

Amulet Motion Controller

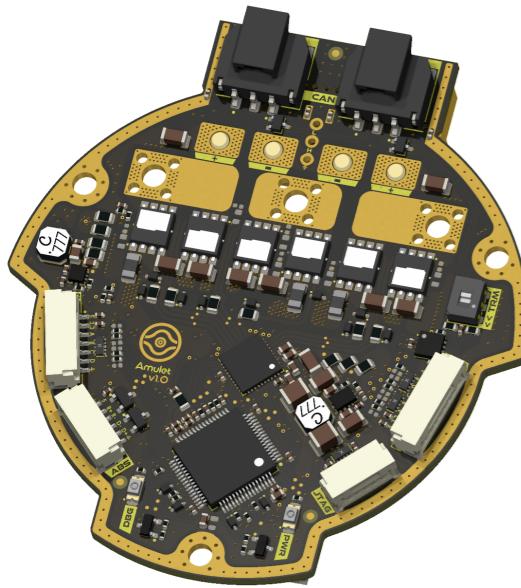
Variant: Released

2024-03-12

Rev 1.0

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TOP VIEW



DESIGN CONSIDERATIONS

DESIGN NOTE:
Example text for informational design notes.

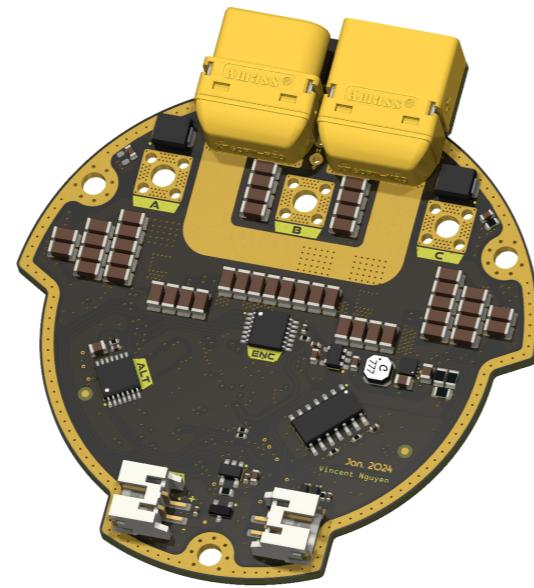
DESIGN NOTE:
Example text for debug notes.

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.

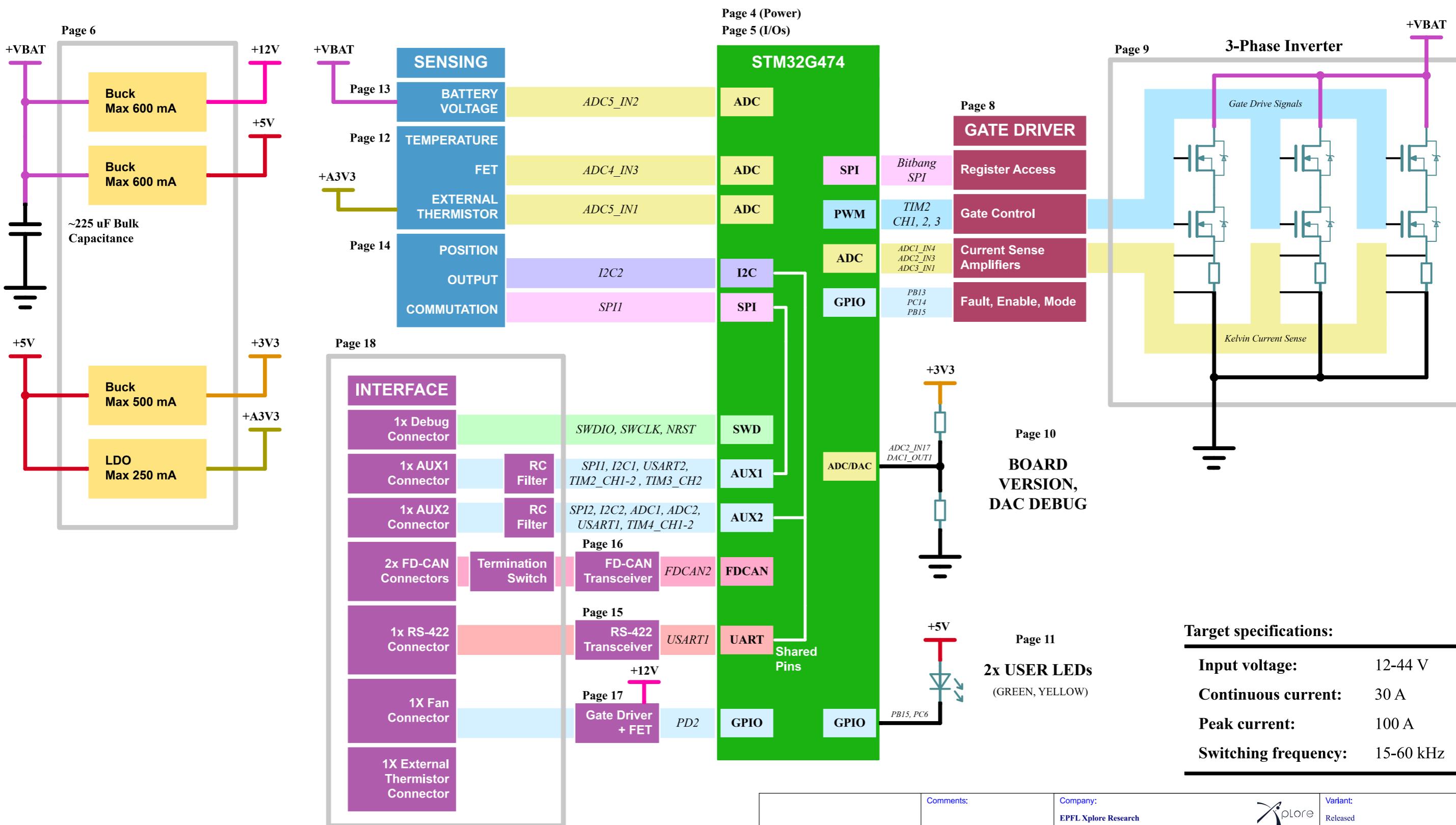
CHECKED - There shouldn't be any mistakes. Contact the engineer if you find any.

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

Released 12-MAR-2024

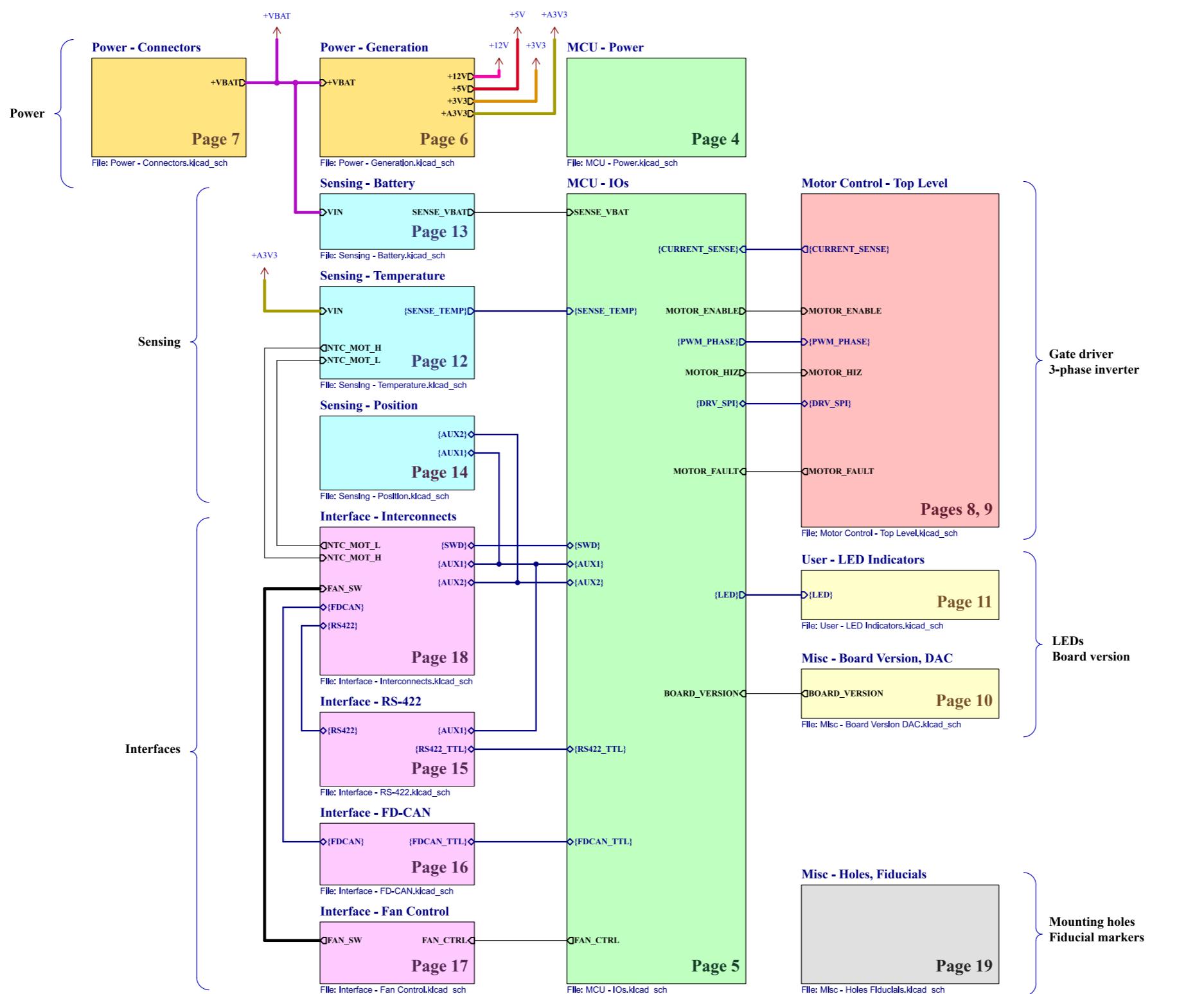
	Comments:	Company: EPFL Xplore Research	Variant: Released
	Board Name: Amulet Motion Controller	Project Name: Chienpanzé	
	Sheet Title: Cover Page	File Name: amulet_controller.kicad_sch	Designer: Vincent Nguyen
	Sheet Path: /	Reviewer:	Date: 2023-12-23 Revision: 1.0
		Size: A3	Sheet: 1 of 21

[2] Block Diagram



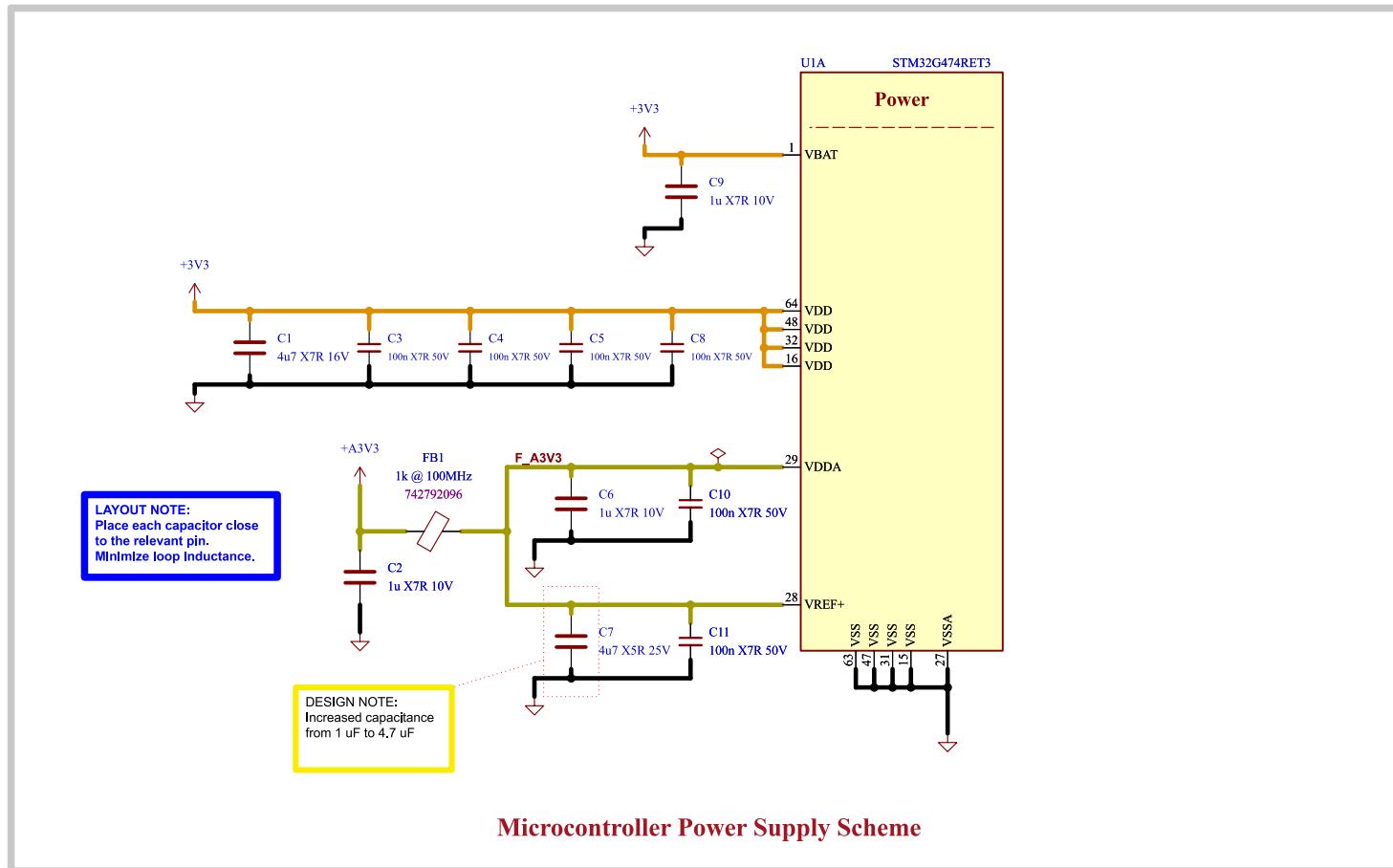
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	Board Name: Amulet Motion Controller		Project Name: Chienpanzé
Sheet Title: Block Diagram	File Name: Block Diagram.kicad_sch	Designer: Vincent Nguyen	Date: 2024-01-03
Sheet Path: /Block Diagram/	Reviewer:	Revision: 1.0	Size: A3
			Sheet: 2 of 21

[3] Project Architecture



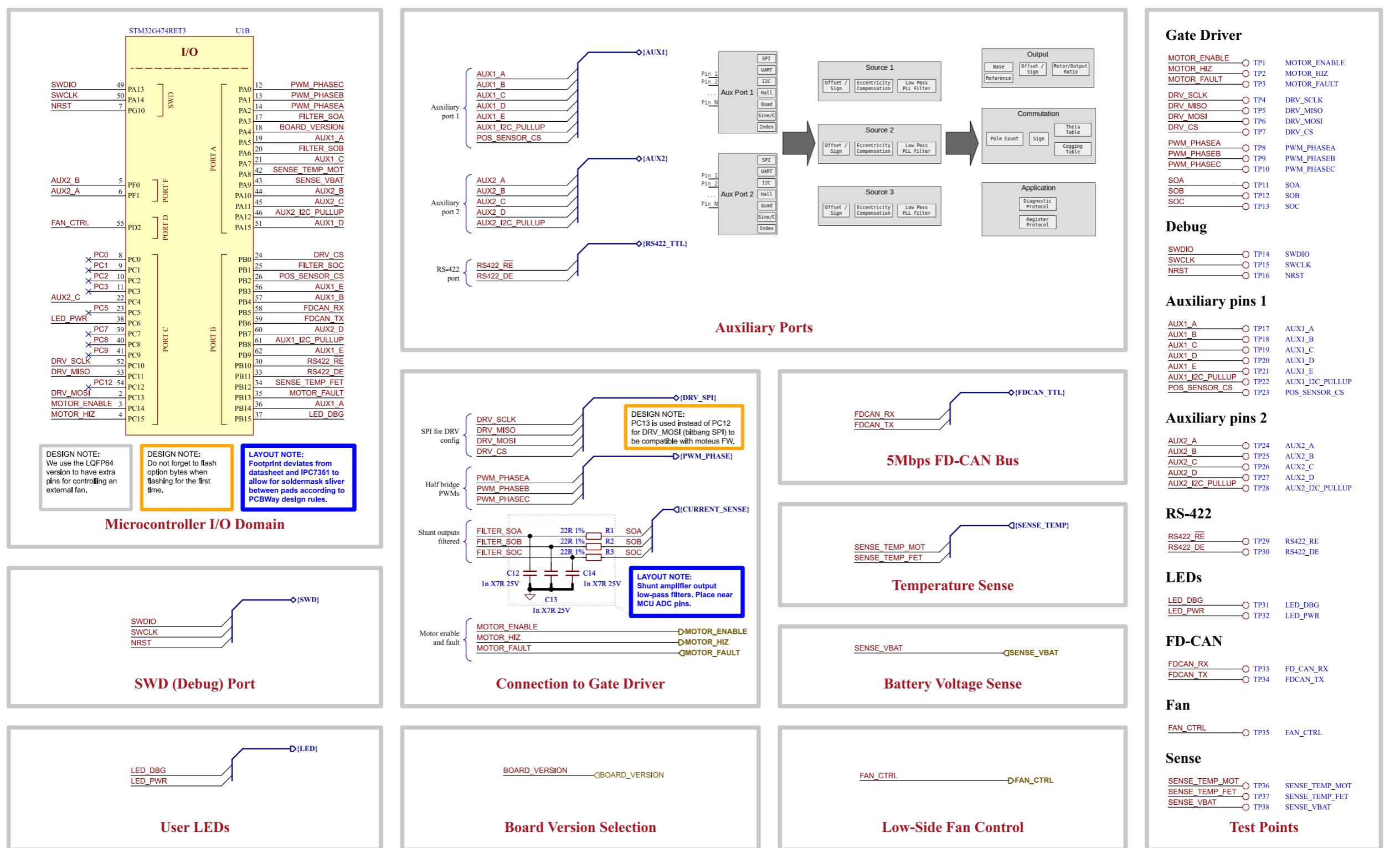
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		EPFL Xplore Research	Xplore	Released
	Board Name:	Amulet Motion Controller		Project Name:
		Chienpanzé		
	Sheet Title:	File Name:	Designer:	Date: Revision:
	Project Architecture	Project Architecture.kicad_sch	Vincent Nguyen	2023-12-22 1.0
	Sheet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

[4] MCU - Power



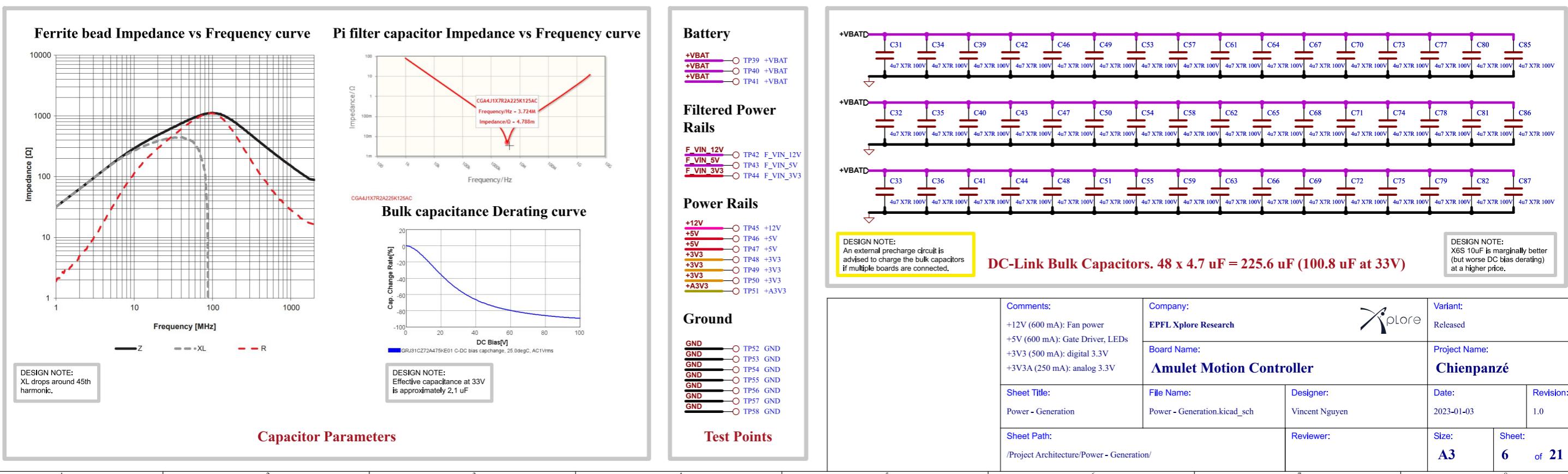
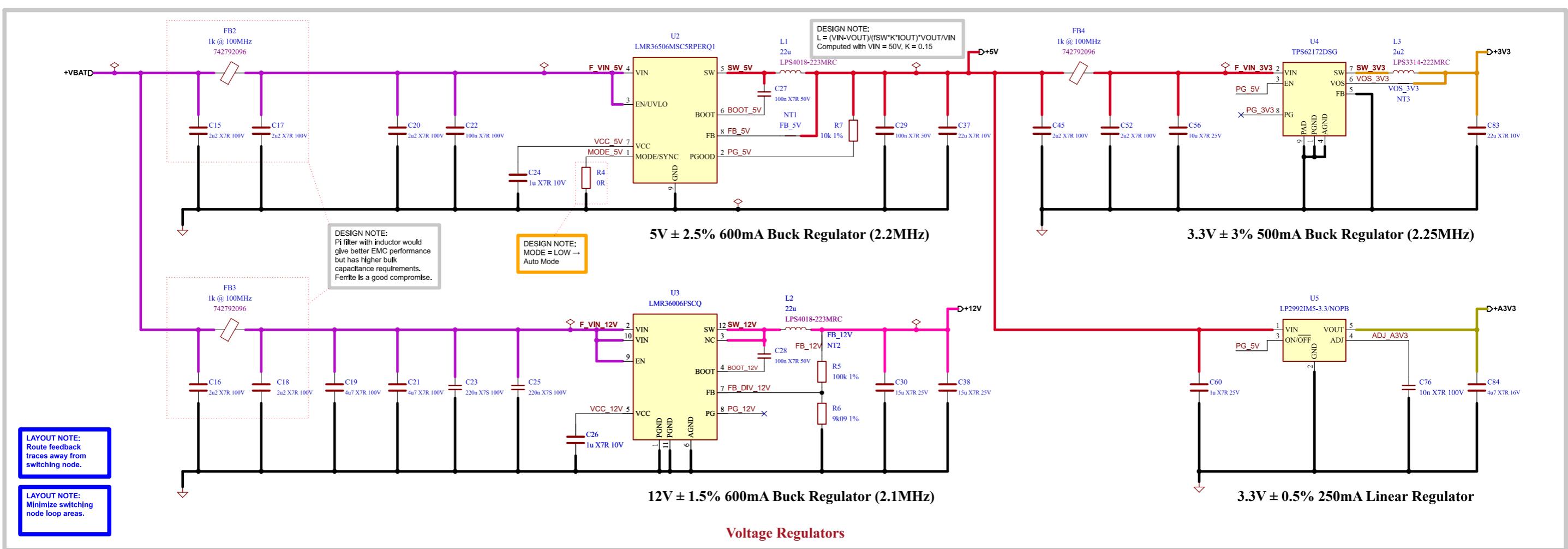
	Comments: AN5346 STM32G474 Datasheet p.81 J. Pieper ADC investigation	Company: EPFL Xplore Research	Variant: Released
	Board Name: Amulet Motion Controller		Project Name: Chienpanzé
	Sheet Title: MCU - Power	File Name: MCU - Power.kicad_sch	Designer: Vincent Nguyen
	Sheet Path: /Project Architecture/MCU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

[5] MCU - I/Os

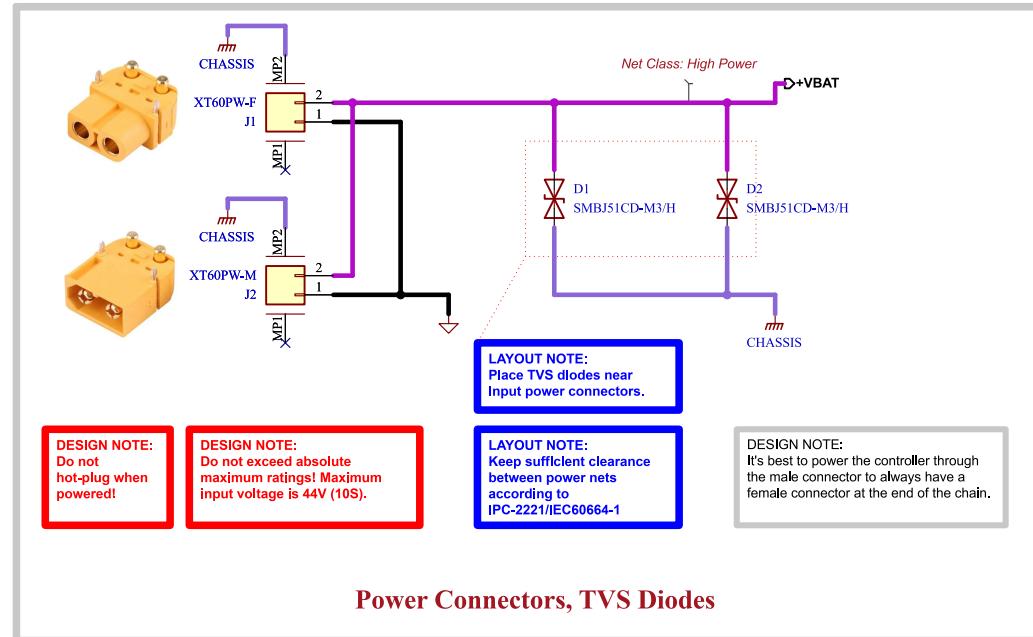


Comments: References: Flexible I/O worked examples Flexible I/O source configuration	Company: EPFL Xplore Research		Variant: Released	
	Board Name: Amulet Motion Controller		Project Name: Chienpanzé	
Sheet Title: MCU - I/Os	File Name: MCU - IOs.kicad_sch	Designer: Vincent Nguyen	Date: 2023-12-20	Revision: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

[6] Power - Generation



[7] Power - Connectors



A

B

C

D

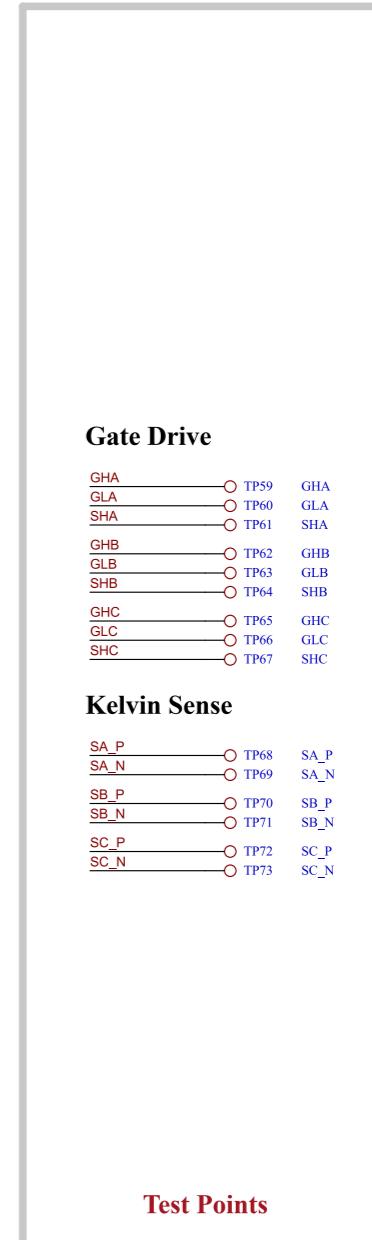
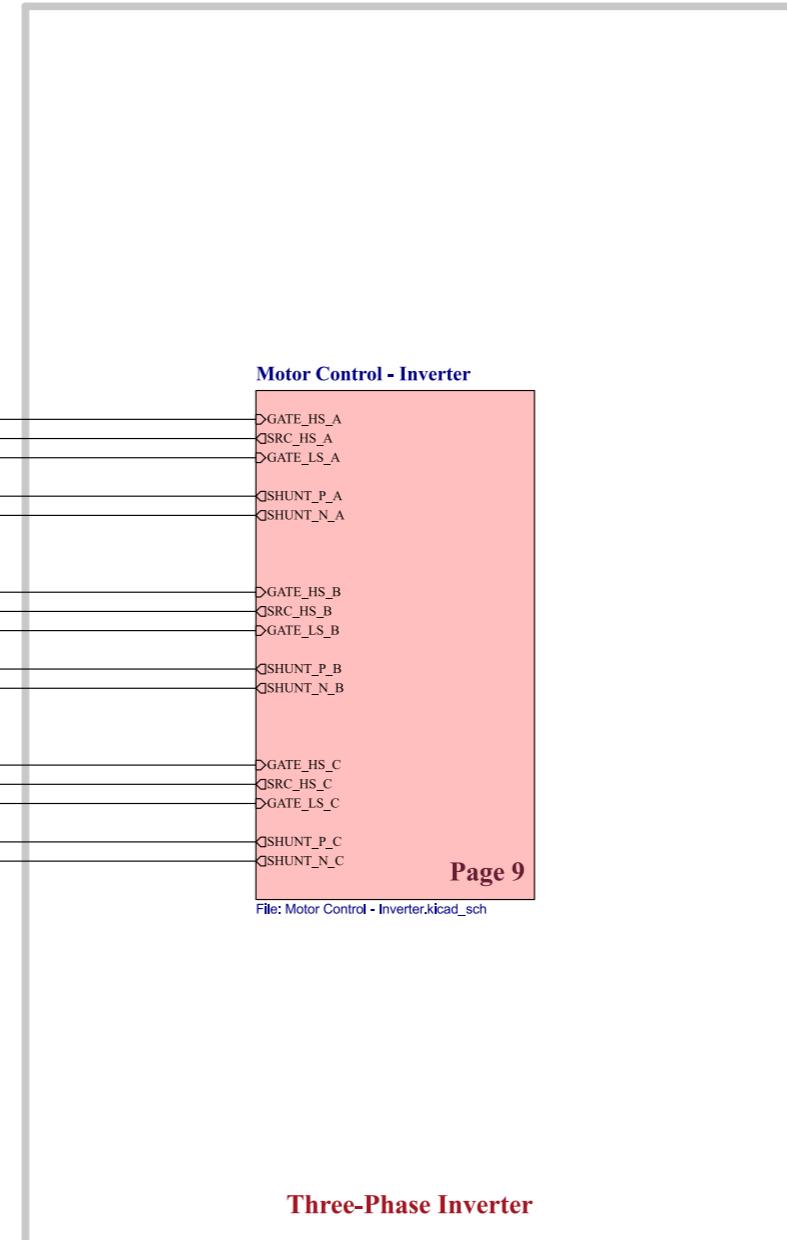
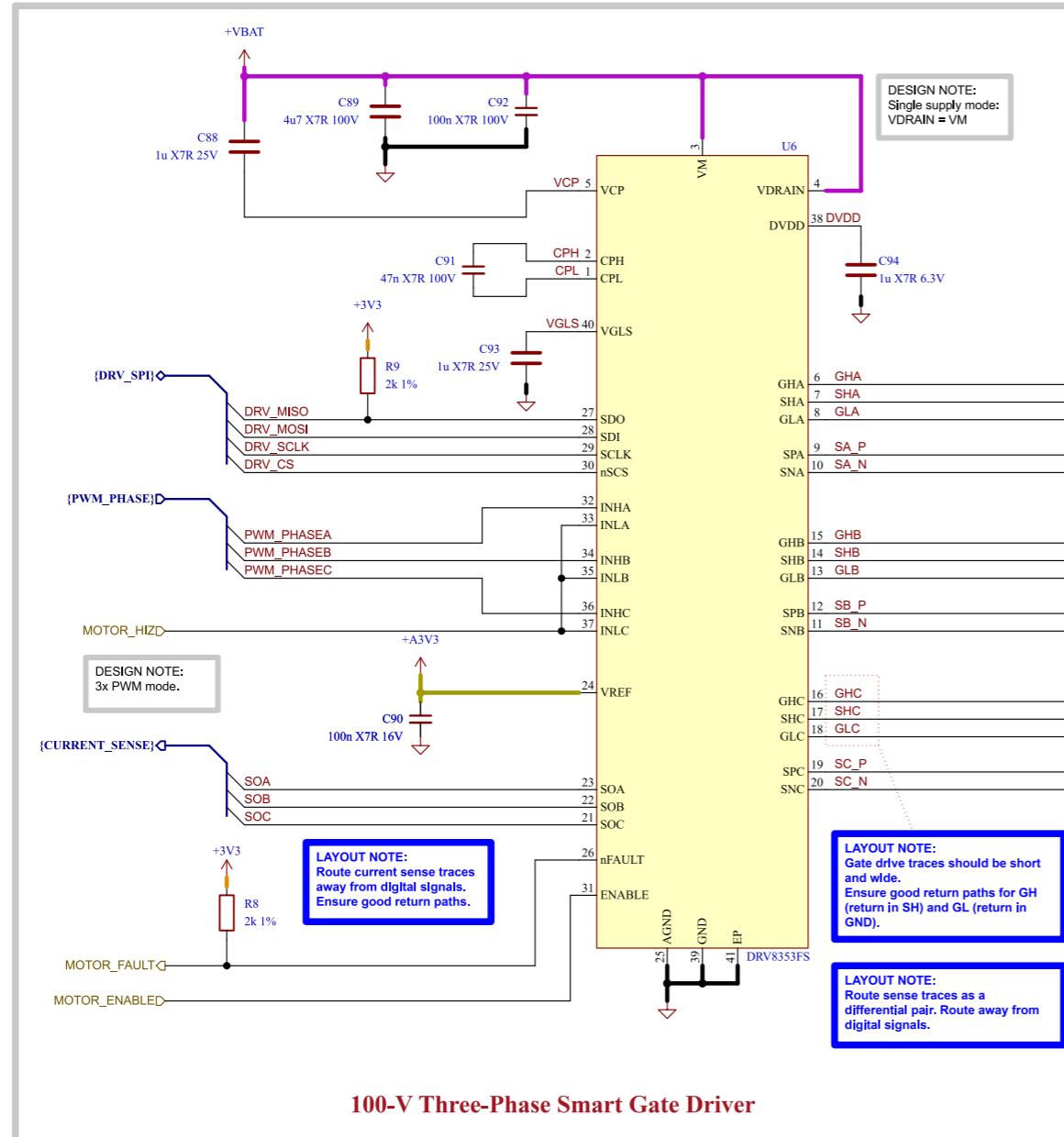
A

B

C

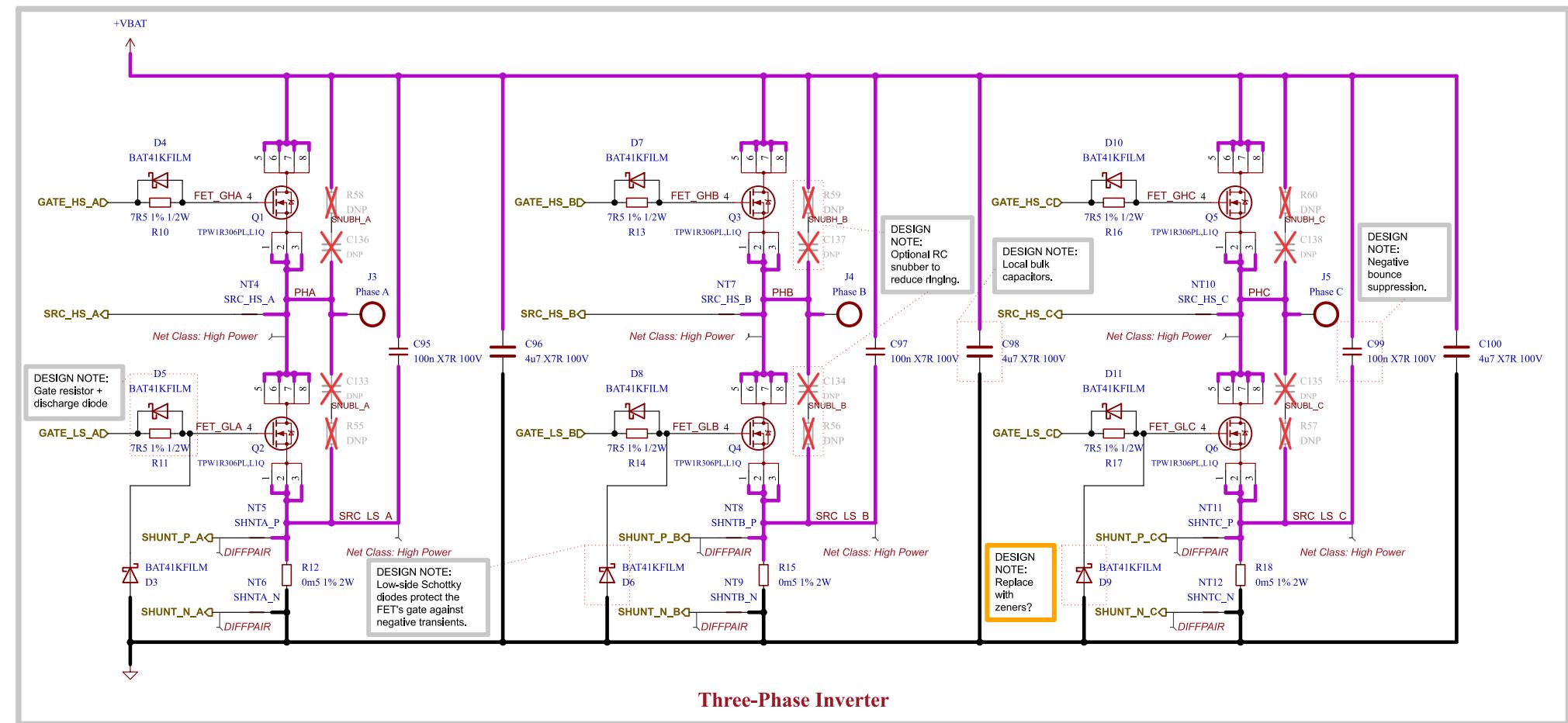
D

[8] Motor Control - Top Level



	Comments:	Company:	Variant:	
		EPFL Xplore Research	Xplore Released	
	Board Name:	Project Name:		
	Amulet Motion Controller		Chienpanzé	
	Sheet Title:	File Name:	Designer:	Date: Revision:
	Motor Control - Top Level	Motor Control - Top Level.kicad_sch	Vincent Nguyen	2023-12-20 1.0
	Sheet Path:	Reviewer:		Size: Sheet:
	/Project Architecture/Motor Control - Top Level/	A3 8 of 21		

[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:
Released

Project Name:
Chienpanzé

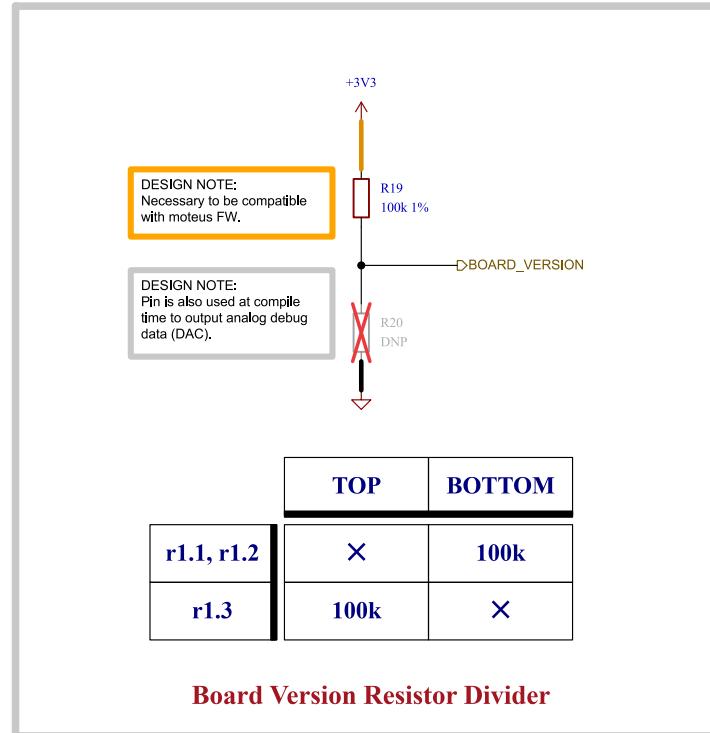
Date:
2024-01-25

Revision:
1.0

Size:
A4

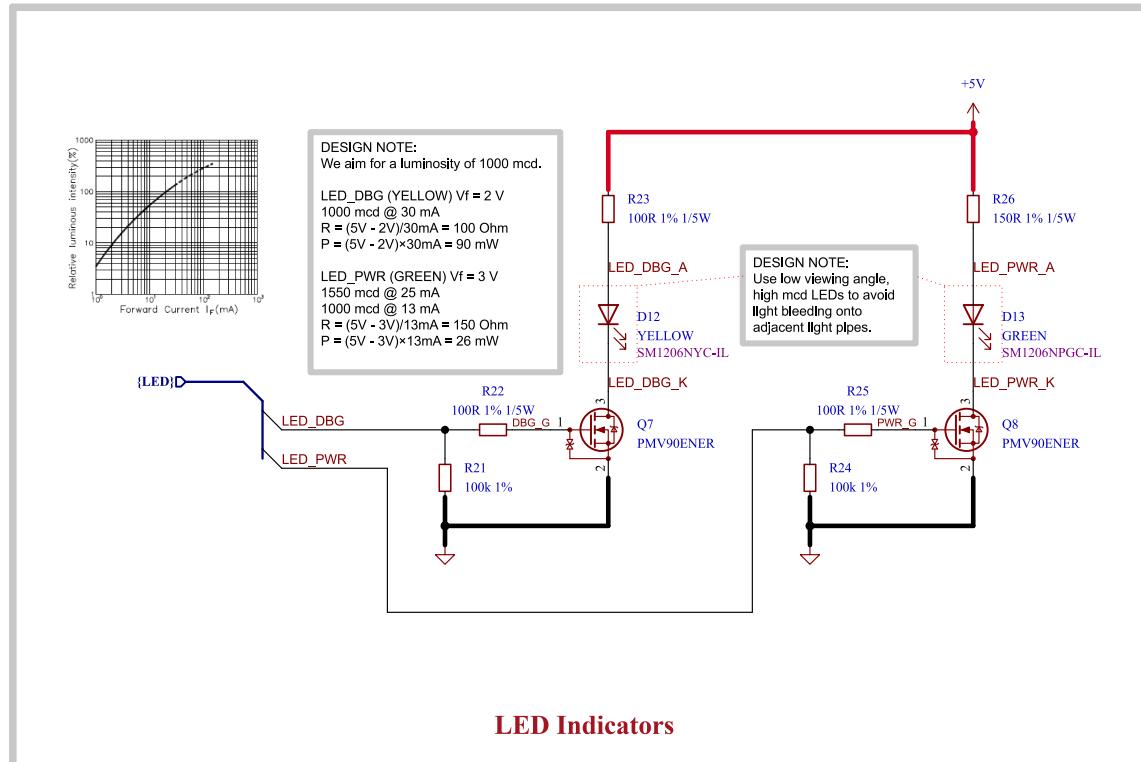
Sheet:
9 of **21**

[10] Misc - Board Version, DAC



	Comments:	Company: EPFL Xplore Research	Variant: Released
	Board Name: Amulet Motion Controller		
	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: Released
	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

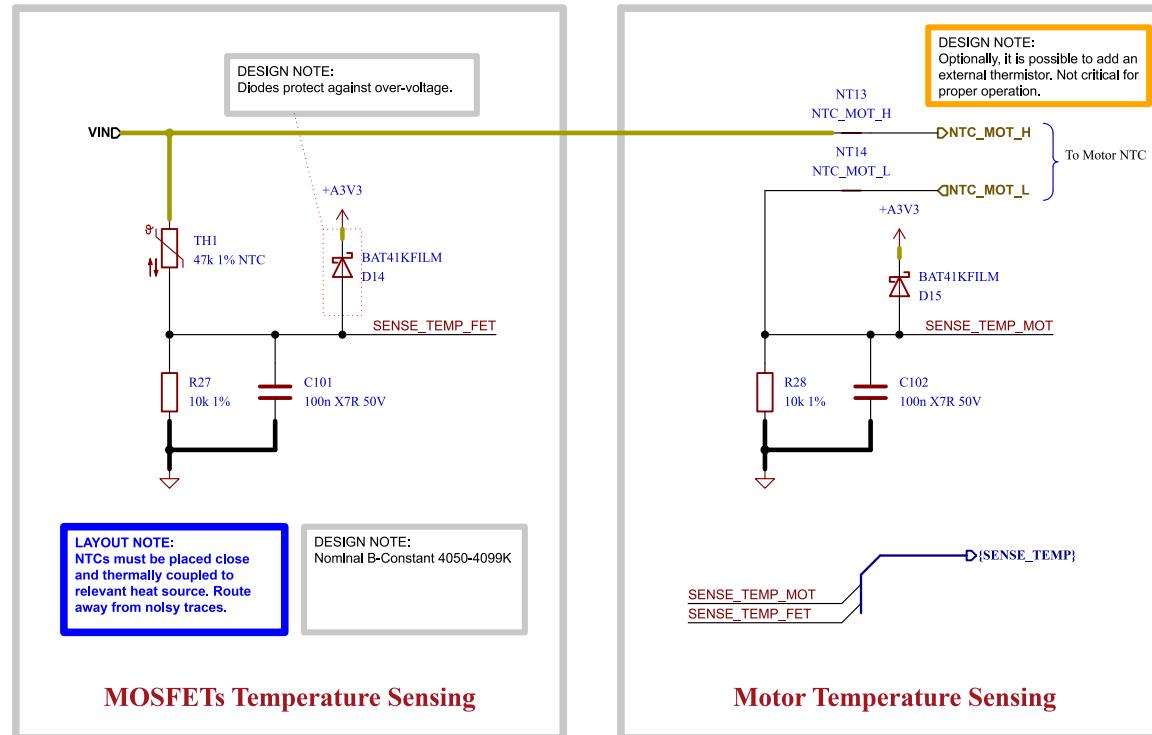
D

A

B

C

D



	Comments:	Company: EPFL Xplore Research	Variant: Released
	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

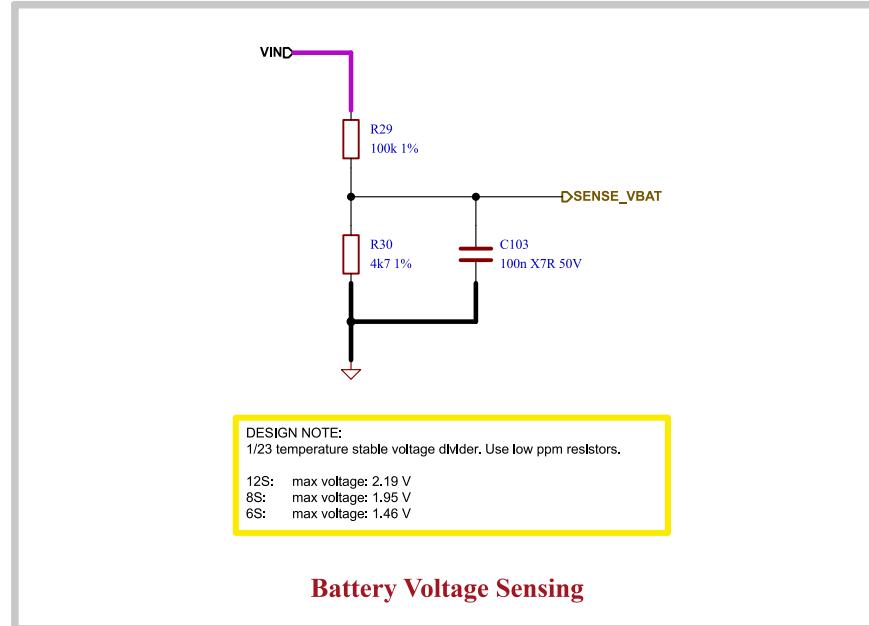
D

A

B

C

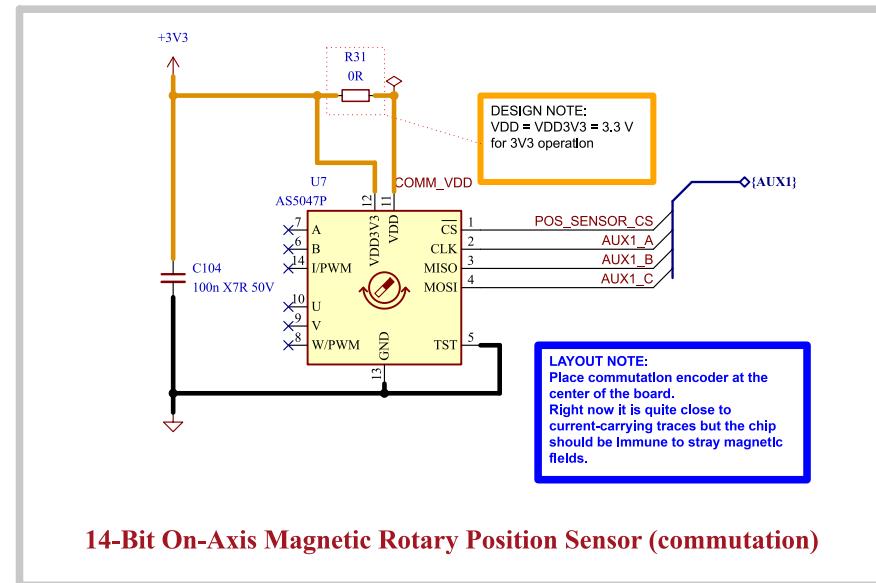
D



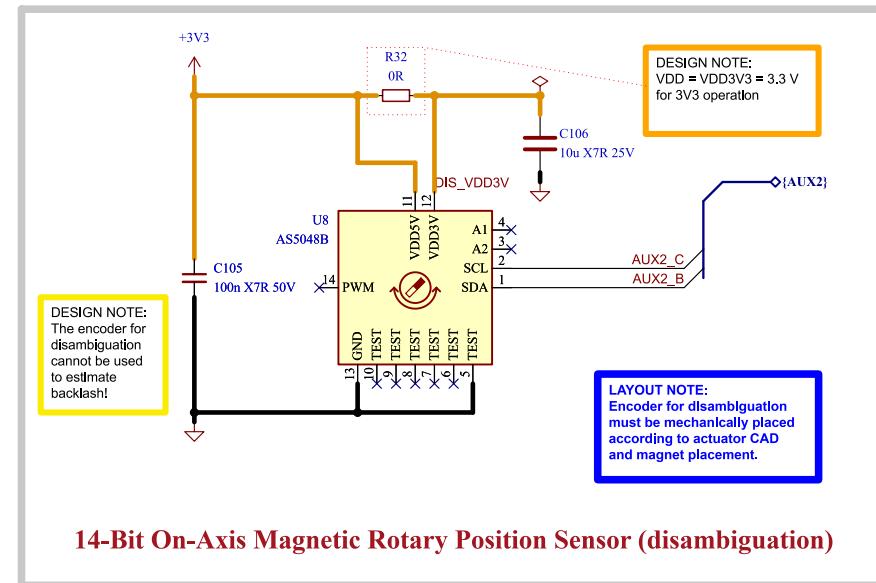
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	Board Name: Amulet Motion Controller		
	Sheet Title: Sensing - Battery	File Name: Sensing - Battery.kicad_sch	Designer: Vincent Nguyen
	Sheet Path: /Project Architecture/Sensing - Battery/	Reviewer:	Date: 2023-10-14 Revision: 1.0

[14] Sensing - Position

A



B



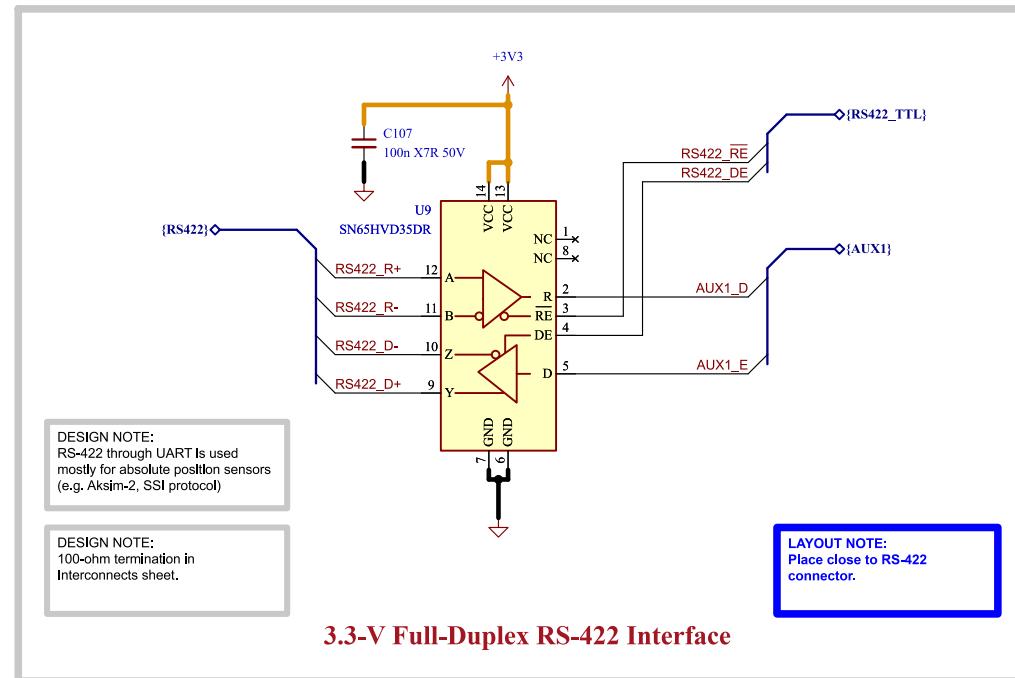
C

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

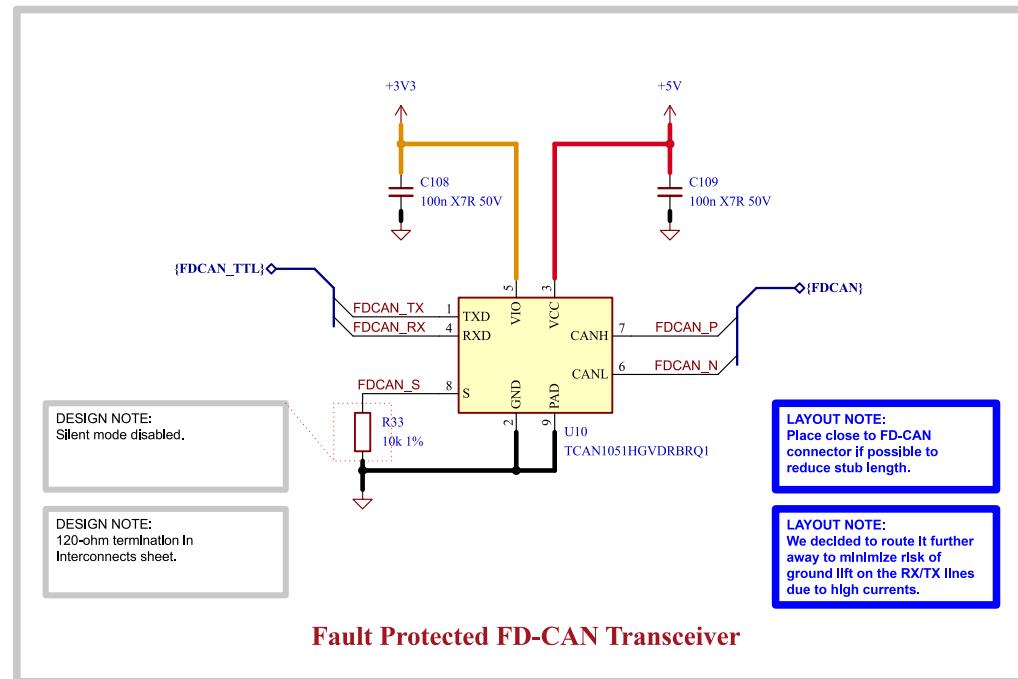
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	Board Name: Amulet Motion Controller		
	Sheet Title: Sensing - Position	File Name: Sensing - Position.kicad_sch	Designer: Vincent Nguyen
	Sheet Path: /Project Architecture/Sensing - Position/	Reviewer:	Date: 2023-10-14 Revision: 1.0

[15] Interface - RS-422



	Comments:	Company: EPFL Xplore Research	Variant: Released
	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
		Size: A4	Revision: 1.0
		Sheet: 15 of 21	

[16] Interface - FD-CAN



A

B

C

D

A

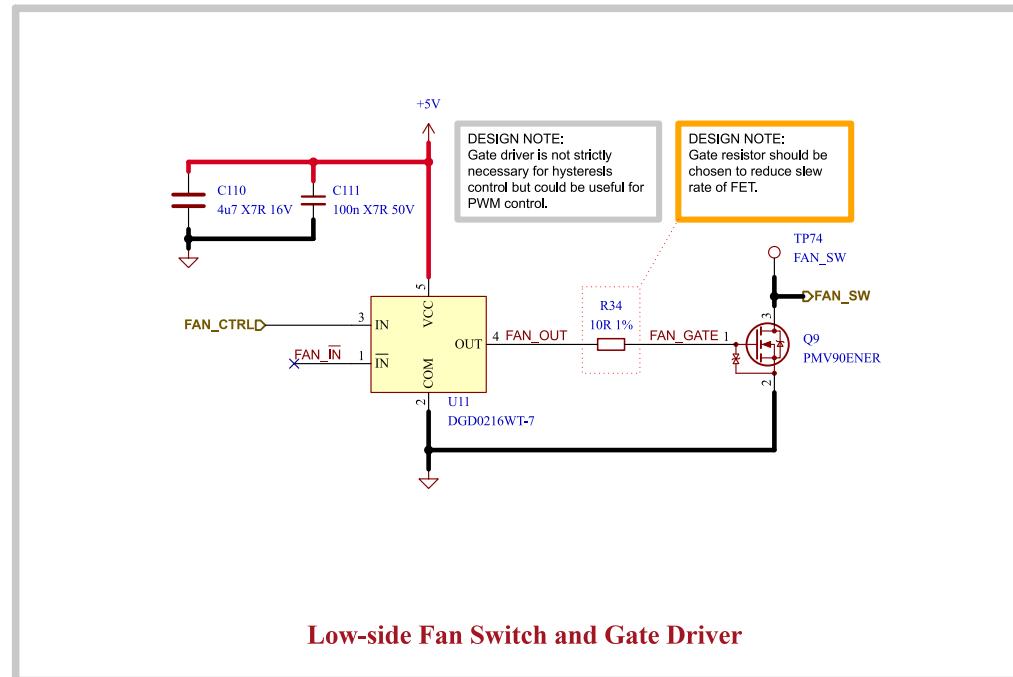
B

C

D

	Comments:	Company: EPFL Xplore Research	Variant: Released
	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
		Size: A4	Revision: 1.0
		Sheet: 16 of 21	

[17] Interface - Fan Control



A

B

C

D

A

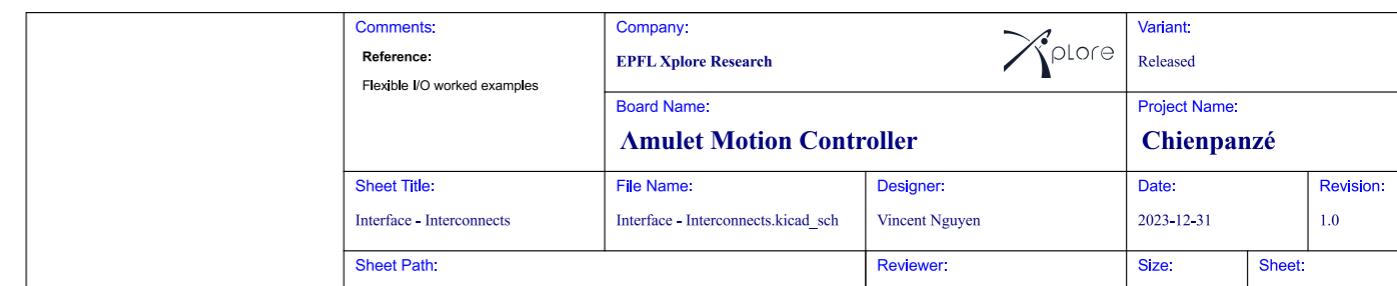
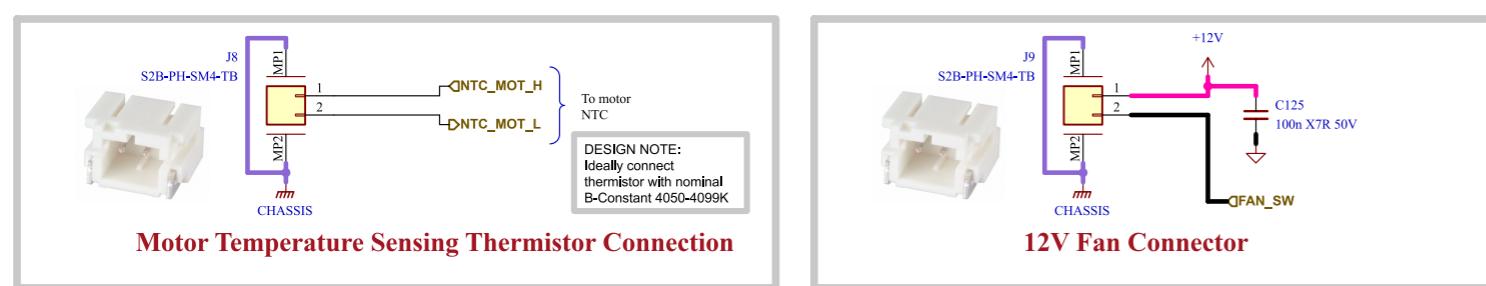
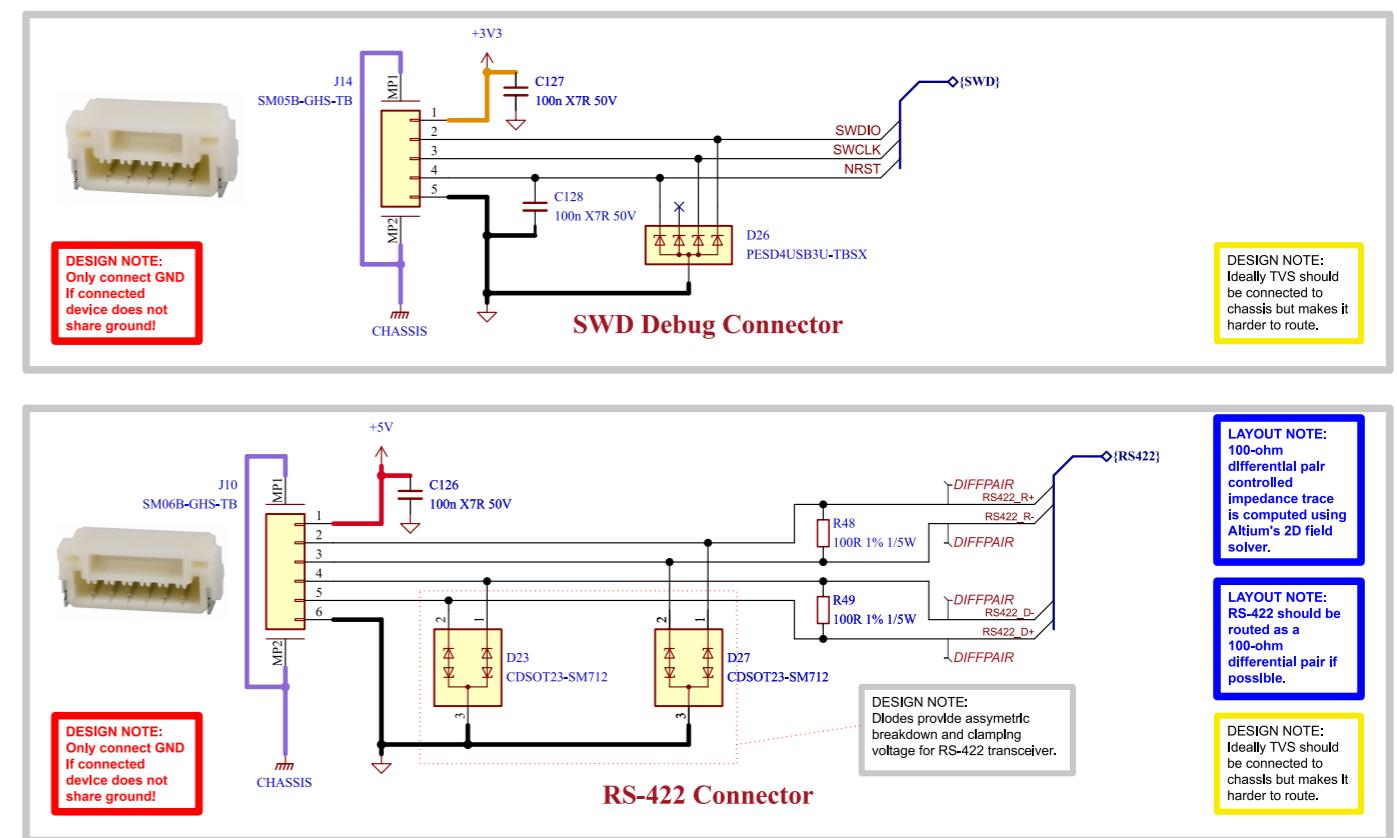
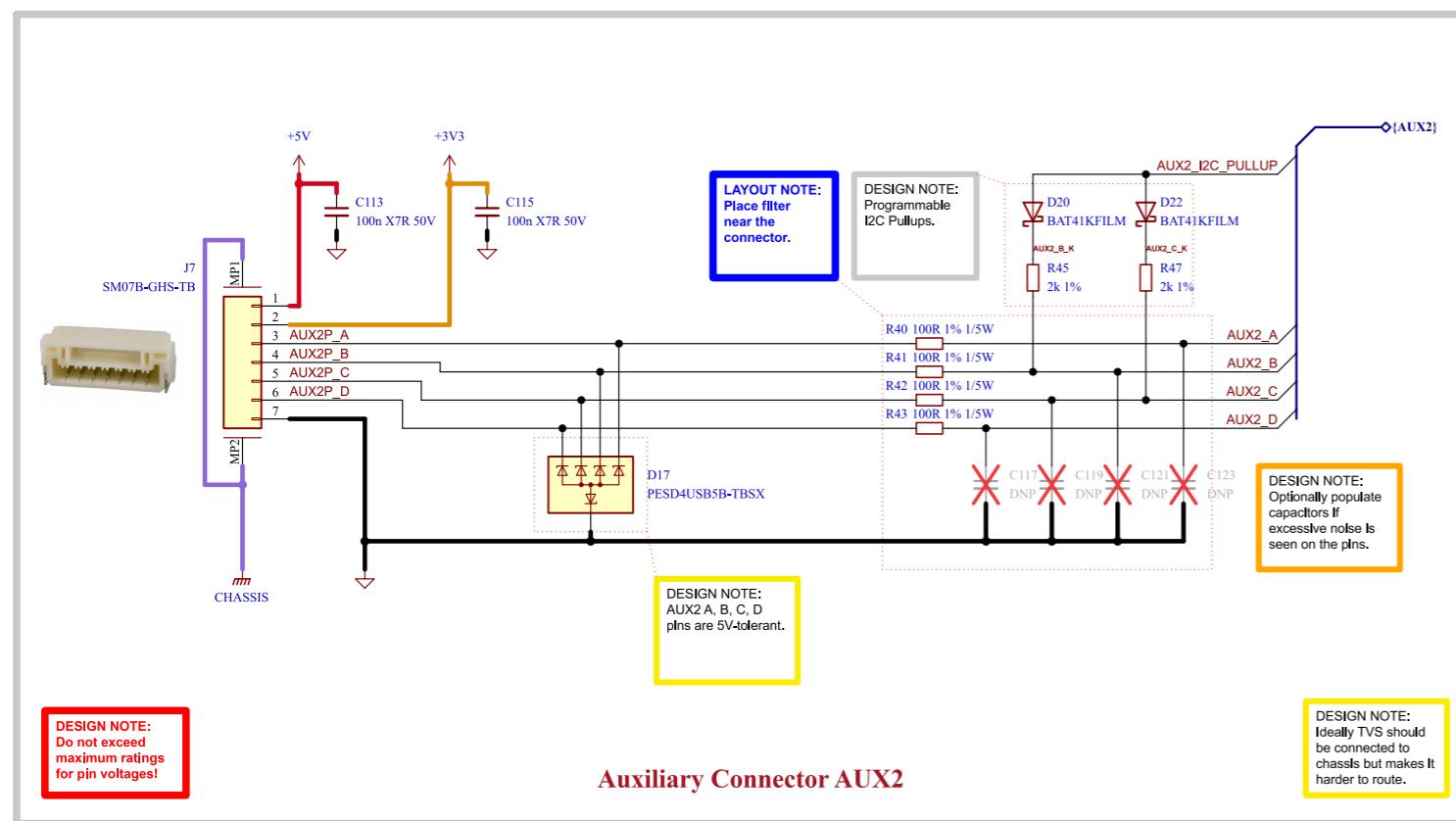
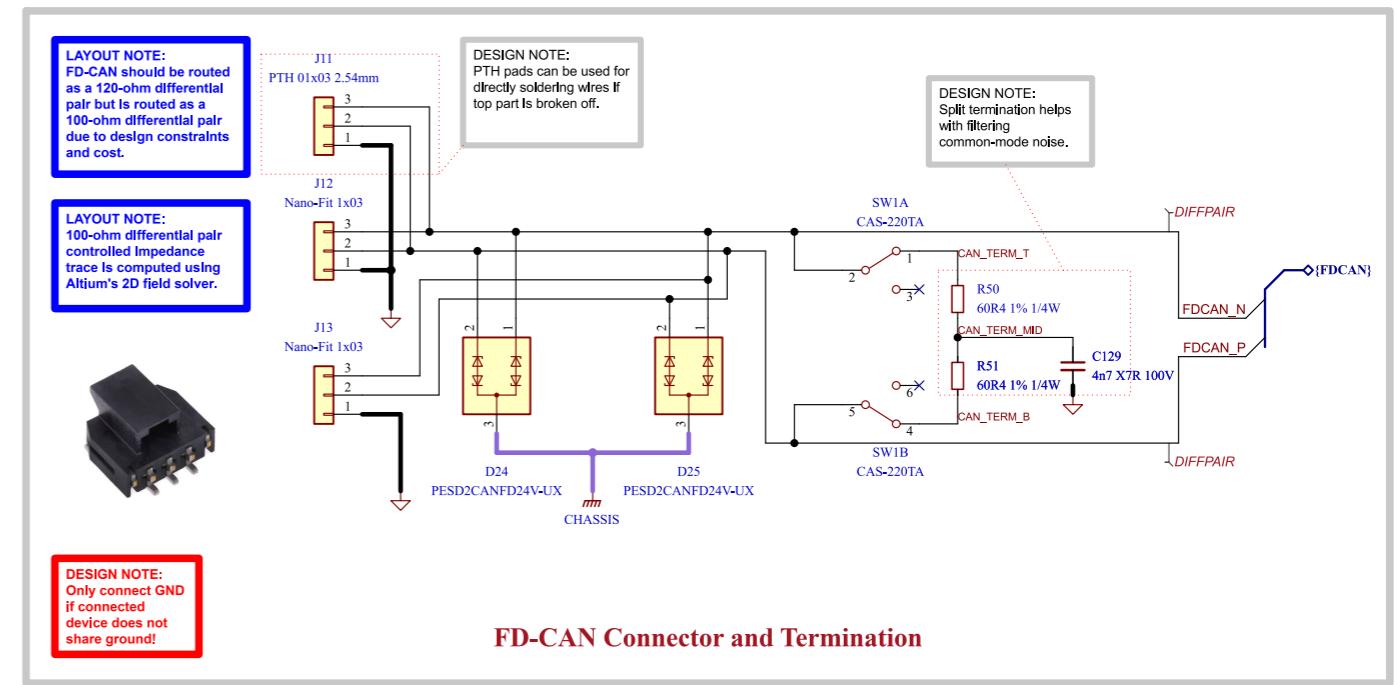
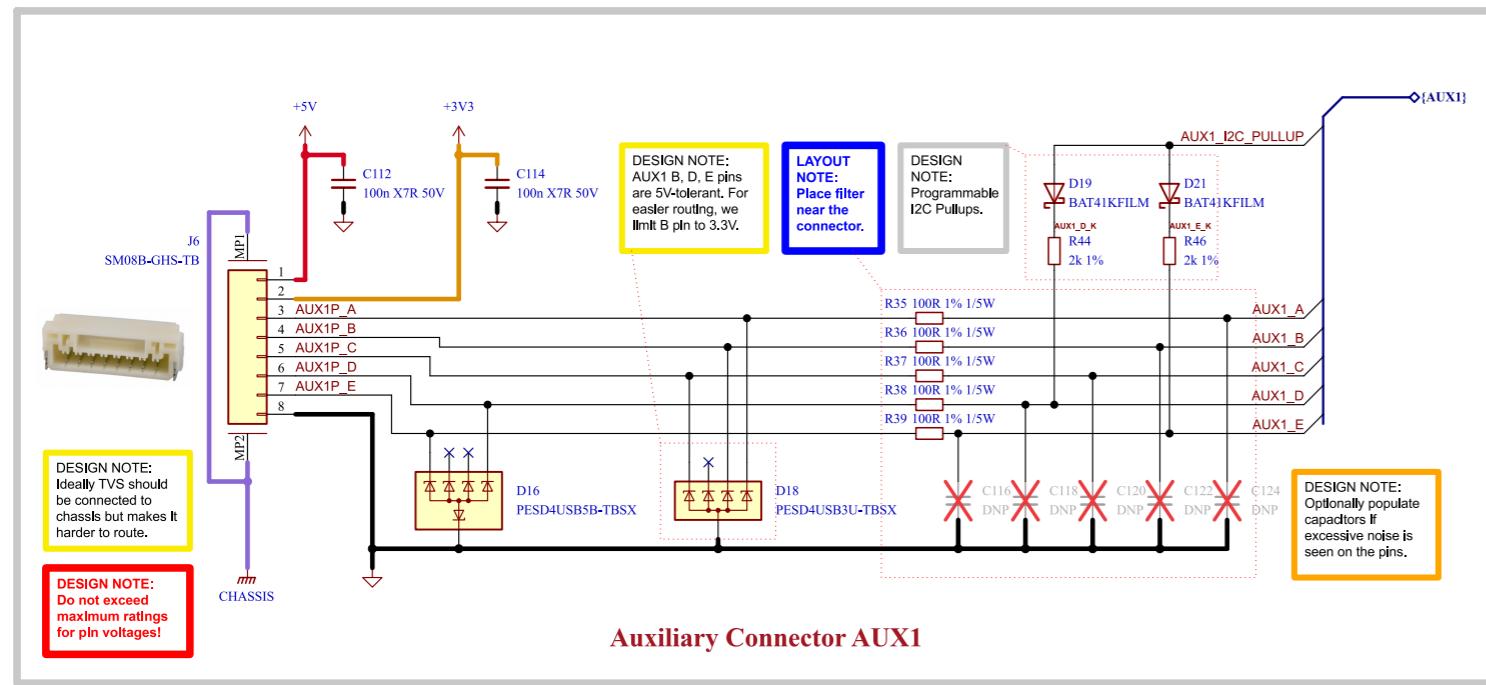
B

C

D

	Comments:	Company: EPFL Xplore Research	Variant: Released
	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

A

A

B

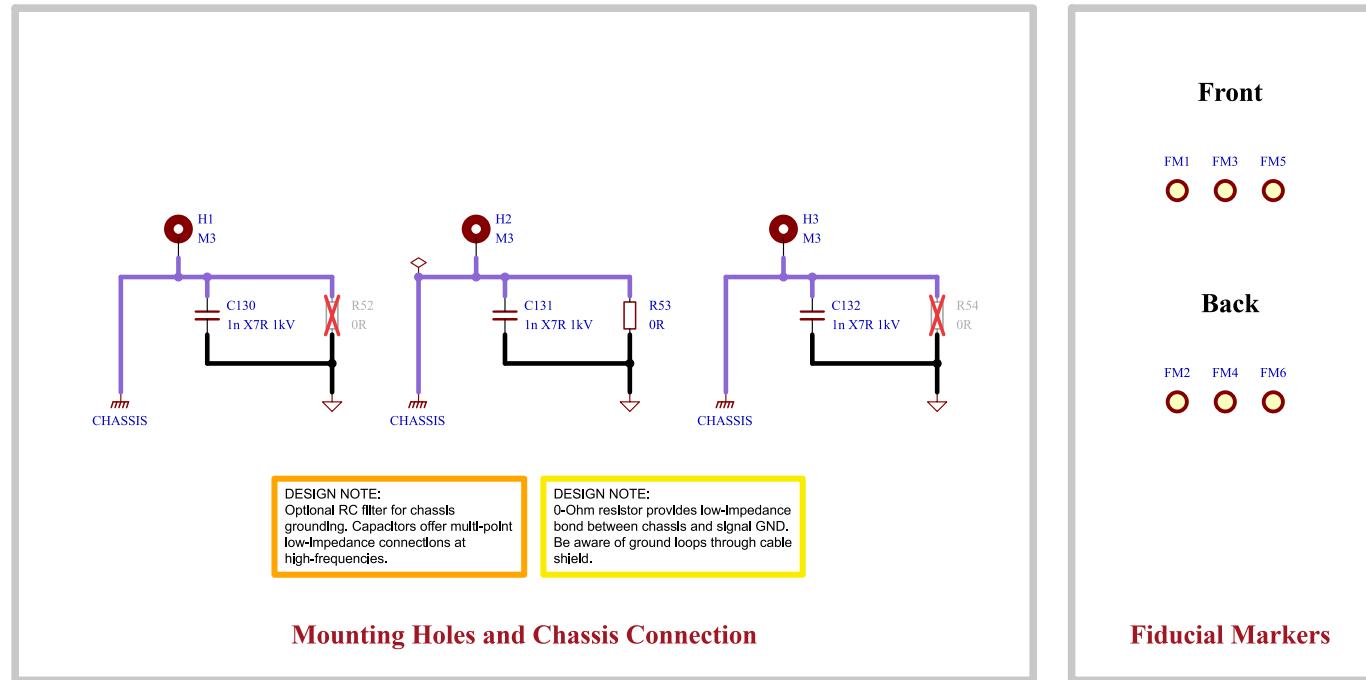
B

C

C

D

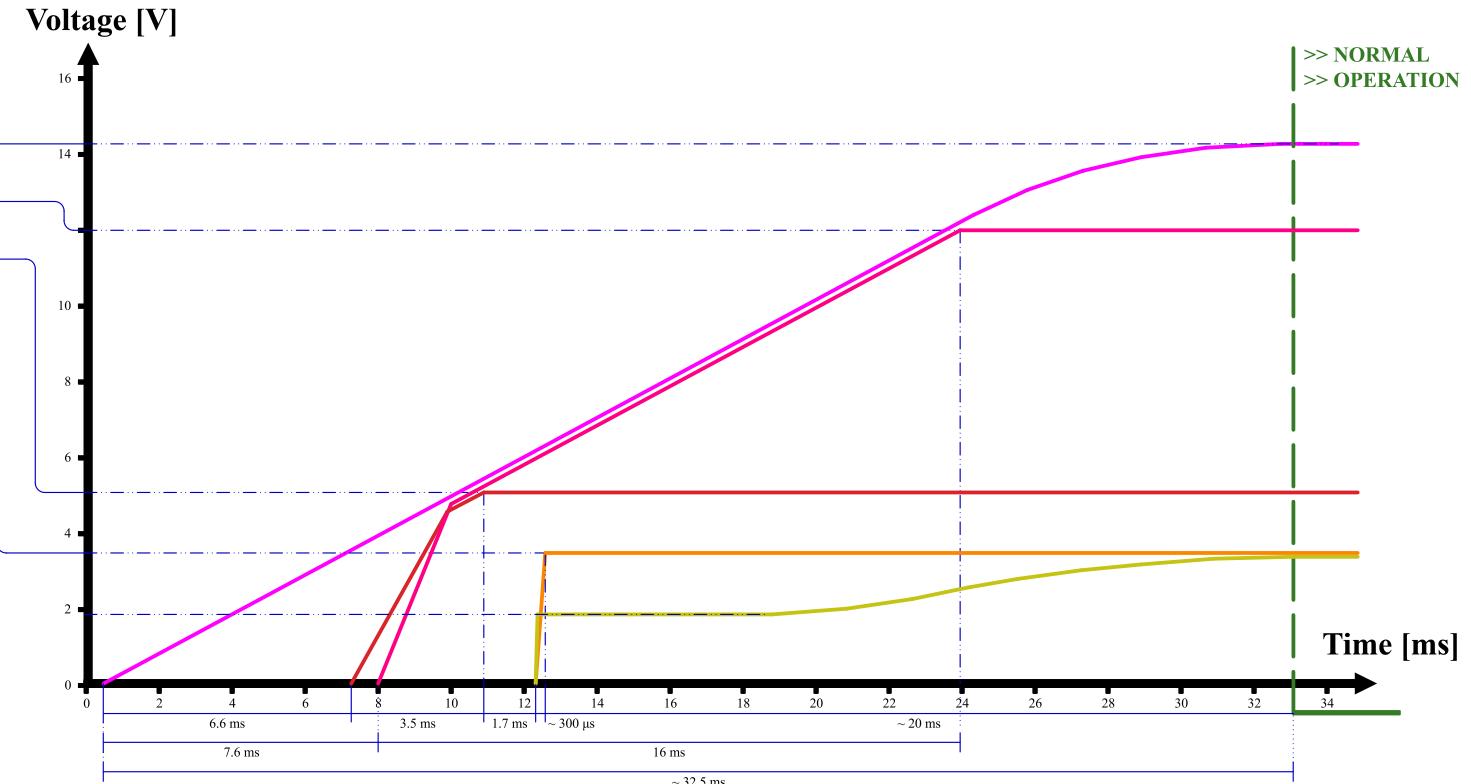
D



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

[20] Power - Sequencing

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



		Comments:	Company: EPFL Xplore Research		Variant: Released
			Board Name: Amulet Motion Controller		
		Sheet Title: Power - Sequencing	File Name: Power - Sequencing.kicad_sch	Designer: Vincent Nguyen	Date: 2024-03-12
		Sheet Path: /Power - Sequencing/		Reviewer:	Size: A4 Sheet: 20 of 21

[21] Revision History

A	12-DEC-2023 - Initial Release Variant: v1.0 Preliminary	25-JAN-2024 - First Revision Variant: v1.0 Checked	12-MAR-2024 - First Revision Variant: v1.0 Released	DD.MM.YYYY - xxx Revision Variant: 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. 	<ul style="list-style-type: none"> - Modified power sequencing graph according to experimental data. 	<ul style="list-style-type: none">
C				
D				