

Amulet Motion Controller

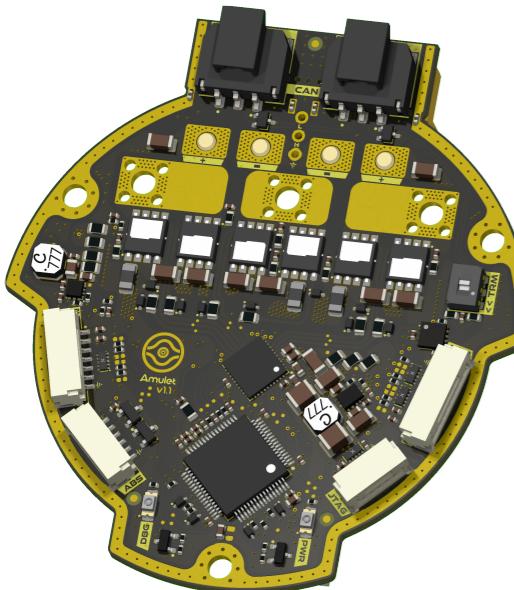
Variant: CHECKED

2024-11-26

Rev 1.2

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.

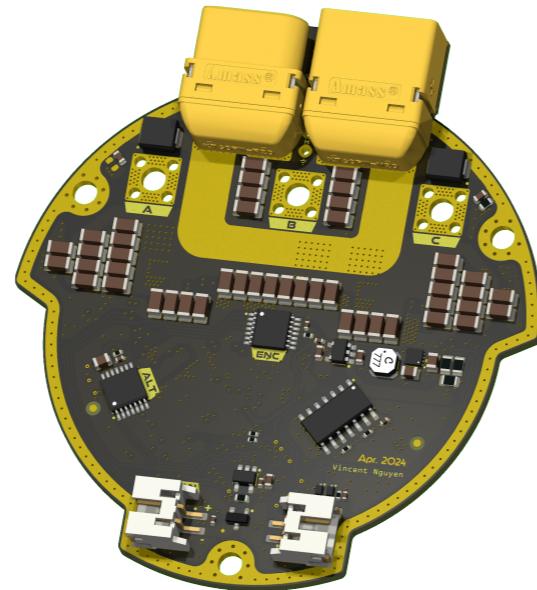
DESIGN NOTE:
Example text for debug notes.

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.

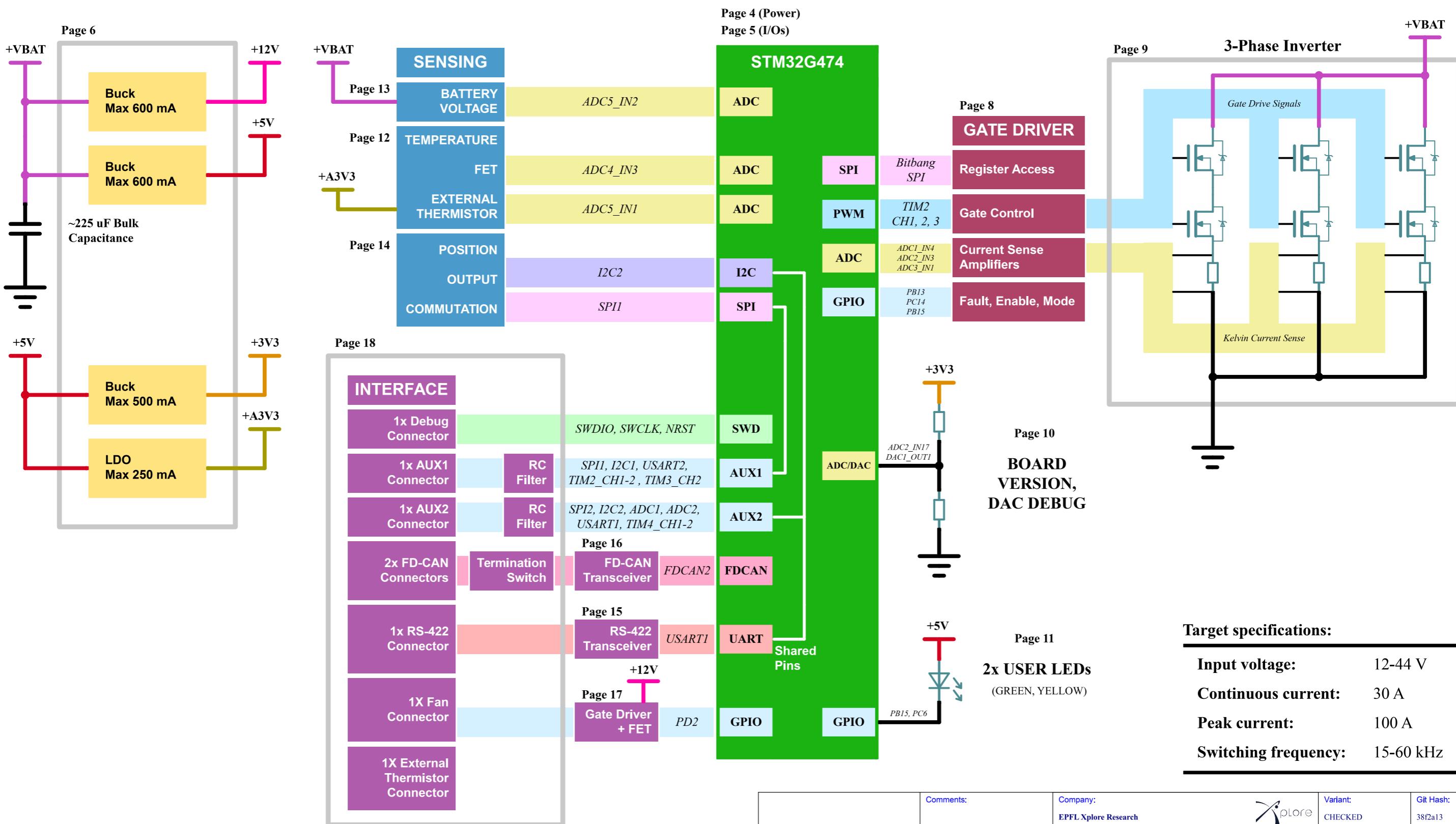
CHECKED - There shouldn't be any mistakes. Contact the engineer if you find any.

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

Date: 26-Nov-2024

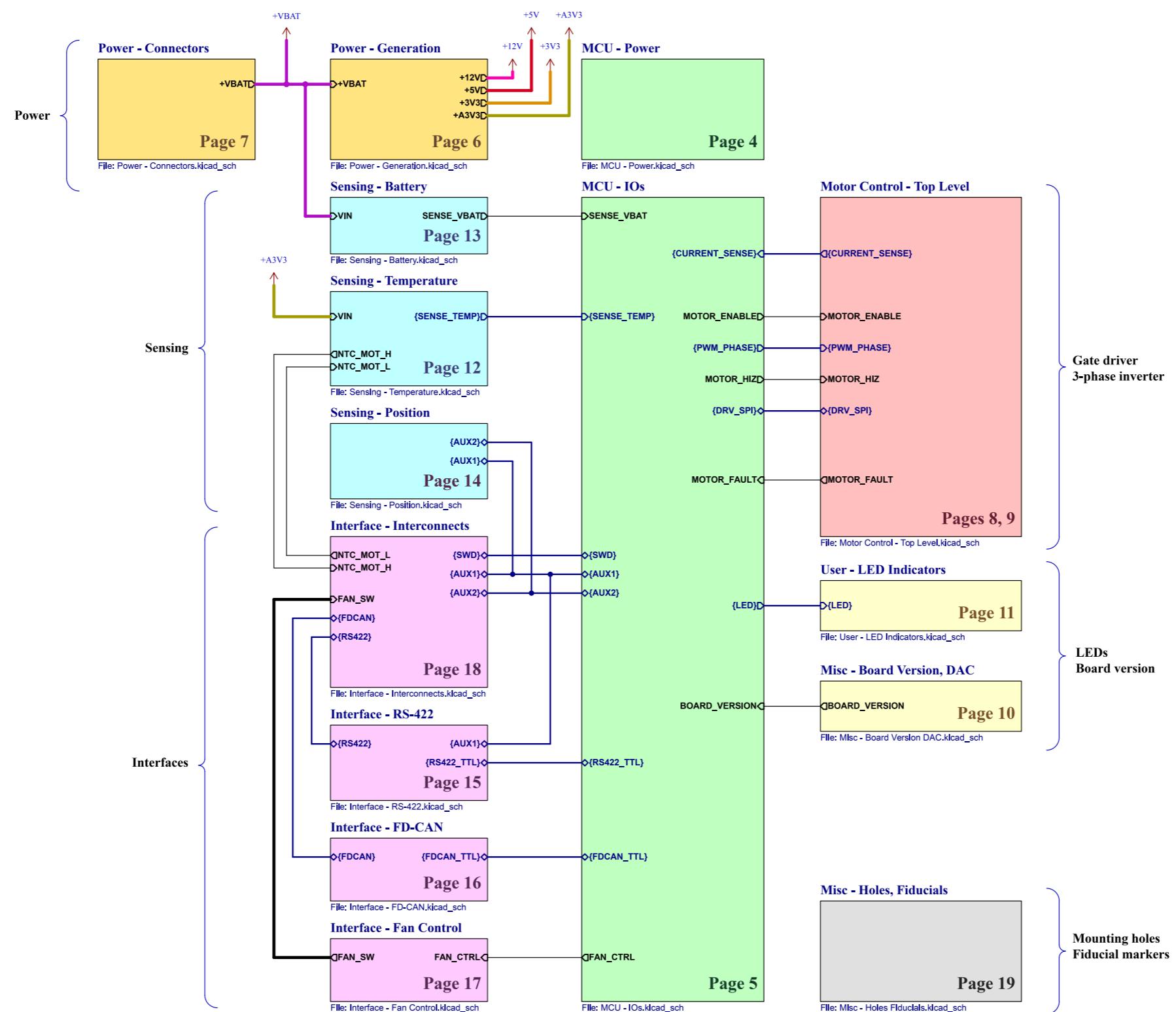
	Comments:	Company: EPFL Xplore Research	Variant: CHECKED	Git Hash: 38f2a13
	Board Name: Amulet Motion Controller	Project Name: Chienpanzé		
	Sheet Title: Cover Page	File Name: amulet_controller.kicad_sch	Designer: Vincent Nguyen	Date: 2024-04-13
	Sheet Path: /		Reviewer:	Size: A3 Sheet: 1 of 21

[2] Block Diagram



Comments:	Company: EPFL Xplore Research		Variant: CHECKED	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



	Comments:	Company: EPFL Xplore Research	Variant: CHECKED	Git Hash: 38f2a13
	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:	Size: A3
				Sheet: 3 of 21

[4] MCU - Power



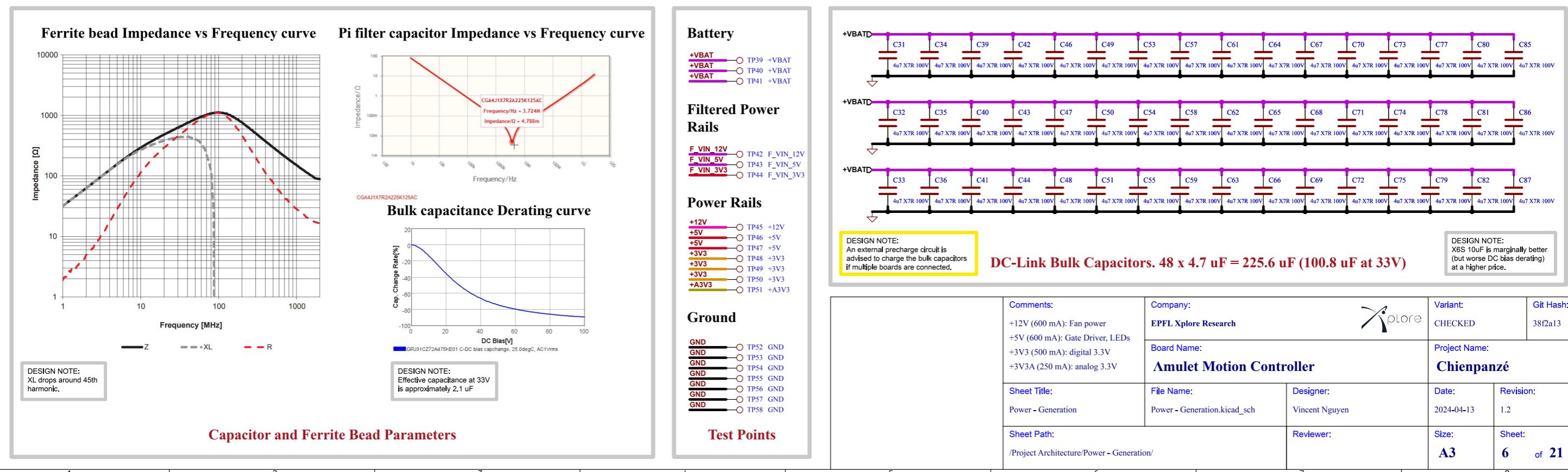
	Comments: AN5346 STM32G474 Datasheet p.81 J. Pieper ADC investigation	Company: EPFL Xplore Research	Variant: CHECKED	Git Hash: 38f2a13
	Board Name: Amulet Motion Controller			Project Name: Chienpanzé
	Sheet Title: MCU - Power	File Name: MCU - Power.kicad_sch	Designer: Vincent Nguyen	Date: 2023-12-18
	Sheet Path: /Project Architecture/MCU - Power/		Reviewer: 	Revision: 1.2

[5] MCU - I/Os



Comments: References: Flexible I/O worked examples Flexible I/O source configuration	Company: EPFL Xplore Research		Variant: CHECKED	Git Hash: 38f2a13
	Board Name: Amulet Motion Controller	Project Name: Chienpanzé		
Sheet Title: MCU - I/Os	File Name: MCU - IOs.kicad_sch		Date: 2023-12-20	Revision: 1.2
Sheet Path: /Project Architecture/MCU - IOs/	Reviewer:		Size: A3	Sheet: 5 of 21

[6] Power - Generation

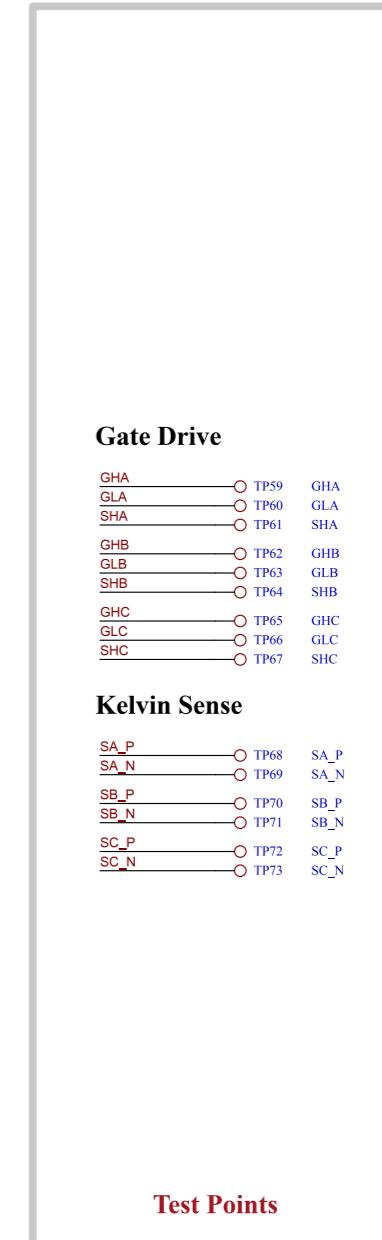
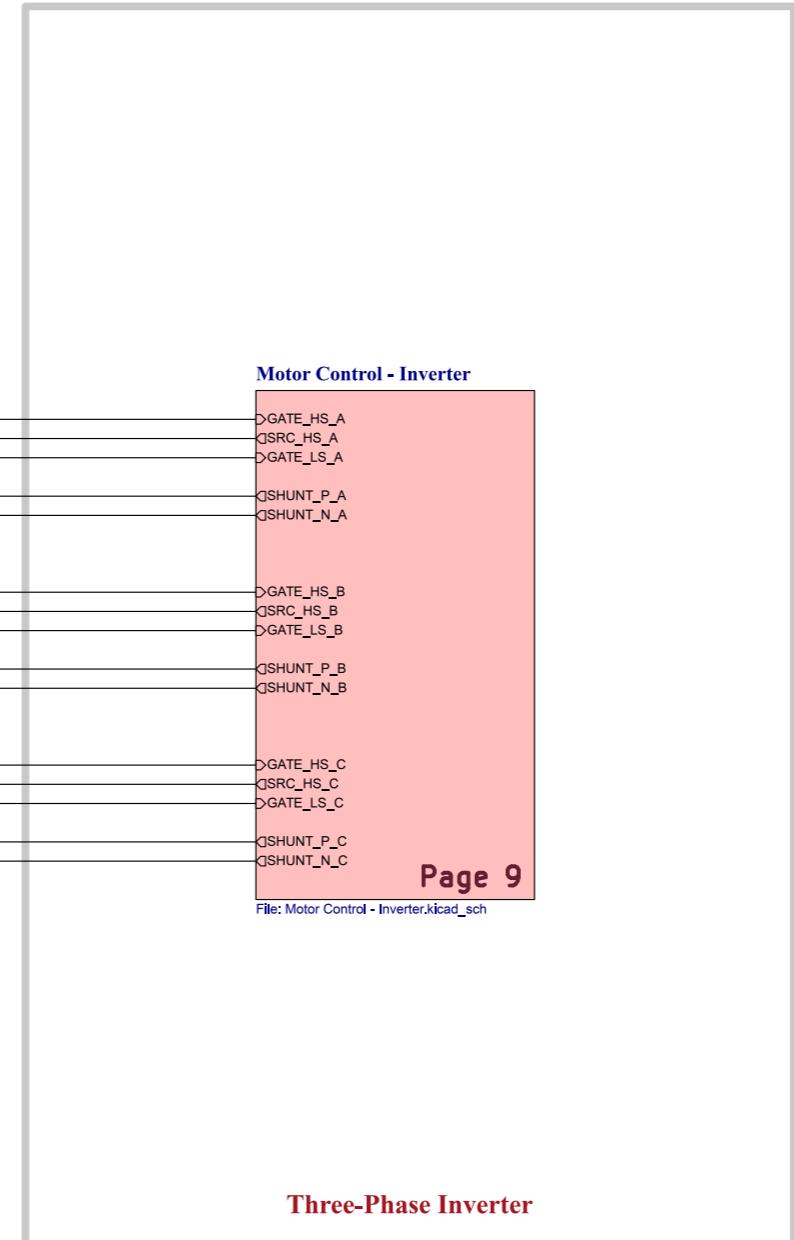
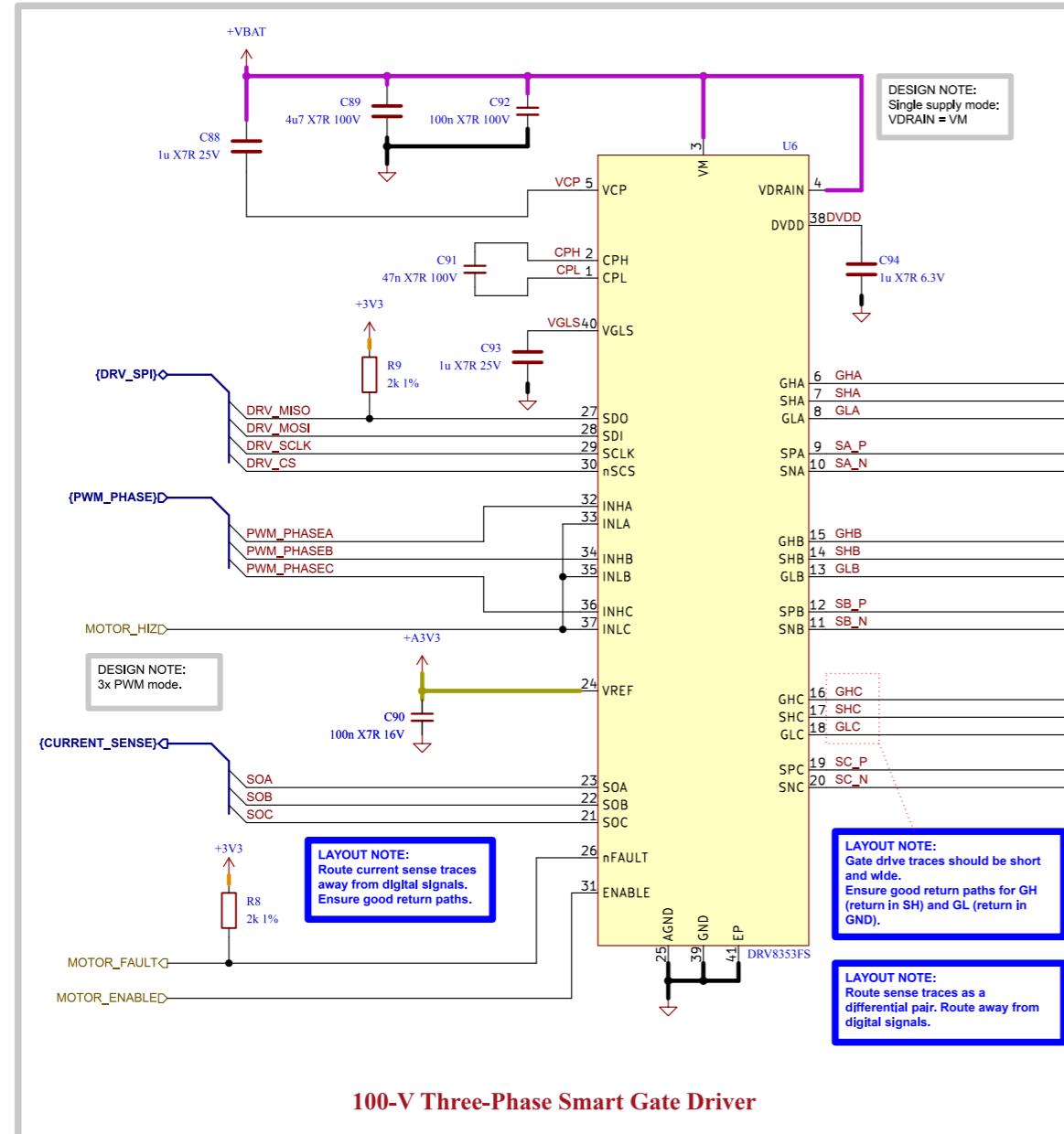


[7] Power - Connectors



	Comments: 	Company: EPFL Xplore Research 	Variant: CHECKED	Git Hash: 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 Revision: 1.2
	Sheet Path: /Project Architecture/Power - Connectors/		Reviewer: 	Size: A4 Sheet: 7 of 21

[8] Motor Control - Top Level



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



Variant:

CHECKED

Git Hash:
38f2a13

Project Name:
Chienpanzé

Date:
2024-01-25

Revision:
1.2

Size:
A4

Sheet:
9 of **21**

[10] Misc - Board Version, DAC



	Comments:	Company: EPFL Xplore Research	Variant: CHECKED	Git Hash: 38f2a13
	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
	Sheet Path: /Project Architecture/Misc - Board Version, DAC/		Reviewer:	Size: A4
			Sheet: 10 of 21	

[11] User - LED Indicators



	Comments:	Company: EPFL Xplore Research	Variant: CHECKED	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 Revision: 1.2
	Sheet Path: /Project Architecture/User - LED Indicators/		Reviewer:	Size: A4 Sheet: 11 of 21

[12] Sensing - Temperature

A

B

C

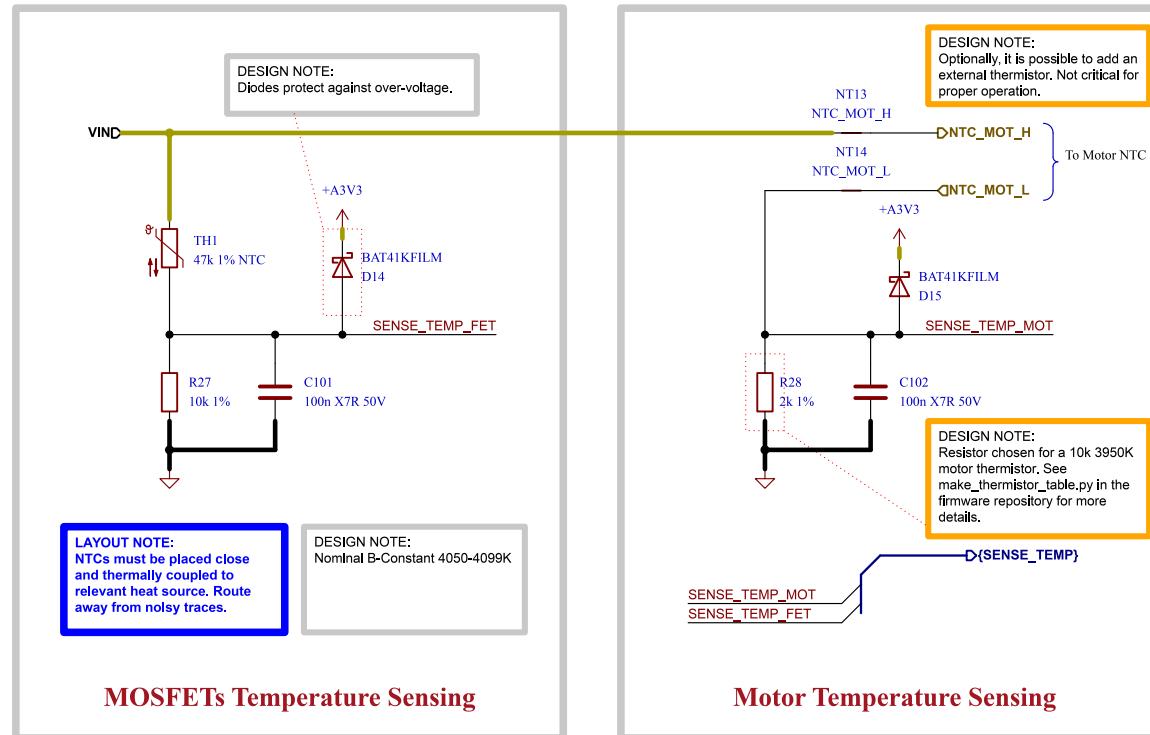
D

A

B

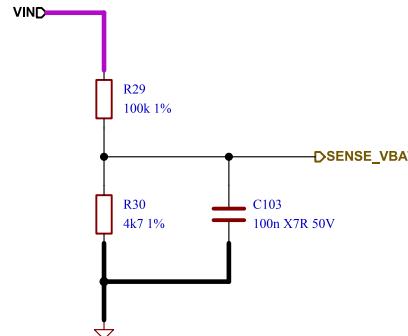
C

D



	Comments:	Company: EPFL Xplore Research	Variant: CHECKED	Git Hash: 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 Revision: 1.2
	Sheet Path: /Project Architecture/Sensing - Temperature/		Reviewer:	Size: A4 Sheet: 12 of 21

[13] Sensing - Battery



DESIGN NOTE:
1/23 temperature stable voltage divider. Use low ppm resistors.

12S: max voltage: 2.19 V
8S: max voltage: 1.95 V
6S: max voltage: 1.46 V

Battery Voltage Sensing

	Comments:	Company: EPFL Xplore Research	Variant: CHECKED	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: CHECKED	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



	Comments:	Company: EPFL Xplore Research 	Variant: CHECKED	Git Hash: 38f2a13
	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: 1.2
	Sheet Path: /Project Architecture/Interface - RS-422/	Reviewer:	Size: A4	Sheet: 15 of 21

[16] Interface - FD-CAN



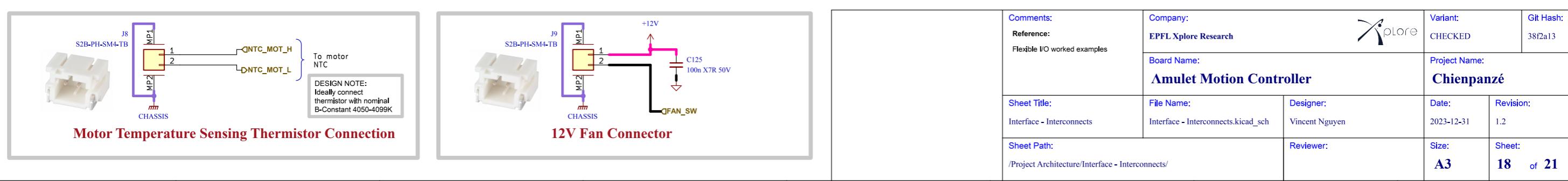
	Comments:	Company: EPFL Xplore Research	Variant: CHECKED	Git Hash: 38f2a13
	Board Name: Amulet Motion Controller			Project Name: Chienpanzé
	Sheet Title: Interface - FD-CAN	File Name: Interface - FD-CAN.kicad_sch	Designer: Vincent Nguyen	Date: 2023-10-15
	Sheet Path: /Project Architecture/Interface - FD-CAN/		Reviewer:	Size: A4
			Sheet: 16 of 21	

[17] Interface - Fan Control

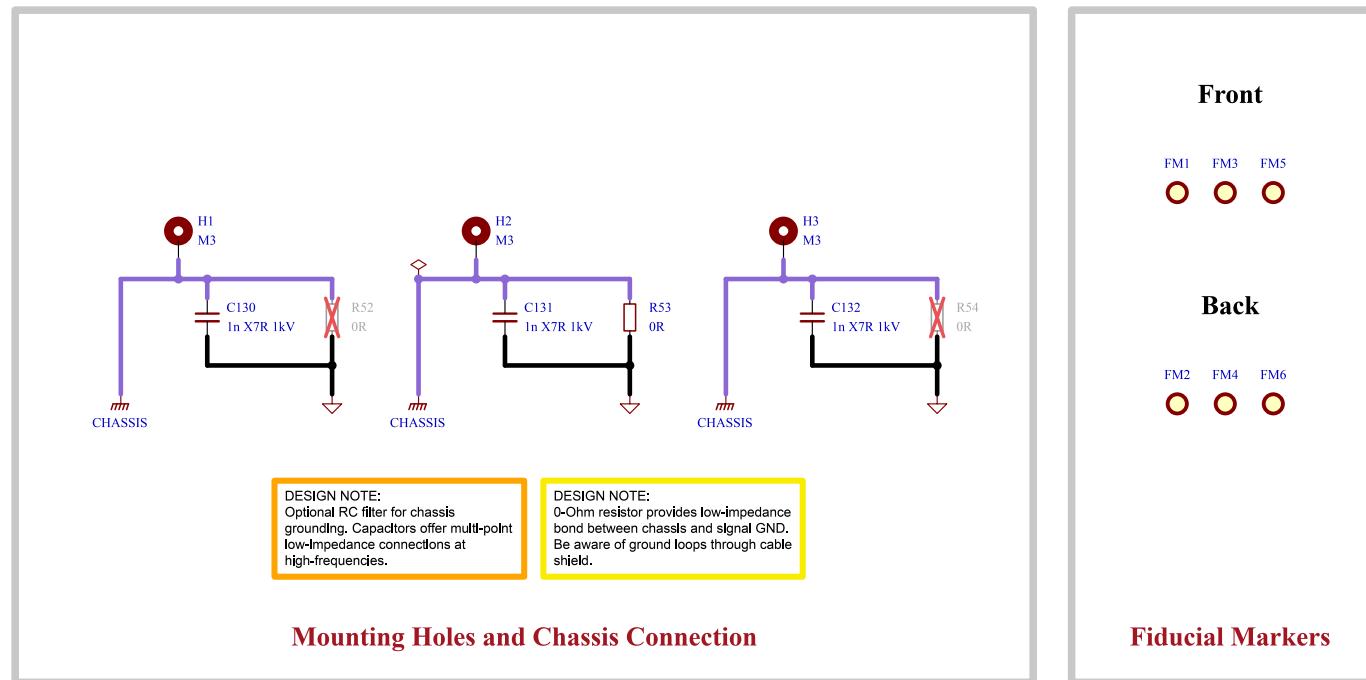


	Comments:	Company: EPFL Xplore Research	Variant: CHECKED	Git Hash: 38f2a13
	Board Name: Amulet Motion Controller	Project Name: Chienpanzé		
	Sheet Title: Interface - Fan Control	File Name: Interface - Fan Control.kicad_sch	Designer: Vincent Nguyen	Date: 2023-11-19 Revision: 1.2
	Sheet Path: /Project Architecture/Interface - Fan Control/		Reviewer:	Size: A4 Sheet: 17 of 21

[18] Interface - Interconnects



[19] Misc - Holes, Fiducials



		Comments:	Company: EPFL Xplore Research	Variant: CHECKED	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/	Reviewers:		Size: A4
			Sheet: 19 of 21		

[20] Power - Sequencing

A



B

C

D

	Comments:	Company: EPFL Xplore Research	Variant: CHECKED	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.

B

C

D

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.

	Comments:	Company: EPFL Xplore Research	Variant: CHECKED	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 Revision: 1.2
	Sheet Path: /Revision History/	Reviewer:	Size: A4	Sheet: 21 of 21