

# Amulet Motion Controller

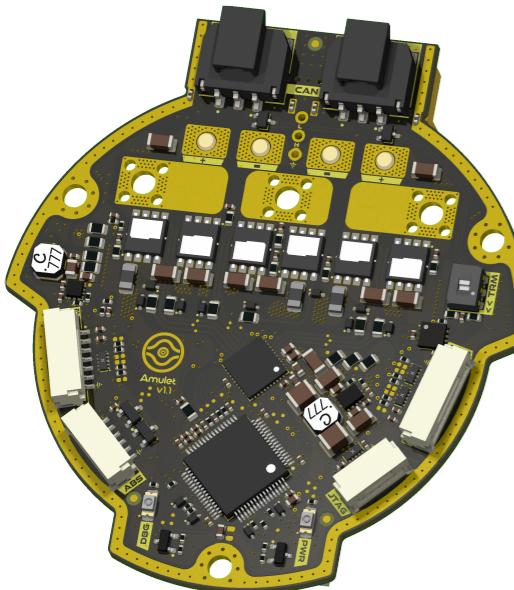
Variant: CHECKED

2024-11-26

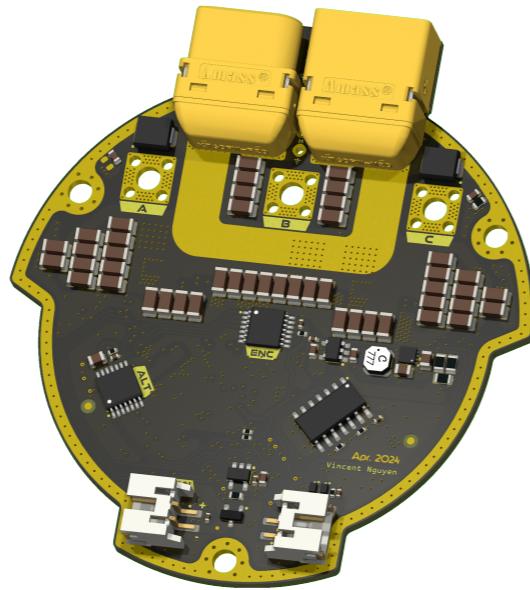
Rev 1.2

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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.

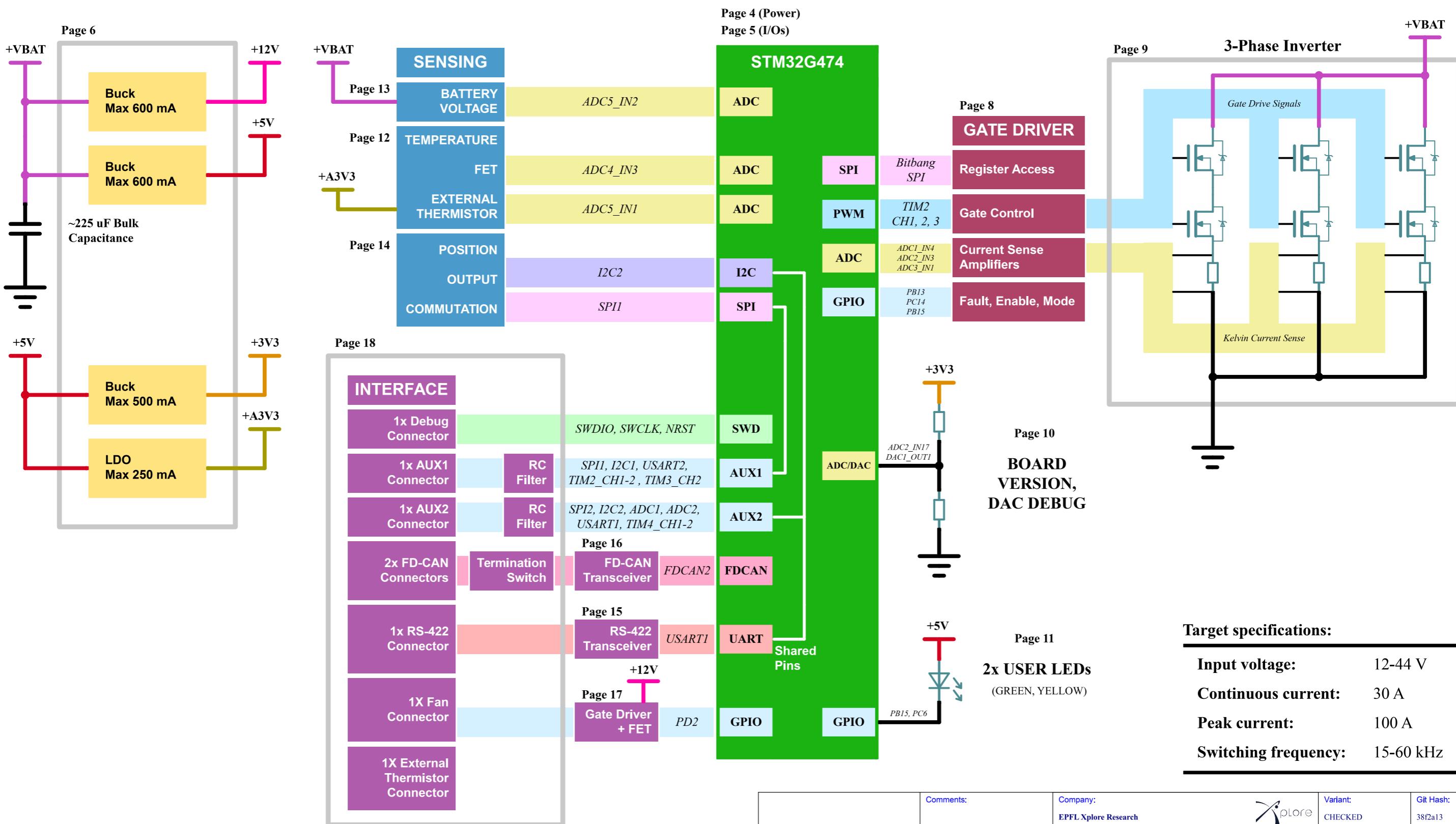
CHECKED - There shouldn't be any mistakes. Contact the engineer if you find any.

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

Date: 26-Nov-2024

	Comments:	Company: EPFL Xplore Research	Variant: CHECKED	Git Hash: 38f2a13
	Board Name: <b>Amulet Motion Controller</b>		Project Name: <b>Chienpanzé</b>	
Sheet Title: Cover Page	File Name: amulet_controller.kicad_sch	Designer: Vincent Nguyen	Date: 2024-04-13	Revision: 1.2
Sheet Path: /		Reviewer:	Size: <b>A3</b>	Sheet: <b>1 of 21</b>

# [2] Block Diagram

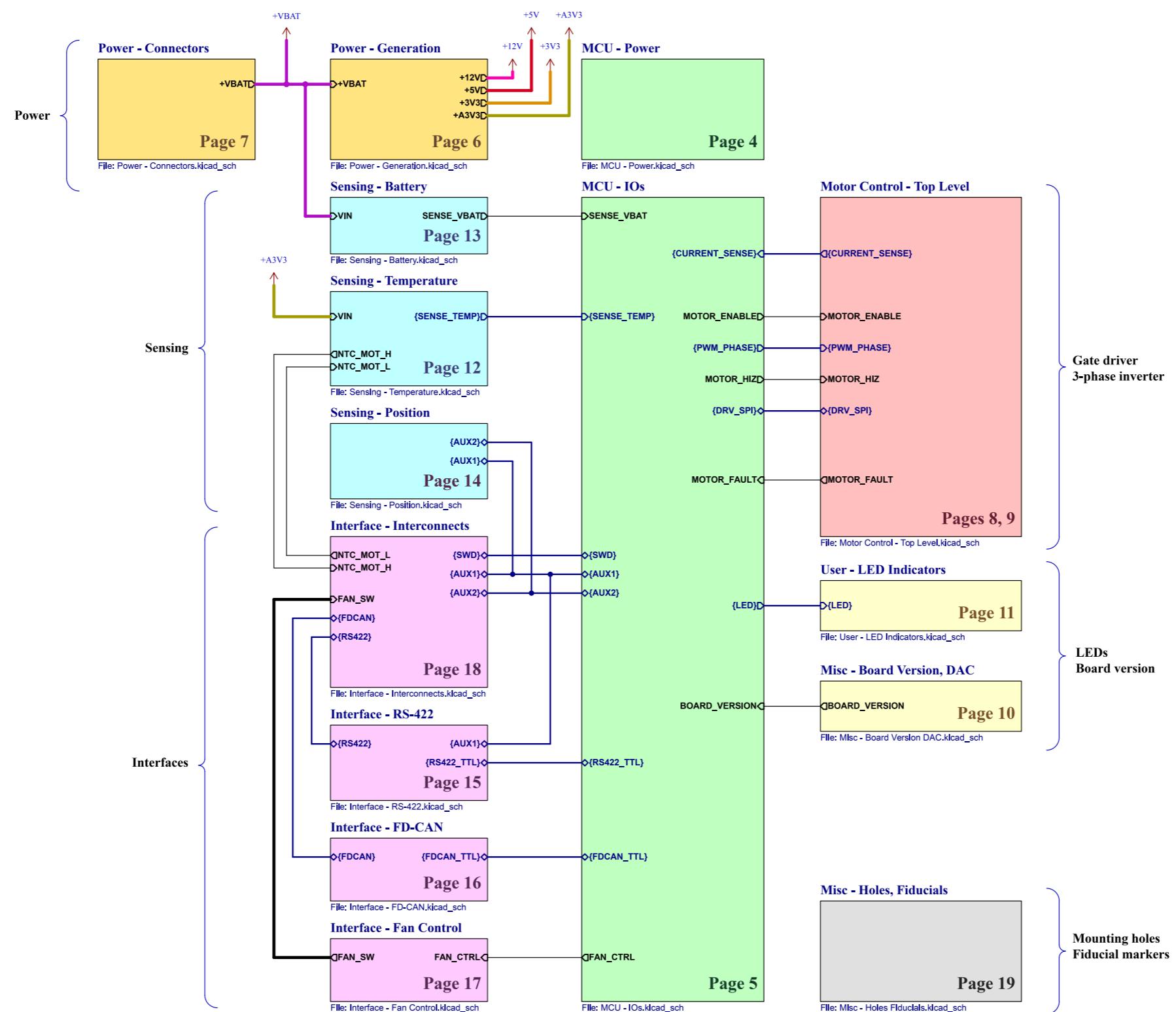


## Target specifications:

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: <b>Amulet Motion Controller</b>		Project Name: <b>Chienpanzé</b>	
Sheet Title: Block Diagram	File Name: Block Diagram.kicad_sch		Designer: Vincent Nguyen	Date: 2024-04-13
Sheet Path: /Block Diagram/	Reviewer:		Size: <b>A3</b>	Sheet: <b>2</b> of <b>21</b>

# [3] Project Architecture



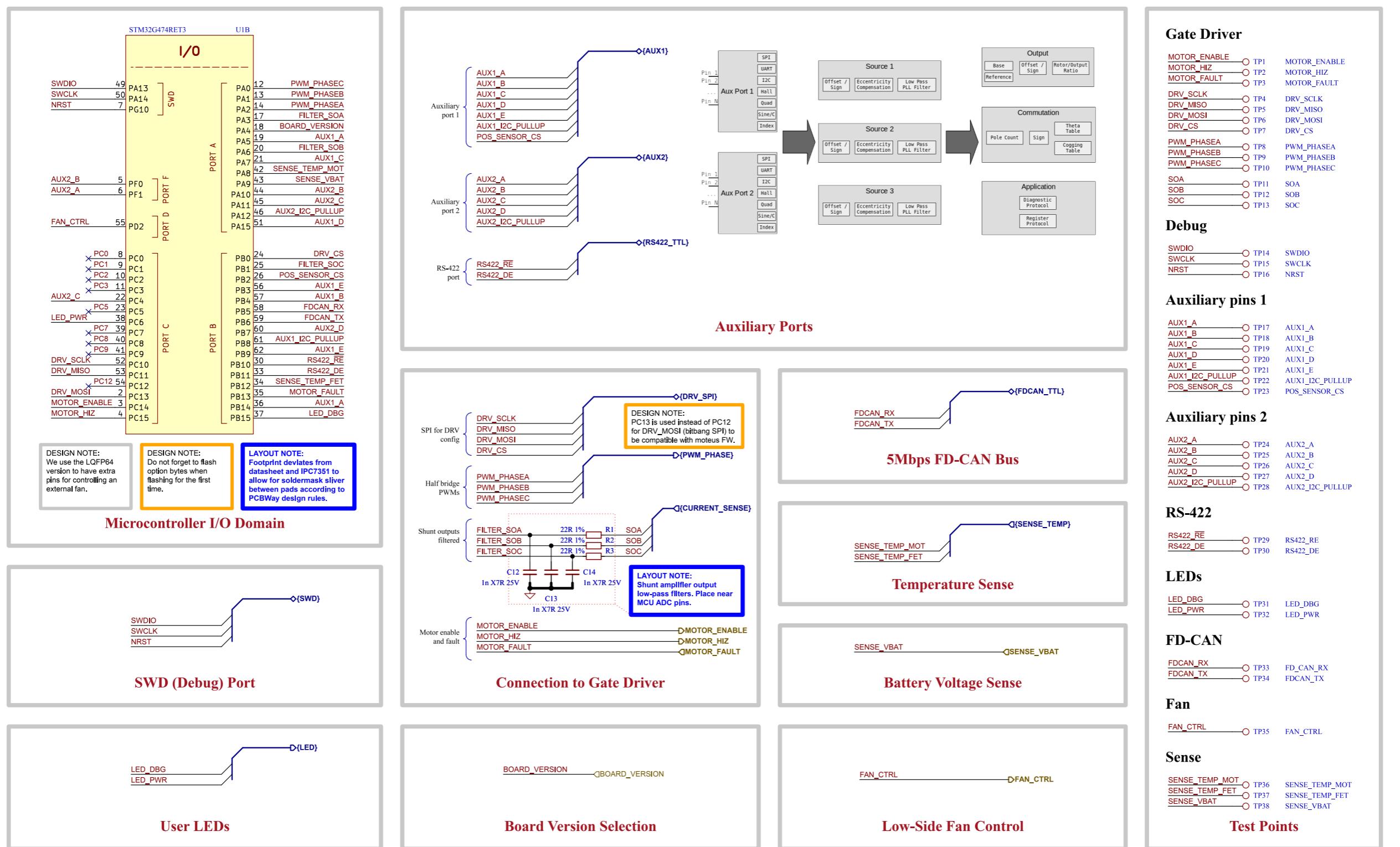
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		EPFL Xplore Research	Variant: CHECKED	
	Board Name:	<b>Amulet Motion Controller</b>		
	Sheet Title:	File Name:	Date:	
	Project Architecture	Project Architecture.kicad_sch	2023-12-22	
	Designer:	Vincent Nguyen	Revision:	
	Sheet Path:	Reviewer:		
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

# [4] MCU - Power



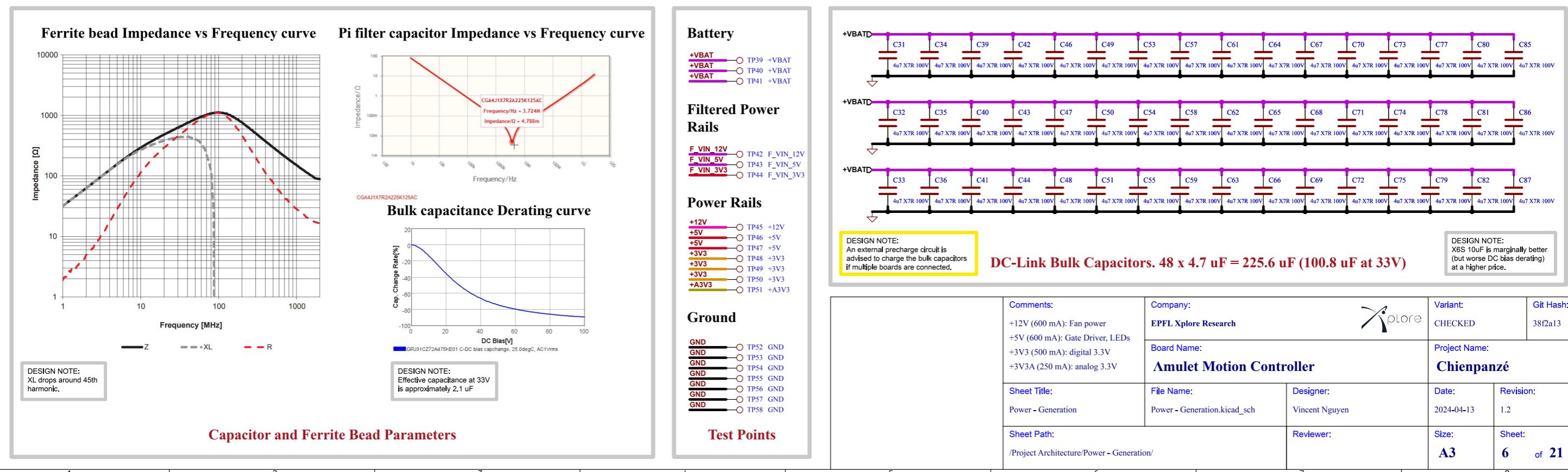
	Comments: AN5346 STM32G474 Datasheet p.81 J. Pieper ADC investigation	Company: EPFL Xplore Research 	Variant: CHECKED	Git Hash: 38f2a13
	<b>Board Name:</b> <b>Amulet Motion Controller</b>			Project Name: <b>Chienpanzé</b>
	Sheet Title: MCU - Power	File Name: MCU - Power.kicad_sch	Designer: Vincent Nguyen	Date: 2023-12-18    Revision: 1.2
	Sheet Path: /Project Architecture/MCU - Power/		Reviewer: 	Size: <b>A4</b> Sheet: <b>4</b> 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: 38f2a13
	Board Name: <b>Amulet Motion Controller</b>	Project Name: <b>Chienpanzé</b>		
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: <b>A3</b>	Sheet: <b>5</b> of <b>21</b>

# [6] Power - Generation



# [7] Power - Connectors



A

B

C

D

A

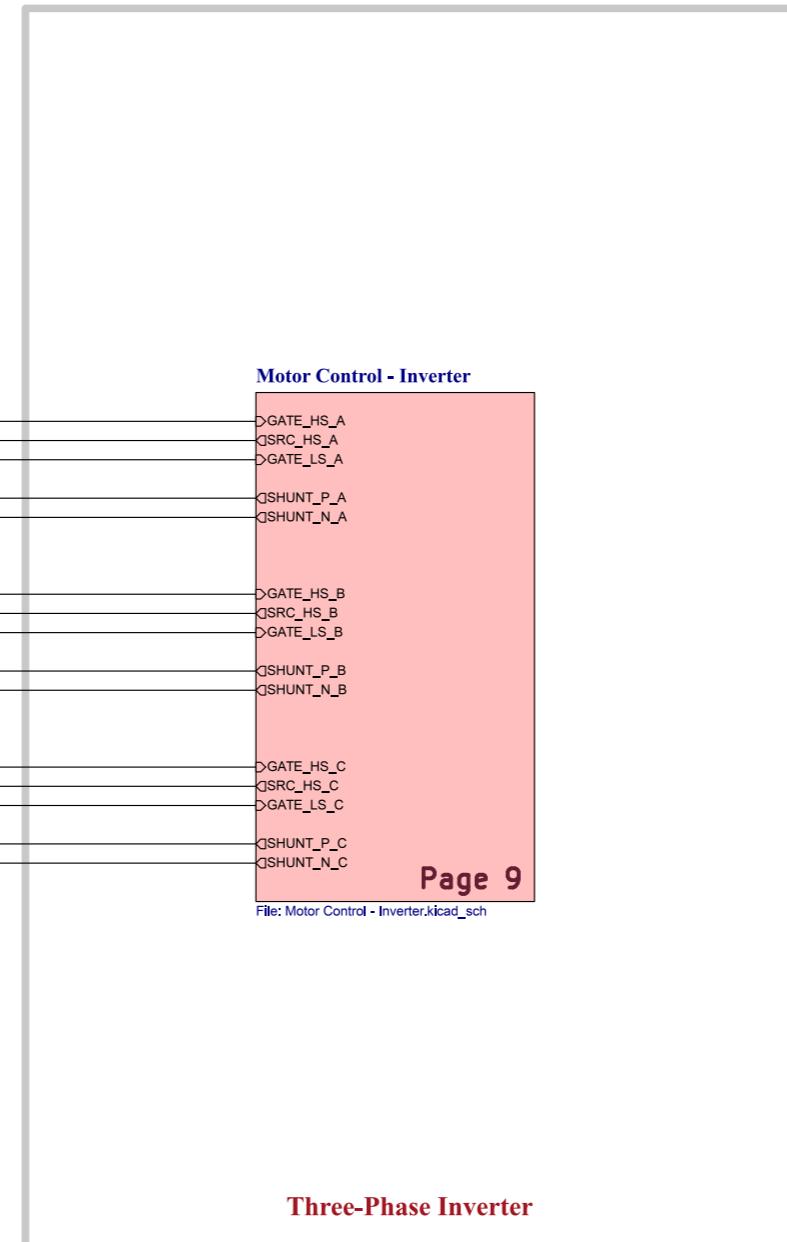
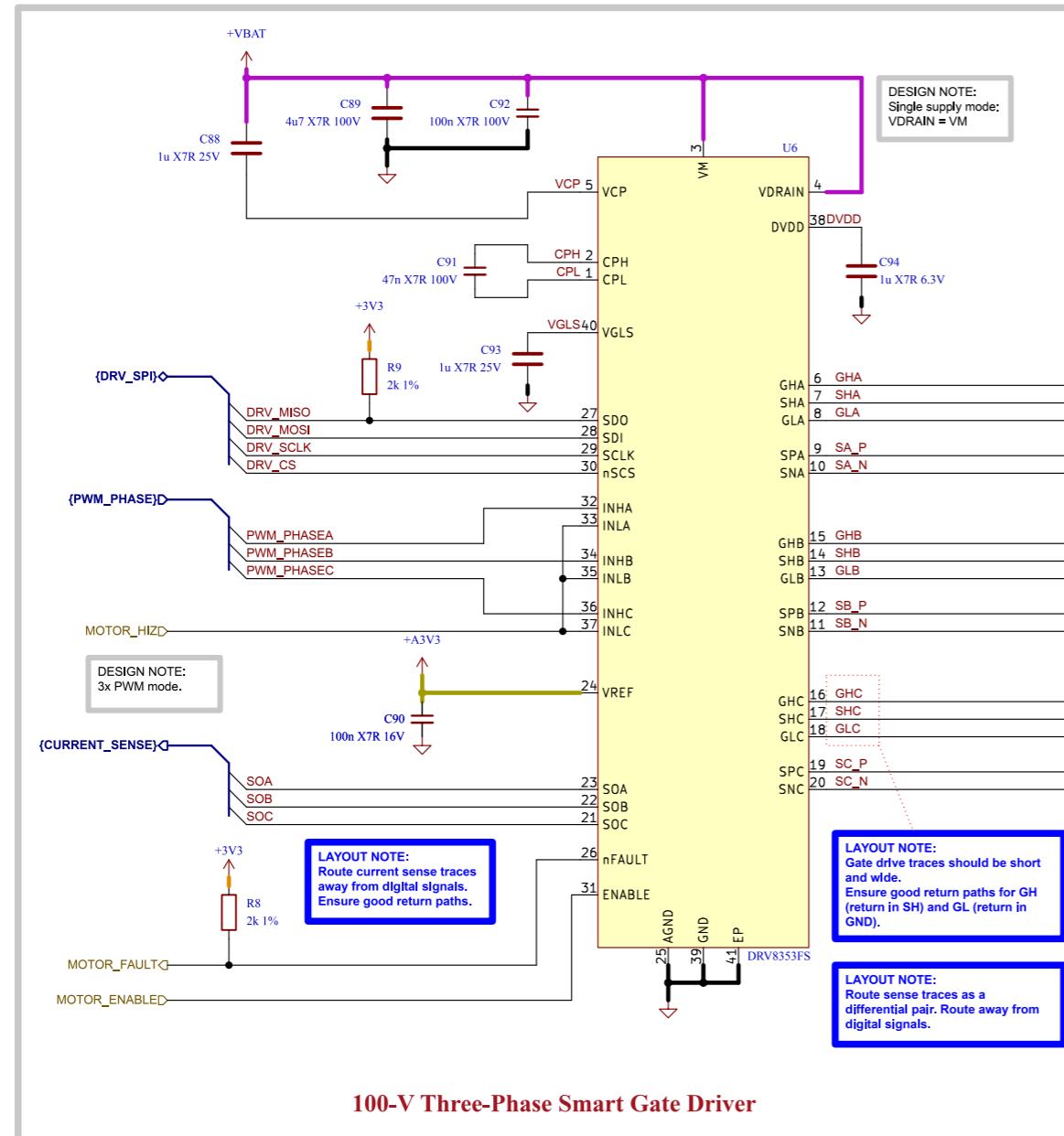
B

C

D

	Comments:	Company: EPFL Xplore Research	Variant: CHECKED	Git Hash: 38f2a13
	Board Name: <b>Amulet Motion Controller</b>			Project Name: <b>Chienpanzé</b>
	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: <b>A4</b> Sheet: <b>7</b> of <b>21</b>

# [8] Motor Control - Top Level



	Comments:	Company:	xplore	Variant:	CHECKED
	Board Name:	EPFL Xplore Research		Project Name:	
	<b>Amulet Motion Controller</b>			<b>Chienpanzé</b>	
	Sheet Title:	File Name:	Designer:	Date:	Revision:
	Motor Control - Top Level	Motor Control - Top Level.kicad_sch	Vincent Nguyen	2023-12-20	1.2
	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:**



**Variant:**  
CHECKED

**Project Name:**  
**Chienpanzé**

**Date:**  
2024-01-25

**Revision:**  
1.2

**Size:**

**Sheet:**  
**A4**

**of 21**

# [10] Misc - Board Version, DAC



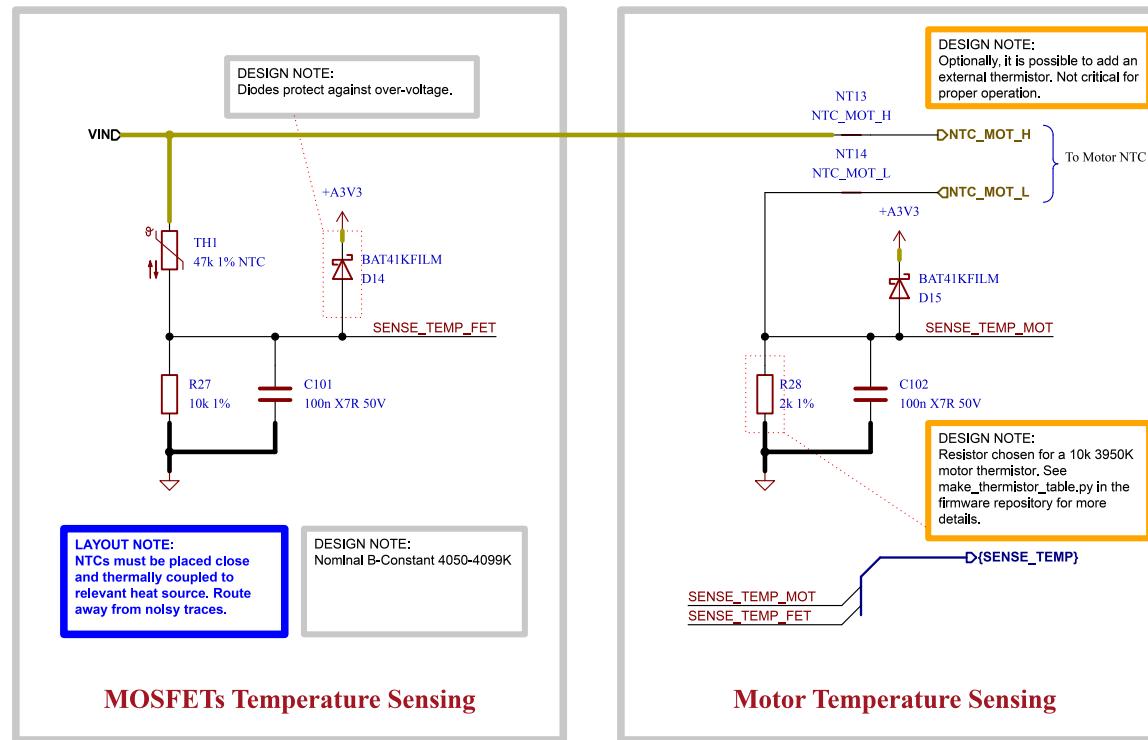
	Comments:	Company: EPFL Xplore Research	Variant: CHECKED	Git Hash: 38f2a13
	Board Name: <b>Amulet Motion Controller</b>	Project Name: <b>Chienpanzé</b>		
	Sheet Title: Misc - Board Version, DAC	File Name: Misc - Board Version DAC.kicad_sch	Designer: Vincent Nguyen	Date: 2024-04-13      Revision: 1.2
	Sheet Path: <a href="#">/Project Architecture/Misc - Board Version, DAC/</a>		Reviewer:	Size: <b>A4</b> Sheet: <b>10</b> of <b>21</b>

# [11] User - LED Indicators



	Comments:	Company: EPFL Xplore Research	Variant: CHECKED	Git Hash: 38f2a13
	Board Name: <b>Amulet Motion Controller</b>	Project Name: <b>Chienpanzé</b>		
	Sheet Title: User - LED Indicators	File Name: User - LED Indicators.kicad_sch	Designer: Vincent Nguyen	Date: 2023-12-19    Revision: 1.2
	Sheet Path: <a href="#">/Project Architecture/User - LED Indicators/</a>		Reviewer:	Size: <b>A4</b> Sheet: <b>11</b> of <b>21</b>

## [12] Sensing - Temperature



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

# [13] Sensing - Battery

A

B

C

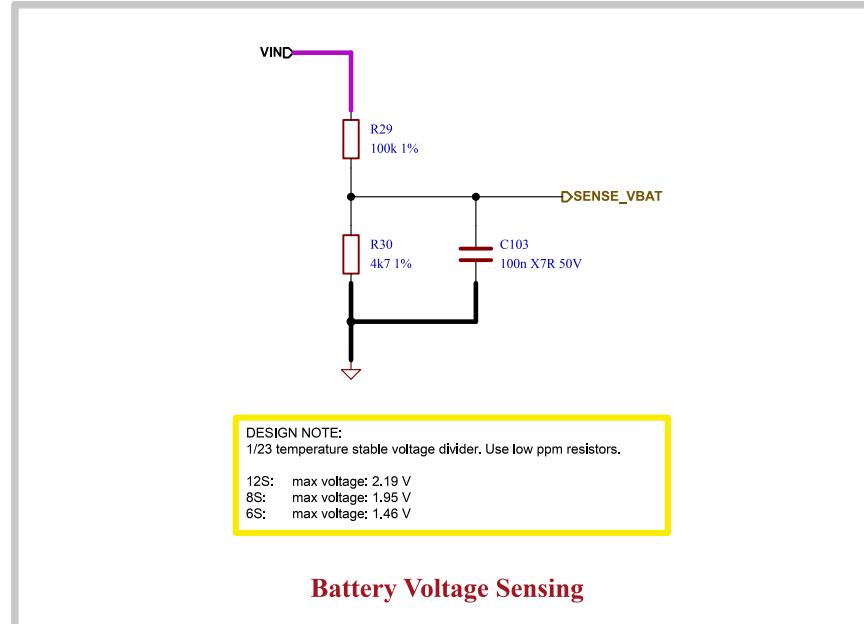
D

A

B

C

D



	Comments:	Company: EPFL Xplore Research	Variant: CHECKED	Git Hash: 38f2a13
	Board Name: <b>Amulet Motion Controller</b>			Project Name: <b>Chienpanzé</b>
	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: <b>A4</b> Sheet: <b>13</b> of <b>21</b>

# [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.



B

C

D

	Comments:	Company: EPFL Xplore Research	Variant: CHECKED	Git Hash: 38f2a13
	Board Name: <b>Amulet Motion Controller</b>			Project Name: <b>Chienpanzé</b>
	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: <b>A4</b>
				Sheet: <b>14 of 21</b>

# [15] Interface - RS-422



	Comments:	Company: EPFL Xplore Research 	Variant: CHECKED	Git Hash: 38f2a13
	Board Name: <b>Amulette Motion Controller</b>			Project Name: <b>Chienpanzé</b>
	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: <b>A4</b>	Sheet: <b>15</b> of <b>21</b>

# [16] Interface - FD-CAN



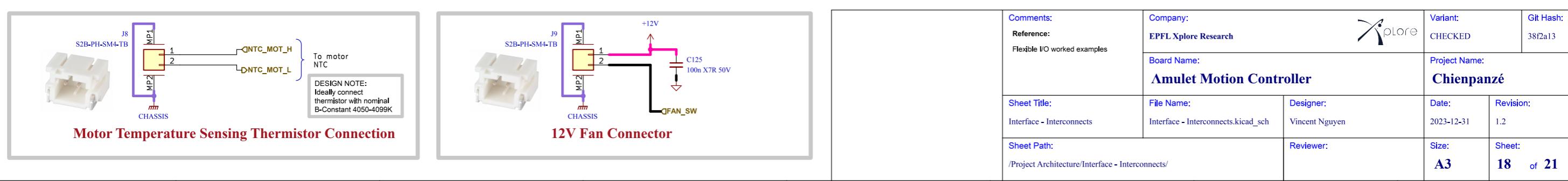
	Comments:	Company: EPFL Xplore Research	Variant: CHECKED	Git Hash: 38f2a13
	Board Name: <b>Amulet Motion Controller</b>			Project Name: <b>Chienpanzé</b>
	Sheet Title: Interface - FD-CAN	File Name: Interface - FD-CAN.kicad_sch	Designer: Vincent Nguyen	Date: 2023-10-15
	Sheet Path: /Project Architecture/Interface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

# [17] Interface - Fan Control

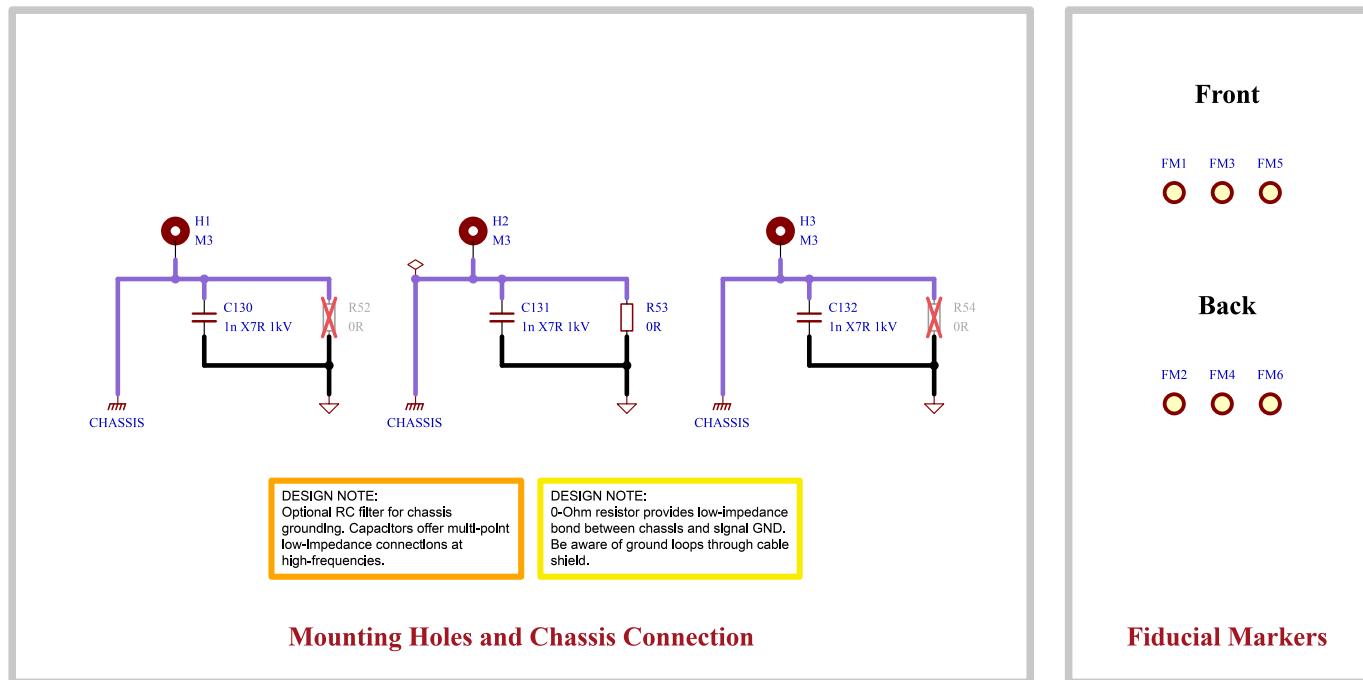


	Comments:	Company: EPFL Xplore Research	Variant: CHECKED	Git Hash: 38f2a13
	Board Name: <b>Amulet Motion Controller</b>	Project Name: <b>Chienpanzé</b>		
	Sheet Title: Interface - Fan Control	File Name: Interface - Fan Control.kicad_sch	Designer: Vincent Nguyen	Date: 2023-11-19    Revision: 1.2
	Sheet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

# [18] Interface - Interconnects



# [19] Misc - Holes, Fiducials



		Comments:	Company: EPFL Xplore Research	Variant: CHECKED	Git Hash: 38f2a13
		Board Name: <b>Amulet Motion Controller</b>	Project Name: <b>Chienpanzé</b>		
		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: <b>A4</b>
			Sheet: <b>19 of 21</b>		

# [20] Power - Sequencing

A



B

C

D

	Comments:	Company: EPFL Xplore Research	Variant: CHECKED	Git Hash: 38f2a13
		Board Name: <b>Amulet Motion Controller</b>	Project Name: <b>Chienpanzé</b>	
	Sheet Title: Power - Sequencing	File Name: Power - Sequencing.kicad_sch	Designer: Vincent Nguyen	Date: 2024-03-12    Revision: 1.2
	Sheet Path: /Power - Sequencing/		Reviewer:	Size: <b>A4</b> Sheet: <b>20</b> of <b>21</b>

## [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	13-APR-2024 - Second Revision Variant: v1.1 Released
B	<ul style="list-style-type: none"> <li>- Changed CPH-CPL capacitor to 47nF (gate driver).</li> <li>- Changed FD-CAN transceiver IC.</li> <li>- Changed FETs for top cooled variant.</li> <li>- Added TVS protection and termination switch to FD-CAN.</li> <li>- Added low-side switched 12V 600mA source for external fan.</li> <li>- Added LDO for analog supply.</li> <li>- Changed input power TVS diode to bidirectional and added one diode per connector.</li> <li>- Moved SOx low-pass filter to MCU section. Should be placed near MCU to avoid noise coupling into ADC lines.</li> <li>- Added second onboard I2C magnetic encoder for disambiguation.</li> <li>- Switched PWM_PHASEA with PWM_PHASEC on STM32G474 pinout for easier routing.</li> <li>- Changed RS422 pinout on connector.</li> <li>- Added ESD protection to all interfaces.</li> <li>- Added overvoltage protection on thermistor ADC inputs.</li> <li>- Changed buck regulators to optimize for low noise.</li> <li>- Added Pi filters to inputs of buck regulators and MCU analog supply.</li> <li>- Added decoupling caps next to power pins of connectors.</li> </ul>	<ul style="list-style-type: none"> <li>- Added controller target specifications.</li> <li>- Replaced 5V 300mA buck converter with 600mA version.</li> <li>- Added credits to moteus on cover page.</li> <li>- Added optional RC-Snubber to power stage.</li> <li>- Increased chassis length to go around the board.</li> <li>- CAN and power TVS diodes now go to chassis.</li> <li>- Changed clearance between nets to respect IEC60664-1 where possible.</li> <li>- Rectified comment on precharge.</li> <li>- Changed power TVS diode reference designator from "U" to "D".</li> <li>- Replaced chassis-GND capacitor by 1nF 1kV.</li> </ul>	<ul style="list-style-type: none"> <li>- Modified power sequencing graph according to experimental data.</li> </ul>	<ul style="list-style-type: none"> <li>- Added RC snubber passive values.</li> <li>- Added more vias for VBUS and LMR36006 GND pads.</li> <li>- Changed board version voltage reference from +3V3 to +A3V3.</li> <li>- Changed motor thermistor resistor divider to 2kOhm for a 10k 3950K thermistor.</li> </ul>
C				
D				

	Comments:	Company: <b>EPFL Xplore Research</b>	 xplore	Variant: CHECKED	Git Hash: 38f2a13
		Board Name: <b>Amulet Motion Controller</b>		Project Name: <b>Chienpanzé</b>	
	<b>Sheet Title:</b> Revision History	<b>File Name:</b> Revision History.kicad_sch	<b>Designer:</b> Vincent Nguyen	<b>Date:</b> 2024-01-03	<b>Revision:</b> 1.2
	<b>Sheet Path:</b> /Revision History/		<b>Reviewer:</b>	<b>Size:</b> <b>A4</b>	<b>Sheet:</b> <b>21</b> of <b>21</b>