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.

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 Activation

The `POWER_SW` header must closed for battery or USB voltage to be applied to the Teensy's VIN pin, enabling the system. The location of these connection points can be seen in Fig. 1.

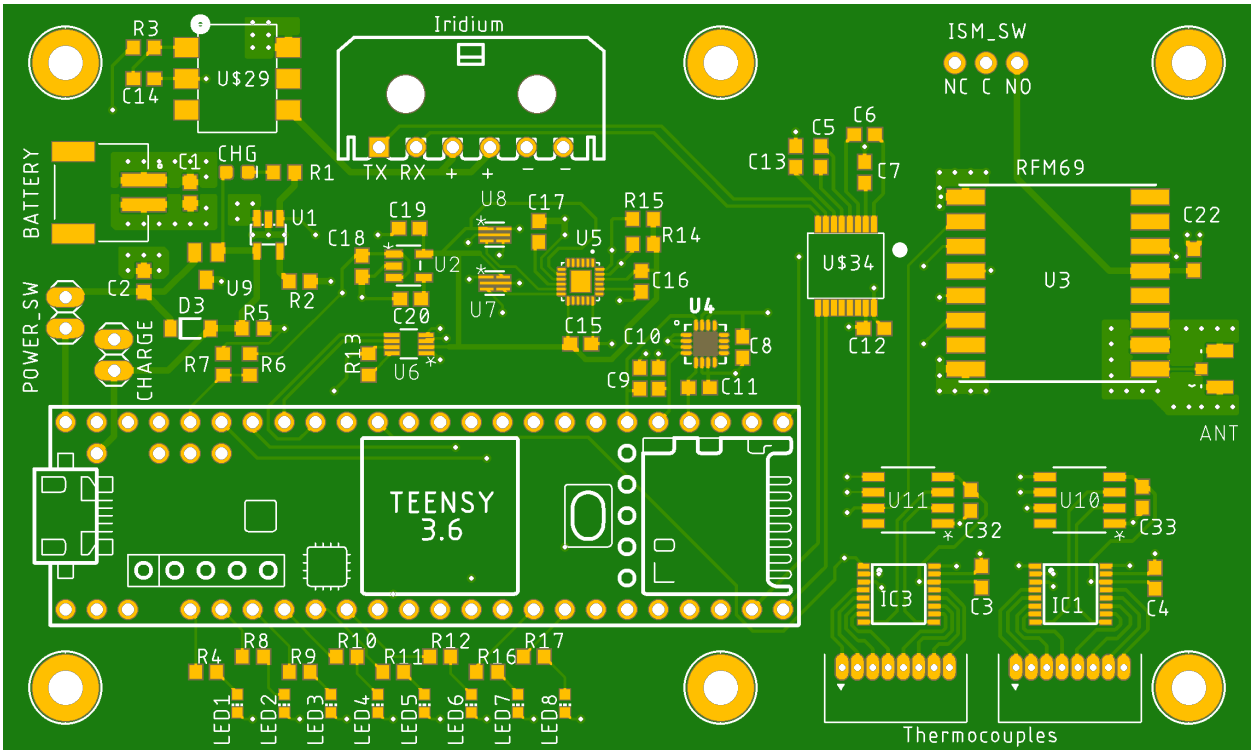


Figure 1: Rendering of the top of the KREPE control board.

The `ISM_SW` header is meant to enable and disable the RFM69. If 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 3.3V center pin, the RFM69 is enabled.

This way, a switch can be used with a pull pin to enable debug communication while testing in a way that also ensures it will be off when on a live mission.

This radio is only used for ground communication purposes, and once handed over for final integration, will never be enabled or able to receive power.

1.2 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	3.3v Iridium TX UART
31	RIRI	3.3v Iridium RX UART
19	SCL	I^2C bus clock
18	SDA	I^2C bus data

Table 1: Pins used with SPI, I^2C, and UART interfaces.

2 Subsystems

2.1 Status and Error Indicators

Teensy Pin	Net Name	Teensy Configuration
3	LED1	`OUTPUT`
4	LED2	`OUTPUT`
5	LED3	`OUTPUT`
6	LED4	`OUTPUT`
7	LED5	`OUTPUT`
8	LED6	`OUTPUT`
24	LED7	`OUTPUT`
25	LED8	`OUTPUT`

Table 2: Debug LED Connections.

2.2 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. 1). 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.

2.3 Iriduim 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. 2.

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 2: RF specifications of the AL3A-RS Iridium modem.

2.3.1 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.

2.4 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.

2.4.1 Thermocouple Connections

See datasheet and connections in the relevant schematics in Fig. 5 in Appendix A.

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

2.5 Motion Sensor Connections

Teensy Pin	Net Name	Description	Teensy Configuration
36	XOUT	Analog out from accel (x axis)	INPUT
37	YOUT	Analog out from accel (y axis)	INPUT
38	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.

2.6 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. 6 in Appendix A.

2.6.1 Battery Status Interface

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

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

2.6.2 Planned Protection

When we receive the tabbed cells from NASA we will implement the TI BQ2970 Voltage and Current Protection IC (http://www.ti.com/lit/ds/symlink/bq2970.pdf). Protection circuitry is shown in Fig. 3 as seen in the BQ2970 datasheet.

I was thinking make a battery interface board that just has the protection circuitry and connects to the cells, or integrate this circuitry onto a corner of the main control board.

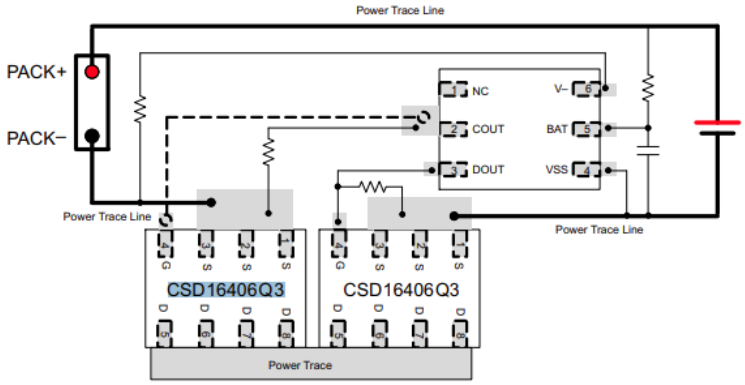


Figure 3: Example protection circuitry layout from BQ2970 datasheet.

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

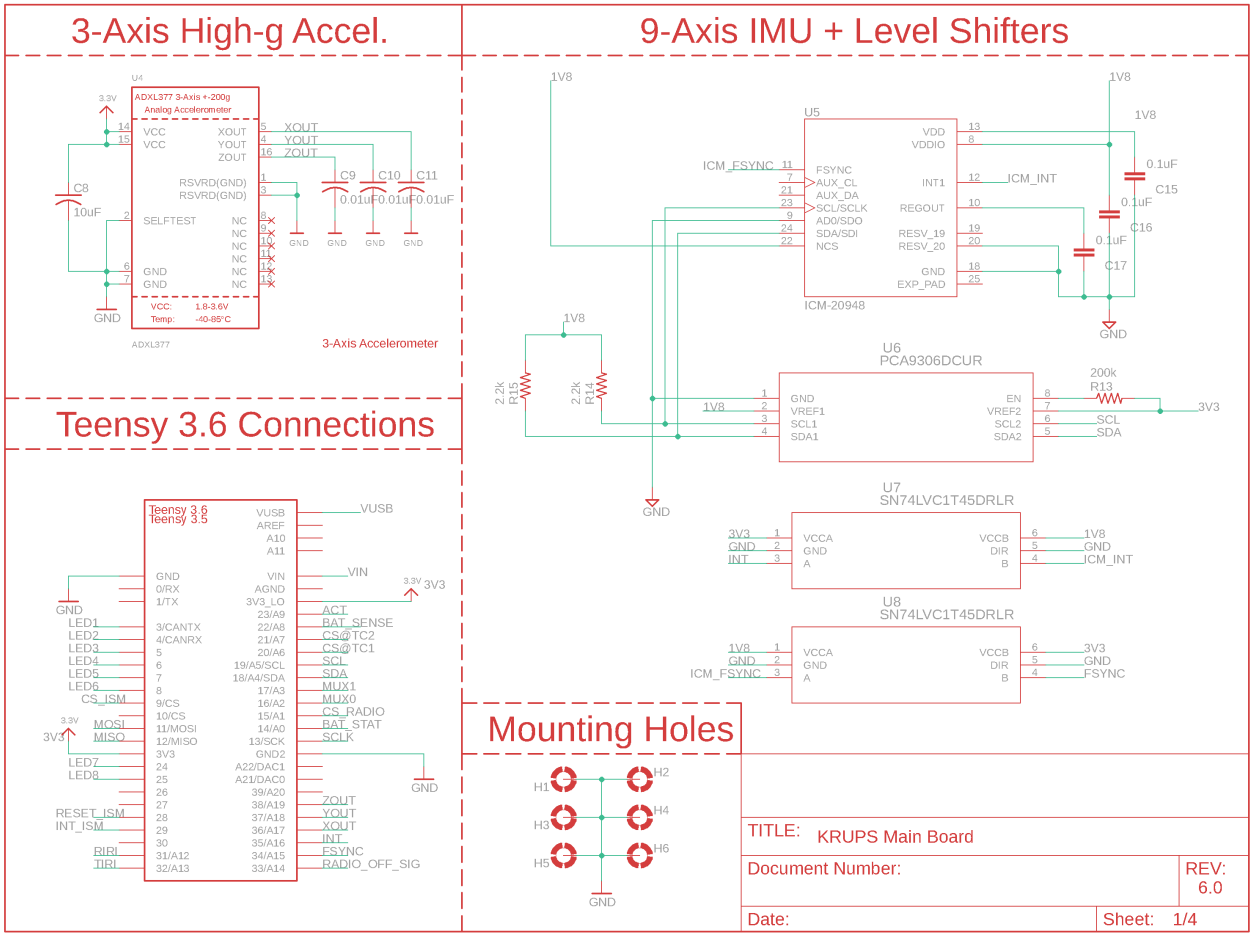


Figure 4: Page one of schematics.

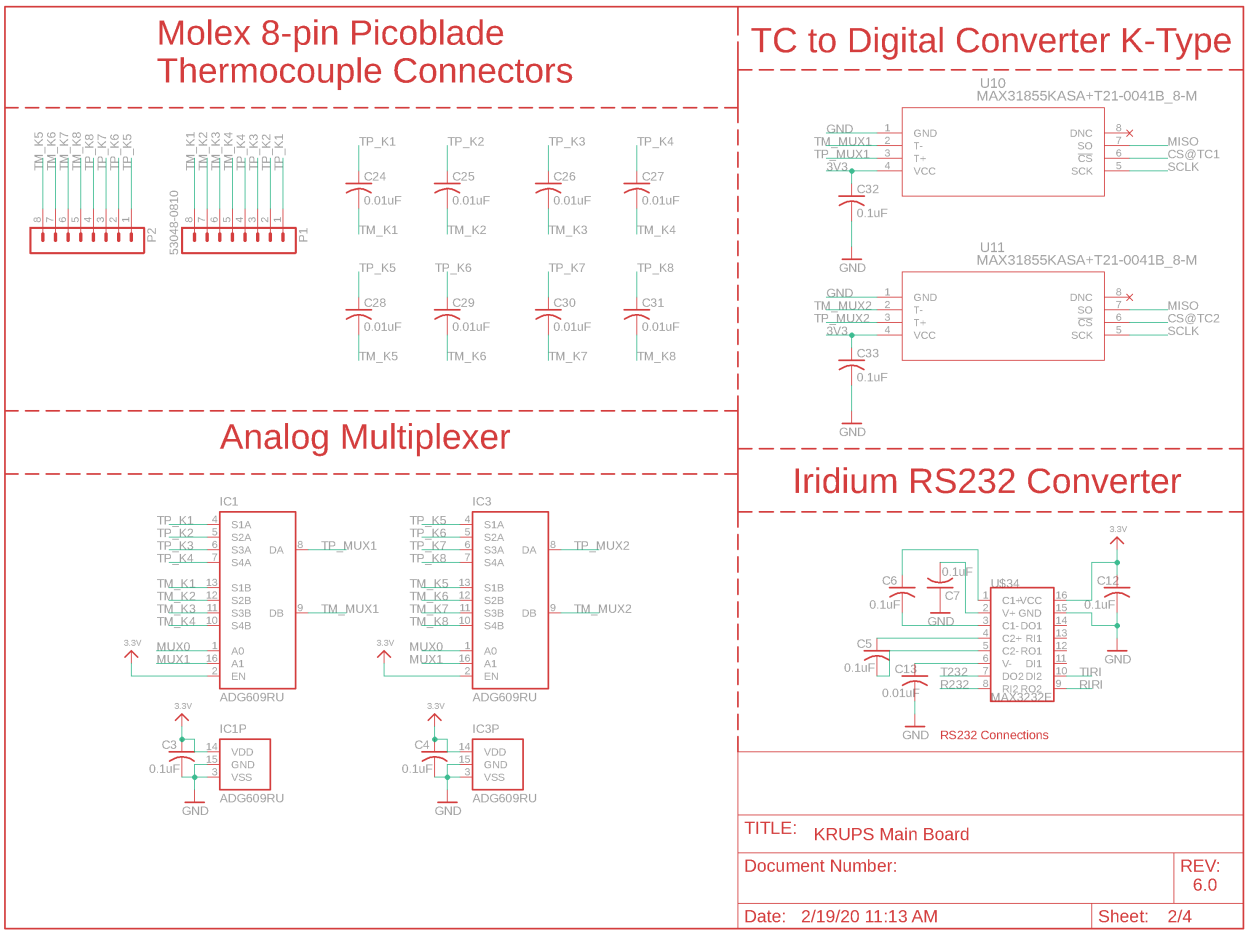


Figure 5: Page two of schematics.

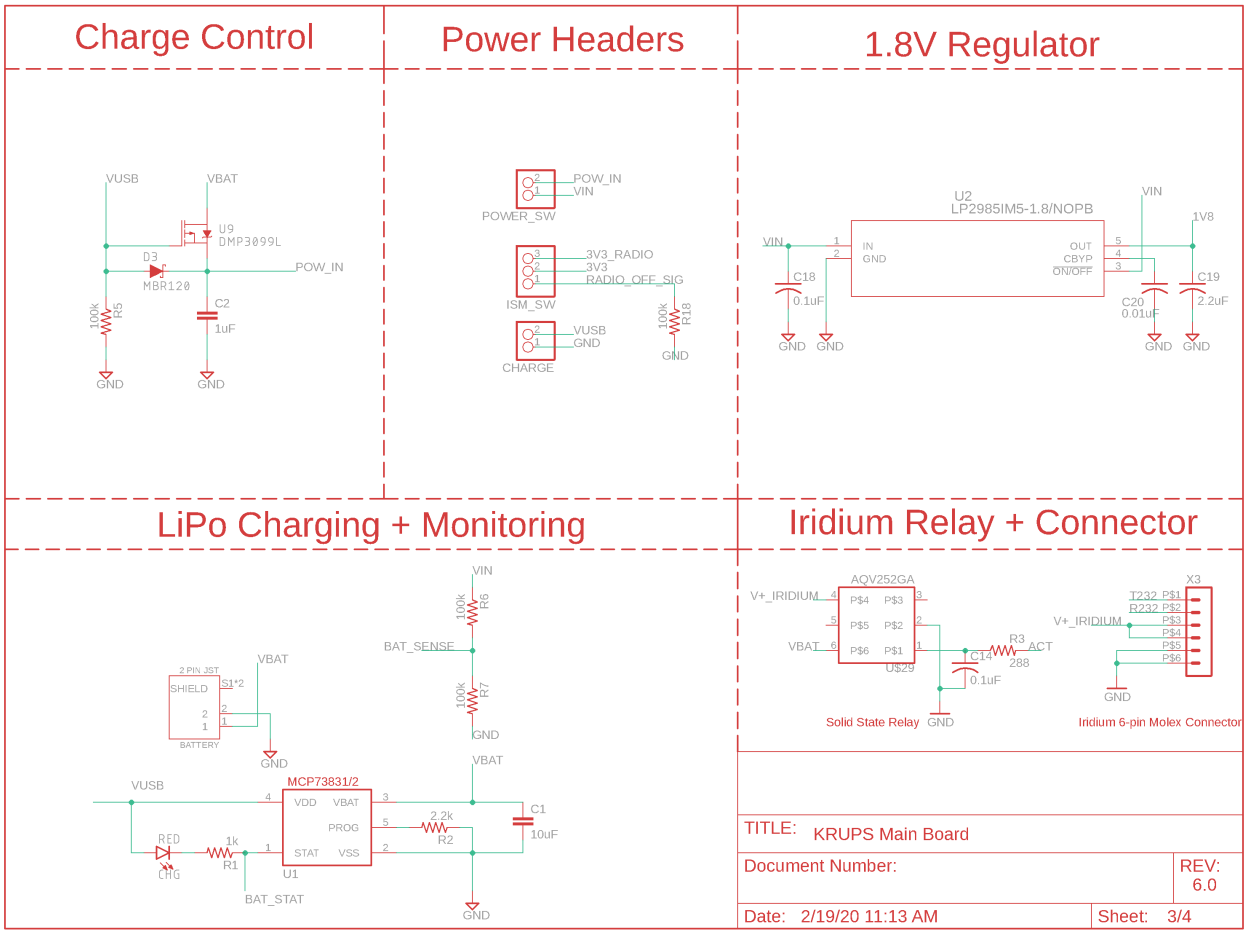


Figure 6: Page three of schematics.

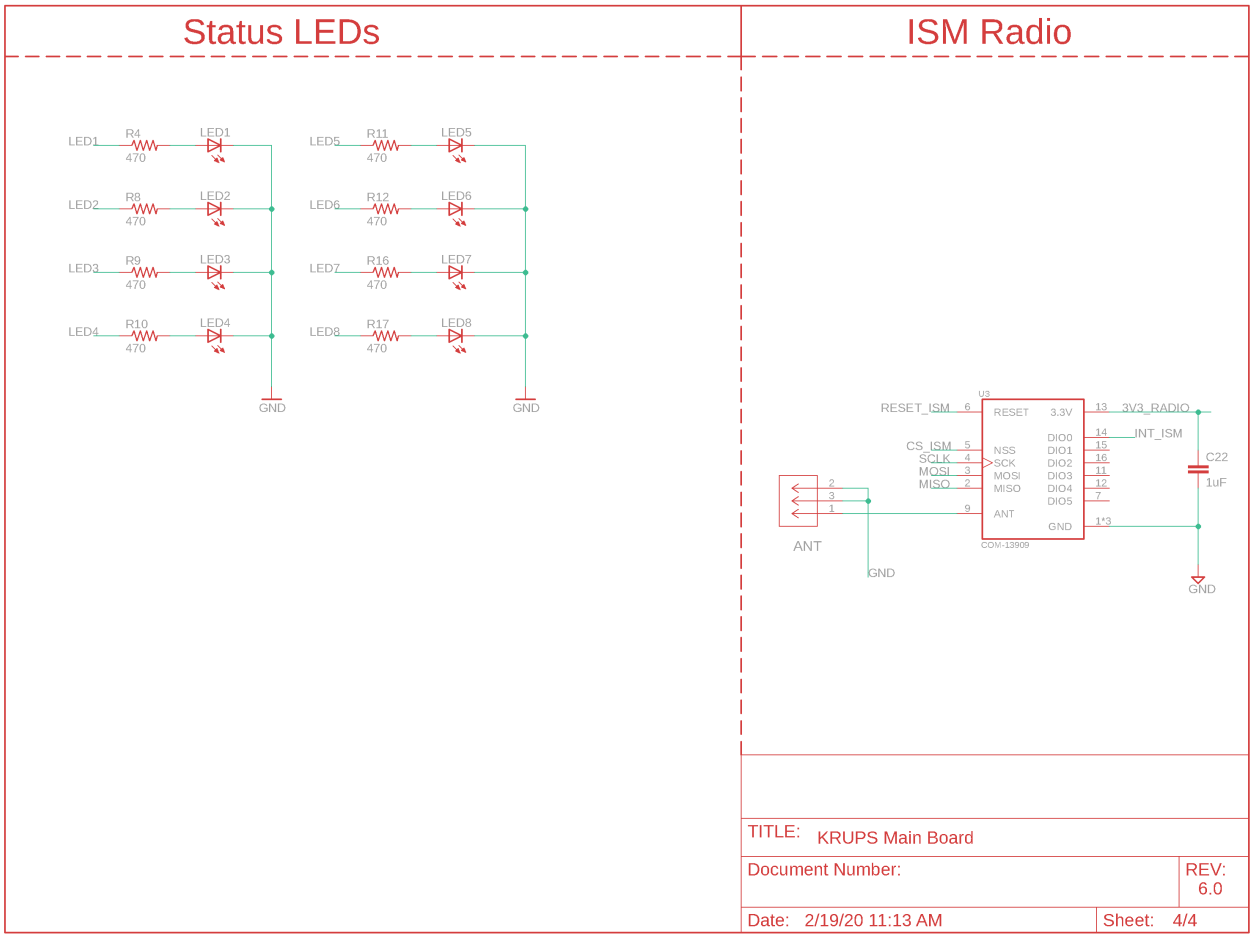


Figure 7: Page four of schematics.

B Teensy 3.5 Reference

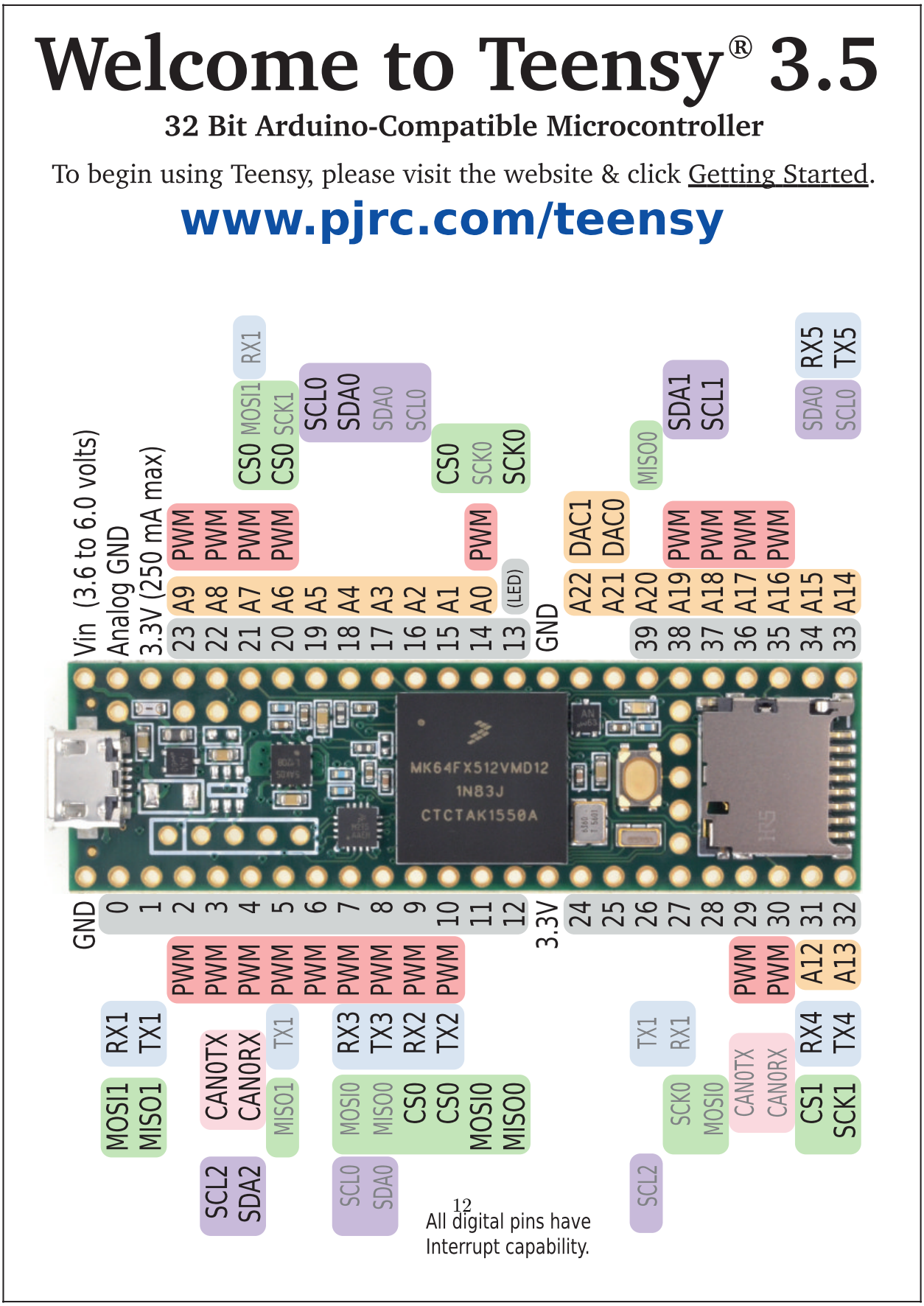
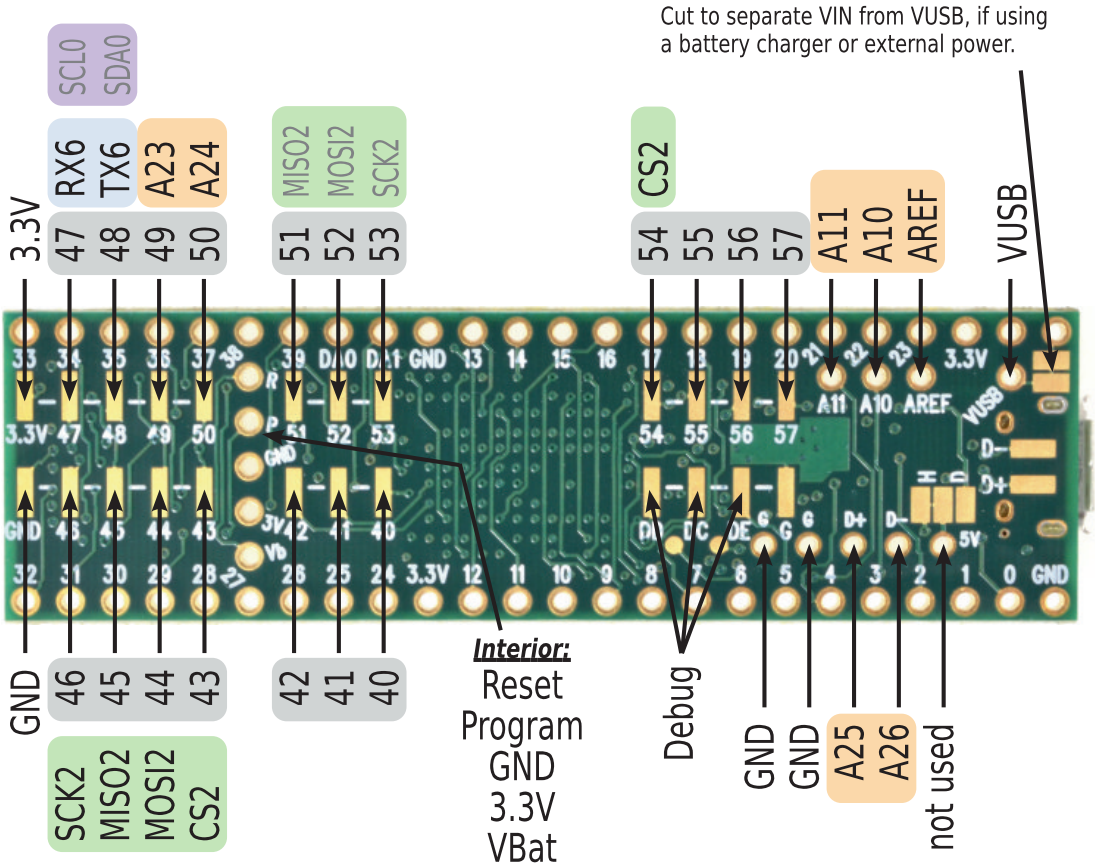


Figure 8: Teensy 3.5 Front

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

Figure 9: Teensy 3.5 Back

C Partslist

Partlist

Exported from kreme-iss.sch at 3/10/20 10:49 AM

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Assembly variant:

Part	Value	Device	Package	Library	Sheet
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	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
C12	0.1uF	C-USC0603	C0603	adafruit	2
C13	0.01uF	C-USC0603	C0603	adafruit	2
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
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
LED6		LEDCHIP-LED0603	CHIP-LED0603	adafruit	4
LED7		LEDCHIP-LED0603	CHIP-LED0603	adafruit	4
LED8		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
POWER_SW		PINHD-1X2	1X02	pinhead	3
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	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
R16	470	R-US_R0603	R0603	rcl	4
R17	470	R-US_R0603	R0603	rcl	4
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
U$34	MAX3232E	MAX3232E	SSOP-16	TI_radio	2
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	MAX31855KASA+T21-0041B_8-M	MAX31855KASA+T21-0041B_8-M	21-0041B_8-M	max31855	2
U11	MAX31855KASA+T21-0041B_8-M	MAX31855KASA+T21-0041B_8-M	21-0041B_8-M	max31855	2
X3		HEADER_POS6_43650-0600	43650-0600	con-molex-micro-fit-3_0	3