

Amulet Motion Controller

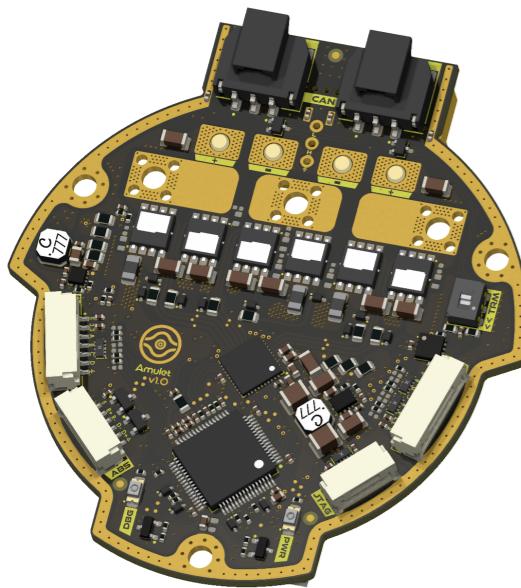
2024-01-27

Variant: Checked

Rev 1.0

Page	Index	Page	Index	Page	Index	Page	Index
1	Cover Page	11	User - LED Indicators	21	Revision History	31
2	Block Diagram	12	Sensing - Temperature	22	32
3	Project Architecture	13	Sensing - Battery	23	33
4	MCU - Power	14	Sensing - Position	24	34
5	MCU - I/Os	15	Interface - RS-422	25	35
6	Power - Generation	16	Interface - FD-CAN	26	36
7	Power - Connectors	17	Interface - Fan Control	27	37
8	Motor Control - Top Level	18	Interface - Interconnects	28	38
9	Motor Control - Inverter	19	Misc - Holes, Fiducials	29	39
10	Misc - Board Version, DAC	20	Power - Sequencing	30	40

TOP VIEW



DESIGN CONSIDERATIONS

DESIGN NOTE:
Example text for informational design notes.

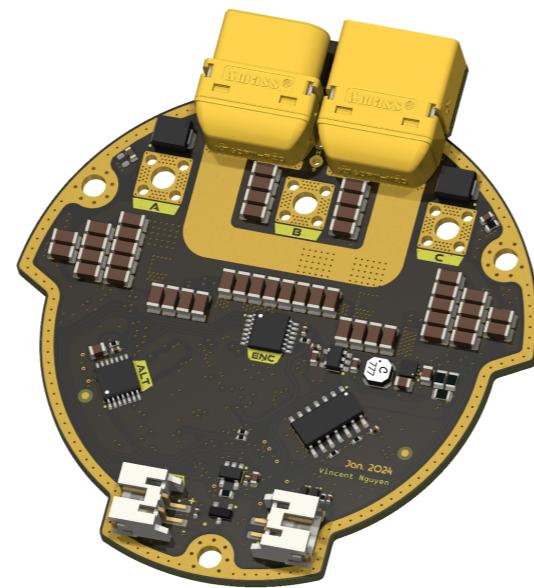
DESIGN NOTE:
Example text for debug notes.

DESIGN NOTE:
Example text for cautionary design notes.

DESIGN NOTE:
Example text for critical design notes.

LAYOUT NOTE:
Example text for critical layout guidelines.

BOTTOM VIEW



NOTES

Schematic based off Josh Pieper's moteus controllers.

Not fitted components are marked as

DRAFT - Very early stage of schematic, ignore details.

PRELIMINARY - Close to final schematic.

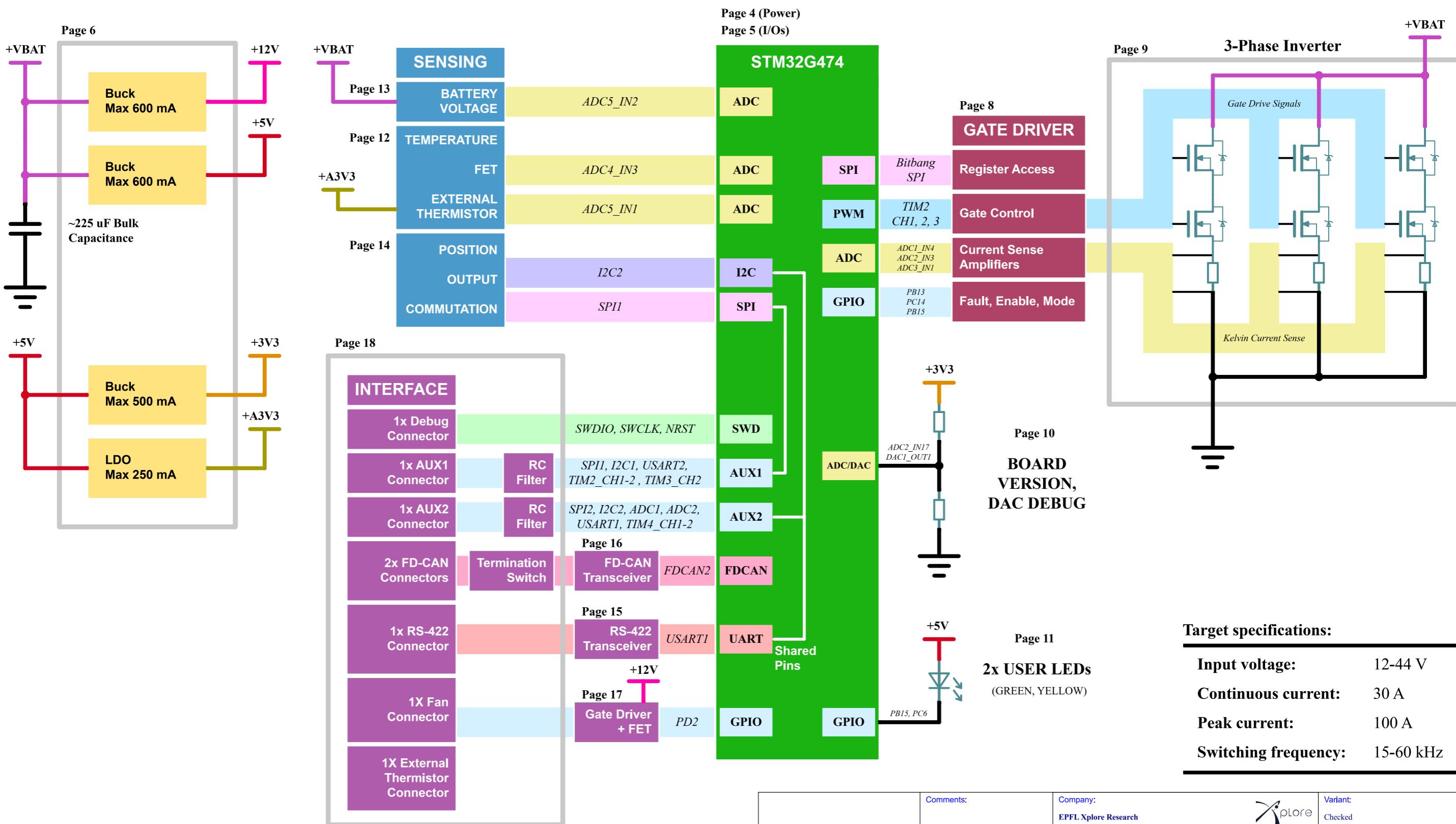
CHECKED - There shouldn't be any mistakes. Contact the engineer if you find any.

RELEASED - A board with this schematic has been sent to production.

Checked 25-JAN-2024

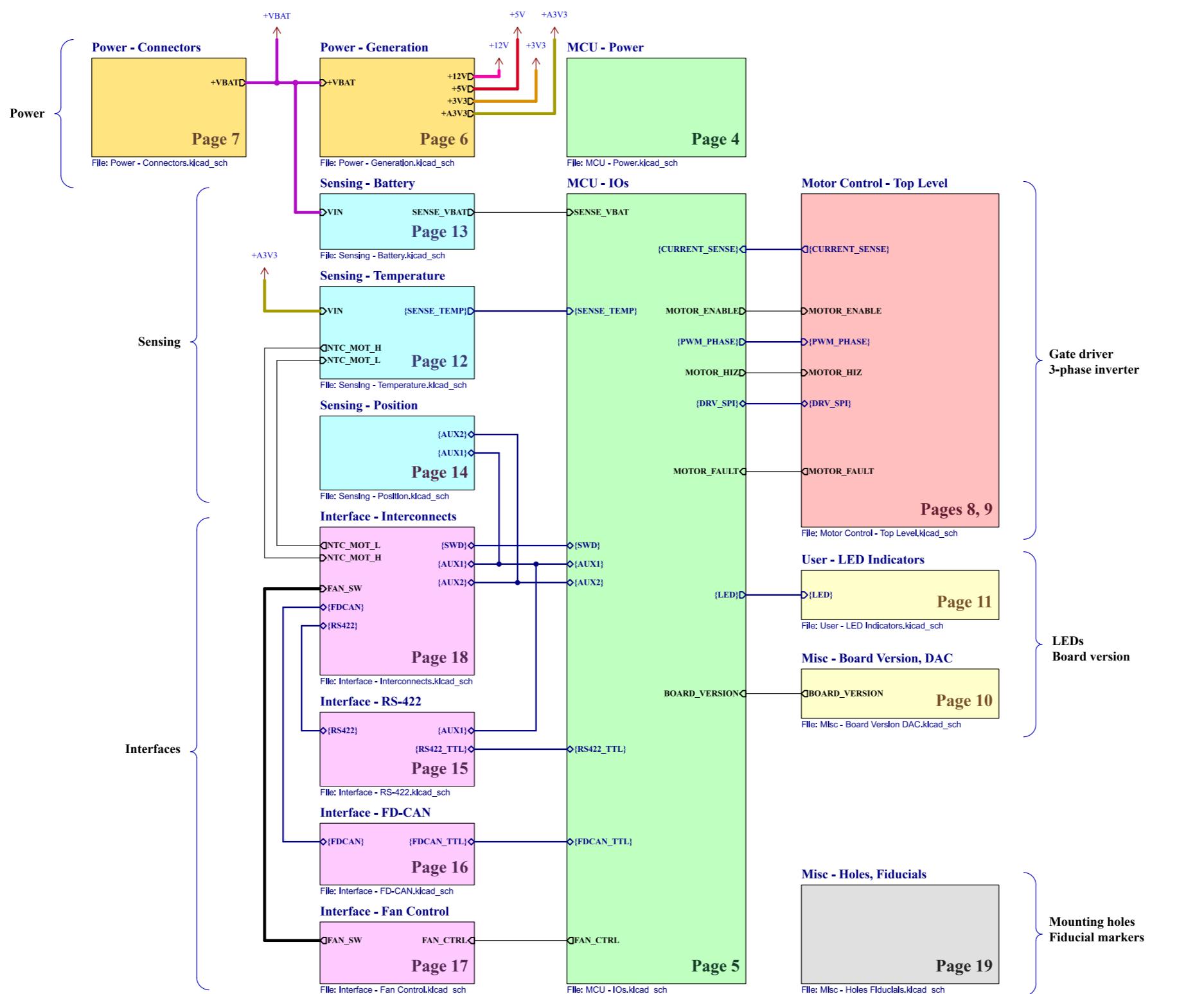
	Comments:	Company: EPFL Xplore Research	Variant: Checked
	Board Name: Amulet Motion Controller	Project Name: Chienpanzé	
	Sheet Title: Cover Page	File Name: amulet_controller.kicad_sch	Designer: Vincent Nguyen
	Sheet Path: /	Reviewer:	Date: 2023-12-23 Revision: 1.0
		Size: A3	Sheet: 1 of 21

[2] Block Diagram



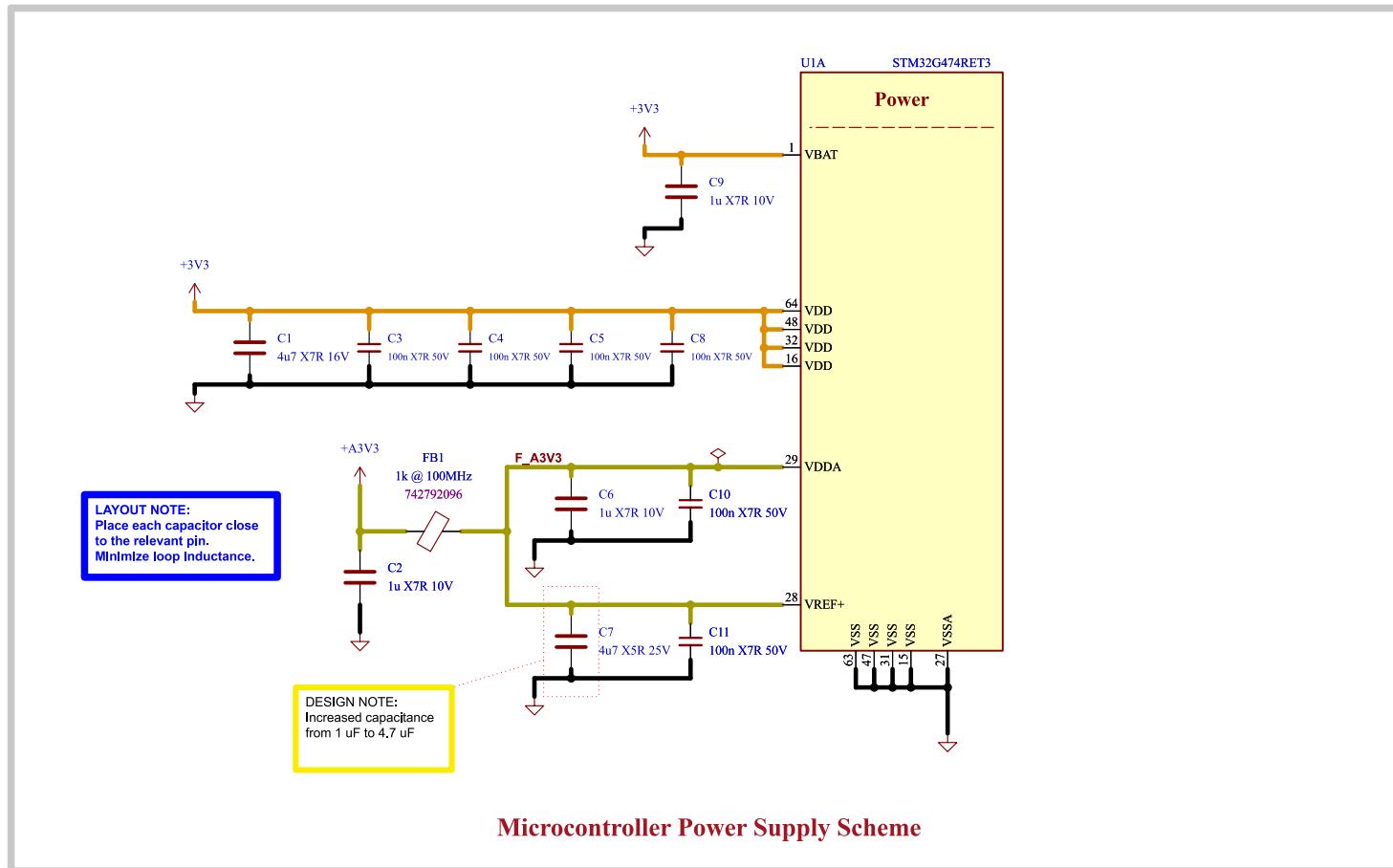
Comments:	Company: EPFL Xplore Research		Variant: Checked
	Board Name: Amulet Motion Controller		Project Name: Chienpanzé
Sheet Title: Block Diagram	File Name: Block Diagram.kicad_sch	Designer: Vincent Nguyen	Date: 2024-01-03
Sheet Path: /Block Diagram/	Reviewer:	Size: A3	Revision: 1.0

[3] Project Architecture



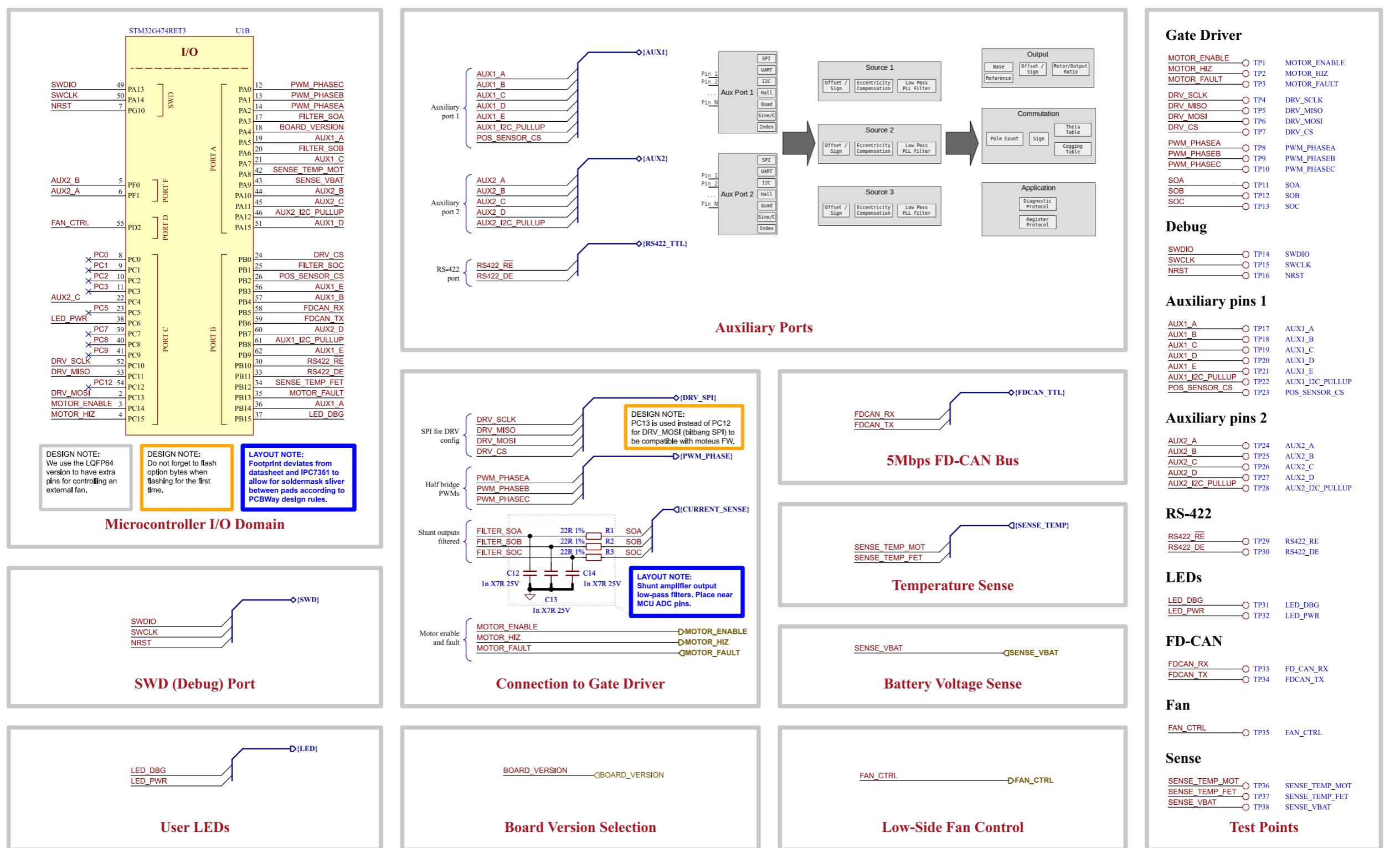
	Comments:	Company: EPFL Xplore Research	Variant: Checked
	Board Name: Amulet Motion Controller	Project Name: Chienpanzé	
Sheet Title:	File Name: Project Architecture	Designer: Vincent Nguyen	Date: 2023-12-22
Sheet Path:	/Project Architecture/	Reviewer:	Revision: 1.0
	Size: A3	Sheet: 3 of 21	

[4] MCU - Power



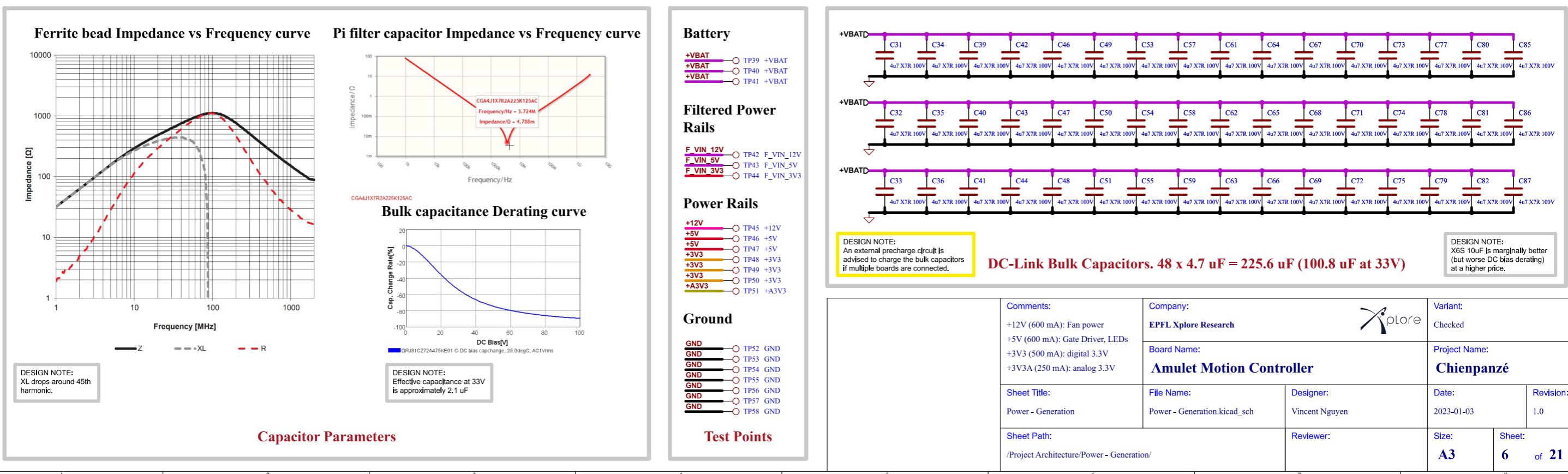
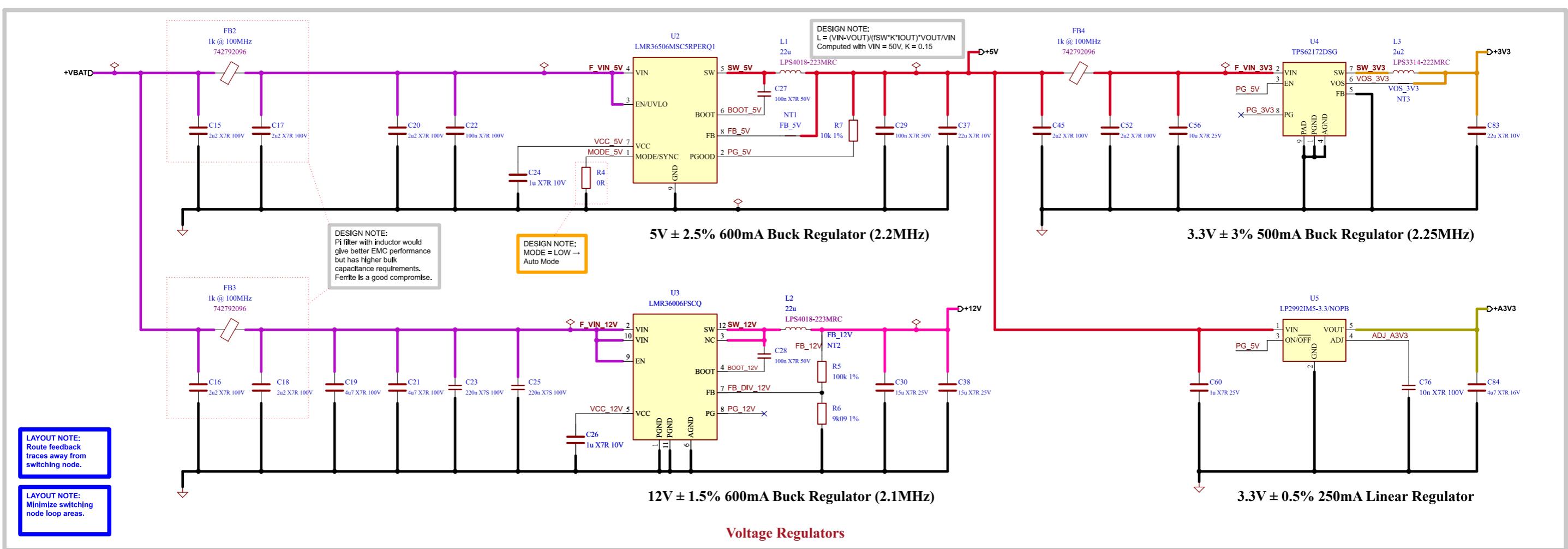
	Comments: AN5346 STM32G474 Datasheet p.81 J. Pieper ADC investigation	Company: EPFL Xplore Research 	Variant: Checked
	Board Name: Amulet Motion Controller		
	Sheet Title: MCU - Power	File Name: MCU - Power.kicad_sch	Designer: Vincent Nguyen
	Sheet Path: /Project Architecture/MCU - Power/	Reviewer:	Date: 2023-12-18 Revision: 1.0

[5] MCU - I/Os

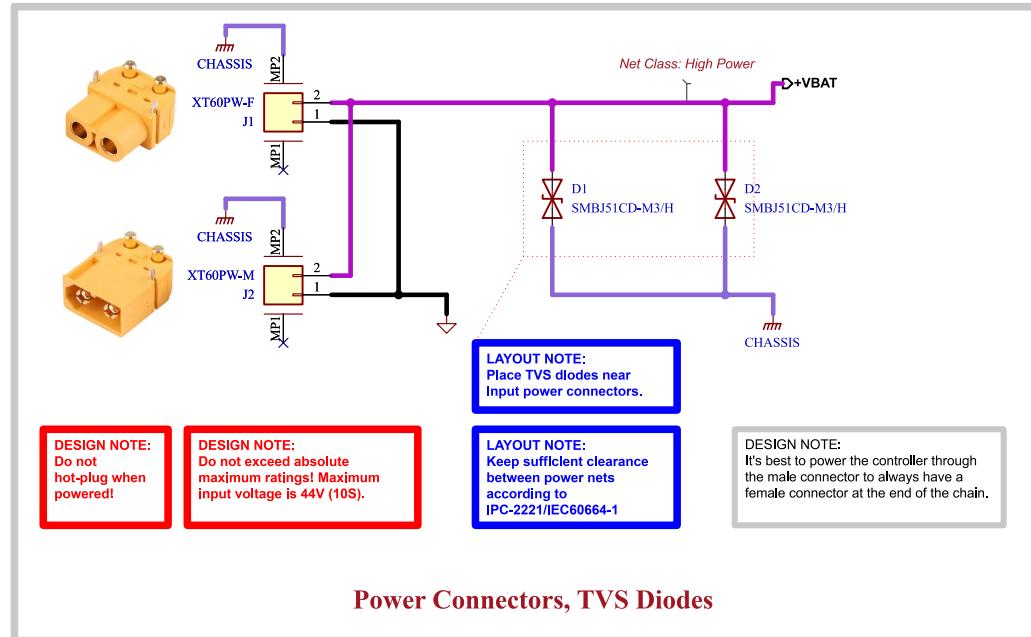


Comments: References: Flexible I/O worked examples Flexible I/O source configuration	Company: EPFL Xplore Research		Variant: Checked	
	Board Name: Amulet Motion Controller			
Sheet Title: MCU - I/Os	File Name: MCU - IOs.kicad_sch	Designer: Vincent Nguyen	Date: 2023-12-20	Revision: 1.0
Sheet Path: /Project Architecture/MCU - IOs/	Reviewer:		Size: A3	Sheet: 5 of 21

[6] Power - Generation

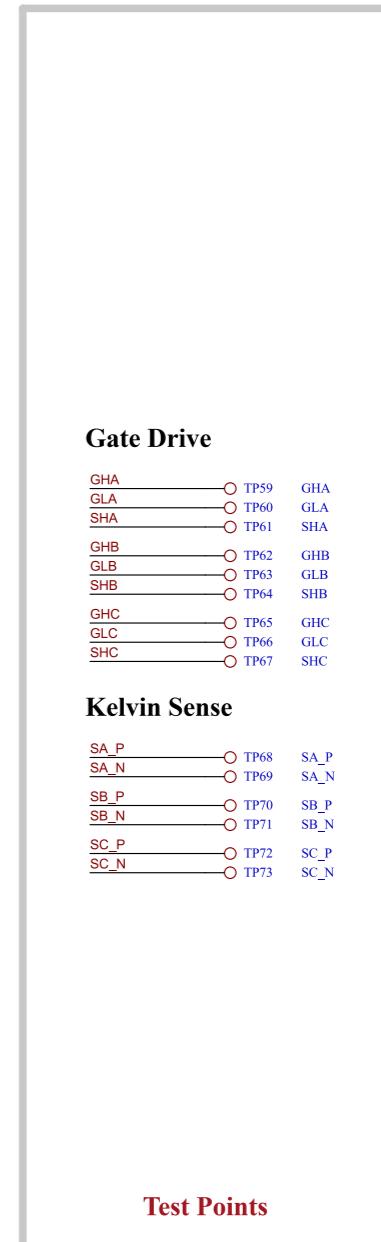
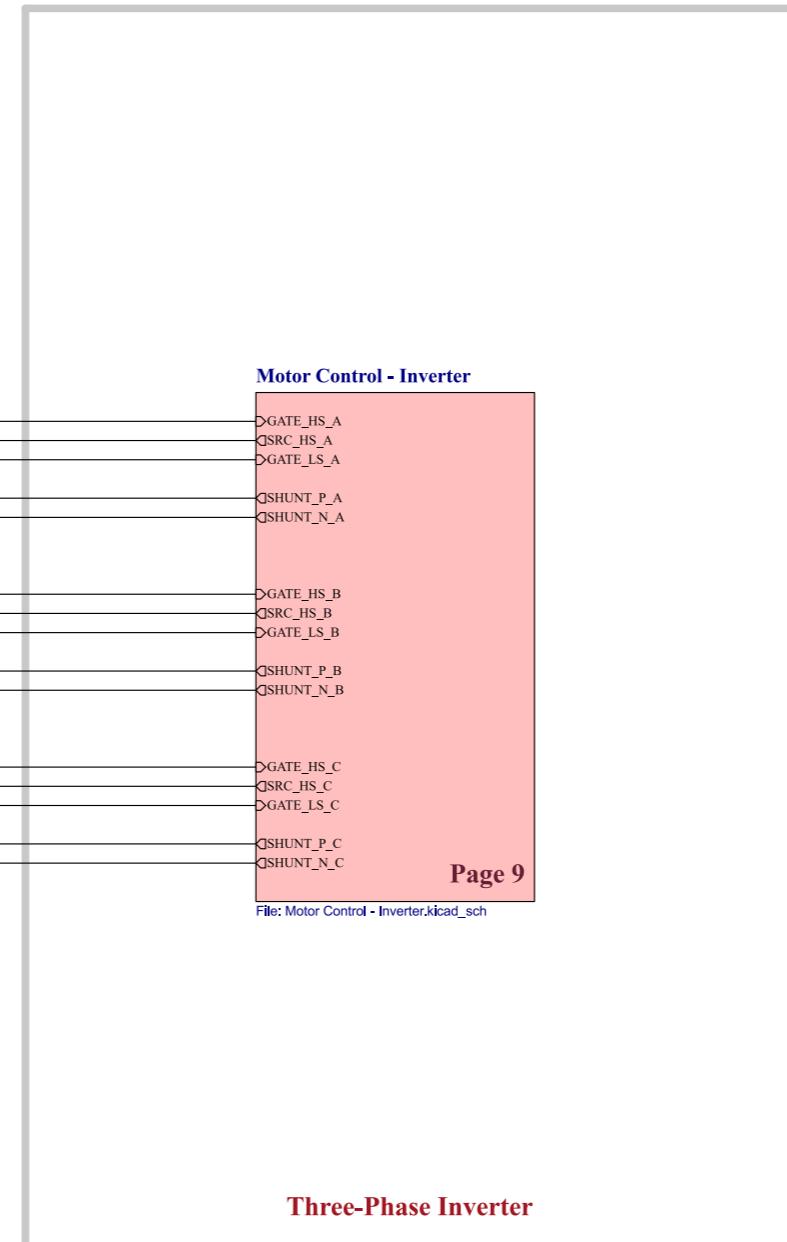
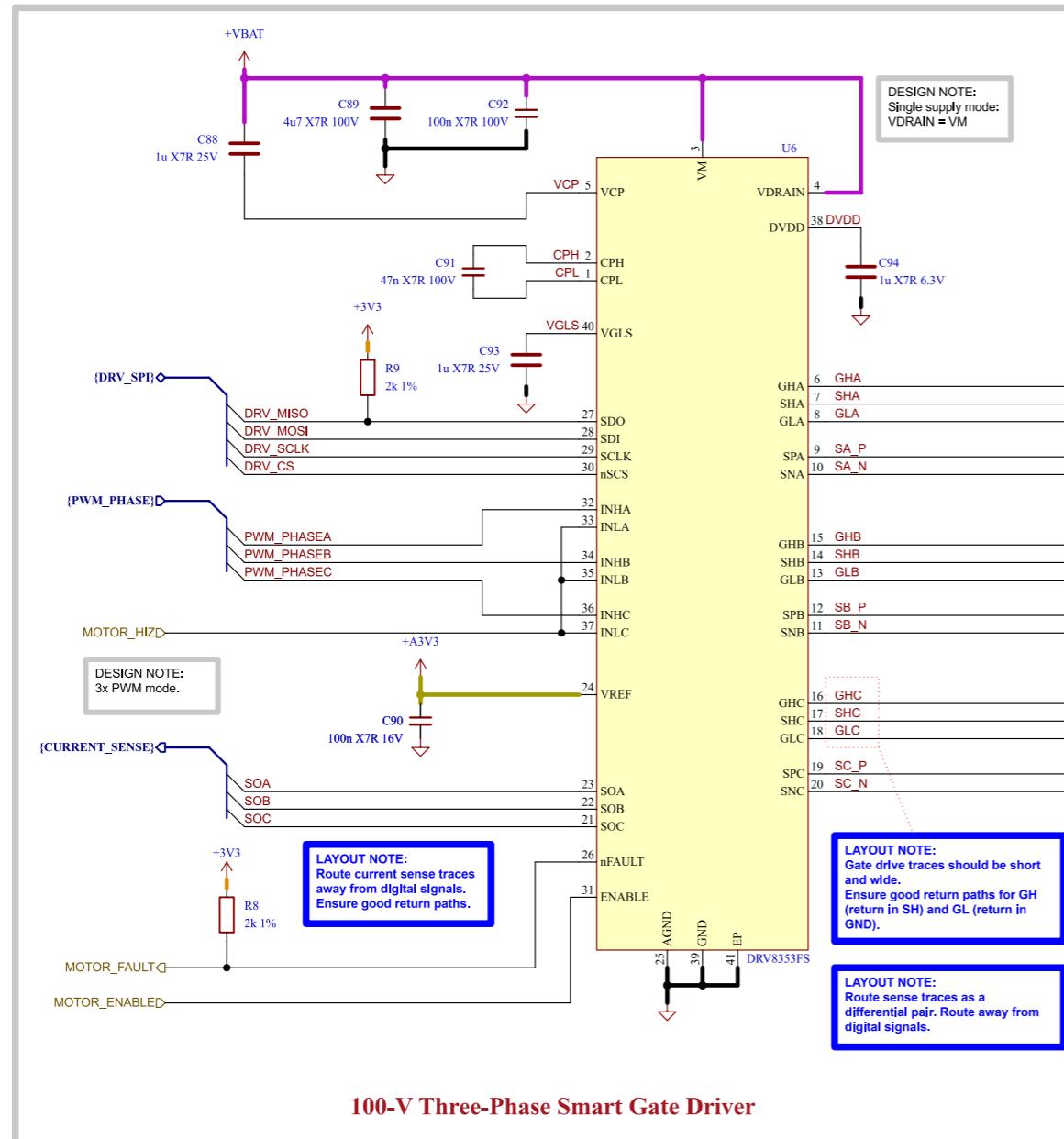


[7] Power - Connectors



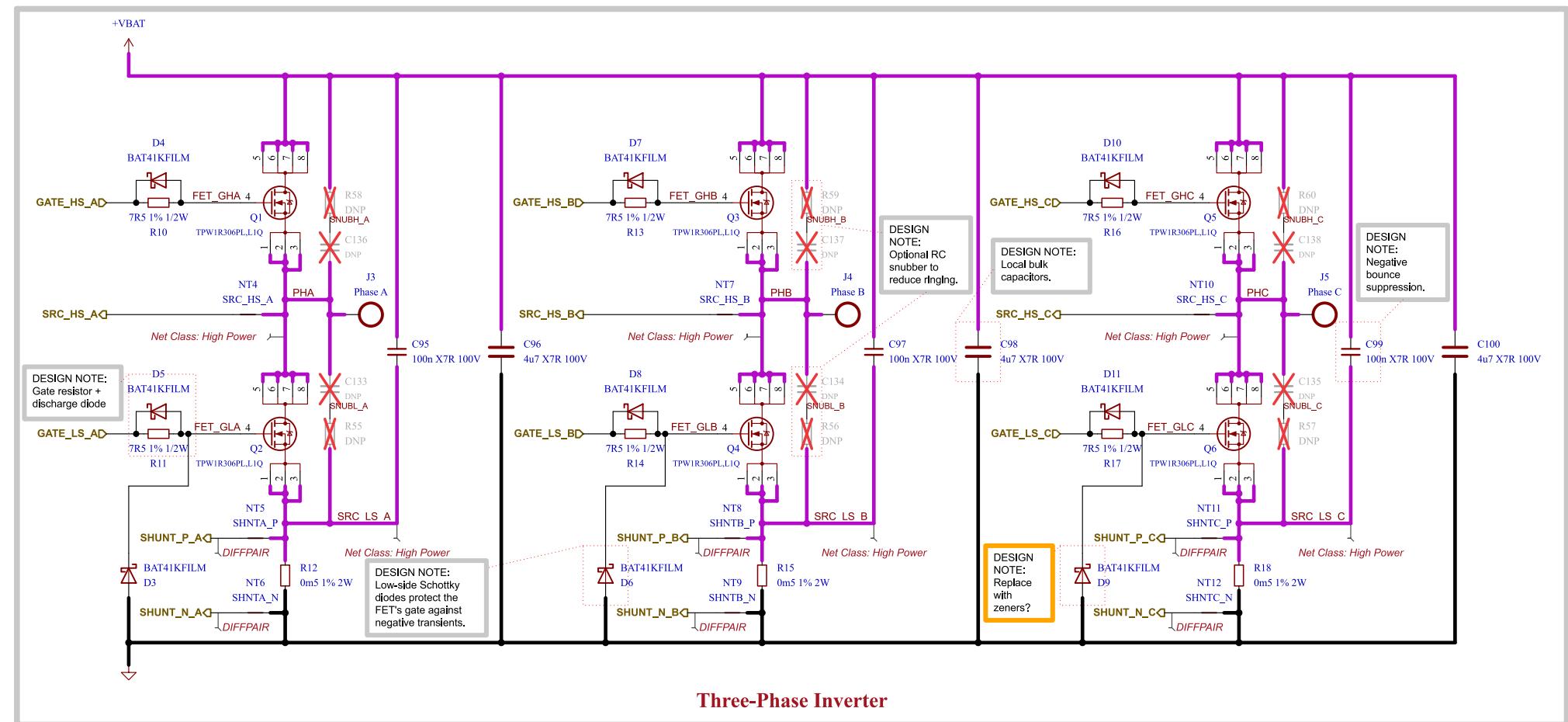
	Comments:	Company: EPFL Xplore Research	Variant: Checked
	Board Name: Amulet Motion Controller		
	Sheet Title: Power - Connectors	File Name: Power - Connectors.kicad_sch	Designer: Vincent Nguyen
	Sheet Path: /Project Architecture/Power - Connectors/	Reviewer:	Date: 2023-12-31 Revision: 1.0

[8] Motor Control - Top Level



	Comments:	Company: EPFL Xplore Research	Variant: Checked
	Board Name: Amulet Motion Controller	Project Name: Chienpanzé	
	Sheet Title: Motor Control - Top Level	File Name: Motor Control - Top Level.kicad_sch	Designer: Vincent Nguyen
	Sheet Path: /Project Architecture/Motor Control - Top Level/	Reviewer:	Date: 2023-12-20 Revision: 1.0

[9] Motor Control - Inverter



LAYOUT NOTE:
High current traces must be carefully designed. Ensure ground return path does not cross sensitive parts of the board. Use multiple planes for higher current carrying capacity.

LAYOUT NOTE:
Keep sufficient clearance between power nets according to IPC-2221/IEC60664-1.

DESIGN NOTE:
A gate drive current that is too large can damage the FETs!

Comments:
System Design Considerations for High-Power Motor Driver Applications
Best Practices for Board Layout of Motor Drivers
Proper RC Snubber Design for Motor Drivers

Sheet Title:
Motor Control - Inverter

Sheet Path:
/Project Architecture/Motor Control - Top Level/Motor Control - Inverter/

Company:
EPFL Xplore Research

Board Name:
Amulet Motion Controller

File Name:
Motor Control - Inverter.kicad_sch

Designer:
Vincent Nguyen



Variant:
Checked
Project Name:
Chienpanzé

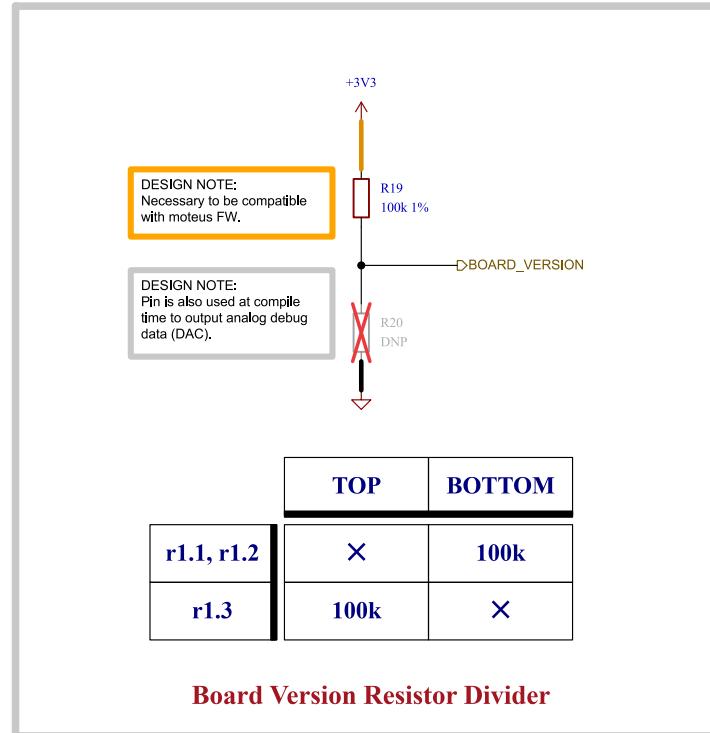
Date:
2024-01-25

Revision:
1.0

Size:
A4

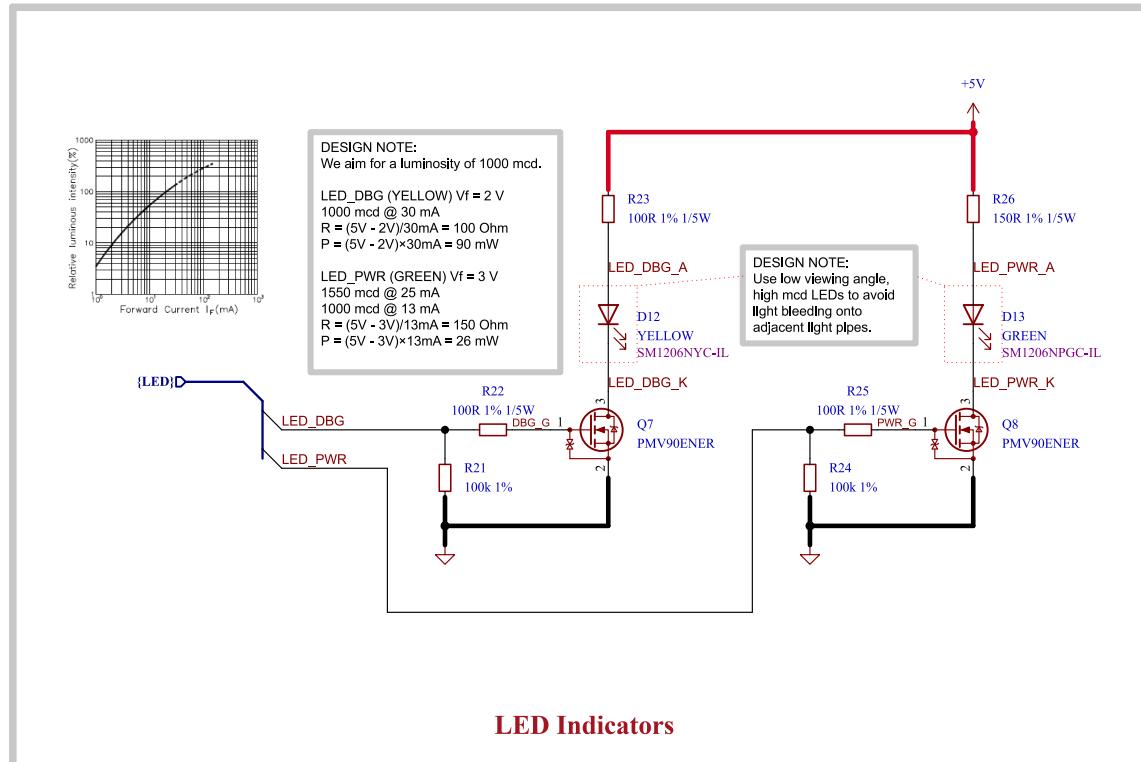
Sheet:
9 of **21**

[10] Misc - Board Version, DAC



	Comments:	Company: EPFL Xplore Research	Variant: Checked
	Board Name: Amulet Motion Controller	Project Name: Chienpanzé	
	Sheet Title: Misc - Board Version, DAC	File Name: Misc - Board Version DAC.kicad_sch	Designer: Vincent Nguyen
	Sheet Path: /Project Architecture/Misc - Board Version, DAC/	Reviewer:	Date: 2023-10-14 Revision: 1.0
		Size: A4	Sheet: 10 of 21

[11] User - LED Indicators



	Comments:	Company: EPFL Xplore Research	Variant: Checked
	Board Name: Amulet Motion Controller	Project Name: Chienpanzé	
	Sheet Title: User - LED Indicators	File Name: User - LED Indicators.kicad_sch	Designer: Vincent Nguyen
	Sheet Path: /Project Architecture/User - LED Indicators/	Reviewer:	Date: 2023-12-19 Revision: 1.0

[12] Sensing - Temperature

A

B

C

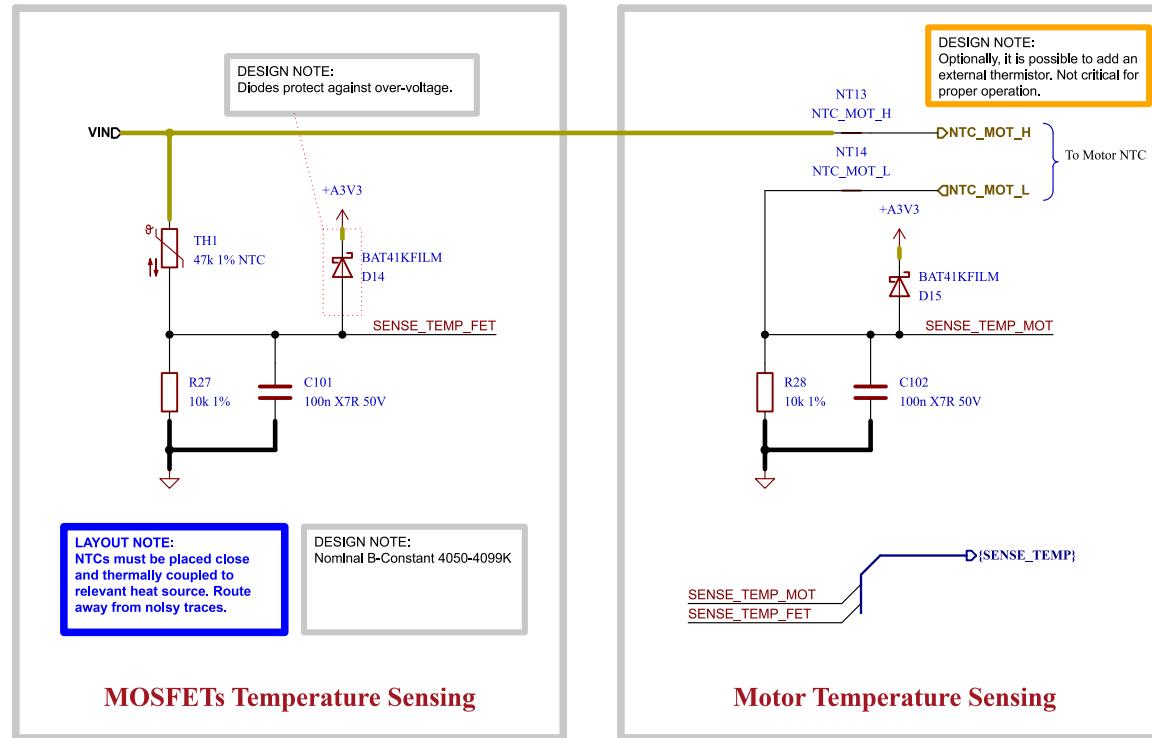
D

A

B

C

D



	Comments:	Company: EPFL Xplore Research	Variant: Checked
	Board Name: Amulet Motion Controller	Project Name: Chienpanzé	
	Sheet Title: Sensing - Temperature	File Name: Sensing - Temperature.kicad_sch	Designer: Vincent Nguyen
	Sheet Path: /Project Architecture/Sensing - Temperature/	Reviewer:	Date: 2023-10-14 Revision: 1.0

[13] Sensing - Battery

A

B

C

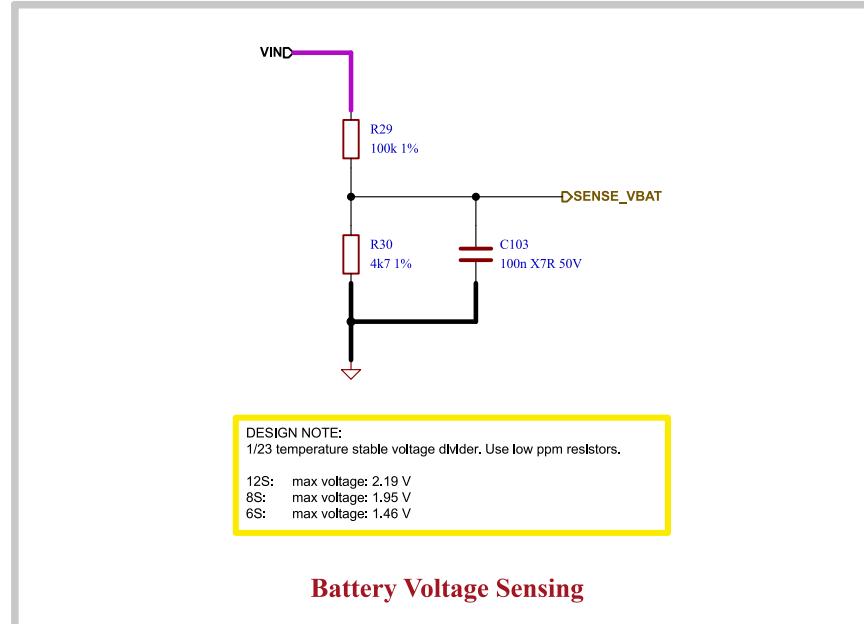
D

A

B

C

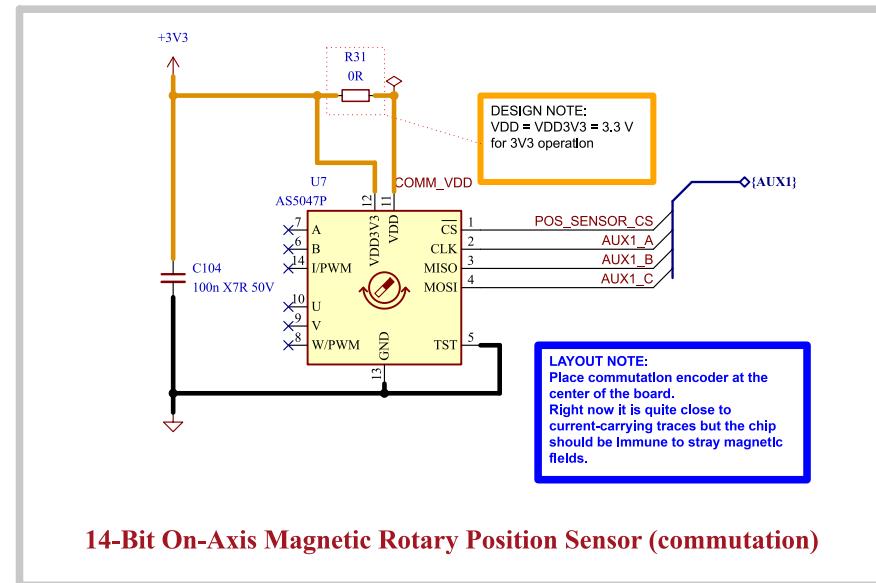
D



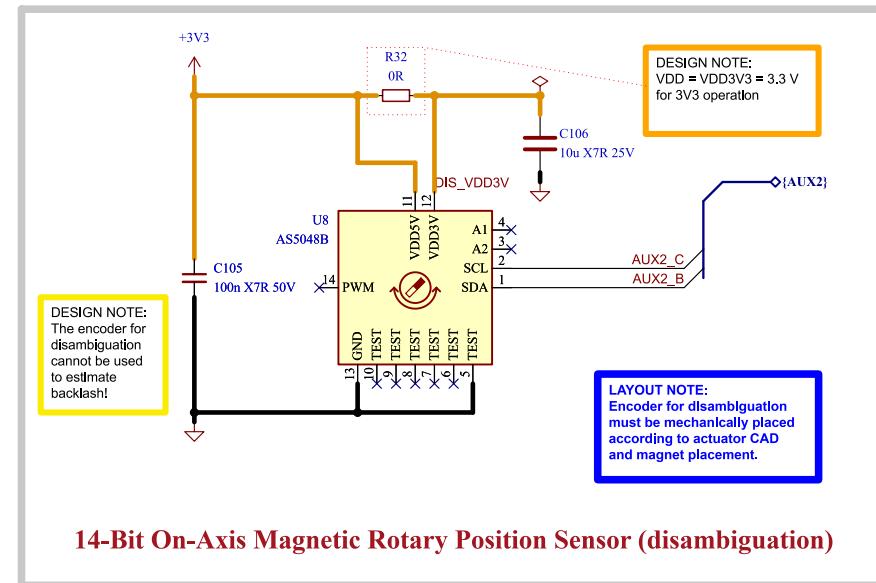
	Comments:	Company: EPFL Xplore Research	Variant: Checked
	Board Name: Amulet Motion Controller		
	Sheet Title: Sensing - Battery	File Name: Sensing - Battery.kicad_sch	Designer: Vincent Nguyen
	Sheet Path: /Project Architecture/Sensing - Battery/	Reviewer:	Date: 2023-10-14 Revision: 1.0
		Size: A4	Sheet: 13 of 21

[14] Sensing - Position

A



B



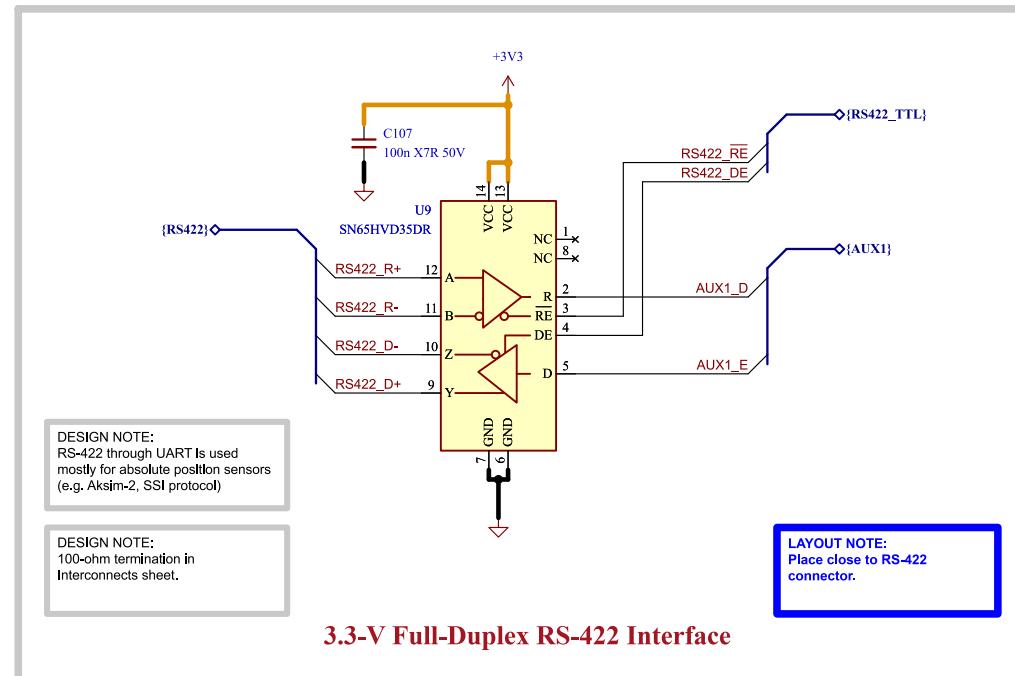
C

DESIGN NOTE:
AS5047P senses magnet mounted on planetary sun gear, for commutation.
AS5048B senses magnet mounted on shaft with same reduction factor as planetary gearbox for disambiguation.

D

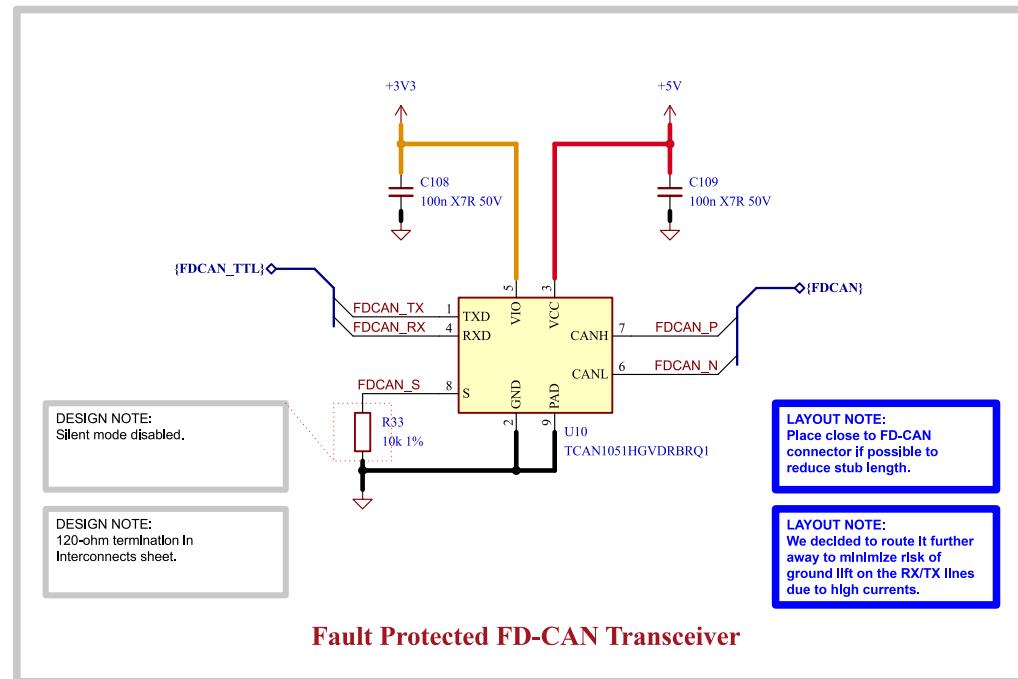
	Comments:	Company: EPFL Xplore Research	Variant: Checked
	Board Name: Amulet Motion Controller		
	Sheet Title: Sensing - Position	File Name: Sensing - Position.kicad_sch	Designer: Vincent Nguyen
	Sheet Path: /Project Architecture/Sensing - Position/	Reviewer:	Date: 2023-10-14 Revision: 1.0

[15] Interface - RS-422



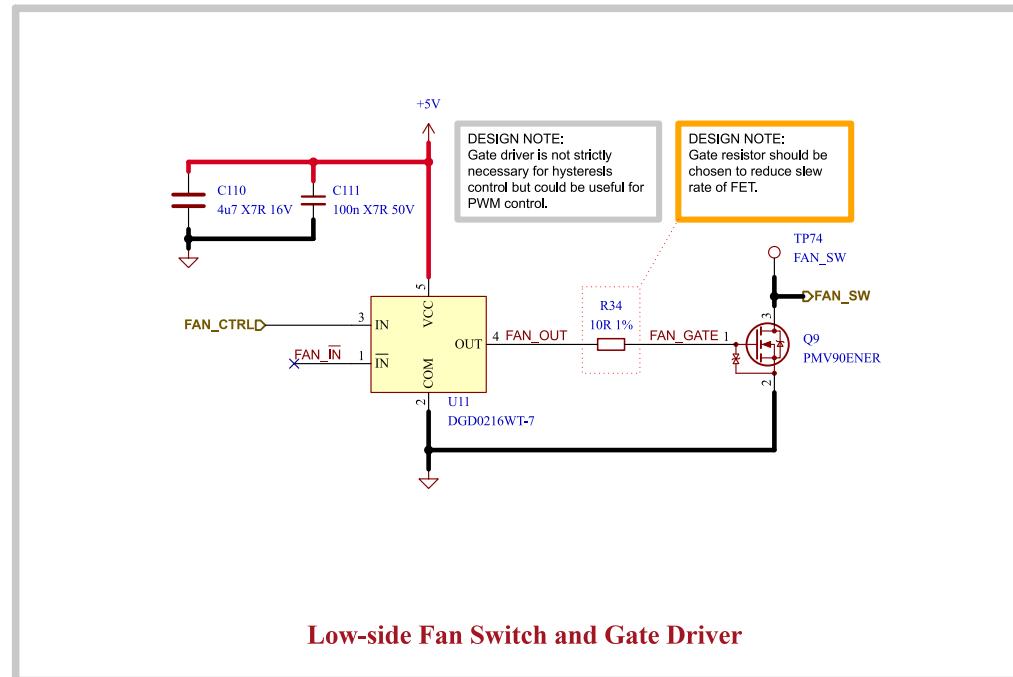
	Comments:	Company: EPFL Xplore Research	Variant: Checked
	Board Name: Amulet Motion Controller		
	Sheet Title: Interface - RS-422	File Name: Interface - RS-422.kicad_sch	Designer: Vincent Nguyen
	Sheet Path: /Project Architecture/Interface - RS-422/	Reviewer:	Date: 2023-10-15 Revision: 1.0

[16] Interface - FD-CAN



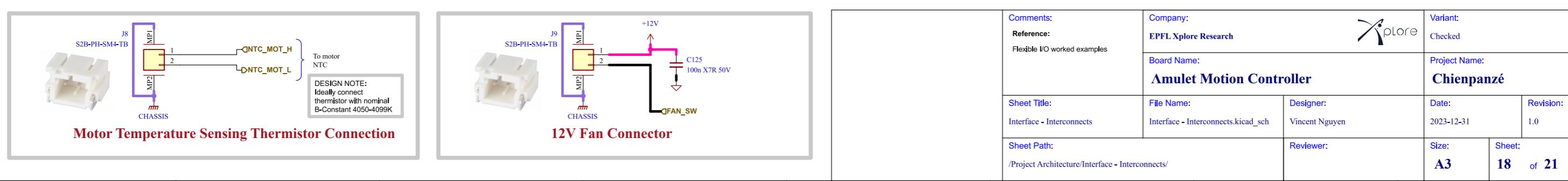
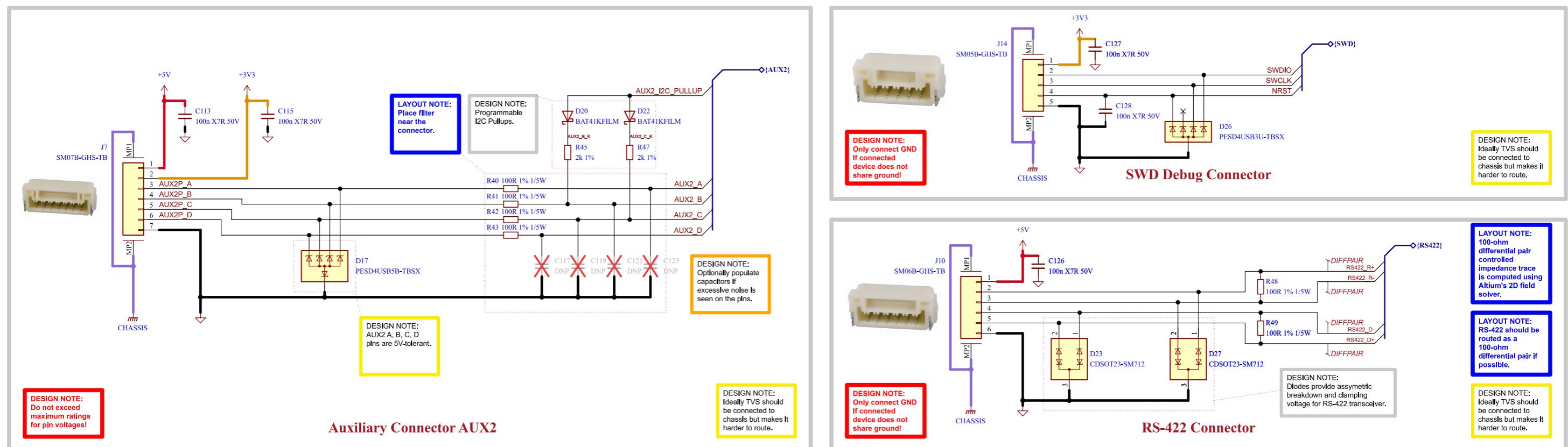
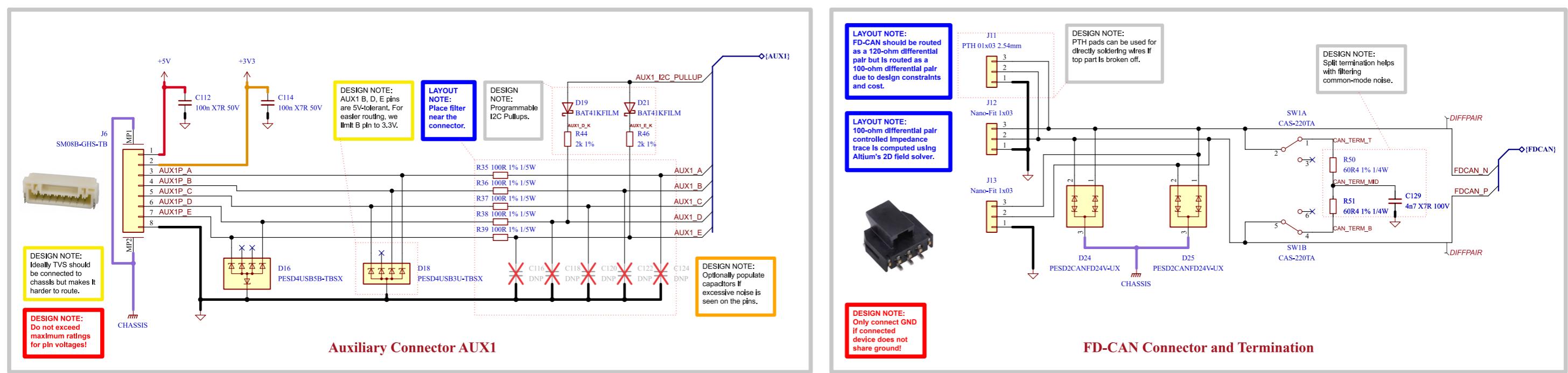
	Comments:	Company: EPFL Xplore Research	Variant: Checked
	Board Name: Amulet Motion Controller		
	Sheet Title: Interface - FD-CAN	File Name: Interface - FD-CAN.kicad_sch	Designer: Vincent Nguyen
	Sheet Path: /Project Architecture/Interface - FD-CAN/	Reviewer:	Date: 2023-10-15 Revision: 1.0
		Size: A4	Sheet: 16 of 21

[17] Interface - Fan Control

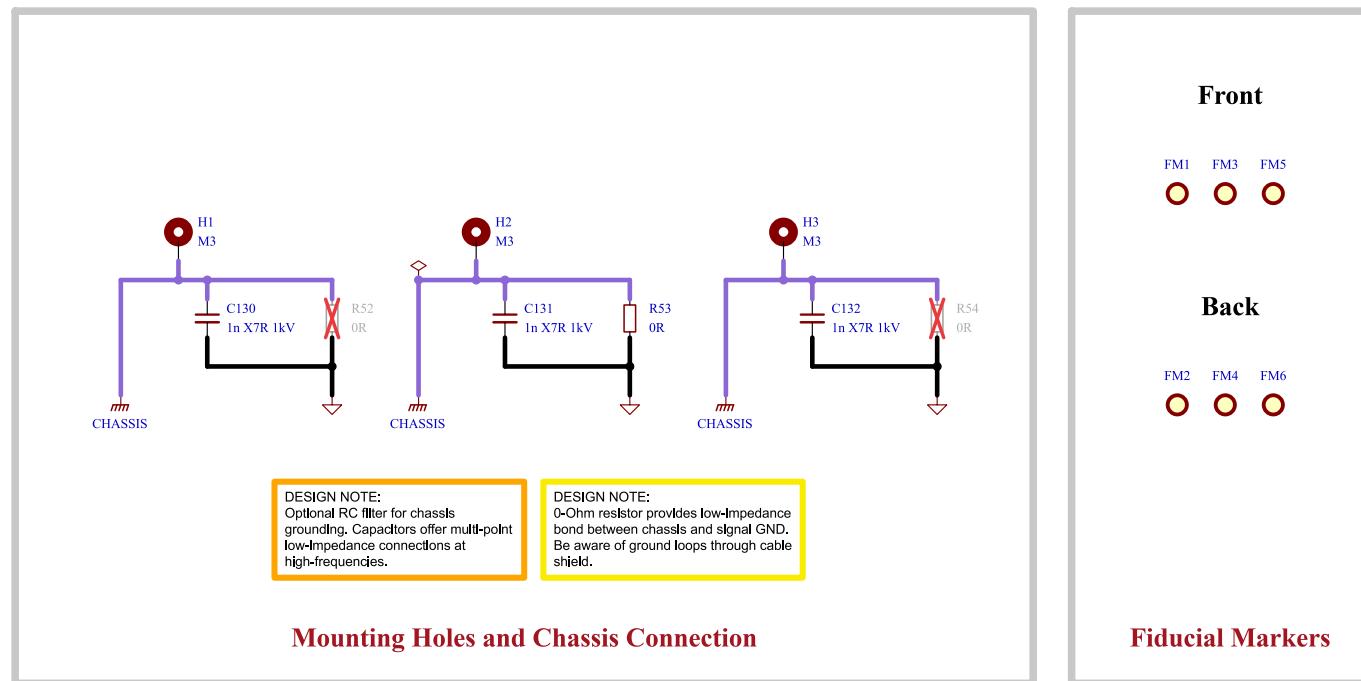


	Comments:	Company: EPFL Xplore Research	Variant: Checked
	Board Name: Amulet Motion Controller		
	Sheet Title: Interface - Fan Control	File Name: Interface - Fan Control.kicad_sch	Designer: Vincent Nguyen
	Sheet Path: /Project Architecture/Interface - Fan Control/	Reviewer:	Date: 2023-11-19 Revision: 1.0

[18] Interface - Interconnects



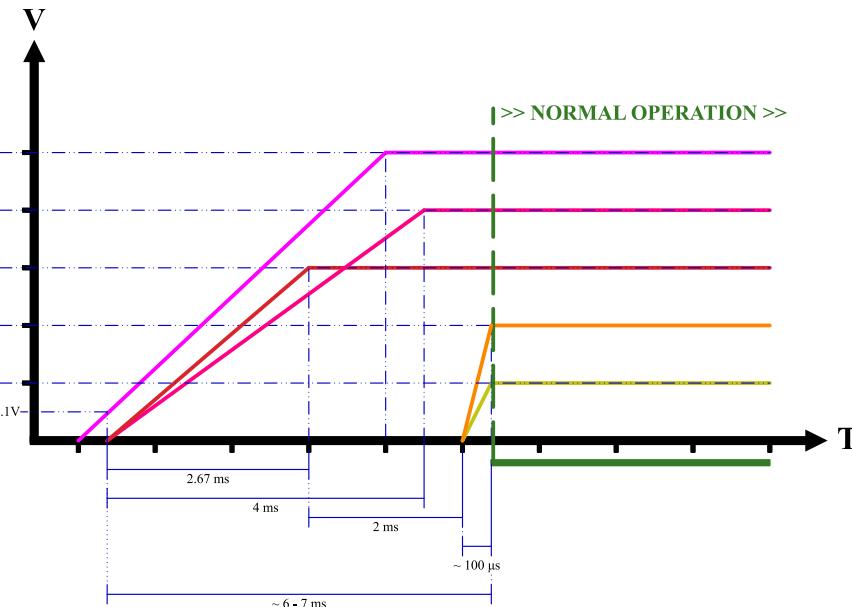
[19] Misc - Holes, Fiducials



	Comments:	Company: EPFL Xplore Research	 Variant: Checked		
		Board Name: Amulet Motion Controller	Project Name: Chienpanzé		
	Sheet Title: Misc - Holes, Fiducials	File Name: Misc - Holes Fiducials.kicad_sch	Designer: Vincent Nguyen	Date: 2023-10-22	Revision: 1.0
	Sheet Path: /Project Architecture/Misc - Holes, Fiducials/		Reviewer:	Size: A4	Sheet: 19 of 21

[20] Power - Sequencing

NAME	SOURCE	LEVEL
+VBAT	BATTERY	12 - 44V
+12V	LMR36006	12V \pm 1.5%
+5V	LMR36506	5V \pm 1.5%
+3V3	TPS62172	3.3V \pm 3%
+A3V3	LP2992	3.3V \pm 0.5%



			Comments:	Company:	 EPFL Xplore Research	Variant:		
				Board Name:		Checked		
				Amulet Motion Controller		Project Name:		
			Sheet Title:	File Name:	Designer:	Date: Revision:		
Power - Sequencing				Power - Sequencing.kicad_sch	Vincent Nguyen	2023-01-03 1.0		
Sheet Path:			/Power - Sequencing/	Reviewer:	Size:	Sheet:		
					A4	20 of 21		

[21] Revision History

A	12-DEC-2023 - Initial Release Variant: v1.0 Preliminary	25-JAN-2024 - First Revision Variant: v1.0 Preliminary	xx.xx.xx - xxx																												
B	<ul style="list-style-type: none"> - Changed CPH-CPL capacitor to 47nF (gate driver). - Changed FD-CAN transceiver IC. - Changed FETs for top cooled variant. - Added TVS protection and termination switch to FD-CAN. - Added low-side switched 12V 600mA source for external fan. - Added LDO for analog supply. - Changed input power TVS diode to bidirectional and added one diode per connector. - Moved SOx low-pass filter to MCU section. Should be placed near MCU to avoid noise coupling into ADC lines. - Added second onboard I2C magnetic encoder for disambiguation. - Switched PWM_PHASEA with PWM_PHASEC on STM32G474 pinout for easier routing. - Changed RS422 pinout on connector. - Added ESD protection to all interfaces. - Added overvoltage protection on thermistor ADC inputs. - Changed buck regulators to optimize for low noise. - Added Pi filters to inputs of buck regulators and MCU analog supply. - Added decoupling caps next to power pins of connectors. 	<ul style="list-style-type: none"> - Added controller target specifications. - Replaced 5V 300mA buck converter with 600mA version. - Added credits to moteus on cover page. - Added optional RC-Snubber to power stage. - Increased chassis length to go around the board. - CAN and power TVS diodes now go to chassis. - Changed clearance between nets to respect IEC60664-1 where possible. - Rectified comment on precharge. - Changed power TVS diode reference designator from "U" to "D". - Replaced chassis-GND capacitor by 1nF 1kV. 																													
C																															
D		<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 25%;"></td> <td style="width: 25%; text-align: center;">Comments:</td> <td style="width: 25%; text-align: center;">Company: EPFL Xplore Research</td> <td style="width: 25%; text-align: center;">Variant: Checked</td> </tr> <tr> <td></td> <td style="text-align: center;">Board Name: Amulet Motion Controller</td> <td></td> <td style="text-align: center;">Project Name: Chienpanzé</td> </tr> <tr> <td></td> <td style="text-align: center;">Sheet Title: Revision History</td> <td style="text-align: center;">File Name: Revision History.kicad_sch</td> <td style="text-align: center;">Designer: Vincent Nguyen</td> </tr> <tr> <td></td> <td style="text-align: center;">Sheet Path: /Revision History/</td> <td style="text-align: center;">Reviewer:</td> <td style="text-align: center;">Date: 2024-01-03</td> </tr> <tr> <td></td> <td></td> <td></td> <td style="text-align: center;">Revision: 1.0</td> </tr> <tr> <td></td> <td></td> <td></td> <td style="text-align: center;">Size: A4</td> </tr> <tr> <td></td> <td></td> <td></td> <td style="text-align: center;">Sheet: 21 of 21</td> </tr> </table>		Comments:	Company: EPFL Xplore Research	Variant: Checked		Board Name: Amulet Motion Controller		Project Name: Chienpanzé		Sheet Title: Revision History	File Name: Revision History.kicad_sch	Designer: Vincent Nguyen		Sheet Path: /Revision History/	Reviewer:	Date: 2024-01-03				Revision: 1.0				Size: A4				Sheet: 21 of 21	
	Comments:	Company: EPFL Xplore Research	Variant: Checked																												
	Board Name: Amulet Motion Controller		Project Name: Chienpanzé																												
	Sheet Title: Revision History	File Name: Revision History.kicad_sch	Designer: Vincent Nguyen																												
	Sheet Path: /Revision History/	Reviewer:	Date: 2024-01-03																												
			Revision: 1.0																												
			Size: A4																												
			Sheet: 21 of 21																												