A4	Date: 2022-10-30	**Rev: v2**
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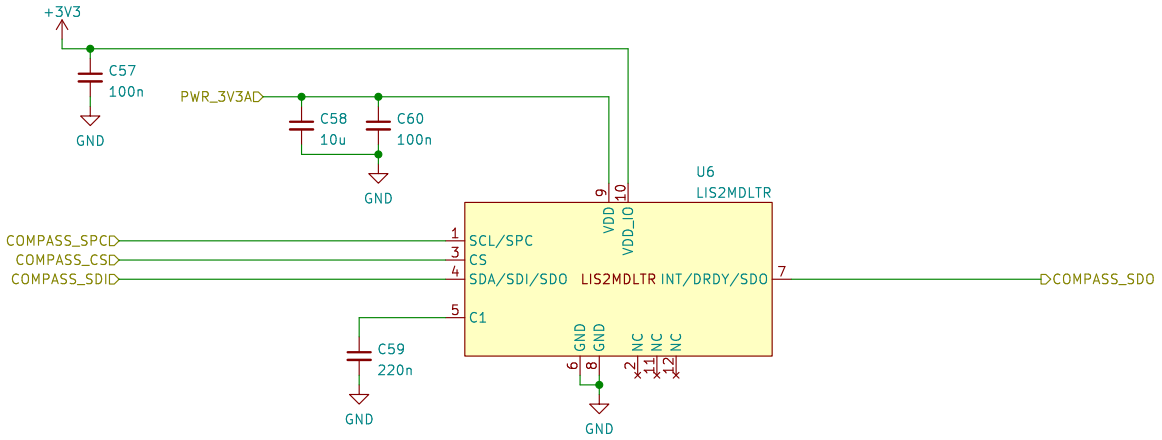
AERONU

Follow application schematic on pg. 19

Must be 200n (pg. 8)



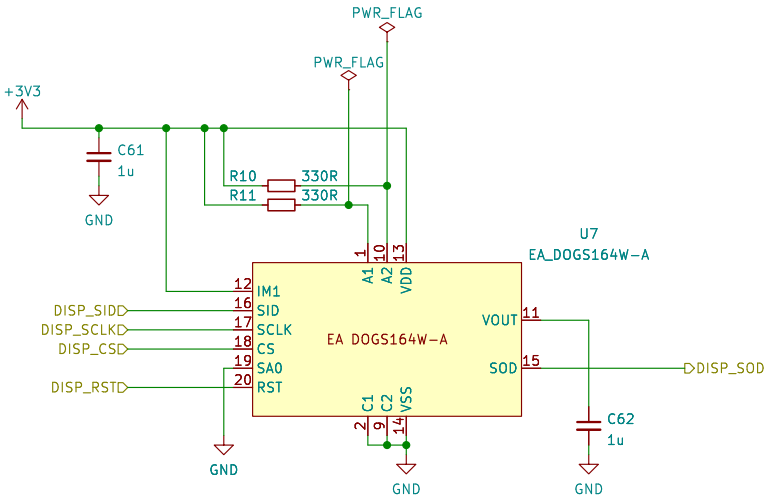
DRDY pin shared with 4-wire SPI so chip must be polled

Groundstation		
AerospaceNU **Designer: Johnny Cao** Sheet: Compass File: compass.kicad_sch		
Size: A4	Date: 2022-10-30	**Rev: v2**
KiCad E.D.A. kicad 7.0.2-0		Page 6 of 13

Follow reference schematic on pg. 4

Tie IM1 to VDD for SPI mode (pg. 8)

Reference schematic ties SA0 to GND for SPI (pg. 4)



Use large resistor to limit current on LED backlight – drop is around 2.1V to 3V so use 330R

Place 1u per reference schematic (pg. 4)

Groundstation

AerospaceNU
Designer: Johnny Cao
Sheet: Display
File: display.kicad_sch

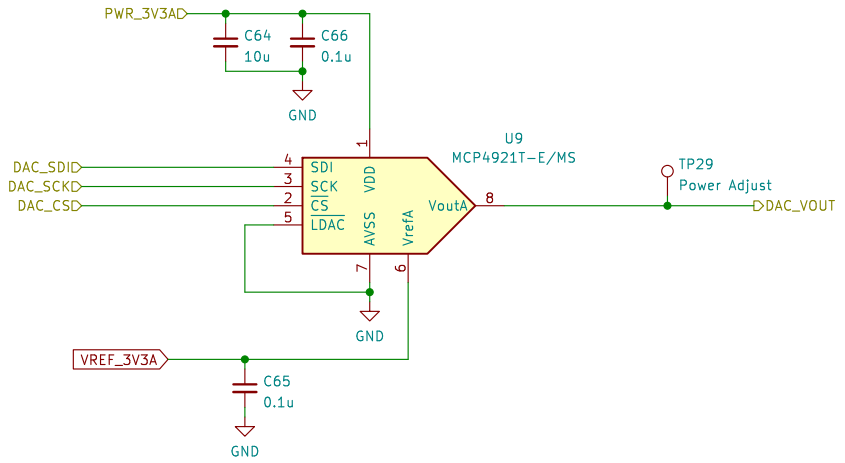
Size: A4	Date: 2022-10-30	**Rev: v2**
KiCad E.D.A. kicad 7.0.2-0		Page 7 of 13

DAC Requirements:
- Used to adjust output power on RFFE block
- 3V3 logic level
- 0–2.50 V output
- 12 bit

0.1u, 10u decoupling (pg. 27)

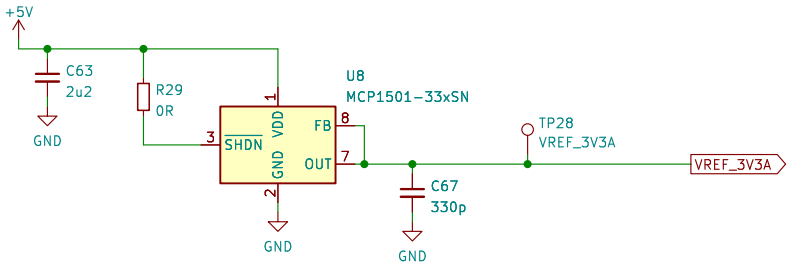
$\overline{\text{LDAC}}$ tied to GND to transfer to output immediately when CS rises (see pg. 15, 20)

Datasheet does not say to place decoupling on Vref, but eval kit contains 0.01u cap. (see DS51523A pg.21)



3V3 Reference
VIN = 5V (3.5 < x < 5.5V pg. 3)
VOUT = 3.3V fixed (pg. 31)
IOUT = +/- 20mA (pg. 4)
60 Hz PSRR = 94 dB (pg. 3)

Place optional caps for better filtering (pg. 15)



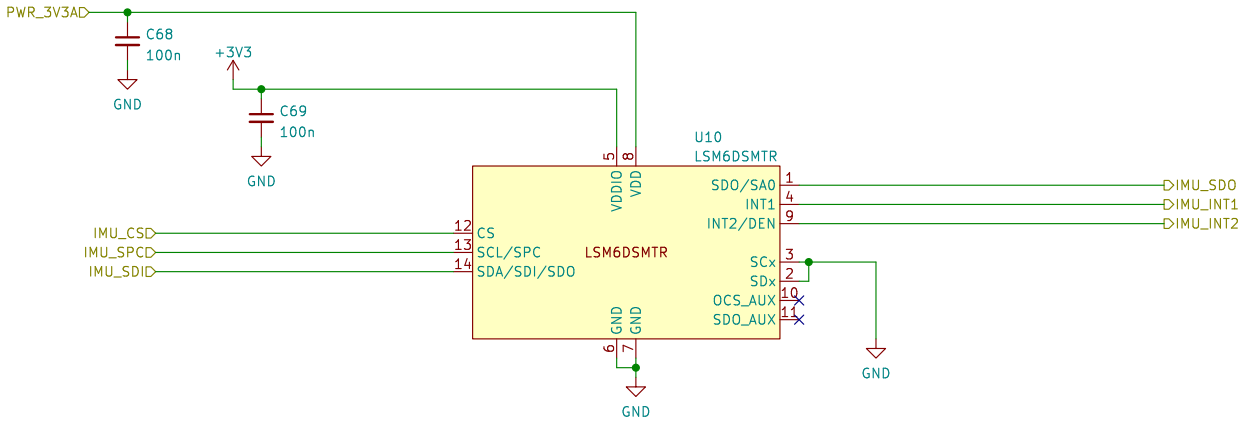
Groundstation

AerospaceNU
Designer: Johnny Cao
Sheet: DAC
File: dac.kicad_sch

Size: A4	Date: 2022-10-30	**Rev: v2**
KiCad E.D.A. kicad 7.0.2-0		Page 8 of 13

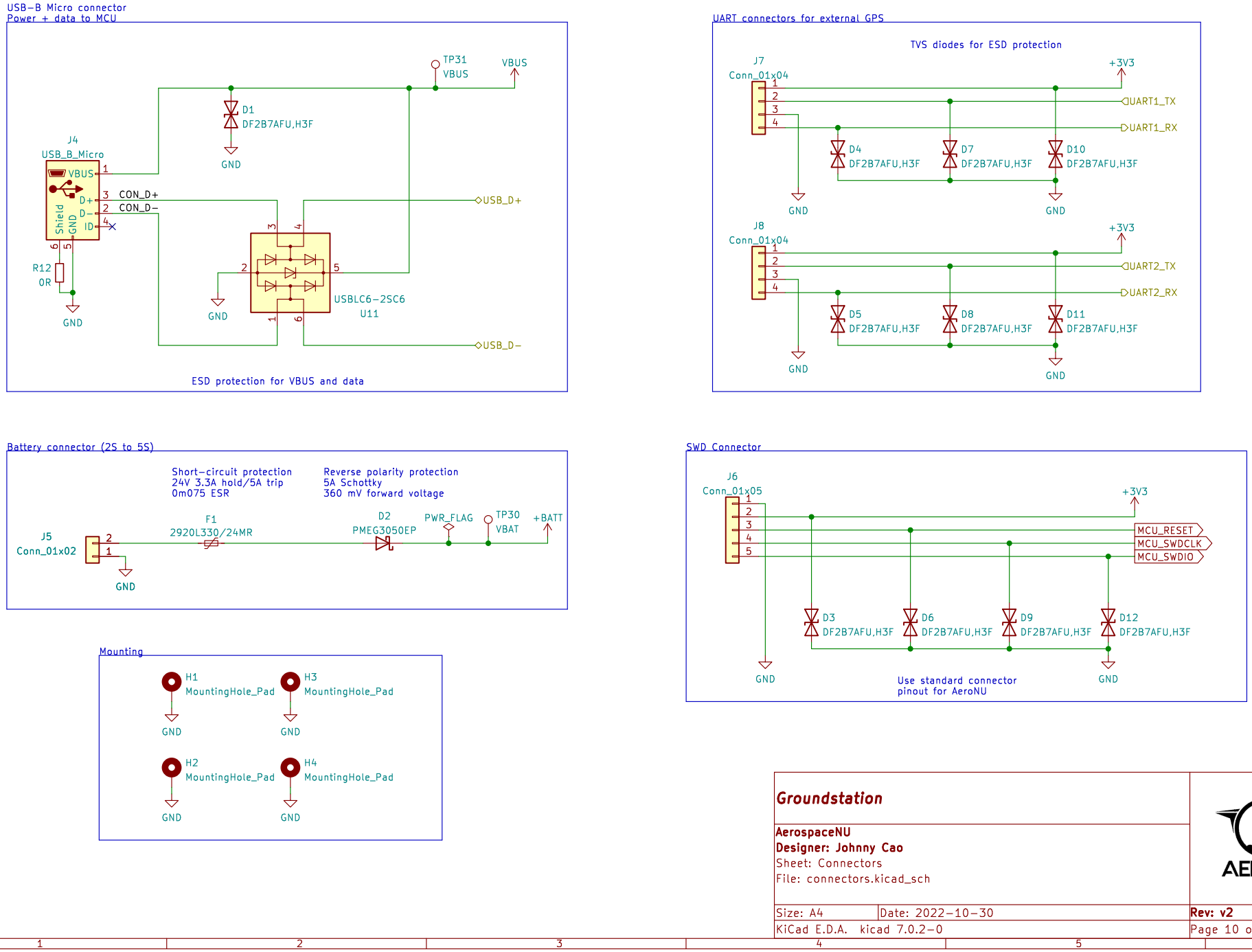
Follow "Mode 1" application on pg. 49 to utilize 4-wire SPI.

100n decoupling as suggested by pg. 49.



Leave OCS_AUX, SDO_AUX unconnected
SCx and SDx connect to GND
(pg. 22)

Groundstation		
AerospaceNU **Designer: Johnny Cao** Sheet: Accelerometer File: accelerometer.kicad_sch		
Size: A4	Date: 2022-10-30	**Rev: v2**
KiCad E.D.A. kicad 7.0.2-0		Page 9 of 13



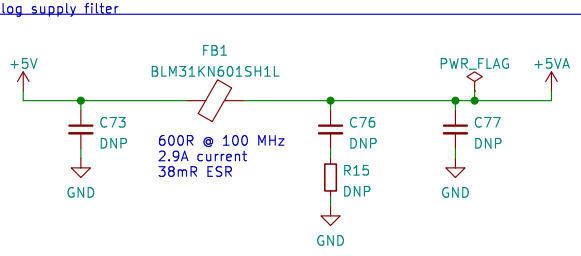
Groundstation

AerospaceNU
Designer: Johnny Cao
Sheet: Connectors
File: connectors.kicad_sch

Size: A4	Date: 2022-10-30	**Rev: v2**
KiCad E.D.A. kicad 7.0.2-0		Page 10 of 13

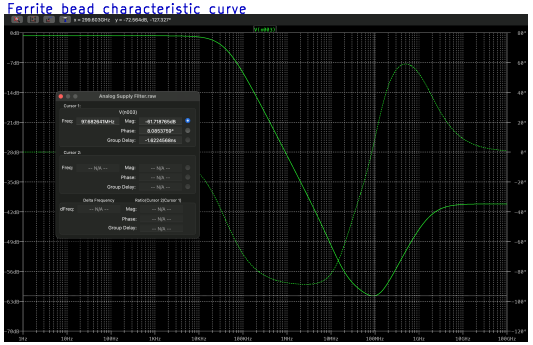
Design requirements:
- 3V0A output @ 50 mA
- 3V3A output @ 2 mA
  - Accelerometer @ 1 mA
  - Compass @ 1 mA
- 3V9A output @ 1A

Analog supply filter

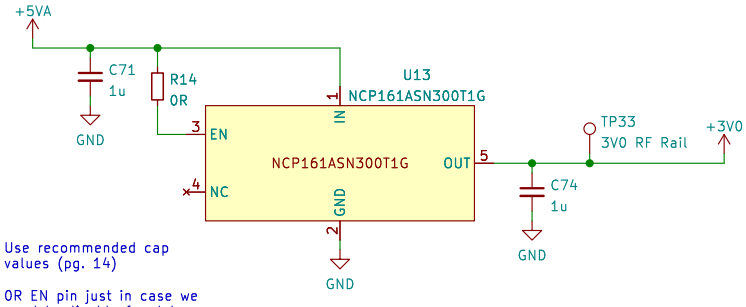


We don't really need a fast roll-off, DNP pi-filter pads just in case though

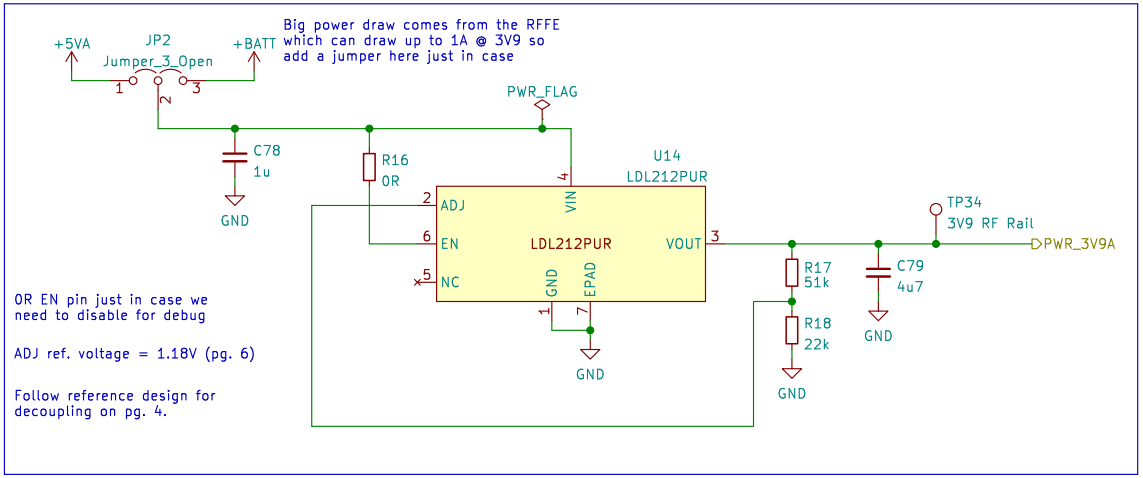
Ferrite bead characteristic curve



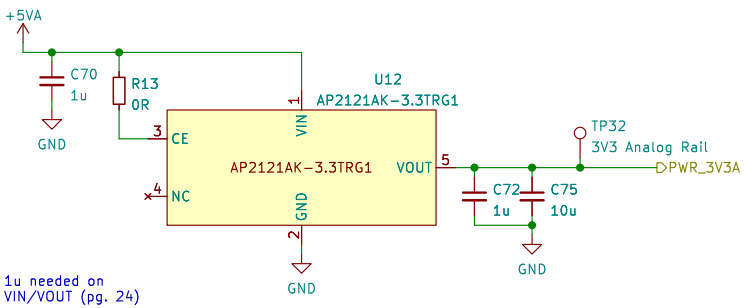
3V0 RF Power Rail
VIN = 5V (1.9 < x < 5.5V pg. 4)
VOUT = 3.0V fixed (pg. 18)
IOUT = 450 mA (pg. 4)
1 kHz PSRR = 98 dB (pg. 4)
Dropout = 275 mV (pg. 4)



3V9 RF Power Rail
VIN = 5V (2.5 < x < 18V pg. 4)
VOUT = 3.9V adjusted
IOUT = 1.2 A (pg. 41)
1 kHz PSRR = 75 dB (pg. 6)
Droupout = 600 mV (pg. 6)



3V3 Analog Rail
VIN = 5V (x < 6V pg. 8)
VOUT = 3.3V fixed (pg. 4)
IOUT = 200 mA (pg. 1)
Dropout = 150 mV (pg. 1)
1kHz PSRR = 70 dB (pg. 17)



Groundstation

AerospaceNU
Designer: Johnny Cao
Sheet: Analog Rails
File: analog-rails.kicad_sch

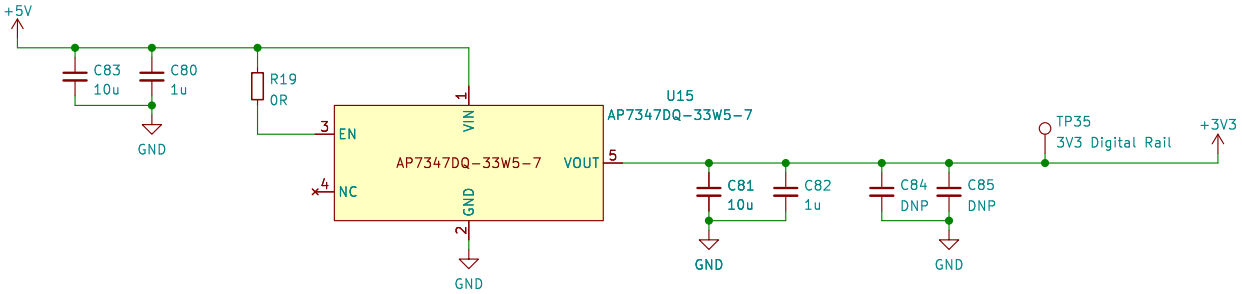
Size: A4	Date: 2022-10-30	**Rev: v2**
KiCad E.D.A. kicad 7.0.2-0		Page 11 of 13

Design requirements:
- 3V3D output @ 300 mA
  - MCU @ 50 mA
  - RFFE @ 25 mA
  - DAC @ 1 mA
  - Accelerometer @ 1 mA
  - Compass @ 1 mA
  - Display @ 60 mA
  - 2x GPS @ 67 mA

3V3 Digital Rail
VIN = 5V (1.7V < x < 5.5V pg. 4)
VOUT = 3.3V fixed (pg. 13)
IOUT = 500 mA (pg. 4)
Dropout = 320 mV (pg. 1)

1u required for input
Include extra 10u bulk
for improved ripple
performance

0R just in case we need to
manually disable for debug



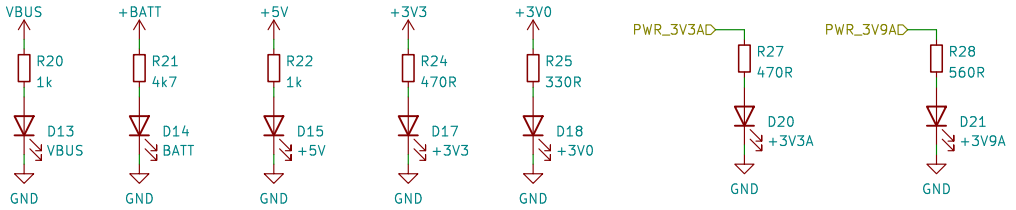
Include extra pads just in
case we need additional bulk
decoupling for digital signals

Groundstation		
AerospaceNU **Designer: Johnny Cao** Sheet: Digital Rails File: digital-rails.kicad_sch		
Size: A4	Date: 2022-10-30	**Rev: v2**
KiCad E.D.A. kicad 7.0.2-0		Page 13 of 13

Power Rail LEDs

LED P/N: 150060VS75000

Target <5mA current through LED
2V drop for Wuerth green LEDs

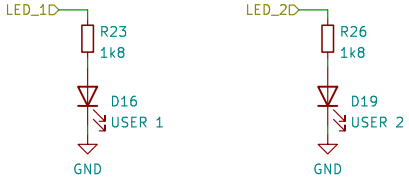


MCU-controlled LEDs

LED P/N: 150060RS75000

nRF52840 can source typ. 2 mA off GPIO
on standard drive

Target 1 mA current through LED
~1.5V drop for Wuerth red LEDs



Groundstation

AerospaceNU
Designer: Johnny Cao
Sheet: LEDs
File: leds.kicad_sch

Size: A4	Date: 2022-10-30	**Rev: v2**
KiCad E.D.A. kicad 7.0.2-0		Page 13 of 13