Developer Guide iOS Power Supply

- **System Overview**

  The iOS Power Supply is a functional bench power supply designed for electrical engineering students. We require smooth power output with minimal output ripple to power and test our creations. The design must be compact, robust and accept US standard plugs for 120 V mains and our USB devices. Since we are so connected to our smart phones, this power supply will feature Bluetooth connectivity through an iOS application for convenient control of both outputs. As an added feature we have included a touch screen that can also control both channels and two dedicated USB charge ports.

- **Electrical Specifications**

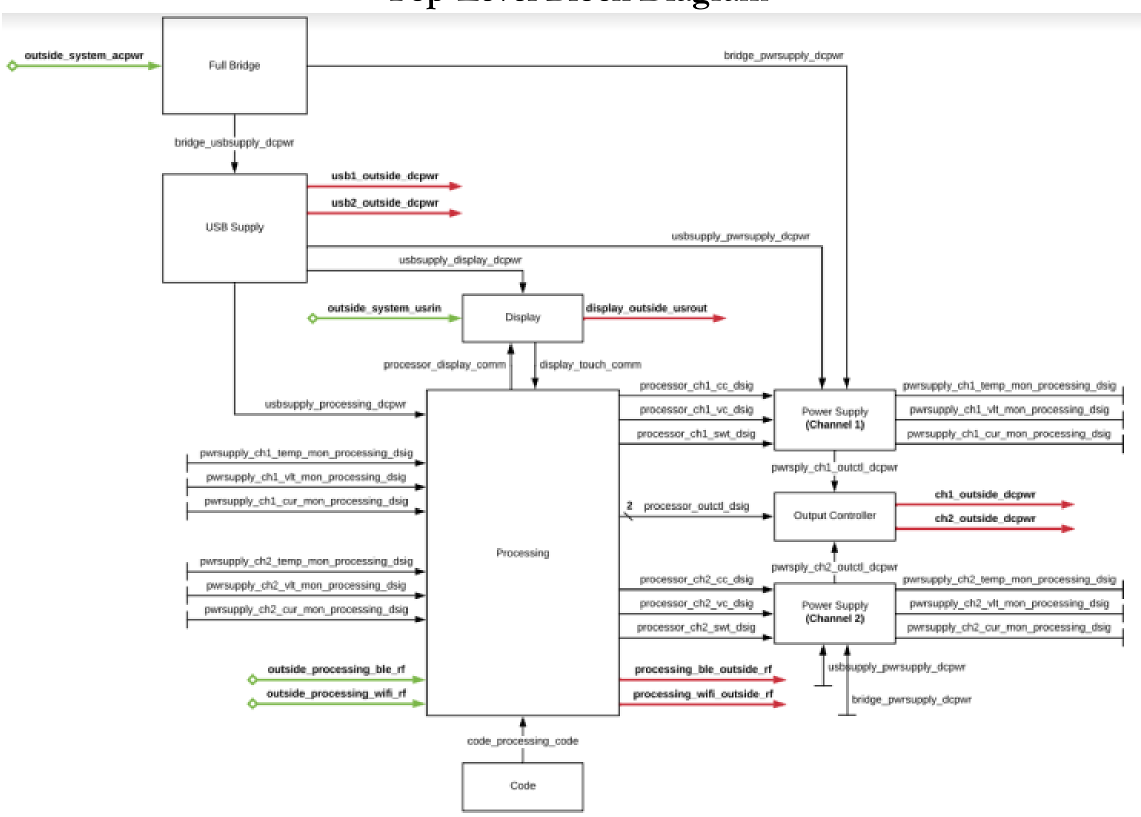
  Two electrically isolated outputs with 0 to 24V @ 3A output. 120V input with 2A overcurrent protection. The main outputs have resolution of 10mV voltage increments and 50mA current increments. Two 5V USB dedicated charge port controllers that can supply up to 2100mA to high power external devices.

- **User Guide**

  The system does not require any setup by the user other than the installation of the iOS application onto their device. The main outputs can be driven by the onboard touchscreen or through the application by incrementing or decrementing the desired voltage or current parameters with buttons. The actual output is visible from the application viewing window and the touchscreen.

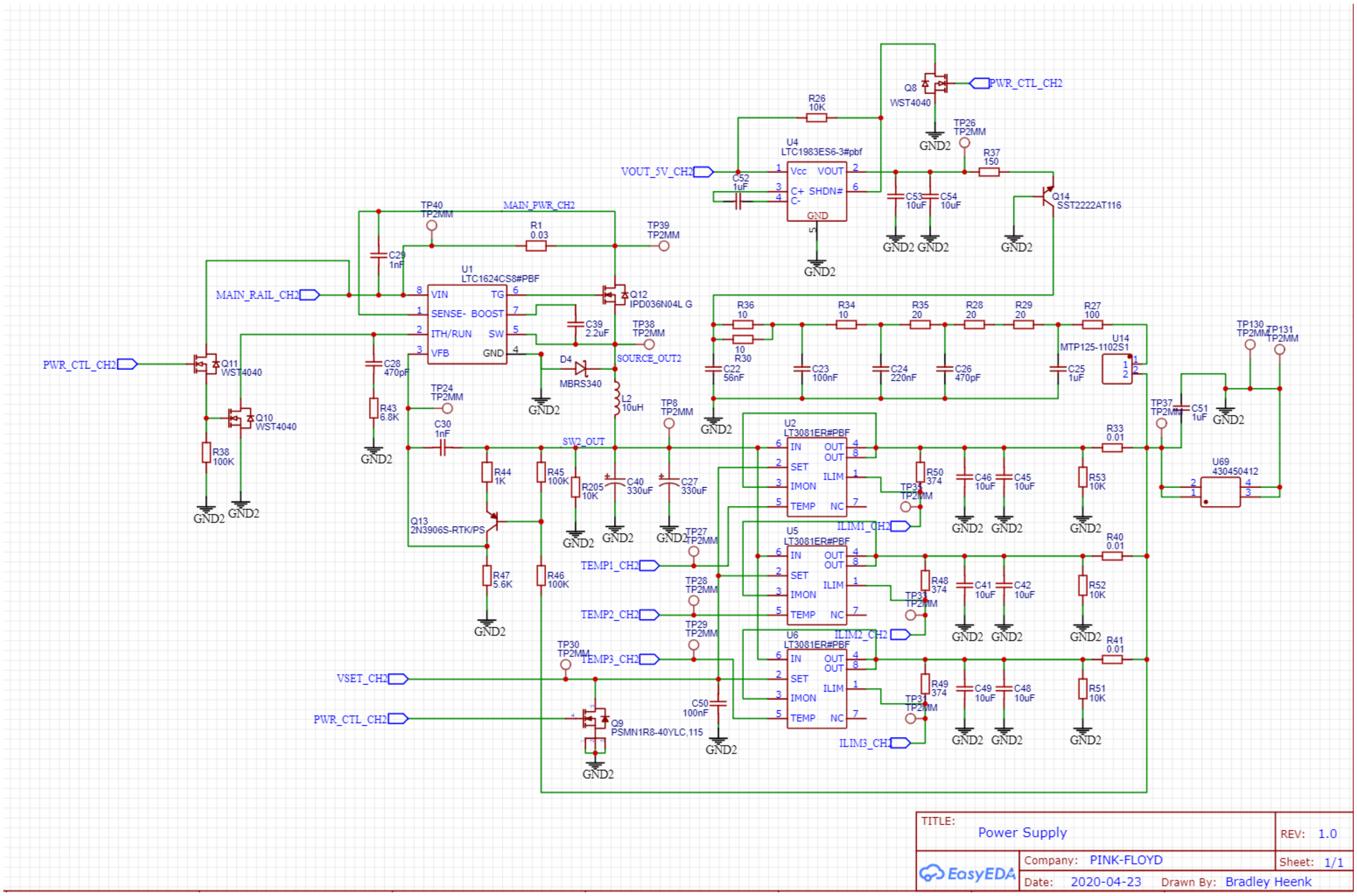
- Design Artifact Figures

Top-Level Block Diagram



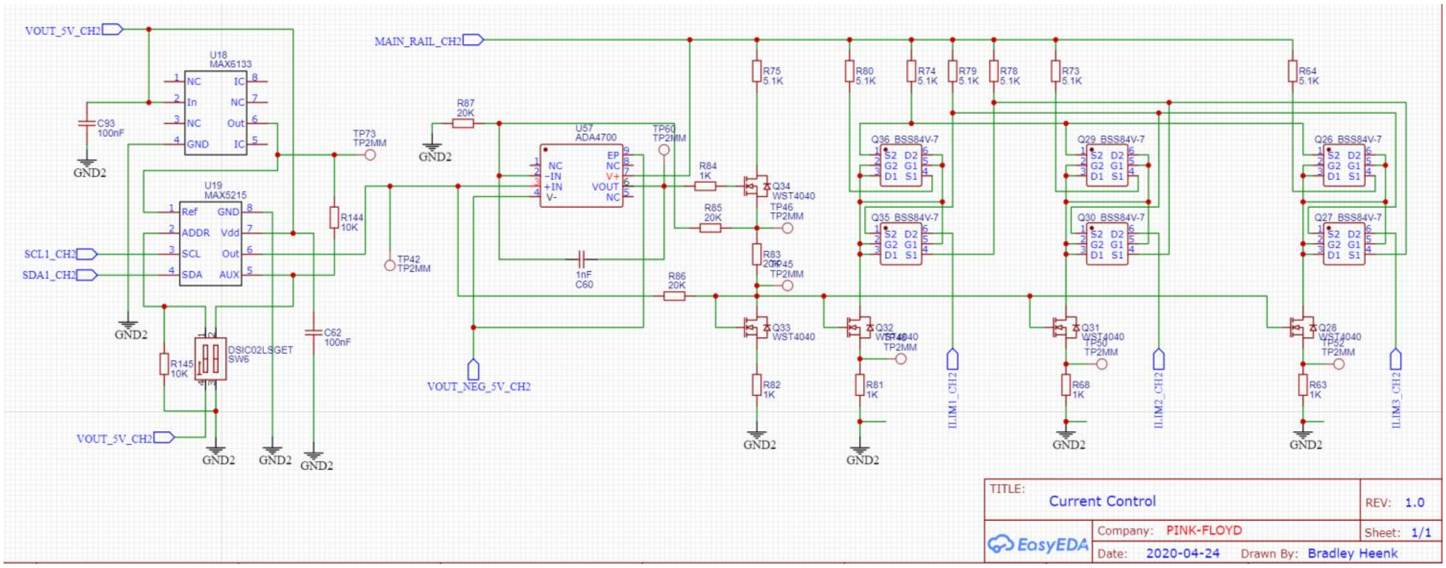
The top-level block diagram shows a general overview of how the smaller blocks are interconnected to form the main power, USB power, and control paths. Internal signals are thin black lines, outputs from the system are in red, and the input signals from the outside are colored in green. The main power path begins at the full bridge block, which supplies 32VDC to the USB and POWER Supply blocks. The USB Supply block is also in control of the 5V to the Processing microcontroller, 5V and -5V rail needed to control the additional control circuitry that drive the Power Supply block. The signal, code_processing_code, is a pseudo signal that commands the pi and its functionality.

Power Supply Schematic



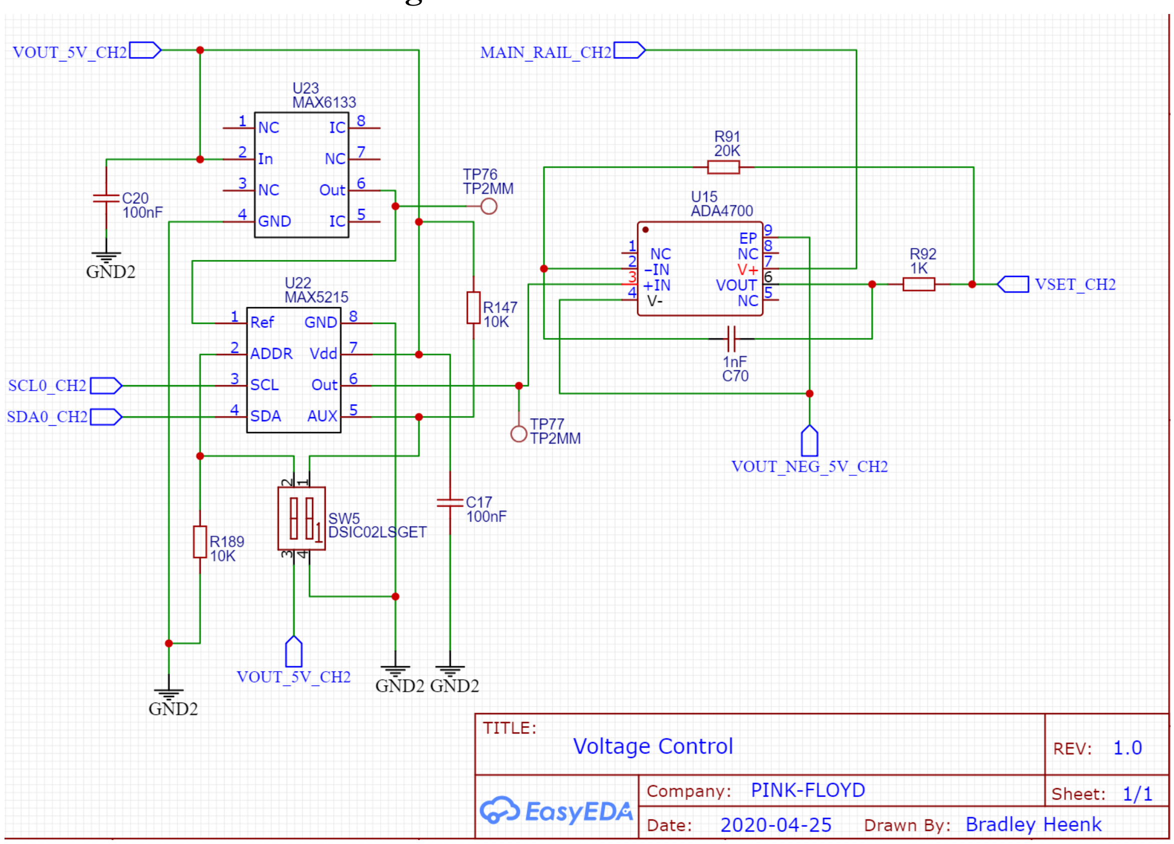
There are two Power supply circuits. They contain all of the elements required to drive the main output terminals to their voltage and current setpoints. There are adequate test pins strategically located to allow for thorough circuit debugging. The LT3081 integrated circuits are the linear voltage regulators wired in parallel such that their output currents sum together. Each is able to supply 1.5 amps max. The LTC1624 is the switching regulator that steps down the 32VDC supply to 1.6 volts above the linear output. This is to increase the efficiency and power consumption of the linear voltage regulators. LTC1983 is a current sinc that will allow the output to be pulled to 0 volts. This was required because the LTC3081s have a minimum output of 1.5 volts. The MOSFETs driven by PWR_CTRL_CH2 function as off switches for the circuit.

Current Control Schematic



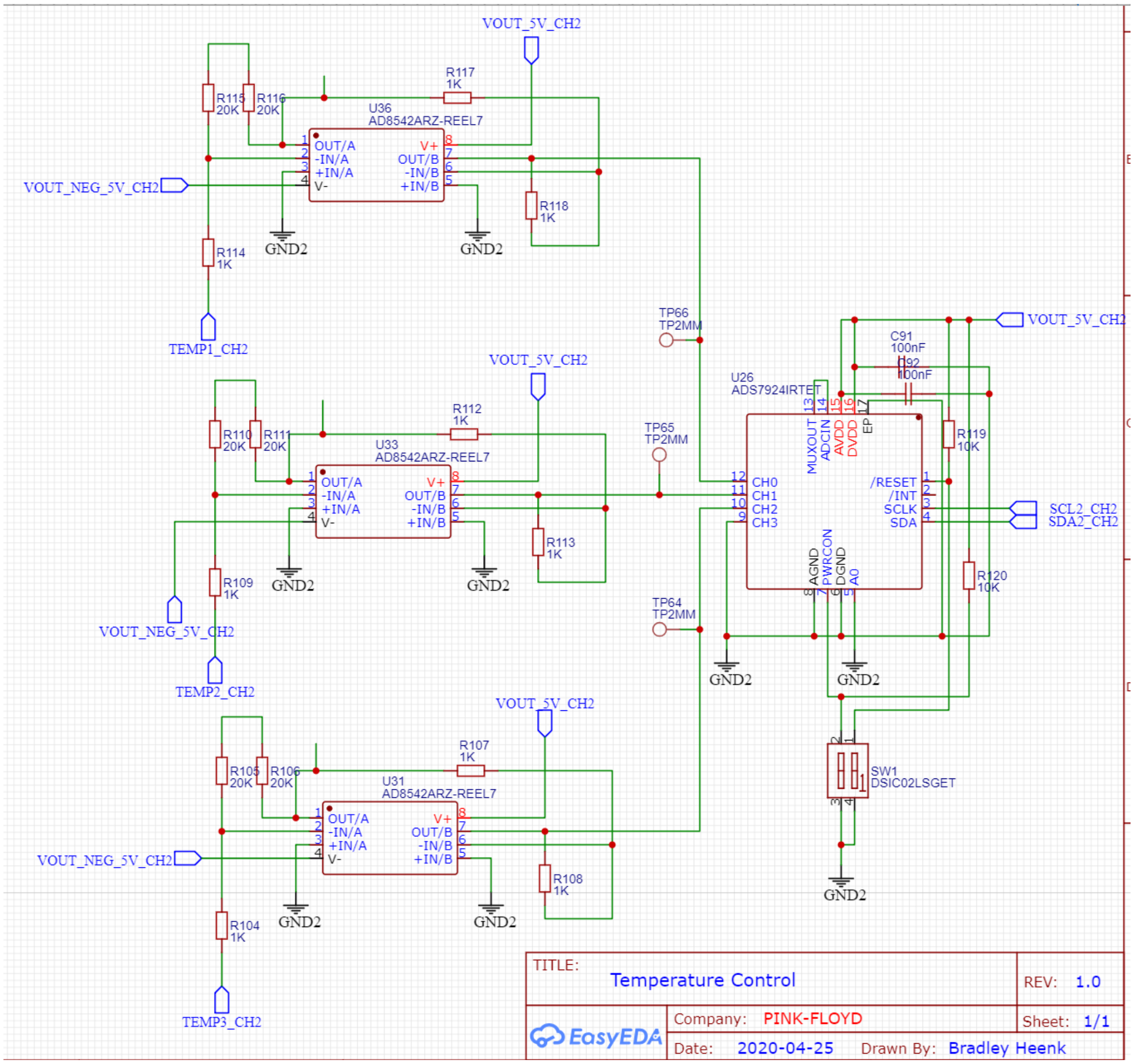
There are 2 Current Control circuits. This circuit takes I2C data from the output of the raspberry pi at SCL1_CH2 and SDA1_CH2 convert it to an analog signal with the MAX5215 14-bit DAC to control the output current. The signal is electrically isolated from the main power circuit through an ADA4700. The CMOS circuit is a current mirror that drives constant current to the ILIMx_CH2 pins at the linear regulators in the Power Supply circuit.

Voltage Control Schematic



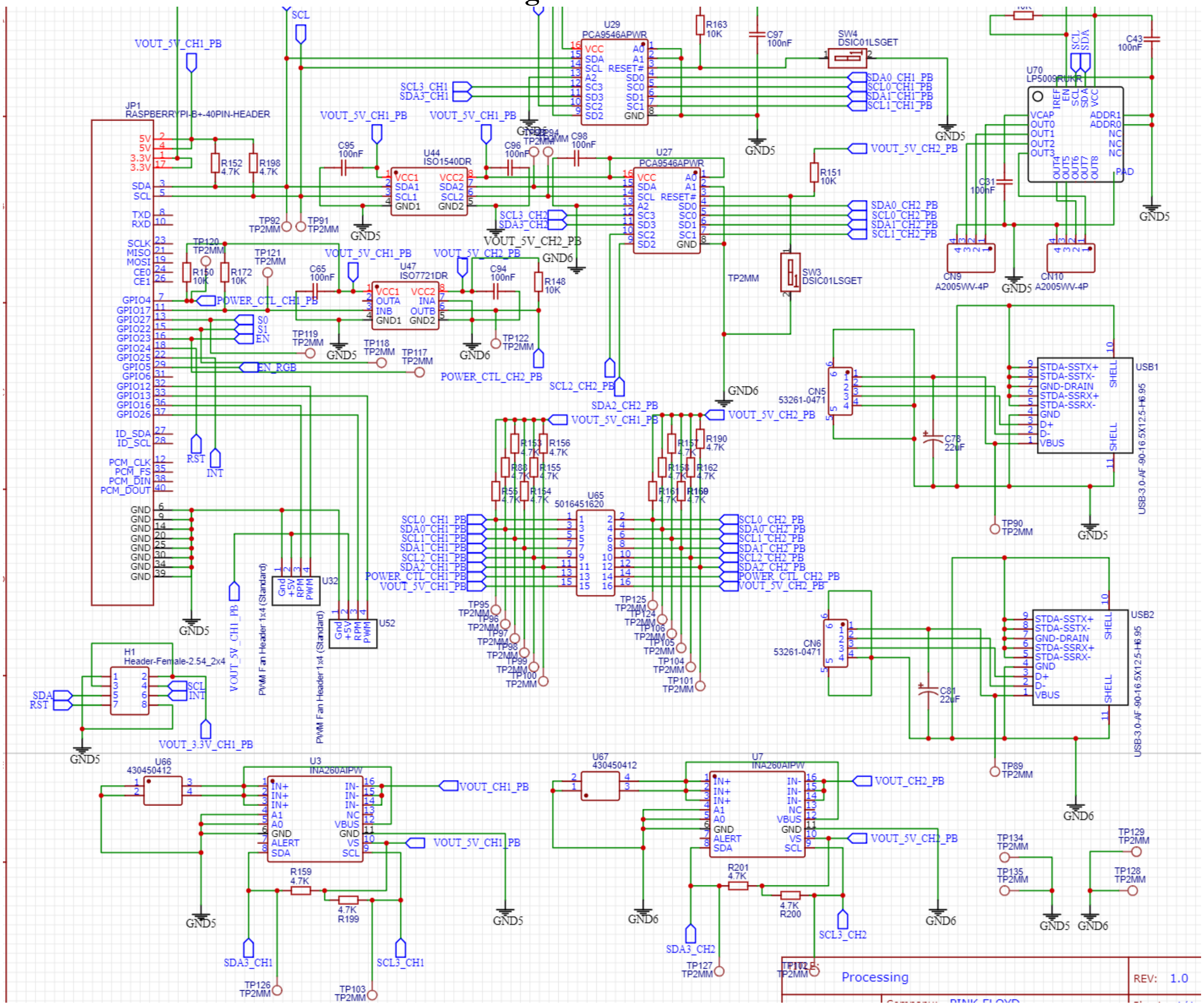
There are 2 voltage control circuits. This one takes in I2C data from the pi on SCL0_CH2 and SDA0_CH2 converts it to an analog signal with the MAX5217 16-bit DAC. The analog signal is fed through the ADA4700 to drive the voltage set pin VOUT_NEG_5V_CH2 and VSET_CH2 that connect to the linear regulators in the Power Supply circuit.

Temperature Control Schematic



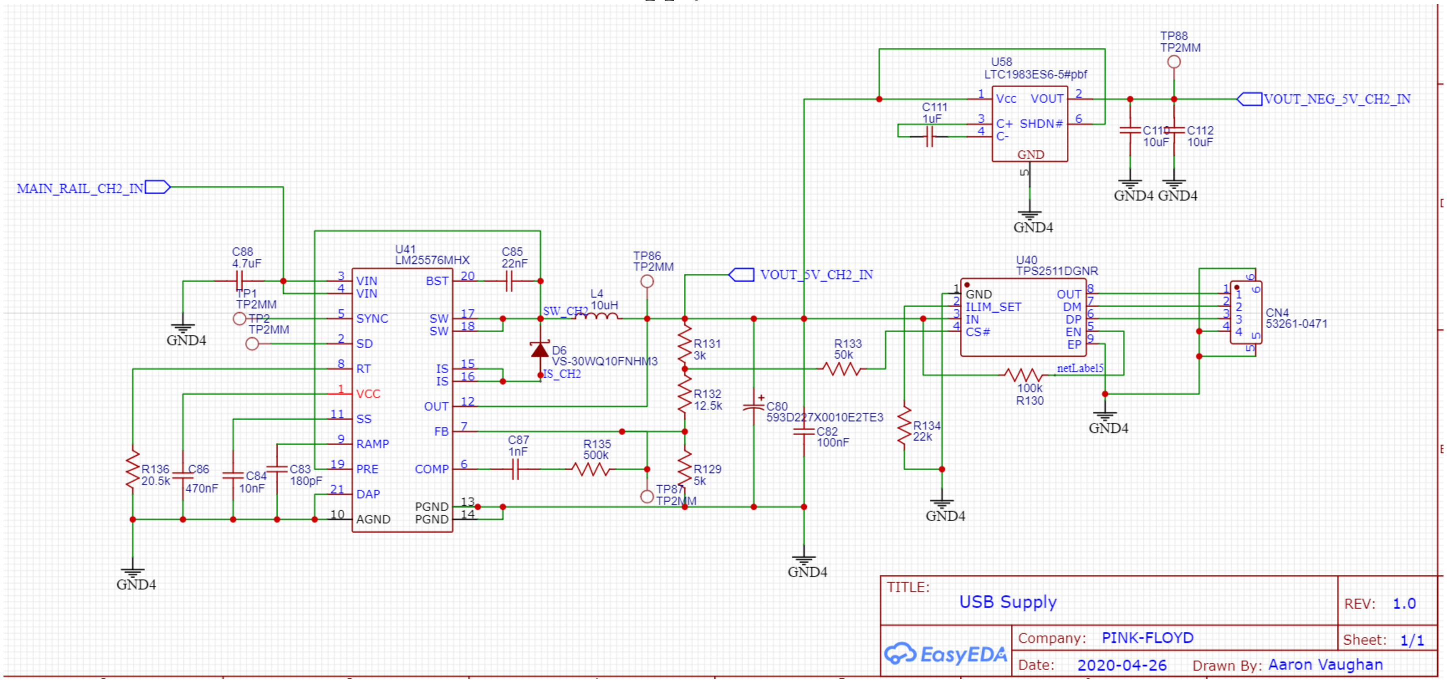
There are two Temperature Control circuits that take in temperature readings from the linear regulators as an analog signal from TEMPx_CH2. The signal is converted to a digital signal with the ADS7924 and fed to the pi through SDA2_CH2 and SCL2_CH2 signals via I2C communication protocol. These temperature readings are used by the pi to regulate a PWM controlled fan if the temperature exceeds some maximum threshold.

Processing Schematic



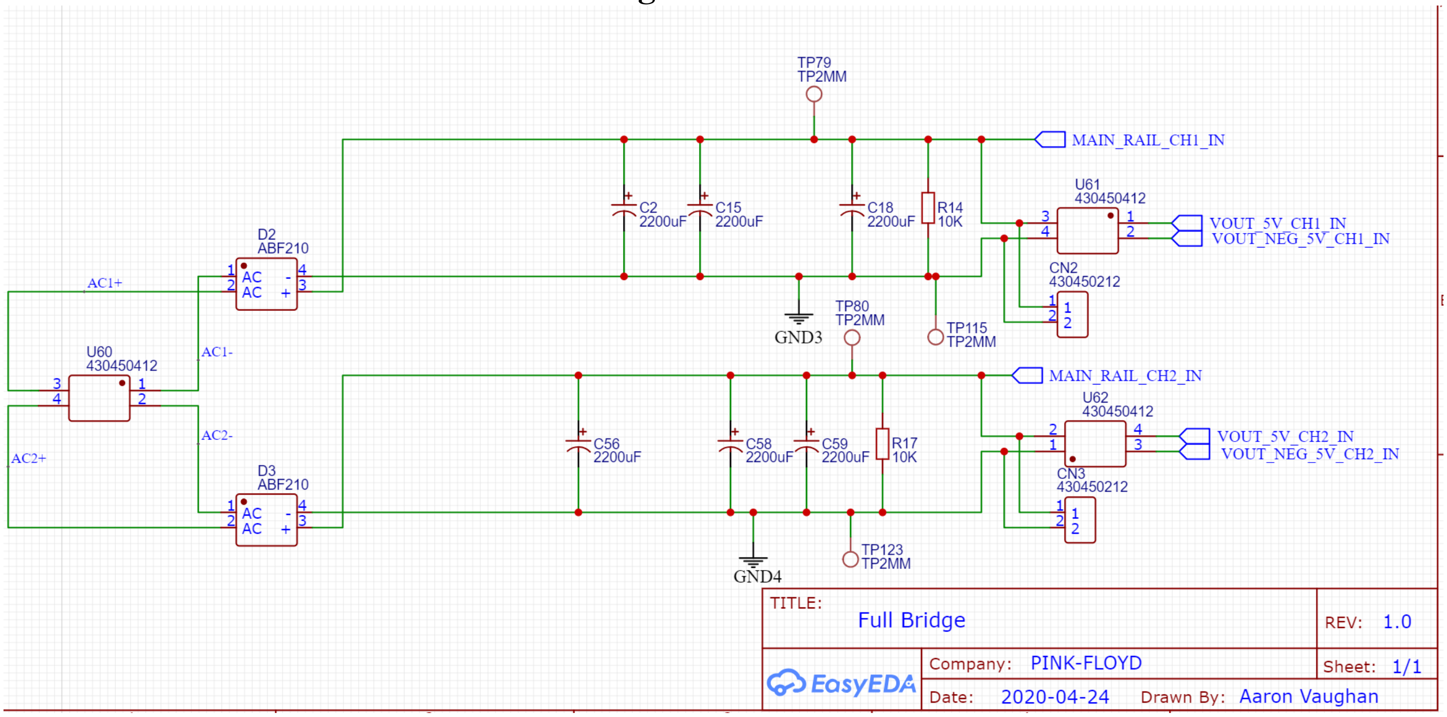
The processing circuit interfaces to the pi through a 40-pin connector on the left. The main function of this circuit is to feed all of the data into and out of the microcontroller. This circuit separates all of the I2C data bus lines Through PCA9546 addressing ICs. The main SDA and SCL lines from the pi are isolated through ISO1540 optocouplers. Also included in this schematic are INA260 ICs that monitor the output current with a sampling rate of 400kHz and output I2C data to be read by the pi. The output connectors for the USB dedicated charge port controllers are also featured in this schematic for the purpose of laying out the PCB's.

USB Supply Schematic



There are three USB Supply circuits in our design. One is dedicated to drive all the microcontroller power needs, and the TFT touch screen. There is one for each channel used for DCP function to drive high current devices such as iPads and tablets. The LM25576 is a switching regulator in a buck topology. It will drive 3A in this configuration at 5 to 5.1 volts. The TPS2511 is the DCP controller IC that monitors the downstream device demand for current. If the device requires more than 500 mA there is an internal MOSFET that drives the switching regulator to a slightly higher voltage through the CS pin's interaction with the feedback voltage divider circuit shown at R131. This circuit also contains an LTC1983 -5V charge pump circuit that delivers -5V to the voltage control circuit among others.

Full Bridge Schematic

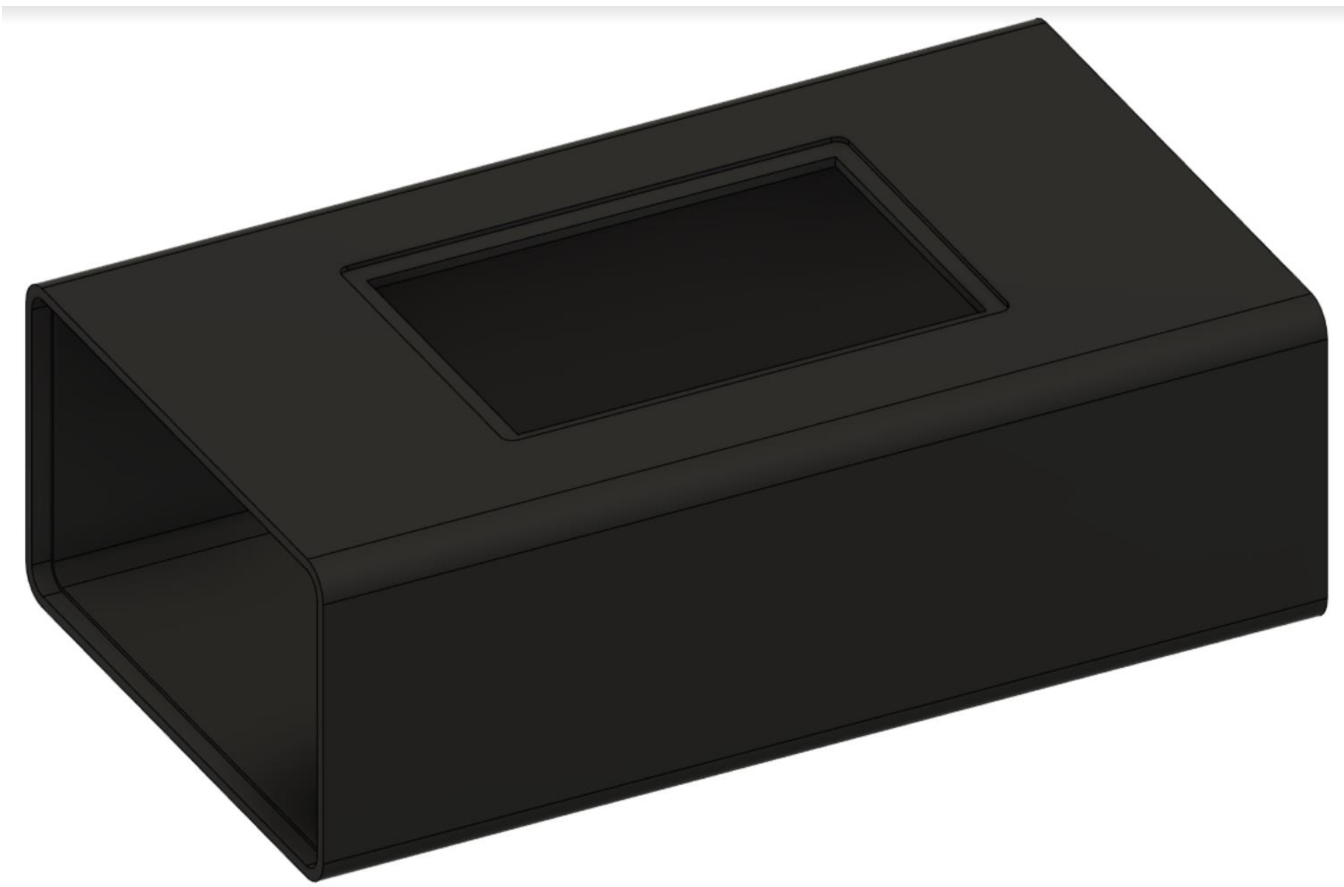


There is only one Full Bridge Circuit in our design. The ABF210 ICs are simply bridge rectifiers. The transformer supplies 26VAC to their input and after rectification the circuit provides 32VDC to the USB and Power Supply modules. This signal is passed through a low pass filter bank of capacitors and resistors to smooth the output ripple.

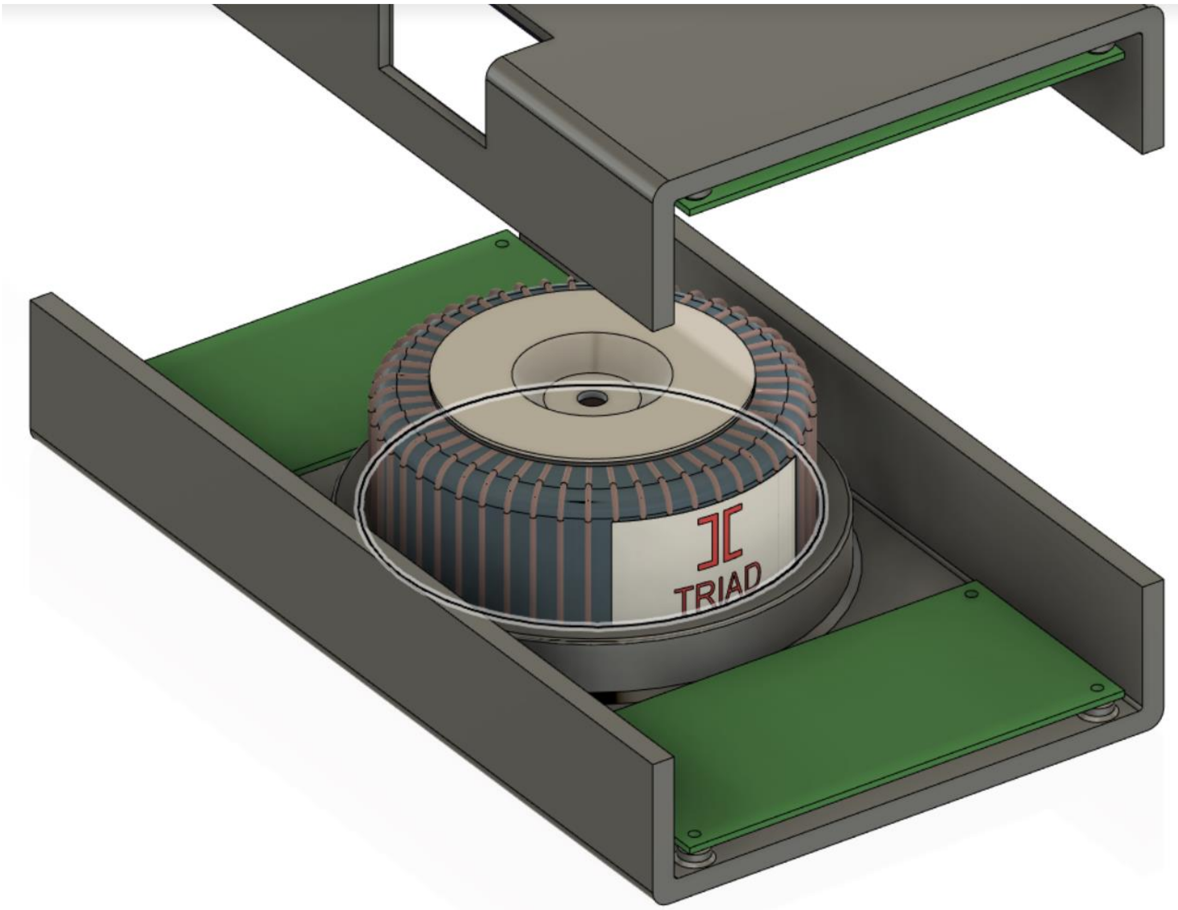
- **3-D printed Enclosure**

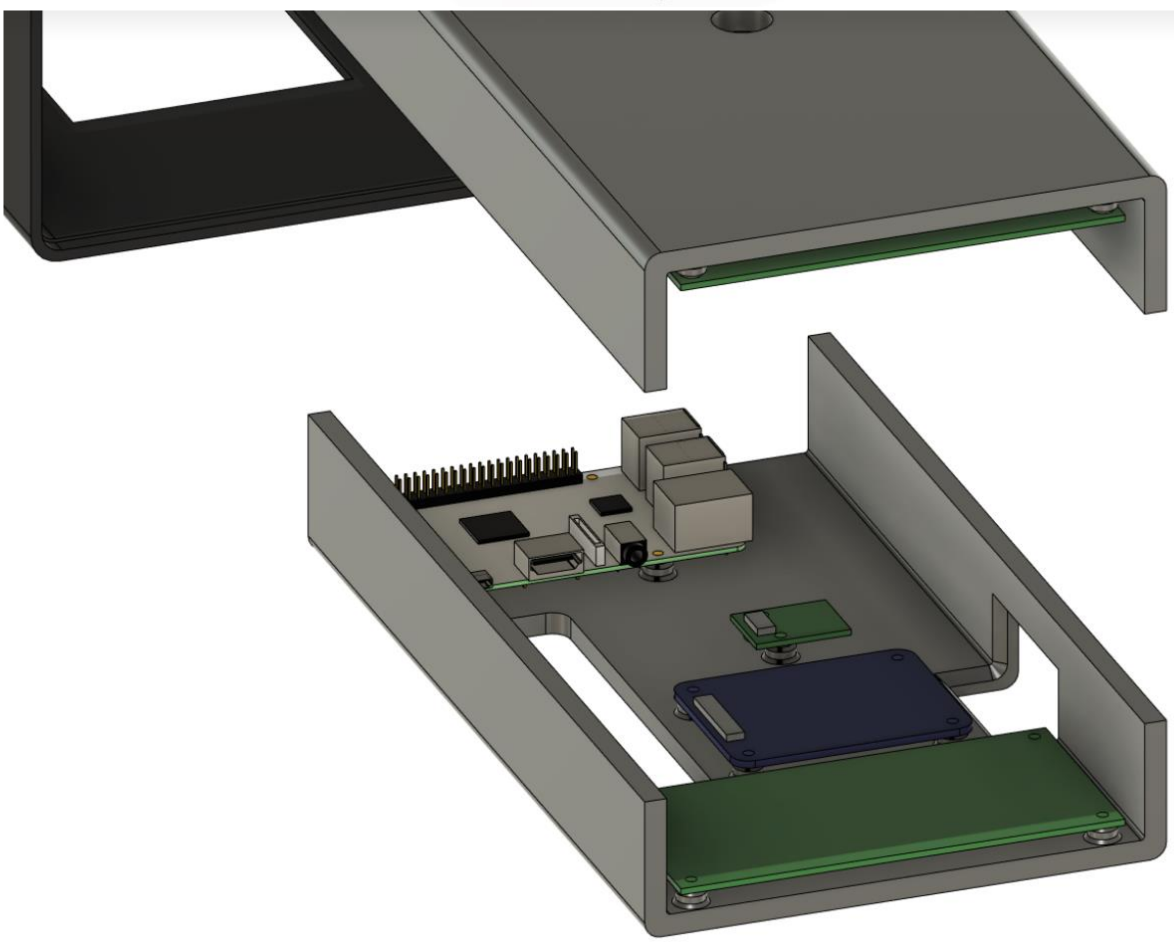
The enclosure is constructed of 5 individually printed components. The Outer shell houses the TFT display at the top opening, while the guts of the device will slide in through the end. They are held in place wit the help of the two endcaps. The endcaps have air holes of 1mm for cooling. Their size was limited to 1mm to decrease the risk of safety hazards involved with users coming in contact with the high current circuitry within. The inner components will slide in on a tray comprised of a two-piece clam shell configuration. The toroidal transformer mounts to the bottom with two of the PCBs and the top portion holds the processing PCB that interfaces with the pi as well as the raspberry pi itself. Please see the images below for greater detail.

The Outer Shell

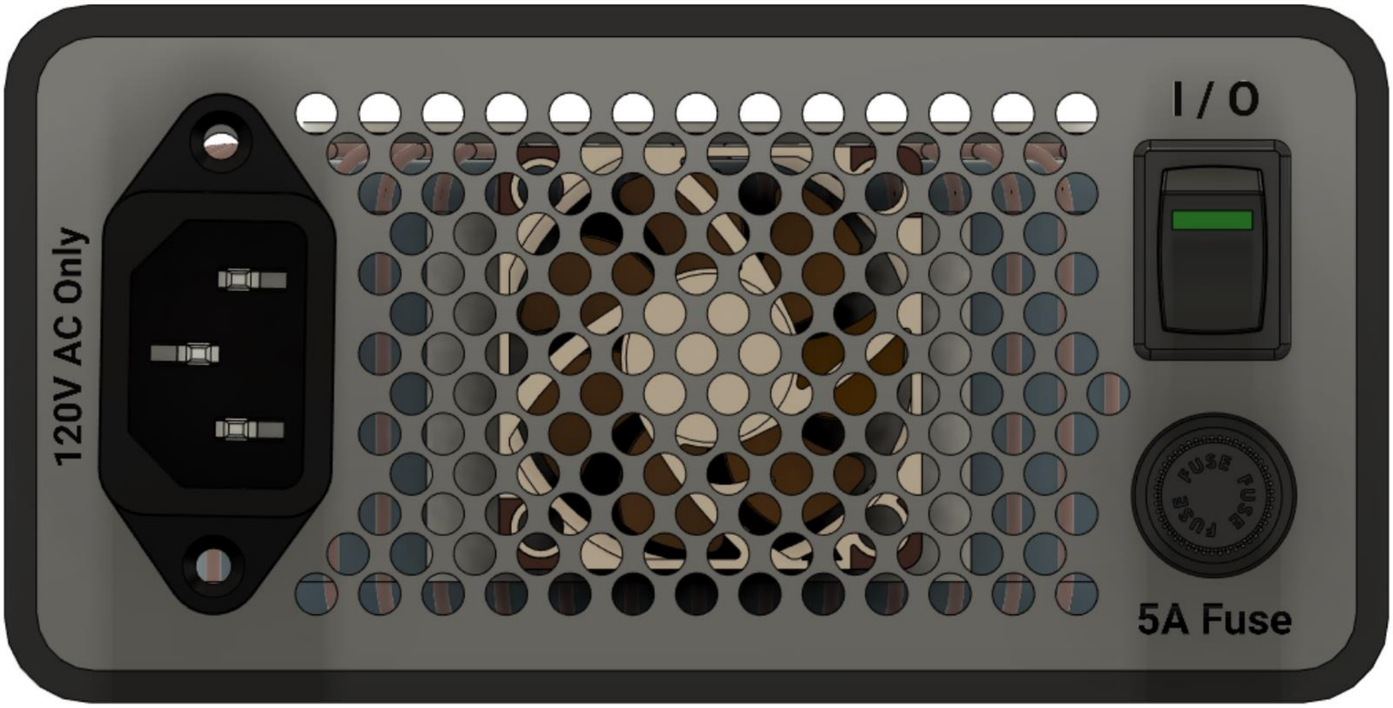


The Inner Clam Shells





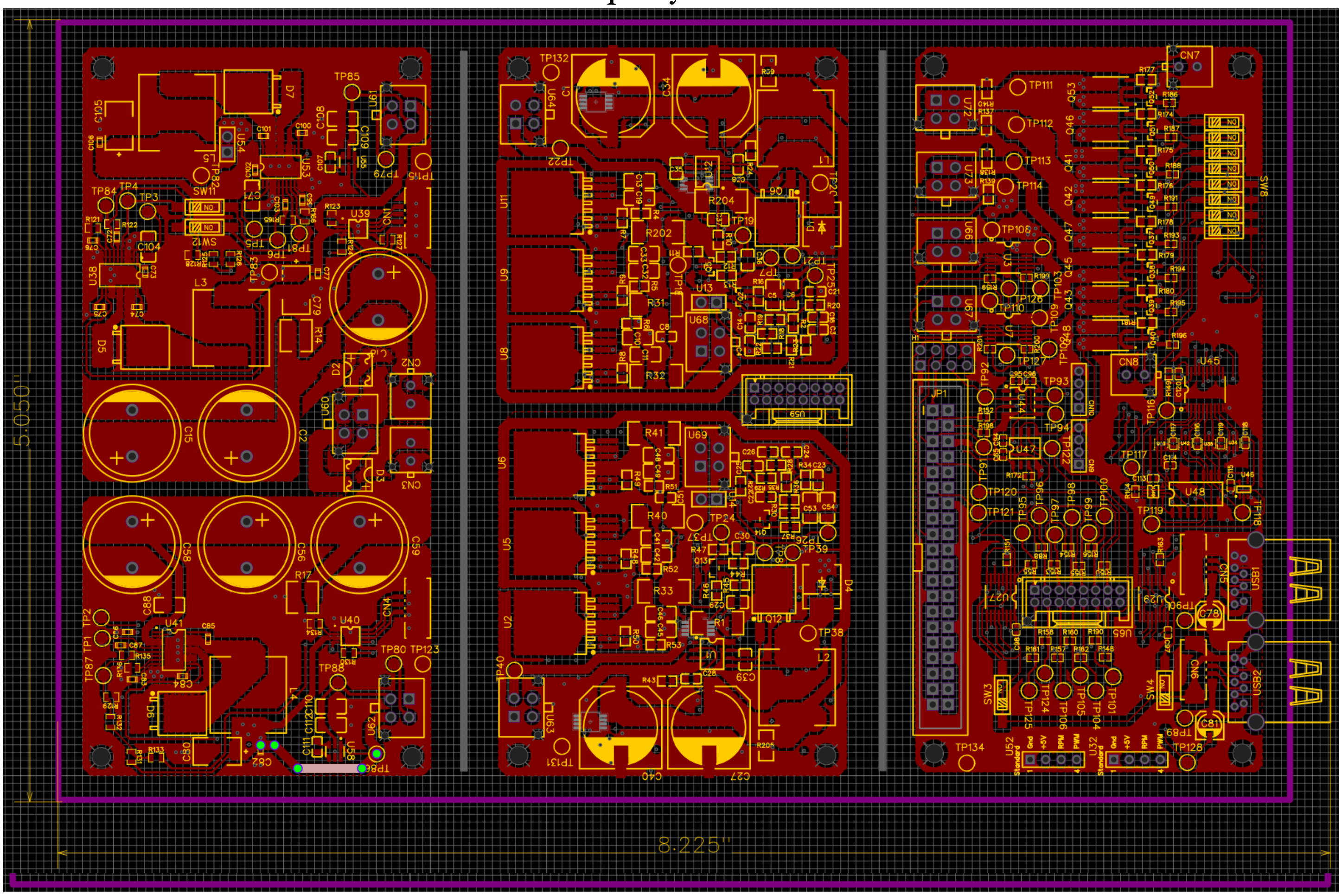
The End Caps



- **PCB Information**

  The PCB is roughly 8 ¼ inches by 5 inches in total. The entire PCB was designed to be separated into three smaller sections delineated by the thick grey lines which are actually channels milled out of the PCB material for easy separation. The first section (left) contains the full bridge rectification, and all three of the 32V to 5V DC-DC Buck regulator circuits along with their -5V charge pump circuits. The seconds section (middle) is the high current switching regulators and linear regulators that make up the two main output channels. The third section (right) is the control circuit which interfaces all of the devices that communicate to the raspberry pi. This section is sensitive to noise and needed to be completely isolated from the noisy switching supplies.

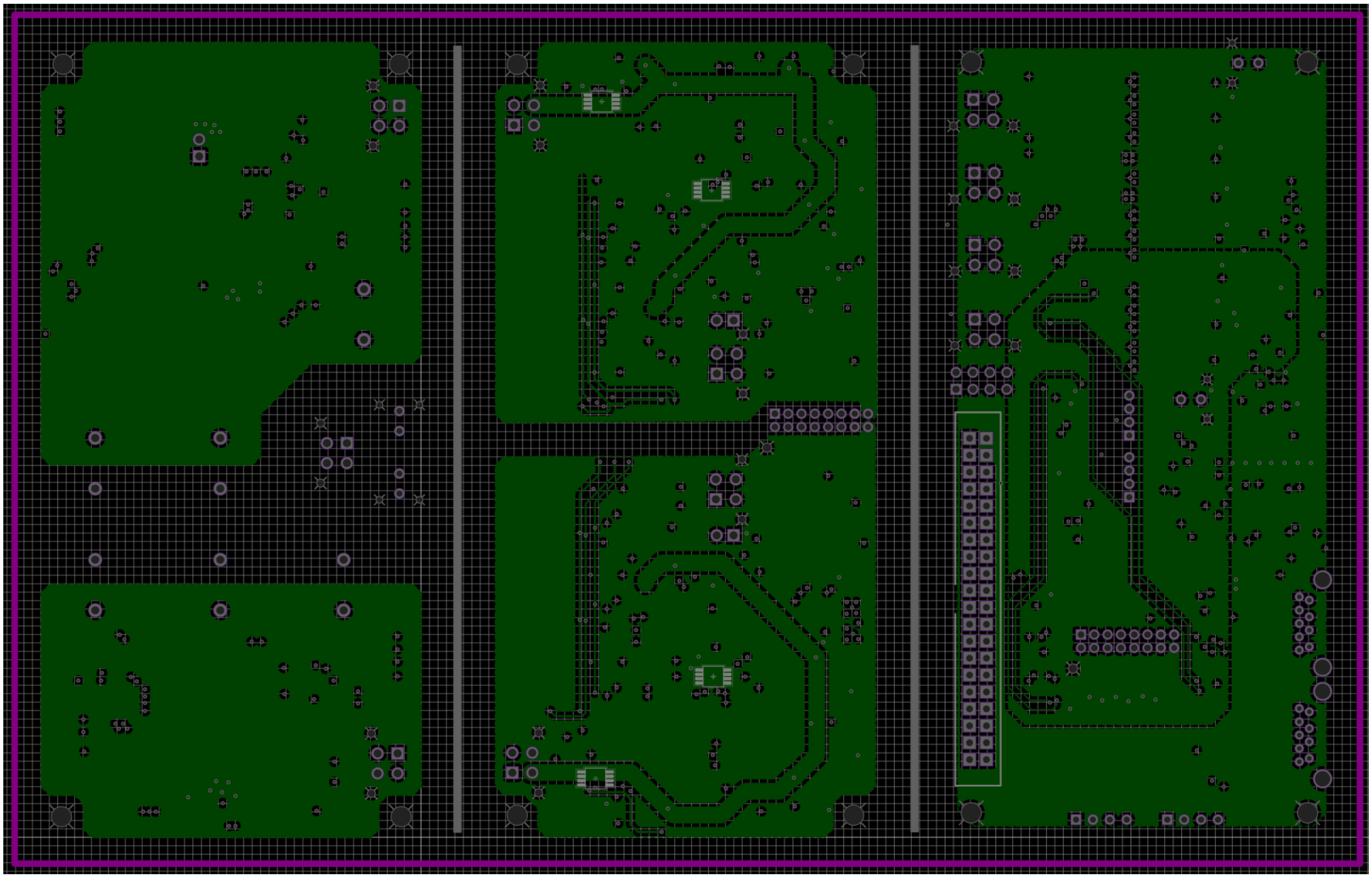
Top Layer PCB



Layer 2 (inner) PCB

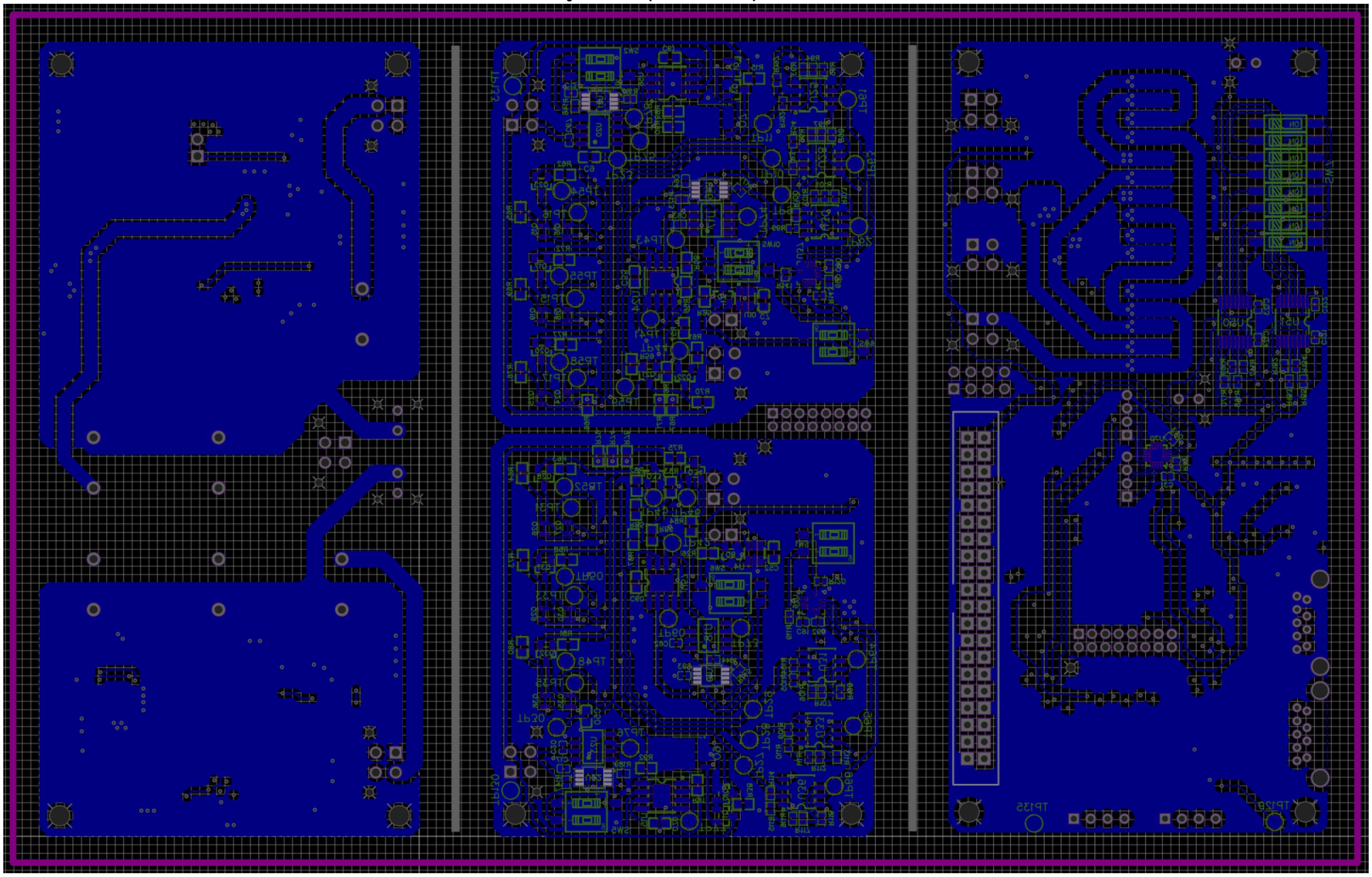
This layer is the power ground for all sections.

Layer 3 (inner) PCB



This layer is the analog ground for all sections.

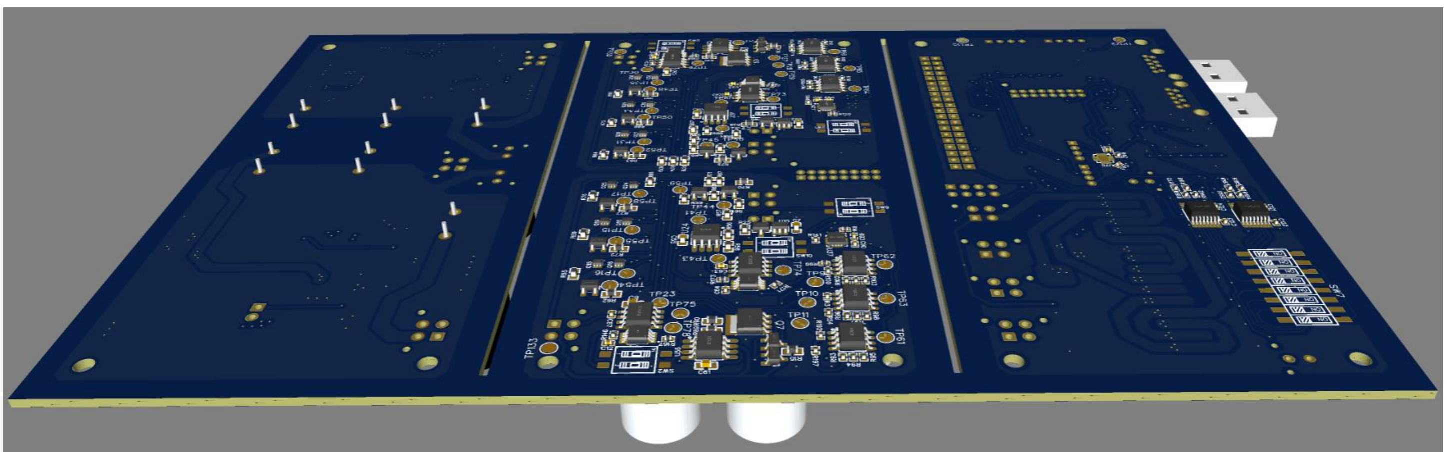
Layer 4 (bottom) PCB



The bottom traces are surrounded by the analog ground planes to further isolate their signals from noise.

3-D Top View

3-D Bottom View



- **Part Information**

ID	Name	Quantity	Manufacturer Part	Manufacturer	Supplier	Supplier Part
1	N-channel MOSFET	24	WST4040	Winsok Semicon	LCSC	C377863
2	150	2	AR03DTCX1500	Viking Tech	LCSC	C319857
3	100nF	2	CL10F104ZB8NNNC	SAMSUNG	LCSC	C1688
4	22uF	2	UZG0J220MCL1GB	Nichicon	LCSC	C250865
5	2mm Test Pin	117	N/A	N/A	N/A	N/A
6	0.01	6	RLM25FEER010	TA-I Tech	LCSC	C192580
7	1K	8	ARG03FTC1001	Viking Tech	LCSC	C217840
8	20K	12	AR02DTD2002	Viking Tech	LCSC	C319759
9	220uF	3	593D227X0010E2TE3	VISHAY	Digi-Key	478-6163-1-ND
10	10K	2	AR06DTDV1002	Viking Tech	LCSC	C319943
11	1K	4	AR03BTDX1001	Viking Tech	LCSC	C319812
12	Linear regulator	2	LTC1624CS8#PBF	LINEAR	LCSC	C107744
13	470pF	2	CL10B471KB8NNNC	SAMSUNG	LCSC	C22396
14	Header-Female-2.54_2x4	1	220S-2*4P H=8.5MM Ytype Gold-plated	Ckmtw	LCSC	C124422
15	2200uF	6	2200uF 50V ±20%	ValuePro	LCSC	C13917
16	1K	2	AR03BTCX1001A010	Viking Tech	LCSC	C374414
17	10	6	AR03DTCX0100	Viking Tech	LCSC	C319921
18	DPST dip switch	6	DSIC02LSGET	KE	LCSC	C54949
19	OR gates	1	SN74LVC1G32DCKR	TI	LCSC	C7840
20	Digital Isolator	1	ISO7721DR	Texas Instruments	LCSC	C366164
21	5V reference voltage	4	MAX6133	Maxim Integrated	Digi-Key	MAX6133BASA25+-ND
22	4.7K	18	AR02BTC4701	Viking Tech	LCSC	C317921
23	N-channel mosfet array	8	BUK7K6R2-40EX	Nexperia	LCSC	C458245
24	USB charge port controller	2	TPS2511DGNR	TI	LCSC	C68648
25	100nF	32	CL05B104KB54PNC	Samsung Electro-	LCSC	C307331
26	Molex connector	4	53261-0471	MOLEX	LCSC	C240847
27	6.8K	2	R0603RXX682XF10LTS	Shenzhen Eyang	LCSC	C267593
28	10K	8	RMS06JT103	TA-I Tech	LCSC	C209220
29	SPST dip switch	4	DSIC01LSGET	KE	LCSC	C54948
30	20	6	AR03DTDX0200	Viking Tech	LCSC	C319746
31	-5V charge pump	2	LTC1983ES6-5#pbf	LINEAR	LCSC	C117346
32	-3V charge pump	2	LTC1983ES6-5#pbf	LINEAR	LCSC	C117346
33	56nF	2	CL10B563KB8NNNC	Samsung Electro-	LCSC	C318655
34	Molex connector	2	5016451620	MOLEX	LCSC	C293576
35	1nF	4	CL10B102KC8NNNC	SAMSUNG	LCSC	C153291
36	10K	36	AR02DTD1002	Viking Tech	LCSC	C319933
37	100nF	2	0603F104Z500CT	Guangdong TOPA	LCSC	C180398
38	P-channel Mosfet array	12	BSS84V-7	Diodes Incorporat	LCSC	C459524
39	4.7uF	3	CC1206ZRY5V6BB475	Yago	Digi-Key	311-2008-1-ND
40	1nF	3	CC0603KRX7R9BB102	Yago	Digi-Key	311-1080-1-ND
41	470nF	3	CC0603KRX5R8BB474	Yago	Digi-Key	311-3365-1-ND
42	180pF	3	C0603C181J5GACTU	Yago	Digi-Key	399-1064-1-ND
43	100nF	3	C0603C104Z3VACTU	Kmet	Digi-Key	399-1100-1-ND
44	10nF	3	C0603C103M5RACTU	Kmet	Digi-Key	399-7842-1-ND
45	22nF	3	C0603C223K1RACTU	Kmet	Digi-Key	399-3476-1-ND
46	2.2uF	2	UMK212ABJ225KG-T	Taiyo Yuden	LCSC	C337444
47	1K	18	AR02DTC1001	Viking Tech	LCSC	C319808
48	Schottky diode	2	ABF210	Jingdao	LCSC	C169534
49	330uF	4	VZH331M1HTR-1313	LELON	LCSC	C164077
50	20K	10	AR03BTDX2002	Viking Tech	LCSC	C319765
51	NPN Transistor	2	SST2222AT116	ROHM	LCSC	C79976
52	10K	2	CR1218J10KE04	Ever Ohms Tech	LCSC	C175611
53	4-channel digital isolator	2	ISO7140CCDBQR	Texas Instruments	LCSC	C205953
54	I2C digital isolator	1	ISO1540DR	TI	LCSC	C179739
55	10uF	20	C3216X7R1V106MT000E	TDK	LCSC	C361179
56	1uF	6	CL10A105KB8NNNC	SAMSUNG	LCSC	C15849
57	1nF	4	GCJ216R72A102KA01D	Murata Electronics	LCSC	C354376
58	N-channel MOSFET	2	IPD036N04L G	Infineon Technolo	LCSC	C152354
59	100	2	AR03BTCX1000	Viking Tech	LCSC	C319953
60	3k	2	MCT06030C3001FP500	VISHAY	Digi-Key	MCT0603-3.00K-CFCT-ND
61	100k	2	MCT06030C1003FP500	VISHAY	Digi-Key	MCT0603-100K-CFCT-ND
62	12.5k	2	CRCW060312K4FKEA	VISHAY	Digi-Key	541-12.4KHCT-ND

ID	Name	Quantity	Manufacturer Part	Manufacturer	Supplier	Supplier Part
61	100k	2	MCT06030C1003FP500	VISHAY	Digi-Key	MCT0603-100K-CFCT-ND
62	12.5k	2	CRCW060312K4FKEA	VISHAY	Digi-Key	541-12.4KHCT-ND
63	50k	2	MCT06030C4992FP500	VISHAY	Digi-Key	749-1660-1-ND
64	22k	2	MCT06030C2202FP500	VISHAY	Digi-Key	MCT0603-22.0K-CFDKR-ND
65	20.5k	3	CRCW060320K5FKEA	VISHAY	Digi-Key	541-20.5KHCT-ND
66	500k	3	MCT06030C4993FP500	VISHAY	Digi-Key	749-1661-1-ND
67	5k	2	MCT06030C4991FP500	VISHAY	Digi-Key	MCT0603-4.99K-CFCT-ND
68	BUCK regulator	3	LM25576MHX	TI	LCSC	C14654
69	RGB LED driver	1	LP5009RUKR	Texas Instruments	Texas Instruments	Texas Instruments
70	8PST dip switch	2	DSIC08LSGET	KE	LCSC	C54953
71	374	6	ARG03FTC3740	Viking Tech	LCSC	C217990
72	USB jack	2	USB-3.0-AF-90-16.5X12.5-H6.95	LCSC	LCSC	C69073
73	N-Channel MOSFET	2	PSMN1R8-40YLC,115	Nexperia	LCSC	C88071
74	Logic Buffer	1	SN74LVC541APWR	TI	LCSC	C113281
75	I2C Addresser	2	PCA9546APWR	Texas Instruments	LCSC	C400705
76	14-bit DAC	4	MAX5215	Maxim Integrated	Digi-Key	MAX5217BGUA+-ND
77	Shottky Diode	3	VS-30WQ10FNHM3	VISHAY	LCSC	C145461
78	OPAMP	6	AD8542ARZ-REEL7	ADI	LCSC	C45344
79	12-bit ADC	2	ADS7924IRTET	Texas Instruments	LCSC	C201603
80	Digital resistor	6	LT3081ER#PBF	LINEAR	LCSC	C117395
81	Inverter gate	4	SN74LVC2G04DCKR	TI	LCSC	C105251
82	470pF	2	GRM188R72E471KW07D	Murata Electronics	LCSC	C117800
83	100K	12	ARG03FTC1003	Viking Tech	LCSC	C217682
84	1uF	2	CL10A105KA8NNNC	SAMSUNG	LCSC	C5673
85	100K	6	AR03BTC1003A010	Viking Tech	LCSC	C374388
86	Connector	2	A2005WV-4P	Changjiang Conne	LCSC	C225256
87	Connector	1	RASPBERRYPI-B+-40PIN-HEADER	Adafruit	adafruit	
88	Schottky diode	2	MBRS340	ON Semicon	LCSC	C117937
89	Molex connector	11	430450412	MOLEX	LCSC	C277721
90	0.03	2	RLP25FEER030	TA-I Tech	LCSC	C393083
91	Molex connector	4	430450212	MOLEX	LCSC	C293362
92	PWM Fan Header 1x4 (Standard)	2	PWM Fan Header 1x4 (Standard)	Adafruit	adafruit	
93	220nF	2	CL10B224KA8NNNC	SAMSUNG	LCSC	C21120
94	PNP Transistor	2	2N3906S-RTK/PS	KEC	LCSC	C147294
95	Current sensor	2	INA260AIPW	Texas Instruments	LCSC	C181331
96	10uH	5	SCDS125T-100M-N	Chilisin Elec	LCSC	C329747
97	5.6K	2	AR03BTC5601	Viking Tech	LCSC	C309088
98	Inverter Gate Array	1	SN74LVC3G04DCUR	Texas Instruments	LCSC	C153799
99	5.1K	14	AR03DTDX5101	Viking Tech	LCSC	C319560
100	Connector	3	MTP125-1102S1	MINTRON	LCSC	C358684
101	NAND Gate	1	SN74ACT00DR	Texas Instruments	LCSC	C352946
102	OPAMP	4	ADA4700-1	Analog Devices	LCSC	C207958