Make To Innovate

Project (FlyHy)

Iowa State University

Power Monitering System Rev 1

2/19/2023

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Revision History		
Rev #	**Description**	**Hardware Manager**
1	**Power Monitoring**	**Thomas Gaul**

Contents

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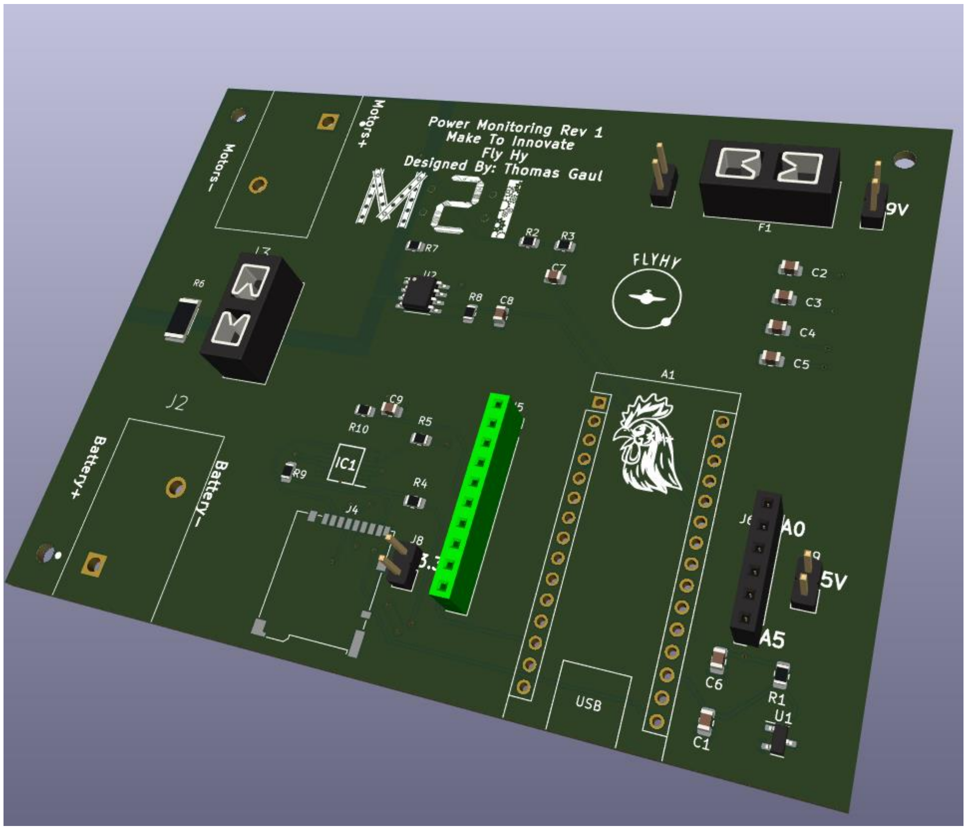

Theory of Operation

Description

The Power monitoring system's purpose is to watch the voltage and current produced by the hydrogen fuel cell and record the information for future use. As of right now the data can be stored on the micro-SD card that can be directly connected to the board. The board has an Arduino nano built in for monitoring and recording the data that the board reads.

Purpose

The hydrogen generator can output various voltages and current depending on a wide range of variables. As we are running flight tests and calculating future needs of the flight test to optimize flight times through hydrogen flow control as well as varying the storage capacity of the aircraft data as to the power consumption will be important and prove important in optimizing.

Application

System Level

Block Diagram

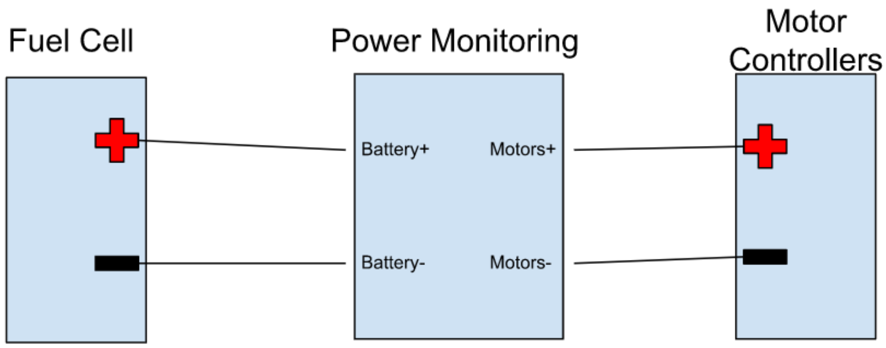

Figure 1 Block diagram

Pin Diagram

Connector	Connector Type	Pin Number	Connector Function
J1	2-Pin Header	1	Power supply 5-18 V
		2	Ground
J2	2-Pin Terminal Block	1	To Fuel Cell Positive
		2	Fuel Cell Ground
J3	2-Pin Terminal Block	1	Motors Positive
		2	Motors Ground
J5	10-Pin Header	1-10	Unused Digital Arduino Pins
J6	6-Pin Header	1-6	Unused Analog Arduino Pins
J7	2-Pin Header	1	Filtered Power Supply Out
		2	Ground
J8	2-Pin Header	1	3.3 Volts Out
		2	Ground
J9	2-Pin Header	1	5 Volts Out
		2	Ground

Fuel Cell Requirements

Fuel Cell Output	Voltage	Current
Upper	36V	8.3A

Lower	20V	0A

*Although intended use is with the fuel Cell it also should work with the test flights with a battery instead of the fuel cell running to it

Batter Output	**Voltage**	**Current**
Upper	22.2V	30+A?

Board Level

Power Supplies

Arduinos handle most of the power regulation heavy lifting for this board and can take a generously variable 5 to 18 Volts input. A half amp blade fuse is call for the input line (+9V) but any low current fuse would work fine. From there that power is filtered by the filtering caps at the bottom of the schematic. Perhaps overkill for this application we always use them on the solar car team and for 40 cents was worth keeping up with my habits. The filtering caps remove noise in input power to the Arduino.

Additionally, the battery/ fuel cell input is fused as well. It is marked down as a 50A fuse which would be the correct fit for when testing with a battery. When running with the fuel cell a 10 Amp fuse would match the max 8.3Amp output better.

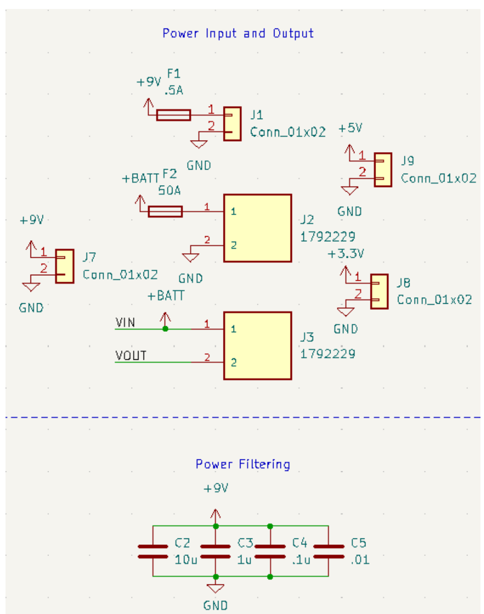

Figure 2 Input Output Circuitry

Reference Voltage

To help achieve maximum precision on the Arduino a reference voltage is being generated by a LM404 diode. To generate the precise voltage of 4.096 this circuit uses the Zener diodes reverse breakdown voltage. The diode will let any current pass through at 4.096 volts keeping the line stable at 4.096 V. This voltage works out nicely for Arduinos because they have a 10-bit ADC (Analog to Digital Converter) allowing for 2^10 = 1024 values taking 4.096/1024 gives us a precision of 0.004 Volts. AN

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IMPORTANT NOTE FOR CODING: we need the command “analogReference(EXTERNAL);” in the code to specify we are using the external reference voltage. This will prevent you from shortening the active internal reference voltage and the AREF pin, which can damage the microcontroller on the board. The 1.8k resistor is the current limit of the diode so it does not burn up and it allows the entire 5V line to be pulled down to 4.096V.

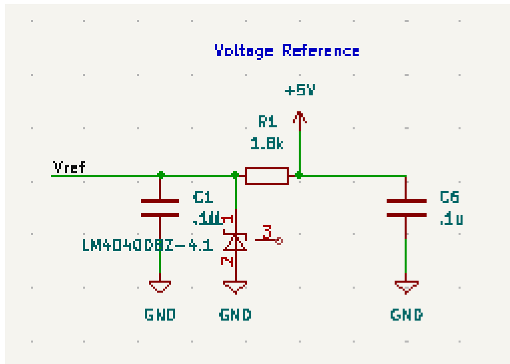

Figure 3 Reference Voltage

Voltage Monitor

Achieving voltage monitoring is simple given we have the ADC (analog to digital converter) in the Arduino. To properly monitor the voltage of the battery/fuel cell we need to get it to a low enough voltage to be read by the Arduino specifically the maximum voltage needs to line up to line up with at most the 4.096 reference voltage. To accomplish this can just use the voltage divider equation derived from Ohms law. $V_{out} = V_{in}\left(\frac{R_3}{(R_2+R_3)}\right)$. Where we want Vout to be less than or equal to 4.096 and Vin can be up to 36 Volts by plugging in R2(43k) and R3(5.1k) we find Vout as 3.8V which is not up to 4.096 but works out nicely with resistor values.

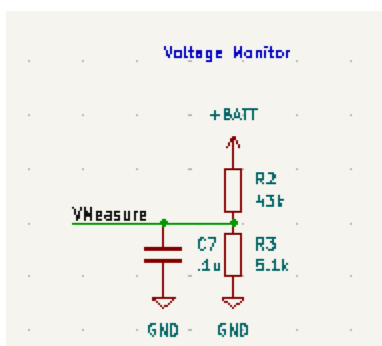

Figure 4 Voltage Monitor

Current Monitor

To monitor the current coming from fuel cell this design uses a shunt resistor in between the negative side of the motor controllers and ground. This design uses this instead of a Hall Effect sensor because it should be more precise, and it was cheaper and easier to spec out the part. The theory behind operation is simple it measures the voltage drop across the resistor which has a known resistance value. With the ohms law equation rearranged I=V/R we can easily calculate the current from a voltage. With a max current of 8.3 Amps, we will see a voltage drop across the resistor of 0.0332 Volts which is not very much to read from, so we put it through the non-inverting op amp to get its range of values to correspond with that of the voltage reference. In the non-inverting configuration, the equation to get the gain is 1+ R8/R7 so in this case 1+620k/5.1k= 122.5V/V which when multiplied by the max input of 0.0332 we get an output to the Arduino max of 4.07 V which is in the reference voltage limit.

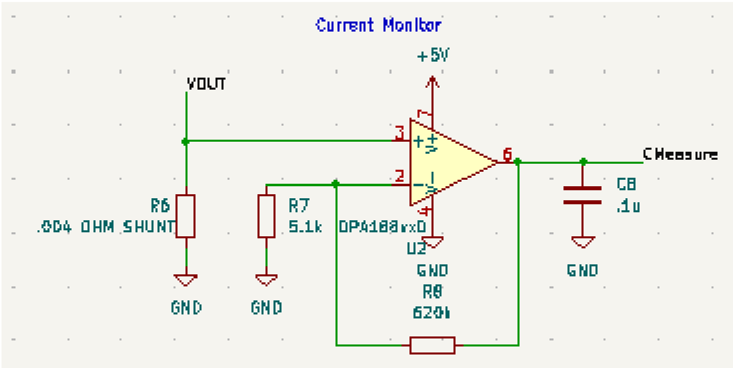

Figure 5 Current Monitor

Data Storage

Data storage is done just by following the schematic on this page (https://circuitdigest.com/microcontroller-projects/interfacing-micro-sd-card-module-with-arduino) this gave me all the parts and schematic and will have all the coding information for the future.

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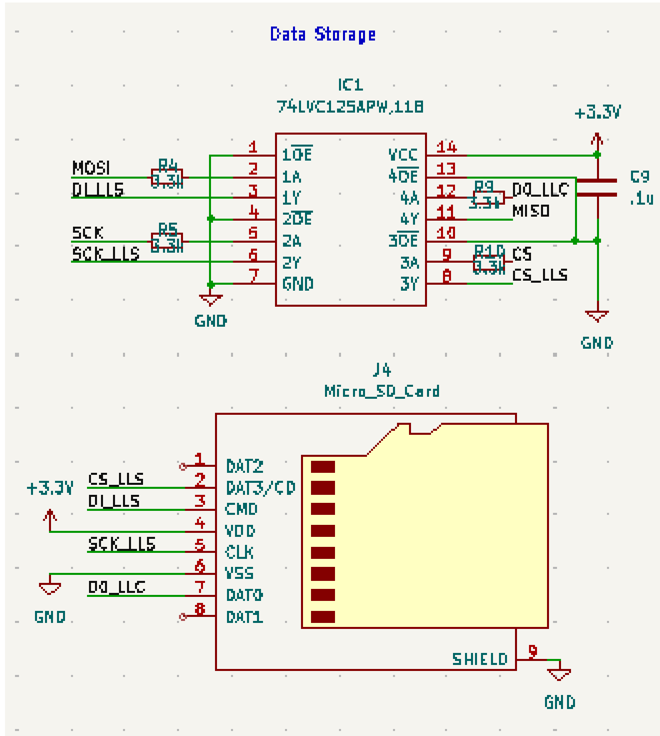

Figure 6 Data Storage

Arduino Nano

The Arduino nano handles the processing for this board. All the unused pins are connected to pin headers so if we have another need for them, they are easy to access. Also, the power outputs 5V and 3.3V are used for the voltage reference and micro-SD card.

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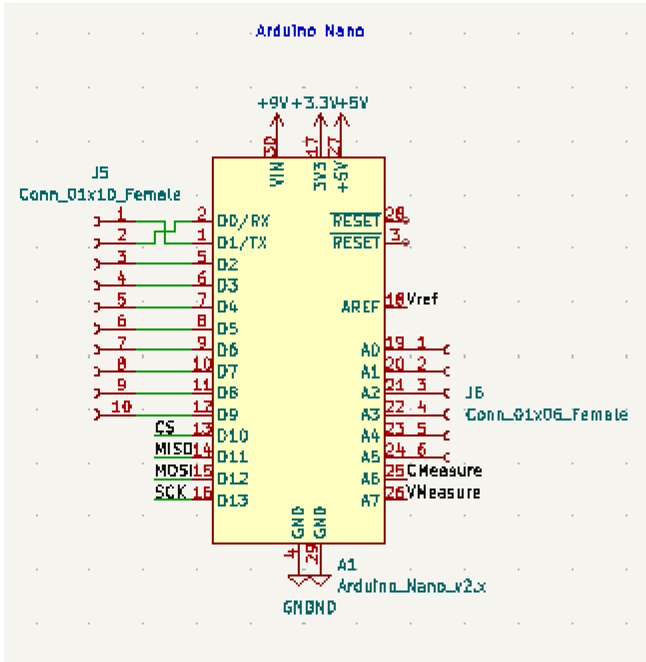

Figure 7 Arduino Nano

PCB Picture

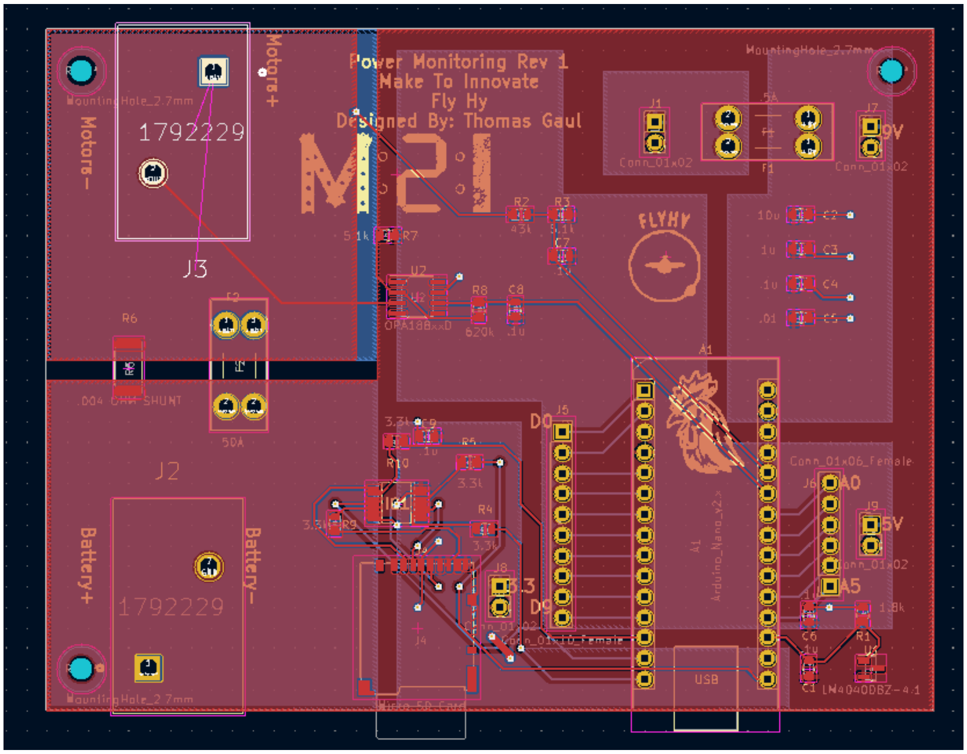

Figure 8 PCB layout of Power Monitoring

Power monitoring PCB is divided into two sections, with the left being electricity transfer from the battery to the motor controllers and the right having the Arduino and all circuitry to support it and its measurements of the power line.

The right side is organized by function. The top right handles the power supply for the Arduino's reference voltage to increase the ADC measurements' precision, Arduino fusing, and filtering the power input for the Arduino. The bottom right creates the reference voltage for the Arduino to increase the precision of the ADC measurements. Bottom middle connects and micro-SD and necessary associated components to the Arduino. Directly above it in the middle of the board handles the current measurement with the shunt resistor on the middle left. Finally, voltage monitoring is handled by the components in the middle of the M2I logo and FlyHy logo. Arduino's reference voltage to increase the ADC measurements' precision Arduino's reference voltage to increase the ADC measurements' precision.

Proof of Operation

Test Procedure

1. Test Voltage divider

   a. Connect Battery+ and Ground to a voltage suppley and give voltages between 20 and 36 volts
   b. Make sure correct corresponding voltages are on the voltage monitoring line with multimeter
2. Test Current Monitor
   a. Provide voltage to the input of the op-amp and ensure its gain is behaving as expected
   b. Use a power resistor as a load give the shunt resistor current and measure the voltage at the resistor and the output of the op-amp to make sure it lines up with the expected value.
3. Test Arduino
   a. Plug in the Arduino and the 9 V power supply
   b. Ensure the Arduino is power by checking the LED
   c. Measure the 5V line and the 3.3V line to ensure that are output close to expected value
   d. Measure the reference line to ensure it is outputting 4.096 V
4. Write code to test and calibrate full system and monitoring and SD card

Test Results

Test results showed that both current measurements as well as voltage measured properly. Once data averaging was added to the test code it preformed quite nicely and functioned within half a volt of precision for low voltage reading and was with int .1 for voltages in the lower 20's which is the desired functioning voltage level with the fuel cell. To test the current measurements, I used a power resistor connected to a power supply that could do up to 5 amps. Unfortunately with the power resistor I could only test it at low voltage but the current was correct .06 amps at all currents 0 to 5.

Testing the SD Card revelled a bug in the SD card read-writing circuit. The document I read online was incorrect with the pinout going to the Arduino, so the onboard SD card read-writer did not work properly. MISO and MOSO had pins mixed up so to get it to work I bought an external sd card reader and connected it with pin headers it worked properly after cutting the traces, so in a future revision a simple fix of changing pinout would allow it to work.

Troubleshooting

Initially when trying to get the Arduino to download initally I found that it has the old bootloader on it still so I had to change that in the Arduino IDE. If having issues programming it try to change that to old bootloader.

Additionally when trying to read the values of the resistors after the fact to refine the values for math in the code I found that once mounted to the board the measured values of the resistors are no longer true due to some being in parallel.

Future Considerations

1. This board could be extended to add power regulation to step the power of the hydrogen fuel cell down to the power required of the motor controllers. Additionally, features could be added to

monitor and control hydrogen pressure or monitor and control power from the batteries vs the fuel cell. To do this hand off it must be made sure that the batteries do not start getting charged from the fuel cell causing unmonitored charging that could damage the batteries.

2. Alternatively charging could be added as a potential freature with the potental challenge of Battery Protection required with the associated charging. Additionally, some form of MPPT (Maximum Power Point Tracker) wouldbe beneficial to get the most power out of this. I have not taken enough electrical engineering classes to tackle this challenge, but future members might.
3. Another beneficial addition would be to add wireless/radio telemetry allowing the team to monitor flight data from the ground while the flight was actively occurring. Other sensors could be added to broaden the variety of data recorded such as GPS or a hydrogen sensor to detect leaks.

Required Changes

1. As mentioned previously a required change for the board would be to change the pinout to the on board SD card read writer
2. Another change is to change the foot print of the precision op amp to make sure it fits properly because right now it is significantly larger than the part.
3. Finally, a change is for the IC for the d card read writer. Something is wrong with the footprint or something causing the silk screen to cover the pads so make sure that gets fixed.

Additional Resources

FlyHy Contacts

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Appendix

Bill Of Materials List

Designator	Package	Quantity	Designater	Digikey part Number	Manufacturing Part Number	Cost	Total
J9,J8,J7,J1	PinHeader_1x02_P2.54mm_Vertical	5	Conn_01x02	2553-2042-1X15G00SA-ND	2042-1X15G00SA	0.74	3.7
R9,R4,R10,R5	R_0805_2012Metric	8	3.3k	RMCF0805FG3K30CT-ND	RMCF0805FG3K30	0.1	0.8
C9,C1,C4,C8,C7,C6	C_0805_2012Metric	10	.1u	399-C0805C104K3RAC7800CT-ND	C0805C104K3RAC7800	0.12	1.2

F2	Fuseholder_Blade_Mini_Keystone_3568	2	50A	36-3568-ND	OPA188AIDGKT	1.33	2.66
R2	R_0805_2012Metric	3	43k	118-CR0805-FX-4302ELFCT-ND	CR0805-FX-4302ELF	0.1	0.3
R8	R_0805_2012Metric	3	620k	118-CR0805-FX-6203ELFCT-ND	CR0805-FX-6203ELF	0.1	0.3
J3,J2	PHOENIX_1792229	2	1792229	277-9886-ND	1792229	5.77	11.54
A1	Arduino_Nano	1	Arduino_Nano_v2.x	1738-1026-ND	DFR0010	9.9	9.9
C3	C_0805_2012Metric	3	1u	1276-2926-1-ND	CL21B105KAFNFNE	0.1	0.3
R7,R3	R_0805_2012Metric	4	5.1k	RMCF0805JT5K10CT-ND	RMCF0805JT5K10	0.1	0.4
U1	SOT-23	1	LM4040DBZ-4.1	LM4040CIM3-4.1NS/NOPBCT-ND	LM4040CIM3-4.1/NOPB	0.96	0.96
C5	C_0805_2012Metric	3	0.01u	478-11898-1-ND	08055C101KAT2A	0.1	0.3
J4	microSD_HC_Hirose_DM3BT-DSF-PEJS	1	Micro_SD_Card	HR1942CT-ND	DM3BT-DSF-PEJS	2.56	2.56
R6	R_2512_6332Metric	2	.004 OHM SHUNT	YAG6123CT-ND	PU2512FKM130R004L	1.3	2.6
U2	SOIC-8_3.9x4.9mm_P1.27mm	1	OPA188xxD	296-35734-1-ND	OPA188AIDGKT	3	3
C2	C_0805_2012Metric	3	10u	1276-6455-1-ND	CL21A106KOQNNNG	0.1	0.3
IC1	SOP65P640X110-14N	1	74LVC125APW,118	1727-3092-1-ND	74LVC125APW,118	0.48	0.48
R1	R_0805_2012Metric	3	1.8k	118-CR0805-FX-1801ELFCT-ND	CR0805-FX-1801ELF	0.1	0.3