

Amulet Motion Controller

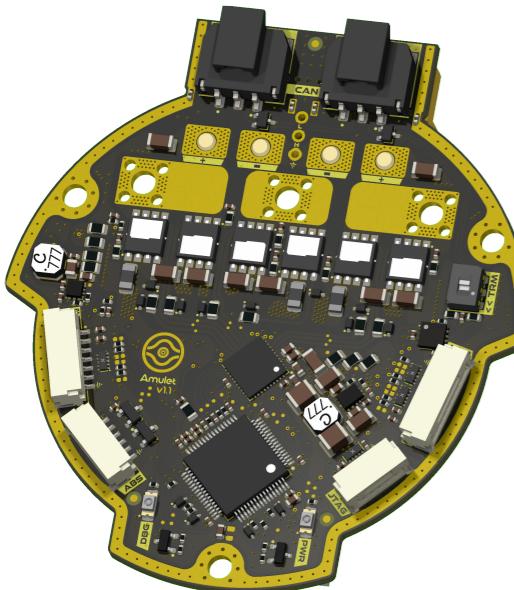
Variant: CHECKED

2025-01-18

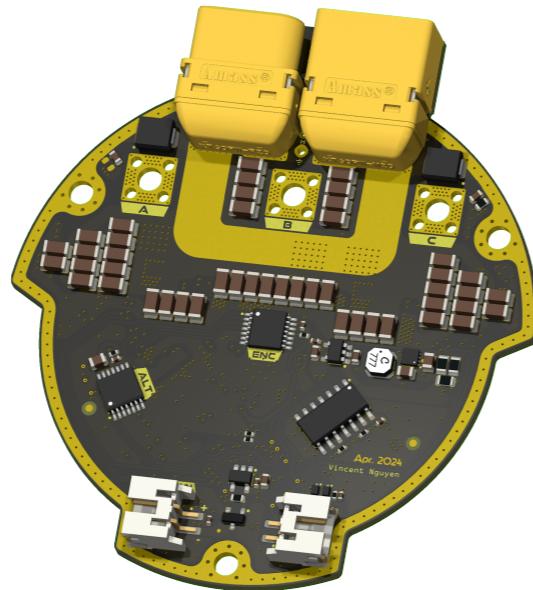
Rev 1.1.1+ (Unreleased)

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 - IOs	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



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.

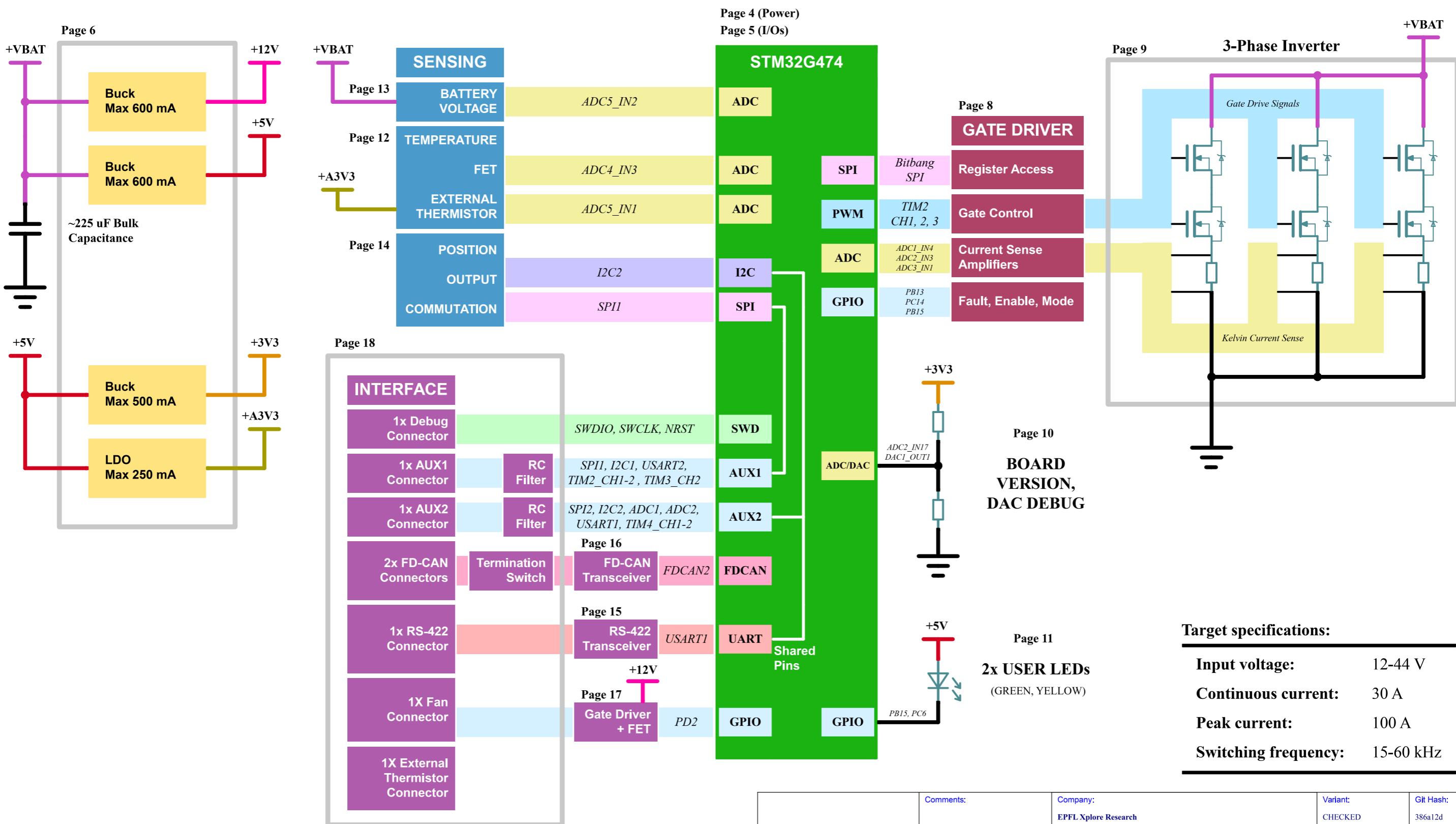
CHECKED - There shouldn't be any mistakes. Contact the engineer if you find any.

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

Date: 18-Jan-2025

	Comments:	Company: EPFL Xplore Research	Variant: CHECKED	Git Hash: 386a12d
	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:	Revision: 1.1.1+ (Unreleased)
			Size: A3	Sheet: 1 of 21

[2] Block Diagram

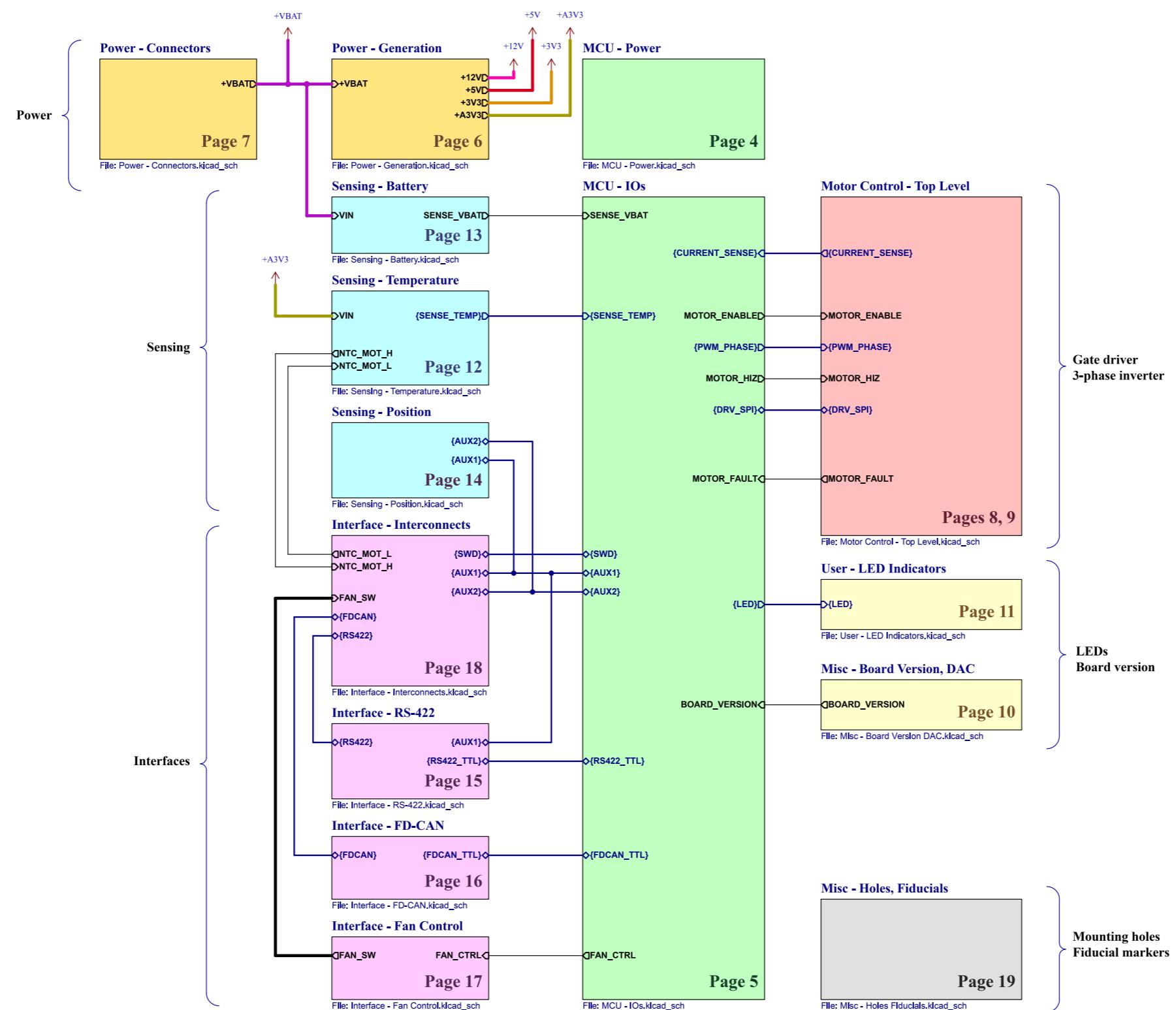


Target specifications:

Input voltage:	12-44 V
Continuous current:	30 A
Peak current:	100 A
Switching frequency:	15-60 kHz

Comments:	Company: EPFL Xplore Research	Variant:	CHECKED
		Git Hash:	386a12d
Board Name:	Amulet Motion Controller		
Sheet Title:	File Name:	Designer:	Date:
Block Diagram	Block Diagram.kicad_sch	Vincent Nguyen	2024-04-13
Sheet Path:	Reviewer:		
/Block Diagram/	Size:		
	Sheet:		
	A3		
	2 of 21		

[3] Project Architecture



	Comments:	Company: EPFL Xplore Research	Variant: CHECKED	Git Hash: 386a12d
	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: 1.1.1+ (Unreleased)
			Size: A3	Sheet: 3 of 21

[4] MCU - Power



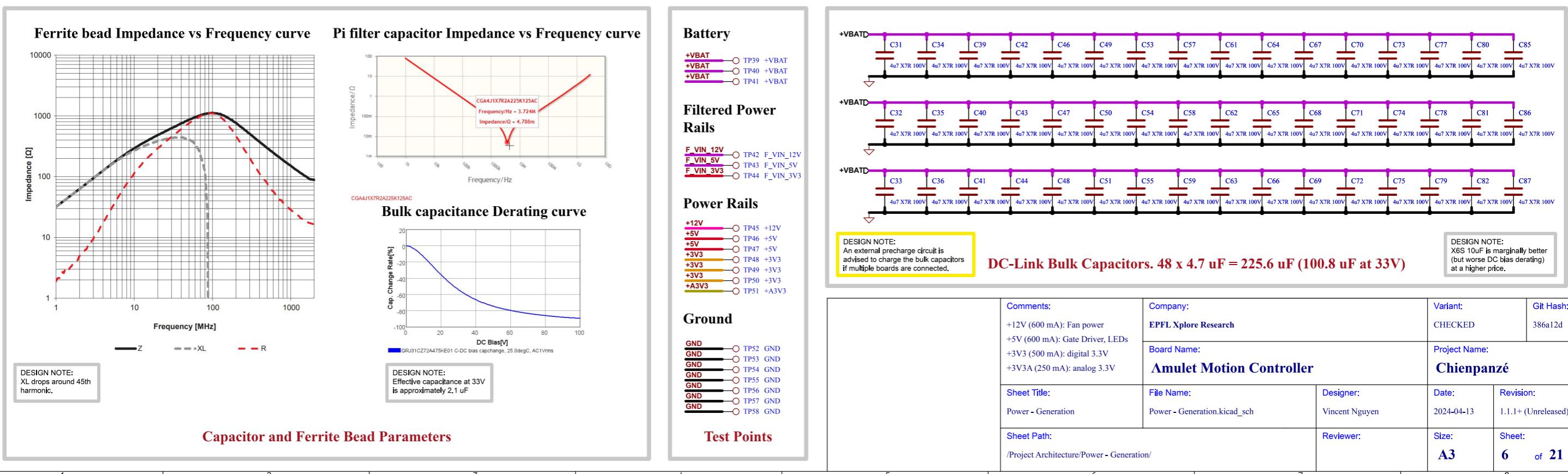
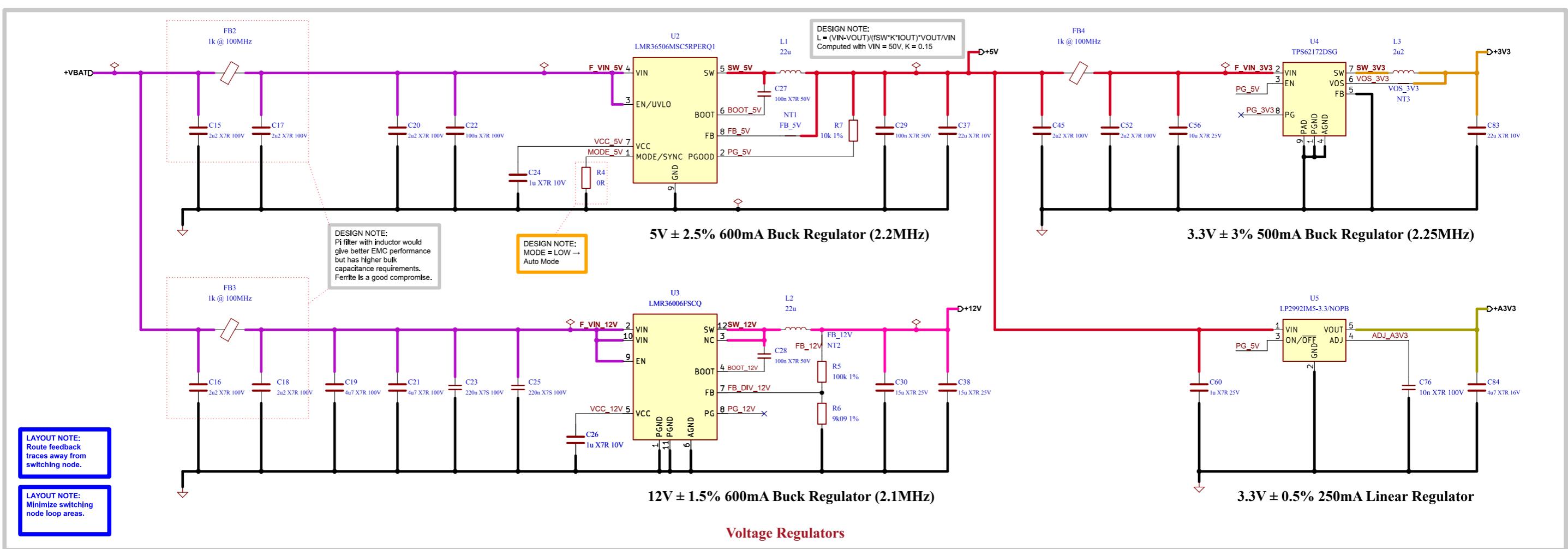
	Comments: AN5346 STM32G474 Datasheet p.81 J. Pieper ADC investigation	Company: EPFL Xplore Research	Variant: CHECKED	Git Hash: 386a12d
	Board Name: Amulet Motion Controller			Project Name: Chienpanzé
	Sheet Title: MCU - Power	File Name: MCU - Power.kicad_sch	Designer: Vincent Nguyen	Date: 2023-12-18 Revision: 1.1.1+ (Unreleased)
	Sheet Path: /Project Architecture/MCU - Power/		Reviewer:	Size: A4 Sheet: 4 of 21

[5] MCU - I/Os

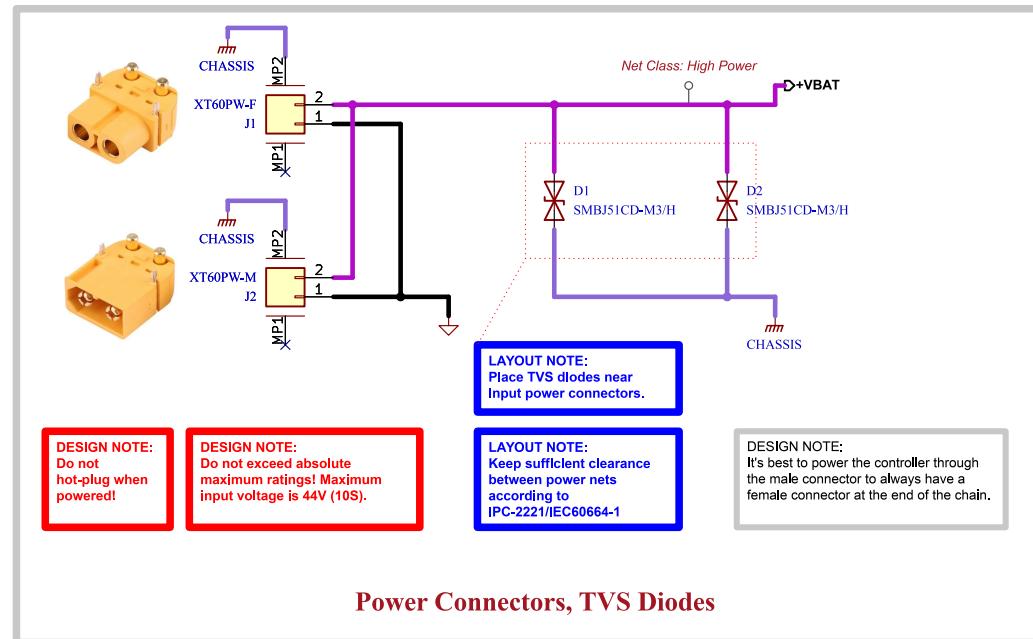


Comments: References: Flexible I/O worked examples Flexible I/O source configuration	Company: EPFL Xplore Research		Variant: CHECKED	Git Hash: 386a12d
	Board Name: Amulet Motion Controller			
Sheet Title: MCU - I/Os	File Name: MCU - IOs.kicad_sch	Designer: Vincent Nguyen	Date: 2023-12-20	Revision: 1.1.1+ (Unreleased)
Sheet Path: /Project Architecture/MCU - IOs/	Reviewer:	Size: A3	Sheet: 5 of 21	

[6] Power - Generation

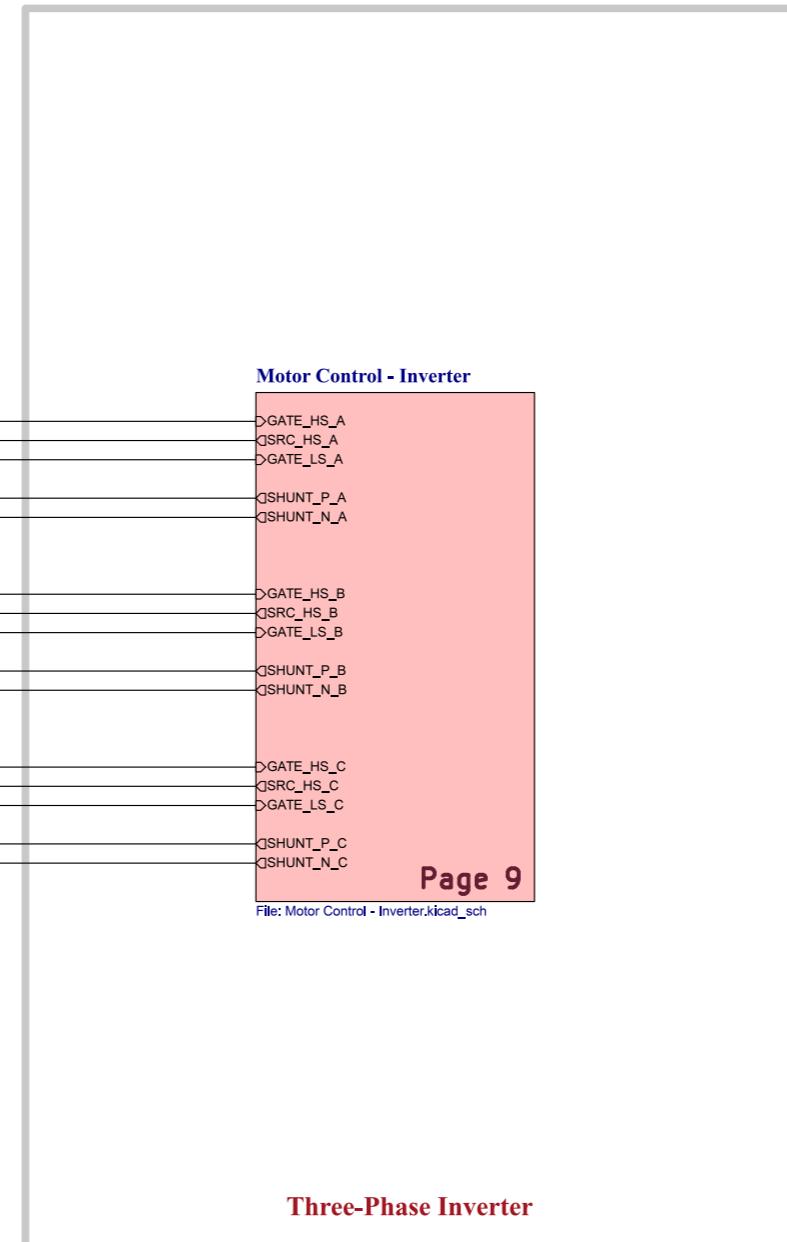
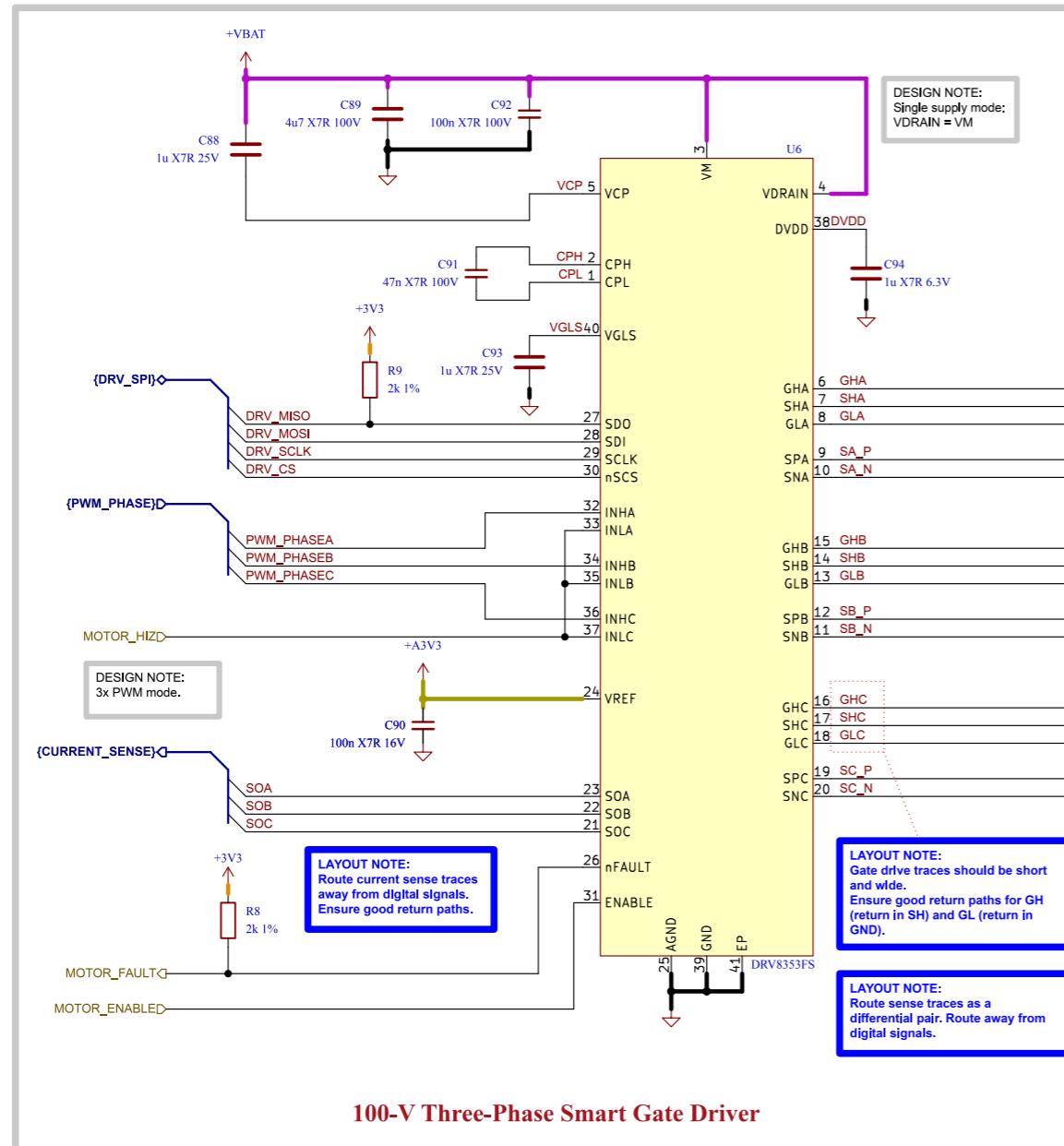


[7] Power - Connectors



	Comments: 	Company: EPFL Xplore Research	Variant: CHECKED	Git Hash: 386a12d
	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 Revision: 1.1.1+ (Unreleased)
	Sheet Path: /Project Architecture/Power - Connectors/		Reviewer: 	Size: A4 Sheet: 7 of 21

[8] Motor Control - Top Level



	Comments:	Company:	Variant:	Git Hash:
		EPFL Xplore Research	CHECKED	386a12d
	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 1.1.1+ (Unreleased)
	Sheet Path:	/Project Architecture/Motor Control - Top Level/	Reviewer:	Size: Sheet:
				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

Reviewer:

Date:
2024-01-25

Revision:
1.1.1+ (Unreleased)

Variant:
CHECKED

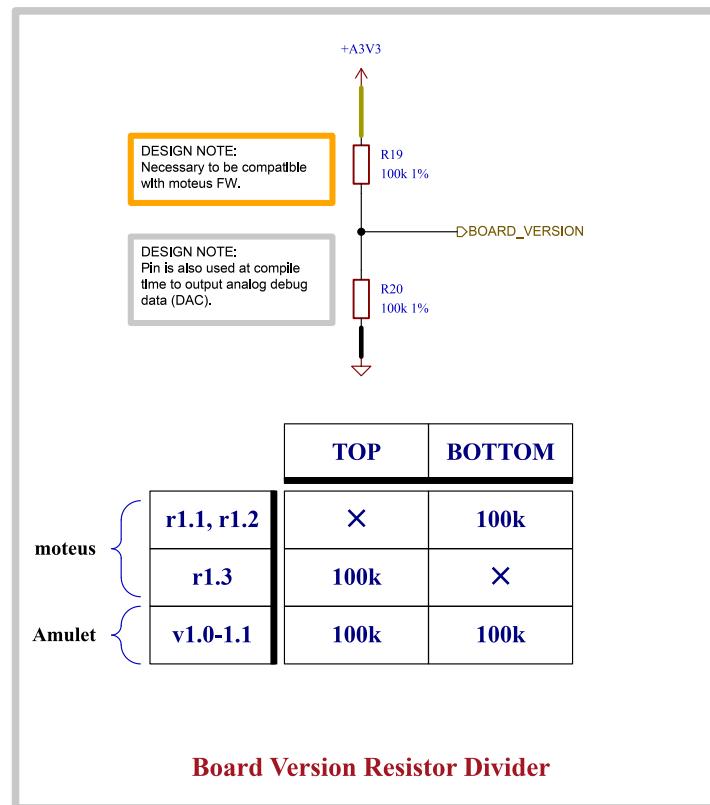
Git Hash:
386a12d

Project Name:
Chienpanzé

Size:
A4

Sheet:
9 of **21**

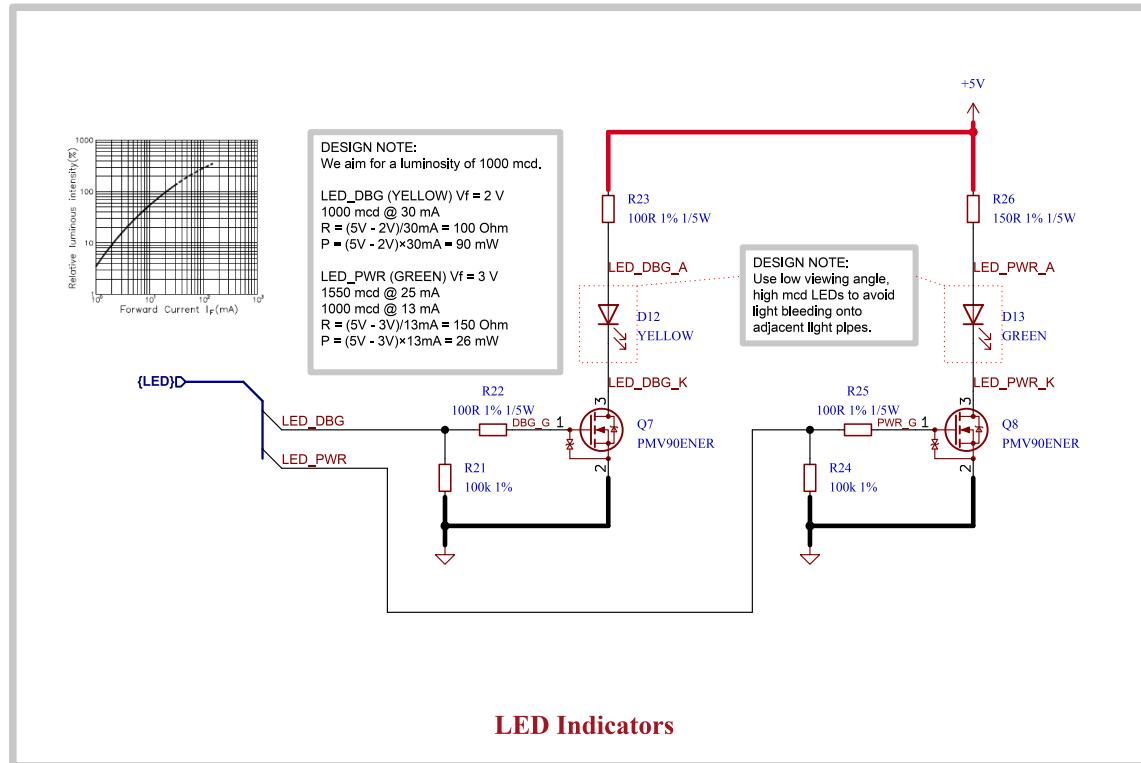
[10] Misc - Board Version, DAC



	Comments:	Company: EPFL Xplore Research		Variant: CHECKED	Git Hash: 386a12d
D		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	Date: 2024-04-13	Revision: 1.1.1+ (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: User - LED Indicators	Company: EPFL Xplore Research	Variant: CHECKED	Git Hash: 386a12d
	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

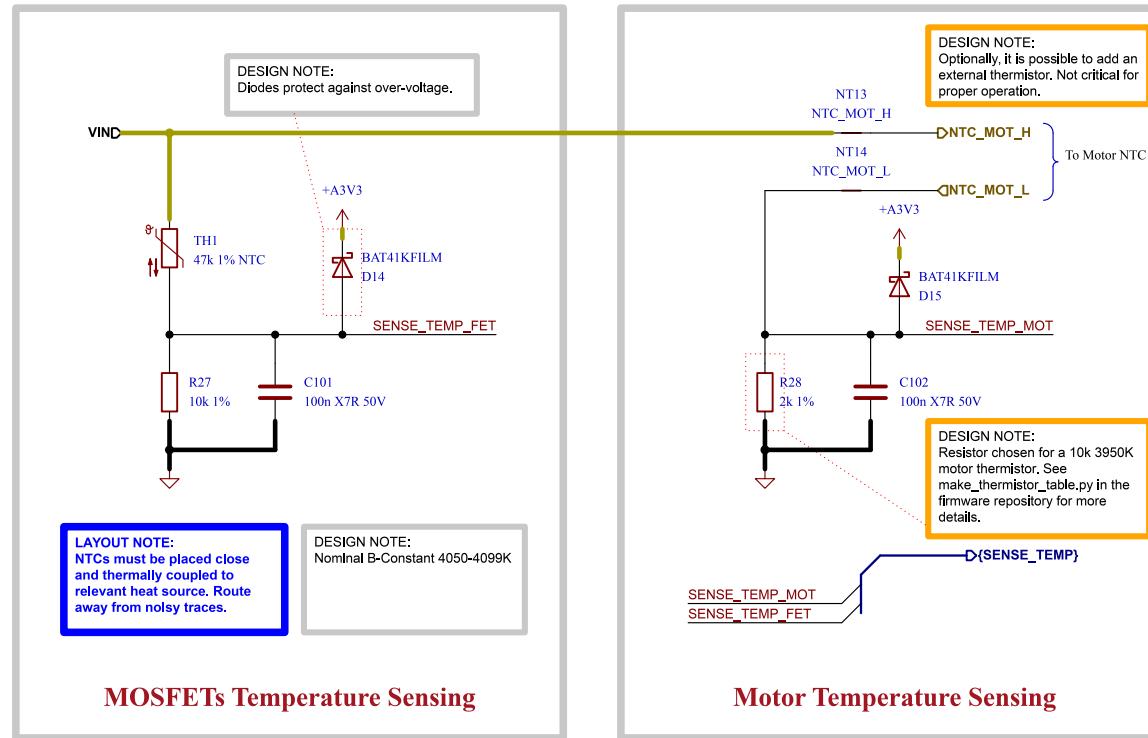
D

A

B

C

D



		Comments:	Company: EPFL Xplore Research	Variant: CHECKED	Git Hash: 386a12d
		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 Revision: 1.1.1+ (Unreleased)
		Sheet Path: /Project Architecture/Sensing - Temperature/		Reviewer:	Size: A4 Sheet: 12 of 21

[13] Sensing - Battery

A

A

B

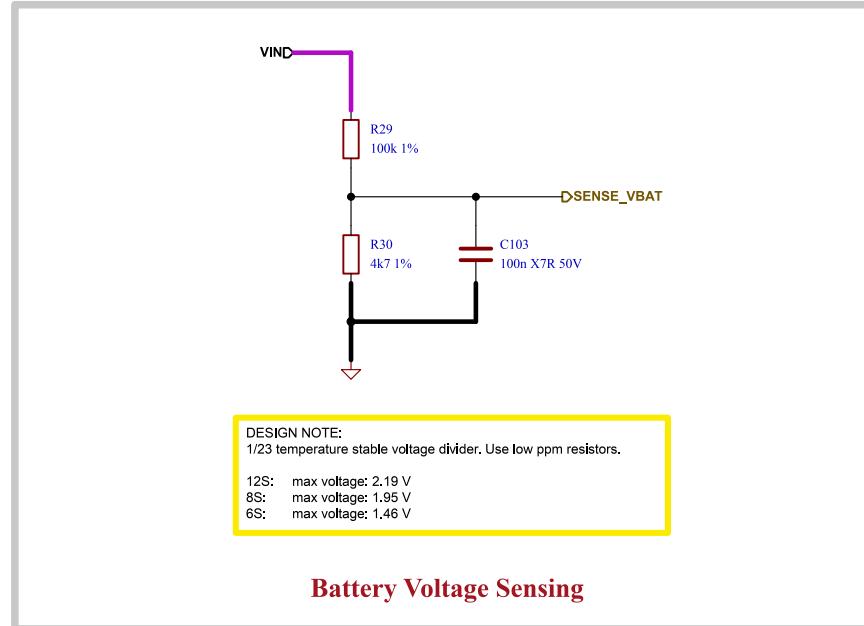
B

C

C

D

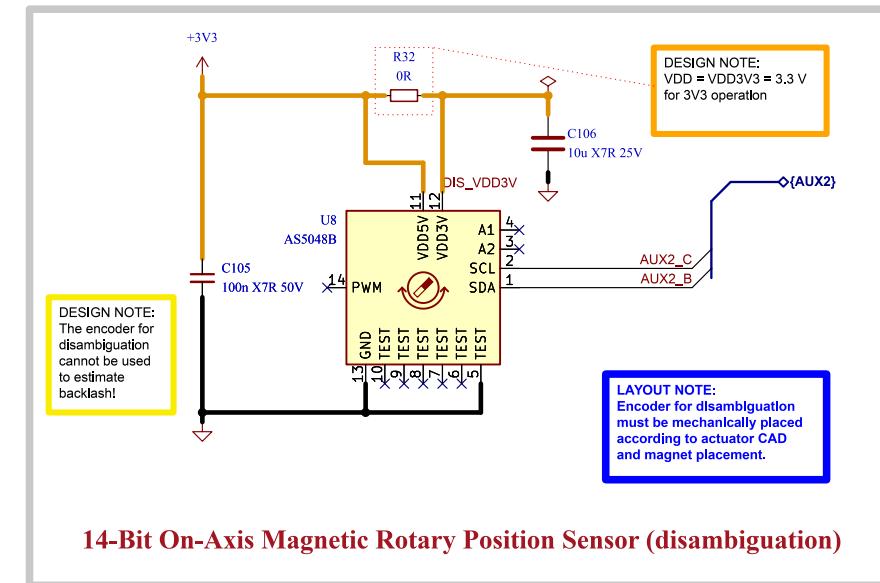
D



	Comments:	Company: EPFL Xplore Research	Variant: CHECKED	Git Hash: 386a12d
	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 Revision: 1.1.1+ (Unreleased)
	Sheet Path: /Project Architecture/Sensing - Battery/		Reviewer:	Size: A4 Sheet: 13 of 21

[14] Sensing - Position

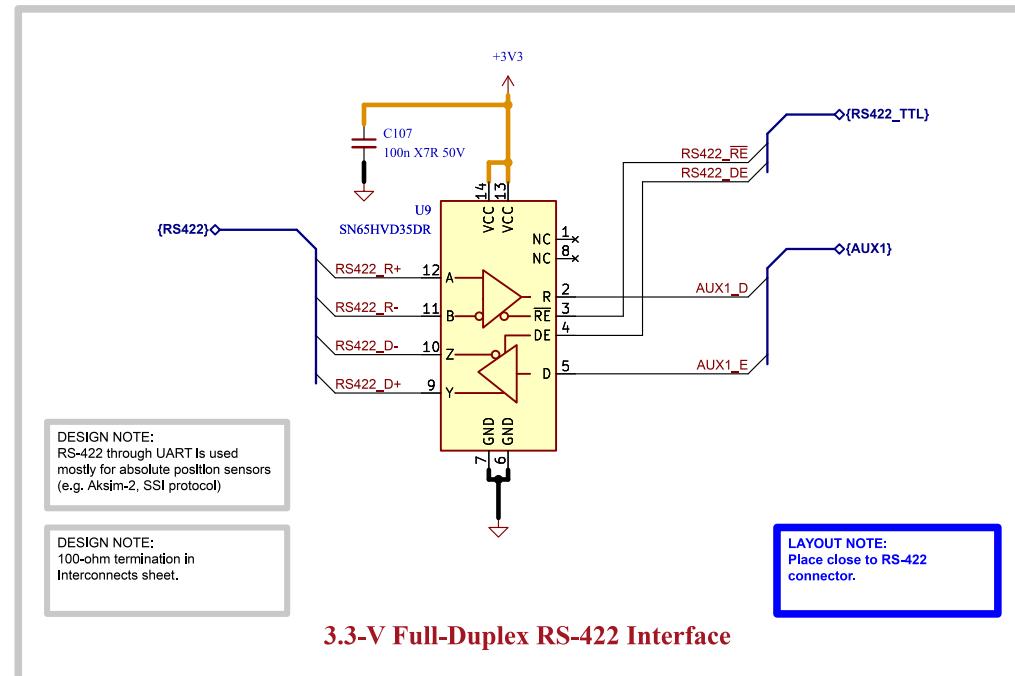
A



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.

Comments:	Company: EPFL Xplore Research		Variant: CHECKED	Git Hash: 386a12d
Board Name:	Amulet Motion Controller			Project Name: Chienpanzé
Sheet Title:	File Name:	Designer:	Date:	Revision:
Sensing - Position	Sensing - Position.kicad_sch	Vincent Nguyen	2023-10-14	1.1.1+ (Unreleased)
Sheet Path:	Reviewer:		Size:	Sheet: A4 of 21
/Project Architecture/Sensing - Position/				

[15] Interface - RS-422



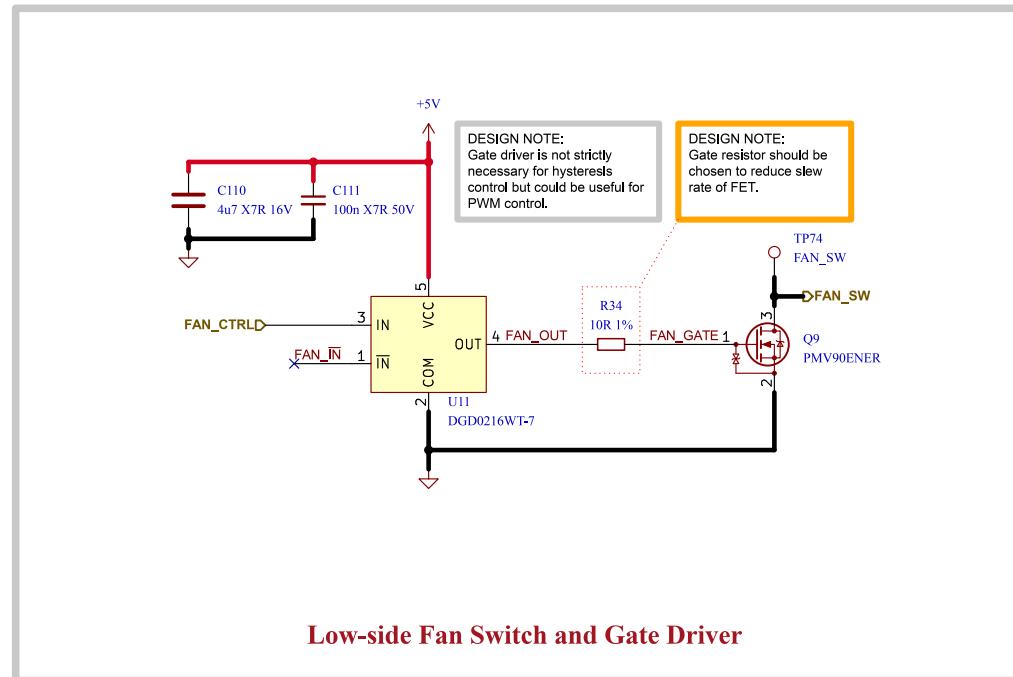
	Comments:	Company: EPFL Xplore Research	Variant: CHECKED	Git Hash: 386a12d
	Board Name: Amulette Motion Controller	Project Name: Chienpanzé		
	Sheet Title: Interface - RS-422	File Name: Interface - RS-422.kicad_sch	Designer: Vincent Nguyen	Date: 2023-10-15 Revision: 1.1.1+ (Unreleased)
	Sheet Path: /Project Architecture/Interface - RS-422/		Reviewer:	Size: A4 Sheet: 15 of 21

[16] Interface - FD-CAN



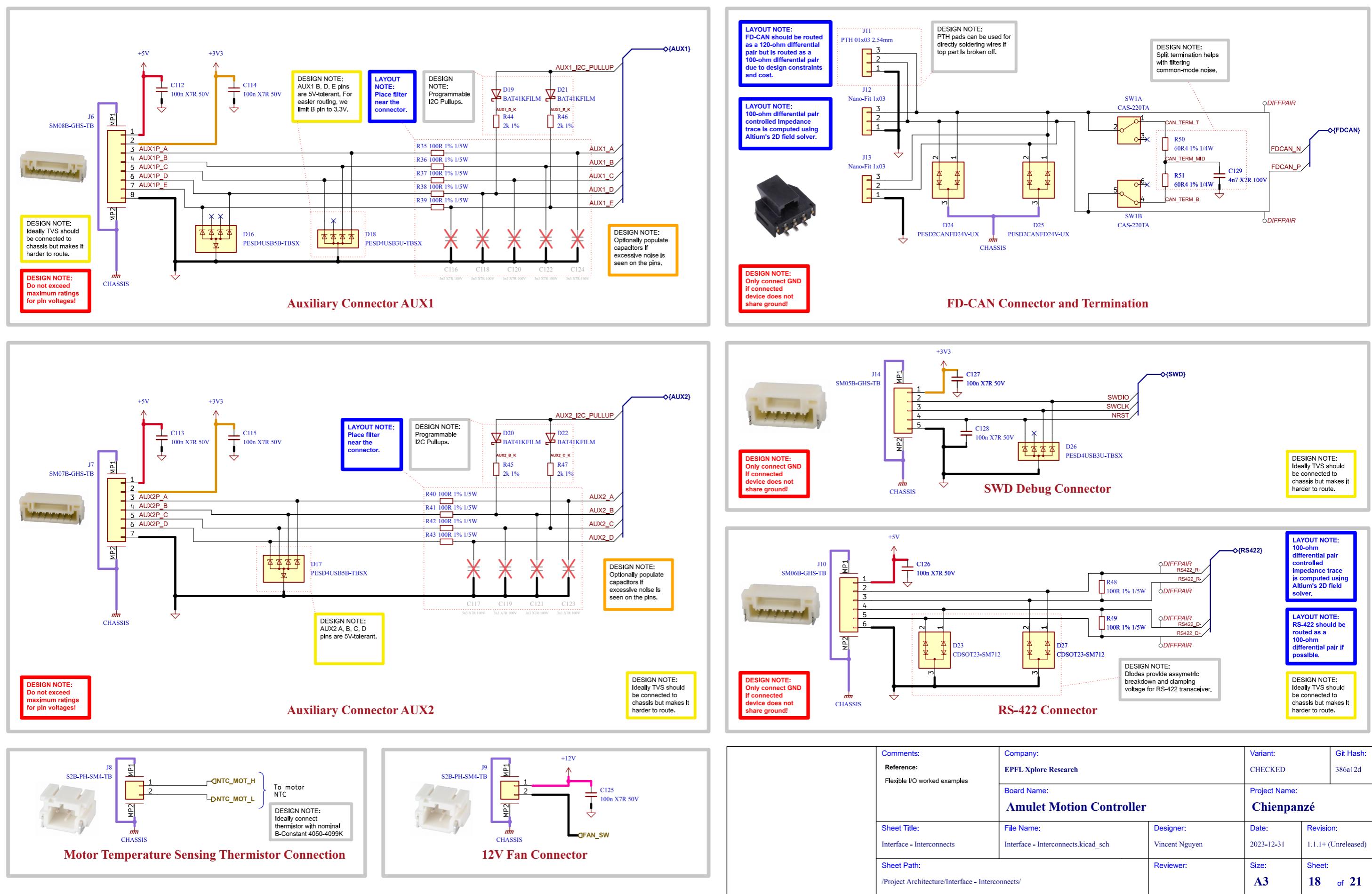
	Comments:	Company: EPFL Xplore Research	Variant: CHECKED	Git Hash: 386a12d
	Board Name: Amulet Motion Controller	Project Name: Chienpanzé		
	Sheet Title: Interface - FD-CAN	File Name: Interface - FD-CAN.kicad_sch	Designer: Vincent Nguyen	Date: 2023-10-15 Revision: 1.1.1+ (Unreleased)
	Sheet Path: /Project Architecture/Interface - FD-CAN/		Reviewer:	Size: A4 Sheet: 16 of 21

[17] Interface - Fan Control



	Comments:	Company: EPFL Xplore Research	Variant: CHECKED	Git Hash: 386a12d
	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 Revision: 1.1.1+ (Unreleased)
	Sheet Path: /Project Architecture/Interface - Fan Control/		Reviewer:	Size: A4 Sheet: 17 of 21

[18] Interface - Interconnects



[19] Misc - Holes, Fiducials

A

A

B

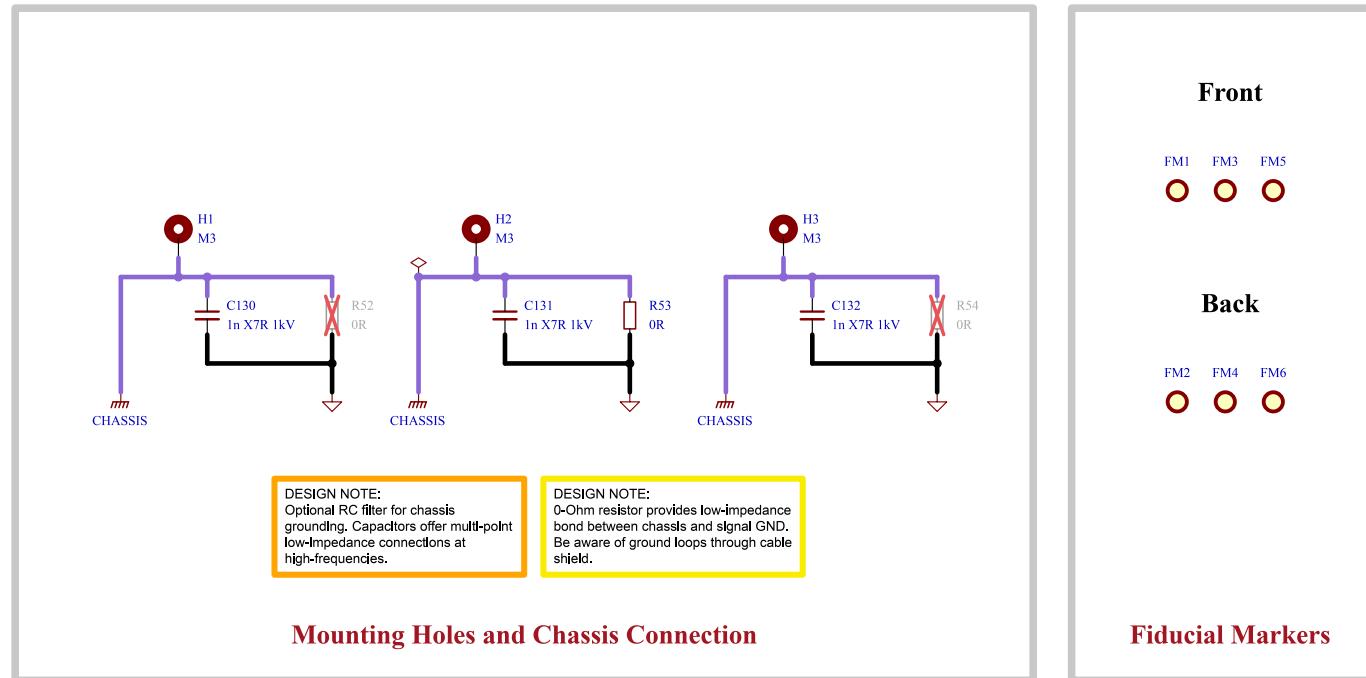
B

C

C

D

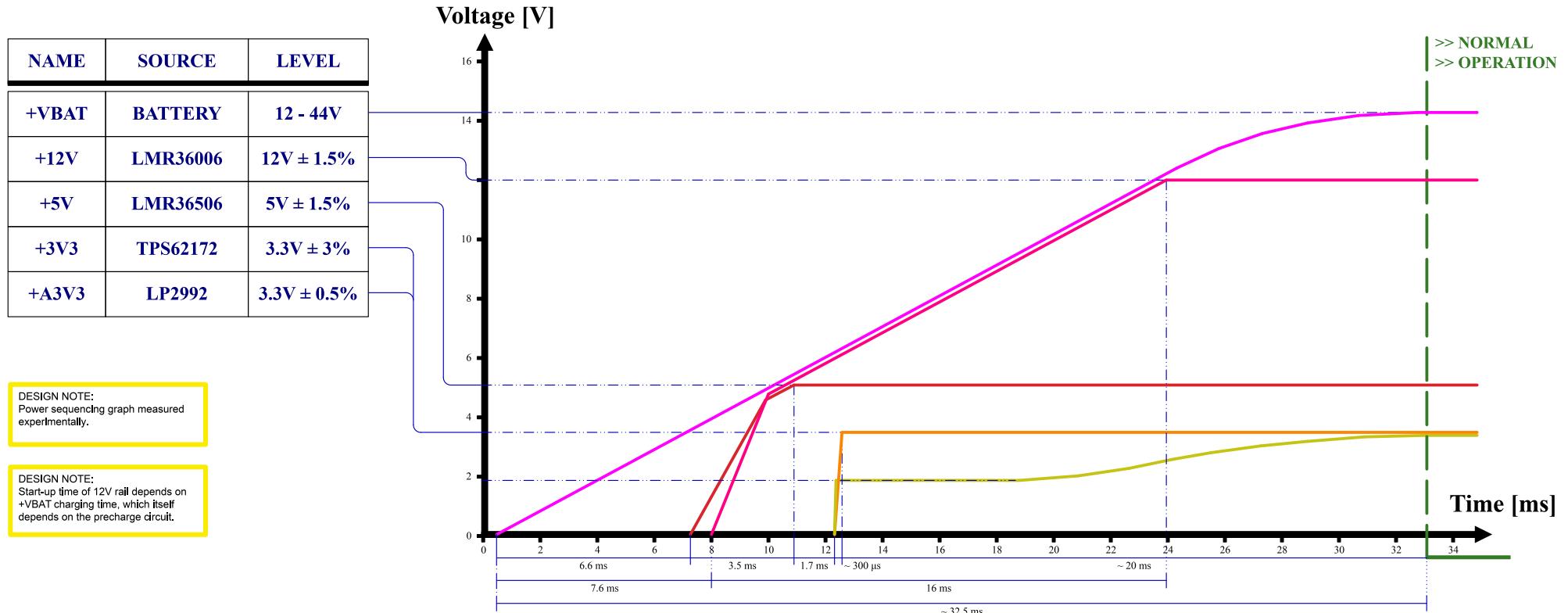
D



	Comments:	Company: EPFL Xplore Research	Variant: CHECKED	Git Hash: 386a12d
	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: 1.1.1+ (Unreleased)
	Sheet Path: /Project Architecture/Misc - Holes, Fiducials/		Reviewer:	Size: A4 Sheet: 19 of 21

[20] Power - Sequencing

A



C

D

	Comments: Amulet Motion Controller	Company: EPFL Xplore Research		Variant: CHECKED	Git Hash: 386a12d
		Board Name: Amulet Motion Controller			
		Sheet Title: Power - Sequencing	File Name: Power - Sequencing.kicad_sch	Designer: Vincent Nguyen	Date: 2024-03-12 Revision: 1.1.1+ (Unreleased)
		Sheet Path: /Power - Sequencing/	Reviewer:	Size: A4	Sheet: 20 of 21

[21] Revision History

A

Version 1.0.0 - 2023-12-12

- Added**
- TVS protection and termination switch to FD-CAN.
 - Low-side switched 12V 600 mA source for external fan.
 - LDO for analog supply.
 - One TVS diode per power connector.
 - Second on-board I2C magnetic encoder for disambiguation.
 - ESD protection to all interfaces.
 - Over-voltage protection on thermistor ADC inputs.
 - Pi filters to inputs of buck regulators and MCU analog supply.
 - Decoupling caps next to power pins of connectors.

B

Changed

- CPH-CPL capacitor to 47 nF (gate driver).
- FD-CAN transceiver IC.
- FETs for top cooled variant.
- Input power TVS diode to bidirectional.
- Moved SOx low-pass filter to MCU section.
- PWM_PHASEA with PWM_PHASEC on STM32G474 pinout for easier routing.
- RS422 pinout on connector.
- Buck regulators to optimize for low noise.

Version 1.0.1 - 2024-01-25

- Added**
- Controller target specifications.
 - Credits to moteus on cover page.
 - Optional RC-Snubber to power stage.

Fixed

- Chassis guard ring to go around the board.
- CAN and power TVS diodes now go to chassis.
- Clearance between nets to respect IEC60664-1 where possible.
- Comment on precharge.
- Power TVS diode reference designator from "U" to "D".

Changed

- 5V 300 mA buck converter with 600 mA version.
- Chassis-GND capacitor by 1nF 1kV.

Version 1.0.2 - 2024-03-12

Changed

- Power sequencing graph according to experimental data.

Version 1.1.0 - 2024-04-13

Added

- RC snubber passive values.

Fixed

- More vias for VBUS and LMR36006 GND pads.
- Board version voltage reference from +3V3 to +A3V3.

Changed

- Motor thermistor resistor divider to 2kOhm for a 10k 3950K thermistor.

Version 1.1.1 - 2024-11-26

Fixed

- Replace non-stocked components.

	Comments:	Company: EPFL Xplore Research	Variant: CHECKED	Git Hash: 386a12d
	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