KREPE Control Board

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1 Introduction

This document has pin names and connections, along with implementation notes and design choice explanations. Schematic designs for this board were adapted from previous designs of KRUPS projects here at the University of Kentucky. Battery charging, improved activation circuitry, a newer IMU, and wireless debug capability are the main additions to previous designs. Newer thermocouple conversion ICs were also added to replace the EOL product that was in previous designs. Activation subsytems and criteria are also outlined.

The following sections outline the electrical connections for control of the board w.r.t. the Teensy 3.5 microcontroller, as well as several relevant subsystem specifications and links to datasheets. Charging and switch wiring for activation are also explained. Schematics are in Appendix A, along with Teensy 3.5 reference card images.

1.1 Primary Activation

Primary activation is triggered by a pin pull out the KREPE enclosure performed by astronauts. Once the pin is pulled, the flight computer is powered on and in standy mode, consuming a minimal amount of power. No radios are powered on in standy mode to ensure no interference with ISS activities.

The `POWER_SW` header must closed for protected battery or USB voltage to be applied to the Teensy's VIN pin, powering on the system. The location of these connection points can be seen in Fig. 2 labelled on the silk screen in the left middle of the PCB. A rendering of the bottom of the board is shown in Fig. 3.

An end-to-end schematic showing battery protection and device activation is shown in Fig. 1.

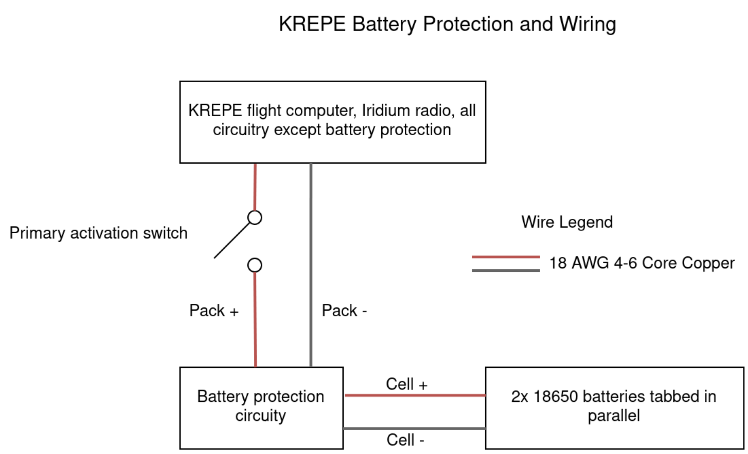


Figure 1: Activation and battery protection schematic overview.

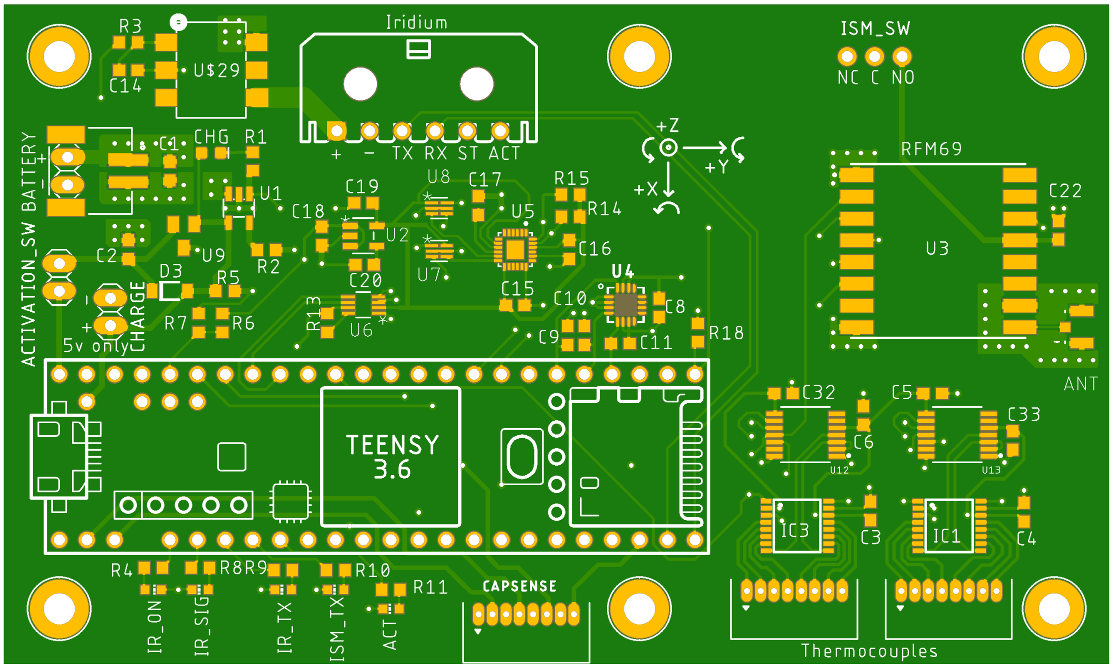


Figure 2: Rendering of the top of the KREPE control board, V1.1.

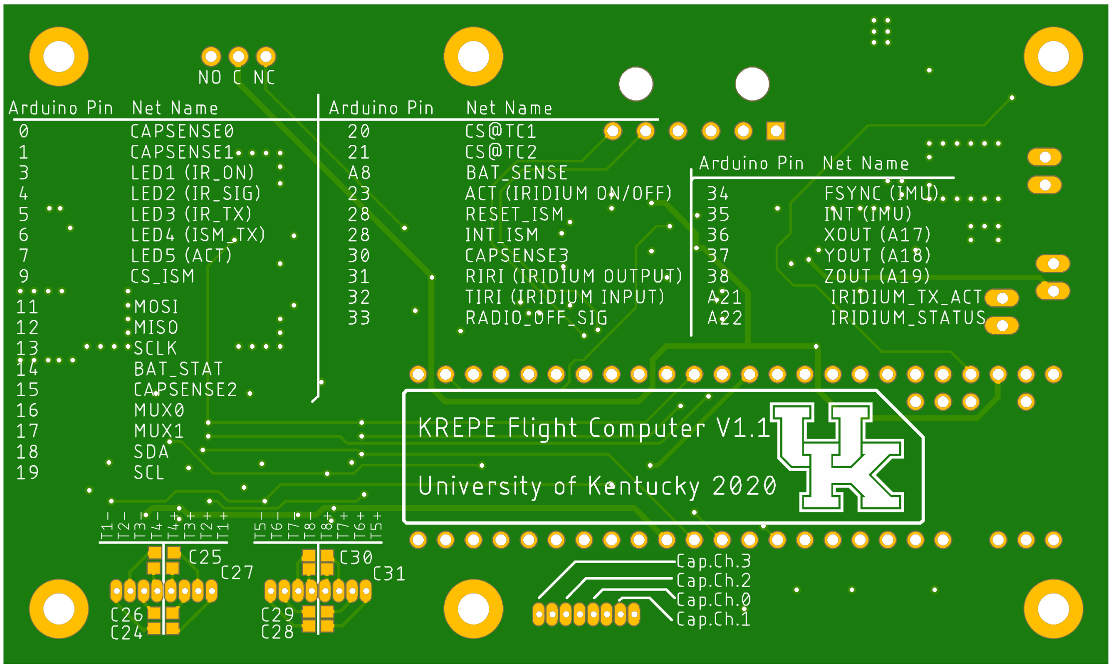


Figure 3: Rendering of the bottom of the KREPE control board, V1.1.

The ISM_SW header is meant to enable and disable the RFM69 debug radio. The center 3.3V pin of this header is connected to the normally closed labeled pin, a GPIO pin is pulled high (see Fig. 3). When the normally closed pin is connected to the center pin, the RFM69 is enabled. This way, debug communication can be used while testing in a way that also ensures it will be off when on a live mission. This radio is only used for ground testing communication purposes, and once handed over for final integration, will never be enabled or able to receive power. These[1] are the switches used for the pin pull activation.

1.2 Secondary Activation

Once primary activation is complete and the flight computer is in standby mode, sensors are polled to check for conditions necessary for secondary activation. Secondary activation is software based and only engaged once the KREPE probe has separated from its protective metal enclosure. No radio transmissions are attempted before secondary activation.

Thermocouples and a capacitive sensing subsystem are polled to check for conditions sufficient for secondary activation. A heating of the metal KREPE enclosure is necessary to melt the plastic bolts that hold it together. This ambient temperature increase of the probe is the primary criteria for secondary activation. The presence of this metal enclosure is also detected by capacitive sensors on the KREPE probe. Once the thermal and capacitive sensing subsystems have detected the separation of the metal enclosure, the Iridium radio is powered on and packet transmission begins.

[1] https://www.digikey.com/product-detail/en/omron-electronics-inc-emc-div/D2SW-3L1H/Z12268-ND/1811989

2 Subsystems

2.1 Status and Error Indicators

Teensy Pin	Net Name	Teensy Configuration
3	LED1 - IRIDIUM ON	OUTPUT
4	LED2 - IRIDIUM SIGNAL OK	OUTPUT
5	LED3 - IRIDIUM RADIO TRANSMITTING	OUTPUT
6	LED4 - ISM RADIO TRANSMITTING	OUTPUT
7	LED5 - GENERAL ACTIVITY	OUTPUT

Table 1: Debug LED Connections.

2.2 Serial Interface Signals

Teensy Pin	Net Name	Description
13	SCLK	SPI Clock
12	MISO	Master In Subject Out
11	MOSI	Master Out Subject In
20	CS@TC1	U10 (MAX31855) chip select, active low
21	CS@TC2	U11 (MAX31855) chip select, active low
9	CS_ISM	RFM69 chip select, active low
32	TIRI	Iridium TX UART
31	RIRI	Iridium RX UART
19	SCL	I^2C bus clock
18	SDA	I^2C bus data

Table 2: Pins used with SPI, I^2C, and UART interfaces.

2.3 RFM69 Radio

Note that this radio is not supplied with power unless the `NO` to `C` connection is made on the `ISM_SW` header (see Fig. 2). Maximum output power according to the radio datasheet (https://cdn.sparkfun.com/datasheets/Wireless/General/RFM69HCW-V1.1.pdf) is 100mW.

Teensy Pin	Net Name	Description	Teensy Configuration
28	RESET_ISM	Pull low to enable RFM69	OUTPUT
29	INT_ISM	GPIO0 interrupt from RFM69	INPUT
33	RADIO_OFF_SIG	Pulled high when the RFM69 is disabled	INPUT

Table 3: Radio module interface signals.

The datasheet for this antenna can be found at https://cdn.taoglas.com/datasheets/FXP290.07.0100A.pdf.

2.4 Iridium Radio

We are using the A3LA-RS type modem seen on the NAL Research site (http://www.nalresearch.com/IridiumHardware.html). The RF specifications, taken from the module's datasheet are shown in Fig. 4.

Operating Frequency:	1616 to 1626.5 MHz
Duplexing Method:	TDD
Multiplexing Method:	TDMA/FDMA
Link Margin:	12 dB average
Average Power during a Transmit Slot (Max):	7W
Average Power during a Frame (Typical):	0.6W
Receiver Sensitivity at 50Ω (Typical):	–118 dBm

Figure 4: RF specifications of the AL3A-RS Iridium modem.

2.4.1 Radio Power Control

Teensy Pin	Net Name	Description	Teensy Configuration
23	ACT	Iridium activation, active high	`OUTPUT`

Table 4: Pin controlling power to the iridium satellite radio.

2.5 Thermocouple Measurement Interface

Note: this board features an update thermocouple interface IC than the previous boards. Among other enhancements it allows for broader temperature range reading and improved precision.

Teensy Pin	Net Name	Description	Teensy Configuration
16	MUX0	IC1 and IC2 mux. select pin	`OUTPUT`
17	MUX1	IC1 and IC2 mux. select pin	`OUTPUT`

Table 5: Analog mux selection pins.

2.5.1 Thermocouple Connections

See datasheet and connections in the relevant schematics in Fig. 9 in Appendix A.

TODO: image of connector placements on board to facilitate wiring of a new connector.

2.6 Motion Sensor Connections

Teensy Pin	Net Name	Description	Teensy Configuration
36 A17	XOUT	Analog out from accel (x axis)	`INPUT`
37 A18	YOUT	Analog out from accel (y axis)	`INPUT`
38 A19	ZOUT	Analog out from accel (z axis)	`INPUT`
35	INT	Interrupt from ICM-20948	`INPUT`
34	FSYNC	Synchronization signal to ICM-20948	`OUTPUT`

Table 6: Pins connecting to the ADXL377 and ICM-20948.

2.7 Charging and Power

Charge current is limited to to 450 mA. Charge power can be delivered via Teensy USB or the `CHARGE` header. Charging input voltage is expected to be 5 volts.

For battery protection, the adafruit batteries we use (https://www.adafruit.com/product/354) have built in protection circuitry. Charge management is handled by an MCP73831 IC (https://www.microchip.

com/wwwproducts/en/MCP73831), with status connections to the Teensy as shown in Table 7. Schematics and electrical connections are shown in Fig. 10 in Appendix A.

2.7.1 Battery Status Interface

Teensy Pin	Net Name	Description	Teensy Configuration
14	BAT_STAT	LiPo charge state	`OUTPUT`
22 A8	BAT_SENSE	Halved battery voltage for monitoring	`INPUT`

Table 7: Pins to monitor battery voltage and charging status.

2.7.2 Battery Protection

Protection circuitry is implemented on the flight board to support 2P1S LiPo packs for system power. We are using a TI BQ2970 Voltage and Current Protection IC (http://www.ti.com/lit/ds/symlink/bq2970.pdf). Protection circuitry as implemented on the KREPE flight computer PCB is shown in Fig. 5.

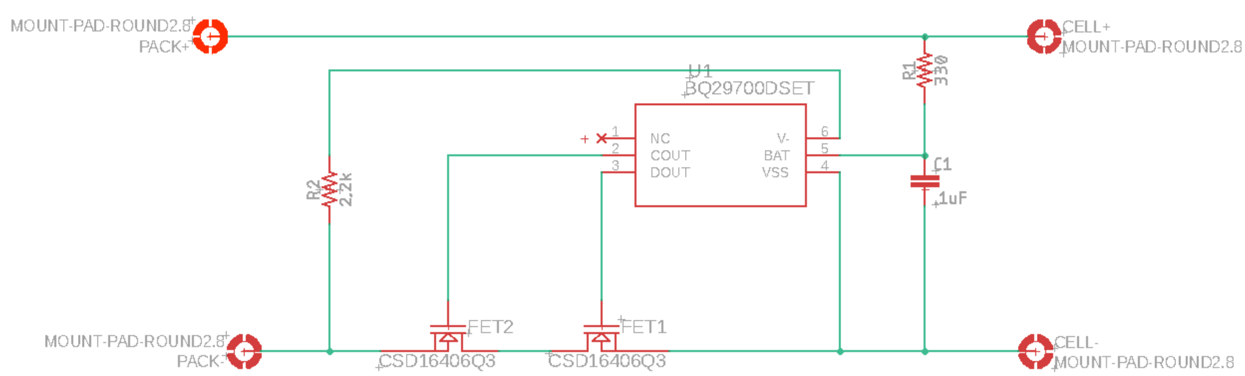


Figure 5: Battery protection circuitry. Cell+ and Cell- attach to the battery pack and Pack+/Pack- face system power. This protection circuitry is upstream of the primary activation switch.

Renderings of the bottom and top of the battery protection PCB can be seen in Figs 6 and 7.

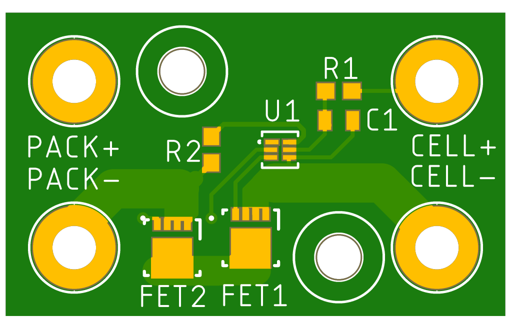


Figure 6: Rendering of the top of the battery protection PCB.

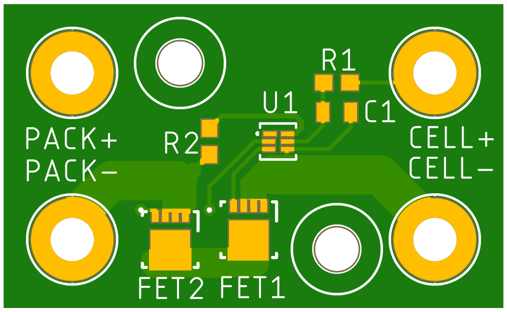


Figure 7: Rendering of the bottom of the battery protection PCB.

3 Testing Software

ICM-20948 testing software is functional. ADXL377 test software is functional. Lipo charge circuitry is functional. Need to test thermocouple hardware still.

TODO: simple sketch that tests a newly assembled board to make sure the IMU, accel, debug radio, iridium radio and thermocouple amplifiers are working as expected.

A Schematics

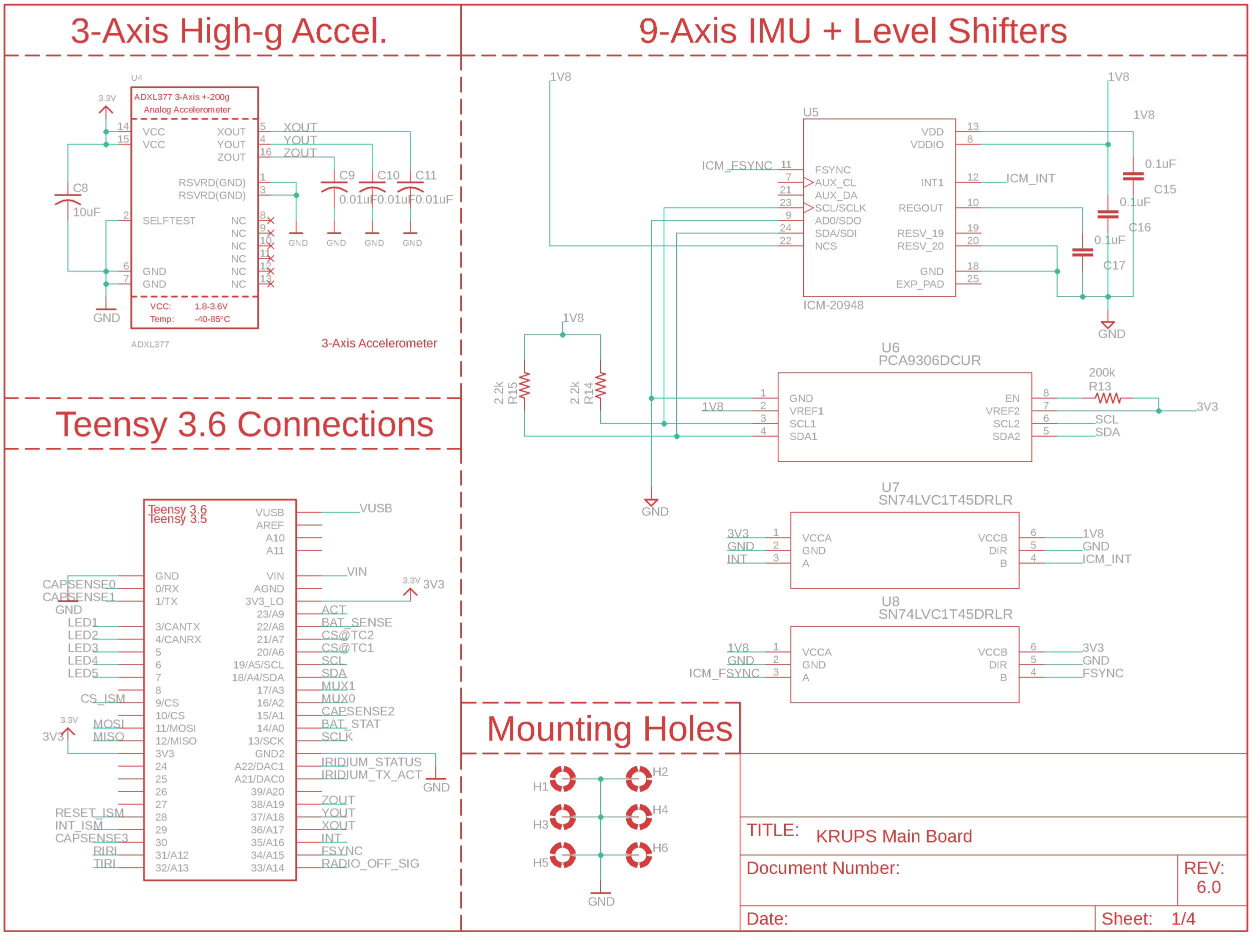


Figure 8: Page one of schematics.

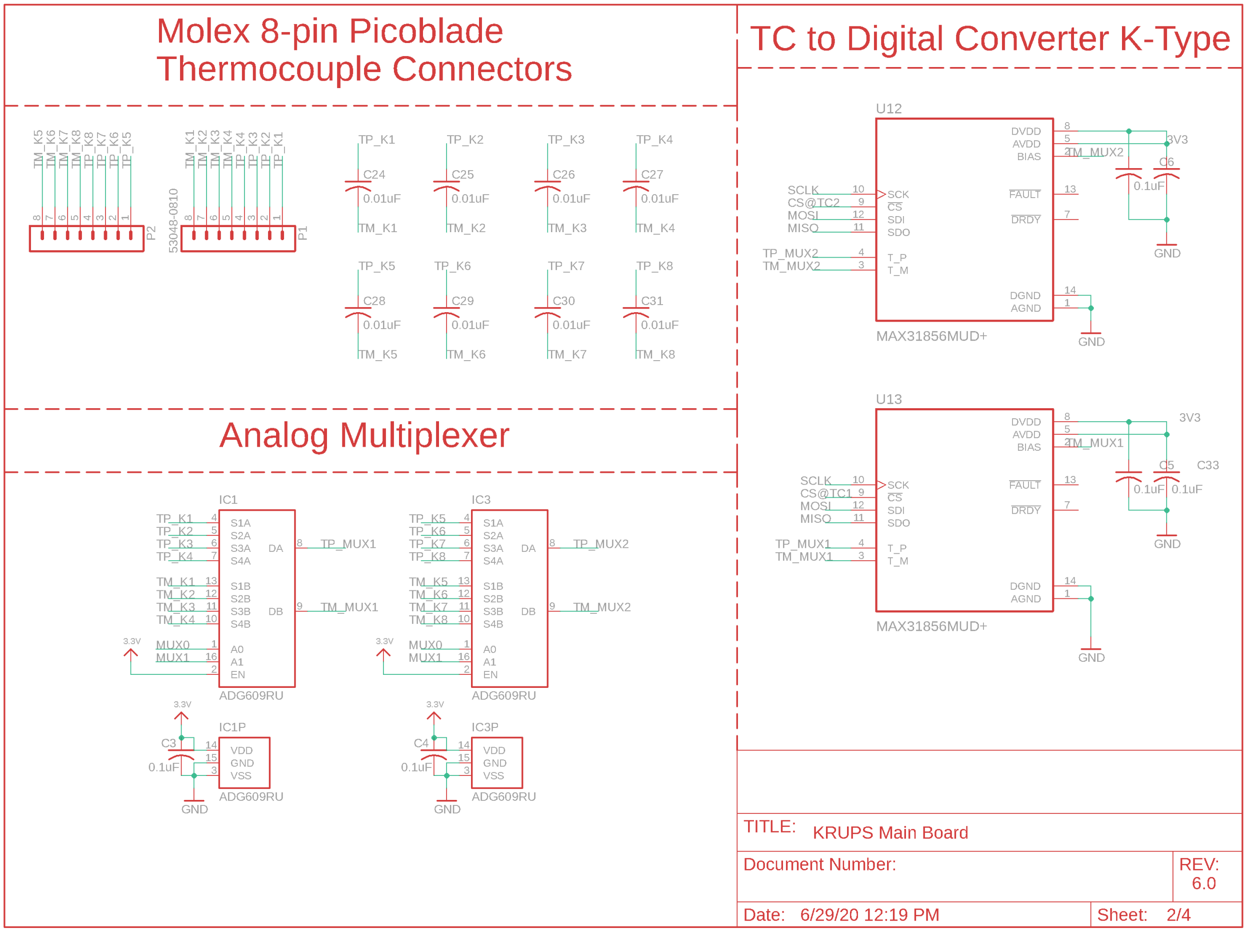


Figure 9: Page two of schematics.

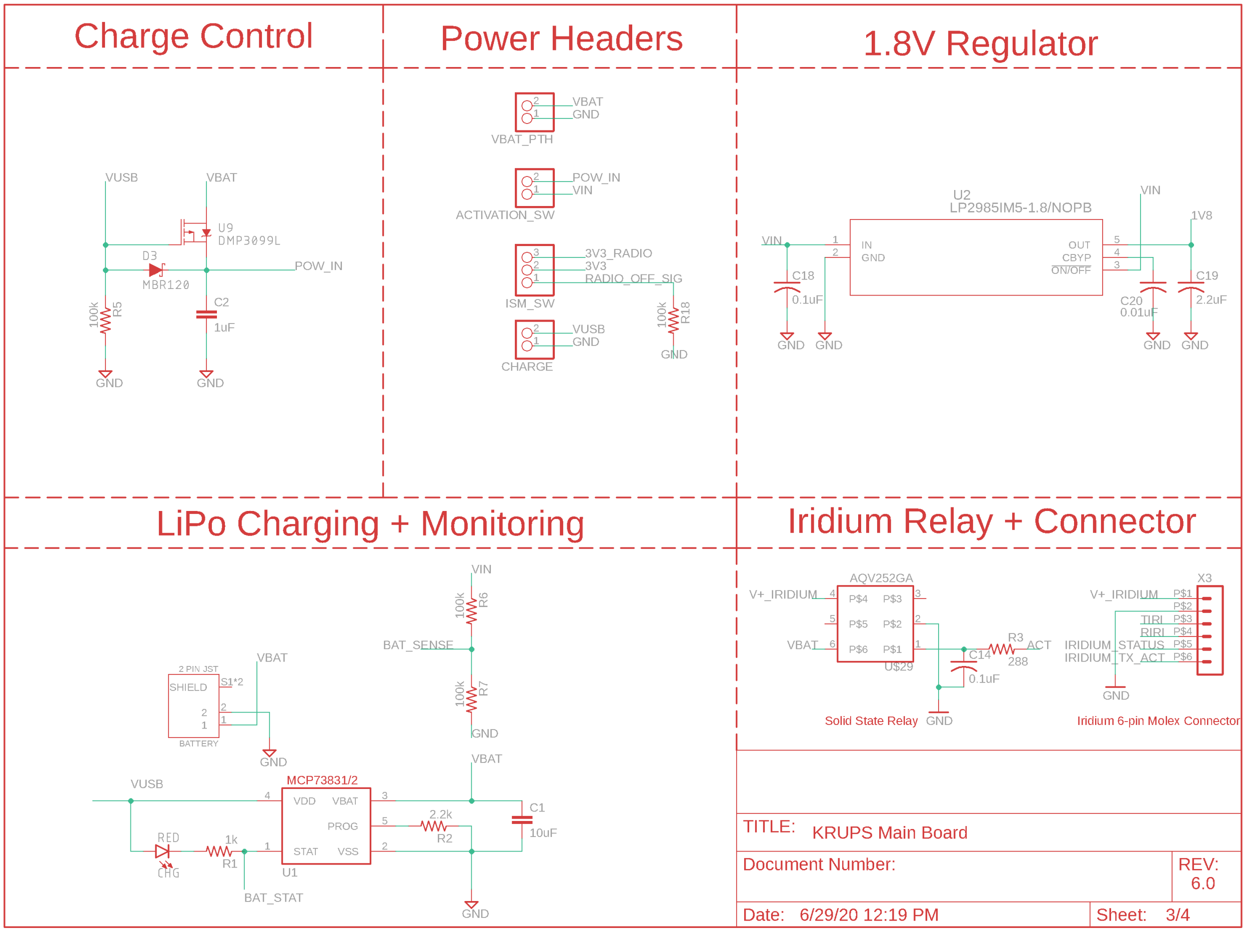


Figure 10: Page three of schematics.

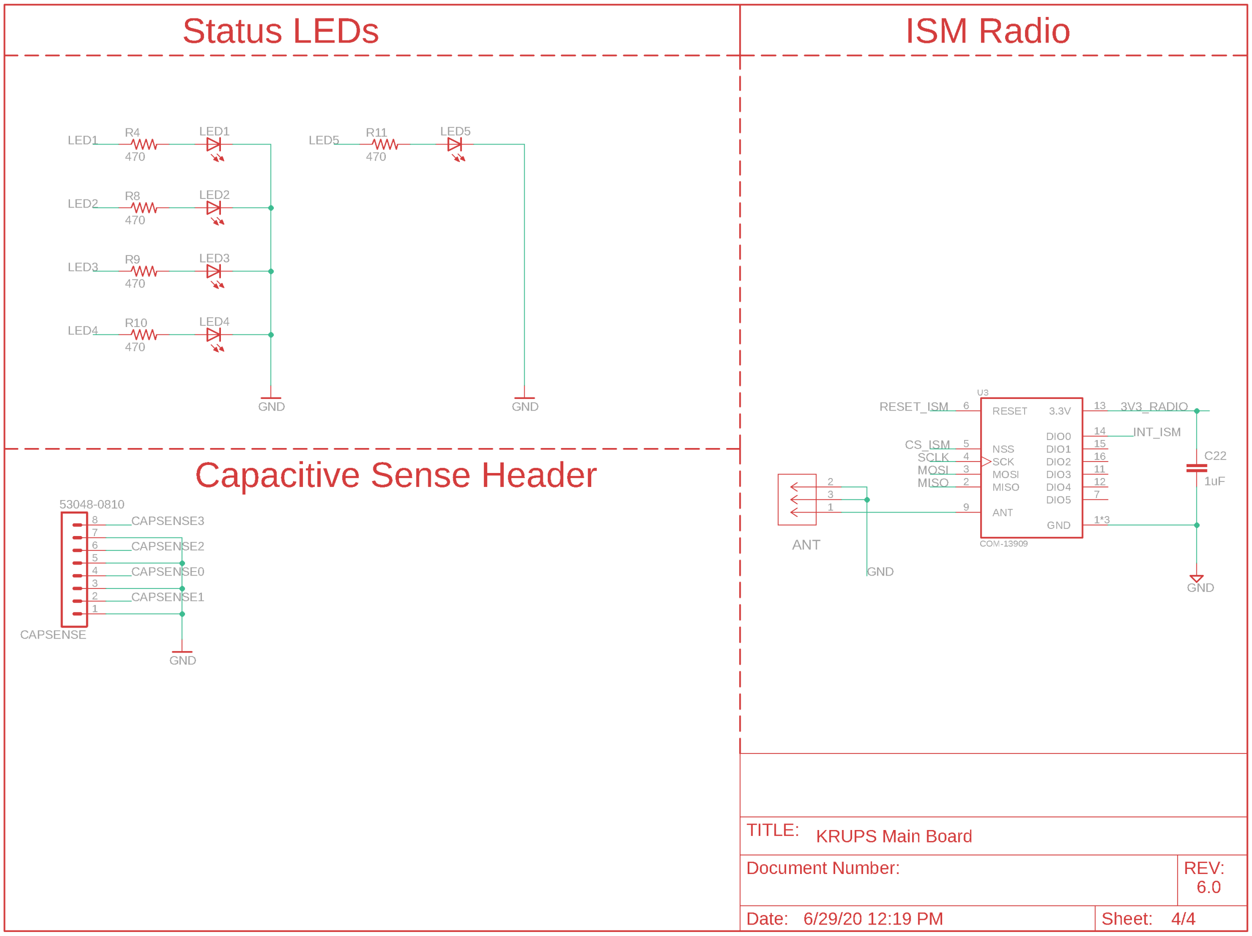


Figure 11: Page four of schematics.

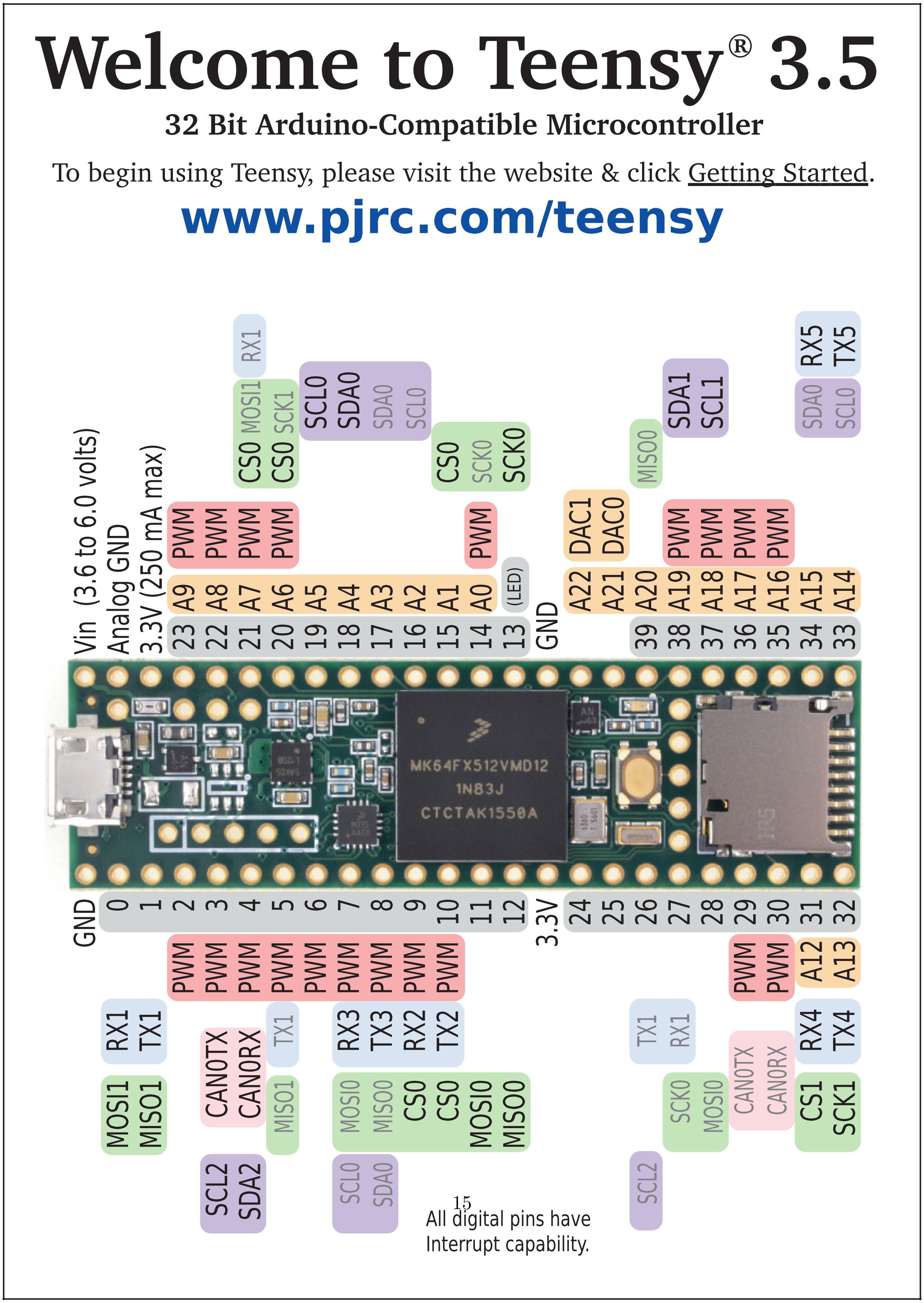
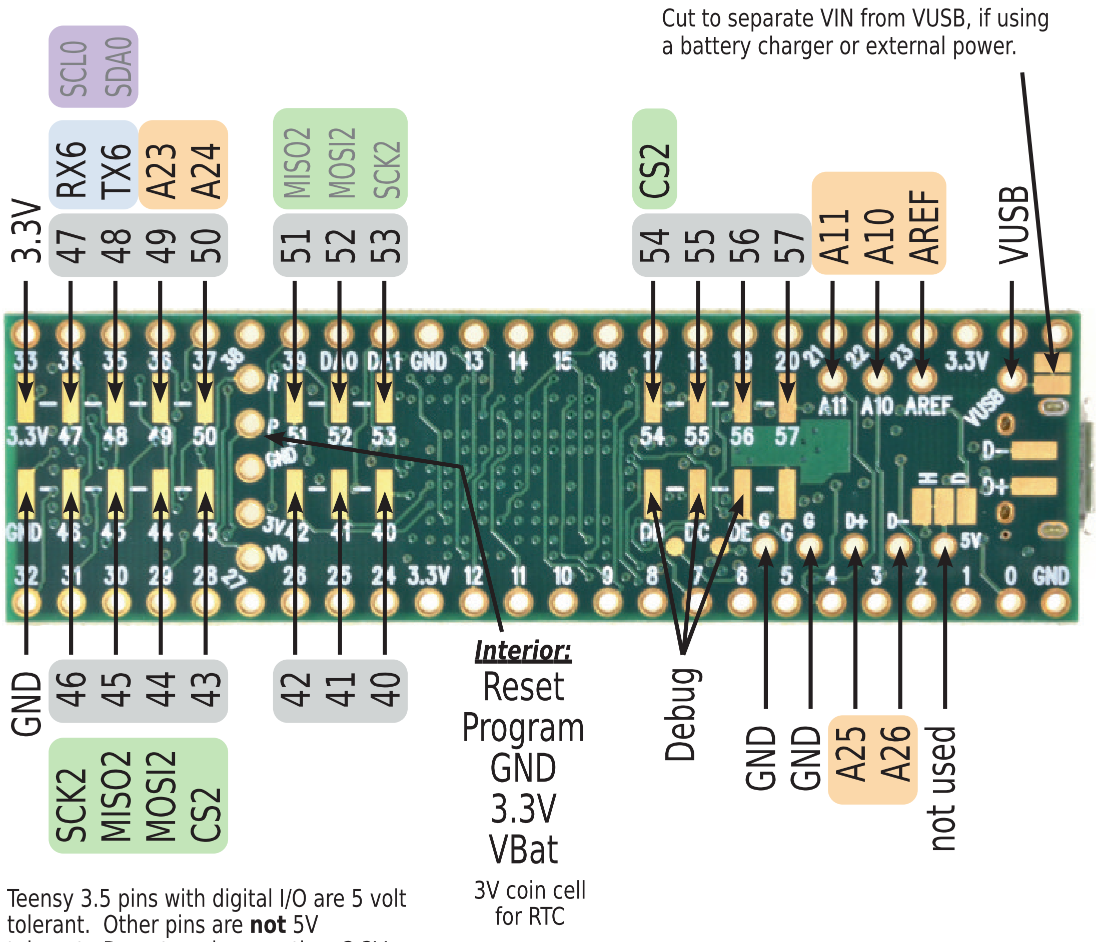


Figure 12: Teensy 3.5 Front

Teensy® 3.5 Back Side

Additional pins and features available on the back side



Teensy 3.5 pins with digital I/O are 5 volt tolerant. Other pins are **not** 5V tolerant. Do not apply more than 3.3V to A10, A11, A21, A22, A25, A26, AREF, Program or Reset.

For solutions to the most common issues
and technical support, please visit:

www.pjrc.com/help

Teensy 3.5 System Requirements:
PC computer with Windows 7, 8, 10 or later
or Ubuntu Linux 12.04 or later
or Macintosh OS-X 10.7 or later
USB Micro-B Cable

7 14833 87942 8

Figure 13: Teensy 3.5 Back

C 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
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
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
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
IC3	ADG609RU	ADG609RU	TSSOP16	analog-devices	2
ISM_SW		PINHD-1X3CB	1X03-CLEANBIG	adafruit	3
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
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
R18	100k	R-US_R0603	R0603	rcl	3
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
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

D Arduino Pin Mapping

Arduino Pin	Net
0	CAPSENSE0
1	CAPSENSE1
3	LED1
4	LED2
5	LED3
6	LED4
7	LED5
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
22 A8	BAT_SENSE
23	ACT (IRIDIUM ON/OFF)
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)
A21	IRIDIUM_TX_ACT
A22	IRIDIUM_STATUS