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.

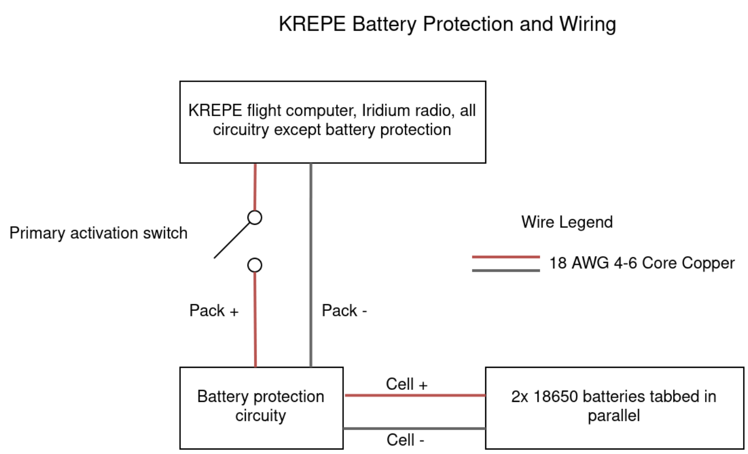

Figure 1: Activation and battery protection schematic overview.

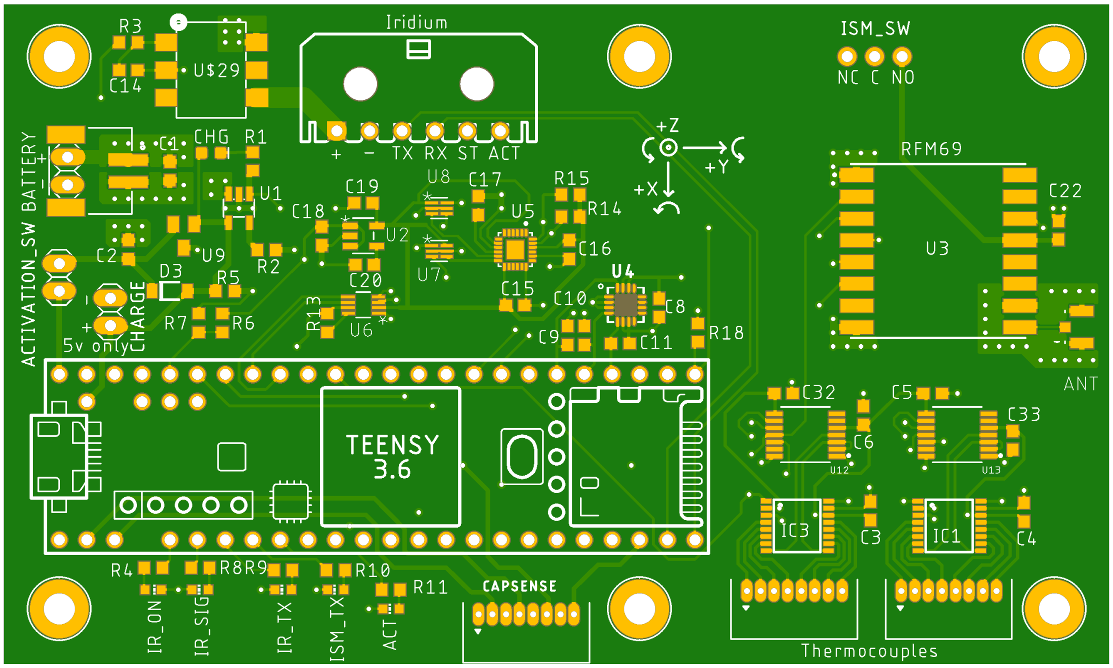

Figure 2: Rendering of the top of the KREPE control board, V1.1.

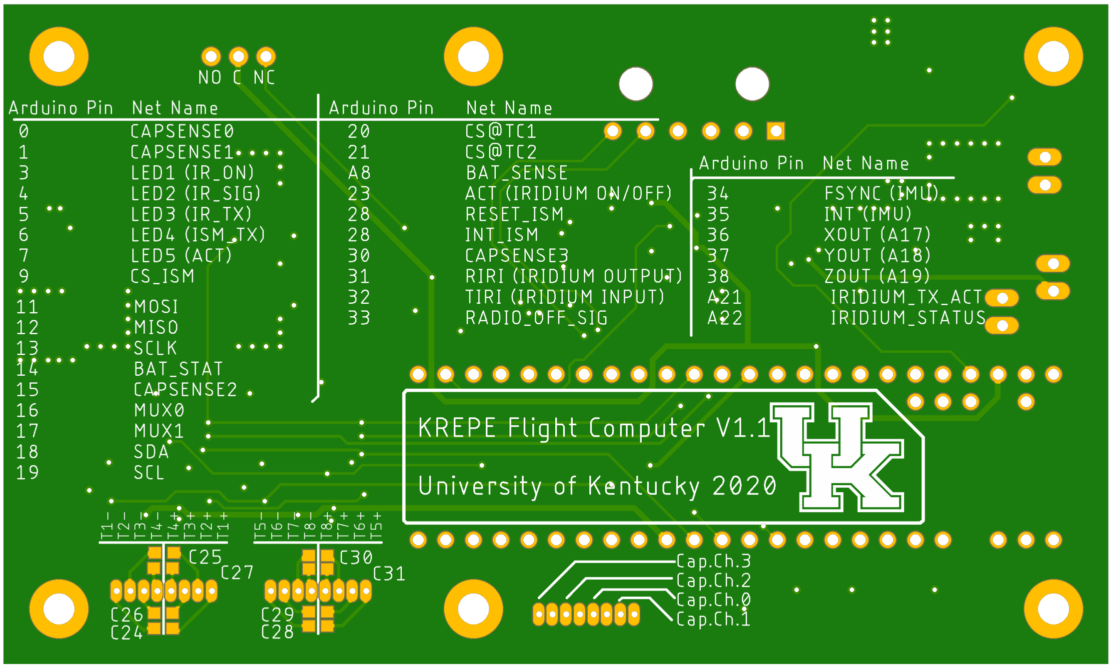

Figure 3: Rendering of the bottom of the KREPE control board, V1.1.

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.

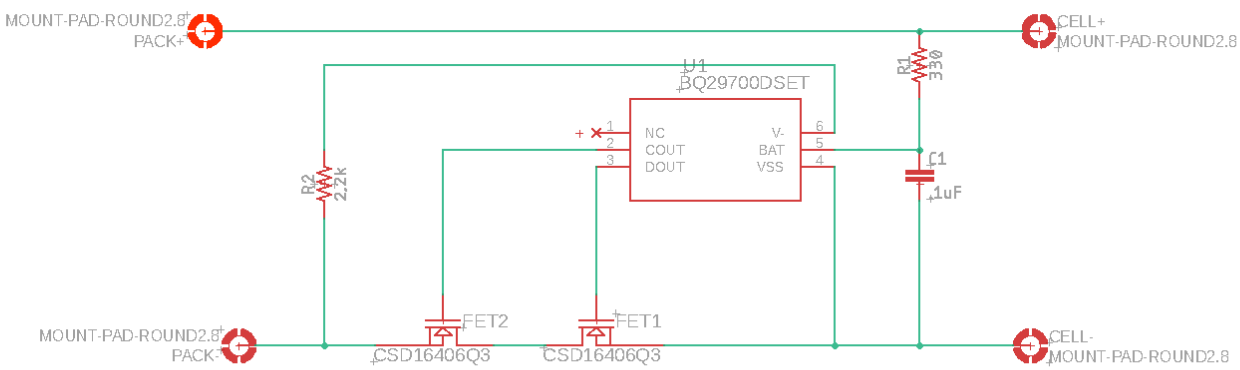

Figure 5: Battery protection circuitry. Cell+ and Cell- attach to the battery pack and Pack+/Pack- face system power. This protection circuitry is upstream of the primary activation switch.

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

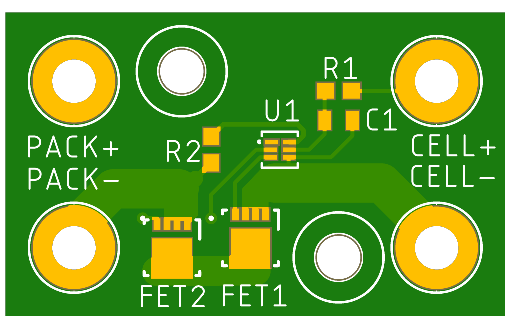

Figure 6: Rendering of the top of the battery protection PCB.

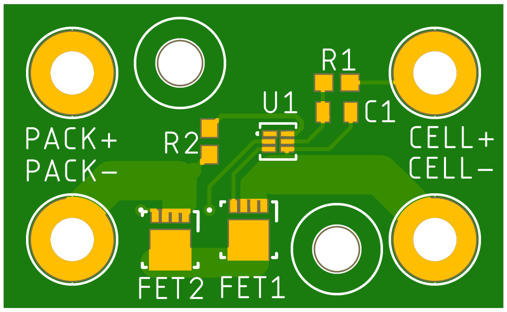

Figure 7: Rendering of the bottom of the battery protection PCB.

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

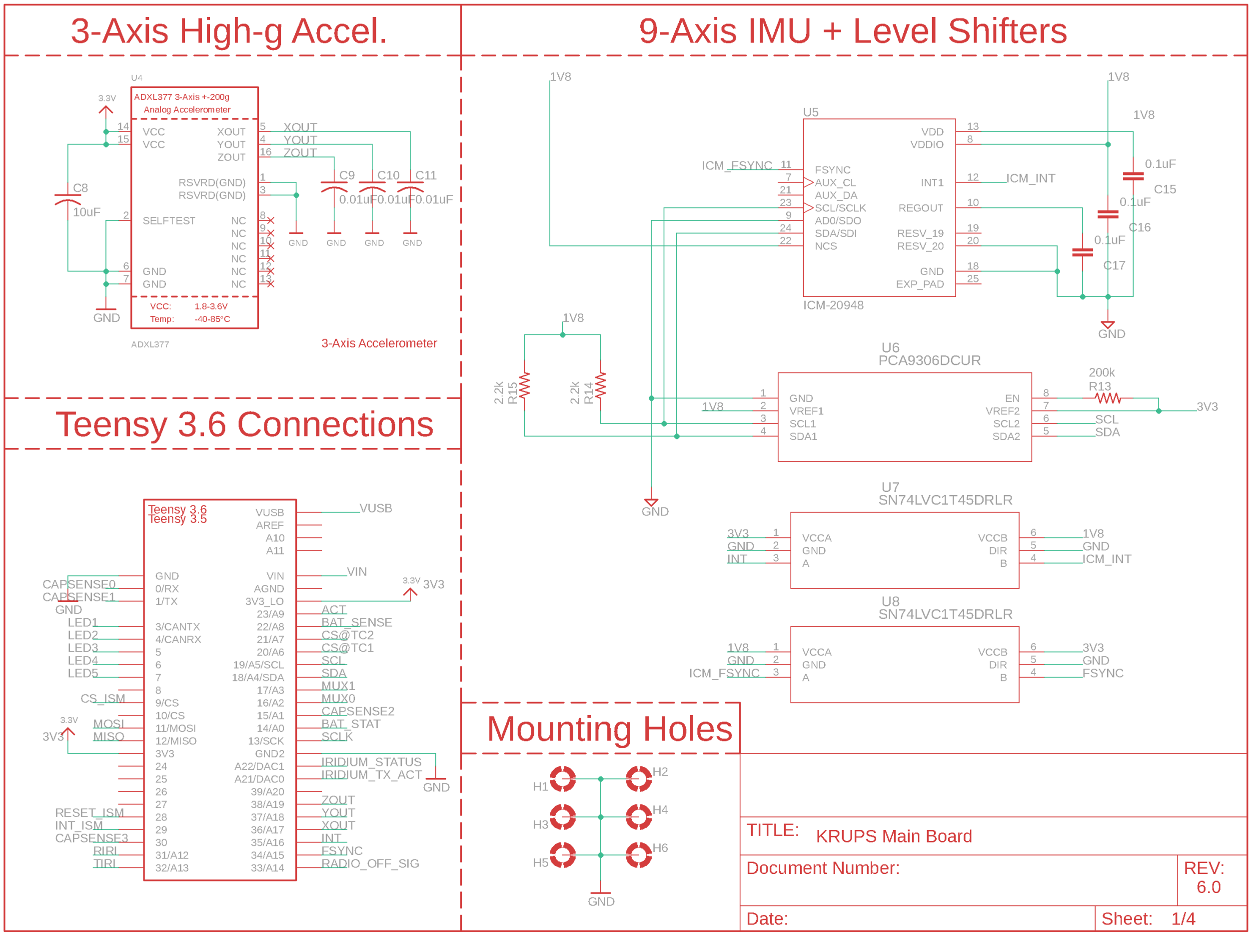

Figure 8: Page one of schematics.

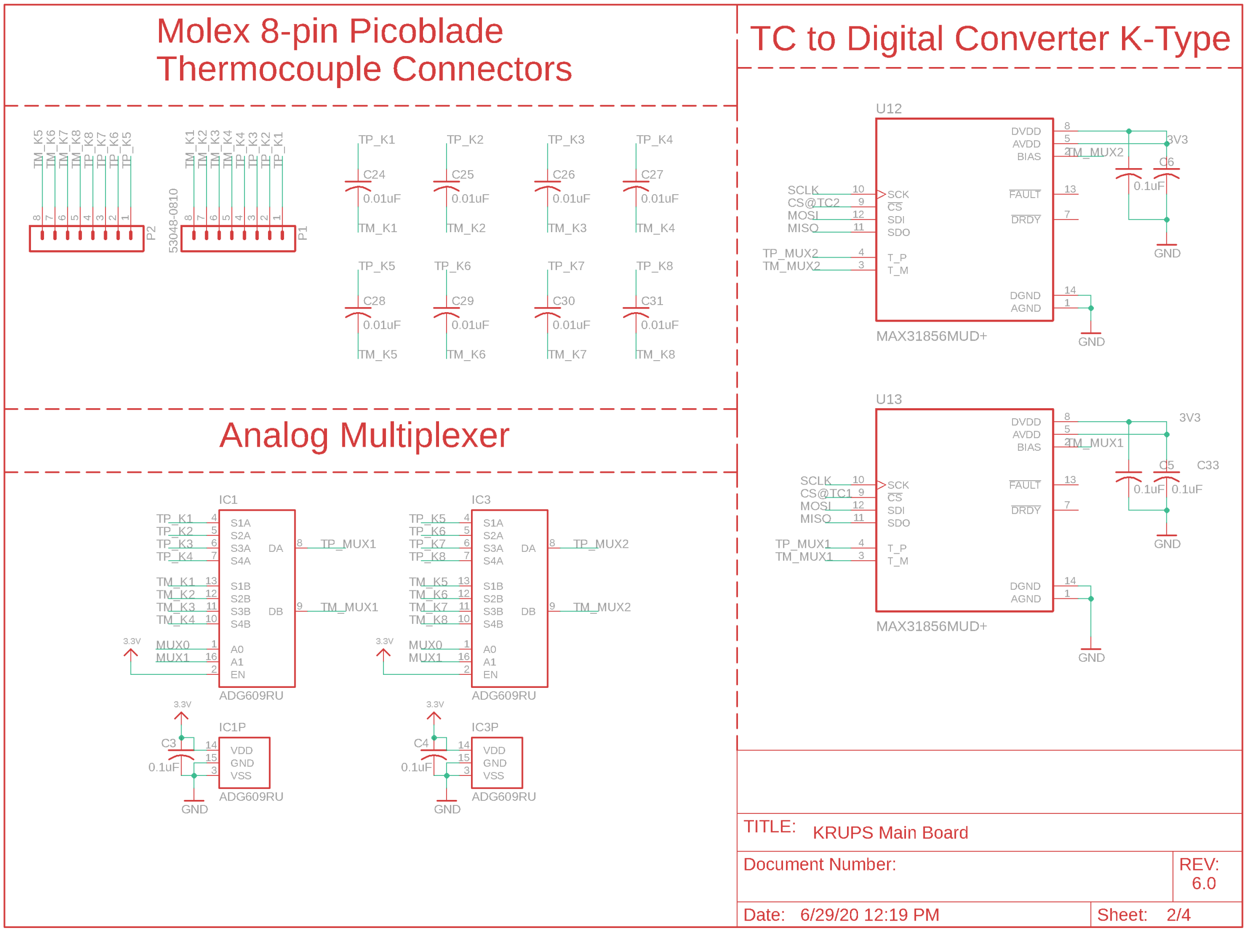

Figure 9: Page two of schematics.

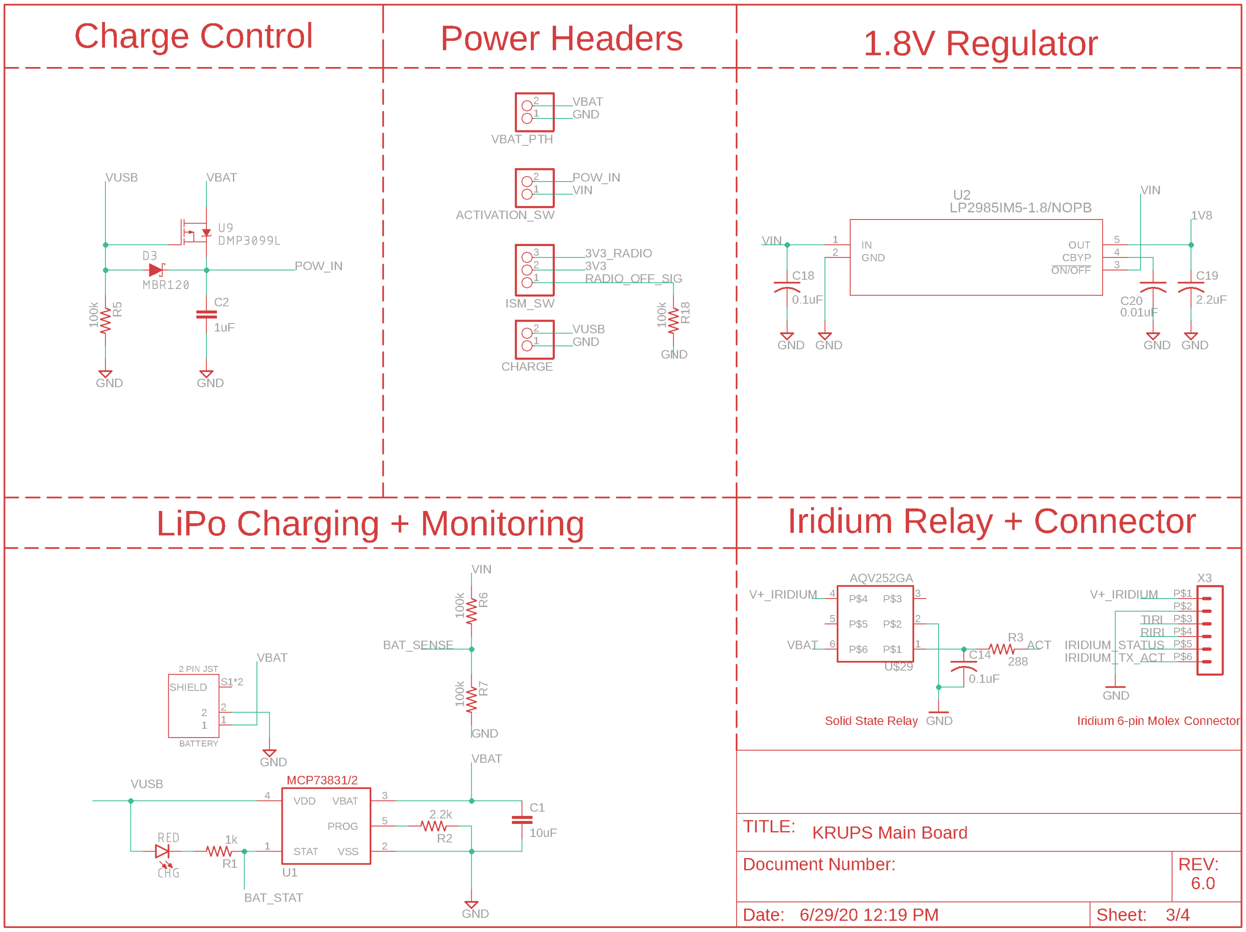

Figure 10: Page three of schematics.

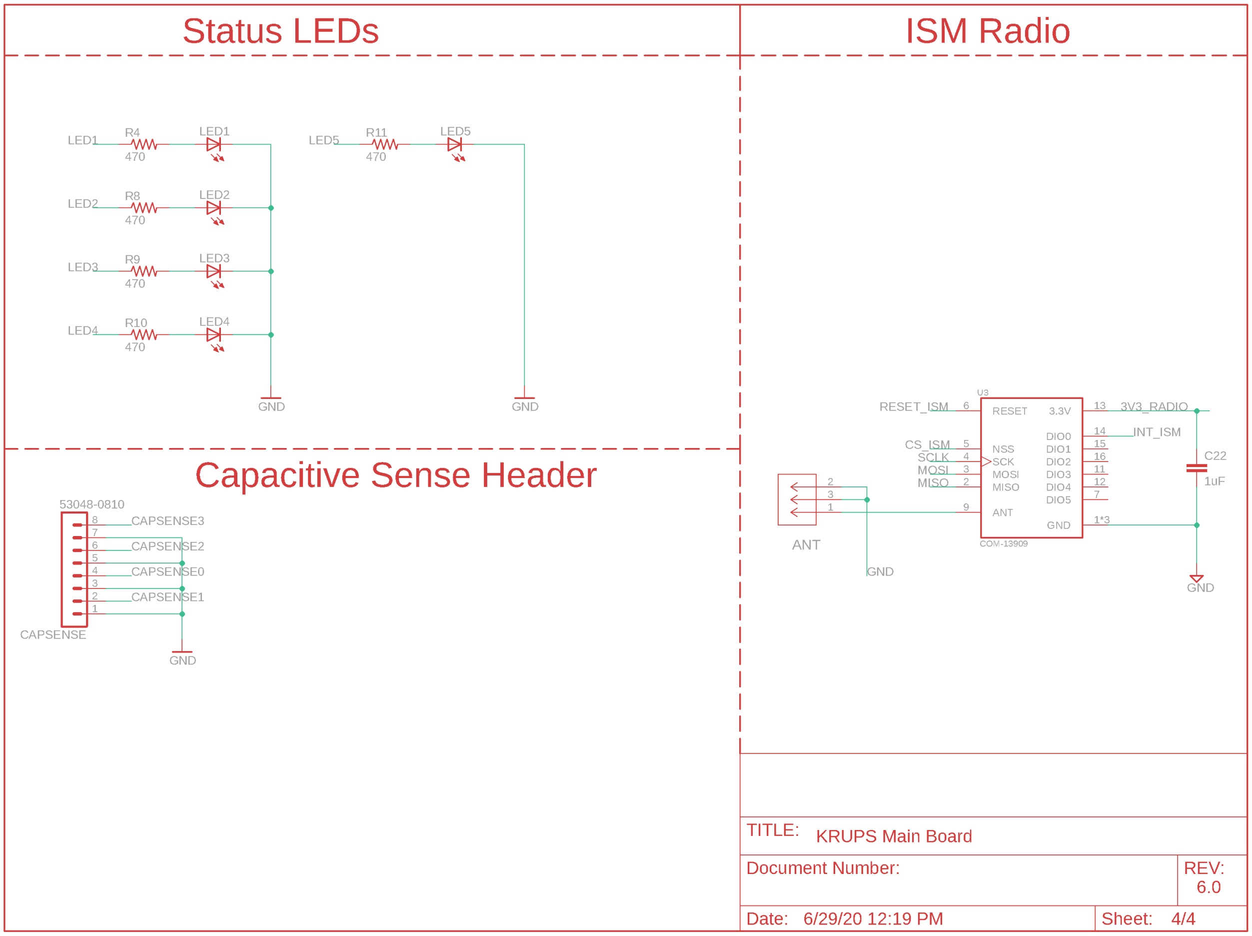

Figure 11: Page four of schematics.

Welcome to Teensy® 3.5

32 Bit Arduino-Compatible Microcontroller

To begin using Teensy, please visit the website & click Getting Started.

www.pjrc.com/teensy

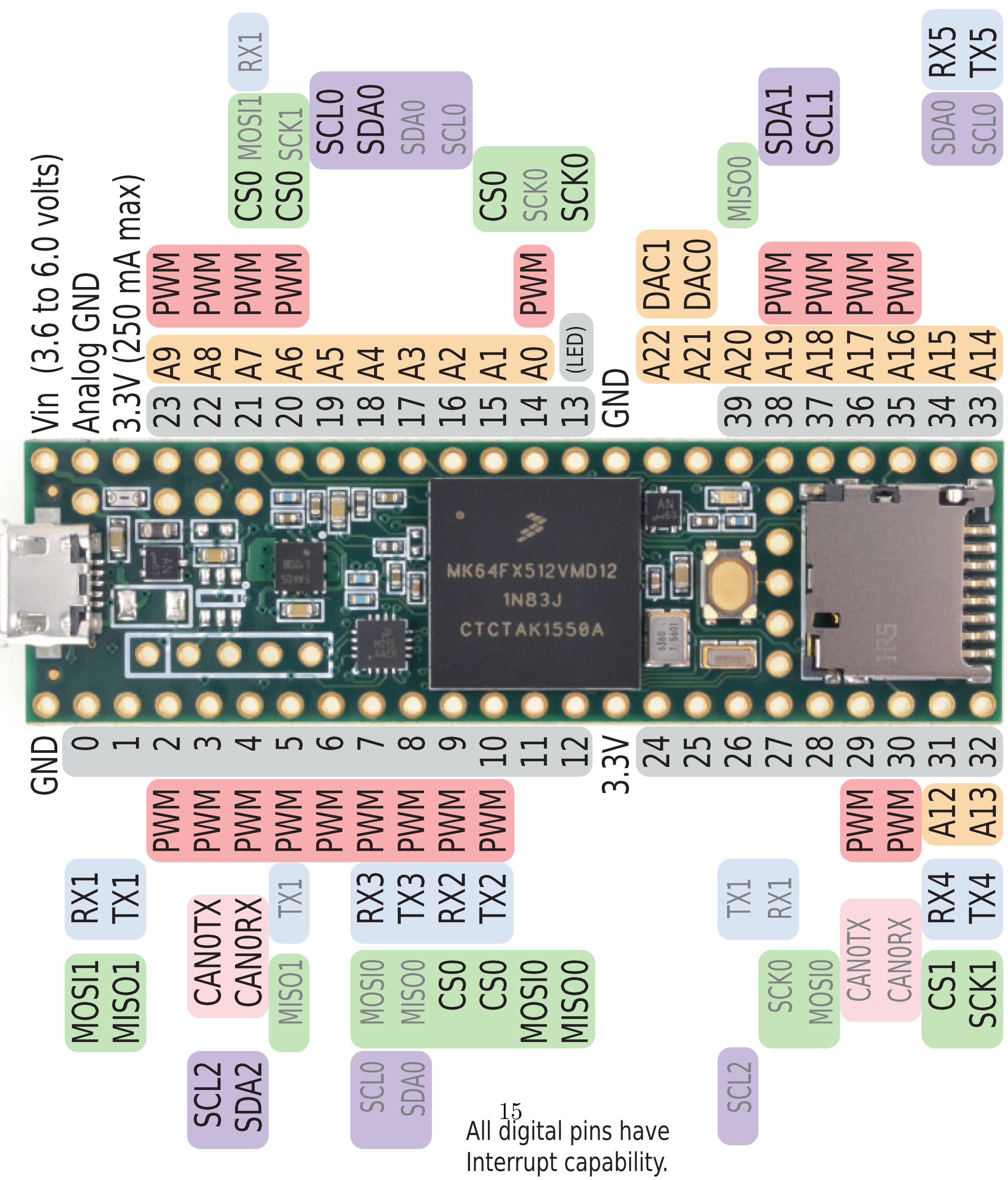

Figure 12: Teensy 3.5 Front

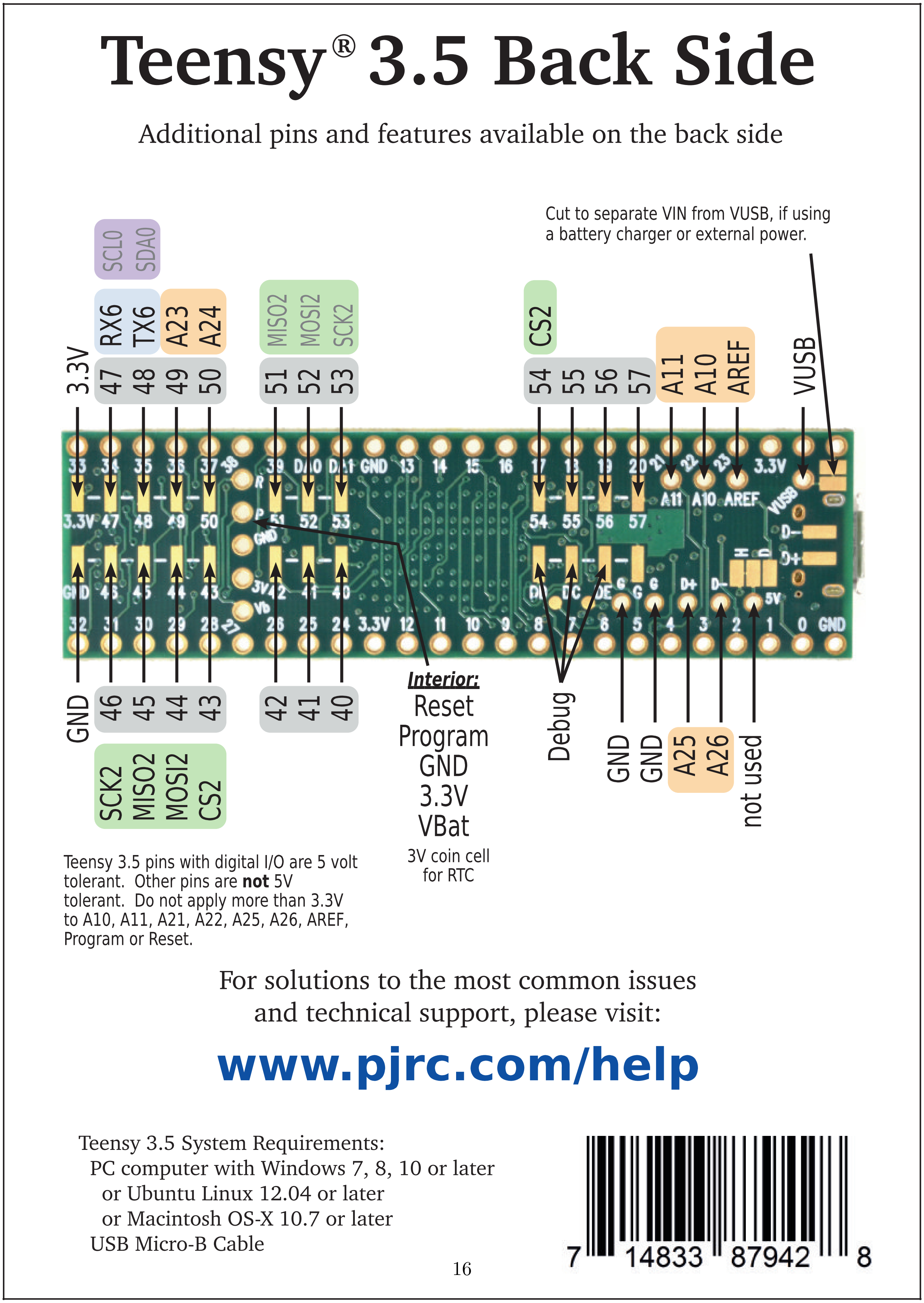

Figure 13: Teensy 3.5 Back

C Partslist

Partlist

Exported from kreme-iss.brd at 6/30/20 4:50 PM

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Assembly variant:

Part	Value	Package	Library	Position (mil)	Orientation
ACTIVATION_SW		1X02	pinhead	(200 1400)	R90
ANT	U.FL-R-SMT-1(10)	CONN_R-SMT-1(10)	ufl	(3840 1220)	R90
BATTERY	2 PIN JST	JST_S2B-PH-SM4-TB(LF)(SN)	S2B-PH-SM4-TB_LF__SN_	(450 1785)	R270
C1	10uF	C0603	rcl	(600 1785)	R270
C2	1uF	C0603	rcl	(450 1500)	R90
C3	0.1uF	C0603	adafruit	(3135 555)	R90
C4	0.1uF	C0603	adafruit	(3690 550)	R90
C5	0.1uF	C0603	adafruit	(3360 980)	R0
C6	0.1uF	C0603	adafruit	(3110 900)	R90
C8	10uF	C0603	adafruit	(2370 1290)	R270
C9	0.01uF	C0603	adafruit	(2040 1190)	R90
C10	0.01uF	C0603	adafruit	(2100 1190)	R90
C11	0.01uF	C0603	adafruit	(2230 1160)	R0
C14	0.1uF	C0603	adafruit	(450 2150)	R0
C15	0.1uF	C0603	rcl	(1850 1300)	R180
C16	0.1uF	C0603	rcl	(2045 1500)	R90
C17	0.1uF	C0603	rcl	(1715 1660)	R270
C18	0.1uF	C0603	rcl	(1150 1550)	R270
C19	2.2uF	C0603	rcl	(1300 1670)	R180
C20	0.01uF	C0603	rcl	(1305 1445)	R180
C22	1uF	C0603	rcl	(3815 1570)	R90
C24	0.01uF	C0603	adafruit	(3420.79995 130.20005)	MR180
C25	0.01uF	C0603	adafruit	(3417.19993 403.80007)	MR180
C26	0.01uF	C0603	adafruit	(3421.19993 185)	MR180
C27	0.01uF	C0603	adafruit	(3421.39998 347.60002)	MR180
C28	0.01uF	C0603	adafruit	(2860.79995 138.20005)	MR180
C29	0.01uF	C0603	adafruit	(2860.79995 190.20005)	MR180
C30	0.01uF	C0603	adafruit	(2860.79995 392.20005)	MR180
C31	0.01uF	C0603	adafruit	(2860.79995 344.20005)	MR180
C32	0.1uF	C0603	adafruit	(2820 980)	R0
C33	0.1uF	C0603	adafruit	(3650 810)	R270
CAPSENSE	53048-0810	53048-0810	con-molex-picoblade	(1880 230)	R0
CHARGE		1X02	pinhead	(385 1275)	R270
CHG	RED	LED-0603	SparkFun-LED	(750 1850)	R0
D3	MBR120	SOD123FL	gsynth	(600 1350)	R0
H1	MOUNT-PAD-ROUND2.8	2,8-PAD	holes	(3800 200)	R0
H2	MOUNT-PAD-ROUND2.8	2,8-PAD	holes	(2300 200)	R0
H3	MOUNT-PAD-ROUND2.8	2,8-PAD	holes	(200 200)	R0
H4	MOUNT-PAD-ROUND2.8	2,8-PAD	holes	(2300 2200)	R0
H5	MOUNT-PAD-ROUND2.8	2,8-PAD	holes	(3800 2200)	R0
H6	MOUNT-PAD-ROUND2.8	2,8-PAD	holes	(200 2200)	R0
IC1	ADG609RU	TSSOP16	analog-devices	(3420 500)	R0
IC3	ADG609RU	TSSOP16	analog-devices	(2870 500)	R0
ISM_SW		1X03-CLEANBIG	adafruit	(3150 2200)	R0
LED1		CHIP-LED0603	adafruit	(540 270)	R270
LED2		CHIP-LED0603	adafruit	(710 270)	R90
LED3		CHIP-LED0603	adafruit	(1010 270)	R90
LED4		CHIP-LED0603	adafruit	(1200 270)	R90
LED5		CHIP-LED0603	adafruit	(1400 200)	R90
P1	53048-0810	53048-0810	con-molex-picoblade	(3418.39998 264.80007)	R0
P2	53048-0810	53048-0810	con-molex-picoblade	(2860 265)	R0
R1	1k	R0603	rcl	(900 1820)	R90
R2	2.2k	R0603	rcl	(950 1500)	R180
R3	288	R0603	adafruit	(450 2250)	R180
R4	470	R0603	rcl	(540 350)	R180
R5	100k	R0603	rcl	(800 1350)	R0
R6	100k	R0603	rcl	(790 1235)	R270
R7	100k	R0603	rcl	(705 1235)	R90
R8	470	R0603	rcl	(710 350)	R0
R9	470	R0603	rcl	(1010 340)	R0
R10	470	R0603	rcl	(1200 340)	R0
R11	470	R0603	rcl	(1400 270)	R0
R13	200k	R0603	rcl	(1170 1235)	R90
R14	2.2k	R0603	rcl	(2050 1620)	R0
R15	2.2k	R0603	rcl	(2050 1700)	R0
R18	100k	R0603	rcl	(2510 1200)	R90
U$1	TEENSY_3.5/3.6_BASIC	TEENSY_3.5/3.6_BASIC	Teensy356	(1300 750)	R0
U$29	AQV252GA	DIP6	TI_radio	(750 2150)	R0
U1	MCP73831/OT	SOT23-5L	adafruit	(850 1650)	R180
U2	LP2985IM5-1.8/NOPB	MF05A	gsynth	(1300 1550)	R0
U3	COM-13909	MOD_COM-13909	COM-13909	(3380 1495)	R0
U4	ADXL377	LFCSP16_LQ	microbuilder	(2250 1300)	R0
U5	ICM-20948	QFN40P300X300X105-25N	ICM-20948	(1850 1500)	R270
U6	PCA9306DCUR	DCU8	gsynth	(1300 1300)	R180
U7	SN74LVC1T45DRLR	DRL6	gsynth	(1575 1495)	R0
U8	SN74LVC1T45DRLR	DRL6	gsynth	(1575 1650)	R0
U9	DMP3099L	SOT23	gsynth	(650 1550)	R180
U12	MAX31856MUD+	SOP65P640X110-14N	MAX31856	(2900 830)	R180
U13	MAX31856MUD+	SOP65P640X110-14N	MAX31856	(3450 830)	R180
VBAT_PTH		1X02	pinhead	(230 1785)	R90
X3		43650-0600	con-molex-micro-fit-3_0	(1500 2100)	R180

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
A8	BAT_SENSE (A8)
23	ACT (IRIDIUM ON/OFF)
25	TC1_FAULT (ACTIVE LOW)
26	TC2_FAULT (ACTIVE LOW)
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