

Amulet Motion Controller

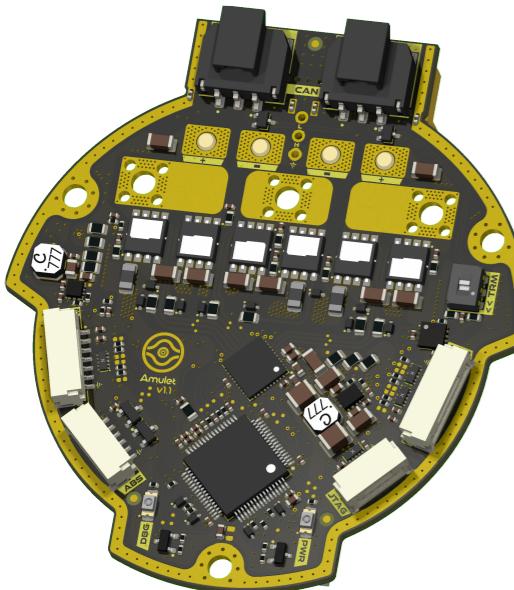
Variant: CHECKED

2024-11-29

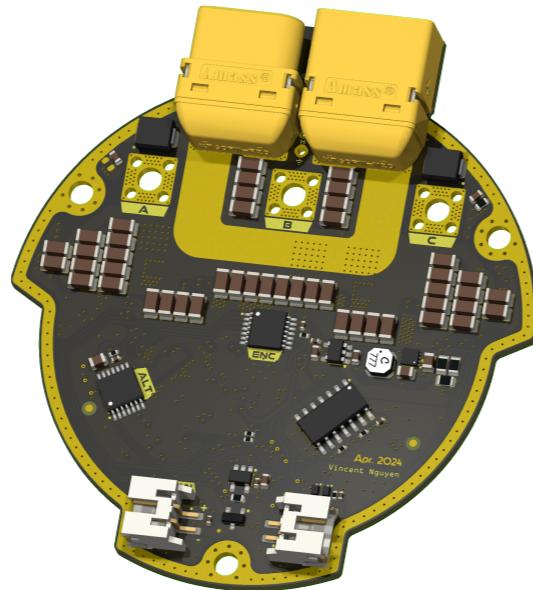
Rev 1.1.1+ (Unreleased)

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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.

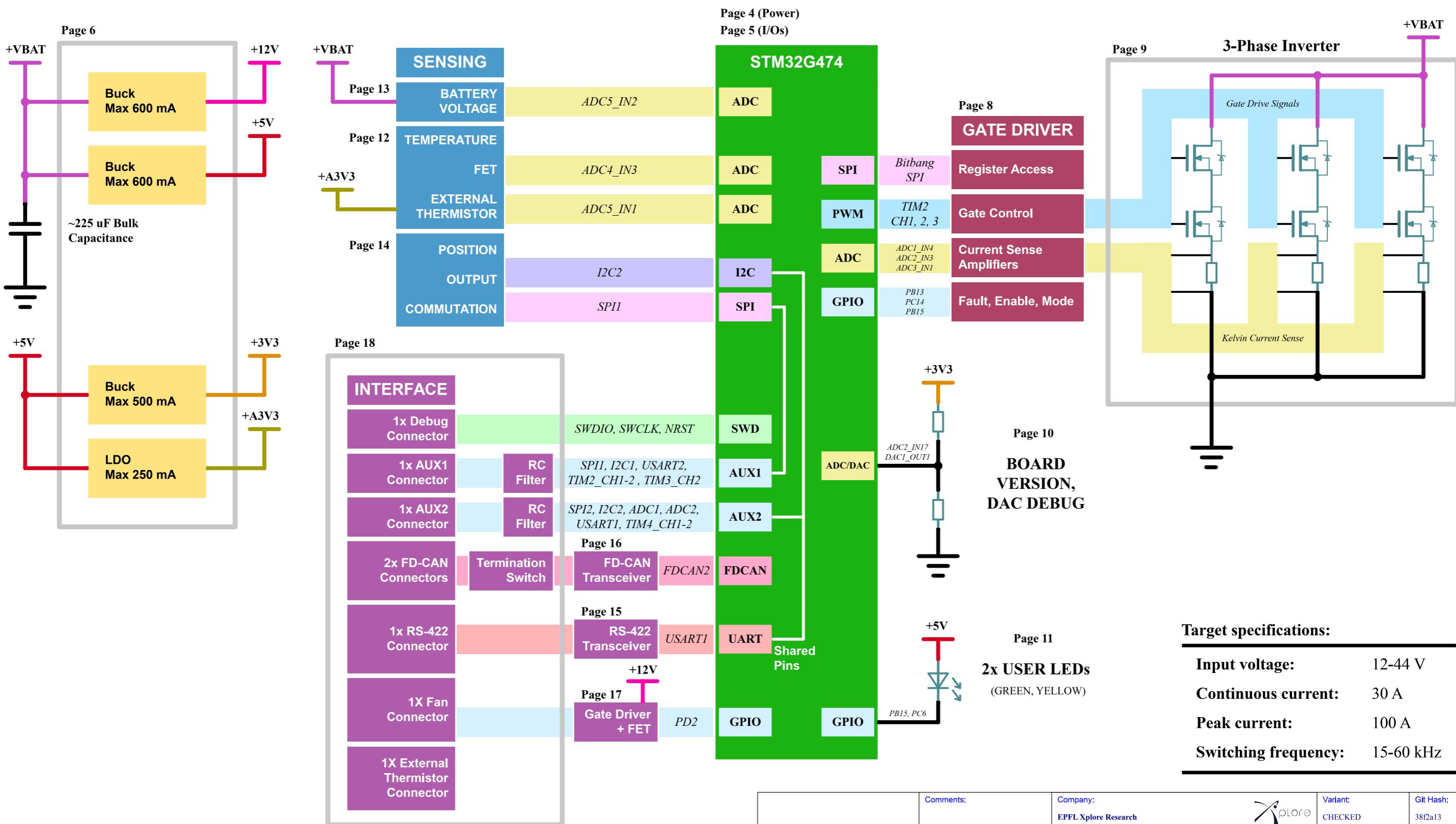
CHECKED - There shouldn't be any mistakes. Contact the engineer if you find any.

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

Date: 29-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:	Revision: 1.1.1+ (Unreleased)
			Size: A3	Sheet: 1 of 21

[2] Block Diagram

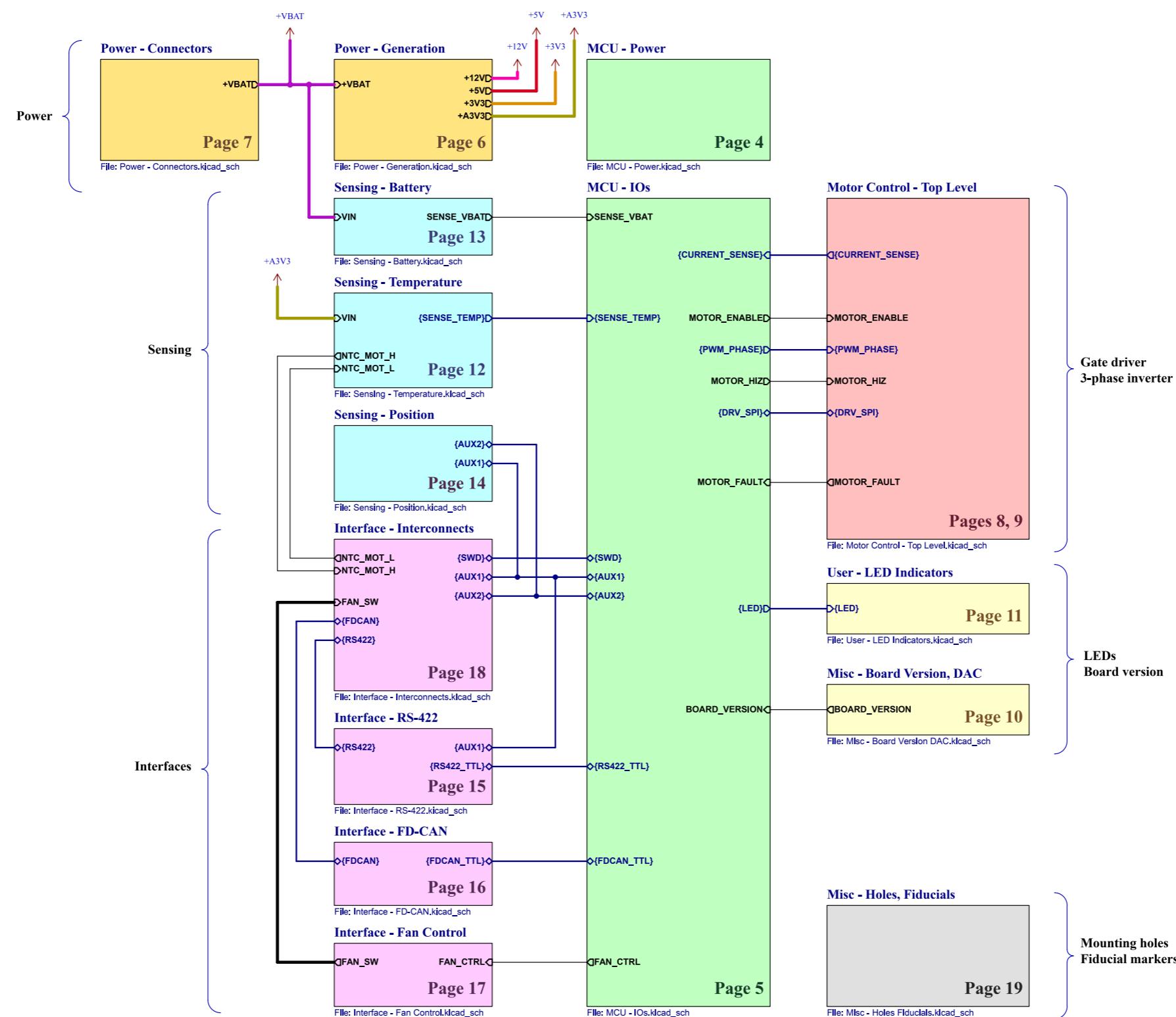


Target specifications:

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: 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:	Variant:	Git Hash:
		EPFL Xplore Research		
	Board Name:	Amulet Motion Controller		Project Name:
	Sheet Title:	File Name:	Designer:	Date:
	Project Architecture	Project Architecture.kicad_sch	Vincent Nguyen	2023-12-22
	Sheet Path:	Reviewer:		Revision:
	/Project Architecture/			1.1.1+ (Unreleased)
	Size:	Sheet:		
	A3	3 of 21		

[4] MCU - Power



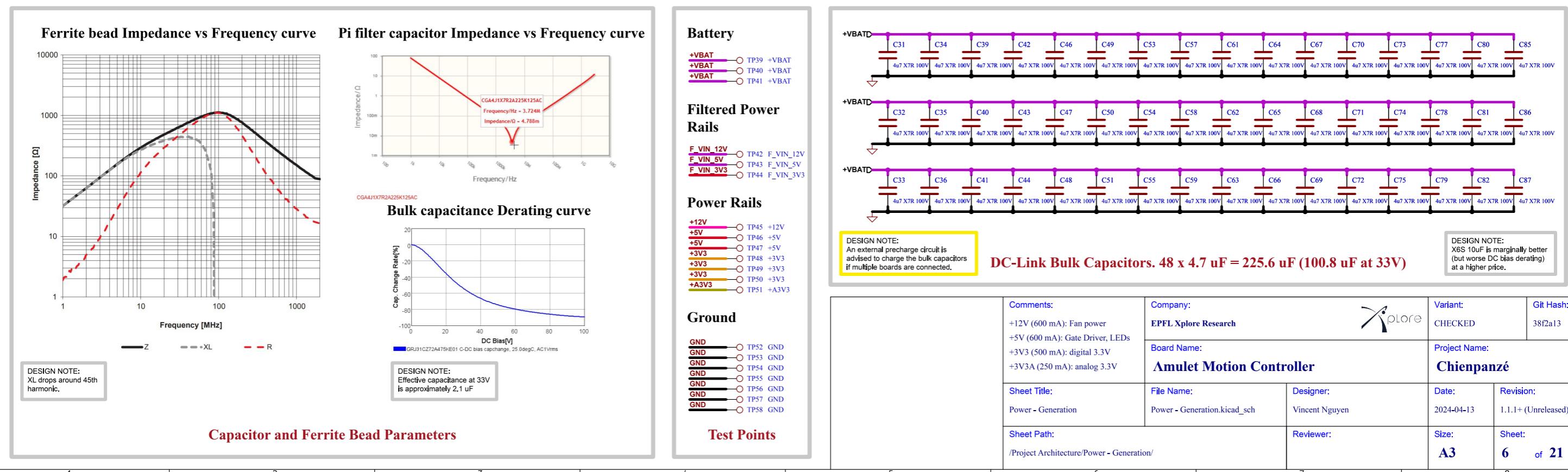
		Comments: AN5346 STM32G474 Datasheet p.81 J. Pieper ADC investigation	Company: EPFL Xplore Research	Variant: CHECKED	Git Hash: 38f2a13
		Board Name: Amulet Motion Controller			Project Name: Chienpanzé
		Sheet Title: MCU - Power	File Name: MCU - Power.kicad_sch	Designer: Vincent Nguyen	Date: 2023-12-18 Revision: 1.1.1+ (Unreleased)
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[5] MCU - I/Os

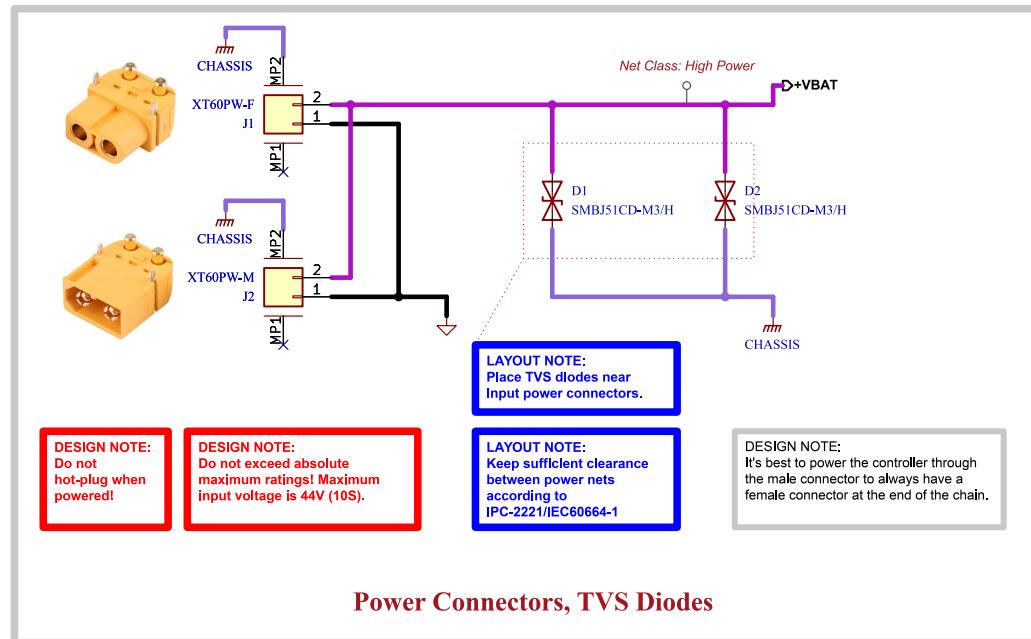


Comments: References: Flexible I/O worked examples Flexible I/O source configuration	Company: EPFL Xplore Research		Variant: CHECKED	Git Hash: 38f2a13
	Board Name:	Amulet Motion Controller		
Sheet Title: MCU - I/Os	File Name: MCU - IOs.kicad_sch		Designer: Vincent Nguyen	Date: 2023-12-20
Sheet Path: /Project Architecture/MCU - IOs/	Reviewer:		Revision: 1.1.1+ (Unreleased)	
	Size: A3	Sheet: 5 of 21		

[6] Power - Generation

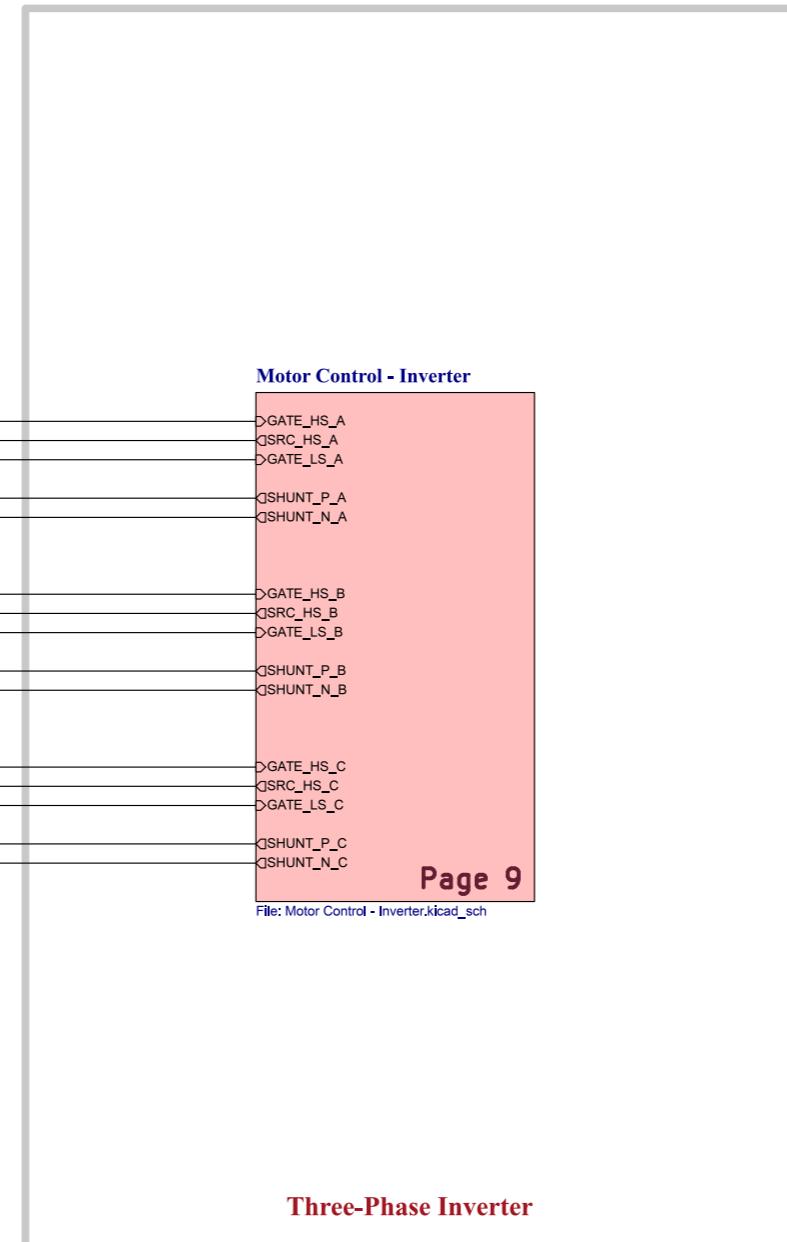
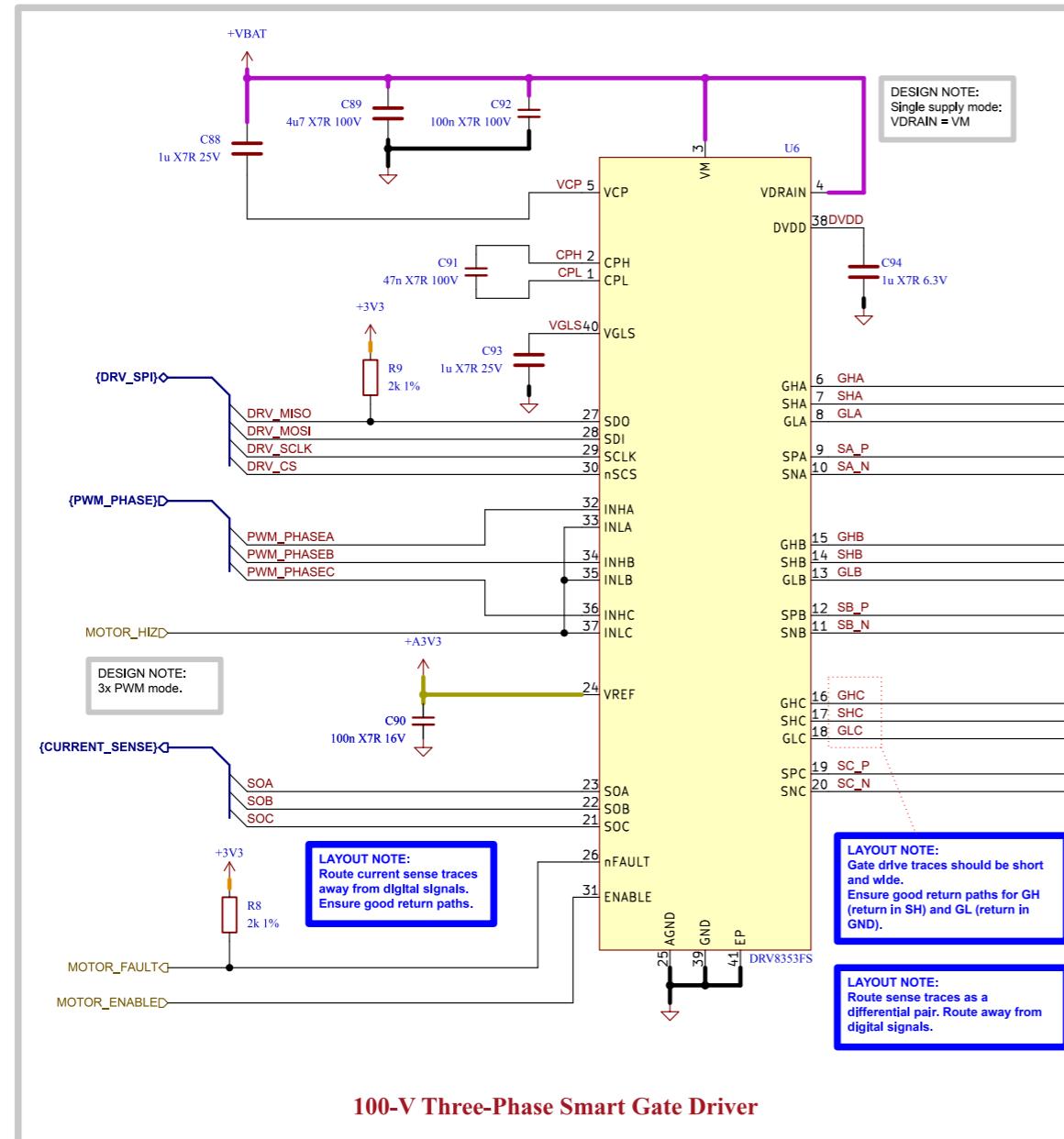


[7] Power - Connectors



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	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



Page 9

File: Motor Control - Inverter.kicad_sch

Gate Drive

GHA	TP59	GHA
GLA	TP60	GLA
SHA	TP61	SHA
GHB	TP62	GHB
GLB	TP63	GLB
SHB	TP64	SHB
GHC	TP65	GHC
GLC	TP66	GLC
SHC	TP67	SHC

Kelvin Sense

SA_P	TP68	SA_P
SA_N	TP69	SA_N
SB_P	TP70	SB_P
SB_N	TP71	SB_N
SC_P	TP72	SC_P
SC_N	TP73	SC_N

Comments: Company: Variant: Git Hash:

EPFL Xplore Research

Xplore
CHECKED
38f2a13

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: Reviewer: Size: Sheet:

/Project Architecture/Motor Control - Top Level/

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[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:
1.1.1+ (Unreleased)

Size:
A4

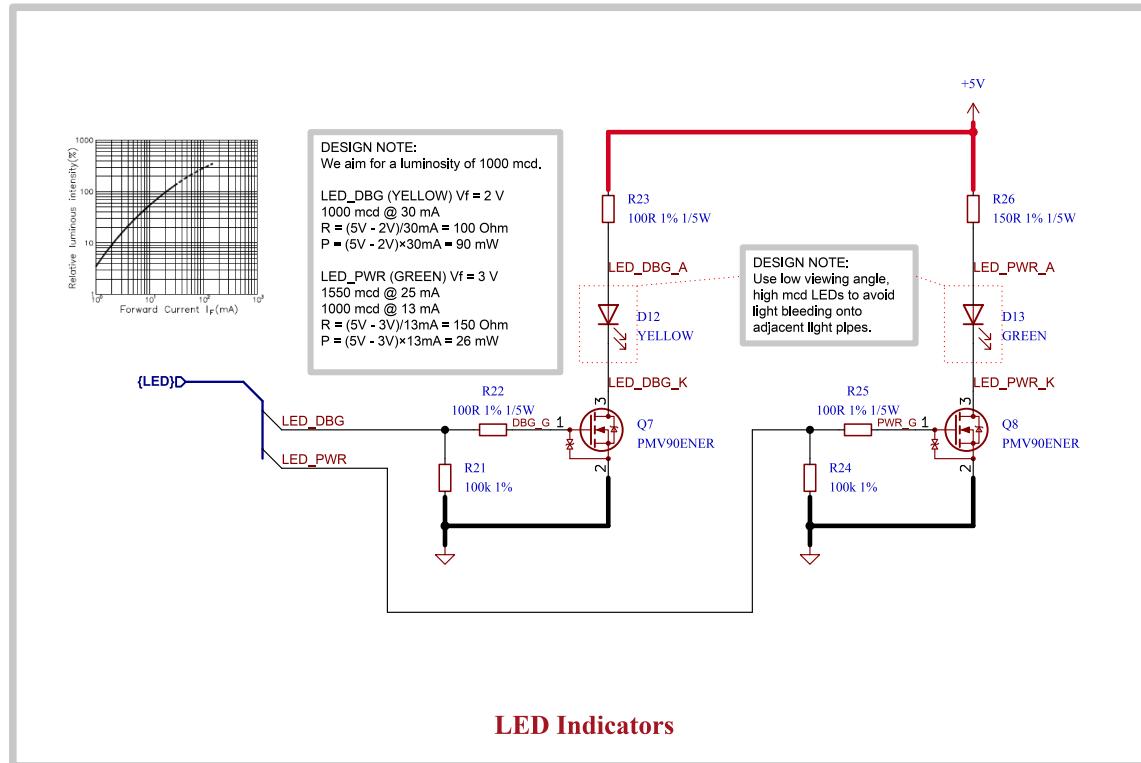
Sheet:
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[10] Misc - Board Version, DAC



	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 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:	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: 1.1.1+ (Unreleased)
	Sheet Path: /Project Architecture/User - LED Indicators/		Reviewer:	Size: A4 Sheet: 11 of 21

[12] Sensing - Temperature

A

B

C

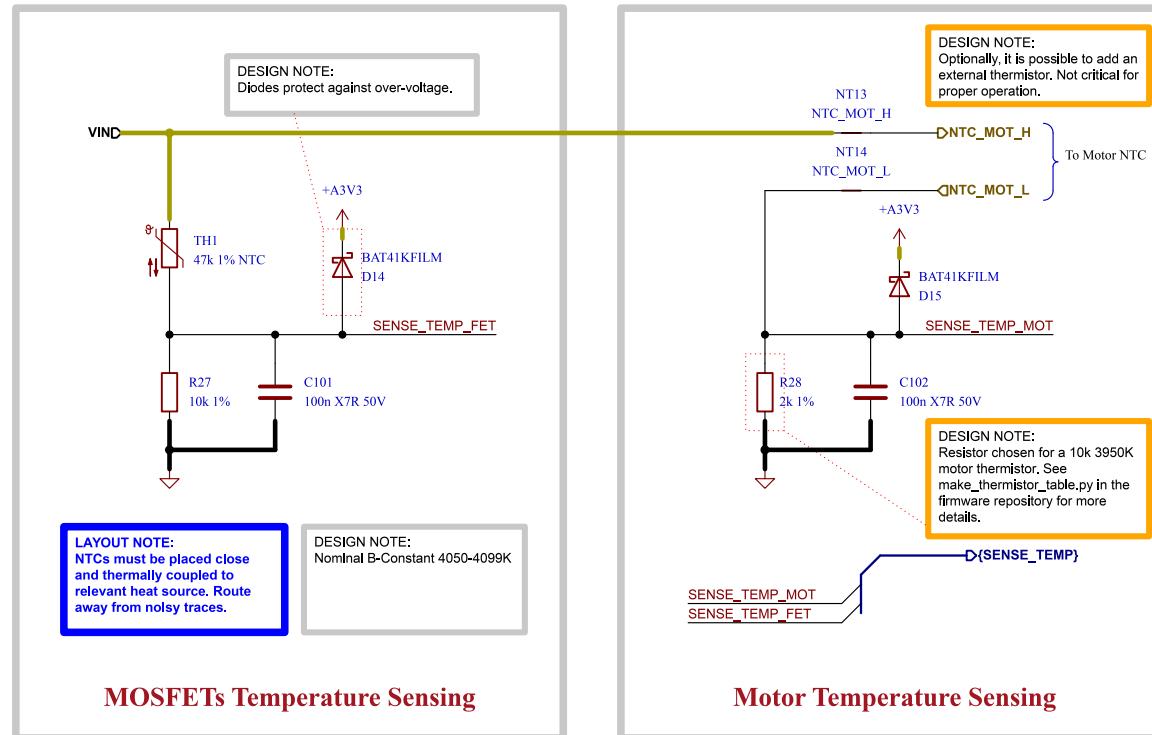
D

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
	Sheet Path: /Project Architecture/Sensing - Temperature/		Reviewer:	Size: A4
			Sheet: 12 of 21	

[13] Sensing - Battery

A

B

C

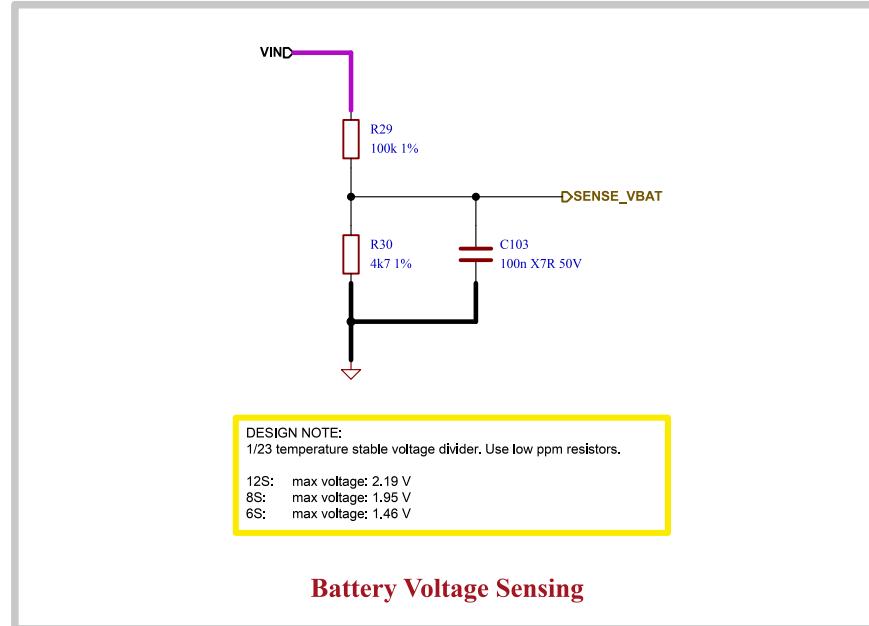
D

A

B

C

D



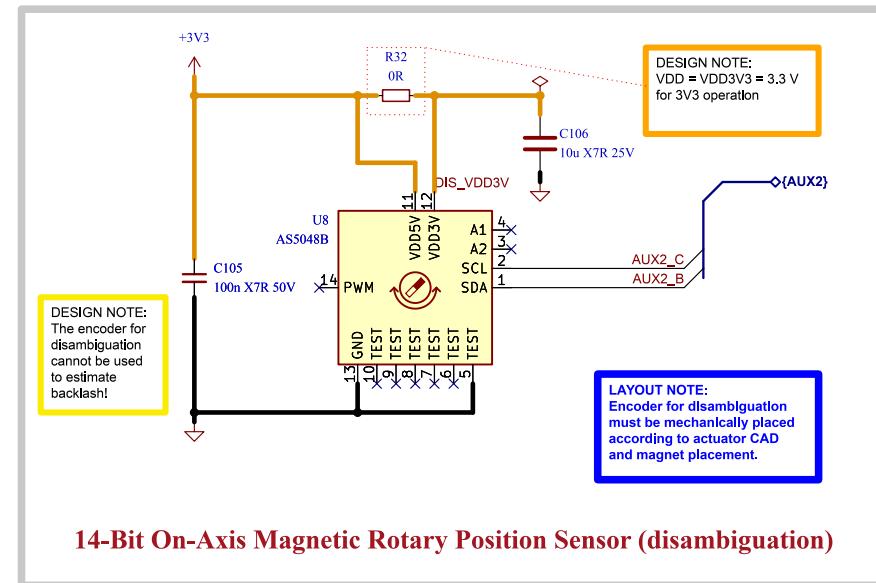
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	Board Name: Amulet Motion Controller			Project Name: Chienpanzé
	Sheet Title: Sensing - Battery	File Name: Sensing - Battery.kicad_sch	Designer: Vincent Nguyen	Date: 2023-10-14
	Sheet Path: /Project Architecture/Sensing - Battery/		Reviewer:	Size: A4 Sheet: 13 of 21

[14] Sensing - Position

A



B



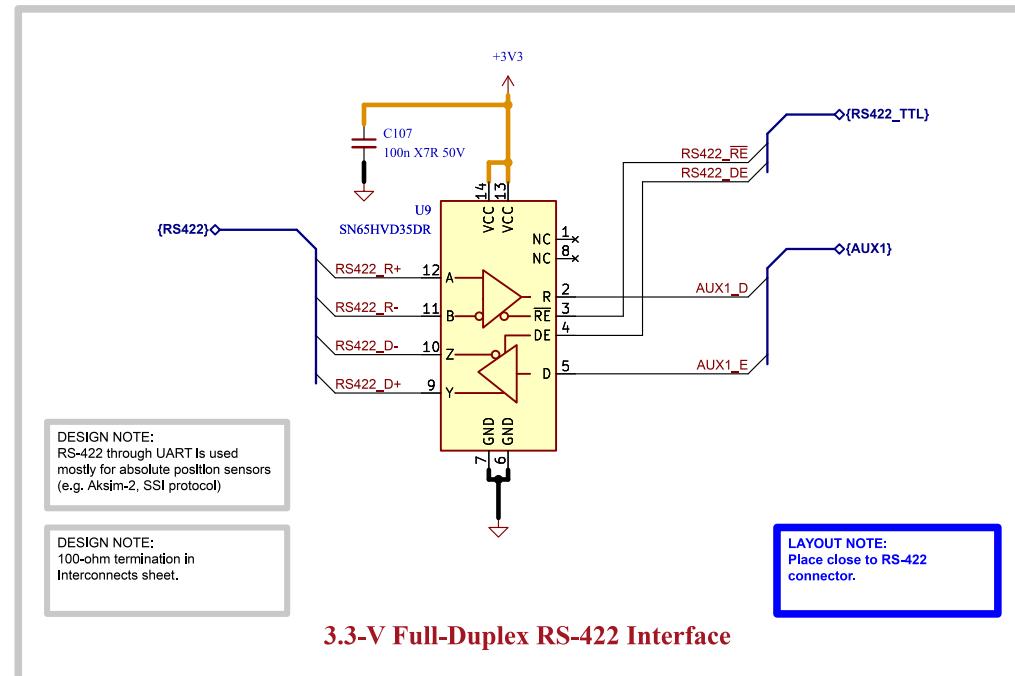
C

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	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
	Revision: 1.1.1+ (Unreleased)		Reviewer:	Size: A4
	Sheet Path: /Project Architecture/Sensing - Position/		Sheet: 14 of 21	

[15] Interface - RS-422



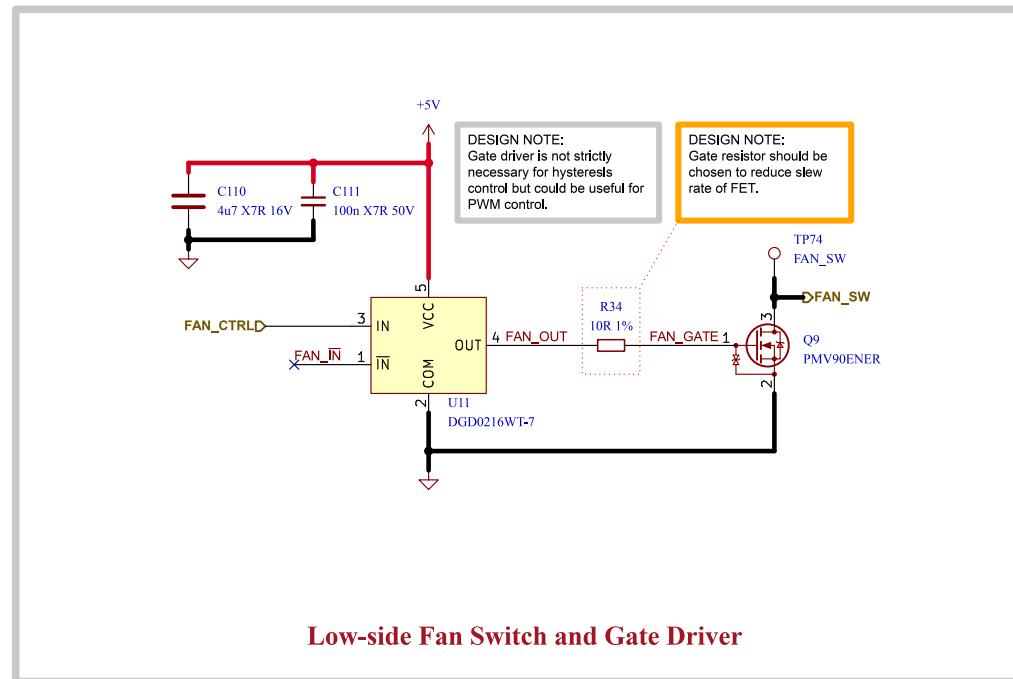
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	Board Name: Amulet Motion Controller			Project Name: Chienpanzé
	Sheet Title: Interface - RS-422	File Name: Interface - RS-422.kicad_sch	Designer: Vincent Nguyen	Date: 2023-10-15
	Sheet Path: /Project Architecture/Interface - RS-422/		Reviewer:	Size: A4
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[16] Interface - FD-CAN



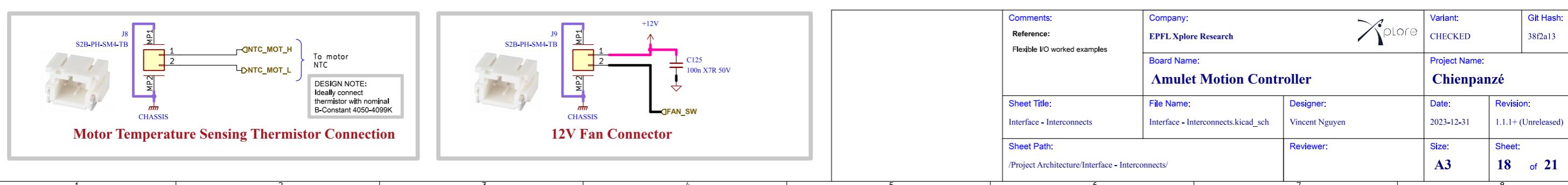
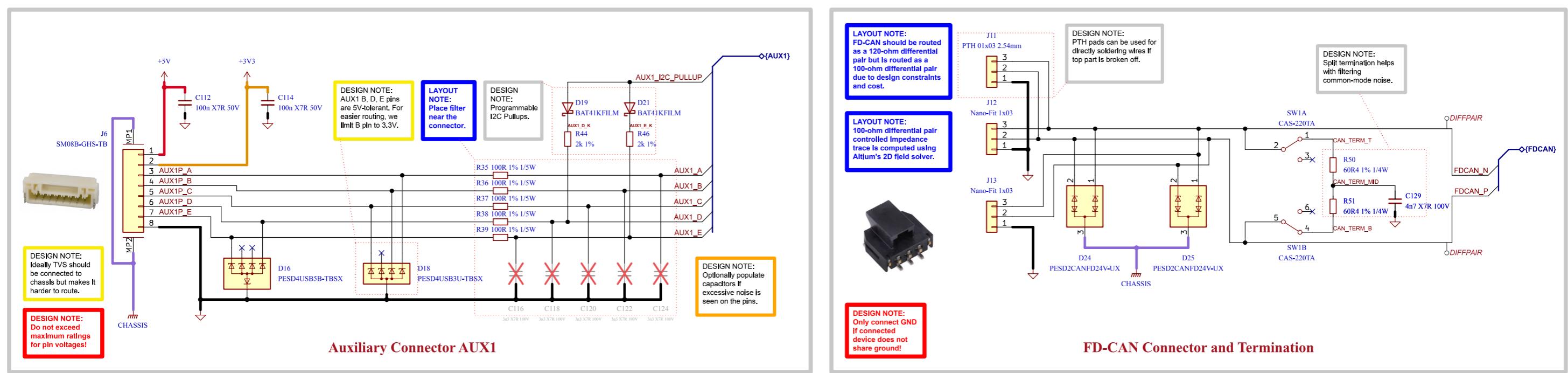
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	Board Name: Amulet Motion Controller			Project Name: Chienpanzé
	Sheet Title: Interface - FD-CAN	File Name: Interface - FD-CAN.kicad_sch	Designer: Vincent Nguyen	Date: 2023-10-15
	Sheet Path: /Project Architecture/Interface - FD-CAN/		Reviewer:	Size: A4
			Revision: 1.1.1+ (Unreleased)	Sheet: 16 of 21

[17] Interface - Fan Control

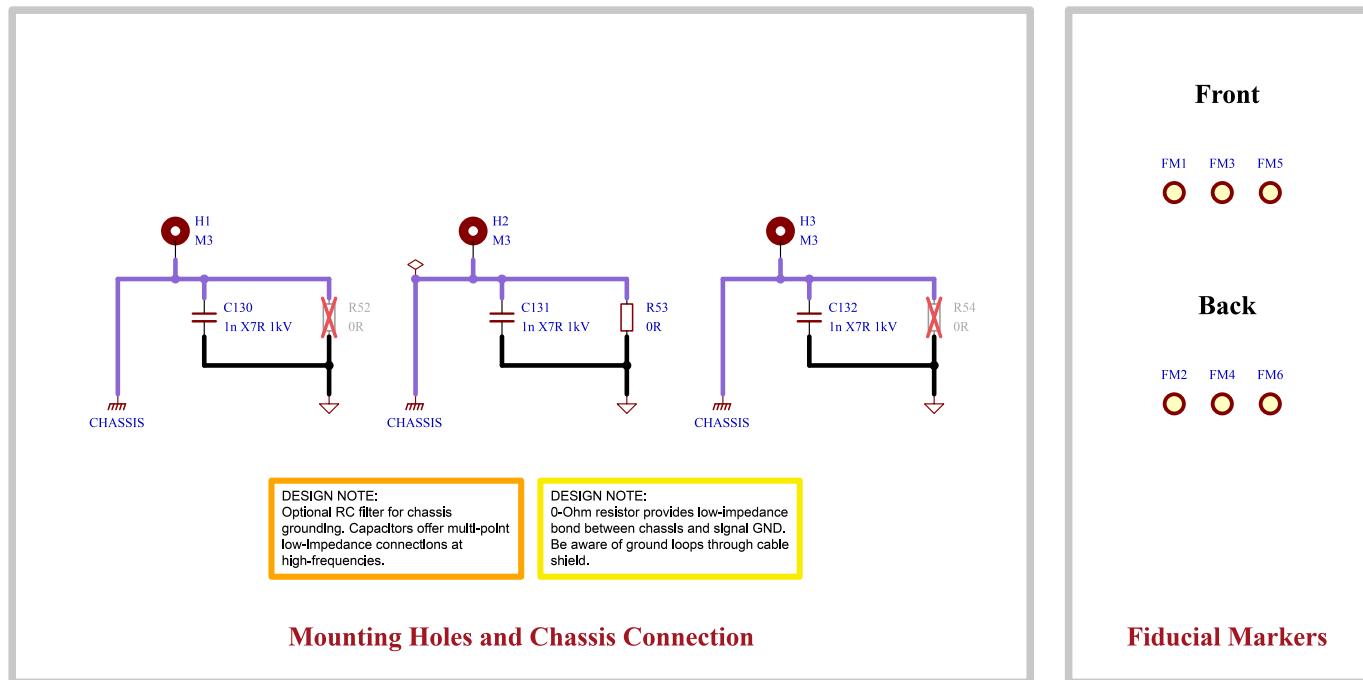


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	Board Name: Amulet Motion Controller	Project Name: Chienpanzé		
	Sheet Title: Interface - Fan Control	File Name: Interface - Fan Control.kicad_sch	Designer: Vincent Nguyen	Date: 2023-11-19 Revision: 1.1.1+ (Unreleased)
	Sheet Path: /Project Architecture/Interface - Fan Control/		Reviewer:	Size: A4 Sheet: 17 of 21

[18] Interface - Interconnects



[19] Misc - Holes, Fiducials



A

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: Misc - Holes, Fiducials	File Name: Misc - Holes Fiducials.kicad_sch	Designer: Vincent Nguyen	Date: 2023-10-22
	Revision: 1.1.1+ (Unreleased)		Reviewer:	Size: A4
	Sheet Path: /Project Architecture/Misc - Holes, Fiducials/			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.

**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

	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
	Sheet Path: /Revision History/	Reviewer:		Revision: 1.1.1+ (Unreleased)
		Size: A4	Sheet: 21 of 21	