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SOLAR POWERED BATTERY CHARGER FOR AN OFFSHORE HYDROPHONE

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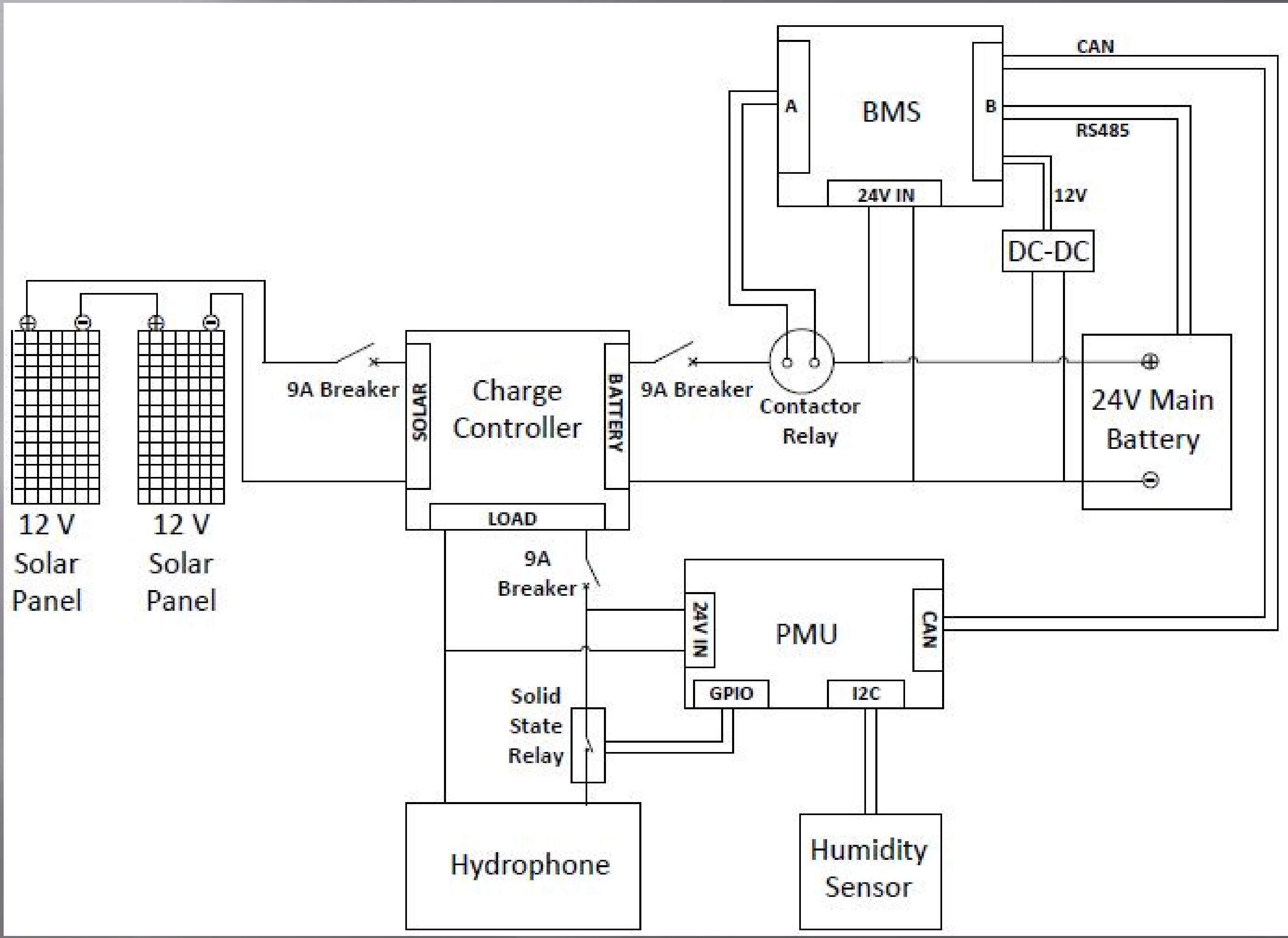
Project Motivation

- Southwestern BC's resident killer whales are endangered and disturbed by vessel traffic.
- Understanding migration patterns is therefore critical.
- DFO: expanding their network of hydrophones to include offshore units.
- Hydrophones: monitor migration patterns of resident killer whales.
- Offshore units: run autonomously on solar power.

High-Level System Overview



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Materials Used

Component	Materials
Lithium batteries	Lithium iron phosphate, plastic, aluminum
Monocrystaline solar panels	Aluminum, silicon, plastic
Charge controller	Plastic, copper, silicon, aluminum
DC circuit breakers, relays, wires	Plastic, copper, aluminum
DC-DC converter	Aluminum, silicon
Interfacing connectors	Plastic, copper, aluminum
Battery management system (BMS)	Plastic, copper, aluminum, silicon
SubConn underwater cable	Plastic, copper, aluminum
Acryllic board	Polyacrylonitrile
Humidity sensor	Aluminum, silicon, plastic
Microcontroller and development board	Plastic, copper, aluminum, silicon, gold
Electronic components	Aluminum, silicon, plastic
PCBs	Plastic, copper, aluminum, silicon
Solder	Tin, traces of other metals

*All materials used were RoHS compliant where applicable.

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Final Mockup Costs

Part	Covered By	Estimated Cost	Actual Cost
Solar Panels	DFO	~$400	~$400
Charge Controller	DFO	$499.99	$299.40
DC Circuit Breakers	DFO	$44.25	$26.55
Batteries, BMS, and Contactor	DFO	~$2500	~$2500
Solid State Relay	TBF	$59.38	$59.38
MCU and Dev Board	TBF	$185	$199
Backup Battery for MCU	TBF	$24.64	$24.64
Hardware Eval Boards	Linear Tech	$225	FREE
PCB manufacturing	TBF	$300	$463.00
PCB and Breadboard Components	ESSEF	$100	$739.85
Misc (RP Electronics, MRO, Sparkfun)	TBF	-	$193.67
Total		**~$4338**	**~$4905**

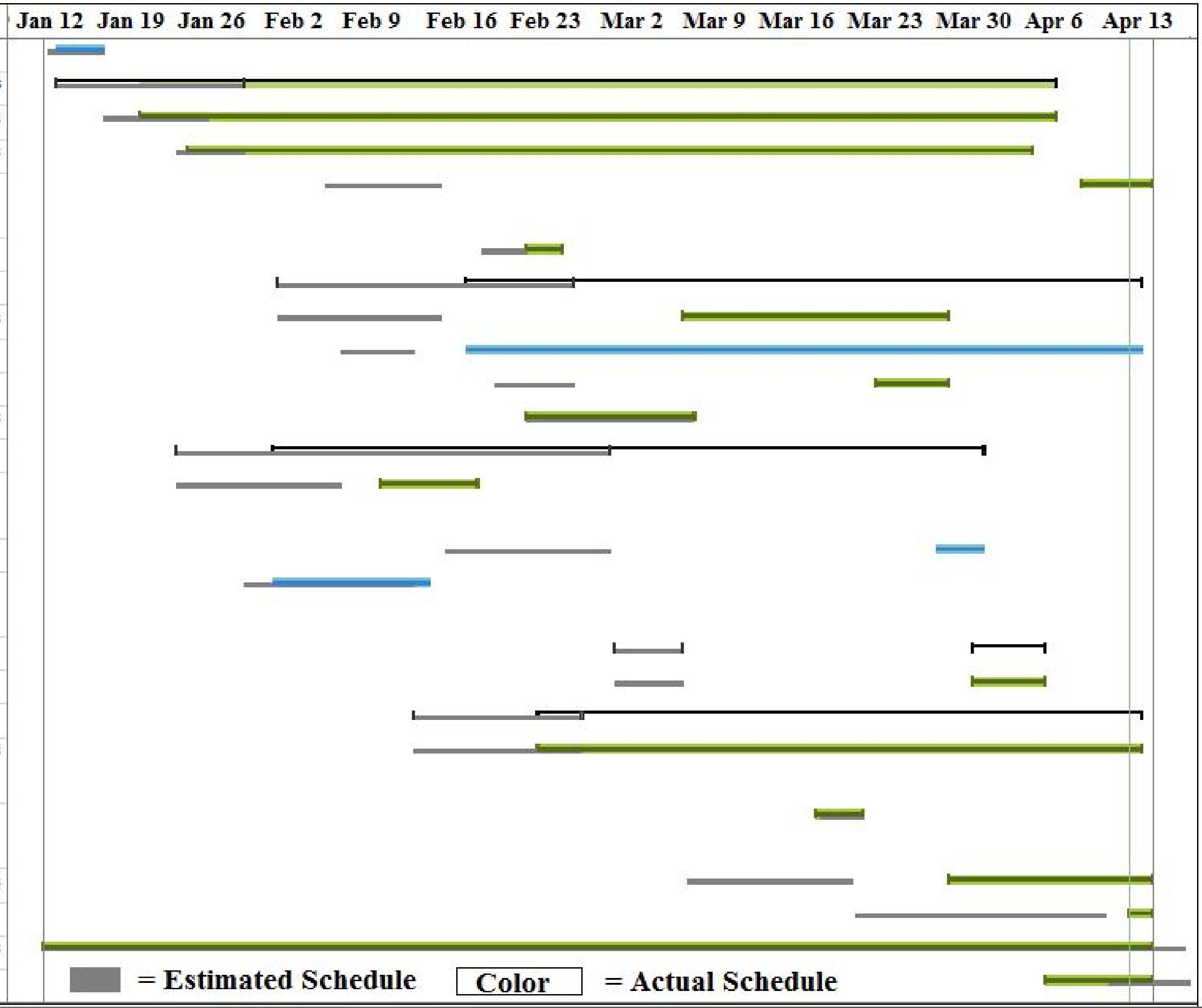
*TBF = To Be Funded.

Final Mockup Costs

- Vastly underestimated the cost of the PCB and breadboard components!
- Midnite Solar: educational discount on charge controller and DC circuit breakers.
- Linear Tech: provided free hardware eval boards for the team.
- In the end, the actual mockup costs worked out to about 114% of the estimated costs.

Project Timeline

ID	Task Name	Duration
1	Proposal	4 days
2	**Project Research**	**83.13 days**
3	Design Planning	76.13 days
4	Component Research	70.13 days
5	Functional Specification	6.13 days
6	Oral Progress Report	3.13 days
7	**Project Design**	**56 days**
8	PCB Design	22.13 days
9	Software Design	56 days
10	Testing Plan	6.13 days
11	Design Specification	14.13 days
12	Component Orders	59 days
13	Evaluation Board Order	8.13 days
14	PCB Order	4 days
15	Microcontroller & Component Order	13 days
16	**Hardware**	**6 days**
17	Hardware Assembly	6.13 days
18	**Software**	**50 days**
19	Microcontroller Programming	50.13 days
20	Written Progress Report #2	4.13 days
21	HW & SW Integration	17.13 days
22	Integrated Testing	2.13 days
23	Documentation	92.13 days
24	Post Mortem	9.13 days



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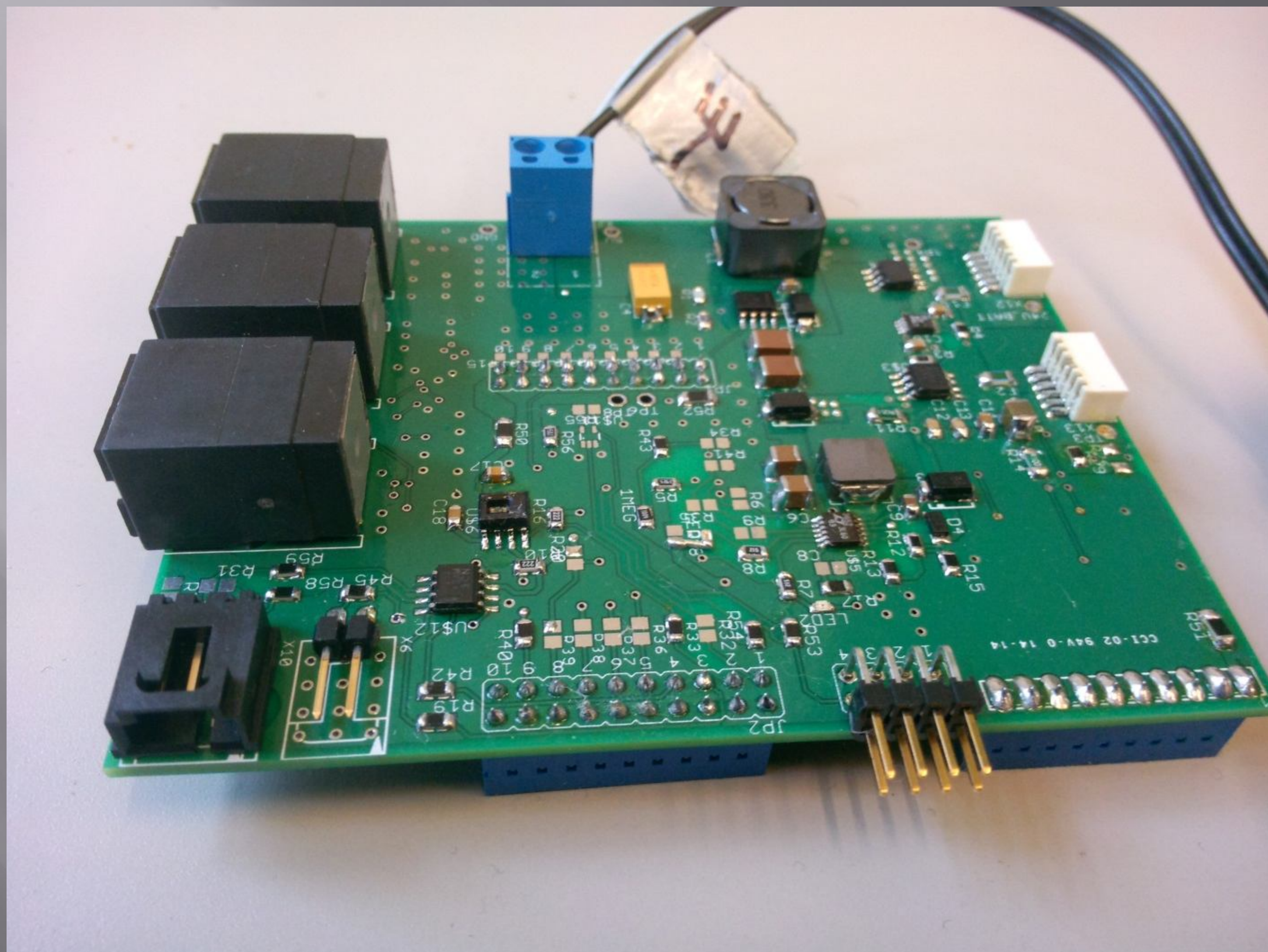
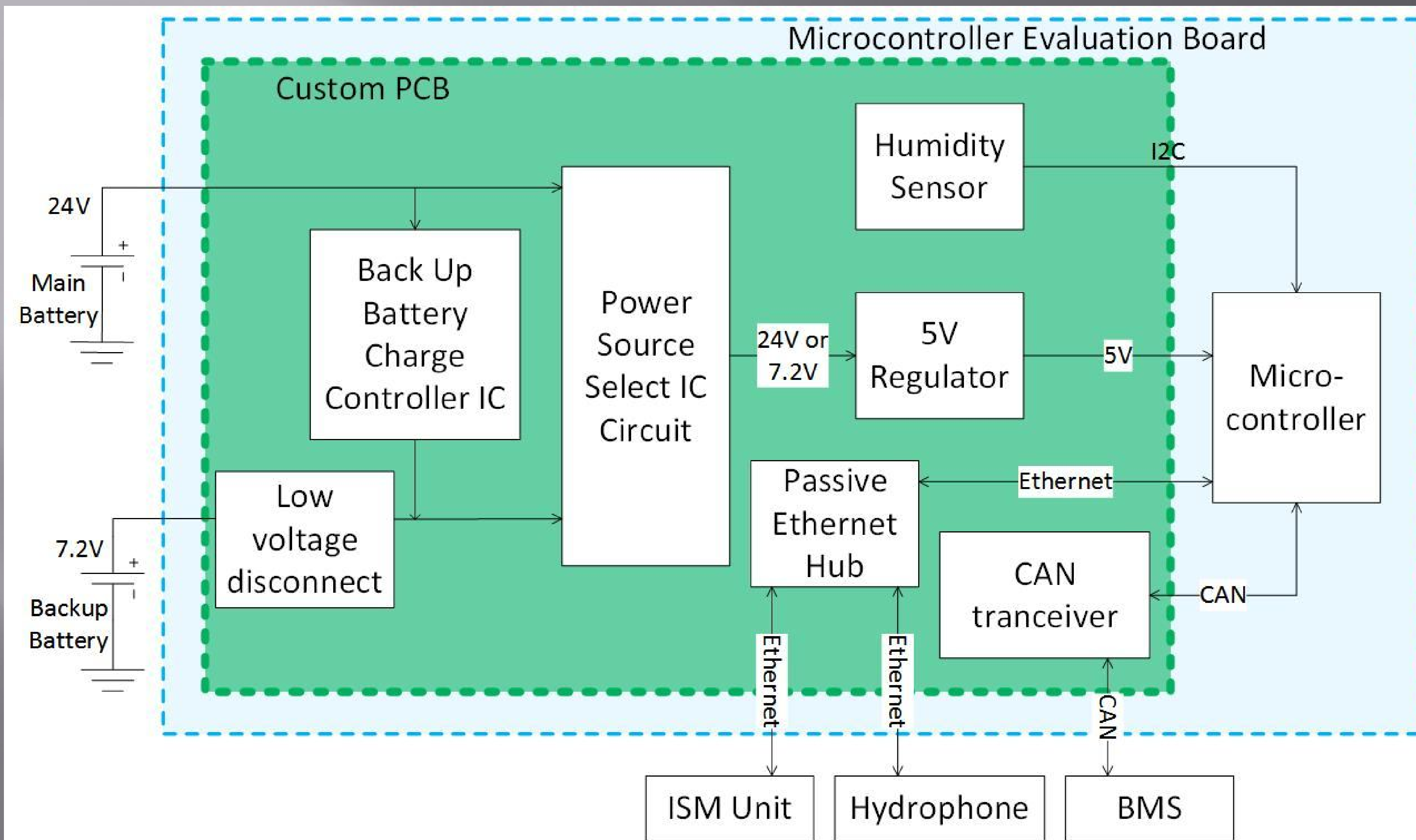
Hardware



Hardware


Microcontroller Evaluation Board
Custom PCB
Humidity Sensor
I2C
24V
Main Battery
Back Up Battery Charge Controller IC
Power Source Select IC Circuit
24V or 7.2V
5V Regulator
5V
Micro-controller
Passive Ethernet Hub
Ethernet
7.2V
Low voltage disconnect
Backup Battery
CAN tranceiver
CAN
Ethernet
Ethernet
CAN
ISM Unit
Hydrophone
BMS

Hardware - Revisions

- Revised PCB schematic and layout multiple times
- CAN transceiver
- Low voltage disconnect circuitry
- Hysteresis on low voltage disconnect

Interface Module

- Centralized module to allow all systems to be connected together
- Utilize DFO standardized marine subconn connectors for all outward facing connections
- Use standardized molex connectors for all internal connections – quick and easy connect / disconnect of systems

Remote Application

- Web server running PHP-based application
- Allow for easy deployment and provides access to data virtually anywhere
- Provides real time view of battery and site specific information – charge levels, temperature, humidity, warning conditions
- Able to update settings on remote device
- Remote device does all uploading and downloading of data from server

Software

- Texas Instruments Tiva M4C Processor
- 4 Main Parts
  - TCP / IP / Ethernet
  - Operating System
  - I^2C
  - CAN

Software – TCP/IP

- MCU acts as a web client
- Web server access via TCP / IP
- TCP / IP implementation in lwIP
- MCU gets dynamic IP via DHCP
  - defaults to static IP if DHCP fails
- TCP message sent every 5 s
  - Emergency signals may happen sooner

Software - Ethernet

- ISM transmitter interface
- MCU connected to PC or router
  - Direct connection (through Ethernet)
  - Indirect connection (through Ethernet, then transmitter)
- Ethernet task runs every 10 ms to maintain an active link between MCU and ISM unit

Software – Operating System

- Limited space – needed light-weight scheduler
- Scheduler
  - Initialize device peripherals
  - Manage tasks of varying frequency and priority
- FreeRTOS
  - Small, open-source real-time operating system
  - Ensures on-time execution of critical monitoring tasks

Software - I^2C Communication

- Humidity sensor interface
- Requests data from sensor every 500 ms
- Sets a warning flag when humidity > 80%
- Sends an interrupt when humidity > 98%, and MCU goes into low-power mode

Software – CAN Module

- CAN – Controller Area Network
- Robust communication protocol
- Allows microcontrollers to communicate directly with devices without a host computer
- BMS → PMU
  - Battery status monitoring
  - Queried every 500 ms
- Periodic CAN messages
  - Battery SOC
  - Voltage, current, temperature
  - Other diagnostics

Software – Challenges

- Changed MCU
  - First one purchased was not able to load programs without significant hardware modification
- Ethernet
  - Debugging TCP connection within multiple interrupts
  - Most modern servers incompatible with HTTP 1.0, had to switch to HTTP 1.1
- CAN connectivity
  - Determining whether problems reside in SW or HW
  - Conclusively proving communication issues

Lessons Learned

- Double check board to Gerber file fidelity.
- Importance of reading datasheets.
- Importance of close communication with software team.
- Enhanced knowledge of PCB design.
- How to debug asynchronous code.
- The challenges of software integration.
- Practical application of the different networking layers.

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Marketing

- There is interest from DFO for a solar powered battery system for their hydrophone systems
- Other possible applications include:
  - Military – offshore sonar systems
  - Offshore weather monitoring stations
- The cost of one whole system is ~$4200
- Considering a 3X markup, the cost of a production unit would be $12600.

Future Work

- Low voltage override on PCB
- Gerber mismatches
- Hub circuit on PCB
  - Using Ethernet controller IC
- Have all components on one PCB

Conclusion

- A pilot unit was developed for DFO.
- Facilitates monitoring of resident killer whale migration patterns.
- Solar panels & batteries: autonomous operation!
- Transmits data recorded by the hydrophone.
- Allows remote monitoring of the battery bank.
- If funding is available, DFO will deploy several of these units to expand their offshore hydrophone network.

Acknowledgements

- Mr. Paul Cottrell – our collaborator from DFO
- Mr. Lukas-Karim Merhi – initial advice on project scope
- Mr. Jamal Bahari– advice on our Design Specifications document

References

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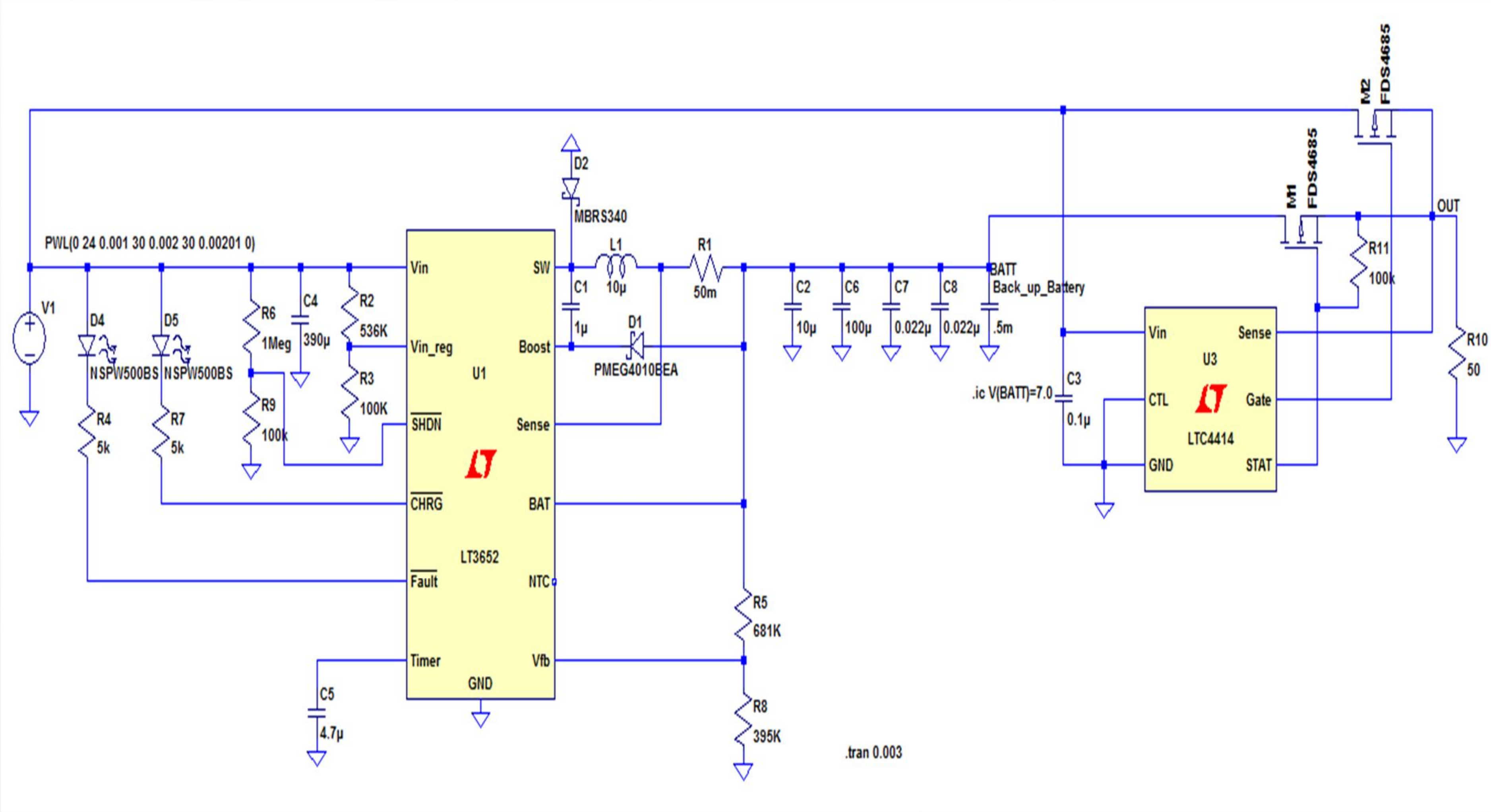
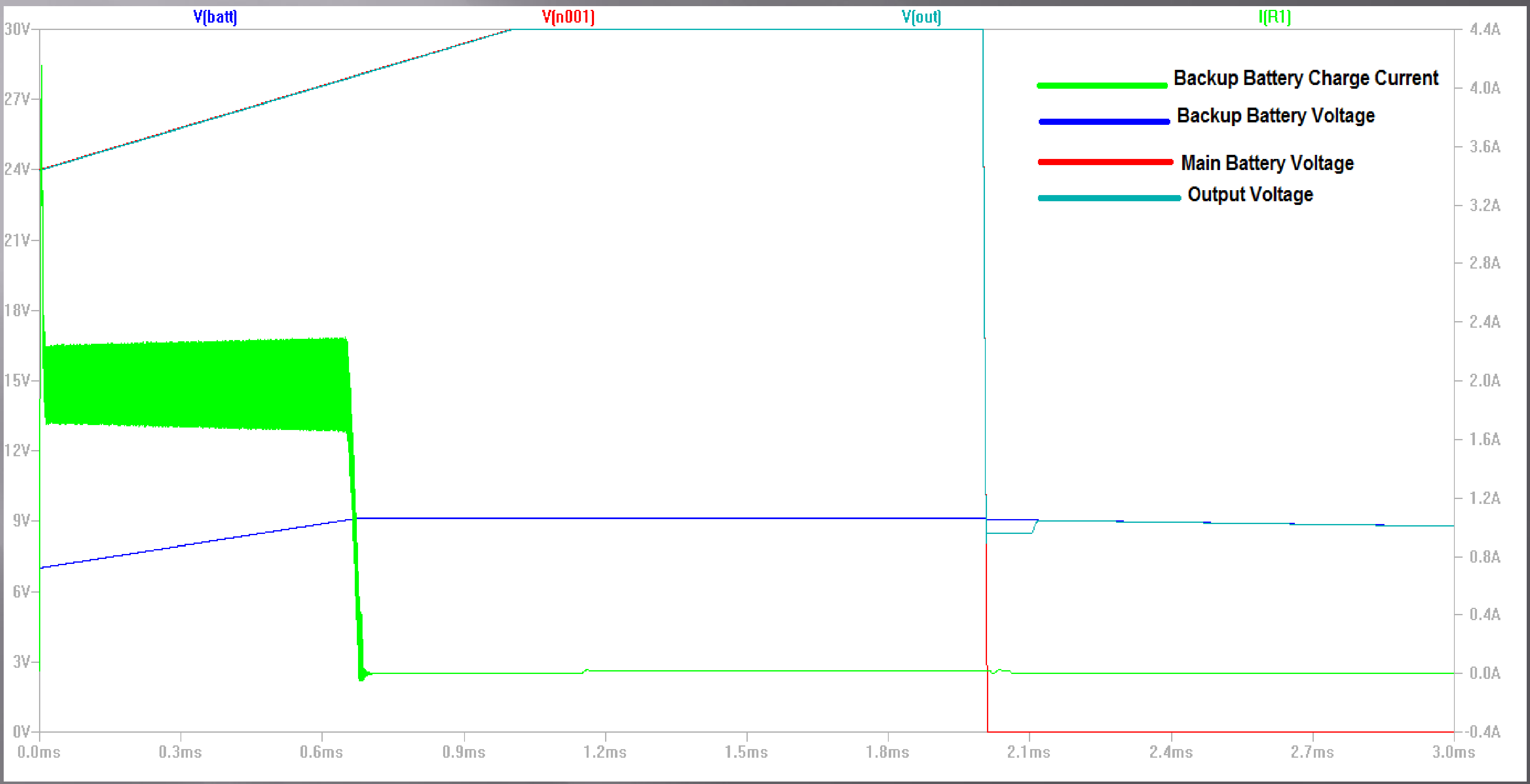
Questions?

Appendix

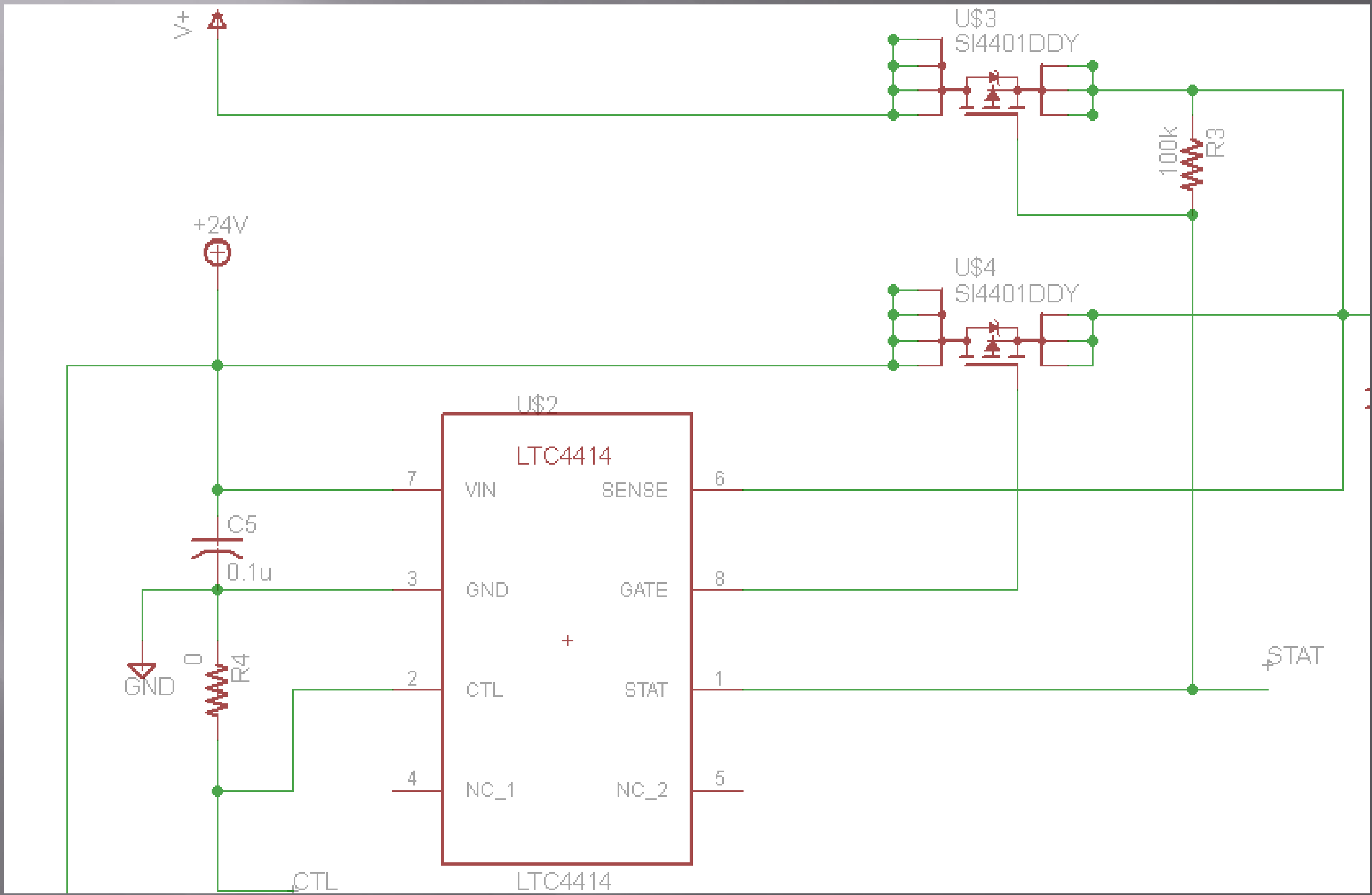
Hardware Simulation



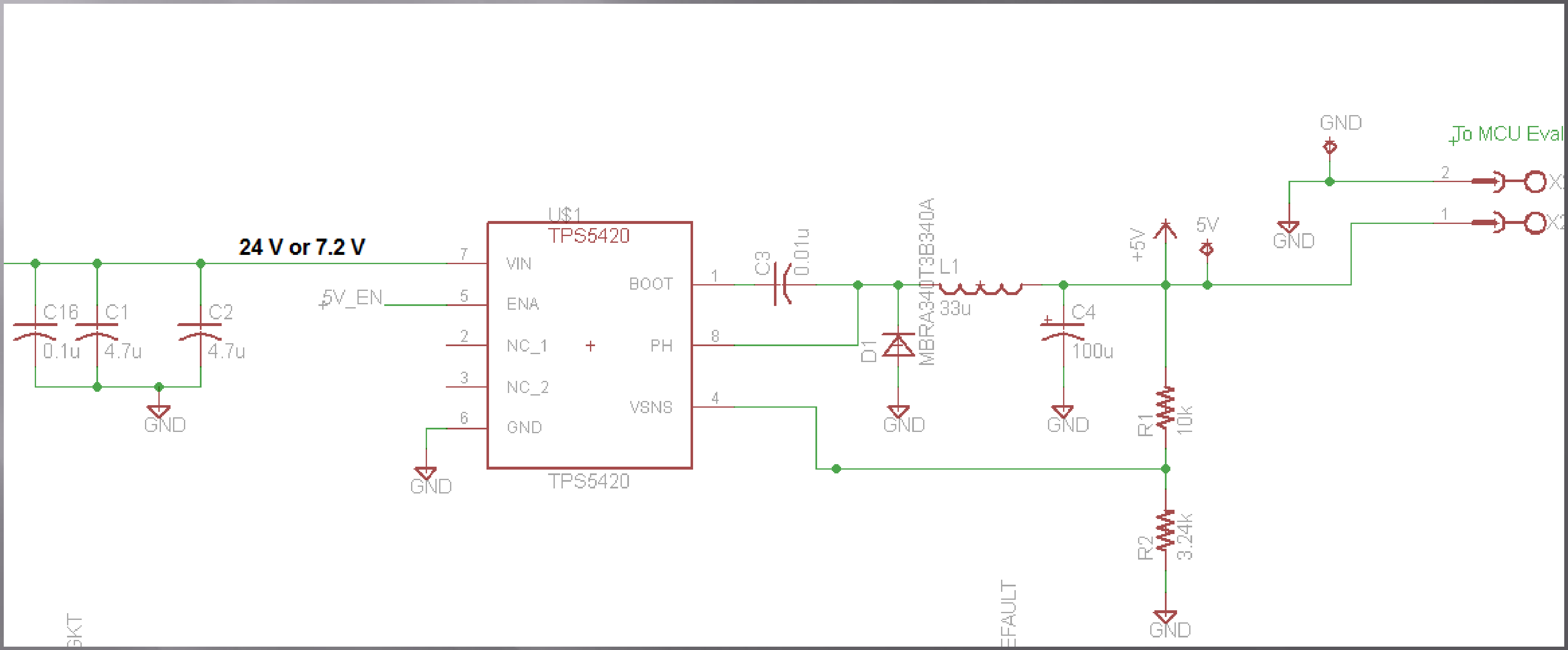
Hardware Simulation



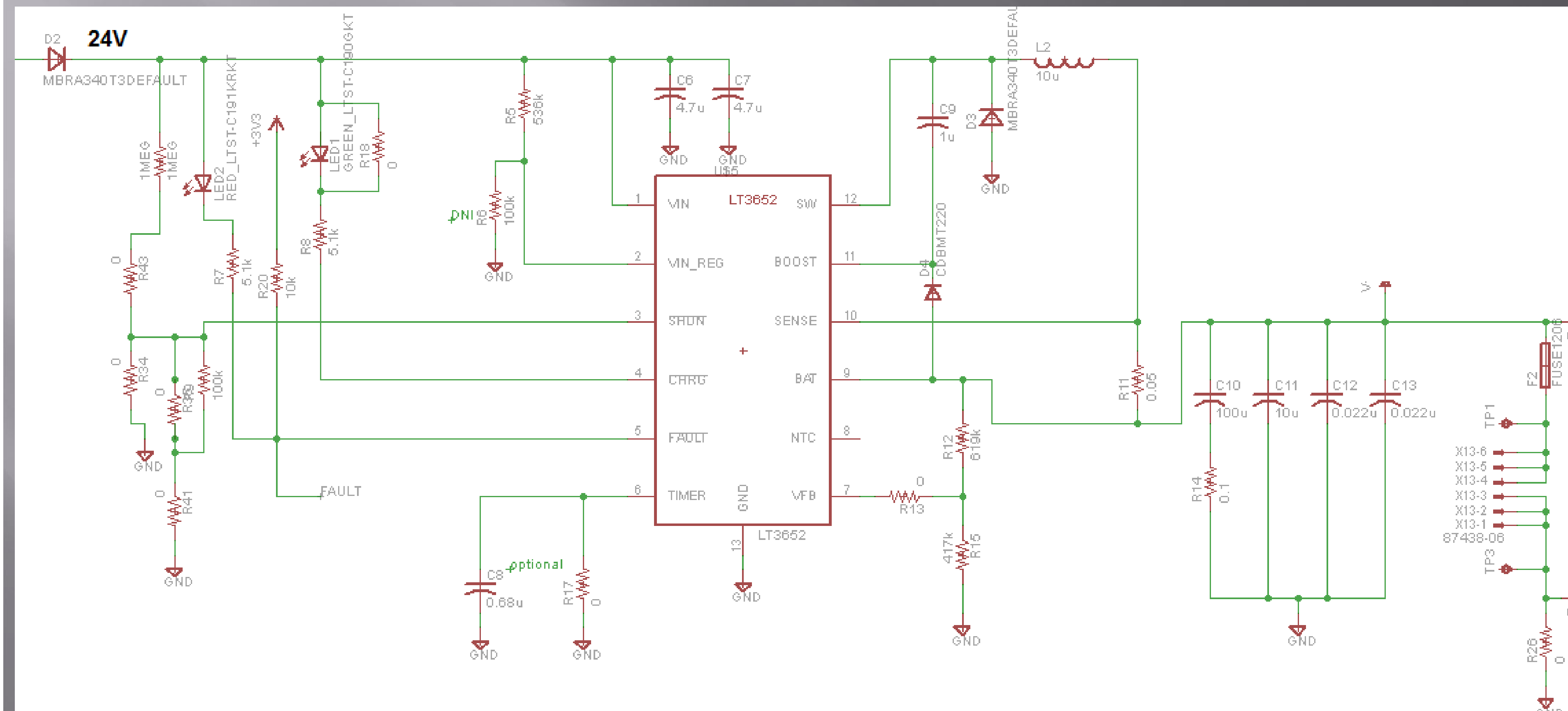
Hardware – Power Source Select



Hardware – 5 V Regulator



Hardware – Battery Charger



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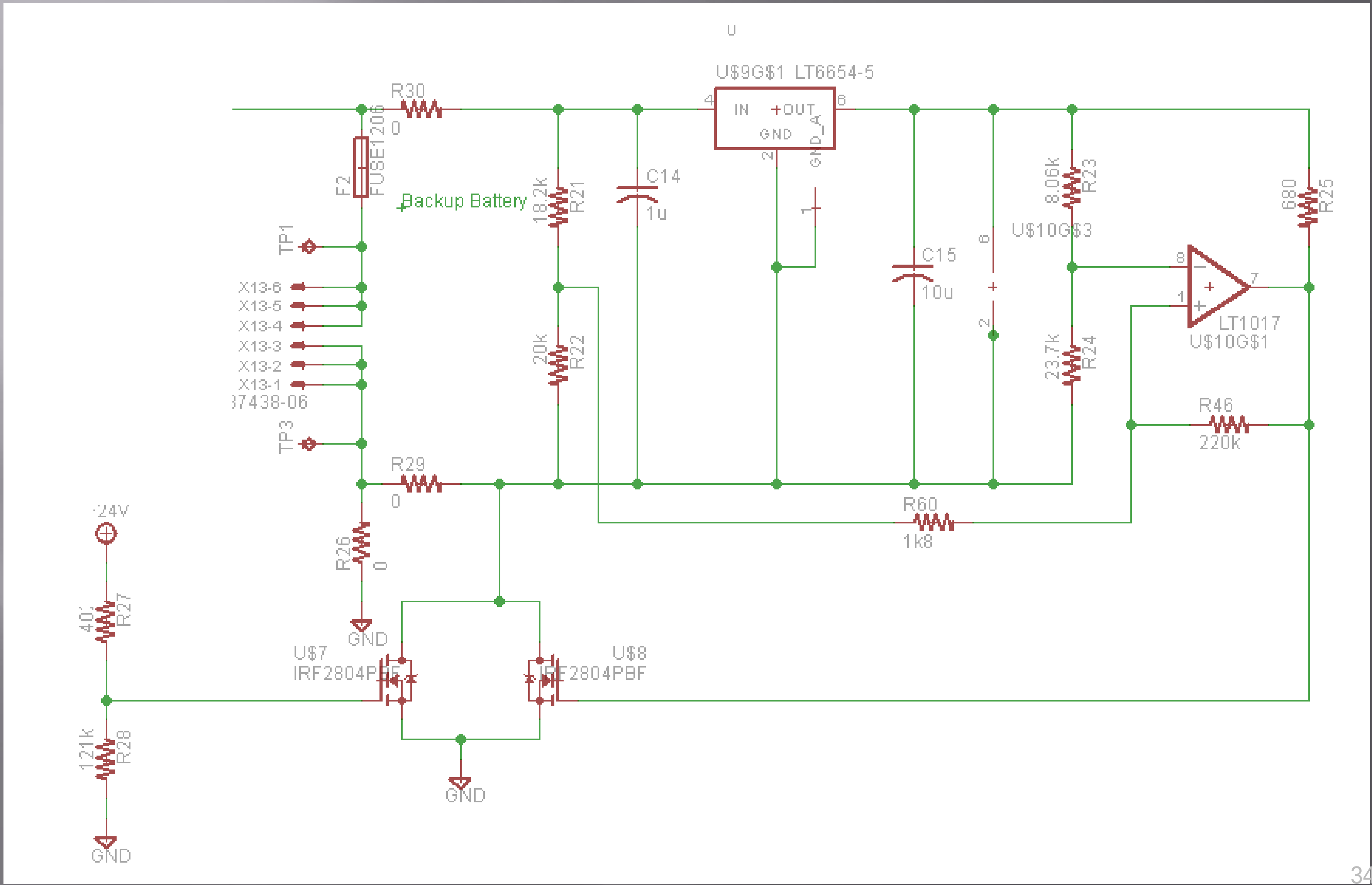
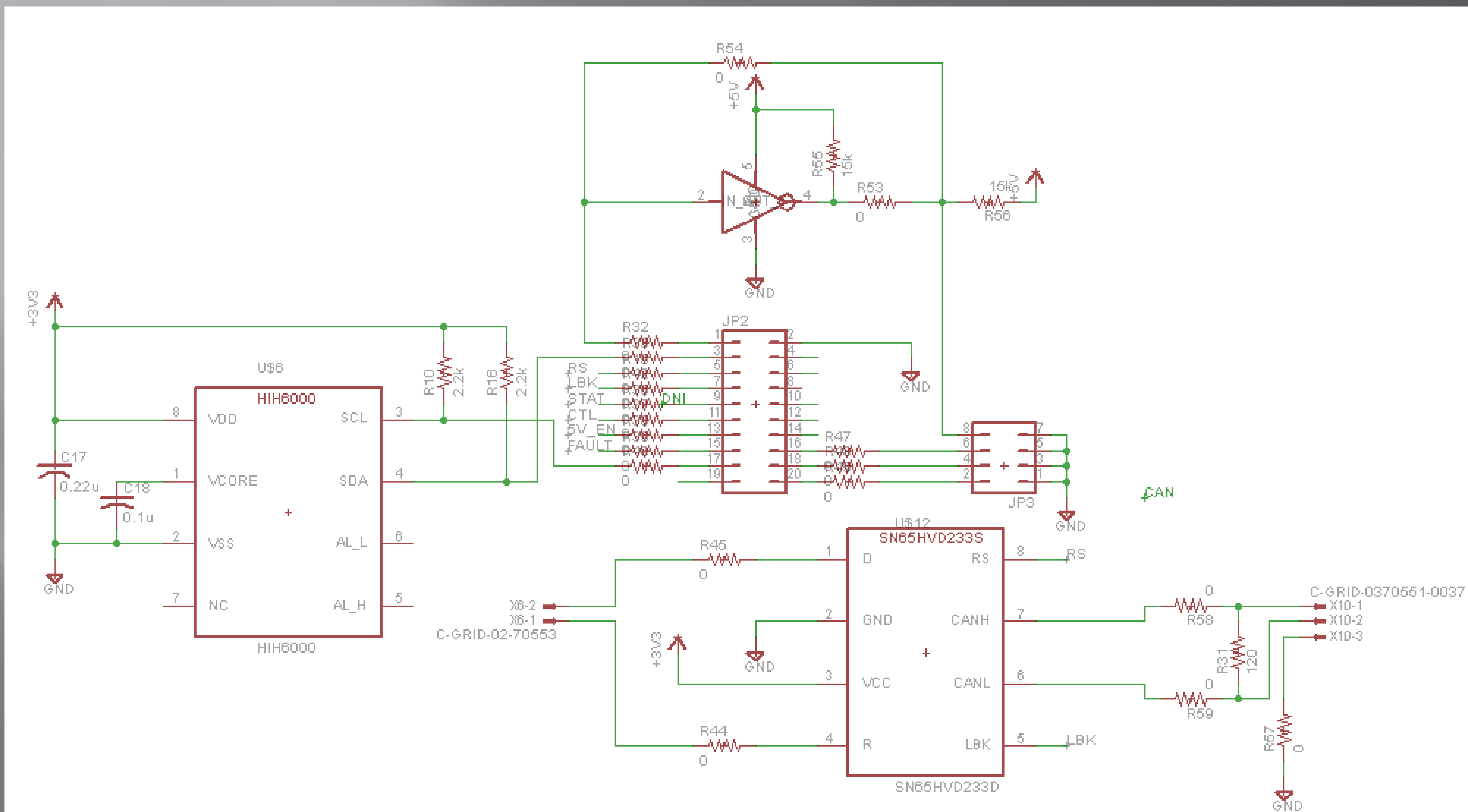
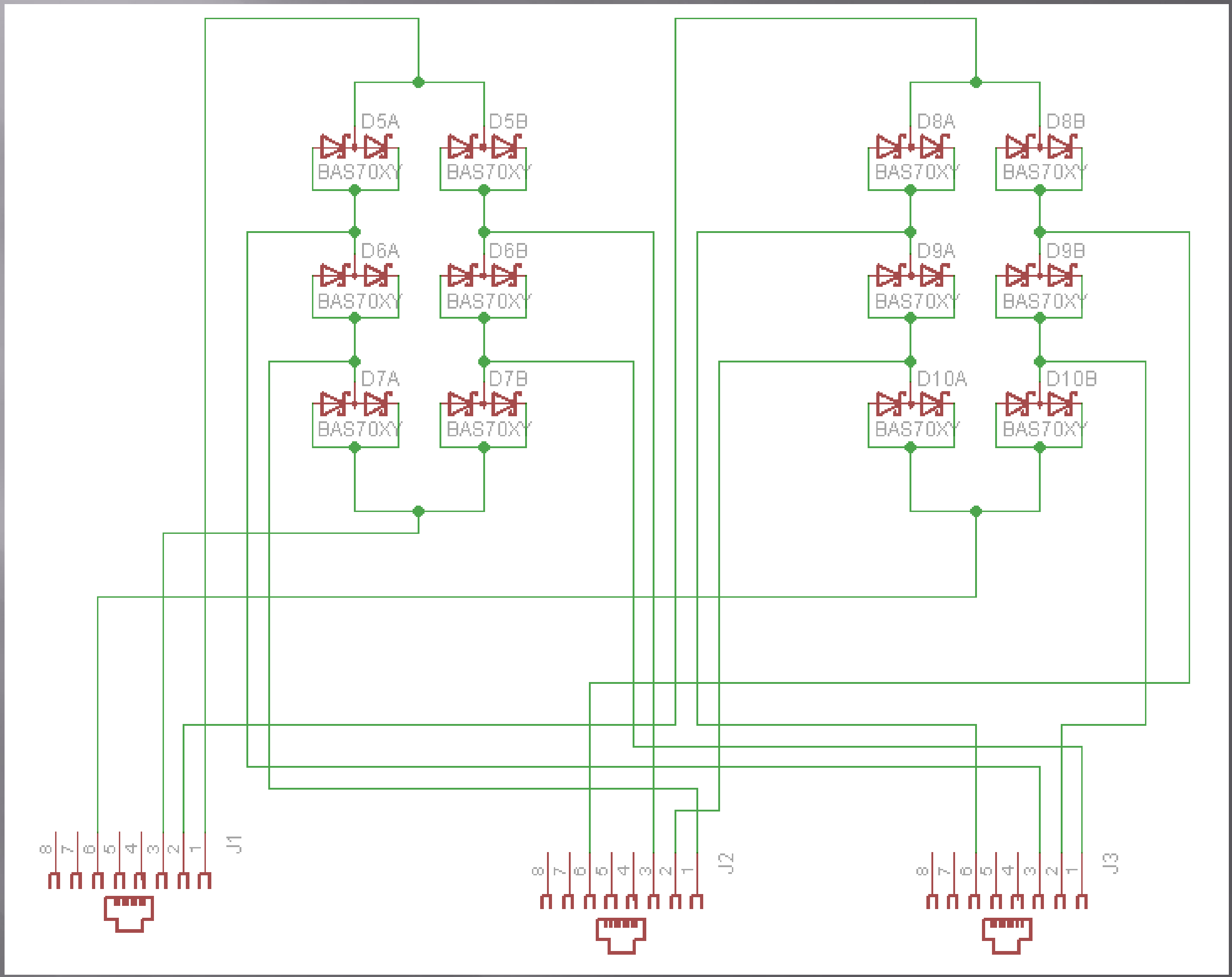
Hardware – Low Voltage Disconnect



Hardware – Humidity and CAN



Hardware – Passive Hub



Software – Monitoring