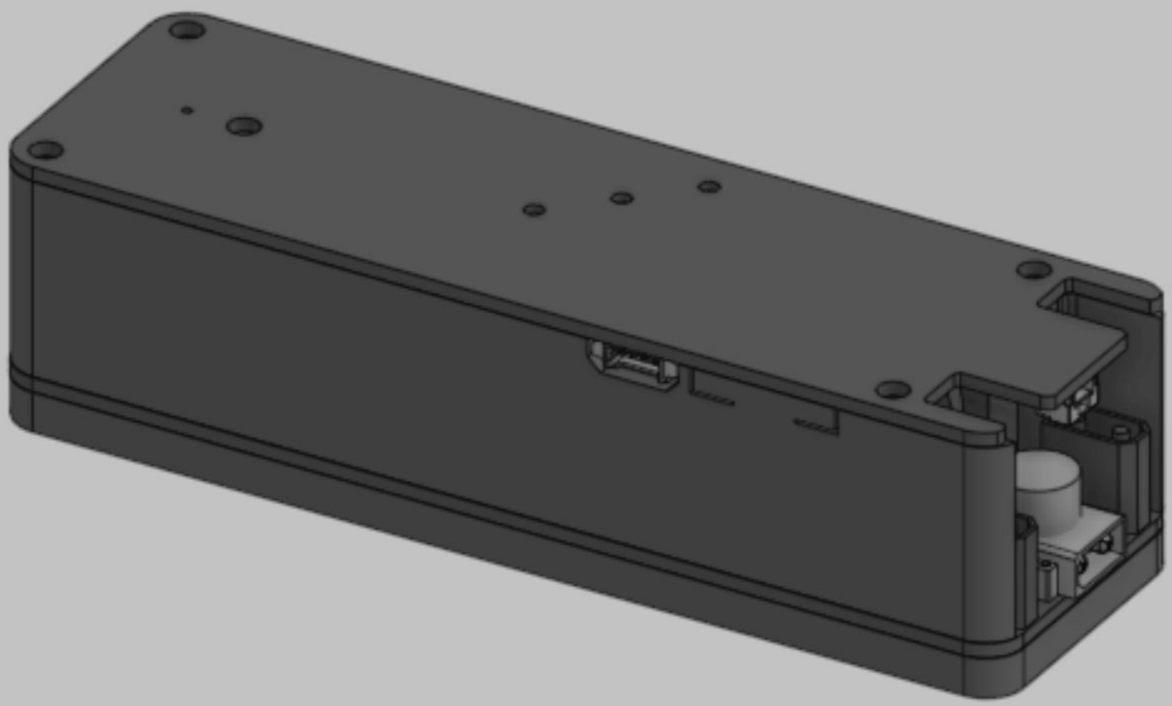
SUPERCAPACITOR BANK SYSTEM MARK IV

SERVICE MANUAL

REVISION
A



SPECIFICATIONS

System	Supercapacitor Bank Control System	Cap Array	60F, 2.7V x9
Capacity	2,000 J (nominal)	Thermal protect	75°C
Current	10 A Maximum, bidirectional	Program	J-Link
Auto Discharge	Discharge to safe level in <135 sec.	Switching Freq.	100 kHz
Dimensions	115 X 35 X 30 mm (L/W/H)	Cooling	Fan, 1.6 CFM

SAFETY-RELATED COMPONENT WARNING!! COMPONENTS MARKED BY SHADING AND MARK ⚠️ ON THE SCHEMATIC DIAGRAMS AND IN THE PARTS LIST ARE CRITICAL TO SAFE OPERATION. REPLACE THESE COMPONENTS WITH EXACTLY WHAT IS LISTED IN THE PARTS LIST ONLY.

CONTENTS:

TECHNICAL DATA

THEORY OF OPERATION

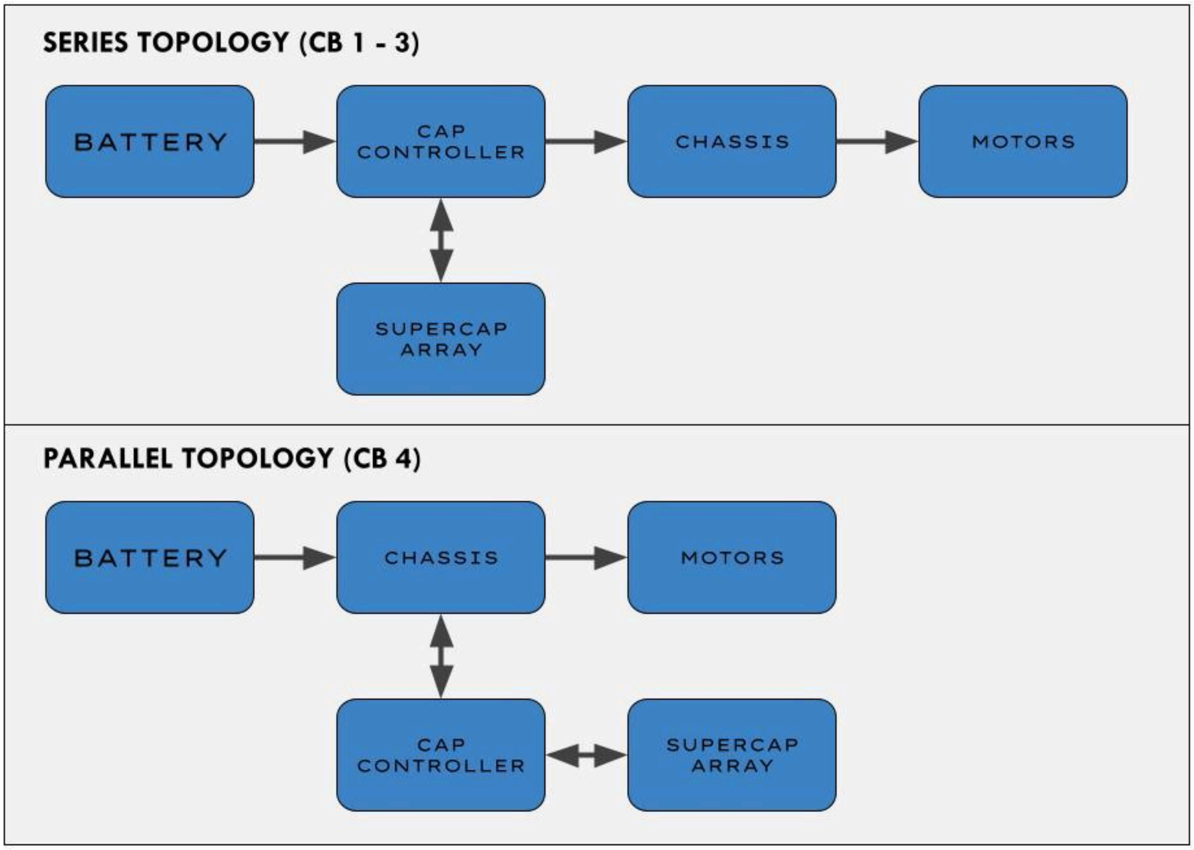
Overview of CB4:

The ARUW 4th generation supercapacitor bank controller has been designed with size reduction and reliability as the primary considerations over the previous iteration. Electrically, the main changes include a switch to a parallel design utilizing a bidirectional buck boost DC-DC converter, a new semi-constant-power discharger circuit, and reduced capacitor count achieved by using higher grade polymer capacitors. These changes, combined with a focus on packaging efficiency, has resulted in a compact and highly integrated cap bank controller that has achieved a [...]% reduction in volume and [...]% reduction in weight over the previous model (CB3).

The Cap-Bank:

The job of the supercapacitor bank is to store surplus energy from the battery when the robot is idle, and allow that surplus energy to boost the robot's power when needed. The Robomaster ref system limits the maximum allowable current draw from the battery, with severe penalties for exceeding this current for an extended period of time. Without the cap bank, the robot's top speed is limited by this maximum current allowed by the ref system.

The cap bank works to improve this situation by charging its capacitors with the extra current available when the robot is using less than the maximum allowable current. This means that the maximum current is always being drawn from the batteries, and any current that doesn't get consumed by the robot goes to charge the capacitors instead (until the capacitors are fully charged). When an extra boost of power is needed, the capacitors supply the robot with extra power on top of the power from the battery, allowing the robot to move faster than normal until the capacitors are depleted, or until boost is no longer needed.

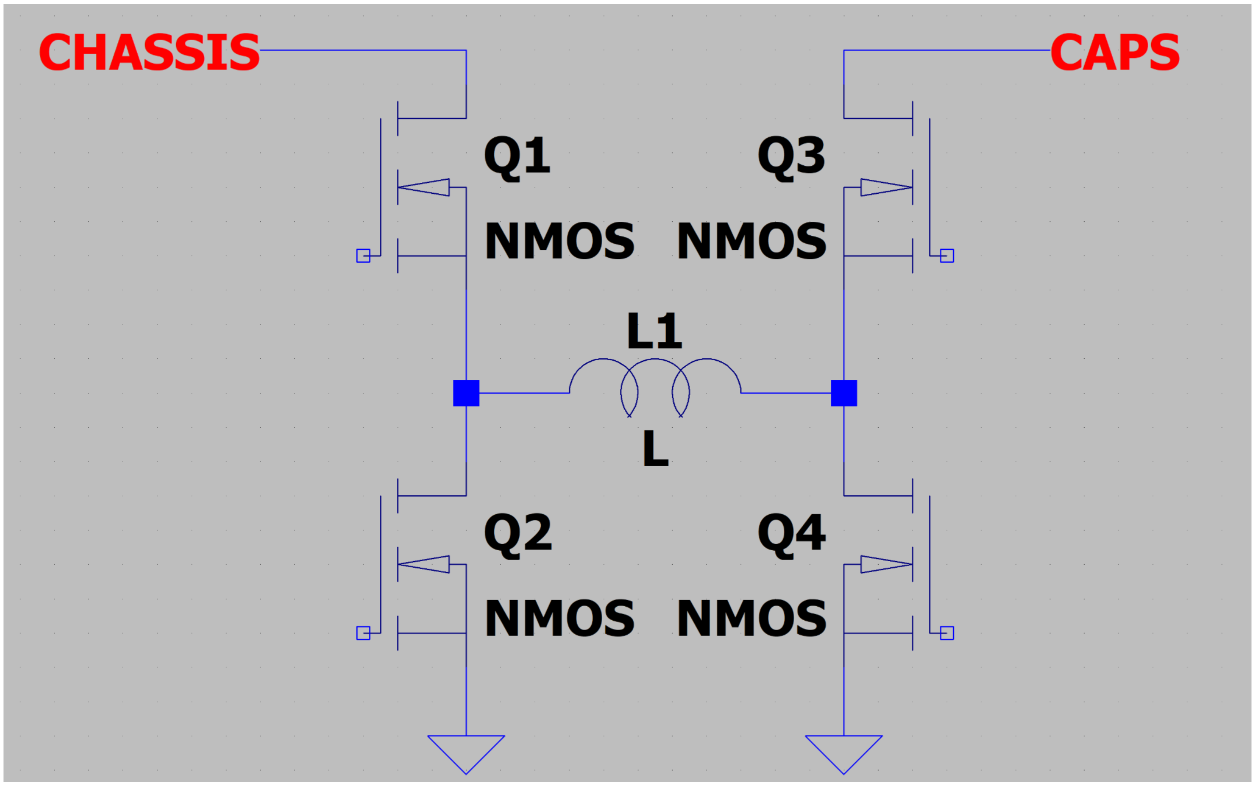


The new parallel design of CB4 allows greater efficiency over previous designs by allowing the bulk of the current to bypass the cap controller under normal operation. Under the previous series topology, all current powering the chassis would have to pass through the cap controller first; through both its input and output DC-DC converters unless the safe-path bypass was enabled. By using the new parallel topology, current can now flow directly from the battery to the chassis and on to the motors, without any energy loss from DC-DC converters. The current that flows through the cap controller's DC-DC converter is only what is needed to charge or discharge the supercapacitors, realizing sizable efficiency gains and allowing for a physically much smaller cap bank controller. This is made possible by the introduction of the new bidirectional DC-DC switching converter design.

<u>Switching Converter:</u>

The job of the switching converter is to facilitate the charging and discharging of the supercapacitors. It has to allow current to flow both directions (robot to caps and caps to robot), and also convert the voltage so that the 24V robot chassis power can be converted to the capacitor voltage, which ranges from 0 to 30V depending on their state of charge, and vice versa.

It consists of four MOSFETs in an H-configuration, with an inductor in-between them.



Q1 and Q4 are paired together, and Q2 and Q3 are paired together.
When Q1 & 4 are on, current begins to flow from the chassis and rightwards through the inductor L1 towards ground.

If Q1 & 4 are switched off and Q2 & 3 are quickly switched on, the current will continue flowing rightwards through L1, but now the current will be going from ground to the caps until the energy stored in the inductor is depleted. If we repeat this process many times per second, this has the effect of charging the capacitors with power from the chassis.
By adjusting the amount of time that each MOSFET pair is on for, the maximum current in L1 can be controlled, allowing the voltage and current being transferred to be adjusted.
By reversing the switching order, current can be made to go left through the inductor, sending power from the caps to the chassis.

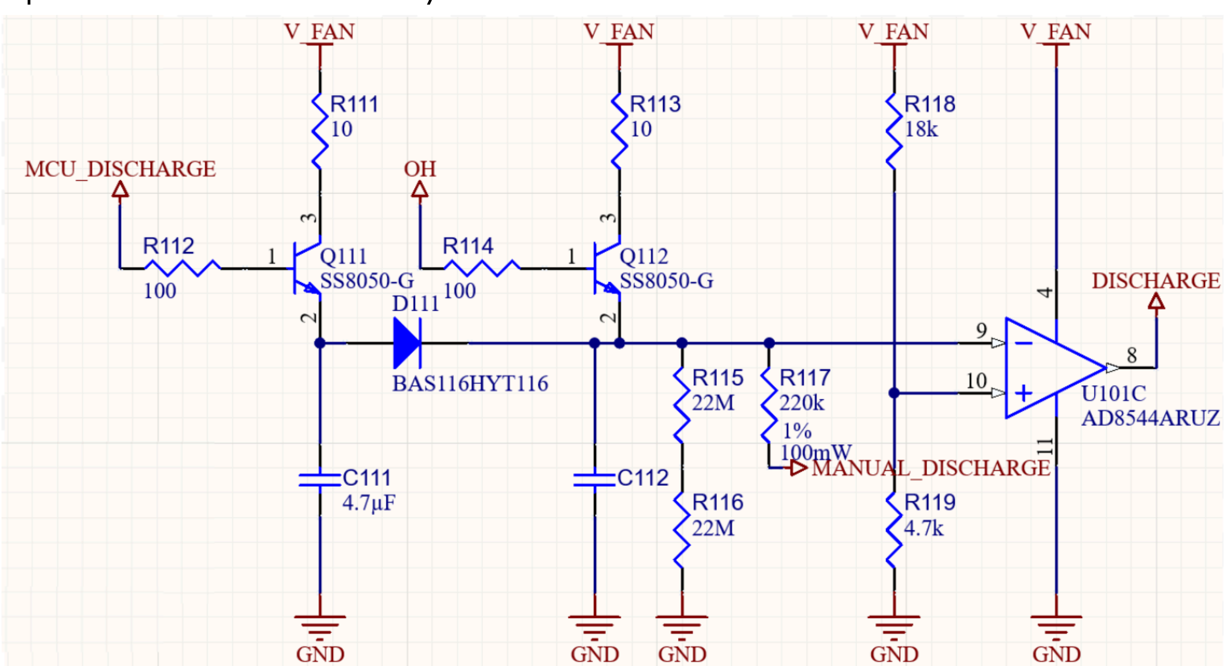
The switching of the MOSFETs is controlled by the microcontroller, which sends its signals through the MOSFET driver to drive the MOSFETs. The microcontroller is able to dynamically adjust the power transfer between the caps and the chassis to achieve optimal power useage based on various factors including the capacitor state of charge, chassis voltage, capacitor and chassis currents, maximum allowable battery current, and the robot's power demands.

<u>Discharger:</u>
There are times when all the power stored in the capacitors needs to be drained for safety reasons. Often, this needs to happen when the robot is powered off and there is no power

available to the cap bank controller apart from what is stored in the capacitors. This means we cannot just send the power to the motors like normal. This is where the discharger circuit comes in. It powers itself off of either the chassis power or the capacitors, depending on what is available, and discharges the capacitors rapidly to a safe voltage of about 5 volts by converting the capacitor energy into heat.

There is a complex analog timer circuit that performs multiple functions and determines whether the discharger is switched on or not. Timer 1 is a roughly 5-minute timer, and Timer 2 is a roughly 10-second timer. Each timer is formed by a capacitor which is normally kept fully charged, but when activated will discharge over the duration of the timer. Only when both timers are in the fully discharged state is the cap bank discharger allowed to run. When the robot is on, the microcontroller normally keeps Timer 1 charged, preventing the discharger from switching on. When either the robot is turned off or the microcontroller decides to allow discharging to occur, Timer 1 is activated, and it begins its 5-minute countdown. When Timer 1 is counting down, the user can hold the two “manual discharge” buttons to speed up the countdown to take only about 3 seconds.

Once Timer 1’s countdown is finished, the discharger is allowed to switch on. It begins discharging the supercapacitors through a transistor to limit the power of the discharge. The transistor is coupled to a heatsink, which absorbs the heat generated by the transistor and allows the cap-bank’s fan to cool it off. There is also a temperatue sensor attached to the heatsink, and if it detects the heatsink getting too hot, it holds Timer 2 high until the overheat condition has gone away. This turns off the discharger, and doesn’t let it start until 10 seconds after the overheating has stopped. This has the effect of adding some hysteresis to the overheat detection, to avoid rapid oscillation of the overheat system.



In the schematic, C111 acts as Timer 1, and C112 acts as Timer 2, with R115 and R116 acting as their discharger to form the time constant. Timer 1 feeds into Timer 2 through the low reverse leakage diode D111, and the combined output of the timers goes into U101C to be compared against a threshold voltage formed by R118 and R119 to determine whether to turn on the discharger or not. R111, R112, and Q111 form the charger for Timer 1 (controlled by the MCU), and R113, R114, and Q112 form the charger for Timer 2 (controlled by the overheat detector). R117 is the quick discharge resistor that quickly discharges the timers if the manual discharge buttons are pressed.

The semi-constant power discharger is basically a constant-current NPN transistor circuit, with an additional op-amp to linearly adjust the reference voltage based on the capacitor voltage. This has the effect of smoothing out the power dissipation of the transistor across the voltage range of the capacitors, so that the power being dissipated by the transistor is closer to the maximum allowable amount across the discharge range, to increase discharge speed while minimizing the required transistor size.

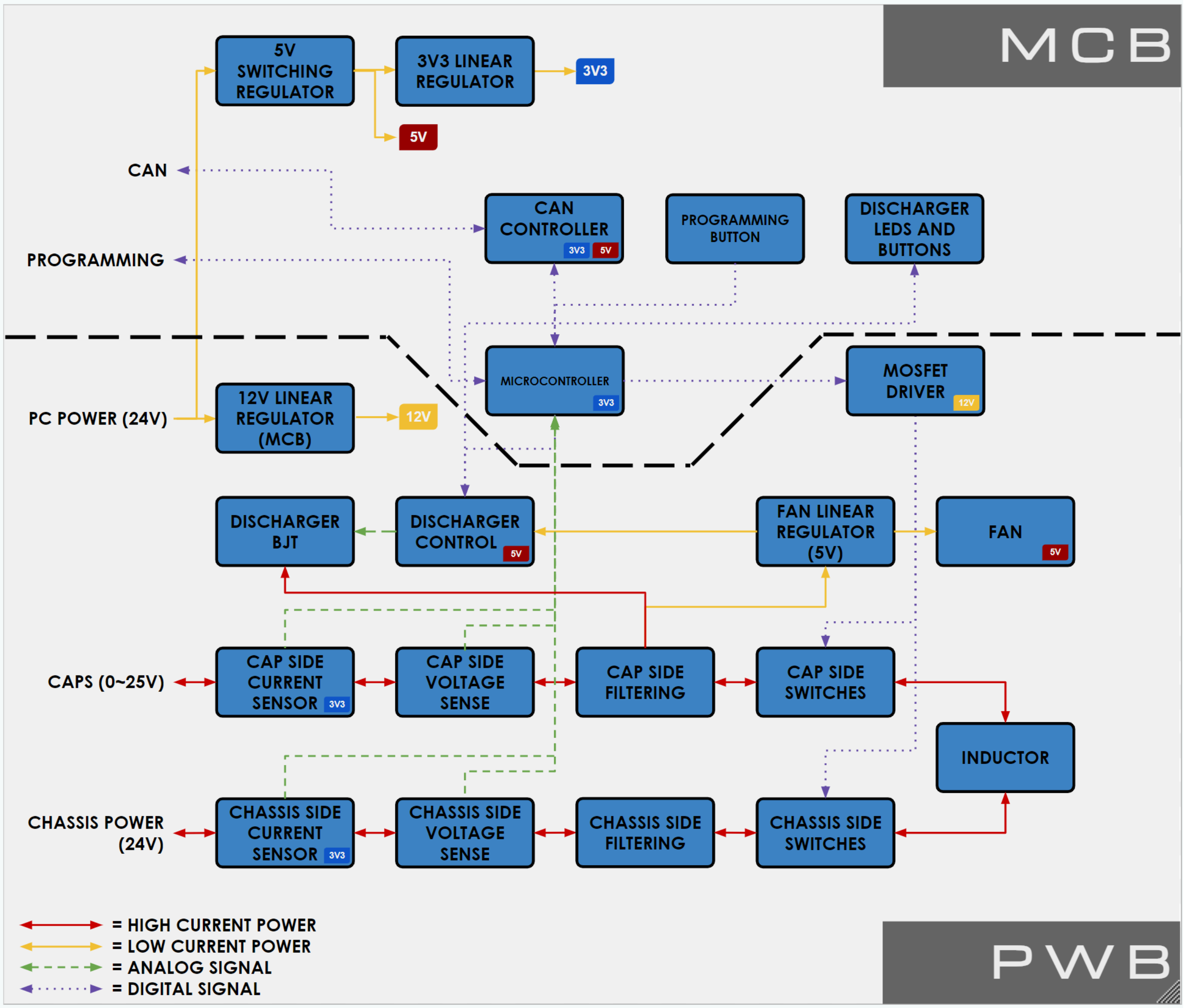
Two Board Design:

The CB4 design has been split into two separate PCBs connected by a ribbon cable. The Power Converter Board (PCB) handles all the high current tasks including the switching converter, current measurement, filtering, and discharging. The Microcontroller Board (MCB) is only low power, and has the microcontroller, CAN communication, user interface, and 5V and 3.3V logic supply regulators.

This design allows for a compact and rigid capacitor bank structure that also acts as an air guide for the cooling fan so that it can effectively cool the entirety of the cap bank circuitry. The back surface of the MCB is deviod of components in order to allow the board to act as the top cover for the cap bank on its own, without any worry of mild damage to that surface causing problems for the cap bank. This also allows the silkscreen on the board to contain most of the outward-facing information and artwork for the cap bank. Through-board SMD LEDs shine through holes in the MCB to act as indicators for power, discharge, and overheat status.

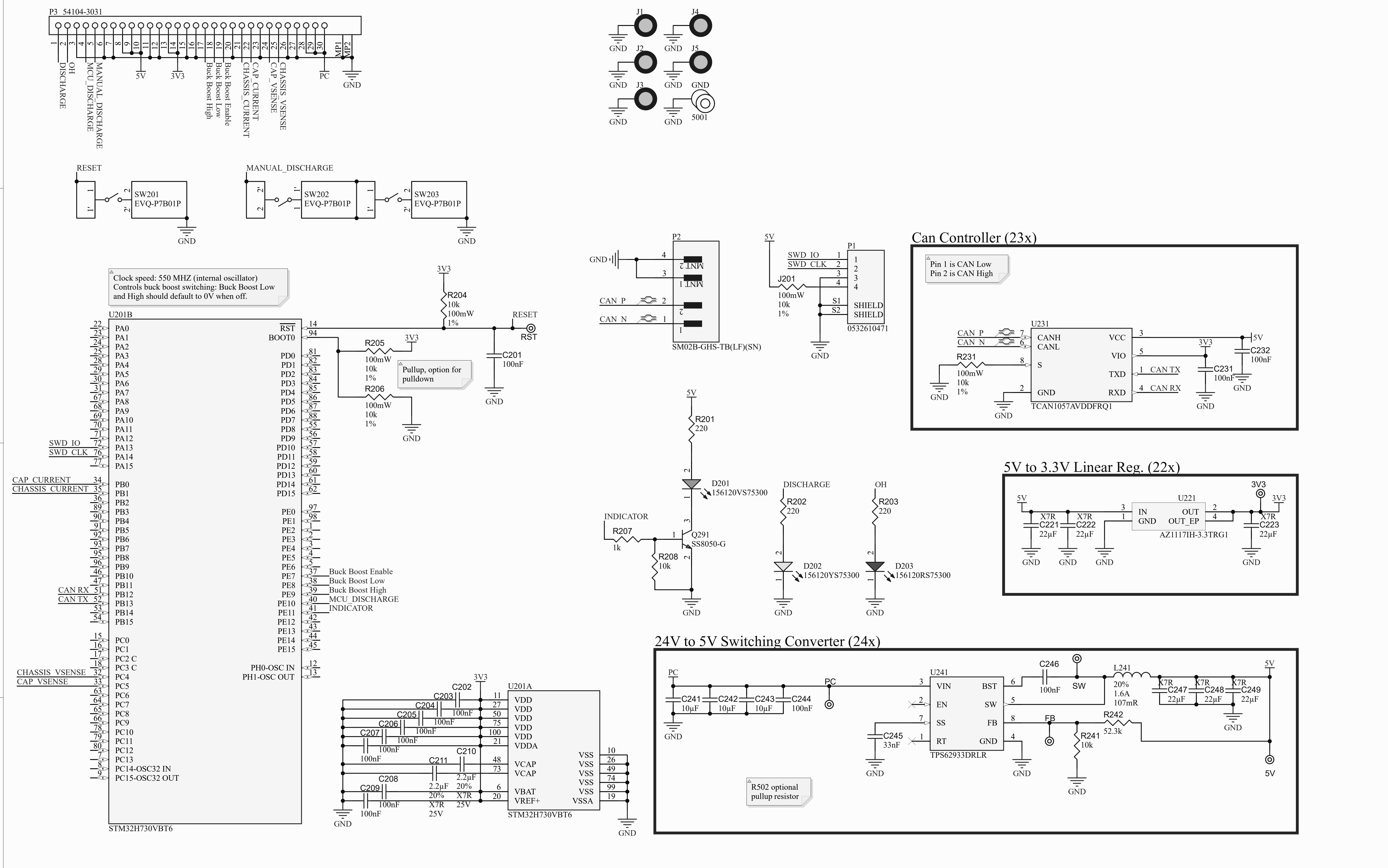
Because no large currents flow between the MCB and PCB, a thin and versatile flat flex cable can be used to connect the two boards, greatly improving manufacturability, serviceability, and size. It also allows for rapid swapping of just the PCB or MCB if one were to fail, without replacing the whole cap bank controller.

BLOCK DIAGRAM



This block diagram shows an overview of how the various power and control systems are interconnected inside of the cap bank contoller. In standard operation, the PC Power rail is derived from the Chassis Power rail through a diode to prevent backfeeding and with extra filtering to keep the logic power supplies clean.

Various connection types are indicated by their color.
The components with voltage indicators in their bottom right corners are partially or entirely powered by those voltage rails.



Title: **Main Control Board**		Author: Nikolas Faulkner	ARUW
		Approved: *	
Size: A3	Prj: Capacitor Bank V4	Edited: 3/12/2025	185 E STEVENS WAY NE
Date: 3/11/2025 5:56:19 PM	Sheet 1 of 1	Variant: [No Variations]	ECE B011 ARUW
Git Hash: d50a86d31e37cc0bb8f8f9c25517b45779a7a581		SW Version: [Not Modified] 25.3.3.18	SEATTLE, WA 98195
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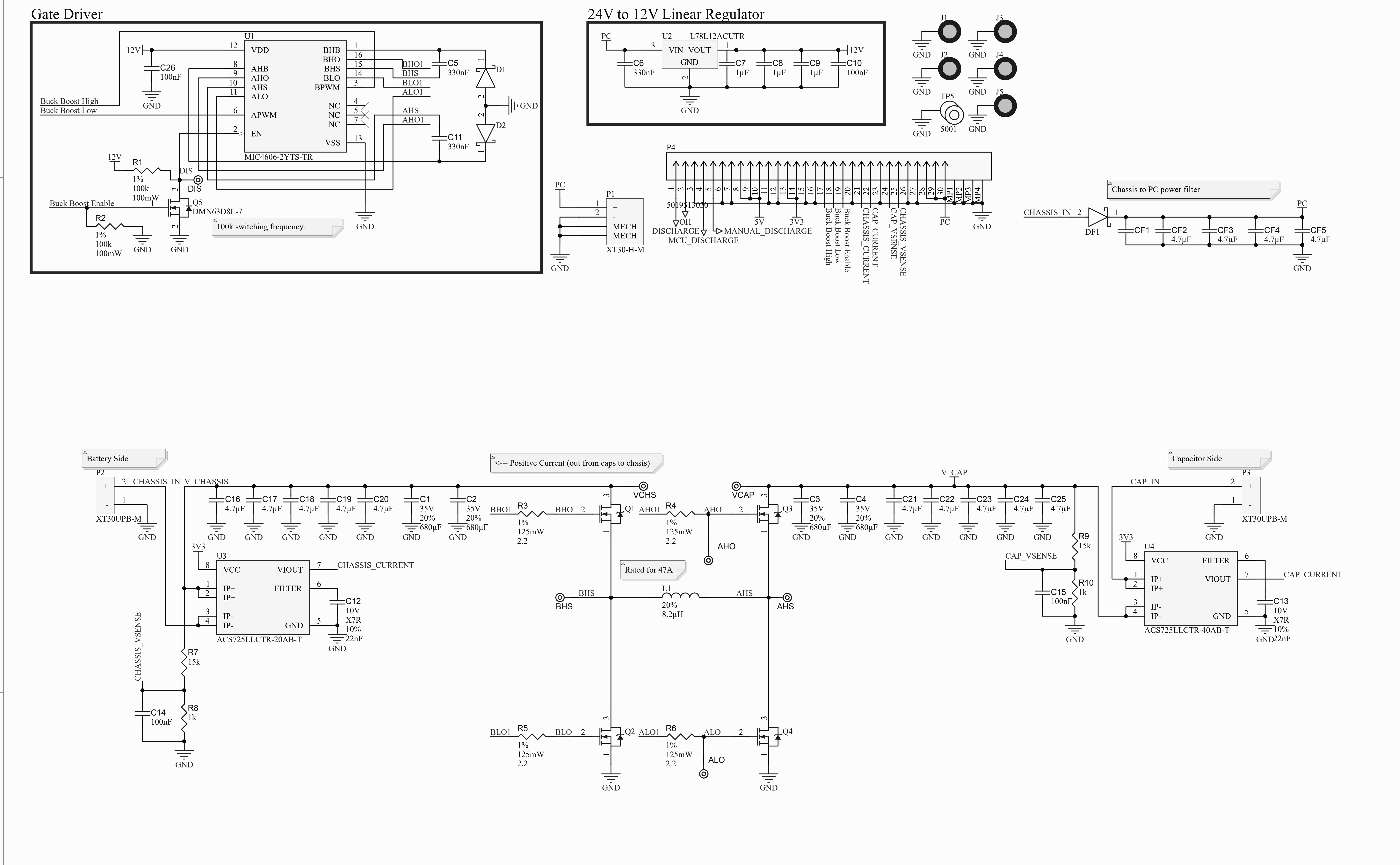

Title: Power Converter Board		Author: Nikolas Faulkner	ARUW
		Approved: *	185 E STEVENS WAY NE
Size: A3	Prj: Capacitor Bank V4	Edited: 3/12/2025	ECE B011 ARUW
Date: 3/11/2025 5:55:52 PM	Sheet 1 of 2	Variant: [No Variations]	SEATTLE, WA 98195
Git Hash: 65652c0346aacbf97d94ac6e0a912d083efd180b		SW Version: [Not Modified] 25.3.3.18	

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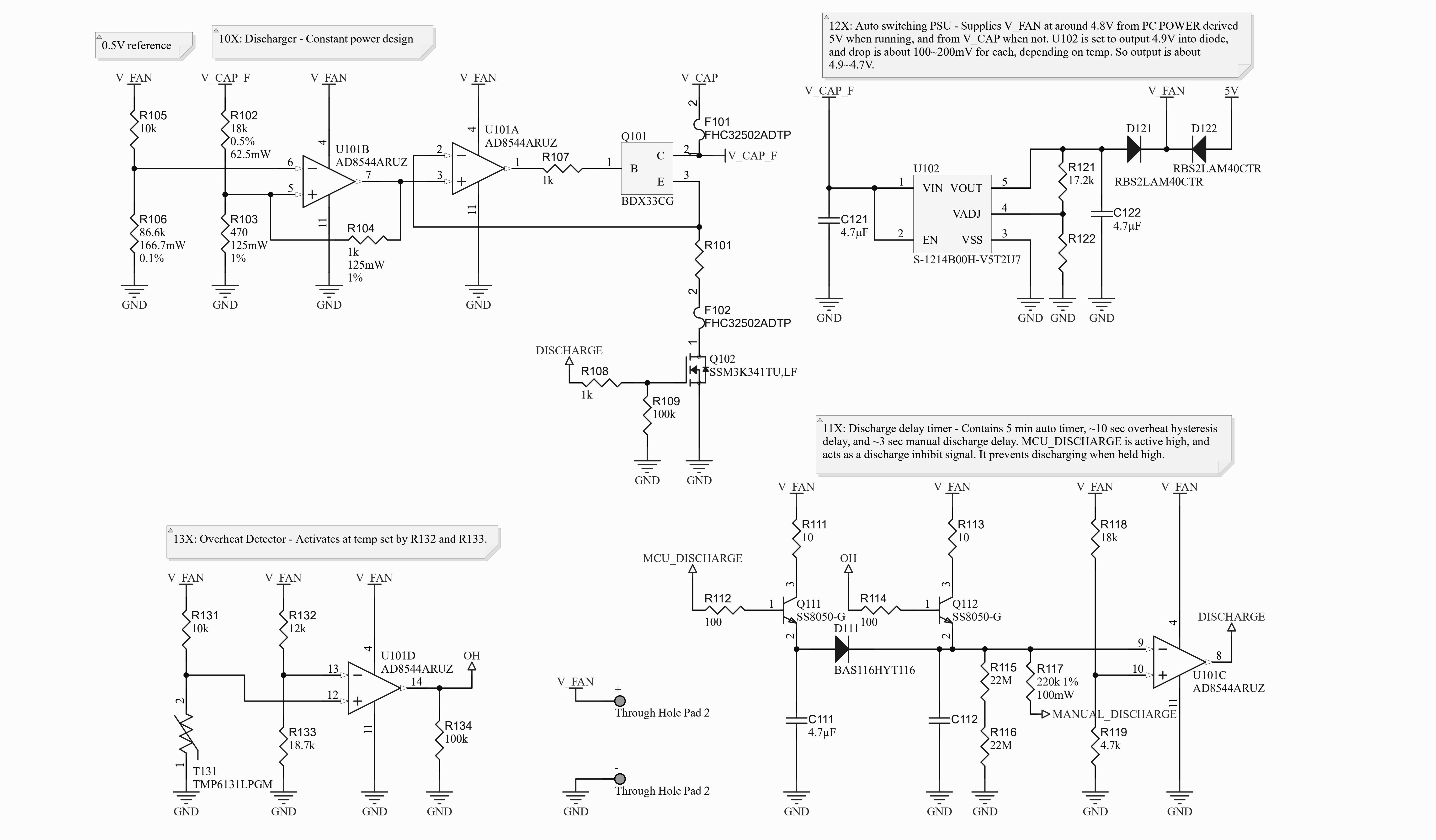
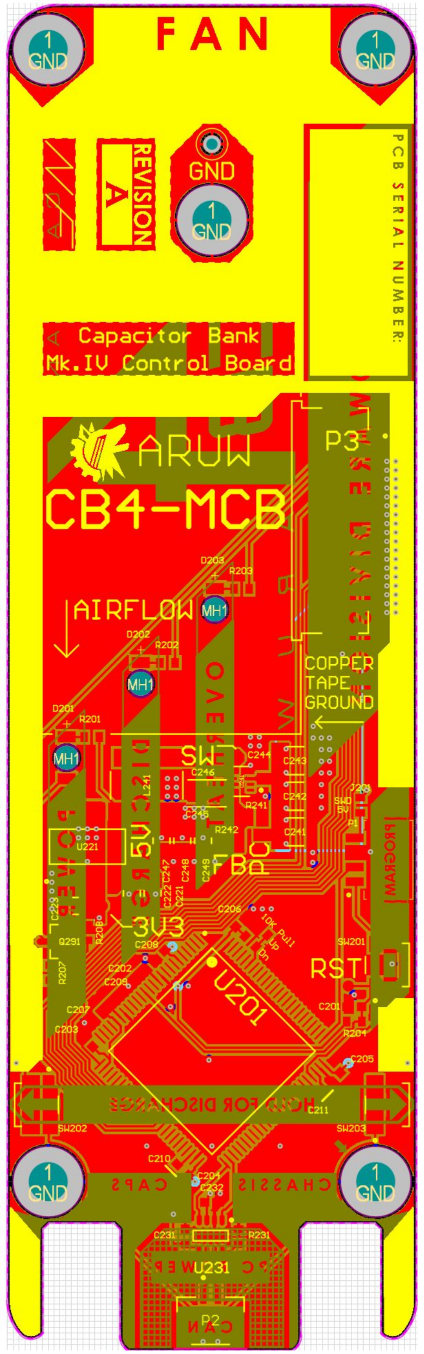


Title: *Discharger*		**Author:** Nikolas Faulkner	ARUW
		Approved: *	185 E STEVENS WAY NE
Size: A4	**Prj:**	**Edited:** 3/12/2025	ECE B011 ARUW
Date: 3/11/2025 5:55:52 PM	Sheet 2 of 2	**Variant:** [No Variations]	SEATTLE, WA 98195
Git Hash: 458c9108133b98e5f9c091d8f0eb7720a60d4e51 [Locally Modified]		**SW Version:** 25.3.3.18	
File: C:\Users\Public\Documents\Altium\Power Converter Board (CB-V4-PCB)\DischargerBoard.SchDoc			

MICROCONTROLLER BOARD

REVISION A



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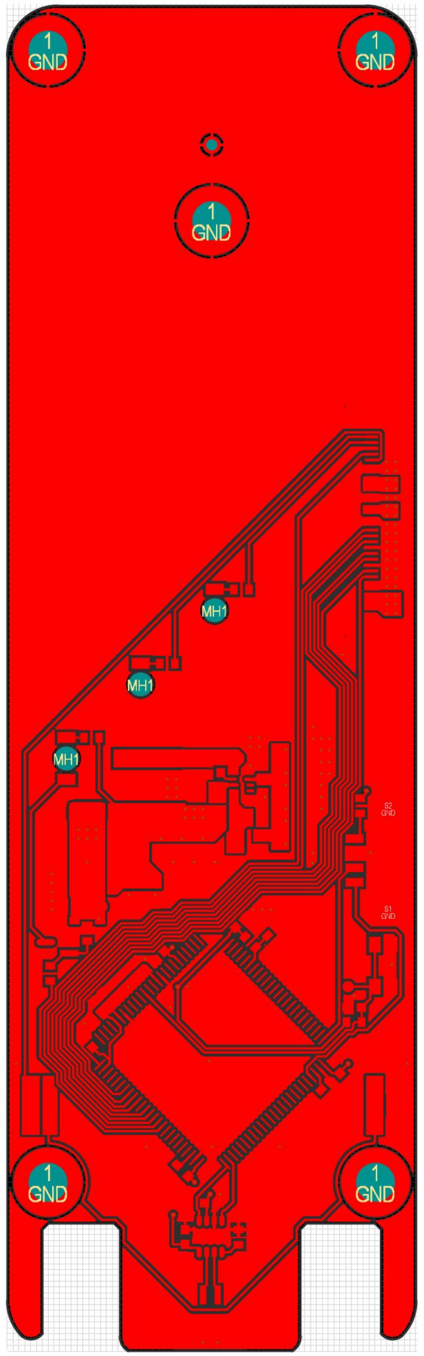
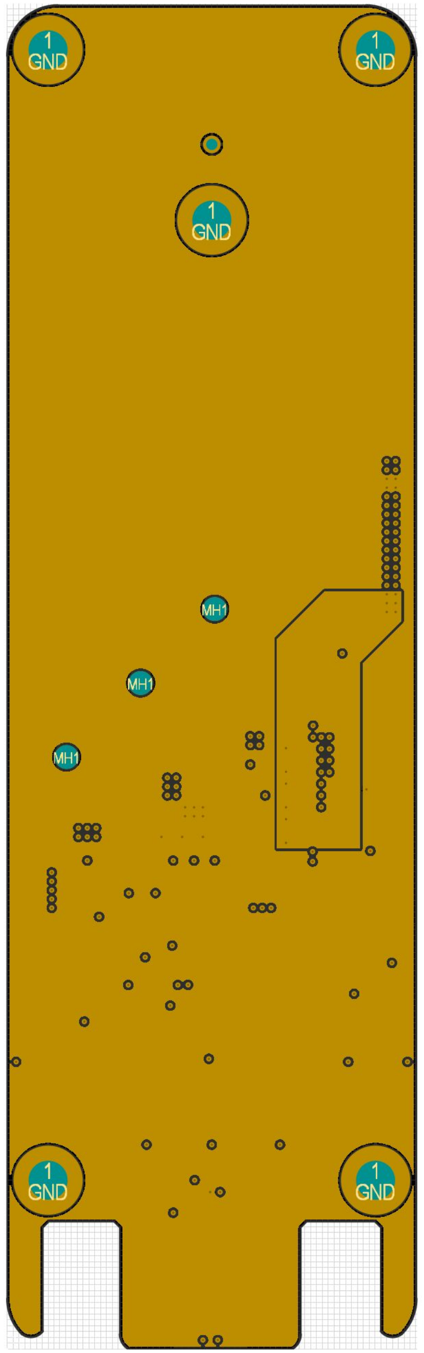
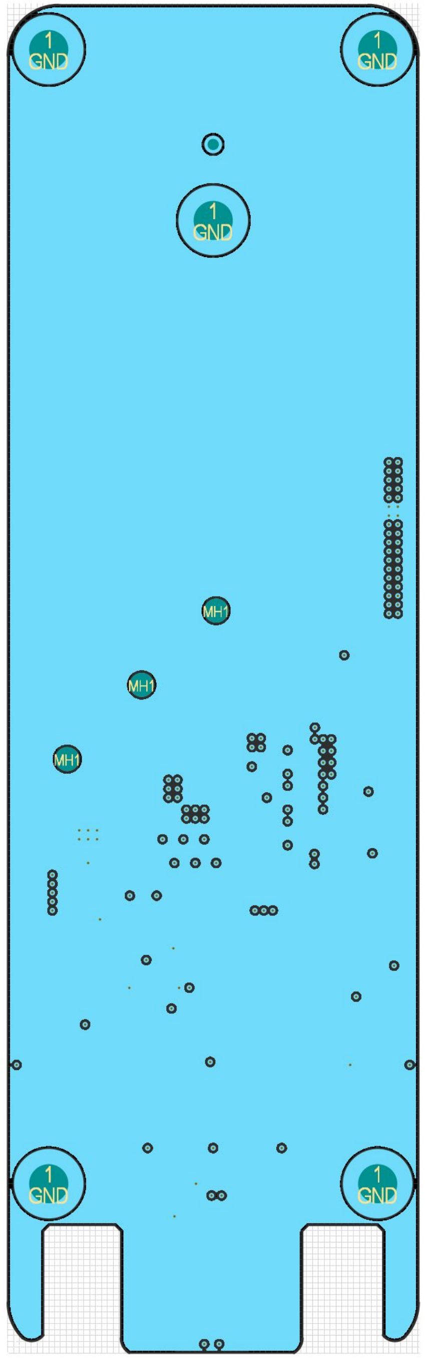


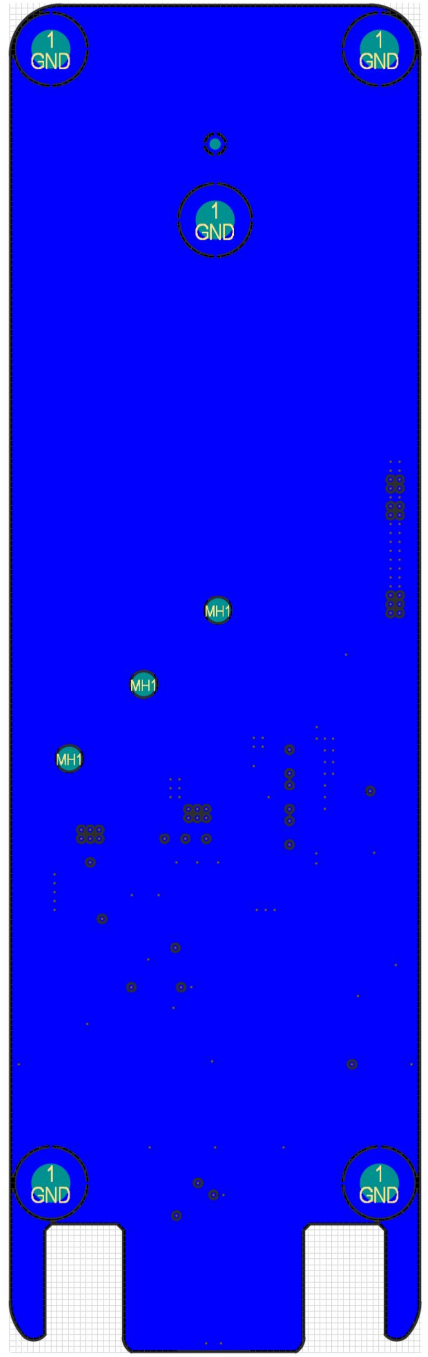
LAYER 1



LAYER 2



LAYER 3



LAYER 4

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POWER CONVERTER BOARD

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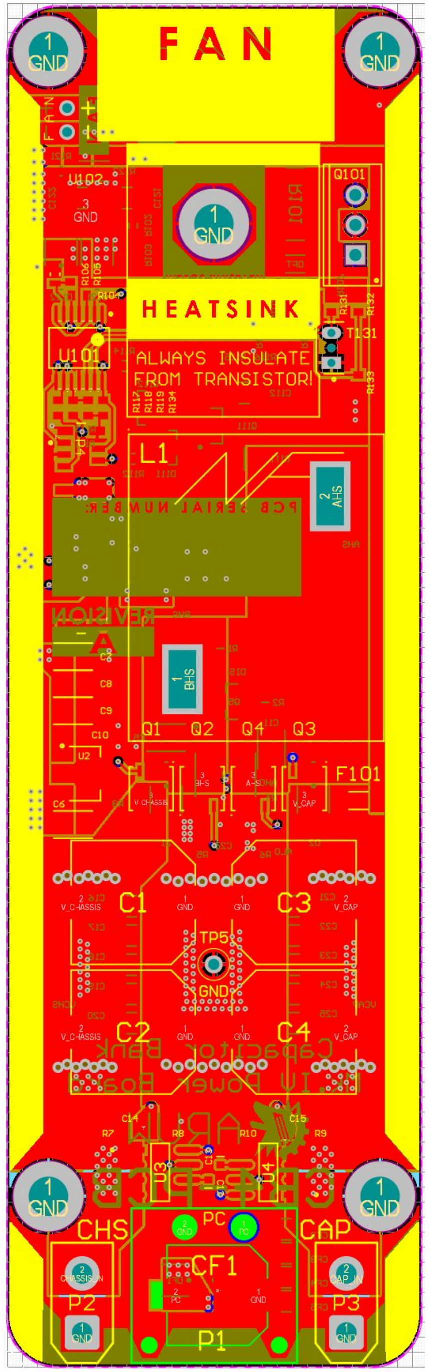

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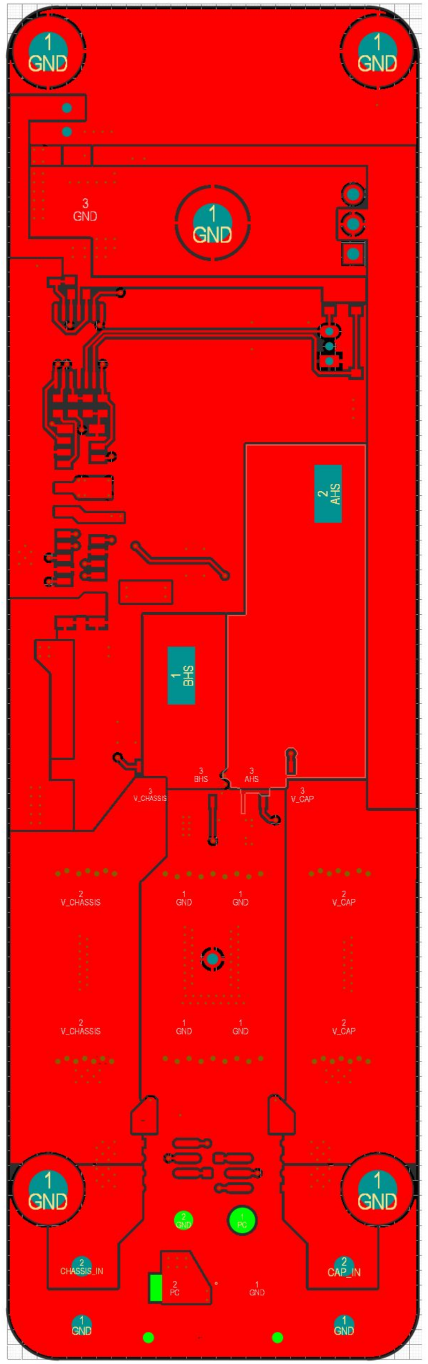
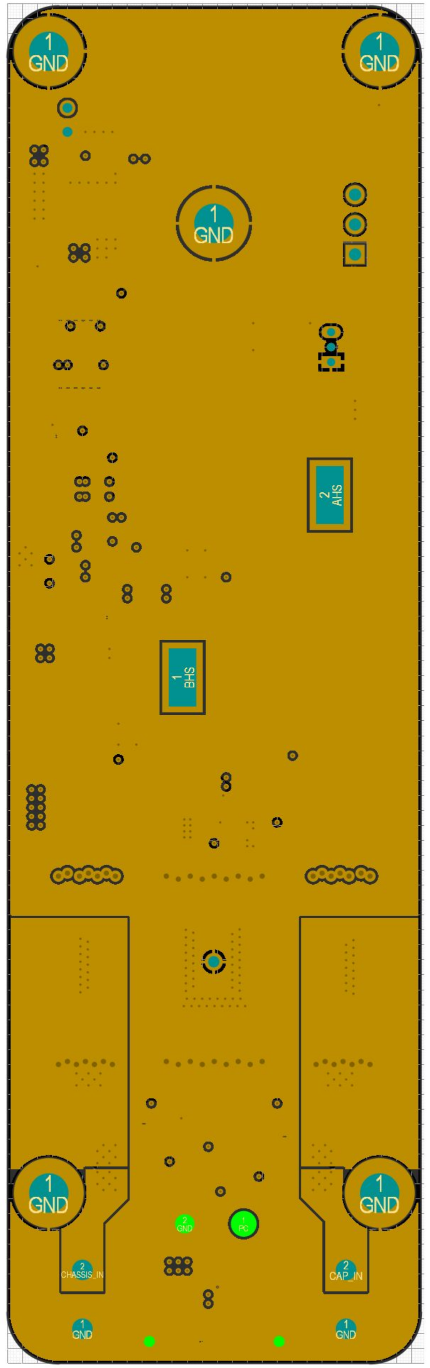

LAYER 1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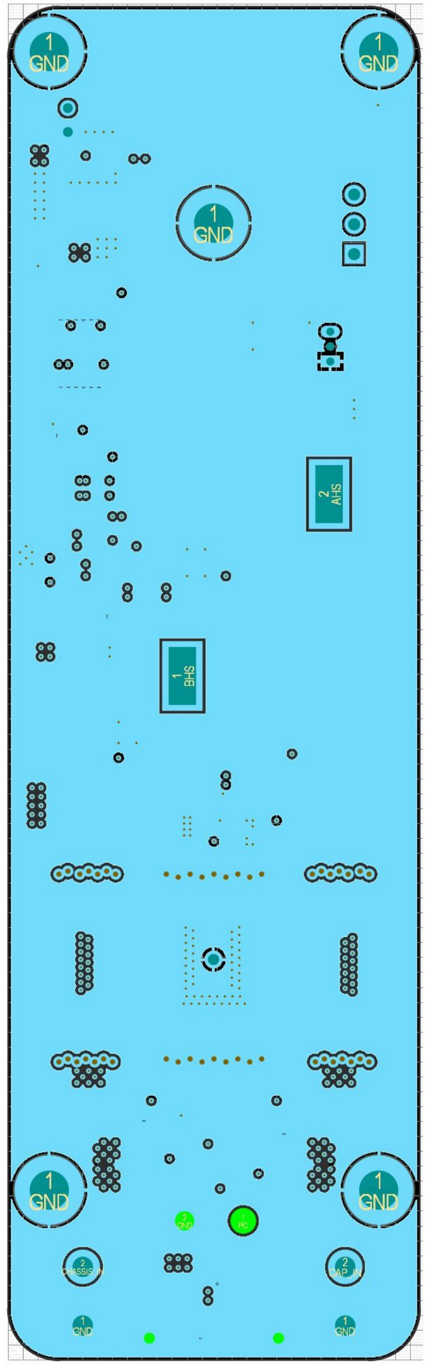
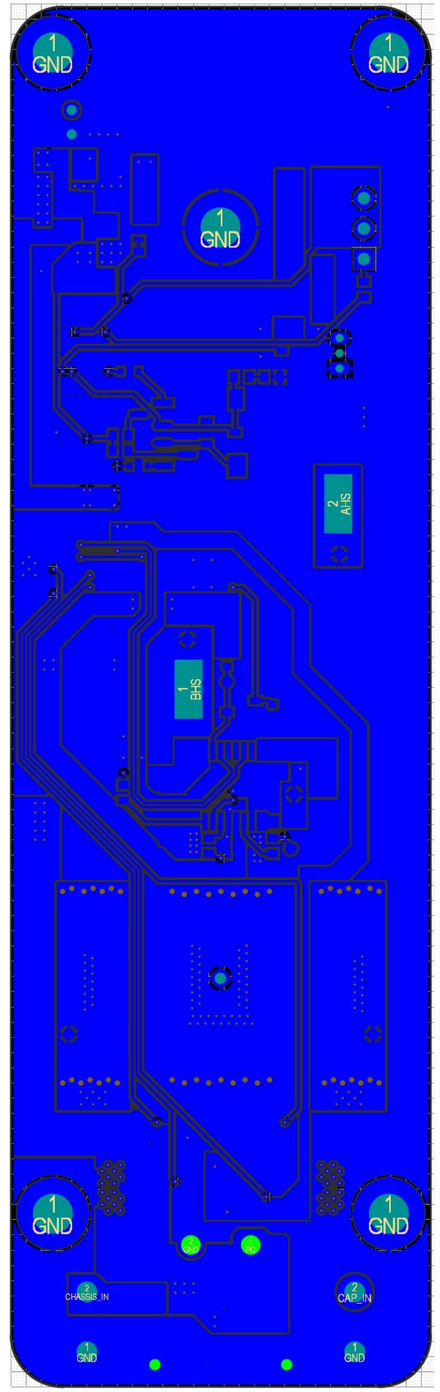
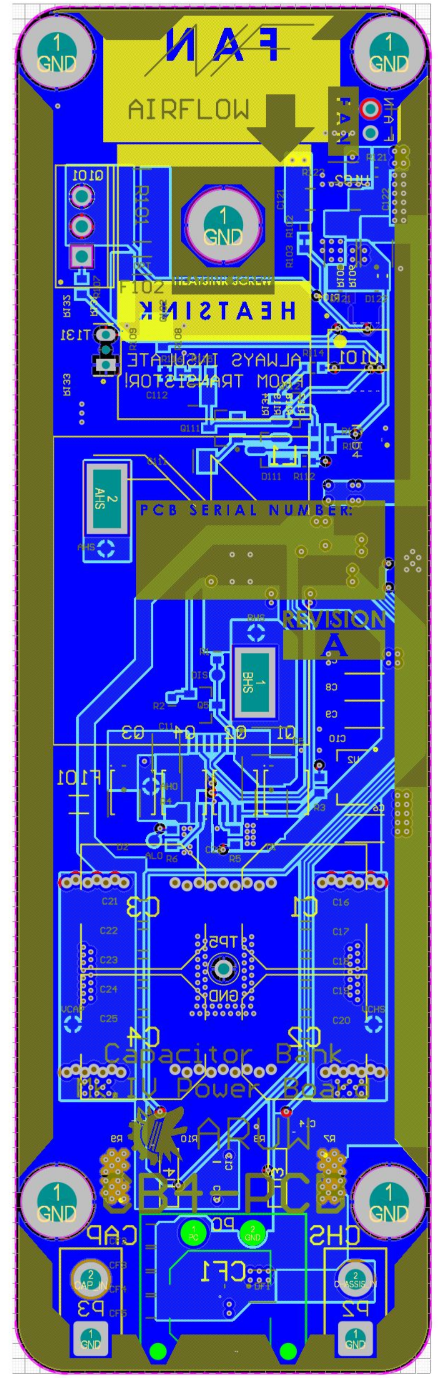

LAYER 3


LAYER 4



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Name	#	Quantity	Description	Designator	Part Number	Manufacturer
Through Hole Pad 2		2	Through Hole Pad for mounting wires	-, +		
A781MS277M1VLAS022		4	Polymer Capacitor 35V, 270uF	C1, C2, C3, C4	A781MS277M1VLAS022	KEMET
GCM219R71H334KA55J		3	Ceramic Capacitor, Multilayer, Ceramic, 50V, 10% +Tol, 10% -Tol, X7R, 15% TC, 0.33uF, Surface Mount, 0805	C5, C6, C11	GCM219R71H334KA55J	Murata
GCM21BR71H105KA03K		3	Ceramic Capacitor, Multilayer, Ceramic, 50V, 10% +Tol, 10% -Tol, X7R, 15% TC, 1uF, Surface Mount, 0805	C7, C8, C9	GCM21BR71H105KA03K	Murata
GCJ188R71H104KA12D		4	Ceramic Capacitor, Multilayer, Ceramic, 50V, 10% +Tol, 10% -Tol, X7R, 15% TC, 0.1uF, Surface Mount, 0603	C10, C14, C15, C26	GCJ188R71H104KA12D	Murata
KGM15AR71A223KT		2	Cap Cer 0.022UF 10V X7R 0603	C12, C13	KGM15AR71A223KT	Kyocera AVX
GRM31CR71H475KA12K		16	Ceramic Capacitor, Multilayer, Ceramic, 50V, 10% +Tol, 10% -Tol, X7R, 15% TC, 4.7uF, Surface Mount, 1206	C16, C17, C18, C19, C20, C21, C22, C23, C24, C25, C121, C122, CF2, CF3, CF4, CF5	GRM31CR71H475KA12K	Murata
GCG31CR71E475JA01L		1	Ceramic Capacitor, Multilayer, Ceramic, 25V, 5% +Tol, 5% -Tol, X7R, 15% TC, 4.7uF, Surface Mount, 1206	C111	GCG31CR71E475JA01L	Murata
GRM31C5C1H154JE02L		1	Ceramic Capacitor, Multilayer, Ceramic, 50V, 5% +Tol, 5% -Tol, C0G, 30ppm/Cel TC, 0.15uF, Surface Mount, 1206	C112	GRM31C5C1H154JE02L	Murata
EMZR350ARA331MHA0G		1	Aluminum Electrolytic Capacitor, Polarized, Aluminum (wet), 35V, 20% +Tol, 20% -Tol, 330uF, Surface Mount, 3333	CF1	EMZR350ARA331MHA0G	United Chemi-Con
PMEG10030ELPX		3	DIODESCHOTTKY100V3ASOD128	D1, D2, DF1	PMEG10030ELPX	Nexperia
BAS116HYT116		1	Diode Switching 100V 215mA 3-Pin SOT-23 Embossed T/R	D111	BAS116HYT116	Rohm
RBS2LAM40CTR		2	Rectifier Diode, Schottky, 1 Phase, 1 Element, 2A, 40V V(RRM), Silicon	D121, D122	RBS2LAM40CTR	Rohm
FHC32502ADTP		2	Fuse Chip Fast Acting 5A 64V SMD Solder Pad 1206 T/R UL/cUL	F101, F102	FHC32502ADTP	Mitsubishi Kamaya
PAD_WITH_HOLE_M3		5	Pad with hole for M3 screw	J1, J2, J3, J4, J5		
CPRX2520L-8R2MC		1	High Current Power Inductors	L1	CPRX2520L-8R2MC	Codaca
XT30-H-M		1	XT30 horizontal connector, male version	P1		
XT30UPB-M		2	Male XT30 Power Connector	P2, P3		

Name	#	Quantity	Description	Designator	Part Number	Manufacturer
5019513030		1	FFC/FPC Connector	P4	5019513030	Molex
BSZ040N06LS5ATMA1		4	OptiMOS™ 5 power MOSFETs logic level provide low RDS(on) in a small package, PG-TSDSON-8, RoHS	Q1, Q2, Q3, Q4	BSZ040N06LS5ATMA1	Infineon
DMN63D8L-7		1	Trans Mosfet N-ch 30V 0.35A 3-PIN SOT-23 T/r	Q5	DMN63D8L-7	Diodes
BDX33CG		1	Power Bipolar Transistor, 10A I(C), 100V V(BR)CEO, 1-Element, NPN, Silicon, TO-220AB, Plastic/Epoxy, 3 Pin	Q101	BDX33CG	ON Semiconductor
SSM3K341TU,LF		1	Trans MOSFET N-CH Si 60V 6A Automotive 3-Pin UFM T/R	Q102	SSM3K341TU,LF	Toshiba
SS8050-G		2	Trans Gp Bjt NPN 25V 1.5A 300MW 3-PIN SOT-23 T/r	Q111, Q112	SS8050-G	Comchip
RK73H1JTTD1003F		2	Fixed Resistor, Metal Glaze/thick Film, 0.1W, 100000ohm, 75V, 1% +/-Tol, 100ppm/Cel, Surface Mount, 0603	R1, R2	RK73H1JTTD1003F	KOA Speer
RK73H1JTTD2R20F		4	Fixed Resistor, Metal Glaze/thick Film, 0.125W, 2.2ohm, 75V, 1% +/-Tol, 200ppm/Cel, Surface Mount, 0603	R3, R4, R5, R6	RK73H1JTTD2R20F	KOA Speer
RK73H1JTTD1502F		2	Fixed Resistor, Metal Glaze/thick Film, 0.1W, 15000ohm, 75V, 1% +/-Tol, 100ppm/Cel, Surface Mount, 0603	R7, R9	RK73H1JTTD1502F	KOA Speer
RK73H1JTTD1001F		5	Fixed Resistor, Metal Glaze/thick Film, 0.125W, 1000ohm, 75V, 1% +/-Tol, 100ppm/Cel, Surface Mount, 0603	R8, R10, R104, R107, R108	RK73H1JTTD1001F	KOA Speer
KRL6432E-C-R150-F-T5		1	KRL6432E-C-R150-F-T5	R101	KRL6432E-C-R150-F-T5	Susumu
RR0816P-183-D		1	Fixed Resistor, Thin Film, 0.0625W, 18000ohm, 75V, 0.5% +/-Tol, 25ppm/Cel, Surface Mount, 0603	R102	RR0816P-183-D	Susumu
RK73H1JTTD4700F		1	Fixed Resistor, Metal Glaze/thick Film, 0.125W, 470ohm, 75V, 1% +/-Tol, 100ppm/Cel, Surface Mount, 0603	R103	RK73H1JTTD4700F	KOA Speer
RK73H1JTTD1002F		2	Fixed Resistor, Metal Glaze/thick Film, 0.1W, 10000ohm, 75V, 1% +/-Tol, 100ppm/Cel, Surface Mount, 0603	R105, R131	RK73H1JTTD1002F	KOA Speer
RG1608P-8662-B-T5		1	Fixed Resistor, Thin Film, 0.1W, 86600ohm, 100V, 0.1% +/-Tol, 25ppm/Cel, Surface Mount, 0603	R106	RG1608P-8662-B-T5	Susumu

Name	#	Quantity	Description	Designator	Part Number	Manufacturer
RK73H1JTTD1003F		2	Fixed Resistor, Metal Glaze/thick Film, 0.1W, 100000ohm, 75V, 1% +/-Tol, 100ppm/Cel, Surface Mount, 0603	R109, R134	RK73H1JTTD1003F	KOA Speer
RK73H1JTTD10R0F		2	Fixed Resistor, Metal Glaze/thick Film, 0.125W, 10ohm, 75V, 1% +/-Tol, 100ppm/Cel, Surface Mount, 0603	R111, R113	RK73H1JTTD10R0F	KOA Speer
RK73H1JTTD1000F		2	Fixed Resistor, Metal Glaze/thick Film, 0.125W, 100ohm, 75V, 1% +/-Tol, 100ppm/Cel, Surface Mount, 0603	R112, R114	RK73H1JTTD1000F	KOA Speer
RK73B1JTTD226J		2	Fixed Resistor, Metal Glaze/thick Film, 0.1W, 22000000ohm, 75V, 5% +/-Tol, 400ppm/Cel, Surface Mount, 0603	R115, R116	RK73B1JTTD226J	KOA Speer
RK73H1JTTD2203F		1	Fixed Resistor, Metal Glaze/thick Film, 0.1W, 220000ohm, 75V, 1% +/-Tol, 100ppm/Cel, Surface Mount, 0603	R117	RK73H1JTTD2203F	KOA Speer
RK73H1JTTD1802F		1	Fixed Resistor, Metal Glaze/thick Film, 0.1W, 18000ohm, 75V, 1% +/-Tol, 100ppm/Cel, Surface Mount, 0603	R118	RK73H1JTTD1802F	KOA Speer
RK73H1JTTD4701F		1	Fixed Resistor, Metal Glaze/thick Film, 0.1W, 4700ohm, 75V, 1% +/-Tol, 100ppm/Cel, Surface Mount, 0603	R119	RK73H1JTTD4701F	KOA Speer
RN73H1JTTD1722B25		1	Fixed Resistor, Thin Film, 0.1W, 17200ohm, 75V, 0.1% +/-Tol, 25ppm/Cel, Surface Mount, 0603	R121	RN73H1JTTD1722B25	KOA Speer
RN73R1JTTD1002D25		1	Fixed Resistor, Thin Film, 0.1W, 10000ohm, 75V, 0.5% +/-Tol, 25ppm/Cel, Surface Mount, 0603	R122	RN73R1JTTD1002D25	KOA Speer
RK73H1JTTD1202F		1	Fixed Resistor, Metal Glaze/thick Film, 0.1W, 12000ohm, 75V, 1% +/-Tol, 100ppm/Cel, Surface Mount, 0603	R132	RK73H1JTTD1202F	KOA Speer
RK73H1JTTD1872F		1	Fixed Resistor, Metal Glaze/thick Film, 0.1W, 18700ohm, 75V, 1% +/-Tol, 100ppm/Cel, Surface Mount, 0603	R133	RK73H1JTTD1872F	KOA Speer
TMP6131LPGM		1	Analog Circuit, 1 Func	T131	TMP6131LPGM	Texas Instruments
5001		1	Interconnection Device	TP5	5001	Keystone Electronics
MIC4606-2YTS-TR		1	Full Bridge Based MOSFET Driver, 1A, PDSO16	U1	MIC4606-2YTS-TR	Microchip
L78L12ACUTR		1	Fixed Positive Standard Regulator, 12VBIPolar, PSSO3	U2	L78L12ACUTR	ST Microelectronics

Name	#	Quantity	Description	Designator	Part Number	Manufacturer
ACS725LLCTR-20AB-T		1	Analog Circuit, 1 Func, BICMOS, PDSO8	U3	ACS725LLCTR-20AB-T	Allegro MicroSystems
ACS725LLCTR-40AB-T		1	Analog Circuit, 1 Func, BICMOS, PDSO8	U4	ACS725LLCTR-40AB-T	Allegro MicroSystems
LMV324IPT		1	Operational Amplifier, 4 Func, 7000uV Offset-Max, CMOS, PDSO14	U101	LMV324IPT	ST Microelectronics
S-1214B00H-V5T2U7		1	LDO Regulator Pos 1.8V to 30V 1A 5-Pin (4+Tab) TO-252-S	U102	S-1214B00H-V5T2U7	ABLIC
GCJ188R71H104KA12D		13	Ceramic Capacitor, Multilayer, Ceramic, 50V, 10% +Tol, 10% -Tol, X7R, 15% TC, 0.1uF, Surface Mount, 0603	C201, C202, C203, C204, C205, C206, C207, C208, C209, C231, C232, C244, C246	GCJ188R71H104KA12D	Murata
GRM188Z71E225ME43D		2	Ceramic Capacitor, Multilayer, Ceramic, 25V, 20% +Tol, 20% -Tol, X7R, 15% TC, 2.2uF, Surface Mount, 0603	C210, C211	GRM188Z71E225ME43D	Murata
GRM21BZ71A226ME15L		6	Ceramic Capacitor, Multilayer, Ceramic, 10V, 20% +Tol, 20% -Tol, X7R, 15% TC, 22uF, Surface Mount, 0805	C221, C222, C223, C247, C248, C249	GRM21BZ71A226ME15L	Murata
GRJ32ER71H106KE11L		3	Ceramic Capacitor, Multilayer, Ceramic, 50V, 10% +Tol, 10% -Tol, X7R, 15% TC, 10uF, Surface Mount, 1210	C241, C242, C243	GRJ32ER71H106KE11L	Murata
GCD21BR71H333KA01L		1	Ceramic Capacitor, Multilayer, Ceramic, 50V, 10% +Tol, 10% -Tol, X7R, 15% TC, 0.033uF, Surface Mount, 0805	C245	GCD21BR71H333KA01L	Murata
156120VS75300		1	Single Color LED, Bright Green, Water Clear	D201	156120VS75300	Wurth Electronics
156120YS75300		1	Single Color LED	D202	156120YS75300	Wurth Electronics
156120RS75300		1	Single Color LED	D203	156120RS75300	Wurth Electronics
5001		1	Interconnection Device	GND	5001	Keystone Electronics
PAD_WITH_HOLE_M3		5	Pad with hole for M3 screw	J1, J2, J3, J4, J5		
RK73H1JTTD1002F		7	Fixed Resistor, Metal Glaze/thick Film, 0.1W, 10000ohm, 75V, 1% +/-Tol, 100ppm/Cel, Surface Mount, 0603	J201, R204, R205, R206, R208, R231, R241	RK73H1JTTD1002F	KOA Speer
NRS6045T220MMGK		1	General Purpose Inductor, 22uH, 20%, 1 Element, SMD, 2424	L241	NRS6045T220MMGK	Taiyo Yuden
0532610471		1	Picoblade Connector, 4 Circuit Single Row, Right Angle Surface Mount SMT PCB	P1		

Name	#	Quantity	Description	Designator	Part Number	Manufacturer
SM02B-GHS-TB(LF)(SN)		1	CONN HEADER GH SIDE 2POS 1.25 MM	P2	SM02B-GHS-TB(LF)(SN)	JST
54104-3031		1	FFC/FPC Connector, 30 Contact(s), 1 Row(s), Female, Right Angle, 0.02 inch Pitch, Surface Mount Terminal, Locking, White Insulator	P3	54104-3031	Molex
SS8050-G		1	Trans Gp Bjt NPN 25V 1.5A 300MW 3-PIN SOT-23 T/r	Q291	SS8050-G	Comchip
RK73H1JTTD2200F		3	Fixed Resistor, Metal Glaze/thick Film, 0.125W, 220ohm, 75V, 1% +/-Tol, 100ppm/Cel, Surface Mount, 0603	R201, R202, R203	RK73H1JTTD2200F	KOA Speer
RK73H1JTTD1001F		1	Fixed Resistor, Metal Glaze/thick Film, 0.125W, 1000ohm, 75V, 1% +/-Tol, 100ppm/Cel, Surface Mount, 0603	R207	RK73H1JTTD1001F	KOA Speer
RMCF0603FT52K3		1	Fixed Resistor, Metal Glaze/thick Film, 0.1W, 52300ohm, 75V, 1% +/-Tol, 100ppm/Cel, Surface Mount, 0603	R242	RMCF0603FT52K3	Stackpole Electronics
EVQ-P7B01P		3	Switch Tactile N.O. SPST Rectangular Button J-Bend 0.05A 12VDC 2.2N SMD T/R	SW201, SW202, SW203	EVQ-P7B01P	Panasonic
STM32H730VBT6		1	RISC Microcontroller	U201	STM32H730VBT6	ST Microelectronics
AZ1117IH-3.3TRG1		1	Fixed Positive LDO Regulator, 3.3V, 1.3V Dropout, PDSO3	U221	AZ1117IH-3.3TRG1	Diodes
TCAN1057AVDDFRQ1		1	Enhanced automotive CAN transceiver with silent and 1.8-V I/O support 8-SOT-23-THIN -40 to 150	U231	TCAN1057AVDDFRQ1	Texas Instruments
TPS62933DRLR		1	3.8-V to 30-V, 3-A, 200-kHz to 2.2-MHz, low-IQ synchronous buck converter in SOT-583 package 8-SOT-5X3 -40 to 150	U241	TPS62933DRLR	Texas Instruments

ASSEMBLY

⚠ Soldering the boards and assembling the cap bank controller should be done with great care to avoid bridging contacts, overheating components, losing parts, or incorrectly installing components. Any mistake at this step can cost a significant amount of money and may even be dangerous.

SOLDERING THE POWER CONVERTER BOARD

Begin by applying solder paste to every surface mount solder pad on the back side of the board. Then proceed to mount every component on the back side of the board, except for the fuse F102.

⚠ F 102 can be omitted and replaced with a wire shunt ONLY if fuse F101 is installed correctly.

Reflow solder the board using the standard profile on the reflow oven.

After the board has cooled down, check for any bridged or broken connections, and manually fix any issues using a soldering iron. Flip the board over and apply solder paste to every surface mount pad except for those for the connector P4 and capacitors C1~ C4 and CF1.

Mount every surface mount component on the front side of the board except for connector P4, fuse F101, and capacitors C1~ C4 and CF1. Reflow solder the board using the standard profile on the reflow oven. Be careful when mounting the board in the oven to ensure that the components on the bottom of the board will not be disturbed. It is recommended to raise the board up on something to prevent the bottom components of the board from coming into contact with the reflow oven tray.

Immediately after the reflow cycle has concluded, leave the board in the drawer of the reflow oven and quickly apply solder paste to the pads for C1~ C4 and CF1 and install the capacitors. Insert the board into the oven and start another reflow cycle, while monitoring the solder joints on the capacitors. Once the solder has melted, wait 5 seconds and then stop the reflow cycle and pull out the drawer to allow the boad to cool.

After the board has cooled down, check for any bridged or broken connections, and manually fix any issues using a soldering iron.

Install the fuses F101 (mandatory) and F102 (optional) by using a soldering iron at a low temperature of about 250°C. Heat up one tinned pad, then install one end of the fuse and quickly remove the iron to avoid overheating the fuse. Then melt the solder of the other pad to solder the fuse in fully.

Manually install the ribbon cable connector P4 by applying solder paste, positioning the connector, and drag soldering it into place using the soldering iron at about 250°C. Check with the multimeter for shorts or loose connections.

Install the through-hole components such as the XT30 connectors, discharge transistor, and thermistor using the soldering iron. When soldering the transistor and thermistor, temporarly install the heatsink and align the parts so that they lay flat against the heatsink's surface and the mounting hole of the transistor lines up with the threaded hole in the heatsink. Proceed to solder in the components using the soldering iron set to about 350°C.

When installing the XT30 connectors, it can be helpful to apply a small amount of solder to the joint first and hold the iron there for a few seconds to allow the metal to heat up, and then apply the rest of the solder to achieve a smooth solder joint.

Install the inductor using either the soldering iron at its max temperature setting, or using a high-power solder gun. use the iron to heat up the lead of the inductor and pad for 15~30 seconds before attempting to add the rest of the solder.

Perform a final check of every solder joint to check for loose or shorted connections.

SOLDERING THE MICROCONTROLLER BOARD

Begin by applying solder paste to every surface mount solder pad on the front side of the board, except the pads for the ribbon cable connector P3. Then proceed to mount every component on the front side of the board except for connector P3. Make especially certain that the microcontroller is mounted correctly and as precicely as possible. Also ensure the LEDs are pointing downwards through the board.

Reflow solder the board using the standard profile on the reflow oven.

After the board has cooled down, check for any bridged or broken connections, and manually fix any issues using a soldering iron.

Manually install the ribbon cable connector P3 by applying solder paste, positioning the connector, and drag soldering it into place using the soldering iron at about 250°C. Check with the multimeter for shorts or loose connections.

Perform a final check of every solder joint to check for loose or shorted connections.

PRINTING CASE PARTS

The 3D printed parts should be manufactured from a rigid material that does not give off dangerous fumes or lose significant structural strength when heated to 120°C.

The fan bumper would ideally be made from a softer material such as TPU, but the temperature resistance is the most important factor.

When printing the central frame piece, make sure to orient the part horizontally with the button tabs at the top.

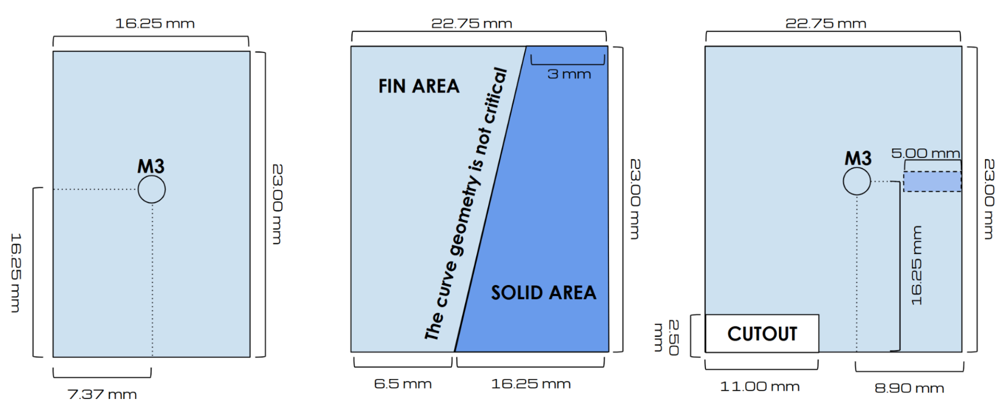
After printing the components, do a test fit of the assembled boards to make sure that the boards and fan fit as they should, the buttons on the MCU can be actuated, and the ports are accessible.

Install two M3X4 threaded inserts into the bottom frame piece into the corner holes as indicated in this diagram:

Install the threaded inserts from the flat side of the part to achieve a stronger part. Ensure the inserts are installed flush with both sides of the part, and remove any plastic that is pushed out of the hole using flush clippers.

HEATSINK

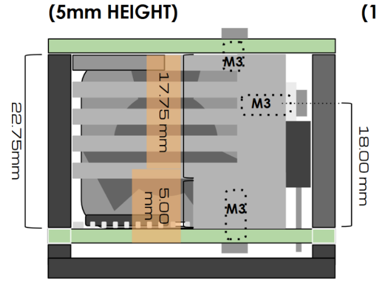
The heatsink should be manufactured from aluminium or copper, and should follow the dimensions shown here:



LOWER SECTION (5mm HEIGHT)

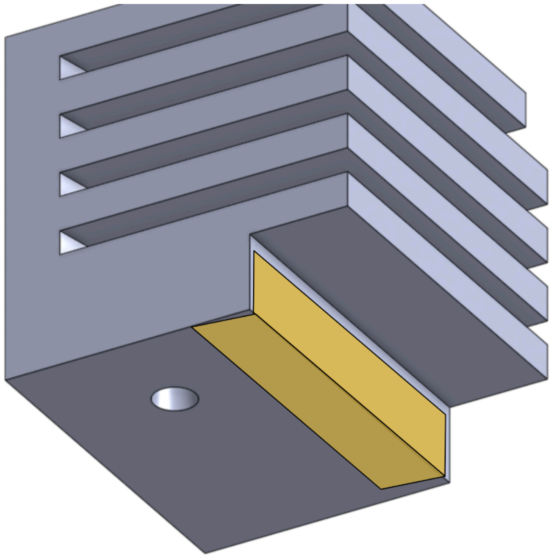
FIN SECTION (17.75mm HEIGHT)

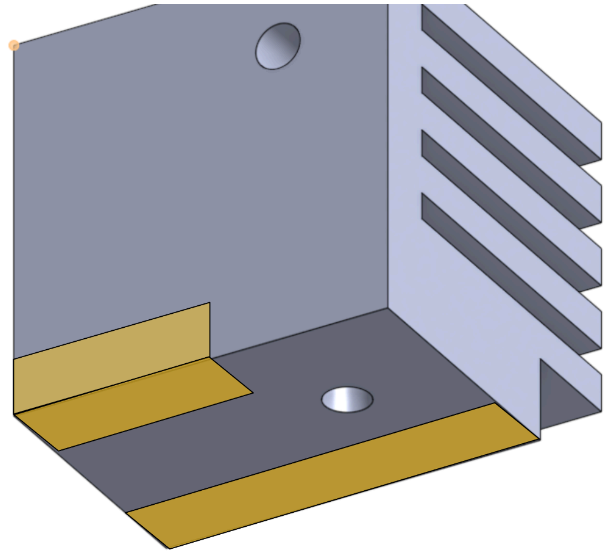
TOPMOST FIN (PART OF FIN SECTION)



DIMENSIONS ARE FROM LOOKING DOWN FROM TOP

Before installing the heatsink, apply pieces of Kapton (polyamide) tape to the bottom of the heatsink as shown in the illustration.





When installing the heatsink, hold it in place on the power converter board and install the thermal isolation pad between the heatsink and the discharger transistor. Apply a small amount of thermal grease between the pad and heatsink, and between the transistor and pad.
Install the screw (M3X5) with its insulation collar through the transistor and into the heatsink. Do not tighten it all the way yet.

⚠ Make sure the insulation collar and pad are properly installed, and there is no continuity from any pin on the transistor to the heatsink!

Make sure the heatsink is positioned exactly where it should be, then Install the heatsink mounting screw (M3X5) from the bottom of the Power Converter Board and tighten it down.

Tighten down the transistor screw, being careful not to crush the insulation collar, and apply thermal glue to the backside of the thermistor and press it against the heatsink. Use Kapton tape and/or a clamp to hold it in place against the heatsink, and leave the glue to cure for at least 2 hours. Once the glue has cured, apply Kapton tape to the back of the thermistor if there isn't any already.

BOARD ASSEMBLY

Prior to testing:
PWB sits on top of the lower panel. Fan, heatsink, and ribbon cable are installed on the PCB, with heatsink held onto board with M3X5 screw. Midframe is fitted over the PCB. Ribbon cable is pluged into the MCB, and copper tape is connected to grounding point. MCB is put into service position and held in place with one M3X30 screw.

Final assembly:

PWB sits on top of the lower panel. Fan, heatsink, and ribbon cable are installed on the PCB, with heatsink held onto board with M3X5 screw. Midframe is fitted over the PCB. Ribbon cable is pluged into the MCB, and copper tape is connected to grounding point. MCB is fully installed on cap bank and held in place with two M3X30 screws through holes not marked with arrows, and M3X5 screw through top heatsink hole. Cap Bank is mounted onto robot with two M3X35 screws through holes marked with arrows.

INSTALLING THE FAN

The 3D printed fan spacer should be manufactured from a rigid material that does not give off dangerous fumes or lose significant structural strength when heated to 120°C.

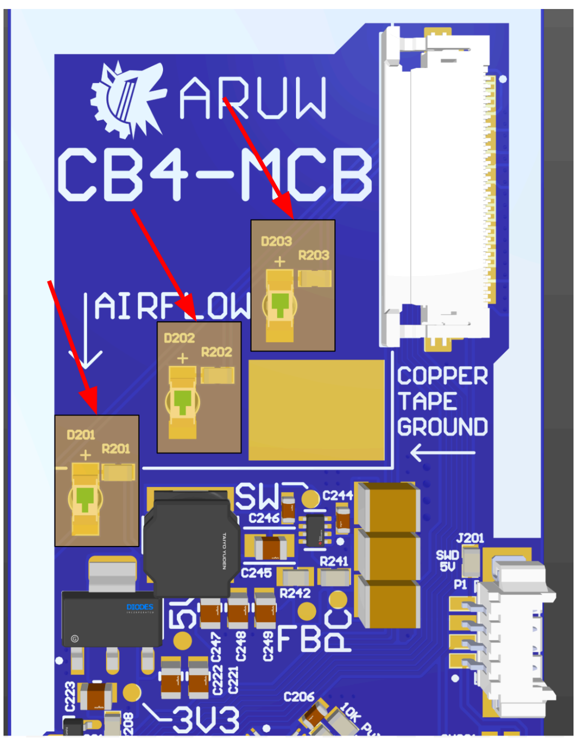
Press the fan spacer onto the side of the fan without the label, making sure the corner without the mounting pin corresponds with the corner of the fan where the wires are kept.

Tuck the fan wires into the spacer so that they are guided along the side of the fan.

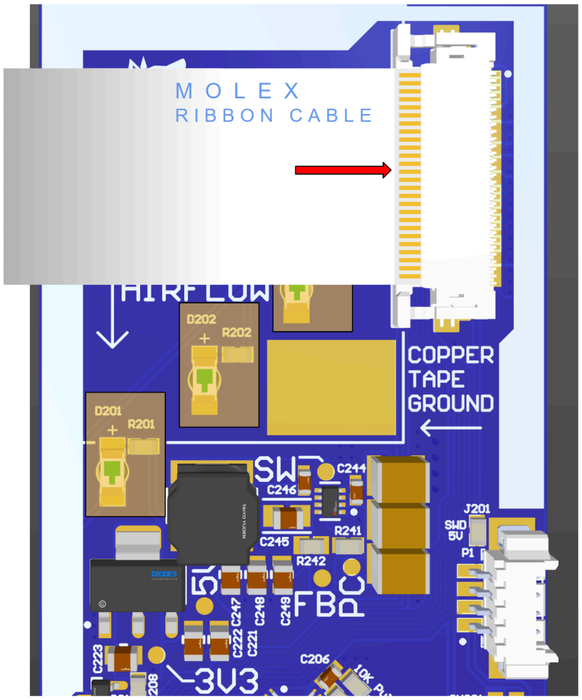
Trim the wires to length, and strip and tin the wire ends. Solder the fan wires into the fan solder points on the top side of the power board.

INSTALLING THE RIBBON CABLE

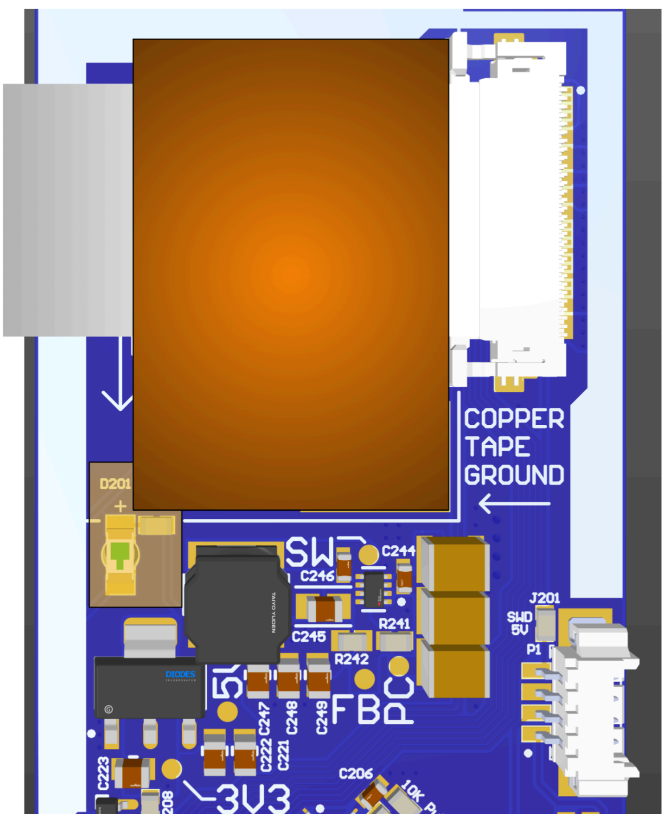
Install 3 pieces of Kapton (polyamide) tape to insulate the solder joints on the LEDs below the ribbon cable.



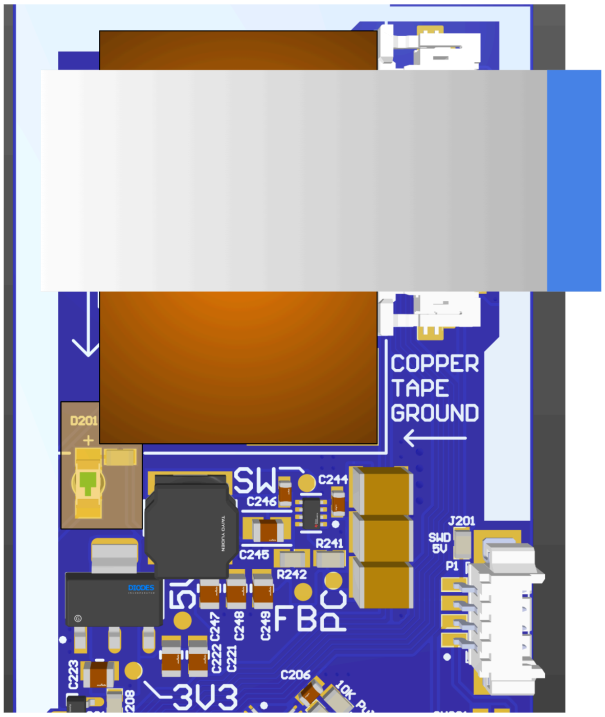
Install the ribbon cable into the MCB, pins facing up.



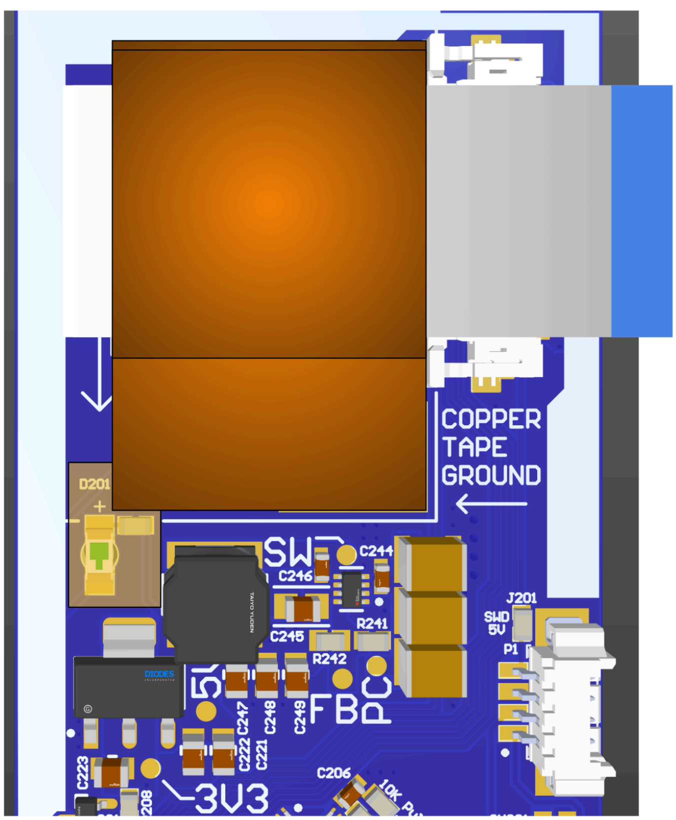
Install the first layer of copper tape, making sure to make contact to the grounding area, and not short any exposed pads.



Fold the ribbon cable back over the copper tape, using a M3 bolt or similar as a folding guide to avoid creasing the cable, and leaving the loop [...] mm beyond/inside the edge of the board.



Place more copper tape over the ribbon cable, making sure to contact the lower layer, but not too much in order to facilitate later removal.



INITIAL POWER UP PROCEDURE

INITIAL POWER UP CHECKLIST

- Check all boards for shorted connections and loose solder joints
- Continuity test across every capacitor, each one should show open
- Continuity test across both fuse positions, each should show shorted

CONNECTING THE CAPACITOR ARRAY

- Ensure capacitor array is fully discharged, voltage should read below 500mV.
- Ensure cap bank controller is powered down, and all lights are off.
- Connect XT-30 male-to-male connector cable from capacitor array to cap port on cap bank controller.

TESTS TO PERFORM

- Full charge and discharge of capacitor array
- Maximum rated current charge and discharge of capacitor array through buck-boost converter
- Full discharge of capacitors through discharger

PROGRAMMING THE CB4

Ensure the “SWD 5V” solder jumper has been bridged/
Plug the J-link’s connector into the port marked “program”
Hold down the programming reset button while loading the new code onto the MCU

USING THE DISCHARGER

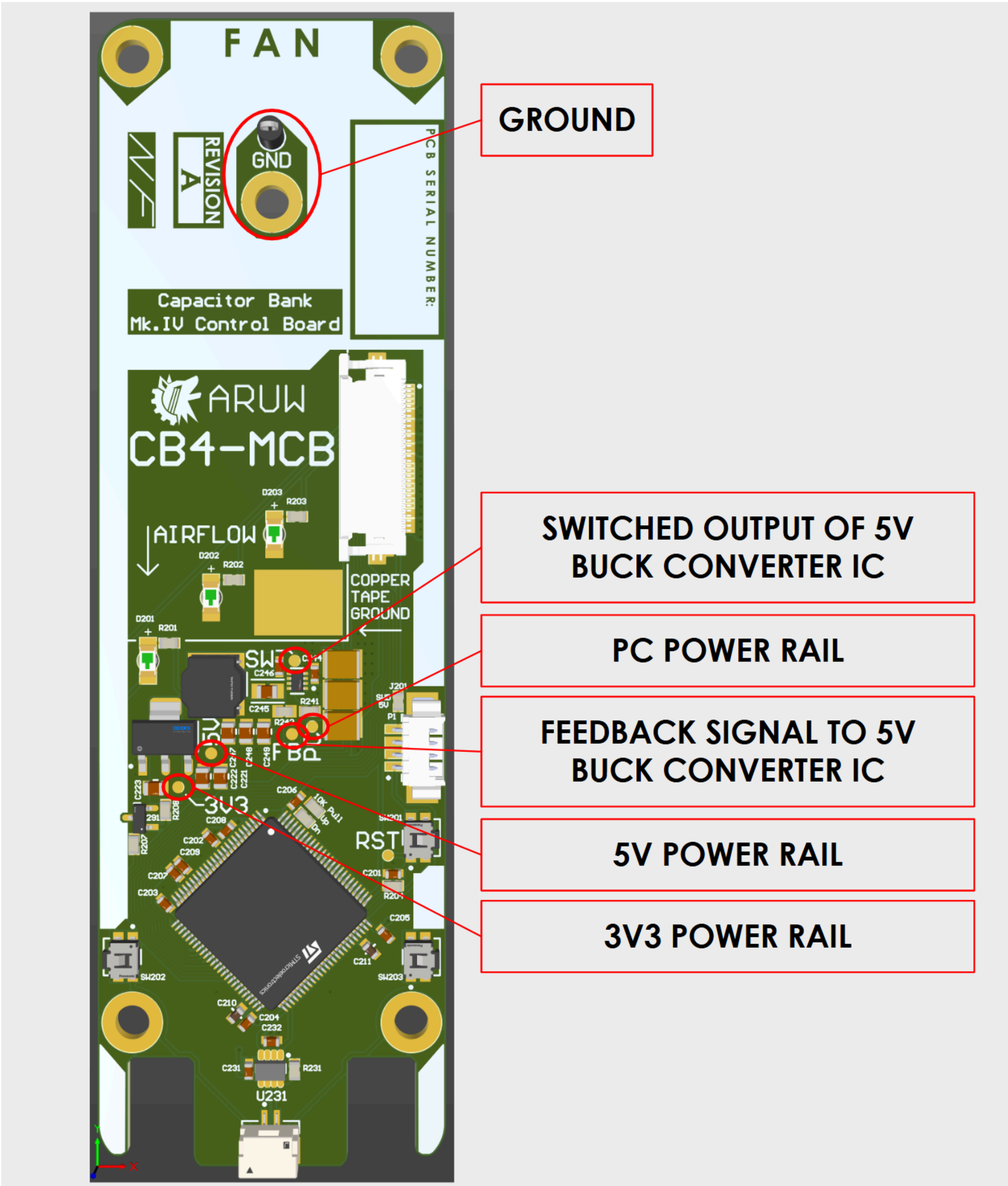
- Ensure it is OK to discharge the capacitor array
- If robot is powred on, either turn off power or send discharge command to cap bank MCU
- Either wait approx. 5 minutes for discharge to automatically engage, or squeeze cap bank controller at points labeled discharge, holding down both discharge buttons for at least 3 seconds to skip the timer.
- Discharge light should illuminate, indicating discharge has begun.
- Ensure cooling fan is operational
- If temperature sensor detects overheating, discharge will temporarily pause and overheat light will illuminate until the temperature has decreased to a safe level.

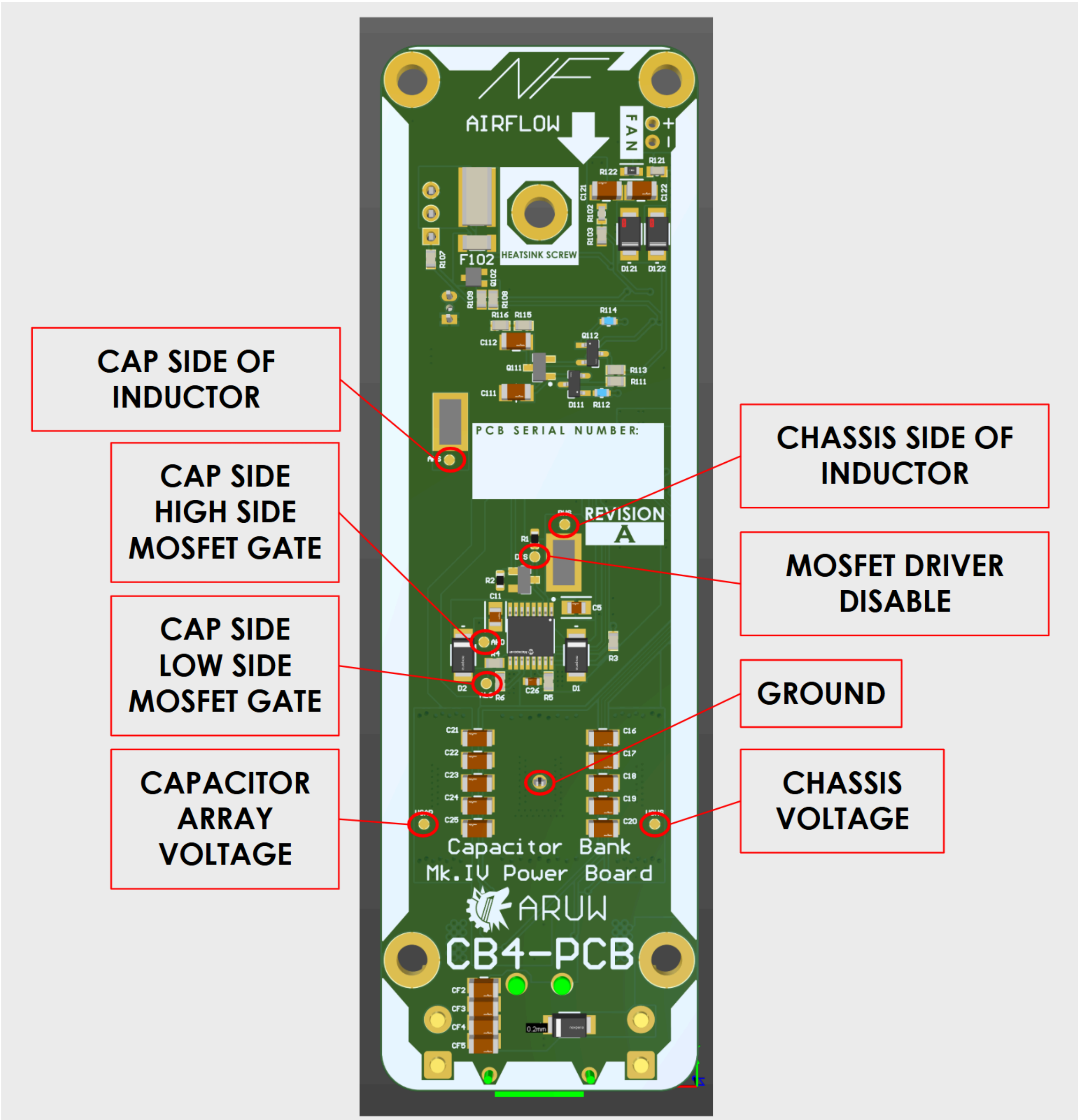
TROUBLESHOOTING

SERVICING POSITION

Assemble midframe and PCB, and mount MCB as shown in picture. All test points should be accessible. Remove bottom cover for access to remaining test points.

TEST POINT LOCATIONS




CAP SIDE OF INDUCTOR
CAP SIDE HIGH SIDE MOSFET GATE
CAP SIDE LOW SIDE MOSFET GATE
CAPACITOR ARRAY VOLTAGE
CHASSIS SIDE OF INDUCTOR
MOSFET DRIVER DISABLE
GROUND
CHASSIS VOLTAGE
AIRFLOW
FAN
HEATSINK SCREW
PCB SERIAL NUMBER:
REVISION
A
Capacitor Bank
Mk.IV Power Board
ARUW
CB4-PCB

TROUBLESHOOTING FLOWCHART

[NOT YET CREATED]