

Amulet Motion Controller

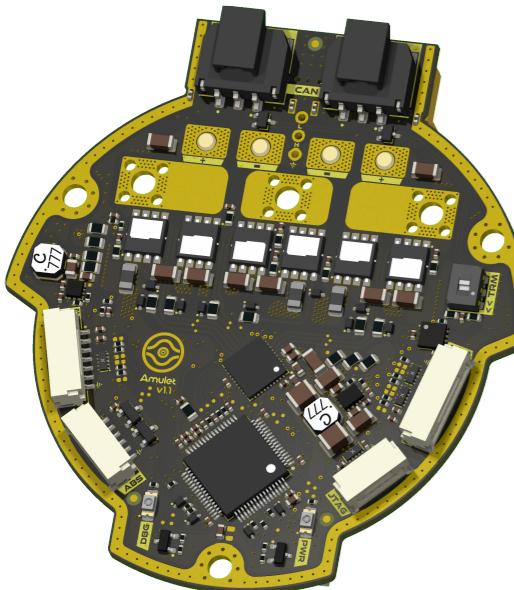
Variant: RELEASED

2024-11-25

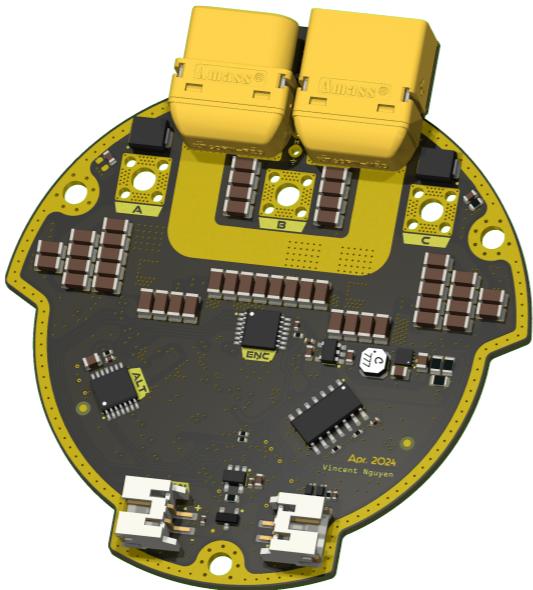
Rev 1.2+ (Unreleased)

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TOP VIEW



BOTTOM 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.

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.

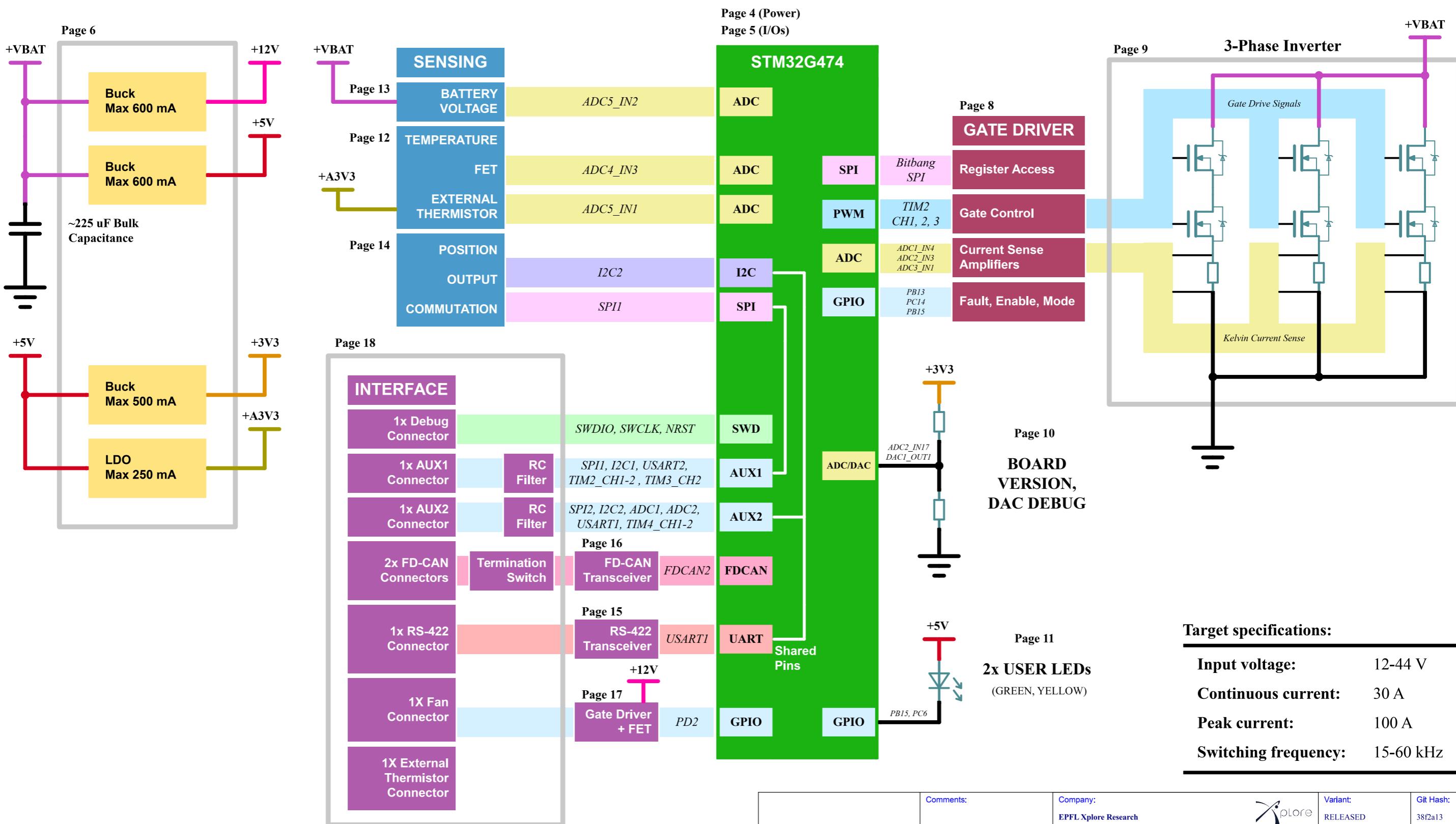
CHECKED - There shouldn't be any mistakes. Contact the engineer if you find any.

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

Date: 25-Nov-2024

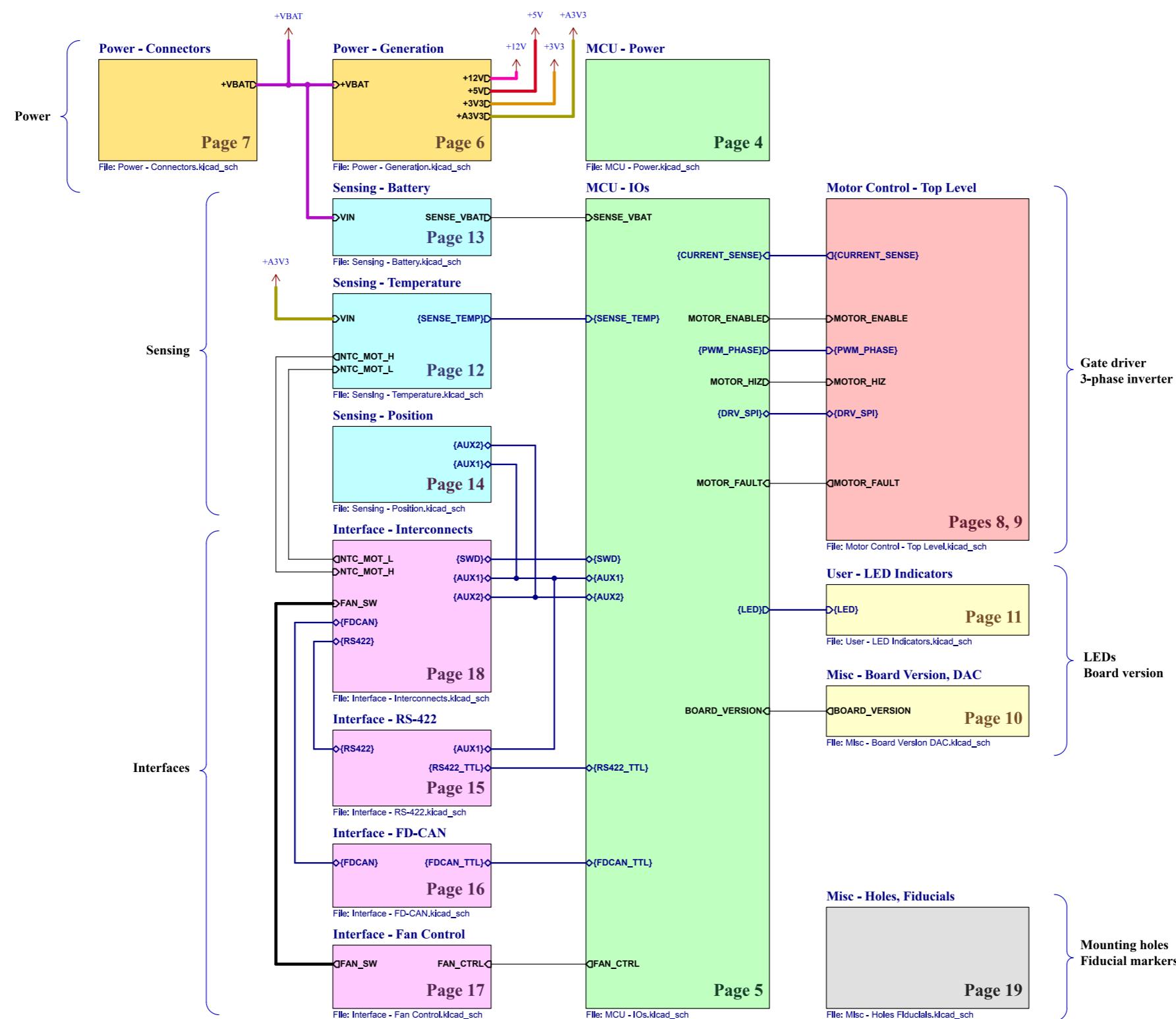
	Comments:	Company: EPFL Xplore Research	Variant: RELEASED	Git Hash: 38f2a13
	Board Name: Amulet Motion Controller	Project Name: Chienpanzé		
	Sheet Title: Cover Page	File Name: amulet_controller.kicad_sch	Designer: Vincent Nguyen	Date: 2024-04-13
	Sheet Path: /		Reviewer:	Size: A3 Sheet: 1 of 21

[2] Block Diagram



Comments:	Company: EPFL Xplore Research		Variant: RELEASED	Git Hash: 38f2a13
	Board Name: Amulet Motion Controller		Project Name: Chienpanzé	
Sheet Title: Block Diagram	File Name: Block Diagram.kicad_sch		Designer: Vincent Nguyen	Date: 2024-04-13
Sheet Path: /Block Diagram/	Reviewer:		Size: A3	Sheet: 2 of 21

[3] Project Architecture



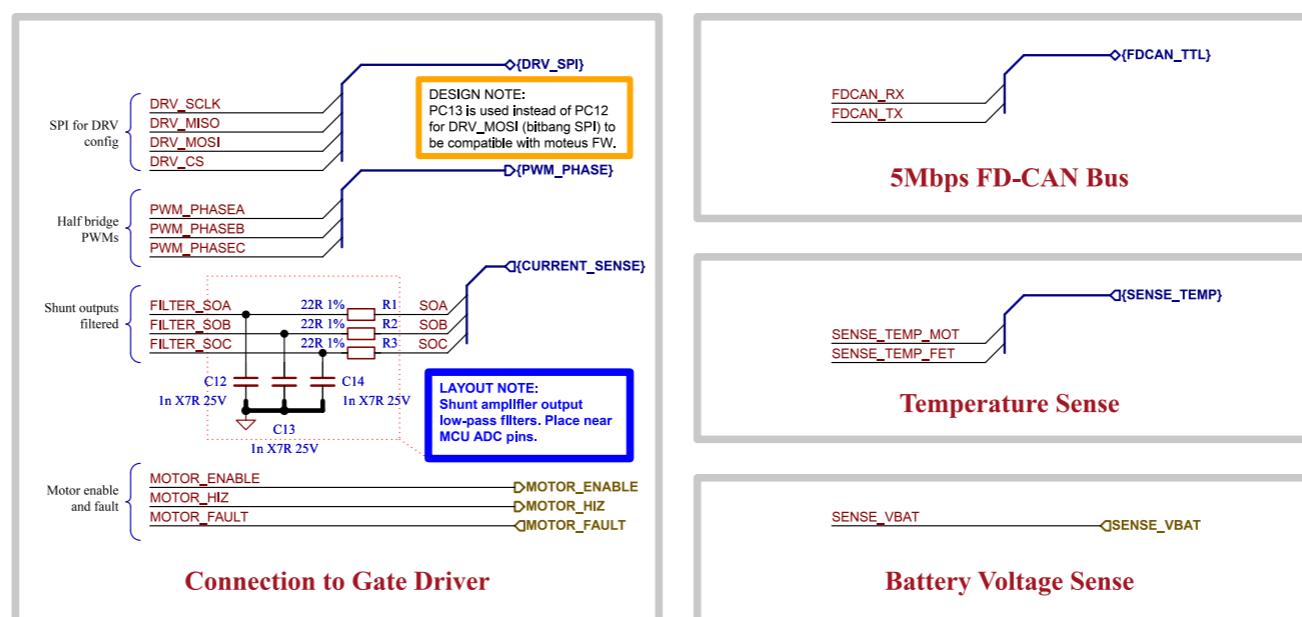
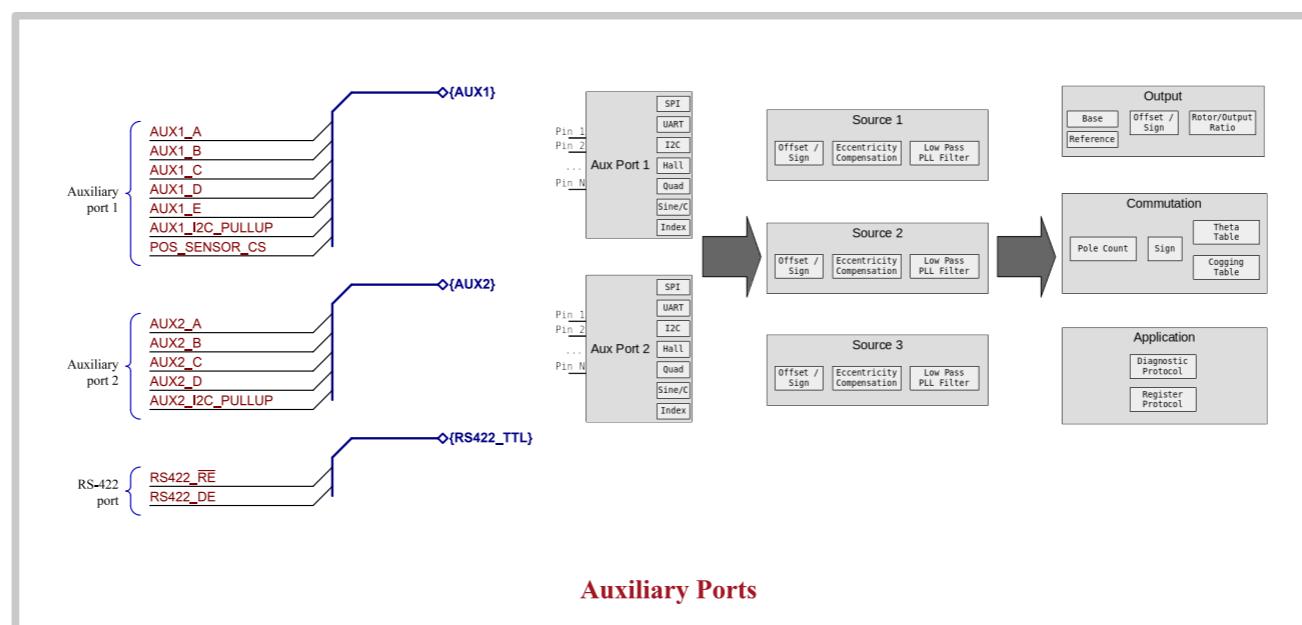
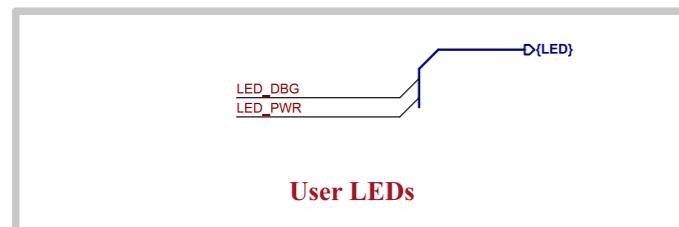
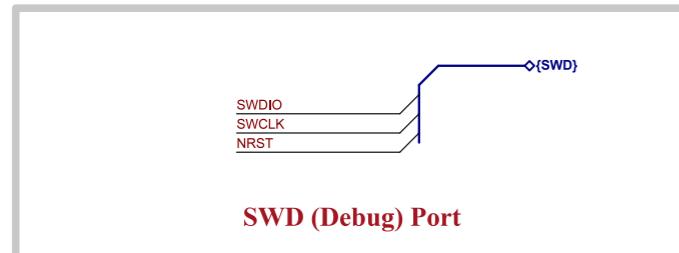
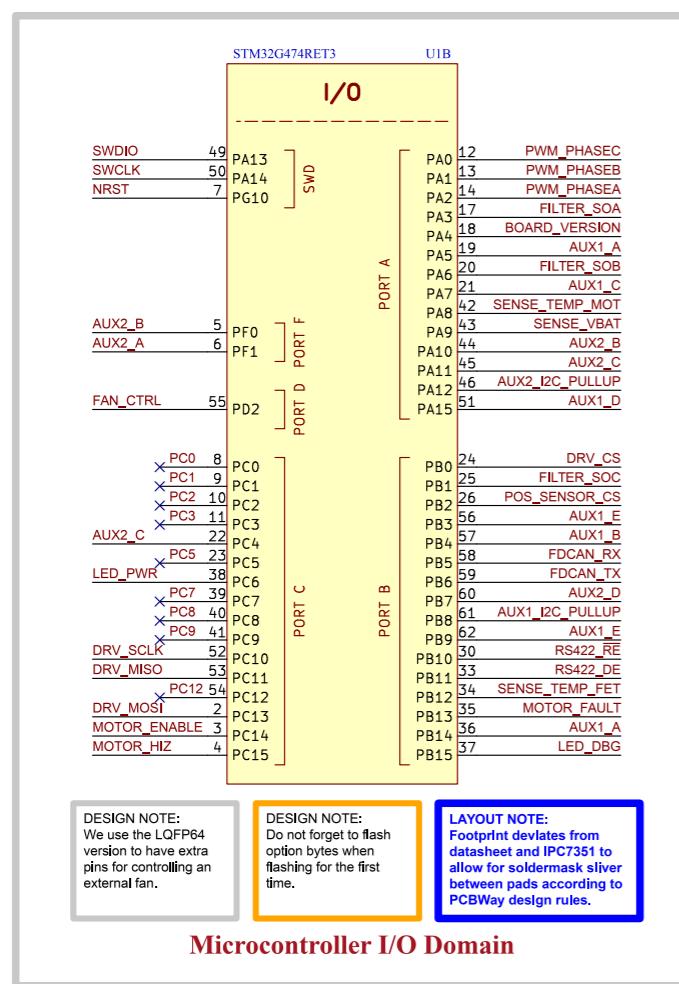
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	Board Name: Amulet Motion Controller	Project Name: Chienpanzé	
Sheet Title: Project Architecture	File Name: Project Architecture.kicad_sch	Designer: Vincent Nguyen	Date: 2023-12-22
Sheet Path: /Project Architecture/	Reviewer:	Revision: 1.2+ (Unreleased)	Size: A3
			Sheet: 3 of 21

[4] MCU - Power



	Comments: AN5346 STM32G474 Datasheet p.81 J. Pieper ADC investigation	Company: EPFL Xplore Research	Variant: RELEASED	Git Hash: 38f2a13
	Board Name: Amulet Motion Controller			Project Name: Chienpanzé
	Sheet Title: MCU - Power	File Name: MCU - Power.kicad_sch	Designer: Vincent Nguyen	Date: 2023-12-18
	Sheet Path: /Project Architecture/MCU - Power/	Reviewer:	Size: A4	Sheet: 4 of 21

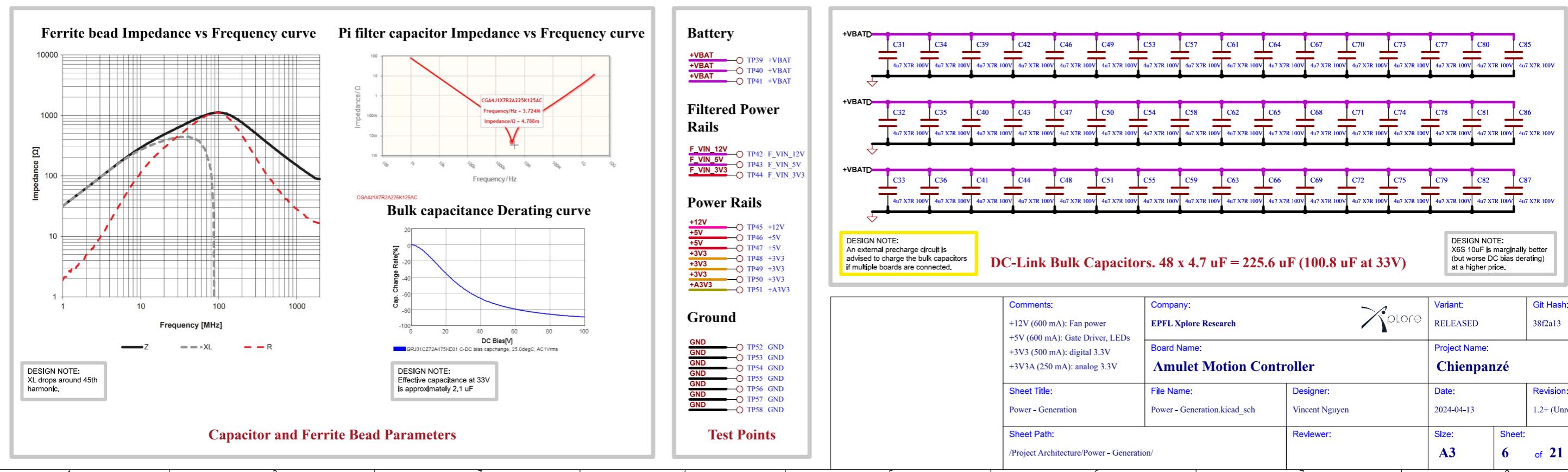
[5] MCU - I/Os



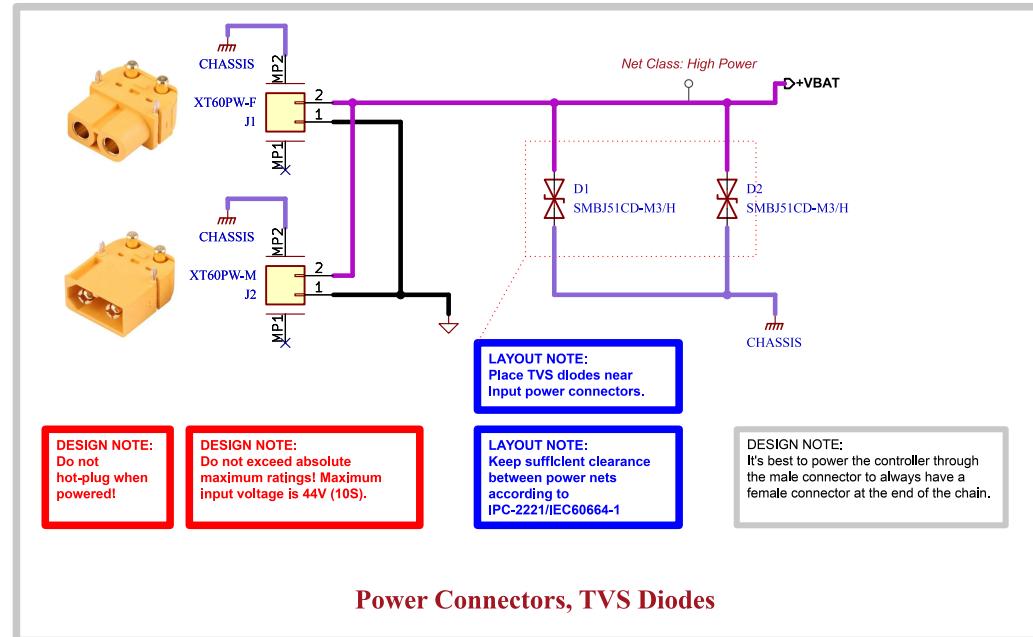
Gate Driver	
MOTOR_ENABLE	TP1
MOTOR_HIZ	TP2
MOTOR_FAULT	TP3
DRV_SCLK	TP4
DRV_MISO	TP5
DRV_MOSI	TP6
DRV_CS	TP7
PWM_PHASEA	TP8
PWM_PHASEB	TP9
PWM_PHASEC	TP10
SOA	TP11
SOB	TP12
SOC	TP13
Debug	
SWDIO	TP14
SWCLK	TP15
NRST	TP16
Auxiliary pins 1	
AUX1_A	TP17
AUX1_B	TP18
AUX1_C	TP19
AUX1_D	TP20
AUX1_E	TP21
AUX1_I2C_PULLUP	TP22
POS_SENSOR_CS	TP23
Auxiliary pins 2	
AUX2_A	TP24
AUX2_B	TP25
AUX2_C	TP26
AUX2_D	TP27
AUX2_I2C_PULLUP	TP28
RS-422	
RS422_RE	TP29
RS422_DE	TP30
LEDs	
LED_DBG	TP31
LED_PWR	TP32
FD-CAN	
FDCAN_RX	TP33
FDCAN_TX	TP34
Fan	
FAN_CTRL	TP35
Sense	
SENSE_TEMP_MOT	TP36
SENSE_TEMP_FET	TP37
SENSE_VBAT	TP38
Test Points	

Comments: References: Flexible I/O worked examples Flexible I/O source configuration	Company: EPFL Xplore Research		Variant: RELEASED	Git Hash: 38f2a13
	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: 1.2+ (Unreleased)
Sheet Path: /Project Architecture/MCU - IOs/	Reviewer:		Size: A3	Sheet: 5 of 21

[6] Power - Generation

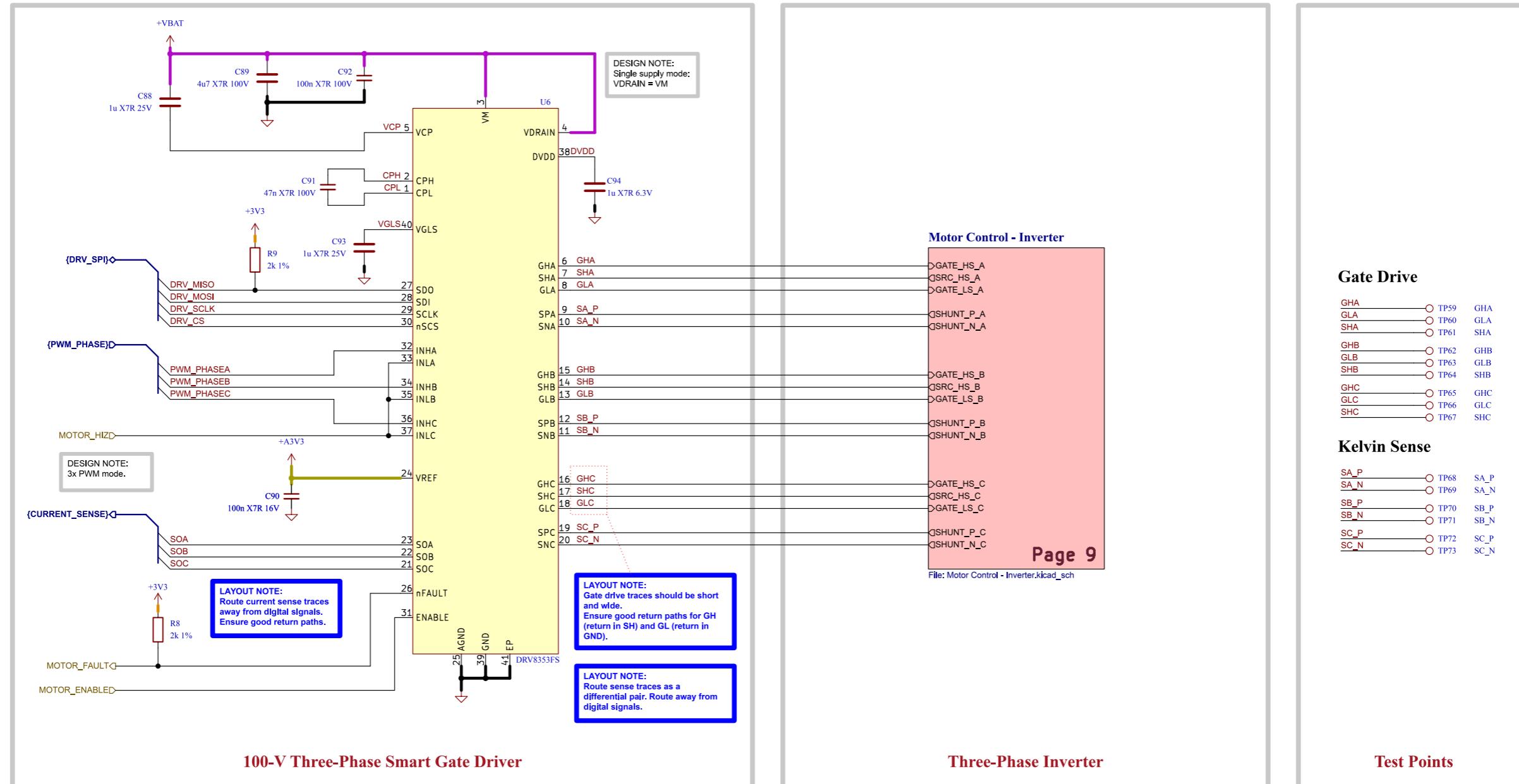


[7] Power - Connectors



	Comments:	Company: EPFL Xplore Research	Variant: RELEASED	Git Hash: 38f2a13
	Board Name: Amulet Motion Controller			Project Name: Chienpanzé
	Sheet Title: Power - Connectors	File Name: Power - Connectors.kicad_sch	Designer: Vincent Nguyen	Date: 2023-12-31
	Sheet Path: /Project Architecture/Power - Connectors/		Reviewer:	Size: A4 Sheet: 7 of 21

[8] Motor Control - Top Level



	Comments:	Company: EPFL Xplore Research	Variant: RELEASED	Git Hash: 38f2a13
	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	Date: 2023-12-20
	Sheet Path: /Project Architecture/Motor Control - Top Level/		Reviewer:	Revision: 1.2+ (Unreleased)
			Size: A3	Sheet: 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

Git Hash:
38f2a13

Project Name:
Chienpanzé

Date:
2024-01-25

Revision:
1.2+ (Unreleased)

Size:
A4

Sheet:
9 of **21**

[10] Misc - Board Version, DAC



	Comments:	Company: EPFL Xplore Research		Variant: RELEASED	Git Hash: 38f2a13
		Board Name: Amulet Motion Controller			
	Sheet Title: Misc - Board Version, DAC	File Name: Misc - Board Version DAC.kicad_sch	Designer: Vincent Nguyen	Date: 2024-04-13	Revision: 1.2+ (Unreleased)
	Sheet Path: /Project Architecture/Misc - Board Version, DAC/		Reviewer:	Size: A4	Sheet: 10 of 21

[11] User - LED Indicators



A

B

C

D

A

B

C

D

	Comments:	Company: EPFL Xplore Research	Variant: RELEASED	Git Hash: 38f2a13
	Board Name: Amulet Motion Controller			Project Name: Chienpanzé
	Sheet Title: User - LED Indicators	File Name: User - LED Indicators.kicad_sch	Designer: Vincent Nguyen	Date: 2023-12-19
	Sheet Path: /Project Architecture/User - LED Indicators/		Reviewer:	Size: A4 Sheet: 11 of 21

[12] Sensing - Temperature

A

B

C

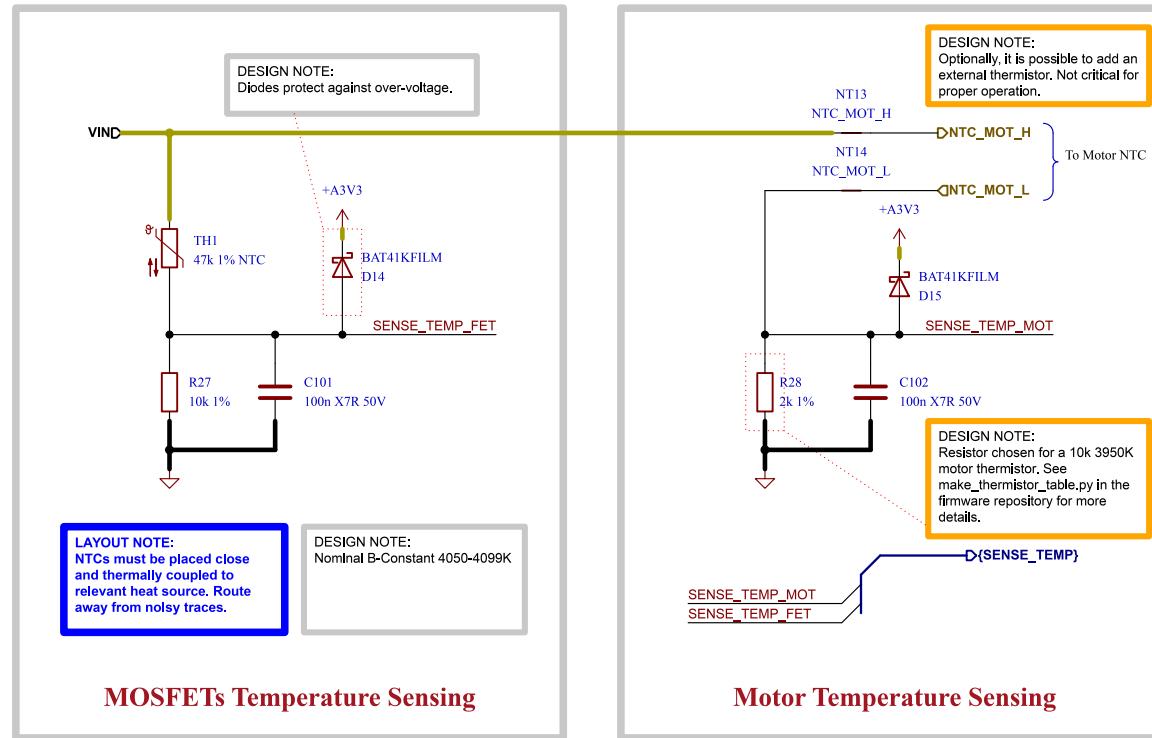
D

A

B

C

D



		Comments:	Company: EPFL Xplore Research	Variant: RELEASED	Git Hash: 38f2a13
		Board Name: Amulet Motion Controller	Project Name: Chienpanzé		
		Sheet Title: Sensing - Temperature	File Name: Sensing - Temperature.kicad_sch	Designer: Vincent Nguyen	Date: 2024-04-13
		Sheet Path: /Project Architecture/Sensing - Temperature/	Revision: 1.2+ (Unreleased)		
			Reviewer:	Size: A4	Sheet: 12 of 21

[13] Sensing - Battery

A

A

B

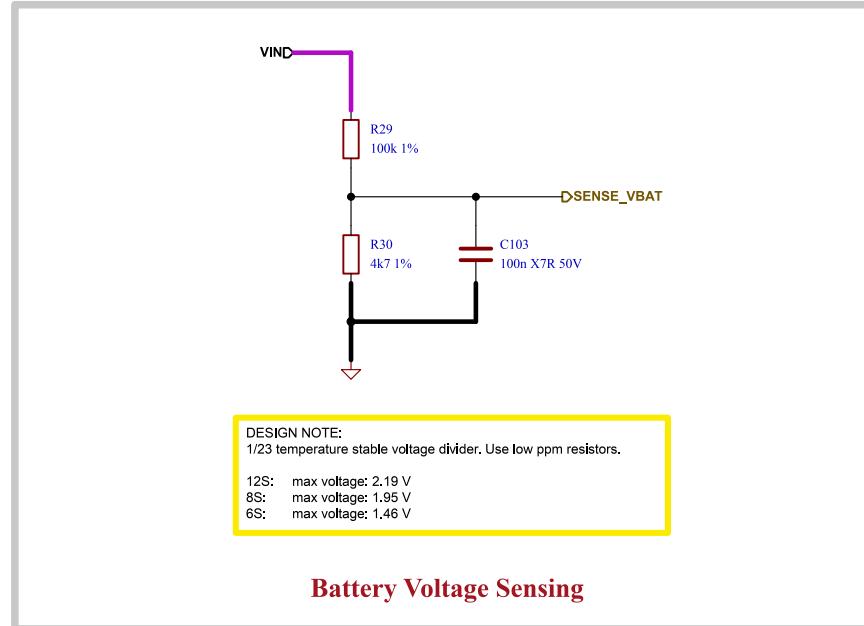
B

C

C

D

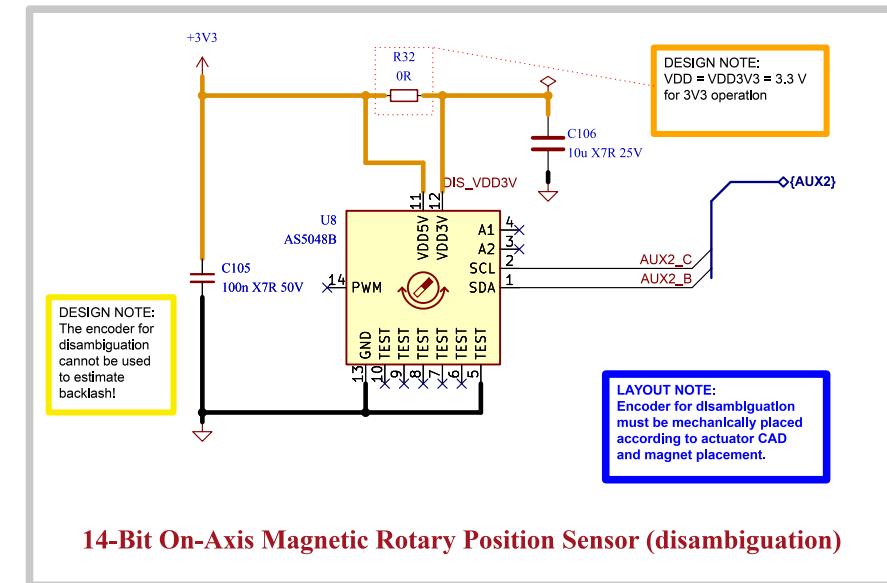
D



	Comments:	Company: EPFL Xplore Research	Variant: RELEASED	Git Hash: 38f2a13
	Board Name: Amulet Motion Controller			Project Name: Chienpanzé
	Sheet Title: Sensing - Battery	File Name: Sensing - Battery.kicad_sch	Designer: Vincent Nguyen	Date: 2023-10-14
	Sheet Path: /Project Architecture/Sensing - Battery/		Reviewer:	Size: A4 Sheet: 13 of 21

[14] Sensing - Position

A



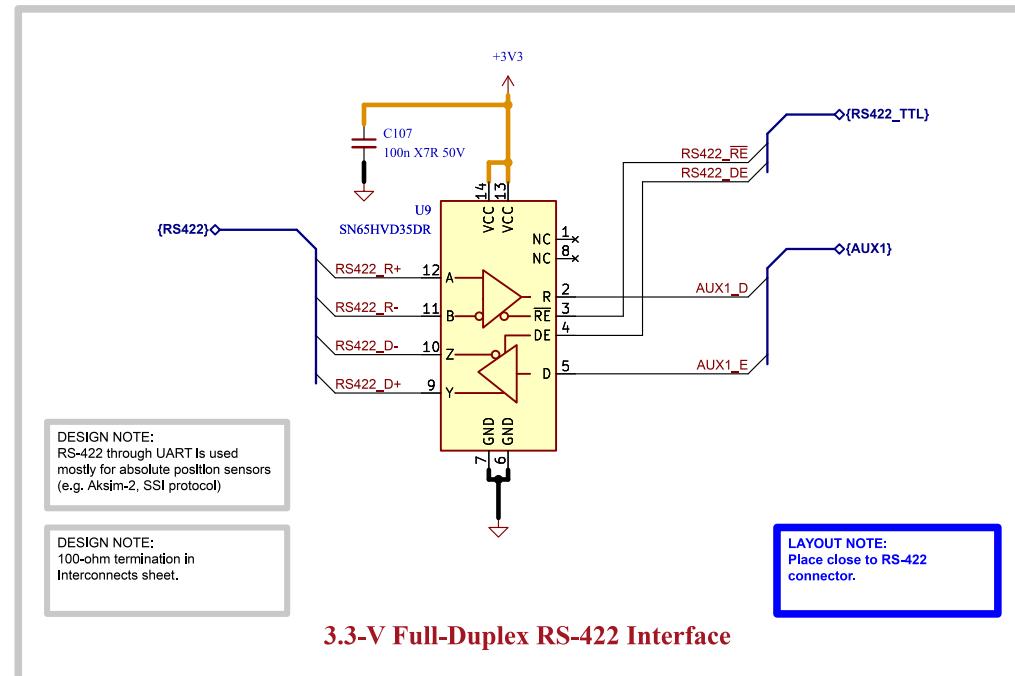
DESIGN NOTE:
AS5047P senses magnet mounted on planetary sun gear, for commutation.
AS5048B senses magnet mounted on shaft with same reduction factor as planetary gearbox for disambiguation.

C

D

	Comments:	Company: EPFL Xplore Research	Variant: RELEASED	Git Hash: 38f2a13
	Board Name: Amulet Motion Controller			Project Name: Chienpanzé
	Sheet Title: Sensing - Position	File Name: Sensing - Position.kicad_sch	Designer: Vincent Nguyen	Date: 2023-10-14
	Sheet Path: /Project Architecture/Sensing - Position/		Reviewer:	Size: A4 Sheet: 14 of 21

[15] Interface - RS-422



A

A

B

B

C

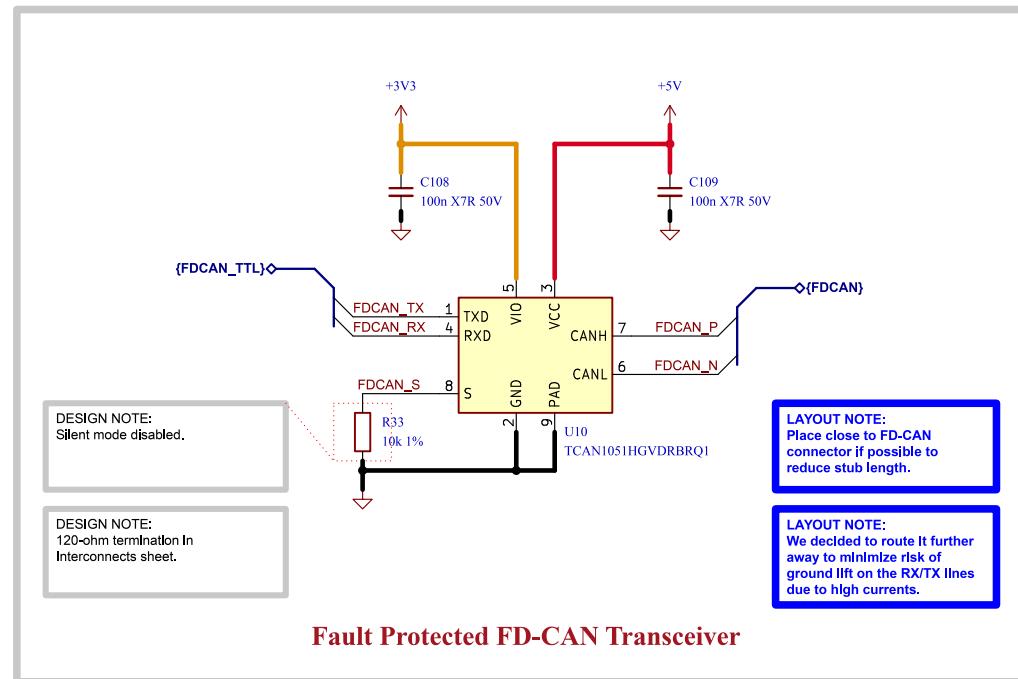
C

D

D

	Comments:	Company: EPFL Xplore Research	Variant: RELEASED	Git Hash: 38f2a13
	Board Name: Amulet Motion Controller			Project Name: Chienpanzé
	Sheet Title: Interface - RS-422	File Name: Interface - RS-422.kicad_sch	Designer: Vincent Nguyen	Date: 2023-10-15
	Sheet Path: /Project Architecture/Interface - RS-422/		Reviewer:	Size: A4 Sheet: 15 of 21

[16] Interface - FD-CAN



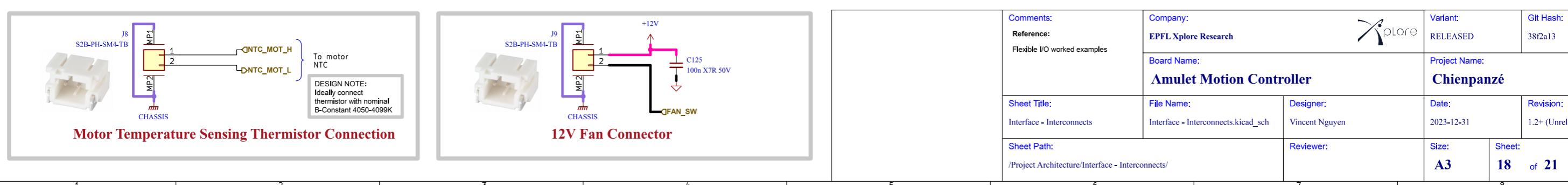
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	Board Name: Amulet Motion Controller			Project Name: Chienpanzé
	Sheet Title: Interface - FD-CAN	File Name: Interface - FD-CAN.kicad_sch	Designer: Vincent Nguyen	Date: 2023-10-15
	Sheet Path: /Project Architecture/Interface - FD-CAN/		Reviewer:	Size: A4 Sheet: 16 of 21

[17] Interface - Fan Control



	Comments:	Company: EPFL Xplore Research	Variant: RELEASED	Git Hash: 38f2a13
	Board Name: Amulet Motion Controller			Project Name: Chienpanzé
	Sheet Title: Interface - Fan Control	File Name: Interface - Fan Control.kicad_sch	Designer: Vincent Nguyen	Date: 2023-11-19
	Sheet Path: /Project Architecture/Interface - Fan Control/		Reviewer:	Size: A4 Sheet: 17 of 21

[18] Interface - Interconnects



[19] Misc - Holes, Fiducials

A

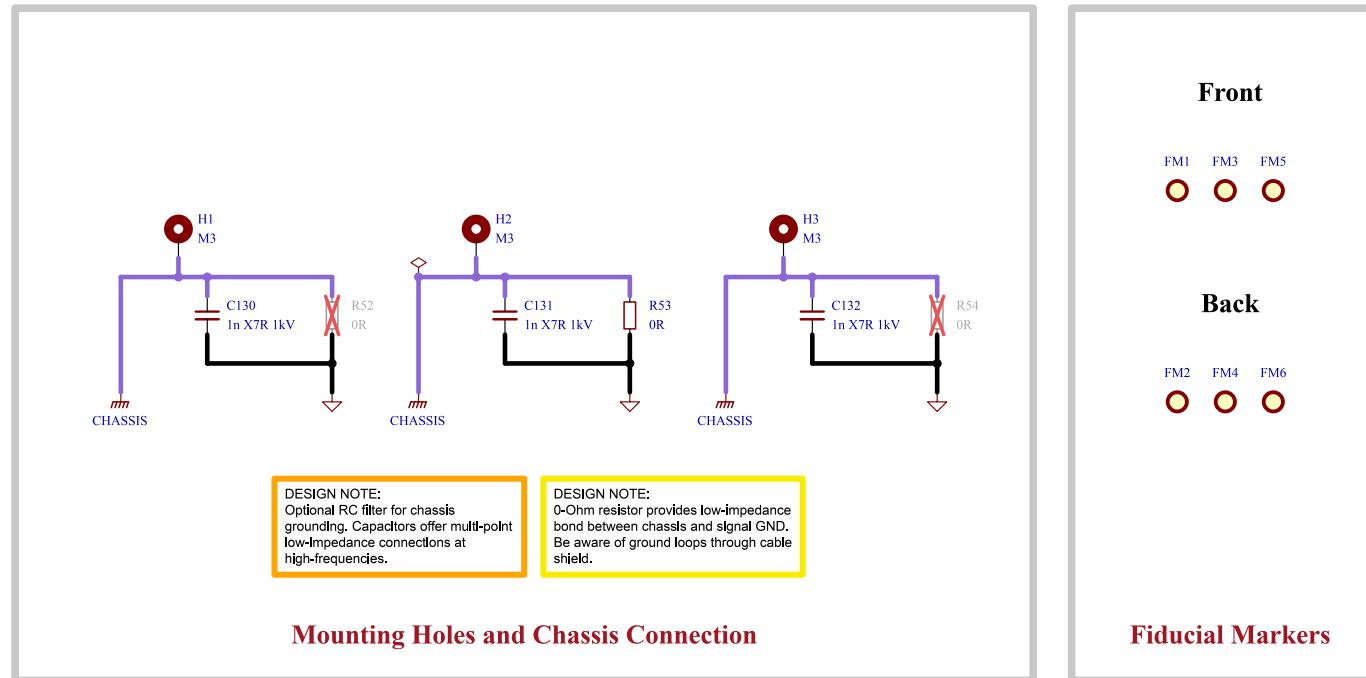
A

B

B

C

C



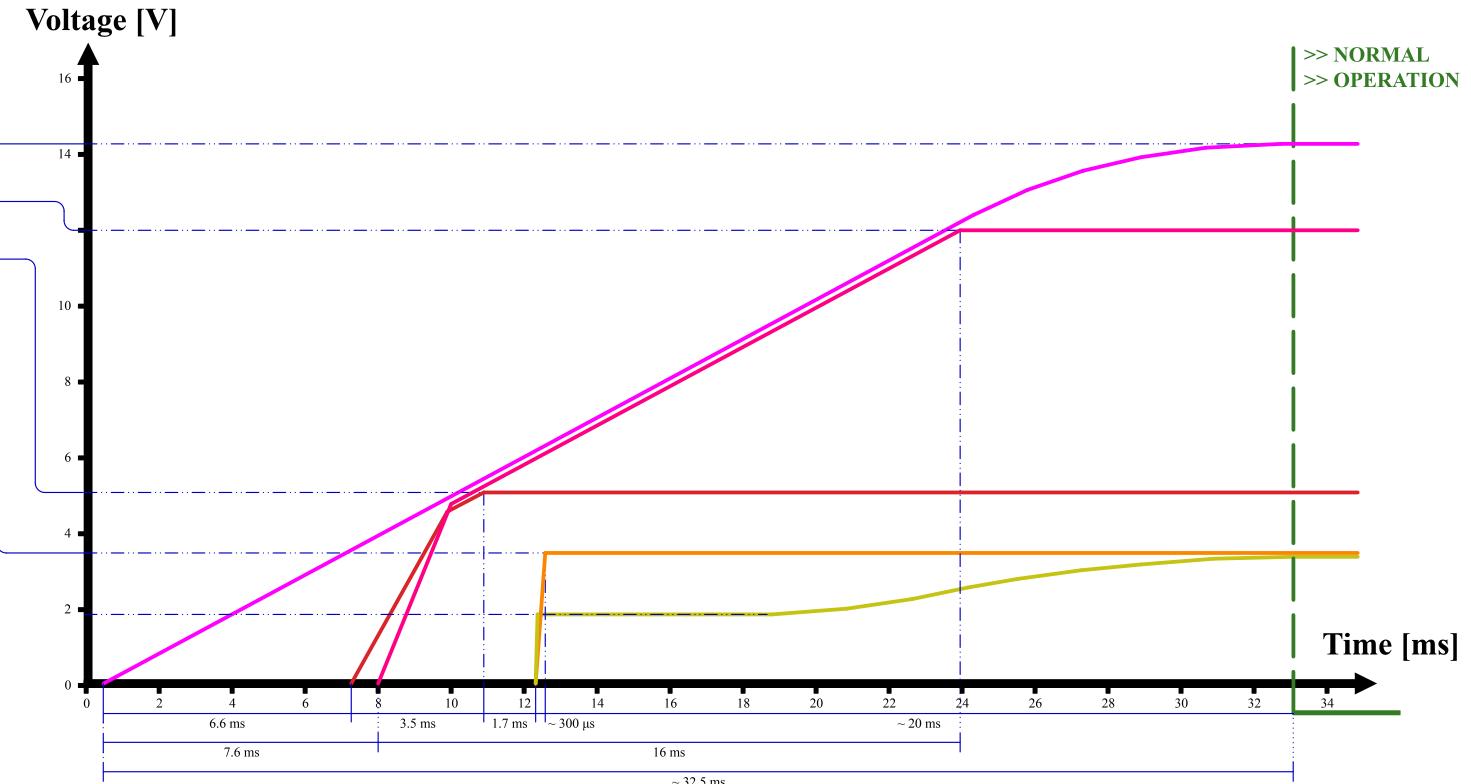
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D

		Comments:	Company: EPFL Xplore Research	Variant: RELEASED	Git Hash: 38f2a13
		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
		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 ± 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	Git Hash: 38f2a13
	Board Name: Amulet Motion Controller			Project Name: Chienpanzé
	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**

- 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.

**25-JAN-2024 - First Revision
Variant: v1.0 Checked**

- 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.

**12-MAR-2024 - First Revision
Variant: v1.0 Released**

- Modified power sequencing graph according to experimental data.

**13-APR-2024 - Second Revision
Variant: v1.1 Released**

- Added RC snubber passive values.
- Added more vias for VBUS and LMR36006 GND pads.
- Changed board version voltage reference from +3V3 to +A3V3.
- Changed motor thermistor resistor divider to 2kOhm for a 10k 3950K thermistor.

B

C

D

A

B

C

D

	Comments:	Company: EPFL Xplore Research	Variant: RELEASED	Git Hash: 38f2a13
	Board Name: Amulet Motion Controller	Project Name: Chienpanzé		
	Sheet Title: Revision History	File Name: Revision History.kicad_sch	Designer: Vincent Nguyen	Date: 2024-01-03
	Sheet Path: /Revision History/	Reviewer:		Size: A4 Sheet: 21 of 21