KREPE-2 Avionics Documentation

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1 Introduction

This document contains information about the flight computer for the KREPE-2 mission as well as the safety precautions taken to ensure the flight hardware is not a danger to the ISS or its astronauts. In addition to electrical designs and schematics, this document contains pin names, links to datasheets, and implementation notes. The following sections outline the subsystems of the flight computer and pin names for software usage. Other details about the power subsystem including battery type and rating are also included.

There are a total of 5 capsules in the KREPE-2 mission, an increase from the 3 capsules present in the original KREPE mission (now referred to as KREPE-1). The table below shows the part names and numbers of the 5 capsules as presented to NASA for integration with a resupply mission.

Table 1: Part names and numbers for the KREPE-2 capsules.

Part Name	Part Number
KREPE-2-SPICA	KREPE-2-001
KREPE-2-CPICA	KREPE-2-003
KREPE-2-AMTPS	KREPE-2-002
KREPE-2-REUSE	KREPE-2-004
KREPE-2-FFORM	KREPE-2-004

The entire flight ready assembly is referred to as KREPE, which consists of a capsule containing the science (flight computer, batteries, etc.) and a metal shell known as KREM that acts as a Faraday cage, inhibiting any inadvertent RF radiation from the capsule. Both primary and secondary activation must occur for the capsule to become fully active and begin RF transmissions. To avoid accidental activation of hazardous subsystems, secondary activation criteria must be met. Primary and secondary activation processes are discussed in sections 1.1,1.2, and **??**.

The subsystems of the flight computer are outlined in Sec. 2. Pin definitions are listed with each hardware or sensor component along with any relevant information regarding safety or implementation. Electrical schematics, microcontroller reference cards, and a partslist are shown in Appendices A, E, and D, respectively.

1.1 Primary Activation

Primary activation is triggered by a pin pulled out of KREPE by astronauts. Once the pin is pulled, a mechanical switch[1] is closed and the flight computer boots to dormant mode where it consumes minimal power. The Iridium radio is not powered on in dormant mode. After pulling the pull tab, an astronaut places a piece of copper tape over the hole, resealing the faraday cage effect of the KREM, and primary activation is the complete. Copper tape ensures the KREM is completely sealed with regard to inadvertent EMI while on station.

A schematic showing battery protection and primary activation circuitry activation is shown in Fig. 1. Less than 5 inches of copper 20 AWG PVC insulated wire is used to connect the batteries to the first power function (battery protection circuitry).

[1] https://www.digikey.com/en/products/detail/panasonic-electric-works/ABJ362860/4691828

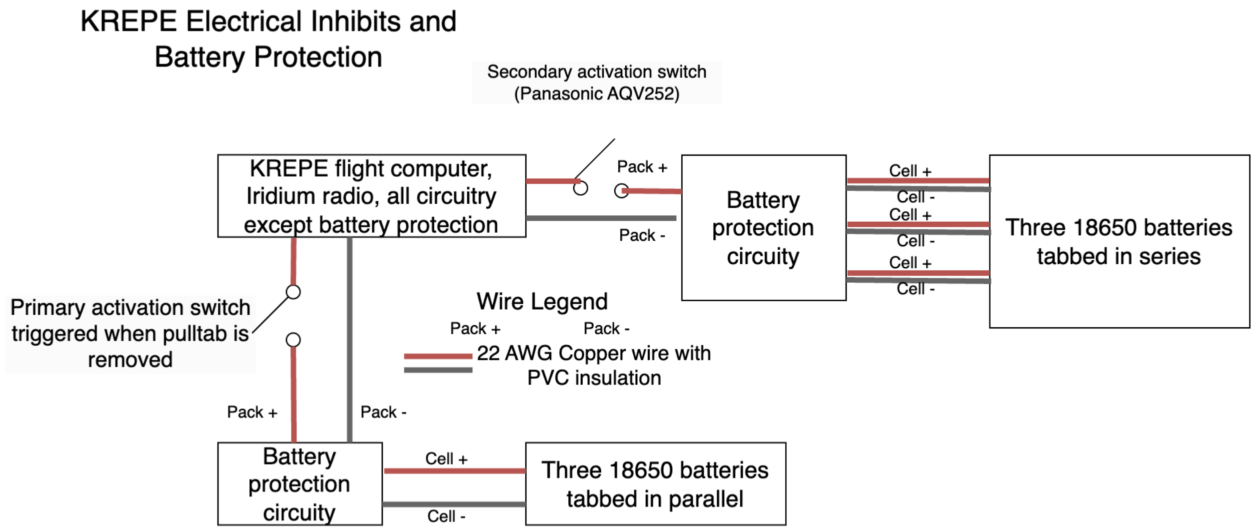

Figure 1: Activation and battery protection schematic overview.

1.2 Secondary Activation

Once primary activation is complete and the flight computer is in dormant mode, a digital input to the flight computer is configured as an interrupt to sense when the KREM separates from around the capsule. This secondary activation interrupt is triggered during re-entry when the KREM heats to a temperature that is sufficient to melt the polycarbonate bolts that hold it together. No radio transmissions are attempted before secondary activation. The Iridium radio remains unpowered until secondary activation.

2 Subsystem Design

The following sections outline the different sensor systems that are present on the KREPE-2 capsules, including their placement along the forebody and relative position to other sensors. An overview of the hardware and sensors that are in a KREPE capsule, along with the electrical connections to the flight computer are shown in Fig. 2.

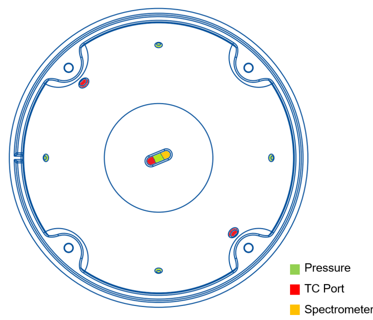

Figure 3: Thermal, pressure, and spectral measurement location on the capsule forebody.

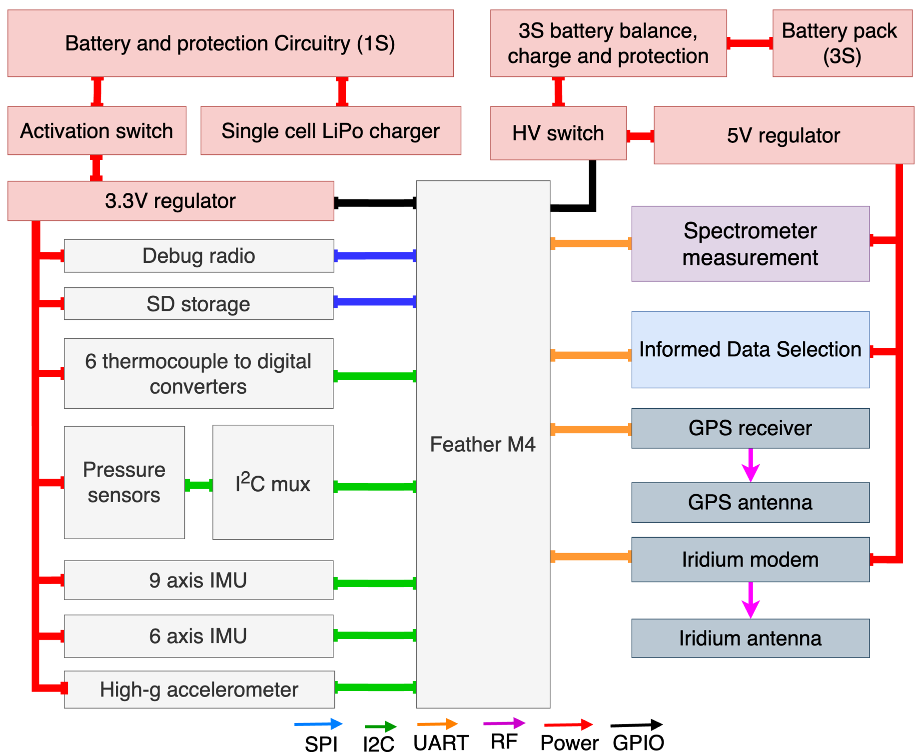

Figure 2: Overview of the KRUPS flight computer and subsystem connections.

2.1 Thermal Measurement

The thermal measurement subsystem is used to take readings from up to six thermocouples (TCs) embedded within the TPS surrounding each capsule. The locations for the thermal measurement points with respect to the internal housing are shown in Fig. 2.1, along with other sensor locations such as ported pressure sensors and spectrometers.

The thermocouple to digital conversion system on KREPE-2 uses 6 MCP-9600 TC to digital converters linked via I2C bus. This is an improvement over the multiplexed converter setup used in the first KREPE mission. A low pass filter is included between the TC connector points and each MCP-9600 to help suppress spurious measurements.

2.2 Pressure Measurement

The KREPE-2 capsule design includes an array of ported pressure sensors in a cross configuration, constitutes what is known as a flushed air data sensing (FADS) system. Such FADS systems are very useful in the reconstruction of the re-entry trajectory attitude?. Flexible PTFE tubing is used to connect the hole in the forebody to the barb on the pressure sensor. An image of the Honeywell sensor used is shown in Fig. 4.

Figure 4: Honeywell ported pressure sensor used for the FADS system.

2.3 Spectrometer Subsystem

Another addition to the sensor suite on the KREPE-2 capsules is a Hamamatsu C12880 miniature spectrometer[2].

Due to the position that the spectrometer must be in, in the nose (stagnation point) of the capsule, there is a need for a processing element in the same region. For this reason we are working on implementing a Battery and Spectrometer Measurement System (BSMS). This BSMS will be able to read the spectrometer as well as monitor the system battery voltages.

2.4 Inertial Measurement

The KREPE-2 flight computer also features multiple inertial measurement sensors to collect rotational rates and accelerations experienced by the capsule during re-entry. Like FADS measurements, the IMU data collected by the capsule will also greatly aid the post-flight reconstruction of the re-entry environment which occurred for each capsule.

The inertial sensors present on the KREPE-2 flight computer are an FSM300, ICM-42670, and an H3LIS100. The FSM300 is a preassembled unit which features a BNO-088 9 axis IMU. The maximum acceleration measurable by the FSM300 is ±16g. The ICM-42670 is an additional 6-axis IMU included as an evaluation platform. The primary IMU is the FSM300. The H3LIS100 is a 3-axis accelerometer, included for measuring accelerations on the capsule which are greater than ±16g.

2.5 Power and Batteries

The power and battery subsystem on the KREPE-2 capsules has improved features and capacity from the KREPE-1 design. Batteries are still provided by NASA Cargo Mission Contract (CMC) fulfilled by JSC and rated at 3200mAh each. KREPE-2 features two separate battery packs which allow for greater flexibility when designing any future capsule instrumentation. Three cells are tabbed in series to provide a 3S1P pack (11.1V nominal), as well as a secondary system pack which consists of 3 cells tabbed in parallel, or 1S3P.

The 3.7V pack powers the flight computer, but not any high-draw peripherals (GPS, Iridium modem, spectrometer, etc). The 11.1V pack is switched on after secondary activation and powers any high draw peripherals through an optional 5V buck regulator.

Battery classification, product, and model number can be seen in Fig. 2.5 (taken from battery specification sheet).

[2] https://www.hamamatsu.com/content/dam/hamamatsu-photonics/sites/documents/99_SALES_LIBRARY/ssd/c12880ma_kacc1226e.pdf

Battery Classification and Product Code

4.1	Battery Classification	Lithium Ion Battery
4.2	Product Code	BJ-A300180AA
4.3	Model Name	NCR18650B-H07XA
4.4	Cell Type	NCR18650BL

Figure 5: Sanyo battery specifications from the datasheet.

The 3.7 pack is able to be recharged through the MCP73831[3] present on the Feather M4, however the 11.1V pack currently be charged externally through a separate balance connector which does not connect to the flight computer.

There is work ongoing which aims to support the monitoring of the 3S1P pack. This system will also interface with the spectrometer.

Charging is only performed on the ground and there is no provision for charging in flight. Schematics and electrical connections are shown in Fig. 14 in Appendix A.

2.5.1 Battery Protection

Protection circuitry is implemented on each of the two battery packs present on the KREPE-2 capsules.

We are using a DW01-P Voltage and Current Protection IC for the 3.7V and 11.1V system packs [4].

The 11.1V auxiliary pack has a separate battery protection circuit that protects it from over current, under voltage, and over voltage conditions.

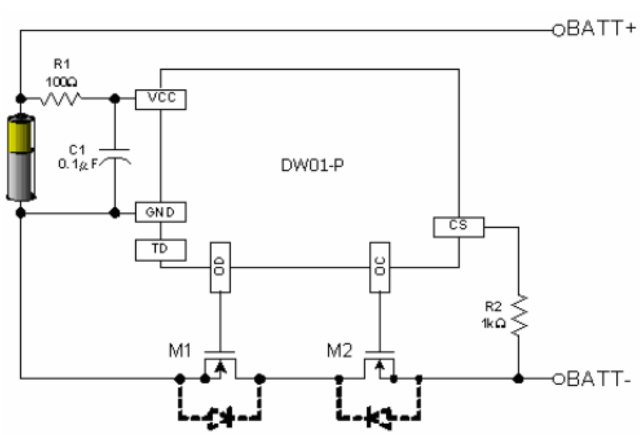

Figure 6: Battery protection circuitry.

Protection circuitry as implemented on the KREPE flight computer PCB is shown in Fig. 6. Our two battery packs are both connected to their respective battery protection circuitry, then to primary activation switches. This protection circuitry is upstream of the primary activation switch. The battery protection PCB can be seen in Fig. 7.

[3](https://www.microchip.com/wwwproducts/en/MCP73831)

[4]https://cdn.sparkfun.com/assets/learn_tutorials/2/5/1/DW01-P_DataSheet_V10.pdf

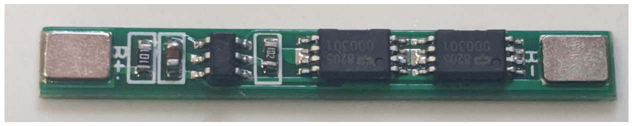

Figure 7: Battery protection PCB.

Over-current protection Both the 3.7V and 11.1 V packs have their own battery protection circuity as the first power function after the batteries and before any cabling goes to the avionics or flight computer. Pictures of the protection PCBs and overcurrent tests proving their effectiveness are shown in the following figures.

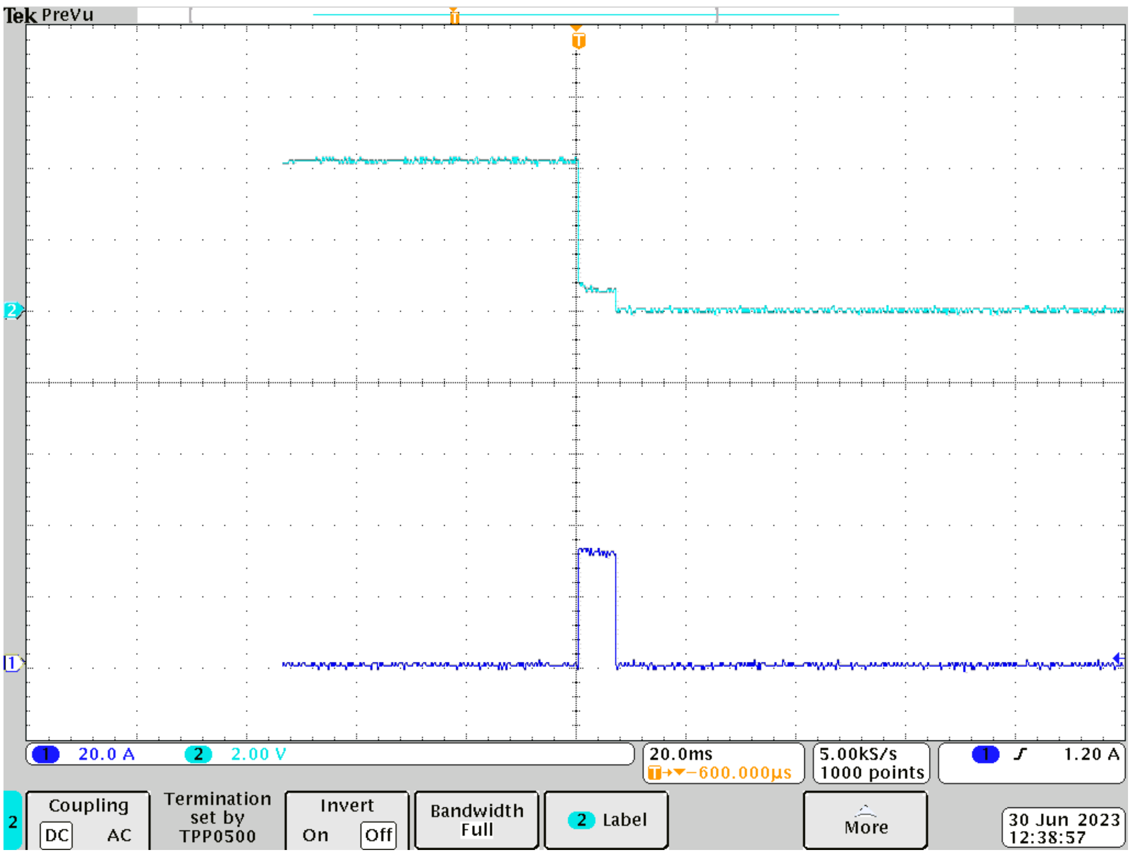

Figure 8: The battery protection circuity disconnecting the cells after 6ms of over current condition. Blue: current. Purple: pack voltage.

The high voltage pack (3S) is protected by another PCB that also uses the DW01 protection IC, except it has three of these chips in the same circuit in order to protect a 3S (series) pack from overvoltage, undervoltage, and overcurrent conditions. An example of the 11.1V pack protection circuitry protecting from over current conditions can be seen in Fig. 10. The circuit protection board for the three cell series pack can be seen in Fig. 9.

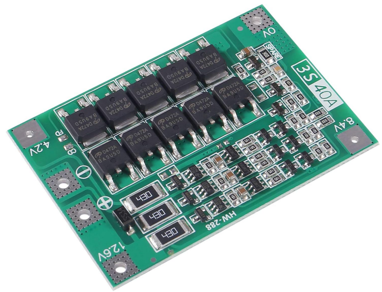

Figure 9: Battery protection board for the 3S 11.1 V pack.

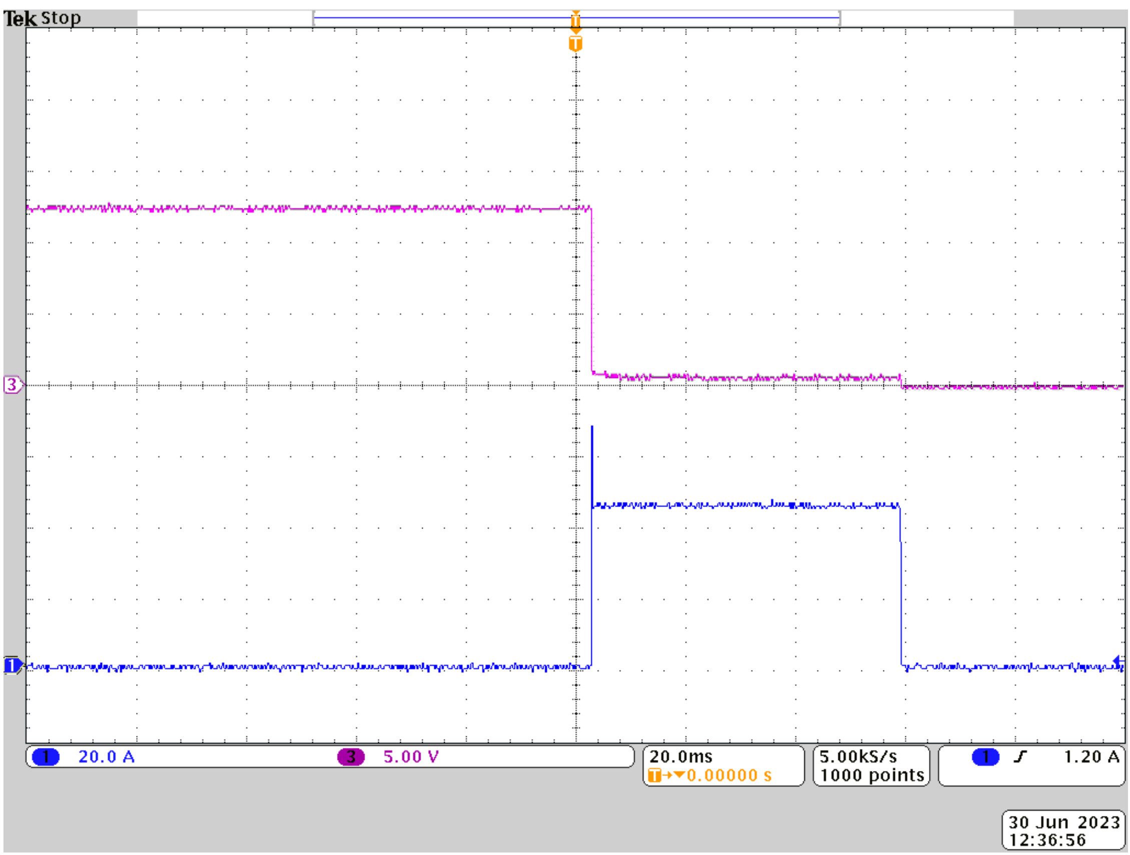

Figure 10: Overcurrent protection test from 3S pack protection circuitry

2.6 Visual Status Indicators

There are individual LEDs on the POL switches connected to each serial port header, in addition to an indicator on the external 3v3 regulator. In addition to these indicators, the Feather M4 board also has an RGB led that is used to indicate program state

3 PCB Assembly and Programming

3.1 Component placement and board bringup

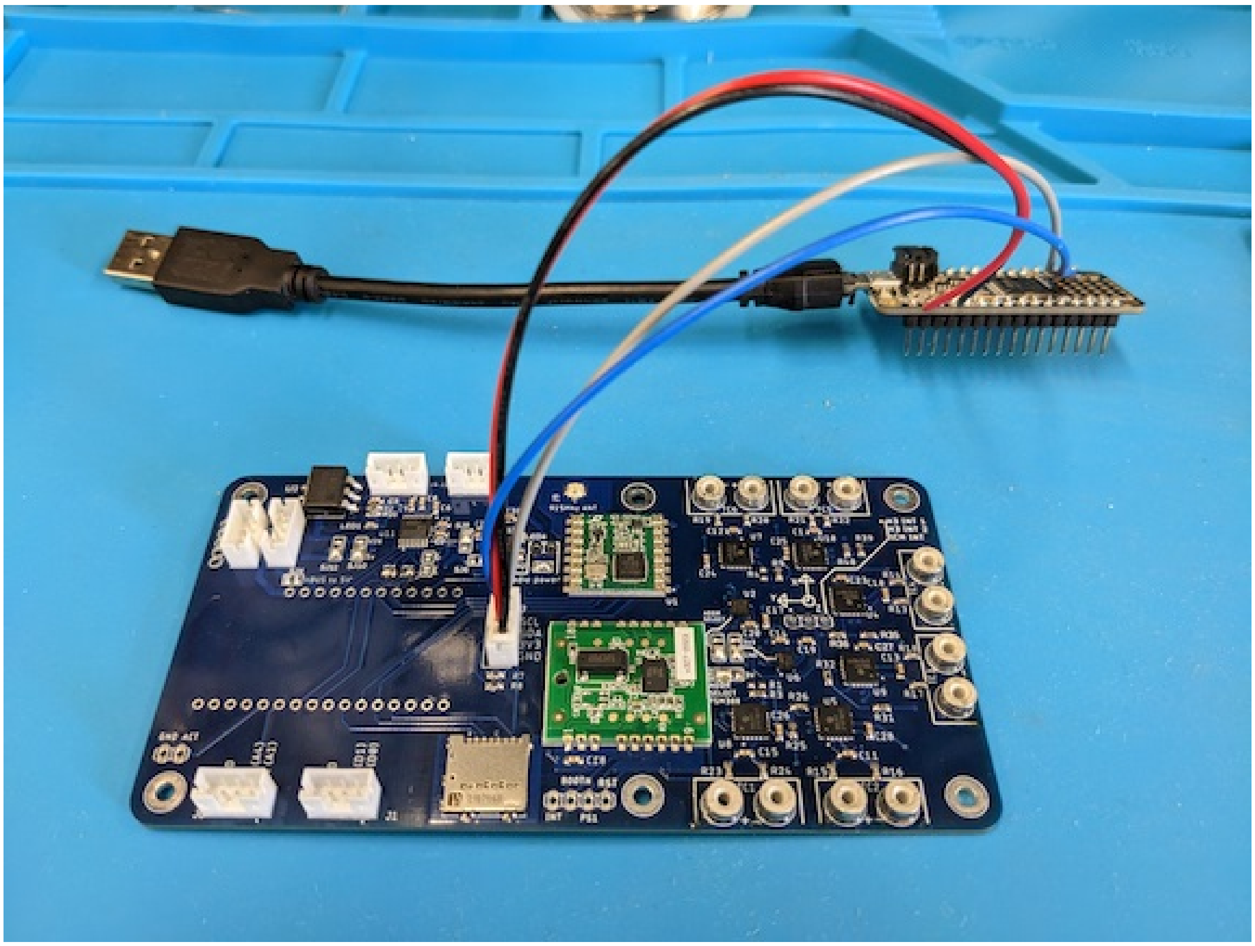

Figure 11: A freshly assembled flight computer with tester attached. The tester performs I^{2}C discovery and ensures all components are electrically connected

3.2 Solder Jumpers

There are several solder jumpers on the KFC.

- **SJ8** selects which 3.3v source the RS232 translator chip will be powered from
- **SJ10** selects the voltage source for the optionally level shifted UART (designated for GPS) to be either 5V or VIN (the high voltage pack)

- **SJ11** selects the voltage source for the level shifted UART (designated for the Iridium modem) to be either 5V or VIN (the high voltage pack).

3.3 Programming

A Schematics

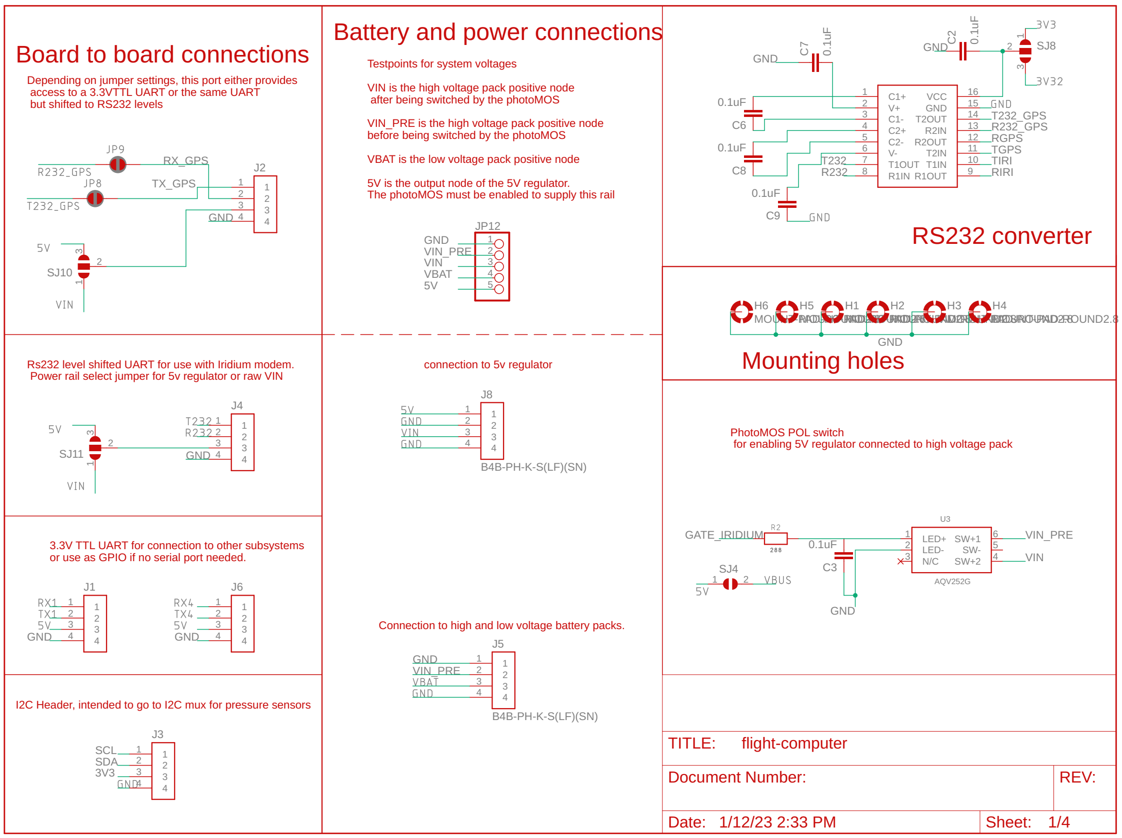

Figure 12: Page one of schematics.

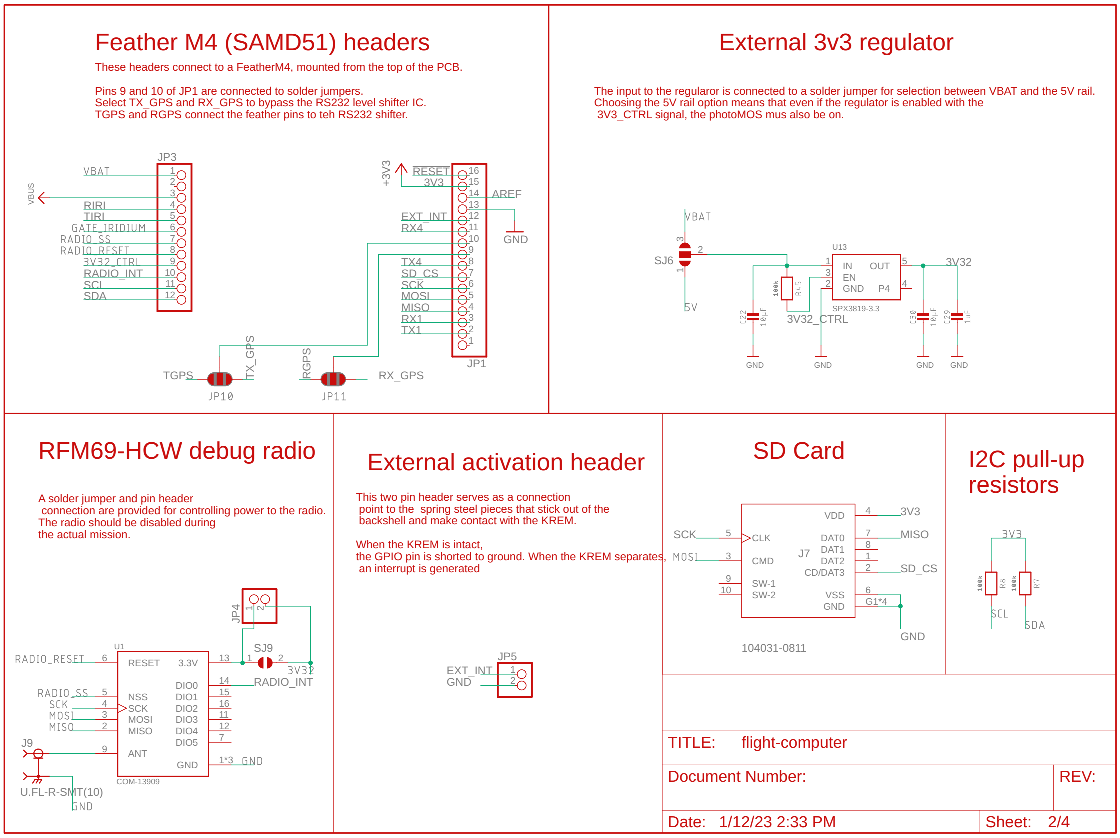

Figure 13: Page two of schematics.

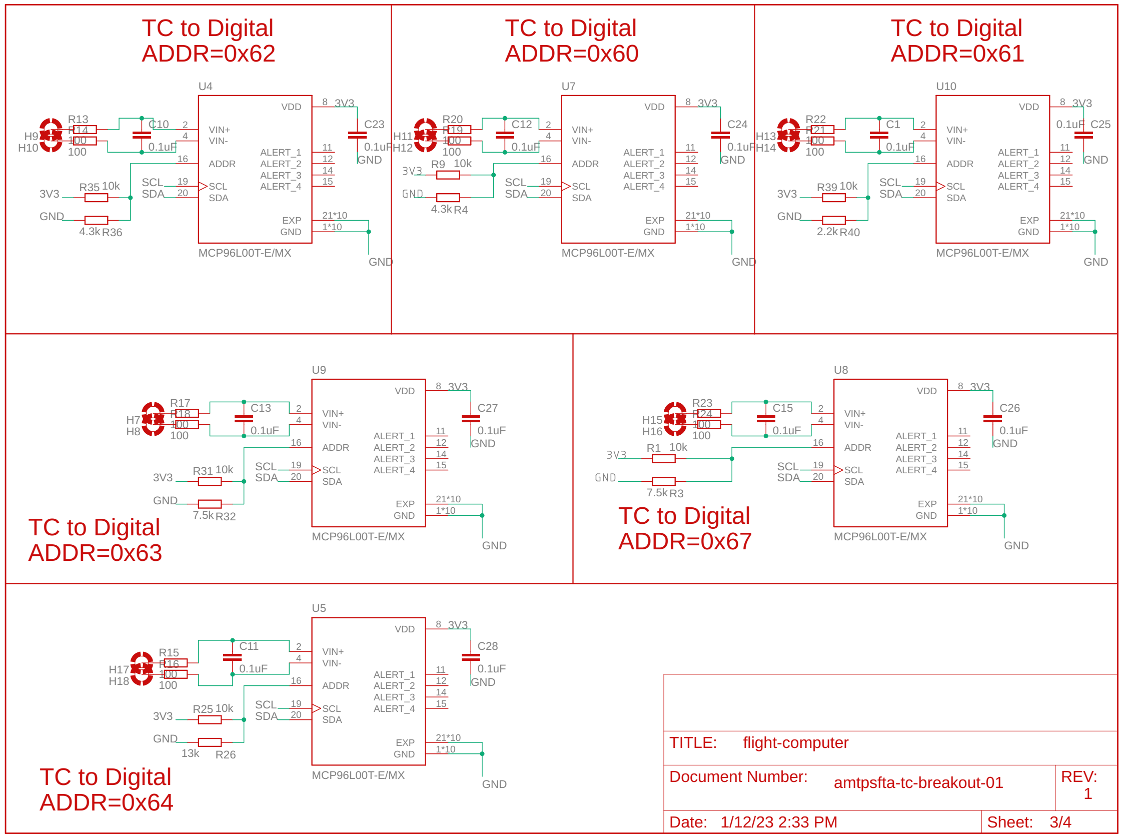

Figure 14: Page three of schematics.

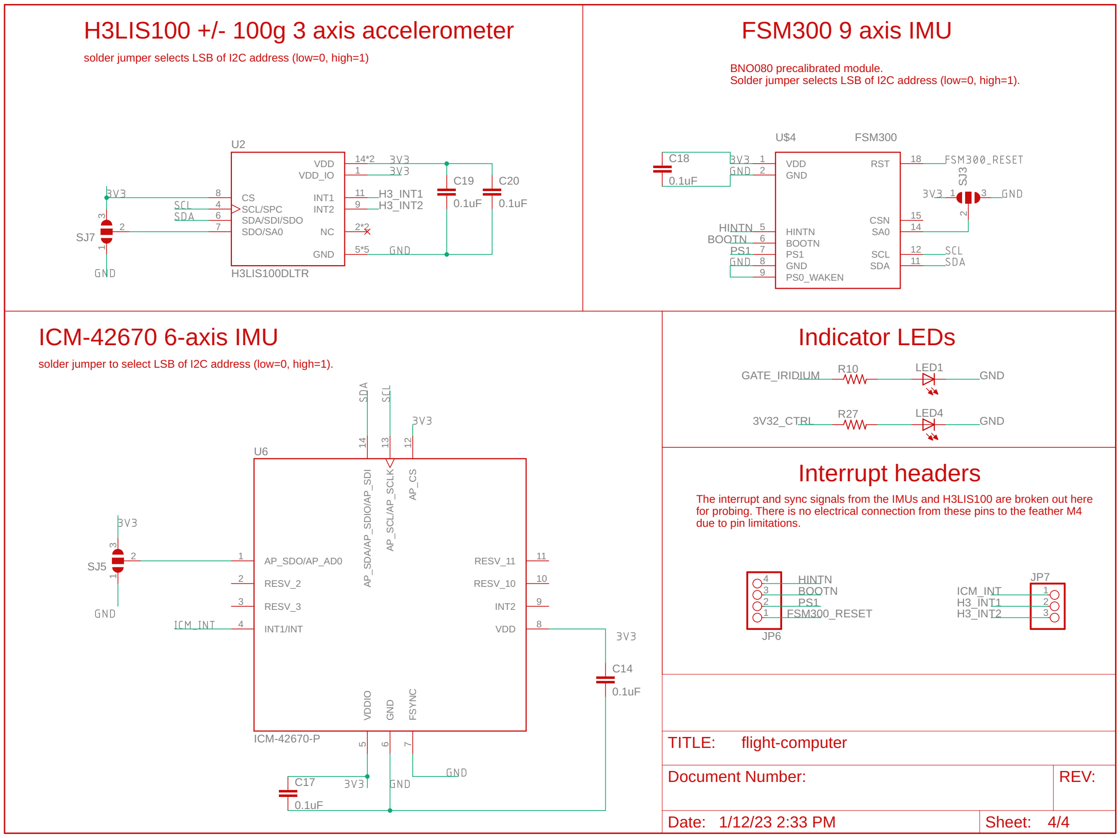

Figure 15: Page four of schematics.

B Board Renderings

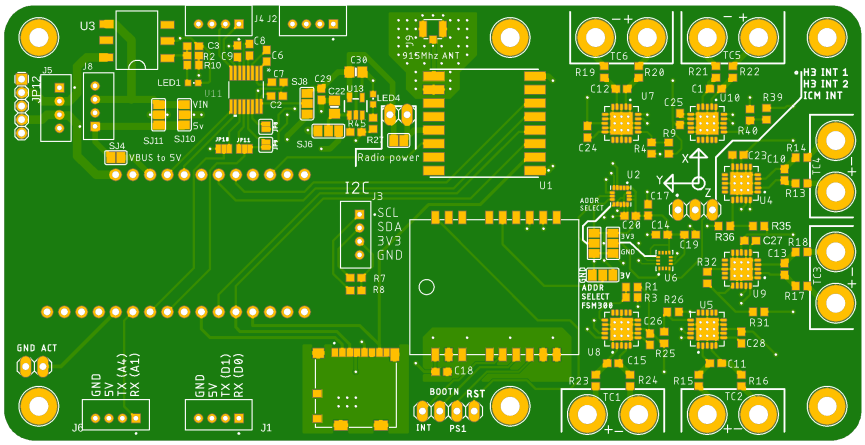

Figure 16: Rendering of the top of the KREPE-2 control board.

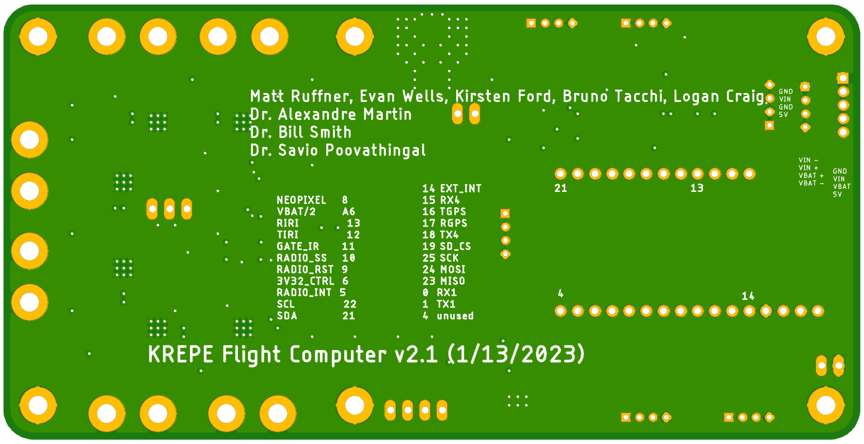

Figure 17: Rendering of the bottom of the KREPE-2 control board.

C COTS hardware references

This section contains reference cards for the COTS components used in the KREPE-2 capsules.

C.1 Feather M4 Express

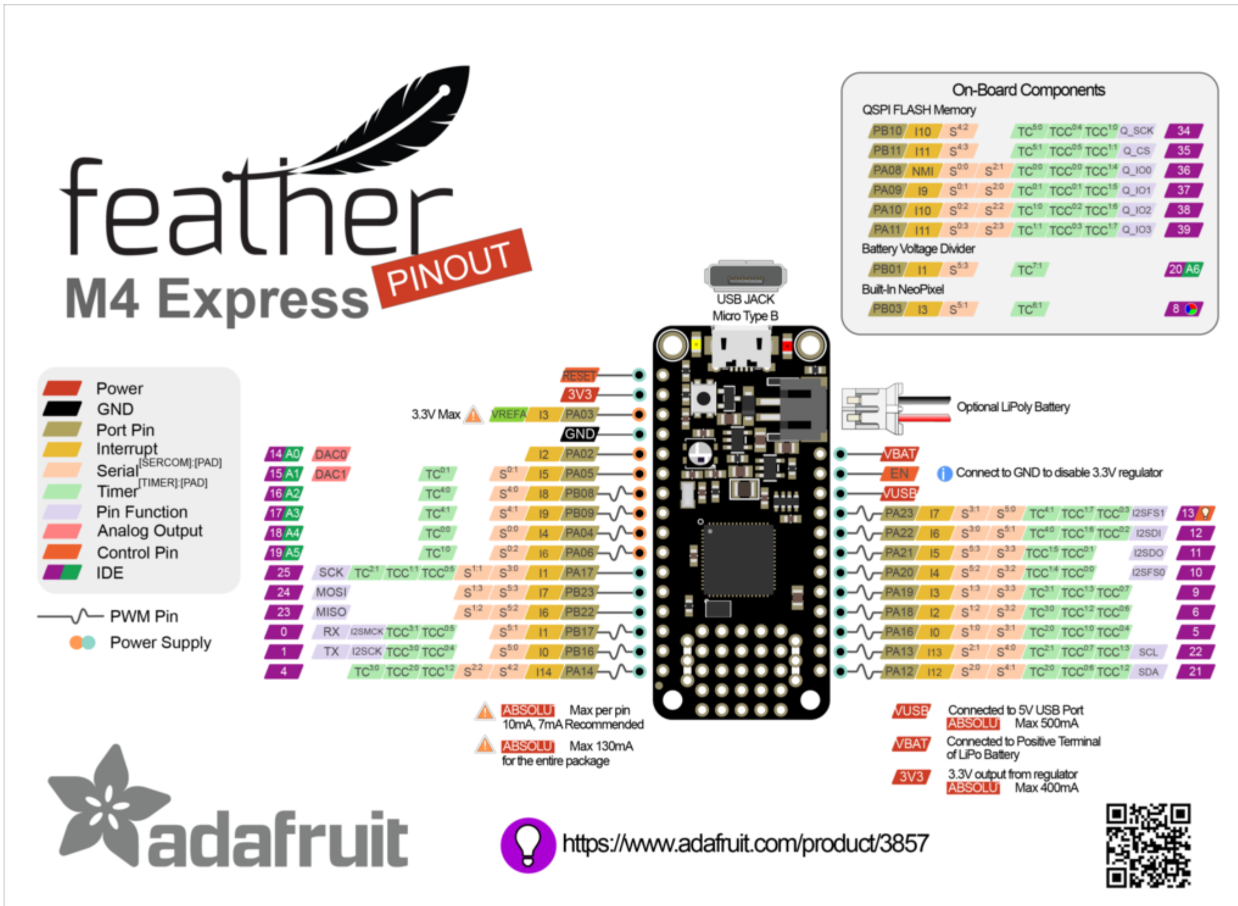

Figure 18: Feather M4 Express

C.2 Nano Pi Neo Air

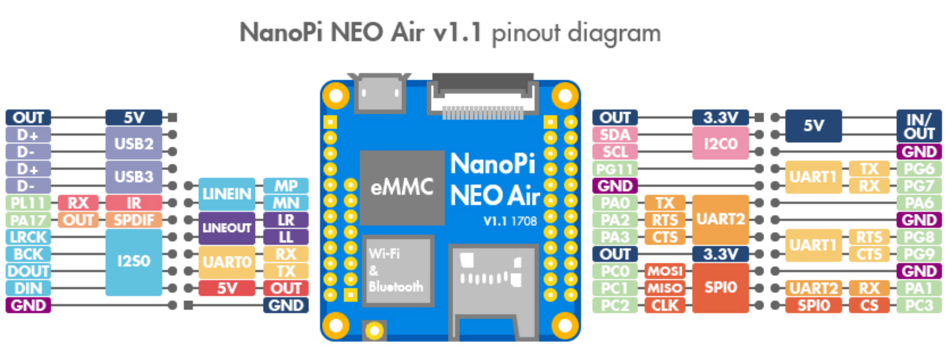

Figure 19: NanoPi Neo Air reference sheet.

D Partslist

Partlist

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Assembly variant:

Part	Value	Device	Package	Library	Sheet
ACTIVATION_SW		PINHD-1X2	1X02	pinhead	3
ANT	U.FL-R-SMT-1(10)	U.FL-R-SMT-1(10)	CONN_R-SMT-1(10)	ufl	4
BATTERY	2 PIN JST	S2B-PH-SM4-TB(LF)(SN)	JST_S2B-PH-SM4-TB(LF)(SN)	S2B-PH-SM4-TB_LF__SN_	3
C1	10uF	C-EUC0603	C0603	rcl	3
C2	1uF	C-EUC0603	C0603	rcl	3
C3	0.1uF	C-USC0603	C0603	adafruit	2
C4	0.1uF	C-USC0603	C0603	adafruit	2
C5	0.1uF	C-USC0603	C0603	adafruit	2
C6	0.1uF	C-USC0603	C0603	adafruit	2
C7	1uF	CAP_CERAMIC0603_NO	0603-NO	microbuilder	5
C8	10uF	C-USC0603	C0603	adafruit	1
C9	0.01uF	C-USC0603	C0603	adafruit	1
C10	0.01uF	C-USC0603	C0603	adafruit	1
C11	0.01uF	C-USC0603	C0603	adafruit	1
C12	0.1uF	C-EUC0603	C0603	rcl	4
C13	0.1uF	C-EUC0603	C0603	rcl	4
C14	0.1uF	C-USC0603	C0603	adafruit	3
C15	0.1uF	C-EUC0603	C0603	rcl	1
C16	0.1uF	C-EUC0603	C0603	rcl	1
C17	0.1uF	C-EUC0603	C0603	rcl	1
C18	0.1uF	C-USC0603	C0603	rcl	3
C19	2.2uF	C-USC0603	C0603	rcl	3
C20	0.01uF	C-USC0603	C0603	rcl	3
C22	1uF	C-EUC0603	C0603	rcl	4
C24	0.01uF	C-USC0603	C0603	adafruit	2
C25	0.01uF	C-USC0603	C0603	adafruit	2
C26	0.01uF	C-USC0603	C0603	adafruit	2
C27	0.01uF	C-USC0603	C0603	adafruit	2
C28	0.01uF	C-USC0603	C0603	adafruit	2
C29	0.01uF	C-USC0603	C0603	adafruit	2
C30	0.01uF	C-USC0603	C0603	adafruit	2
C31	0.01uF	C-USC0603	C0603	adafruit	2
C32	0.1uF	C-USC0603	C0603	adafruit	2
C33	0.1uF	C-USC0603	C0603	adafruit	2
CAPSENSE	53048-0810	53048-0810	53048-0810	con-molex-picoblade	4
CHARGE		PINHD-1X2	1X02	pinhead	3
CHG	RED	LED-RED0603	LED-0603	SparkFun-LED	3
CN1	4U#20329	USB_MICRO_20329_V2	4UCONN_20329_V2	microbuilder	5
D3	MBR120	MBR120	SOD123FL	gsynth	3
H1	MOUNT-PAD-ROUND2.8	MOUNT-PAD-ROUND2.8	2,8-PAD	holes	1
H2	MOUNT-PAD-ROUND2.8	MOUNT-PAD-ROUND2.8	2,8-PAD	holes	1
H3	MOUNT-PAD-ROUND2.8	MOUNT-PAD-ROUND2.8	2,8-PAD	holes	1
H4	MOUNT-PAD-ROUND2.8	MOUNT-PAD-ROUND2.8	2,8-PAD	holes	1
H5	MOUNT-PAD-ROUND2.8	MOUNT-PAD-ROUND2.8	2,8-PAD	holes	1
H6	MOUNT-PAD-ROUND2.8	MOUNT-PAD-ROUND2.8	2,8-PAD	holes	1
IC1	ADG609RU	ADG609RU	TSSOP16	analog-devices	2
IC2	ATSAMD21E	ATSAMD21E	QFN32_5MM	microbuilder	5
IC3	ADG609RU	ADG609RU	TSSOP16	analog-devices	2
JP1		PINHD-1X4	1X04	pinhead	5
JP2		PINHD-1X2	1X02	pinhead	3
JP3		PINHD-1X2	1X02	pinhead	4
LED1		LEDCHIP-LED0603	CHIP-LED0603	adafruit	4
LED2		LEDCHIP-LED0603	CHIP-LED0603	adafruit	4
LED3		LEDCHIP-LED0603	CHIP-LED0603	adafruit	4
LED4		LEDCHIP-LED0603	CHIP-LED0603	adafruit	4
LED5		LEDCHIP-LED0603	CHIP-LED0603	adafruit	4
P1	53048-0810	53048-0810	53048-0810	con-molex-picoblade	2
P2	53048-0810	53048-0810	53048-0810	con-molex-picoblade	2
R1	1k	R-US_R0603	R0603	rcl	3
R2	2.2k	R-US_R0603	R0603	rcl	3
R3	288	R-US_R0603	R0603	adafruit	3
R4	470	R-US_R0603	R0603	rcl	4
R5	100k	R-US_R0603	R0603	rcl	3
R6	100k	R-US_R0603	R0603	rcl	3
R7	100k	R-US_R0603	R0603	rcl	3
R8	470	R-US_R0603	R0603	rcl	4
R9	470	R-US_R0603	R0603	rcl	4
R10	470	R-US_R0603	R0603	rcl	4
R11	470	R-US_R0603	R0603	rcl	4
R12	2.2k	R-US_R0603	R0603	rcl	1
R13	200k	R-US_R0603	R0603	rcl	1
R14	2.2k	R-US_R0603	R0603	rcl	1
R15	2.2k	R-US_R0603	R0603	rcl	1
R16	2.2k	R-US_R0603	R0603	rcl	1
R17	10k	R-US_R0603	R0603	rcl	5
R18	100k	R-US_R0603	R0603	rcl	3
R19	100	R-US_R0603	R0603	rcl	4
SJ1		SJ	SJ	jumper	5
U$1	TEENSY_3.5/3.6_BASIC	TEENSY_3.5/3.6_BASIC	TEENSY_3.5/3.6_BASIC	Teensy356	1
U$29	AQV252GA	AQV252GA	DIP6	TI_radio	3
U1	MCP73831/OT	MCP73831/OT	SOT23-5L	adafruit	3
U2	LP2985IM5-1.8/NOPB	LP2985IM5-1.8/NOPB	MF05A	gsynth	3
U3	COM-13909	COM-13909	MOD_COM-13909	COM-13909	4
U4	ADXL377	ACCEL_ADXL377	LFCSP16_LQ	microbuilder	1
U5	ICM-20948	ICM-20948	QFN40P300X300X105-25N	ICM-20948	1
U6	PCA9306DCUR	PCA9306DCUR	DCU8	gsynth	1
U7	SN74LVC1T45DRLR	SN74LVC1T45DRLR	DRL6	gsynth	1
U8	SN74LVC1T45DRLR	SN74LVC1T45DRLR	DRL6	gsynth	1
U9	DMP3099L	DMP3099L	SOT23	gsynth	3

U10	SN74LVC1G08DCKR	SN74LVC1G08DCKR	SOT65P210X110−5N	SN74LVC1G08DCKR	5
U11	DPS310XTSA1	DPS310XTSA1	XDCR_DPS310XTSA1	DPS310XTSA1	4
U12	MAX31856MUD+	MAX31856MUD+	SOP65P640X110−14N	MAX31856	2
U13	MAX31856MUD+	MAX31856MUD+	SOP65P640X110−14N	MAX31856	2
VBAT_PTH		PINHD−1X2	1X02	pinhead	3
X3		HEADER_POS6_43650−0600	43650−0600	con−molex−micro−fit −3_0	3

E Arduino Pin Mapping

Arduino Pin	Net
Teensy 3.5	
0	CAPSENSE0
1	CAPSENSE1
3	LED_IRIDIUM_ON
4	LED_IRIDIUM_SIGNAL_OK
5	LED_IRIDIUM_TRANSMITTING
6	LED_ISM_TRANSMITTING
7	LED_ACTIVITY
8	CS_DSP
9	CS_ISM
11	MOSI
12	MISO
13	SCLK
14	BAT_STAT
15	CAPSENSE2
16	MUX0
17	MUX1
18	SDA
19	SCL
20	CS@TC1
21	CS@TC2
A8	BAT_SENSE (A8)
23	PRI_ACT (IRIDIUM ON/OFF)
24	BUZZER
25	TC1_FAULT (ACTIVE LOW)
26	TC2_FAULT (ACTIVE LOW)
27	SEC_CTRL_2
28	RESET_ISM
28	INT_ISM
30	CAPSENSE3
31	RIRI (IRIDIUM OUTPUT)
32	TIRI (IRIDIUM INPUT)
33	RADIO_OFF_SIG
34	FSYNC (IMU)
35	INT (IMU)
36	XOUT (A17)
37	YOUT (A18)
38	ZOUT (A19)
39	SEC_CTRL_1
A21	IRIDIUM_TX_ACT
A22	IRIDIUM_STATUS
Safety Processor (ATSAMD21E16B)	
1	CS@TC1
13	CS@TC2
7	SEC_ACT
8	SEC_CTRL_1

0	SEC_CTRL_2
PA14	TC1_FAULT
PA15	TC2_FAULT
PA17	MUX0
PA18	MUX1