Electrical Project Specification

Project Name:	**Battery Management System (BATMAN) 1.1**
Document Rev:	**18**
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Date:	

Document Revisions

Revision	Date	Change(s)
01	2022/17/01	Initial Release.
02	2022/18/01	Incorporated feedback from Evan Gintonis. Revisions to buck converter, block diagram, MOSFETs.
03	2022/22/01	Updated block diagram and kill switch placement with approval from Mohit Aasi and CIRC. Added pinout figures for major chips by Software Team request. Added sleep mode requirement.
04	2022/27/01	Added details about LCD screen location. Added dimensions and mounting holes for selected LCD screen. Added requirement for PACK+ and PACK- cables to be long enough for easy reconnection. Added specific protection cutoff values. Updated block diagram.
05	2022/16/02	Added new requirements for power saving measures.
06	2022/20/02	Added more requirements for power saving, and added provisions for a sleep state diagram
07	2022/27/03	Added pin assignment map for STM32 microcontroller.
08	2022/20/05	Modified to match new Project Spec template.
09	2022/05/09	Major revision for new V2 12S battery pack.
10	2022/14/09	Created MCU pinout assignments for review by software team
11	2022/17/09	MCU pinout updated with pin 22
12	2022/25/09	Added placeholder mechanical dimensions.
13	2022/01/11	Added current ratings for mosfets, added current ratings for current sense resistors, added BATMAN power consumption estimates. Section 3.0
14	2022/12/12	Added requirement for heartbeat LED.
15	2023/18/01	Added fault behaviour
16	2023/18/02	Adjusted mechanical dimensions
17	2023-02-27	Added charging connector harness details: 19436-0413
18	2024-11-12	Added: •

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0.0 Conventions & Terms

0.1 Conventions

"Must" is used to indicate a mandatory requirement.
"Should" is used to indicate an additional nice to have.
"May" is used to indicate an option.

0.2 Terms & Definitions

BATMAN: V2 Rover Battery Management System

0.3 Reference Documents

Table 1: Reference documents

RD#	Document	Link
RD1	BQ769x0 Analog Frontend Datasheet	Link
RD2	BQ78350-R1A Gas Gauge Datasheet	Link
RD3	BQ76200 MOSFET Driver Datasheet	Link
RD4	MAX3051 CAN Transceiver Datasheet	Link
RD5	TATTU Battery Usage Manual	Link
RD6	STM32 Datasheet	Link
RD7	Using the BQ78350 - TI	Link
RD8	DFR0464 LCD Screen Datasheet	Link
RD9	Getting Started with STM32 Hardware Development	Link

1.0 Description

BATMAN is the battery management system designed for implementation on the V2.5 Rover, with the intention to be used on future rover revisions. Its purpose is to manage battery-related functions:

- Protect batteries from stress and damage
- Monitor and report the batteries' charge percentage.
- Enable the safe discharging and charging of the batteries.
- Perform cell balancing to maintain monotonous voltage across all battery cells.
- Communicate power and temperature information to secondary boards via CAN interface.

1.1 Dependencies

BATMAN depends on the following systems for operation:

- Battery pack: UNKNOWN 12S or 2x6S pack
- 2x HANMATEK 30V DC power supply in series to make a 60V DC power supply for charging
- Figure out what this is communicating with via CAN, probably OBC

2.0 Requirements & Constraints

Table 1: Requirements & constraints

Requirement ID	Description	Status
BATMAN-REQ-01	BATMAN must be able to be connected to the battery for long periods of time	
BATMAN-REQ-02	BATMAN must always monitor and communicate the pack current	
BATMAN-REQ-03	BATMAN must always monitor and communicate the voltage for each cell	
BATMAN-REQ-04	BATMAN must always monitor and communicate the temperature for the battery pack	
BATMAN-REQ-05	BATMAN must always monitor and communicate the battery pack state of charge (battery percentage), where 0% is at 3.5V and 100% is at 4.1V	
BATMAN-REQ-06	BATMAN must possess discharge overcurrent and short-circuit protection for the battery pack, cutting off the MOSFETs and generating a unique error code when current exceeds 120A or 200A	
BATMAN-REQ-07	BATMAN must possess overvoltage and undervoltage protection for each cell, cutting off the MOSFETs and generating a unique error code when the cell voltage rises above 4.2V or drops below 3.3V specified by TATTU datasheet	
BATMAN-REQ-08	BATMAN must possess under-temperature and over-temperature protection for the battery pack, cutting off the MOSFETS and generating a unique error code when temperature rises above 43 Celsius or falls below 0 Celsius specified by TATTU datasheet	
BATMAN-REQ-09	BATMAN must fit in a 126mmx215mmx40mm (Length x Width x Height) space under the batteries in the chassis	
BATMAN-REQ-10	BATMAN must use CAN bus to communicate with other subsystems and the operator	
BATMAN-REQ-11	BATMAN must have a power-good LED nearby to the PACK+ output to indicate power good	
BATMAN-REQ-12	BATMAN must have a debug LED to indicate fault conditions	
BATMAN-REQ-13	BATMAN should have an external LCD screen to display voltage, current, temperature, and state of charge • *Note: not currently implemented on Rev.1*	

BATMAN-REQ-14	BATMAN should be easy to manufacture	
BATMAN-REQ-15	BATMAN should include a heatsink to enhance safety and reliability	
BATMAN-REQ-16	BATMAN should be lightweight	
BATMAN-REQ-17	A board, probably not BATMAN should recognise if the rover has been idling for 30 minutes. If it has, then put the rover into a low power mode with disabled motors. TBA	
BATMAN-REQ-18	BATMAN's peripheral LCD screen must mount into a hole in the side of the rover chassis, viewable from outside the rover. The allocated dimensions are ___________ TBA - *Note: LCD screen is not implemented on rover V2.5; requirement stands for future revisions if LCD is implemented*	
BATMAN-REQ-19	BATMAN must possess charge overcurrent protection for the battery pack, cutting off the MOSFETs and generating a unique error code when current exceeds 22A AKA 1C specified by TATTU datasheet	
BATMAN-REQ-20	A board, maybe BATMAN should recognise if the batteries have been stored above 4V for one week. If it has, advise the operator to discharge the batteries to 3.8V-3.9V before continuing long term storage, specified by TATTU datasheet	
BATMAN-REQ-21	BATMAN should balance cell voltages to maximize battery capacity	
BATMAN-REQ-22	BATMAN should have long PACK+ and PACK- cables so that they can be reconnected to a charger easily	
BATMAN-REQ-23	BATMAN should consume less than 10% of the battery charge over a period of 1 month	
BATMAN-REQ-24	BATMAN should have a button nearby the LCD screen that when pressed wakes the microcontroller and LCD screen from sleep mode for 5 seconds - *Note: LCD screen is not implemented on rover V2.5; requirement stands for future revisions if LCD is implemented*	
BATMAN-REQ-25	BATMAN should put the CAN transceiver into standby mode when a fault condition is detected, and wake it up when recovering from fault	

BATMAN-REQ-26	BATMAN's MCU, CAN transceiver, and LCD screen should automatically go into sleep mode. In case of a failure-to-sleep, the buck converter should be turned off to force those devices off. (can use a PMOS or load switch etc to turn off buck converter. Or use enable pins) - *Note: LCD screen is not implemented on rover V2.5; requirement stands for future revisions if LCD is implemented*	
BATMAN-REQ-26	BATMAN gas gauge should leave on the state of charge LEDs when the battery percentage is 80% or higher, or the battery is charging. This should occur even when battery subsystem is outside of rover.	
BATMAN-REQ-27	BATMAN should have a heartbeat LED controlled by the MCU that blinks when the MCU is in normal operation.	
BATMAN-REQ-28	BATMAN FETs must stay disabled when faulted. Faults must be cleared manually	
BATMAN-REQ-29	BATMAN must use a charging connector harness that terminates in a 19436-0413 header	

3.0 Performance Specifications

Table 2: Performance specifications

Specification ID	Parameter	Min.	Nom.	Max.	Unit
BATMAN-SPEC-01	Cell stack voltage	16	30.4	35.2	Volts
BATMAN-SPEC-02	MOSFET design current, constant	-22	120	-	Amps
BATMAN-SPEC-03	Board temperature	0	30	85	Celsius
BATMAN-SPEC-04	Current sense resistor short circuit detection threshold (shutdown)	-50	-	300	Amps
BATMAN-SPEC-05	Current sense resistor overcurrent detection threshold (shutdown)	-25	-	150	Amps
BATMAN-SPEC-06	BATMAN power consumption continuous	0	1	9	Watts

4.0 PCB Layout

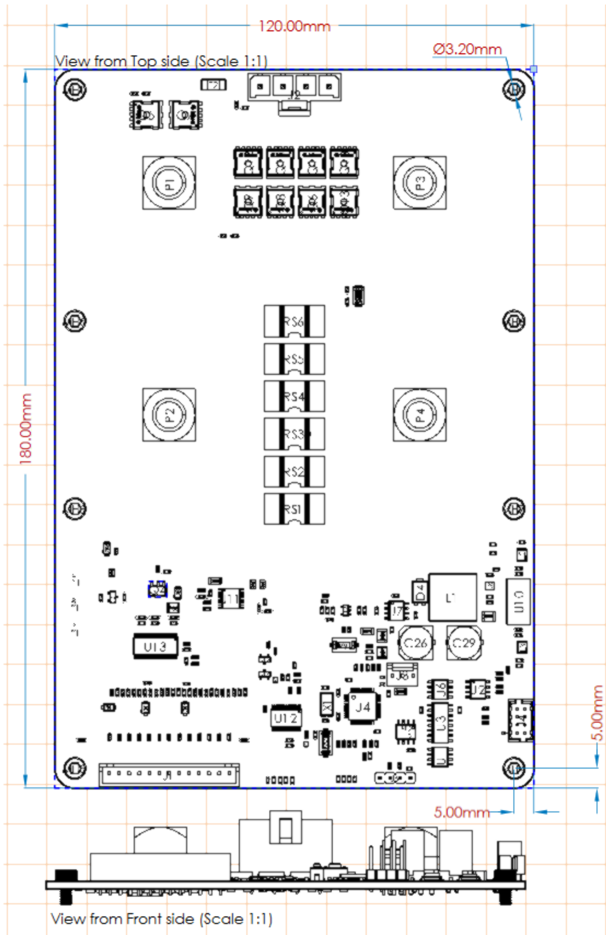
Table 3: PCB parameters

Parameter	Value	Unit
Number of Layers	6	-
PCB Thickness	2.05	mm
Vendor	JLCPCB	-

Table 4: PCB layer stack-up

Layer #	Copper Weight (oz)	Type
1	2	Power
2	0.5	Ground
3	0.5	Signal
4	2	Ground

5.0 Mechanical Interfaces



The size of the BATMAN board is 180 mm long, and 120 mm wide. M3 Mounting holes are used to mount the board to the rover chassis. There are eight mounting holes, centered 5mm away from the edge of the board. Four are placed in each corner, the remaining are placed along the long edge of the board.

<u>Placeholder</u> 50mm height clearance required for connector clearance and REDCUBE lug clearance and heatsink clearance.

The charging harness is terminating with a 19436-0413 connector.

Explain the mechanical elements of your Project. What is the size of your board? How is it mounted to the rover? What are the dimensions of the mounting holes so the Mechanical team can easily create a mounting solution for your board? If you are using tall components like an inductor, list the maximum height for your board to ensure clearance. Will any connectors on your board fit through a faceplate in a panel-mount style?

6.0 Detailed Description (Theory of Operation)

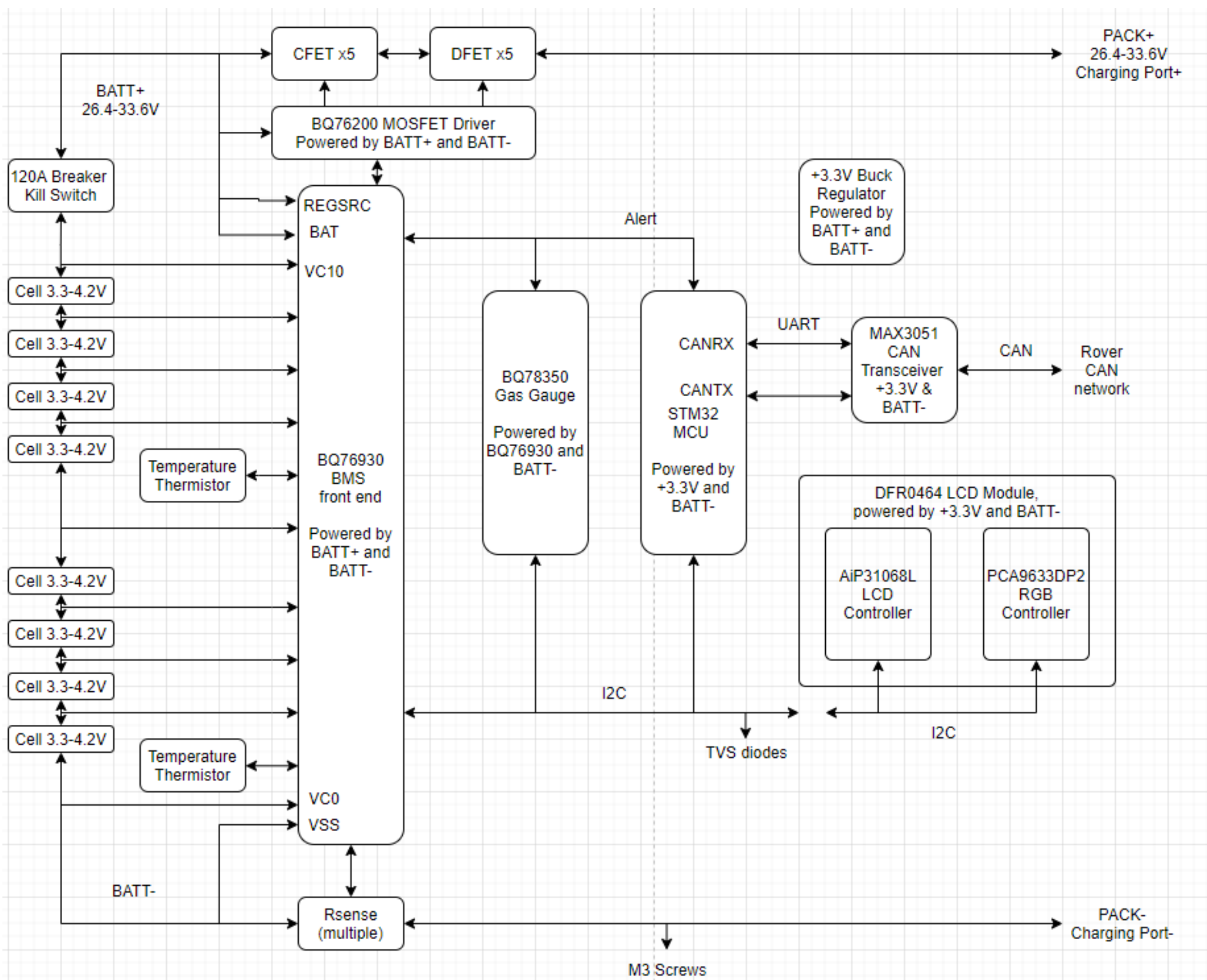


Figure 2: BATMAN block diagram

6.1 Battery Wiring

TBA TODO TODO

6.2 BQ7694003DBT: Battery Management System Analog Front End (AFE)

The BQ76940 family is an analog front-end device which is used for battery pack protection and monitoring. Supporting up to 15-series cells, the BQ76940 monitors cell voltages, pack current, and pack temperatures. Furthermore, it supports several battery pack protection features, such as controlling the charging and discharging of MOSFETS, and battery cell balancing.

The BQ76940 is directly powered by the battery through the BAT pin (P.20). Its function consists of three major subsystems: Battery Measurement, Battery Protection, and Battery Control.

6.2.1 Battery Measurement

The Battery Measurement subsystem digitizes key battery management parameters for communication to a host controller. These measures include cell voltages, pack current, external thermistor temperatures, and internal die temperatures.

The information is then communicated via I2C using a register read request for the desired measured value. Voltage and temperature are digitized using 14-bit ADC. Cell voltages are measured individually (CELL 1-15) and automatically added up for a total battery stack voltage (BATT_HI and BATT_LO).

There are a total of three internal die temperature thermistors and three external thermistors, which share the same register space (controlled via TEMP_SEL register). The external thermistors are wired, and can be oriented in regions of interest (TBC – but likely one near MOSFETS, another near CHARGE connector, and another by current sense resistors).

6.2.2 Battery Protection

The Battery Protection subsystem is implemented as a fail-safe protection system and is designed to be used in events such as loss of communication with the host controller. The protection system is implemented as an Overcurrent in Discharge (OCD) and Short Circuit in Discharge (SCD). This monitors the voltage, and if detected to exceed programmed threshold values, will instantiate a counter. If the counter reaches a programmed delay value, a fault condition is sent, and the $\overline{\mathrm{ALERT}}$ pin is driven high to interrupt the host, with the DSG or CHG FET driver being automatically disabled (depending on the fault).

OCD occurs when the current sense across the current sense resistors exceeds the programmed current threshold. The expected OCD current is 150A

6.2.3 Battery Control

BQ76940 is used to measure voltage, current, and temperature information. The BQ76930 will signal to shut off the MOSFETs if any protection is required. The trip value for each protection mode is configurable in software.

The BQ76930 is powered by the battery through the BAT and REGSRC pins. The BAT pin powers the voltage sensing circuitry, while REGSRC powers communications, MOSFET driving, and everything else.

REGSRC cannot handle the voltage that the battery supplies, so we will use a MOSFET voltage follower circuit to lower the voltage.

The BQ769x0 series has a "fault once and stay disabled" behaviour. Faults must be cleared by BQ78350 to retry.

bq76940 Pin Functions

PIN	NAME	TYPE	DESCRIPTION
1	DSG	O	Discharge FET driver
2	CHG	O	Charge FET driver
3	VSS	—	Chip VSS
4	SDA	I/O	I^2C communication to the host controller
5	SCL	I	I^2C communication to the host controller
6	TS1	I	Thermistor #1 positive terminal(1)
7	CAP1	O	Capacitor to VSS

(1) If not used, pull down to group ground reference (VSS for TS1, VC5X for TS2, and VC10X for TS3) with a 10-kΩ nominal resistor.

bq76940 Pin Functions (continued)

PIN	NAME	TYPE	DESCRIPTION
8	REGOUT	P	Output LDO
9	REGSRC	I	Input source for output LDO
10	VC5X	P	Thermistor #2 negative terminal
11	NC	—	No connect (short to CAP2)
12	NC	—	No connect (short to CAP2)
13	TS2	I	Thermistor #2 positive terminal(1)
14	CAP2	O	Capacitor to VC5X
15	VC10X	P	Thermistor #3 negative terminal
16	NC	—	No connect (short to CAP3)
17	NC	—	No connect (short to CAP3)
18	TS3	I	Thermistor #3 positive terminal(1)
19	CAP3	O	Capacitor to VC10X
20	BAT	P	Battery (top-most) terminal
21	NC	—	No connect
22	NC	—	No connect
23	NC	—	No connect
24	VC15	I	Sense voltage for 15th cell positive terminal
25	VC14	I	Sense voltage for 14th cell positive terminal
26	VC13	I	Sense voltage for 13th cell positive terminal
27	VC12	I	Sense voltage for 12th cell positive terminal
28	VC11	I	Sense voltage for 11th cell positive terminal
29	VC10B	I	Sense voltage for 11th cell negative terminal
30	VC10	I	Sense voltage for 10th cell positive terminal
31	VC9	I	Sense voltage for 9th cell positive terminal
32	VC8	I	Sense voltage for 8th cell positive terminal
33	VC7	I	Sense voltage for 7th cell positive terminal
34	VC6	I	Sense voltage for 6th cell positive terminal
35	VC5B	I	Sense voltage for 6th cell negative terminal
36	VC5	I	Sense voltage for 5th cell positive terminal
37	VC4	I	Sense voltage for 4th cell positive terminal
38	VC3	I	Sense voltage for 3rd cell positive terminal
39	VC2	I	Sense voltage for 2nd cell positive terminal
40	VC1	I	Sense voltage for 1st cell positive terminal
41	VC0	I	Sense voltage for 1st cell negative terminal
42	SRP	I	Negative current sense (nearest VSS)
43	SRN	I	Positive current sense
44	ALERT	I/O	Alert output and override input

Figure 6: Pin names and functions from datasheet

6.3 BQ78350-R1A gas gauge

The BQ78350-R1A is used to record, store, and process voltage and current information to output an accurate battery state of charge (battery percentage) measurement.

The BQ78350-R1A has the most recent firmware version, specifically made to work with the BQ7693x series chips.

From TI document slua924, the information that can be transferred from the BQ76930 and BQ78350-R1A over SMBus includes state of charge (battery percentage), pack current, cell voltage, and temperature. This information can be requested and transferred to an onboard microcontroller.

PIN NUMBER	PIN NAME	TYPE	DESCRIPTION
1	COM	O(1)	Open-drain output LCD common connection. Leave unconnected if not used.
2	ALERT	I	Input from the BQ769x0 AFE
3	SDA	I/O	Data transfer to and from the BQ769x0 AFE. Requires a 10-k pullup to VCC
4	SCL	I/O	Communication clock to the BQ769x0 AFE. Requires a 10-k pullup to VCC
5	$\overline{\text{PRECHG}}$	O	Programmable polarity (default is active low) output to enable an optional precharge FET. This pin requires an external pullup to 2.5 V when configured as active high, and is open drain when configured as active low.
6	VAUX	AI	Auxiliary voltage input. If this pin is not used, then it should be tied to VSS.
7	BAT	AI	Translated battery voltage input
8	$\overline{\text{PRES}}$	I	Active low input to sense system insertion. This typically requires additional ESD protection. If this pin is not used, then it should be tied to VSS.
9	$\overline{\text{KEYIN}}$	I	A low level indicates application key-switch is inactive on position. A high level causes the DSG protection FET to open. If this pin is not used, then it should be tied to VSS.
10	SAFE	O	Active high output to enforce an additional level of safety protection (for example, fuse blow)
11	SMBD	I/OD	SMBus data open-drain bidirectional pin used to transfer an address and data to and from the BQ78350-R1A device
12	VEN	O	Active high voltage translation enable. This open drain signal is used to switch the input voltage divider on/off to reduce the power consumption of the BAT translation divider network.
13	SMBC	I/OD	SMBus clock open-drain bidirectional pin used to clock the data transfer to and from the BQ78350-R1A device
14	$\overline{\text{DISP}}$	I	Display control for the LEDs. This pin is typically connected to BQ78350-R1A device REGOUT via a 100-KΩ resistor and a push-button switch connect to VSS. Not used with LCD display enabled and can be tied to VSS.
15	PWRM	O	Power mode state indicator open drain output
16	LED1	O	LED1/LCD1 display segment that drives an external LED/LCD, depending on the firmware configuration

(1) I = Input, IA = Analog input, I/O = Input/output, I/OD = Input/Open-drain output, O = Output, OA = Analog output, P = Power

PIN NUMBER	PIN NAME	TYPE	DESCRIPTION
17	LED2	O	LED2/LCD2 display segment that drives an external LED/LCD, depending on the firmware configuration
18	LED3	O	LED3/LCD3 display segment that drives an external LED/LCD, depending on the firmware configuration
19	LED4	O	LED4/LCD4 display segment that drives an external LED/LCD, depending on the firmware configuration
20	LED5	O	LED5/LCD5 display segment that drives an external LED/LCD, depending on the firmware configuration
21	GPIO A	I/O	Configurable Input or Output. If not used, tie to VSS.
22	VSS	—	Negative supply voltage
23	VSS	—	Negative supply voltage
24	$\overline{\text{MRST}}$	I	Master reset input that forces the device into reset when held low. This pin must be held high for normal operation.
25	VSS	—	Negative supply voltage
26	VCC	P	Positive supply voltage
27	RBI	P	RAM backup input. Connect a capacitor to this pin and VSS to protect loss of RAM data in case of short circuit condition.
28	GPIO B	I/O	Configurable input or output. If not used, tie to VSS.
29	ADREN	O	Optional digital signal enables address detection measurement to reduce power consumption.
30	SMBA	IA	Optional SMBus address detection input. If this pin is not used, then it should be tied to VSS.

Figure 7: Pin names and functions from datasheet

6.4 BQ76200 MOSFET driver

The BQ76200 is used to drive MOSFETs at voltages higher than the battery stack BATT+ voltage.

The BQ76200 is designed to take signal inputs directly from the BQ76930.

The BQ76200 is powered directly by the battery stack BATT+ voltage, see datasheet pg 3.

The MOSFETs chosen can be driven by the BQ76200. The BQ76200 driving calculations can be found here.

PIN		TYPE[1]	DESCRIPTION
NAME	NO.	I/O	
BAT	2	P	Top of battery stack
CHG[2]	16	O	Gate drive for charge FET
CHG_EN[3]	4	I	Charge FET enable
CP_EN[3]	5	I	Charge pump enable (internally logic OR'ed with CHG_EN and DSG_EN signals)
DSG[2]	12	O	Gate drive for discharge FET
DSG_EN[3]	6	I	Discharge FET enable
NC	3, 13, 15	—	No connect. Leave the pin floating
PACK	11	P	Analog input from PACK+ terminal
PACKDIV[2]	10	O	PACK voltage after internal switch (Connect to MCU ADC via resistor divider.)
PCHG[2]	14	O	Gate drive for precharge FET
PCHG_EN[3]	8	I	Precharge FET enable
PMON_EN[3]	7	I	Pack monitor enable (allows connection of internal switch between PACK and PACKDIV)
VDDCP	1	O	Charge pump output. Connect a capacitor to BAT pin. Do not load this pin.
VSS	9	P	Ground reference

(1) P = Power Connection, O = Digital Output, AI = Analog Input, I = Digital Input, I/OD = Digital Input/Output
(2) Leave the pin float if the function is not used.
(3) It is recommended to connect the pin to ground if the function is not used.

Figure 8: Pin names and functions from datasheet

6.5 STM32F103C8T6 microcontroller

We are using the STM32F103C8T6 microcontroller onboard BATMAN. This microcontroller is used to process the state of charge (battery percentage), pack current, cell voltage, and temperature information from the BQ76930 and BQ78350-R1A over SMBus (I2C and Alert).

Table 2. STM32F103xx medium-density device features and peripheral counts

Peripheral		STM32F103Tx		STM32F103Cx		STM32F103Rx		STM32F103Vx	
Flash - Kbytes		64	128	64	128	64	128	64	128
SRAM - Kbytes		20		20		20		20	
Timers	General-purpose	3		3		3		3	
	Advanced-control	1		1		1		1	
Communication	SPI	1		2		2		2	
	I^2C	1		2		2		2	
	USART	2		3		3		3	
	USB	1		1		1		1	
	CAN	1		1		1		1	
GPIOs		26		37		51		80	
12-bit synchronized ADC Number of channels		2 10 channels		2 10 channels		2 16 channels(1)		2 16 channels	
CPU frequency		72 MHz							
Operating voltage		2.0 to 3.6 V							
Operating temperatures		Ambient temperatures: -40 to +85 °C / -40 to +105 °C (see *Table 9*) Junction temperature: -40 to + 125 °C (see *Table 9*)							
Packages		VFQFPN36		LQFP48, UFQFPN48		LQFP64, TFBGA64		LQFP100, LFBGA100, UFBGA100	

1. On the TFBGA64 package only 15 channels are available (one analog input pin has been replaced by 'Vref+').

Figure 9: Our device has the LQFP48 package and the above specifications. From datasheet page 10

Pinouts and pin description   STM32F103x8, STM32F103xB

Table 5. Medium-density STM32F103xx pin definitions (continued)

Pins											Alternate functions[4]	
LFBGA100	UFBGA100	LQFP48/UFQFPN48	TFBGA64	LQFP64	LQFP100	VFQFPN36	Pin name	Type[1]	I / O Level[2]	Main function[3] (after reset)	Default	Remap
A9	A10	37	A7	49	76	28	PA14	I/O	FT	JTCK/SWCLK	-	PA14
A8	A9	38	A6	50	77	29	PA15	I/O	FT	JTDI	-	TIM2_CH1_ ETR/ PA15 /SPI1_NSS
B9	B11	-	B7	51	78		PC10	I/O	FT	PC10	-	USART3_TX
B8	C10	-	B6	52	79		PC11	I/O	FT	PC11	-	USART3_RX
C8	B10	-	C5	53	80		PC12	I/O	FT	PC12	-	USART3_CK
-	C9	-	C1	-	81	2	PD0	I/O	FT	PD0	-	CANRX
-	B9	-	D1	-	82	3	PD1	I/O	FT	PD1	-	CANTX
B7	C8		B5	54	83	-	PD2	I/O	FT	PD2	TIM3_ETR	-
C7	B8	-	-	-	84	-	PD3	I/O	FT	PD3	-	USART2_CTS
D7	B7	-	-	-	85	-	PD4	I/O	FT	PD4	-	USART2_RTS
B6	A6	-	-	-	86	-	PD5	I/O	FT	PD5	-	USART2_TX
C6	B6	-	-	-	87	-	PD6	I/O	FT	PD6	-	USART2_RX
D6	A5	-	-	-	88	-	PD7	I/O	FT	PD7	-	USART2_CK
A7	A8	39	A5	55	89	30	PB3	I/O	FT	JTDO	-	TIM2_CH2 / PB3 TRACESWO SPI1_SCK
A6	A7	40	A4	56	90	31	PB4	I/O	FT	JNTRST	-	TIM3_CH1/ PB4/ SPI1_MISO
C5	C5	41	C4	57	91	32	PB5	I/O		PB5	I2C1_SMBAI	TIM3_CH2 / SPI1_MOSI
B5	B5	42	D3	58	92	33	PB6	I/O	FT	PB6	I2C1_SCL[9]/ TIM4_CH1[9]	USART1_TX
A5	B4	43	C3	59	93	34	PB7	I/O	FT	PB7	I2C1_SDA[9]/ TIM4_CH2[9]	USART1_RX
D5	A4	44	B4	60	94	35	BOOT0	I		BOOT0	-	-

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Figure 10: Pin layout for ALERT and I2C pins for SMBus. From datasheet page 32

After receiving data from the BQ76930 and BQ78350-R1A, the microcontroller will transmit information over CAN to another device off-board. OBC?

Please see page 27 to 33 of the datasheet for the pin names and functions.

The pin assignments that we will use is shown below:

Pin Number for LQFP48	Pin Name	I/O Voltage Tolerance	Function	Connect to…
1	VBAT	3.3V	-	VCC3V3
5	OSC_IN	3.3V	-	Oscillator
6	OSC_OUT	3.3V	-	Oscillator
7	NRST	3.3V	-	Reset switch
8	VSSA	3.3V	-	VCC3V3, capacitor decoupled close to VDDA
9	VDDA	3.3V	-	Buck Converter GND, capacitor decoupled close to VDDA
18	PB0	3.3V	PB0	GAUGE_GPIOA, unused GPIO signal from Gas Gauge
19	PB1	3.3V	PB0	GAUGE_GPIOB, unused GPIO signal from Gas Gauge
20	PB2	5V	BOOT1	Unused, switch
21	PB10	3.3V	PB10	AFE_BOOT, signal used to boot analog front end
22	PB11	5V	PB11	GAUGE_LED for turning on LEDs when needed
23	VSS1	3.3V	-	Buck Converter GND
24	VDD1	3.3V	-	VCC3V3
25	PB12	5V	PB12	GAUGE_PGOOD, the Gauge's pgood signal
30	PA9	5V	USART1_TX	CAN_TX to the CAN transceiver
31	PA10	5V	USART1_RX	CAN_RX to the CAN transceiver
34	PA13	5V	SWDIO	SWDIO
35	VSS2	3.3V	-	Buck Converter GND
36	VDD2	3.3V	-	VCC3V3
37	PA14	5V	SWCLK	SWCLK
42	PB6	5V	I2C1_SCL	SMB_CK to gas auge
43	PB7	5V	I2C1_SDA	SMB_to gas gauge
44	BOOT0	3.3V	BOOT0	Switch
47	VSS3	3.3V	-	Buck Converter GND
48	VDD3	3.3V	-	VCC3V3

6.6 MAX3051ESA+ CAN transceiver

We are using the MAX3051ESA+ CAN transceiver. This communicates with the STM32 and converts the signals between UART and CAN.

The destination is the rover-wide CAN network and the OBC.

The CAN transceiver has optional termination nearby so that the CAN bus can be terminated if needed.

CAN contains differential signals and is not referenced to any grounds. This means that deviations in grounding between boards are tolerated.

PIN	NAME	DESCRIPTION
1	TXD	Transmit Data Input. TXD is a CMOS/TTL-compatible input from a CAN controller. TXD has an internal 75kΩ pullup resistor.
2	GND	Ground
3	V_{CC}	Supply Voltage. Bypass V_{CC} to GND with a 0.1μF capacitor.
4	RXD	Receive Data Output. RXD is a CMOS/TTL-compatible output.
5	SHDN	Shutdown Input, CMOS/TTL-Compatible. Drive SHDN high to put the MAX3051 in shutdown. SHDN has an internal 75kΩ pulldown resistor to GND.
6	CANL	CAN Bus Line Low
7	CANH	CAN Bus Line High
8	RS	Mode-Select Input. Drive RS low or connect to GND for high-speed operation. Connect a resistor between RS and GND to control output slope. Drive RS high to put into standby mode (see the *Mode Selection* section).

Figure 11: Pin names and functions from datasheet

6.7 Buck regulator

To power the microcontroller and the LCD screen we need a 3.3V supply. We have chosen to use a 3.3V buck converter with a high input voltage of 50V or greater.

This converter is supplied by the battery after the kill switch, a net that we will call BATT+.

The buck regulator will supply power to the microcontroller and LCD screen even when the BQ76830 has opened the MOSFETs. This allows the LCD to display the state of the pack during fault condition.

Because of this, BATMAN will draw a small amount of power from the batteries, even when the batteries are at or below 0% and trigger an undervoltage fault. Prolonged storage of the batteries at or below 0% will cause damage, so it is crucial that the battery pack is charged to between 20-80% (ideally 20-40%) when stored. It is also crucial that the kill switch is opened when putting the battery into storage to avoid the power consumption from BATMAN.

EXACT REGULATOR USED IS TBA

6.8 LEDs

BATMAN has one debug LED that is activated when an SMBus alert is thrown, when the ALERT bus is high.

BATMAN has one power-good LED that is activated when PACK+ voltage is HIGH. This notifies any users that the output is hot and good to go.

6.9 MOSFETs

To disconnect the batteries from the rover, BATMAN uses MOSFETs. BATMAN uses two sets of MOSFETs facing each other. This is because MOSFETs inherently have a diode and can only stop current in one direction.

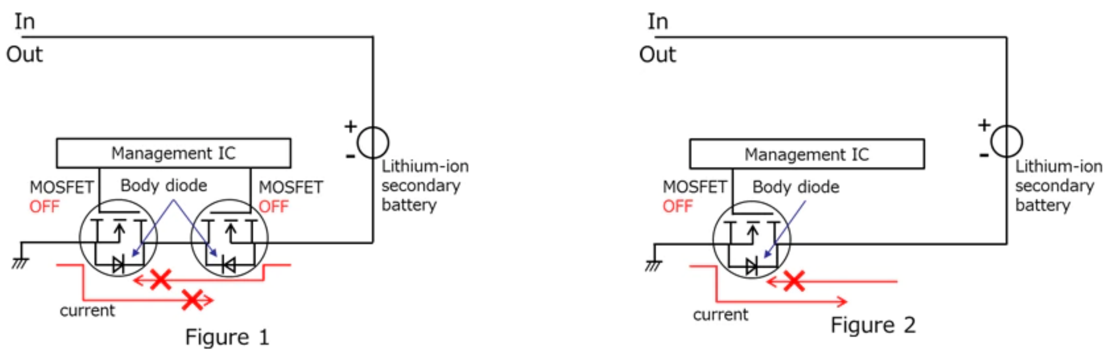

Figure 13: Why we need MOSFETs facing eachother, from [here](#)

Because we are expecting 90A of current with spikes up to 120A, we need many MOSFETs in parallel and extremely wide copper traces.

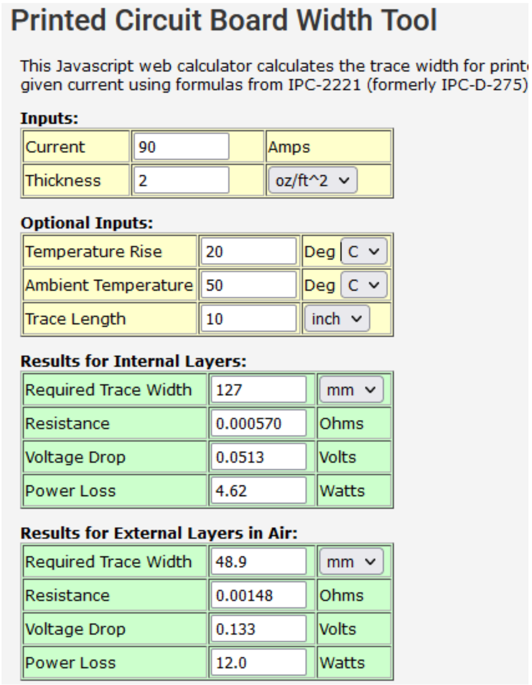

Figure 14: Trace width calculator, external layers in air. From here

We have chosen MOSFETs with low RDSon (resistance) to reduce heat generation.

See here for the choice of MOSFET and the heat calculations.

6.10 Current sense

To measure the current going in and out of the pack, we use current sense resistors in parallel. These resistors have a set resistance that is relatively temperature consistent. When the current flows across the resistor, it creates a voltage drop that varies based on the amount of current flow.

The selected current sense resistors are 15X 2mΩ resistors, with an effective resistance of 0.13mΩ. This selection was made based on the coulomb counter range CC_{range}, which is used to detect short-current and over-current in discharge (SCD and OCD). The selected current resistors are based on the expected nominal short-circuit in discharge current, which is 100A; the calculation is as follows:

$$RSNS = \frac{SCD_{max}}{I_{SCD}} = \frac{200mV}{I_{SCD}}$$

The calculation is the following for OCD:

$$RSNS = \frac{OCD_{max}}{I_{OCD}} = \frac{100mV}{I_{OCD}}$$

The expected maximum OCD current is 150A, and the expected maximum SCD current is 300A. This results in the following voltage seen for both the OCD and SCD.

$$SCD(V) = RSNS * I_{SCD} = 0.13m\Omega * 300A = 39mV$$

$$OCD(V) = RSNS * I_{OCD} = 0.13m\Omega * 150A = 19.5mV$$

Which is within the voltage range of SCD_{max} and OCD_{max} of 200mV and 100mV, respectively. The lower range % reduced the accuracy and resolution of the system, however, is necessary due to cooling constraints of the selected current resistors with regards to power dissipation. Future designs can consider selecting more costly sense resistors with better performing power dissipation characteristics.

6.11 Thermistors

To measure the temperature of the battery pack, we are using two temperature thermistors. These thermistors greatly change resistance based on temperature. This resistance can be measured and converted into temperature by the BQ76930.

On page 23, the BQ76930 datasheet recommends using 10k NTC 103AT thermistors.

Figure 15: Lug style thermistors

The best mounting solution for thermistors is to use lug style thermistors that are screwed directly onto the battery. However, our batteries do not have lugs and are very inaccessible. Our best option is to tape thermistors onto the batteries.

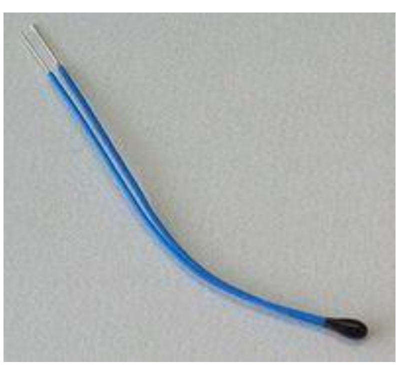

Figure 16: Traditional thermistor package

6.12 TVS diodes

Every exposed header on a PCB is susceptible to electrostatic discharge from people handling the board. Because of this, we need electrostatic protection on most exposed headers.

The I2C headers connecting to the LCD screen need TVS diodes.

The CAN headers do not need TVS diodes because the MAX3051 has robust ESD protection built into the chip.

6.13 State diagram

BATMAN is a battery and safety critical system. Create a state diagram that illustrates the conditions for when the MCU should go into sleep mode. And show what happens when an illegal state occurs. And show what happens when there is a failure to sleep.

Repeat for the CAN transiever sleep modes. And the buck converter sleep modes. And maybe the BQ chips sleep modes if needed.