

Amulet Motion Controller

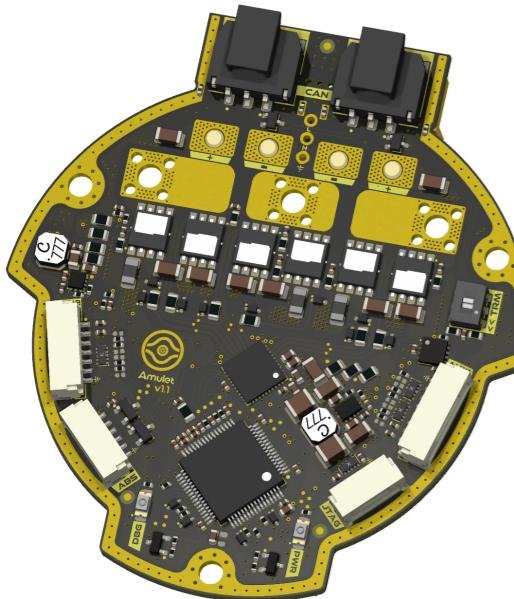
Variant: Released

2024-04-13

Rev 1.1

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TOP VIEW



DESIGN CONSIDERATIONS

DESIGN NOTE:
Example text for informational design notes.

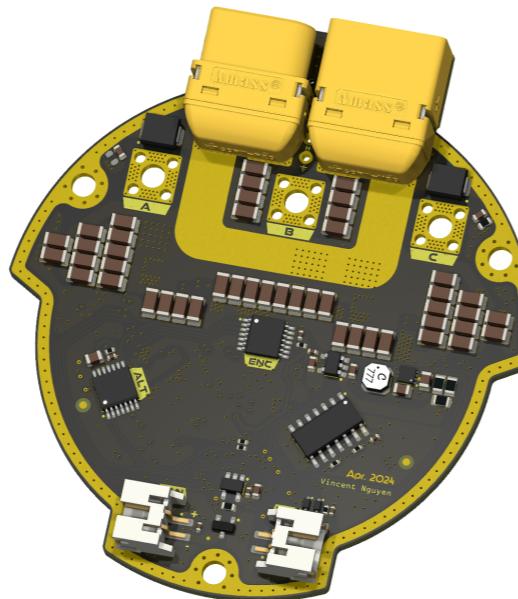
DESIGN NOTE:
Example text for debug notes.

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.

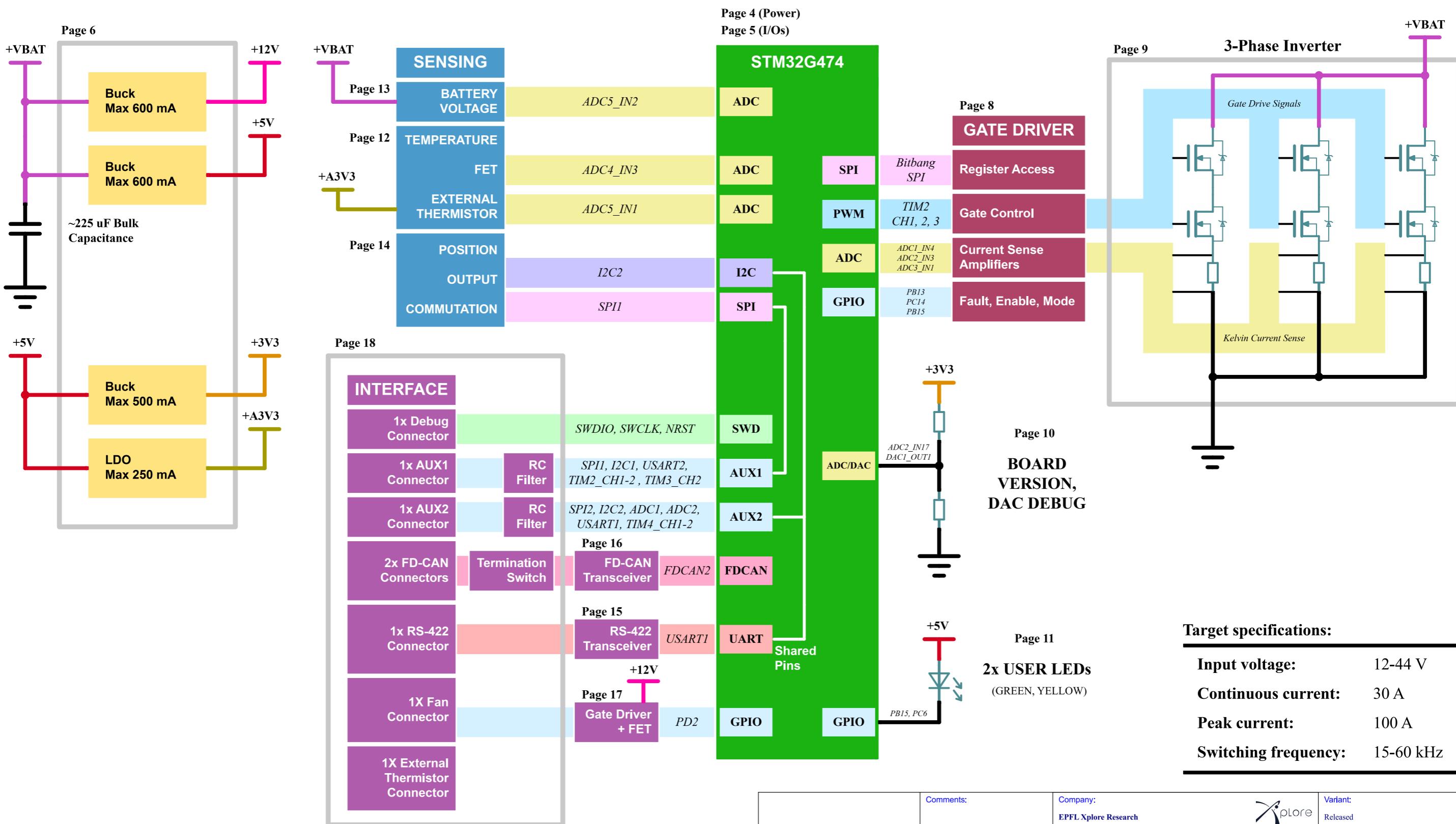
CHECKED - There shouldn't be any mistakes. Contact the engineer if you find any.

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

Released 13-APR-2024

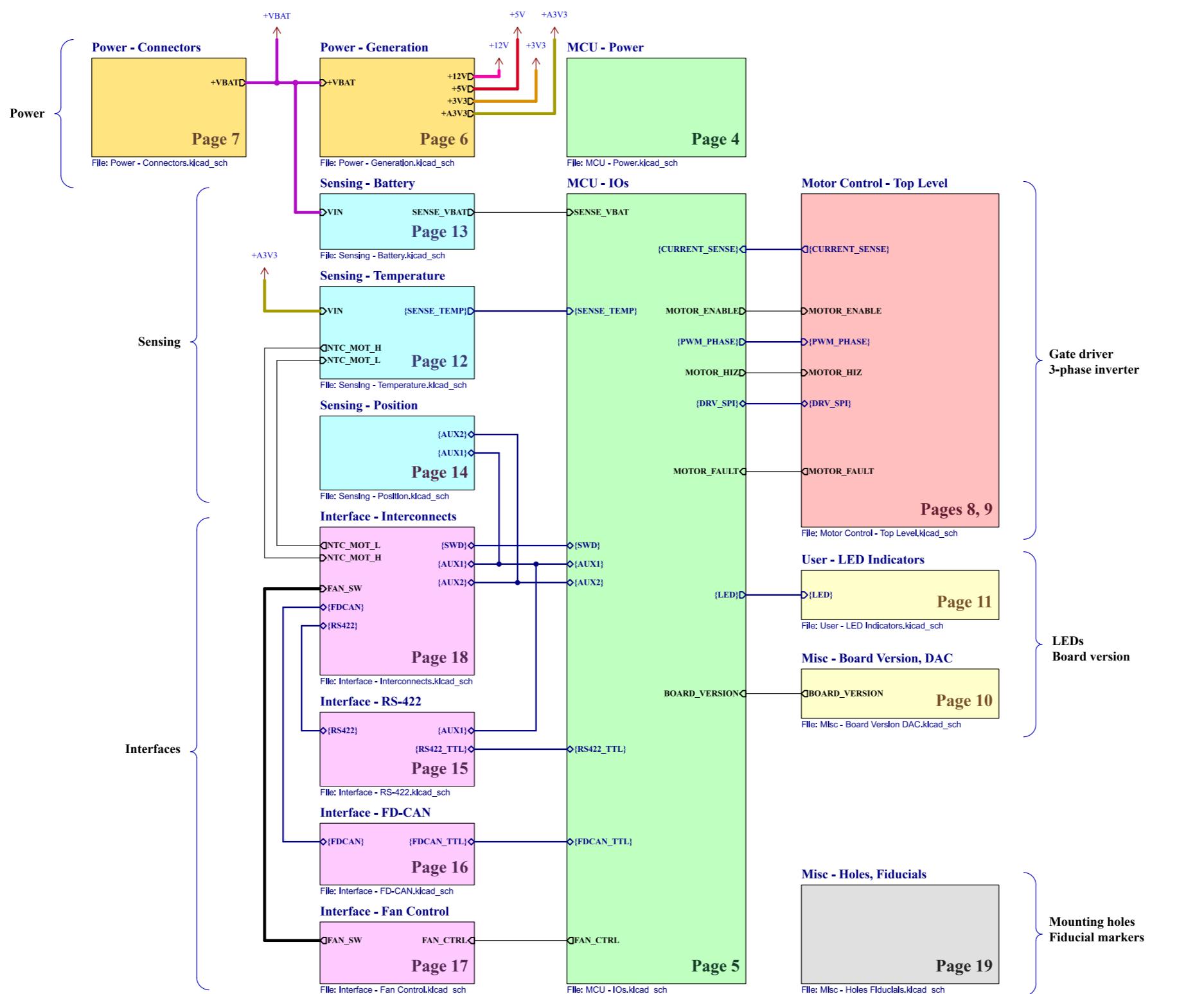
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| | Comments: | Company: EPFL Xplore Research | Variant: Released |
| | Board Name: Amulet Motion Controller | Project Name: Chienpanzé | |
| | Sheet Title: Cover Page | File Name: amulet_controller.kicad_sch | Designer: Vincent Nguyen |
| | Sheet Path: / | Reviewer: | Date: 2024-04-13 |
| | | | Revision: 1.1 |
| | | Size: A3 | Sheet: 1 of 21 |

[2] Block Diagram



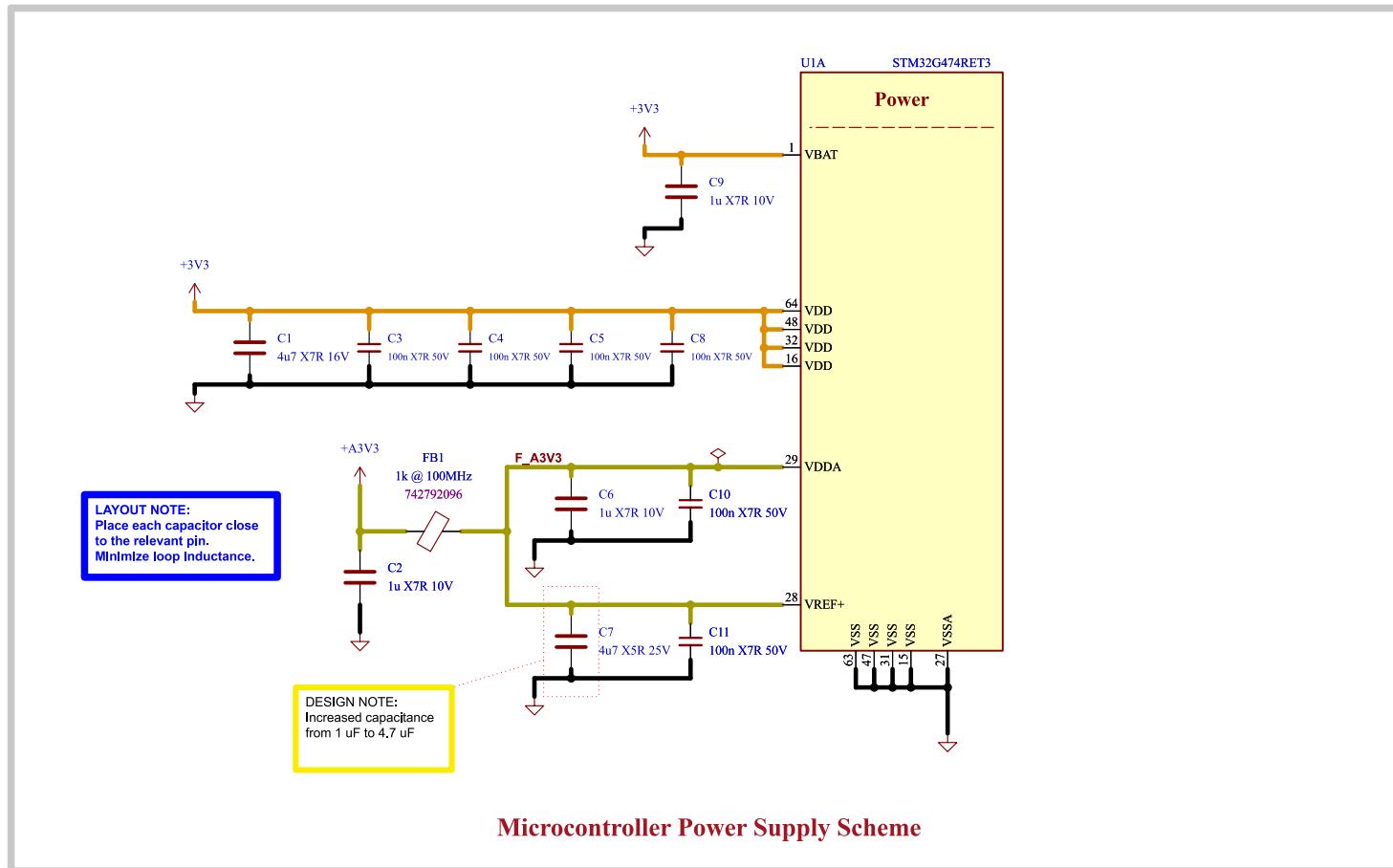
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| Sheet Title: Block Diagram | File Name: Block Diagram.kicad_sch | Designer: Vincent Nguyen | Date: 2024-04-13 |
| Sheet Path: /Block Diagram/ | Reviewer: | Size: A3 | Revision: 1.1 |

[3] Project Architecture



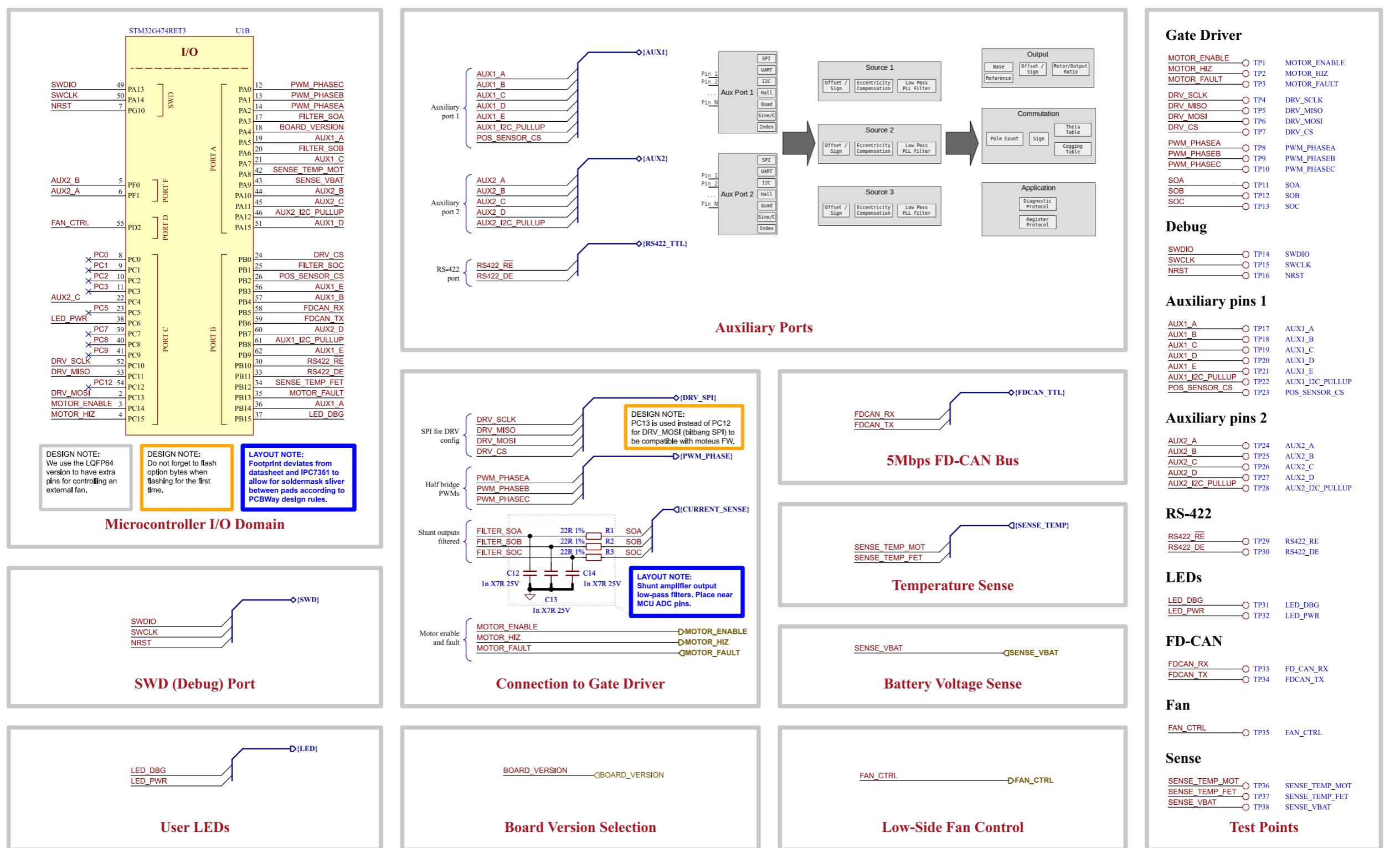
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| Sheet Title: | File Name: Project Architecture | Designer: Vincent Nguyen | Date: 2023-12-22 |
| Sheet Path: | /Project Architecture/ | Reviewer: | Revision: 1.1 |
| | Size: A3 | Sheet: 3 of 21 | |

[4] MCU - Power



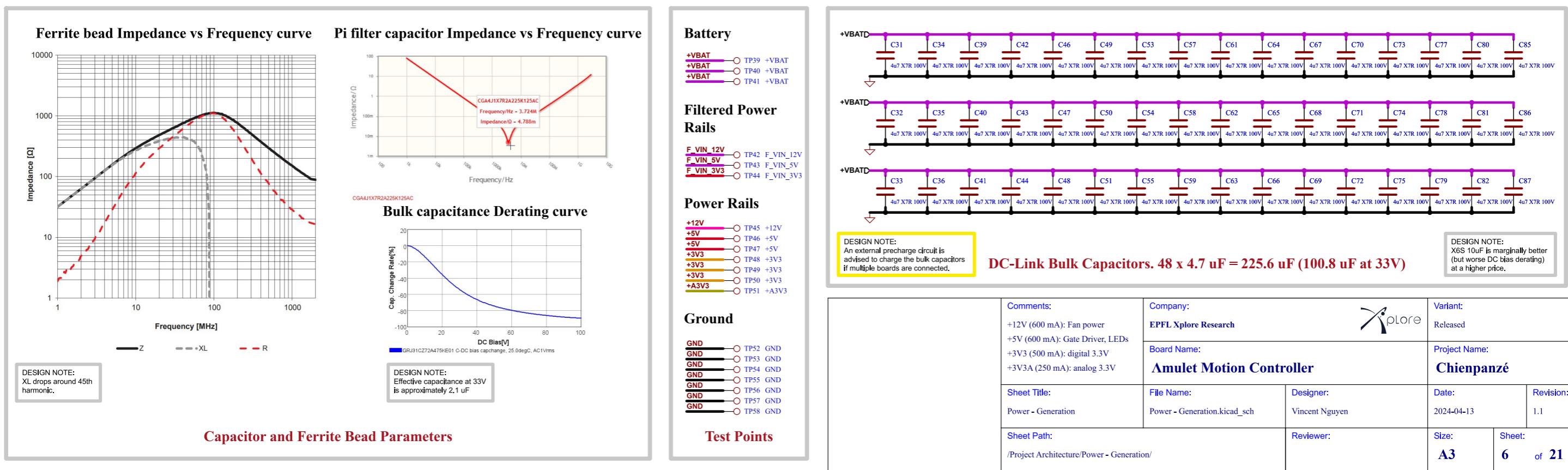
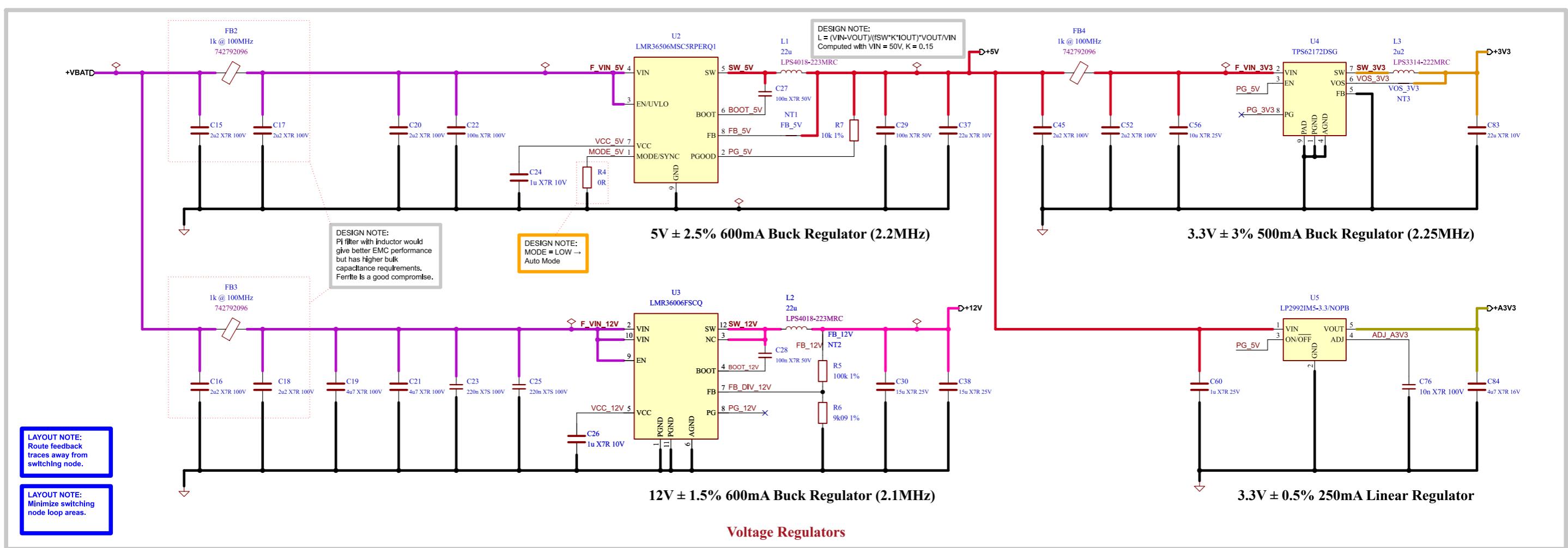
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| | Comments: AN5346 STM32G474 Datasheet p.81 J. Pieper ADC investigation | Company: EPFL Xplore Research  | Variant: Released |
| | Board Name: Amulet Motion Controller | | |
| | Sheet Title: MCU - Power | File Name: MCU - Power.kicad_sch | Designer: Vincent Nguyen |
| | Sheet Path: /Project Architecture/MCU - Power/ | Reviewer: | Date: 2023-12-18 Revision: 1.1 |

[5] MCU - I/Os

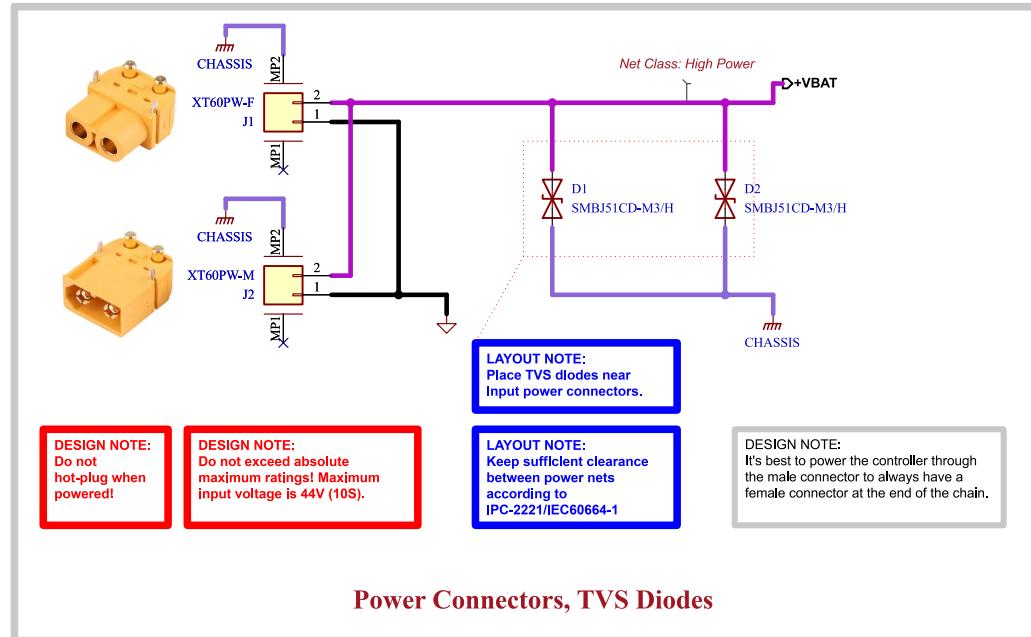


| | | | | |
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| Comments: References: Flexible I/O worked examples Flexible I/O source configuration | Company: EPFL Xplore Research | | Variant: Released | |
| | Board Name: Amulet Motion Controller | | Project Name: Chienpanzé | |
| Sheet Title: MCU - I/Os | File Name: MCU - IOs.kicad_sch | Designer: Vincent Nguyen | Date: 2023-12-20 | Revision: 1.1 |
| Sheet Path: /Project Architecture/MCU - IOs/ | Reviewer: | | Size: A3 | Sheet: 5 of 21 |

[6] Power - Generation

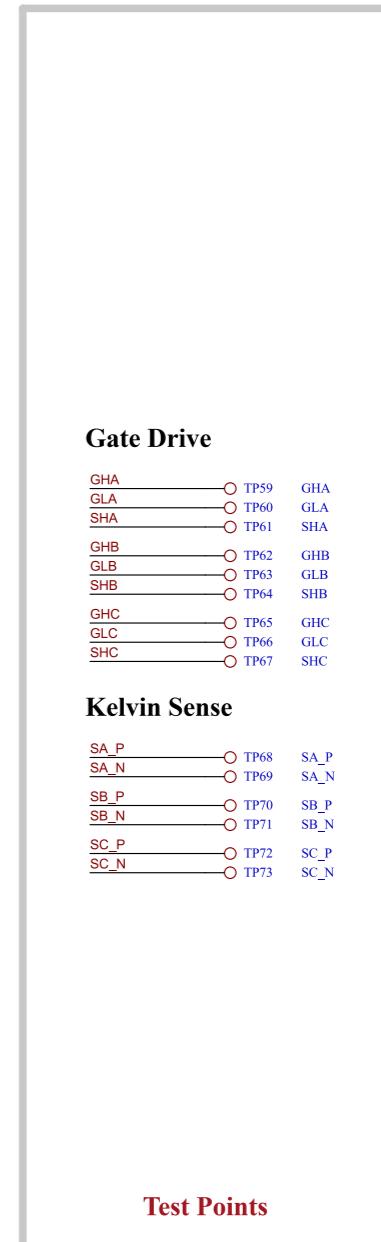
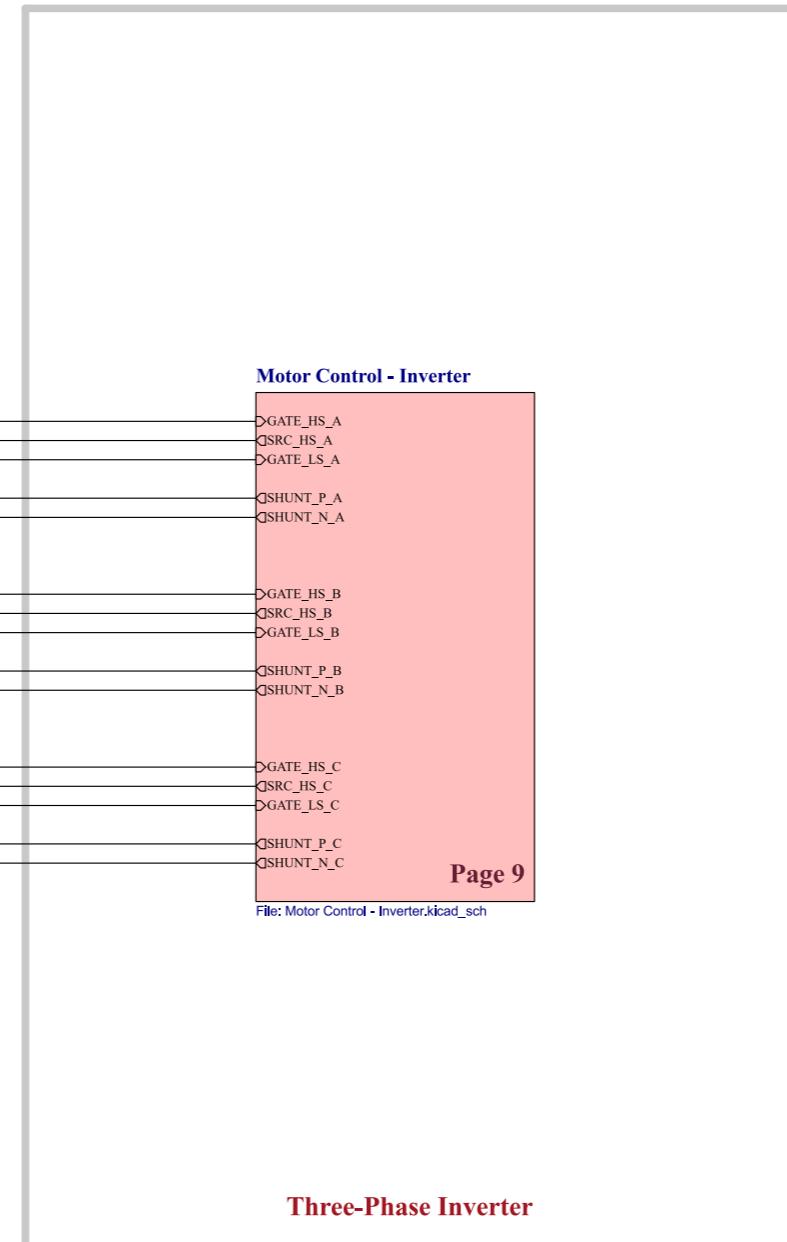
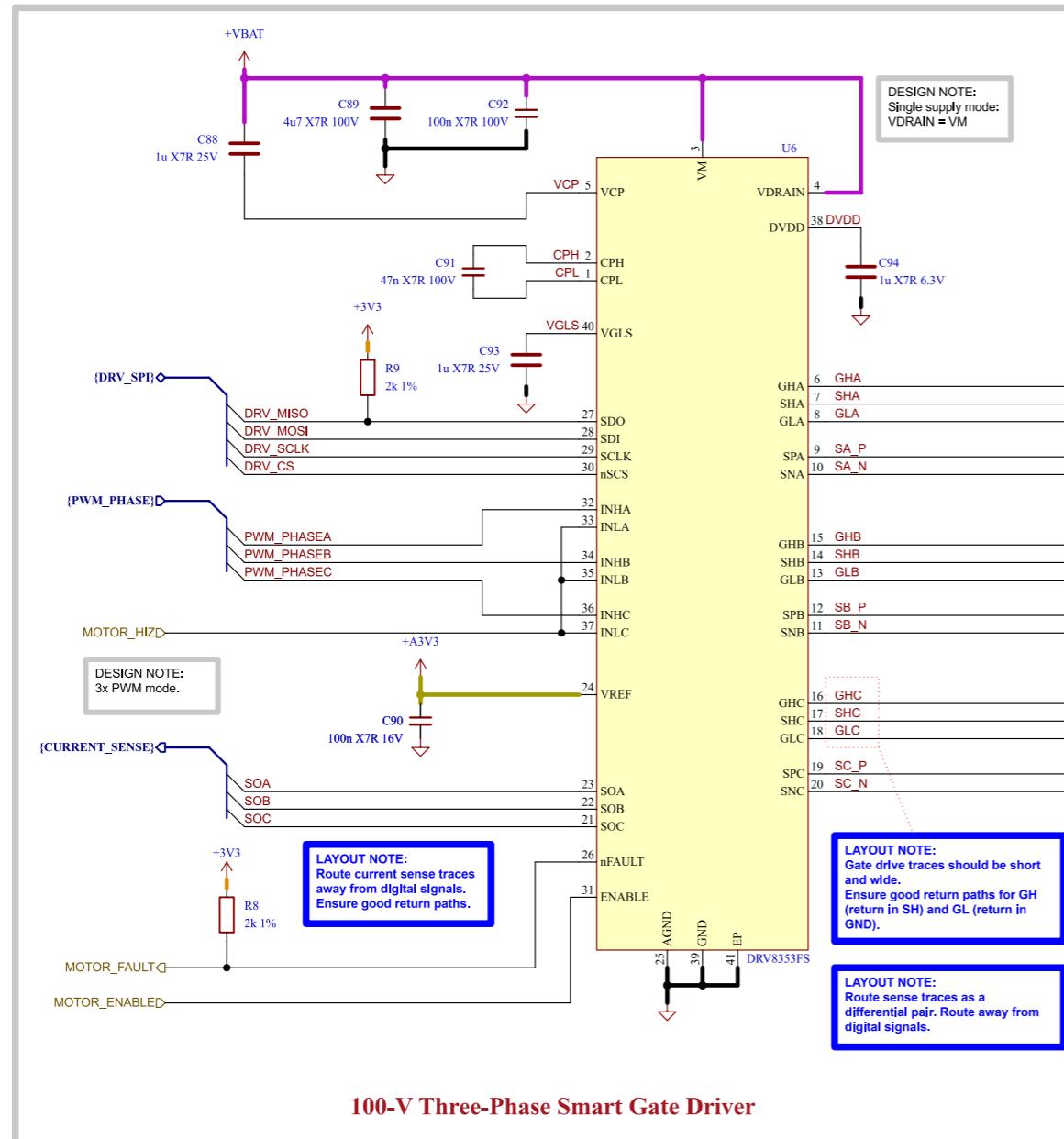


[7] Power - Connectors



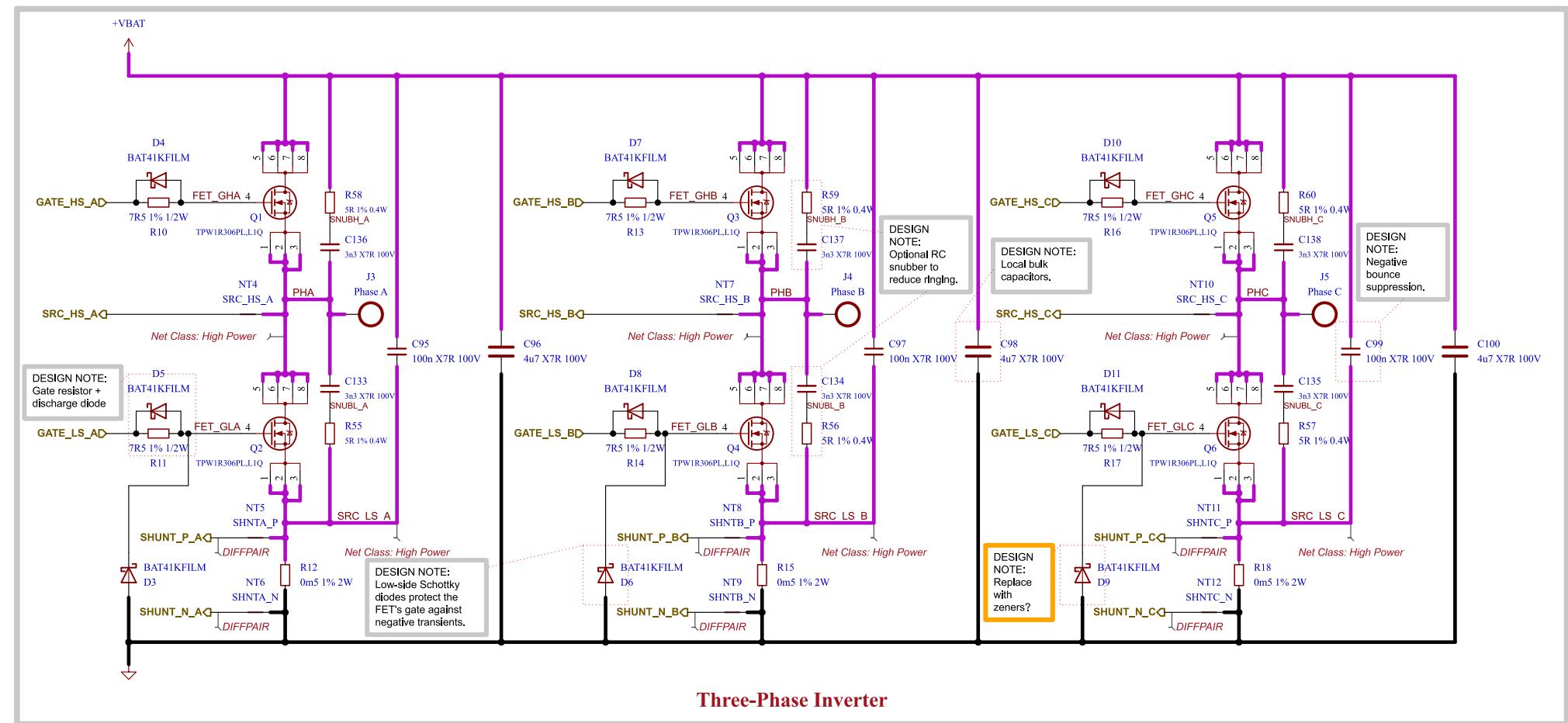
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| | Board Name: Amulet Motion Controller | | |
| | Sheet Title: Power - Connectors | File Name: Power - Connectors.kicad_sch | Designer: Vincent Nguyen |
| | Sheet Path: /Project Architecture/Power - Connectors/ | Reviewer: | Date: 2023-12-31 Revision: 1.1 |

[8] Motor Control - Top Level



| | | | | |
|--|--|-------------------------------------|-------------------|-----------------|
| | Comments: | Company: | Variant: | |
| | | EPFL Xplore Research | Xplore Released | |
| | 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 |
| | Sheet Path: | Reviewer: | | Size: Sheet: |
| | /Project Architecture/Motor Control - Top Level/ | 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:
Released

Project Name:
Chienpanzé

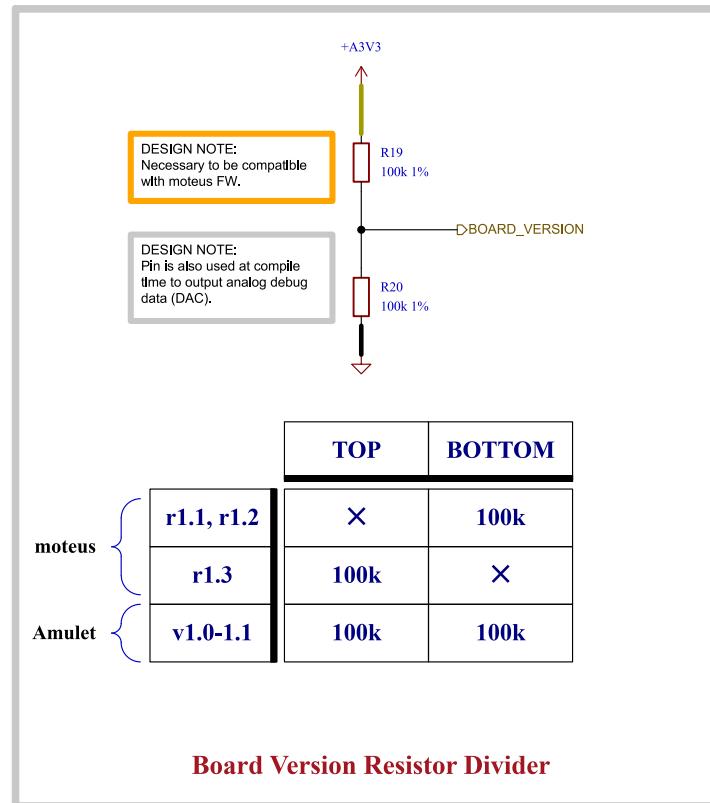
Date:
2024-01-25

Revision:
1.1

Size:
A4

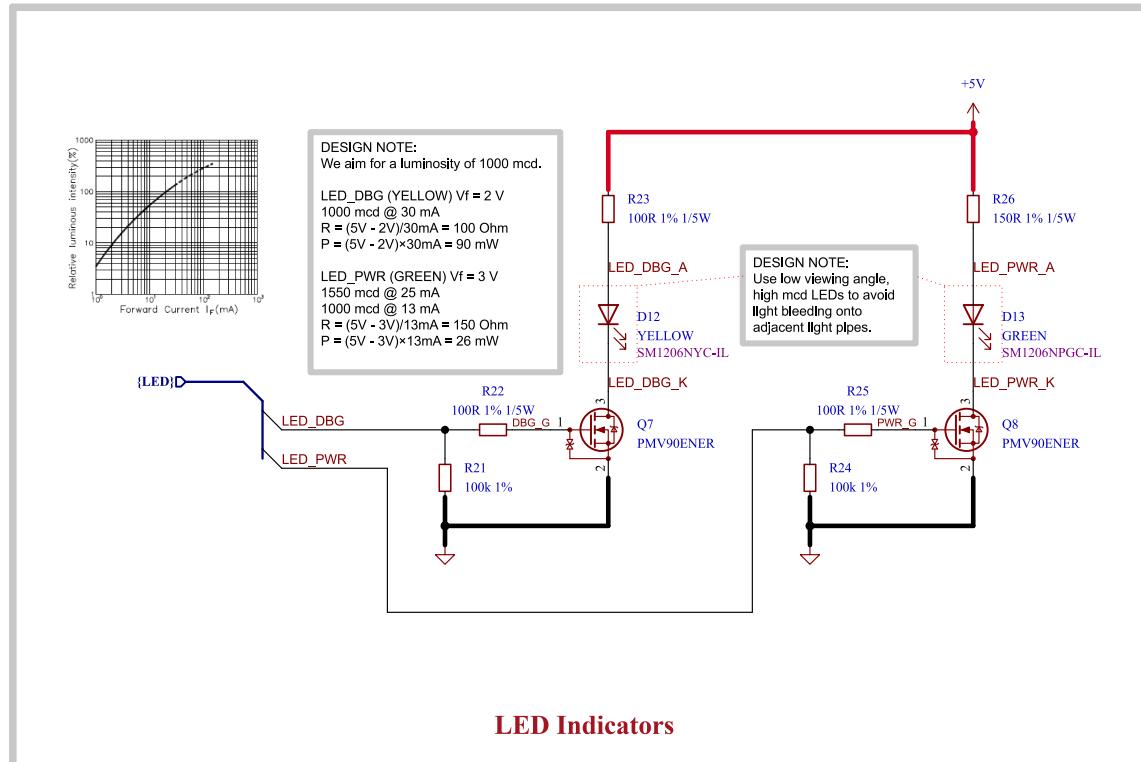
Sheet:
9 of **21**

[10] Misc - Board Version, DAC



| | | | | | |
|---|---|--|-----------------------------|------------------------------------|----------------------------------|
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| 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 |
| | 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: Released |
| | Board Name: Amulet Motion Controller | Project Name: Chienpanzé | |
| | Sheet Title: User - LED Indicators | File Name: User - LED Indicators.kicad_sch | Designer: Vincent Nguyen |
| | Sheet Path: /Project Architecture/User - LED Indicators/ | Reviewer: | Date: 2023-12-19 Revision: 1.1 |

[12] Sensing - Temperature

A

B

C

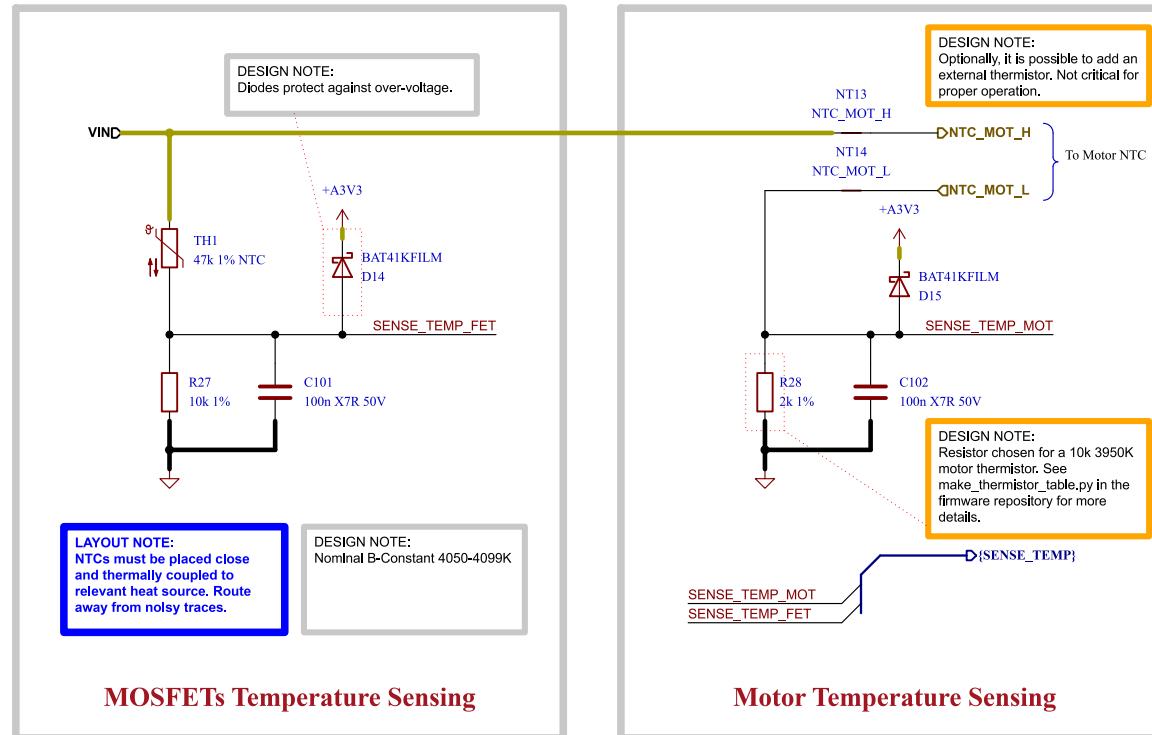
D

A

B

C

D



| | | | |
|--|---|---|-----------------------------------|
| | Comments: | Company: EPFL Xplore Research | Variant: Released |
| | Board Name: Amulet Motion Controller | | |
| | Sheet Title: Sensing - Temperature | File Name: Sensing - Temperature.kicad_sch | Designer: Vincent Nguyen |
| | Sheet Path: /Project Architecture/Sensing - Temperature/ | Reviewer: | Date: 2024-04-13 Revision: 1.1 |

[13] Sensing - Battery

A

B

C

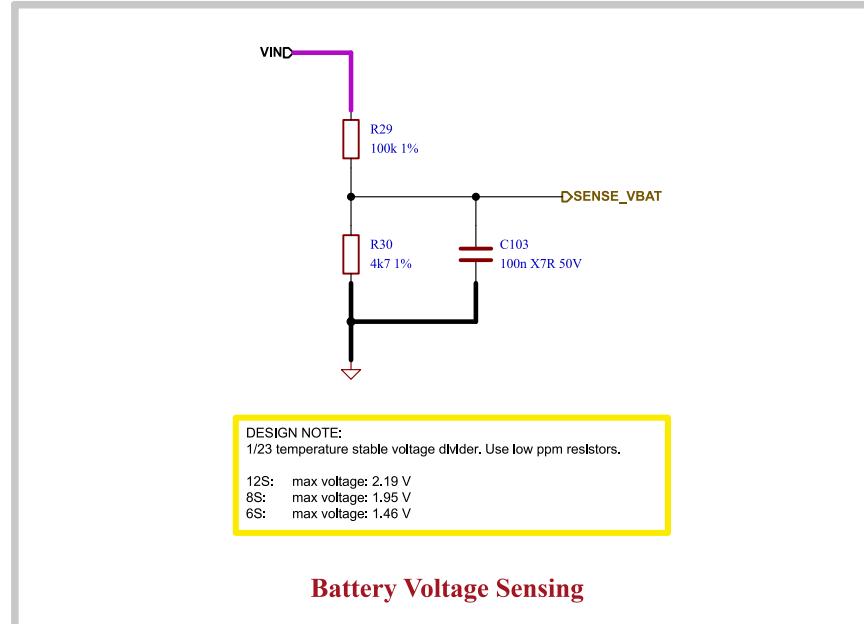
D

A

B

C

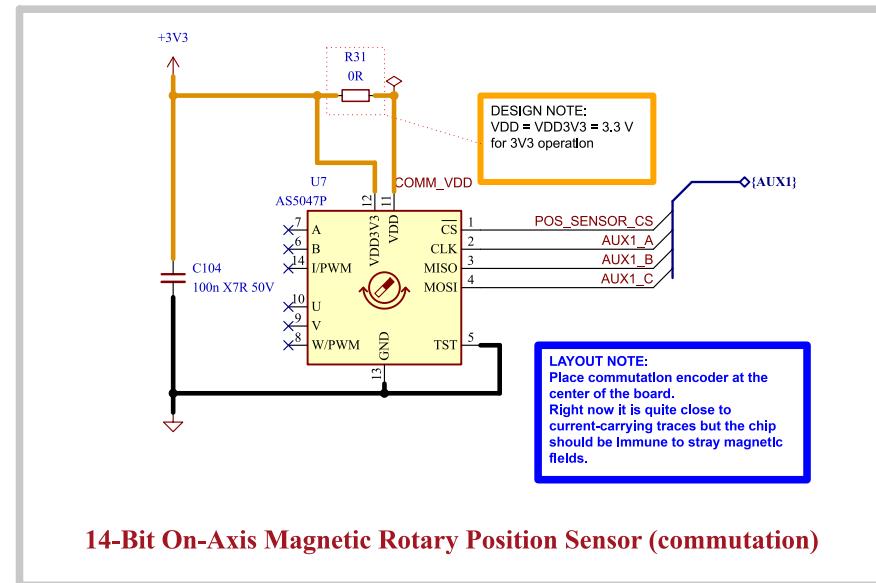
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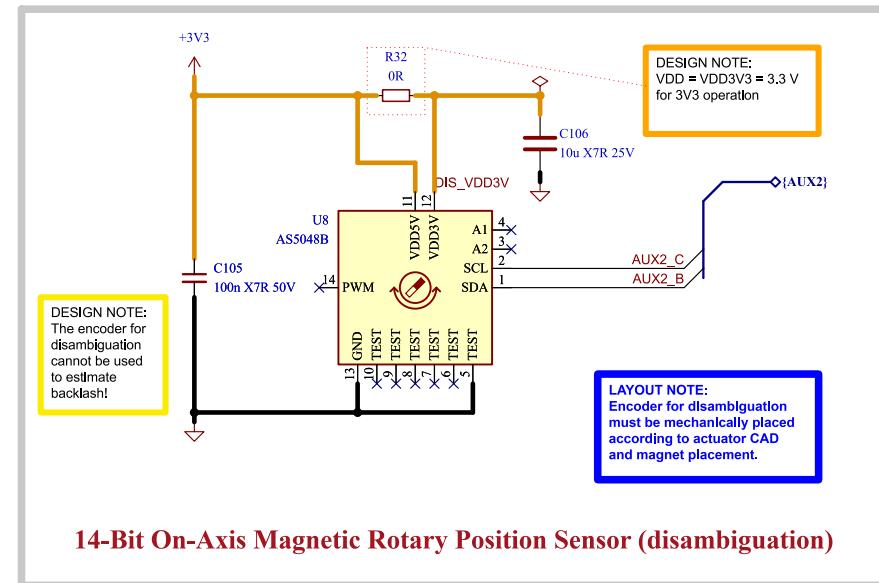
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| | Board Name: Amulet Motion Controller | | |
| | Sheet Title: Sensing - Battery | File Name: Sensing - Battery.kicad_sch | Designer: Vincent Nguyen |
| | Sheet Path: /Project Architecture/Sensing - Battery/ | Reviewer: | Date: 2023-10-14 Revision: 1.1 |

[14] Sensing - Position

A



B



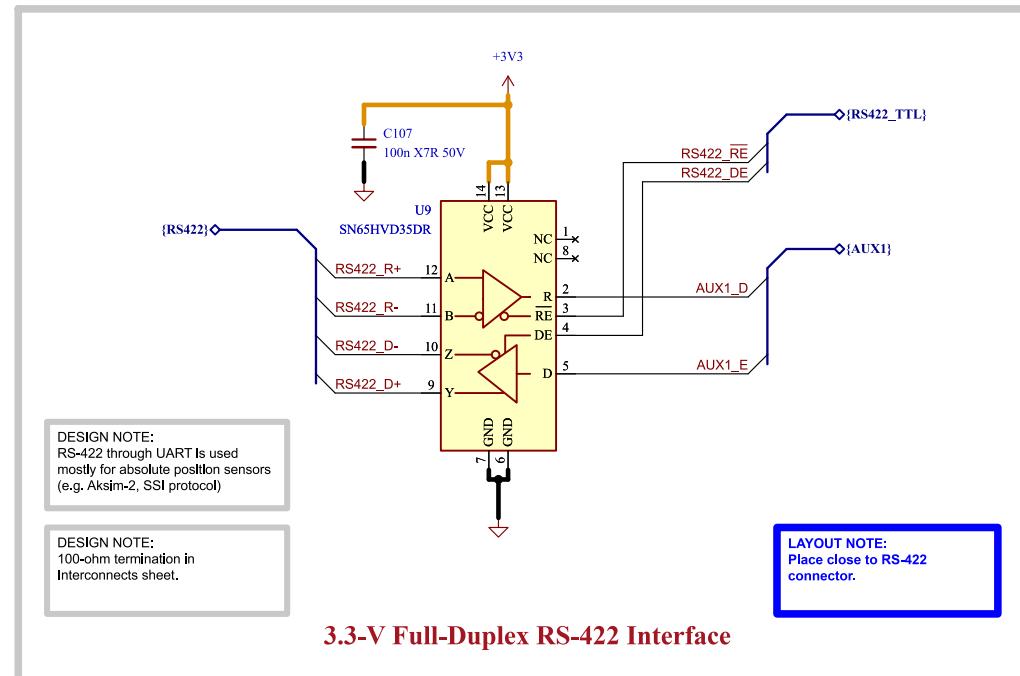
C

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

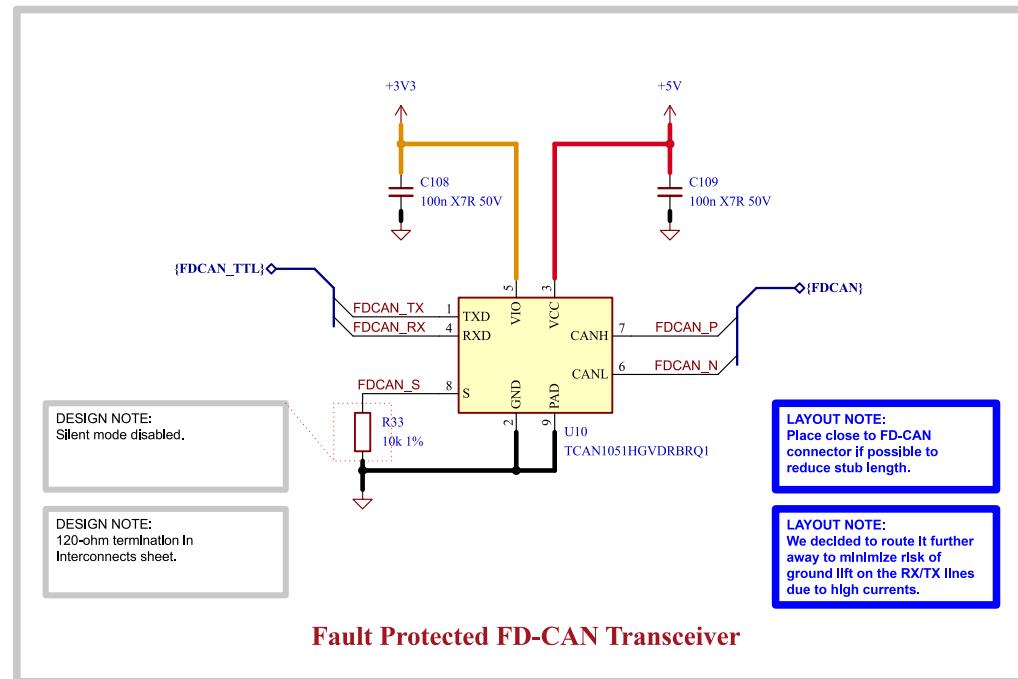
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| | Sheet Path: /Project Architecture/Sensing - Position/ | Reviewer: | Date: 2023-10-14 Revision: 1.1 |

[15] Interface - RS-422



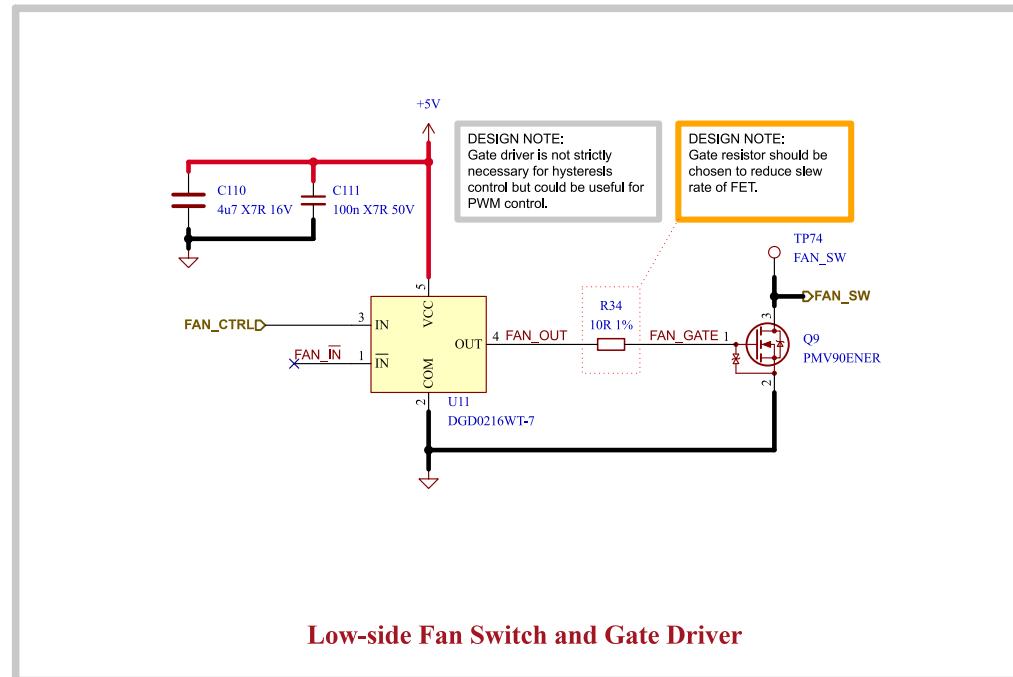
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| | Board Name: Amulet Motion Controller | | |
| | Sheet Title: Interface - RS-422 | File Name: Interface - RS-422.kicad_sch | Designer: Vincent Nguyen |
| | Sheet Path: /Project Architecture/Interface - RS-422/ | Reviewer: | Date: 2023-10-15 |
| | | Size: A4 | Revision: 1.1 |
| | | Sheet: 15 of 21 | |

[16] Interface - FD-CAN



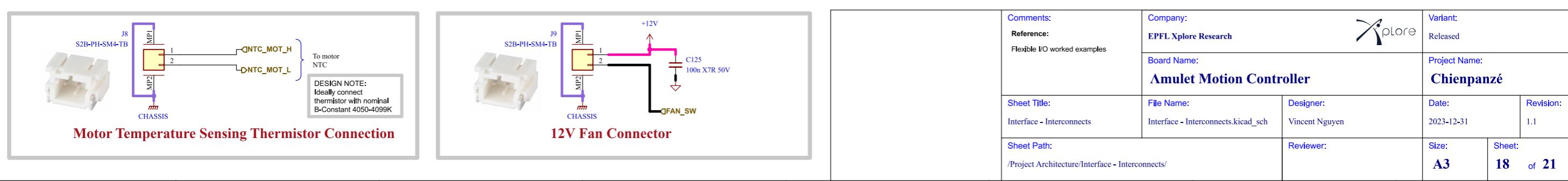
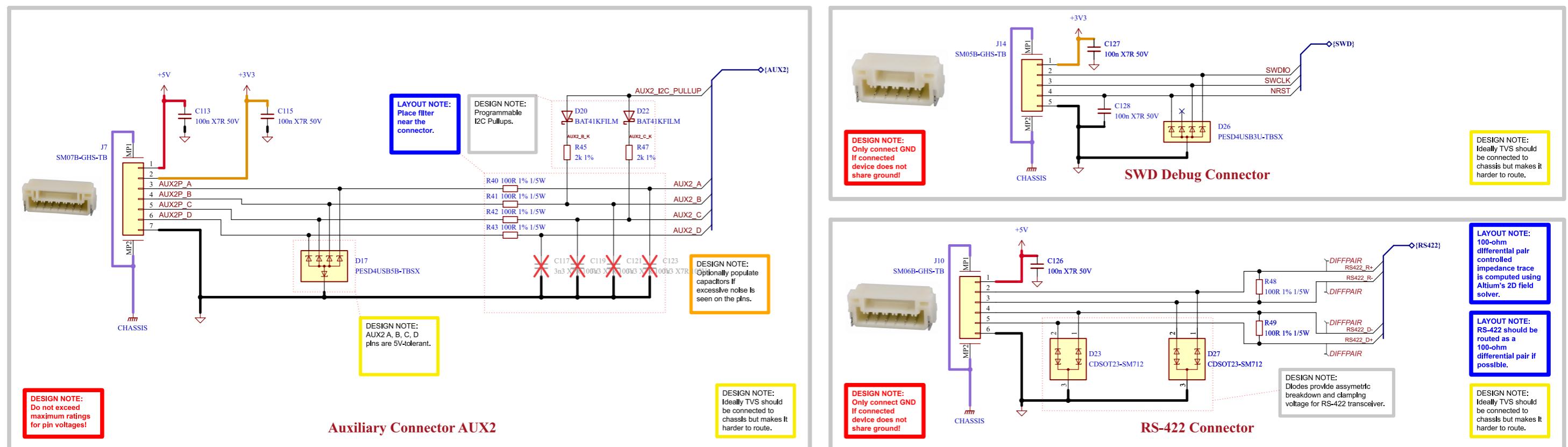
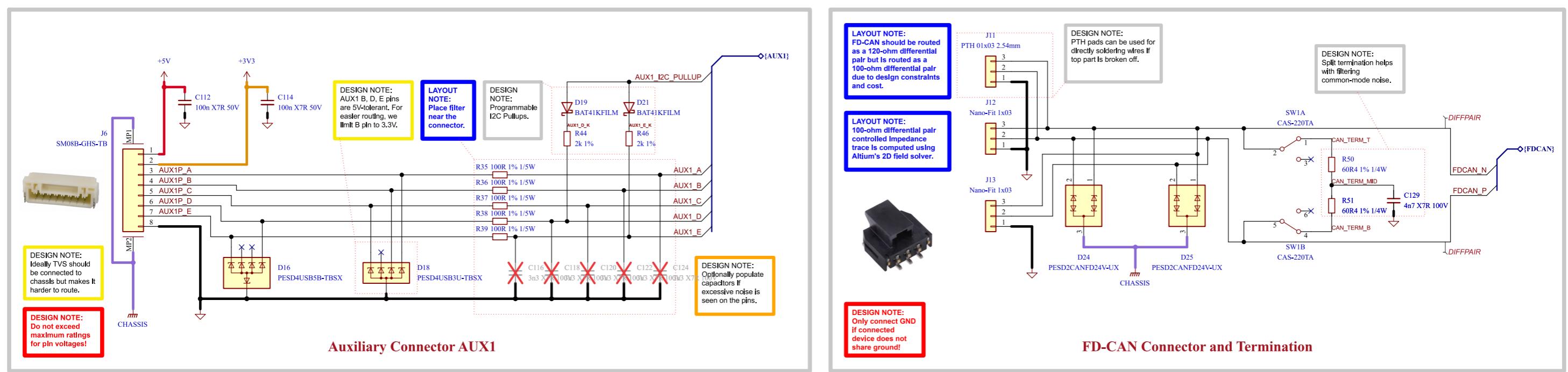
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| | Sheet Path: /Project Architecture/Interface - FD-CAN/ | Reviewer: | Date: 2023-10-15 |
| | | Size: A4 | Revision: 1.1 |
| | | Sheet: 16 of 21 | |

[17] Interface - Fan Control



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

[18] Interface - Interconnects



[19] Misc - Holes, Fiducials

A

A

B

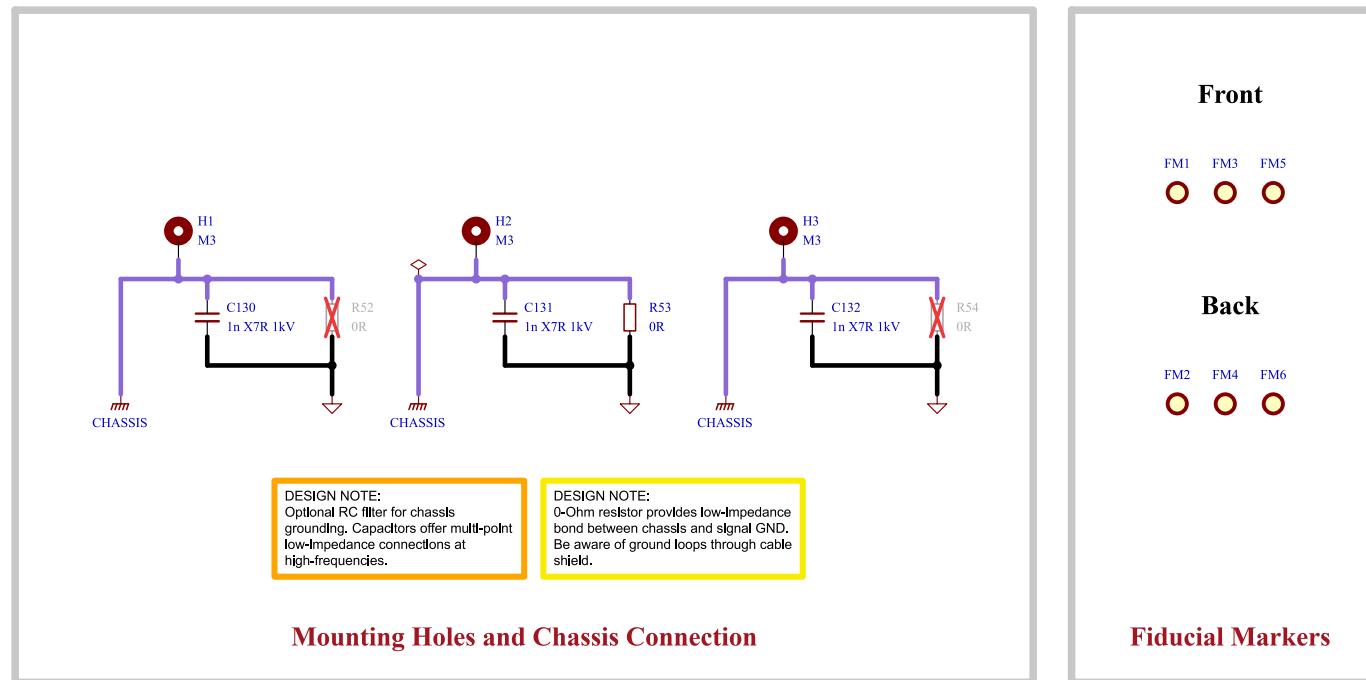
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C

C

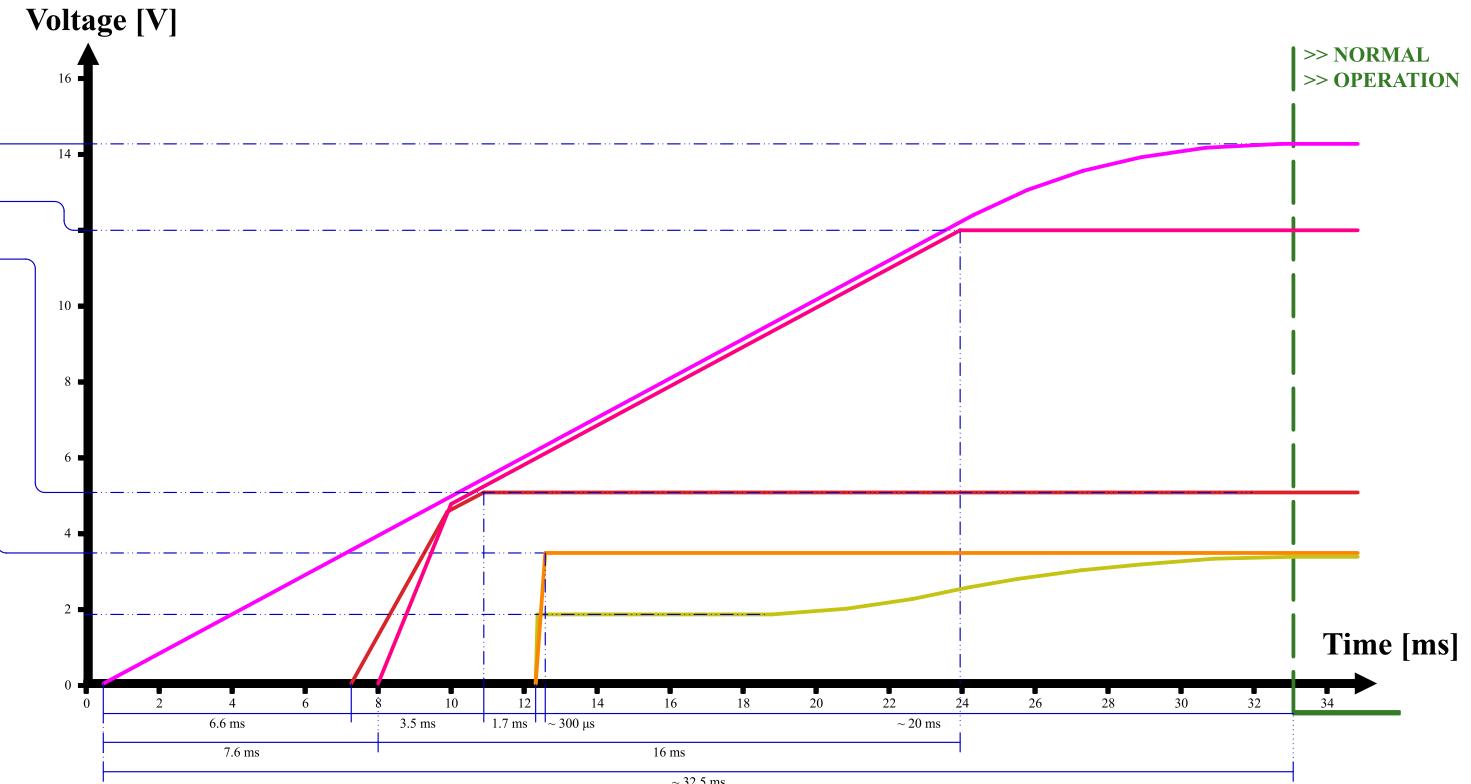
D

D



[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 | |
| 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 | Revision: 1.1 |
| Sheet Path: /Power - Sequencing/ | Reviewer: | | Size: A4 | Sheet: 20 of 21 |

[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"> - 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. | <ul style="list-style-type: none"> - 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. | <ul style="list-style-type: none"> - Modified power sequencing graph according to experimental data. | <ul style="list-style-type: none"> - 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. |
| C | | | | |
| D | | | | |