

# Amulet Motion Controller

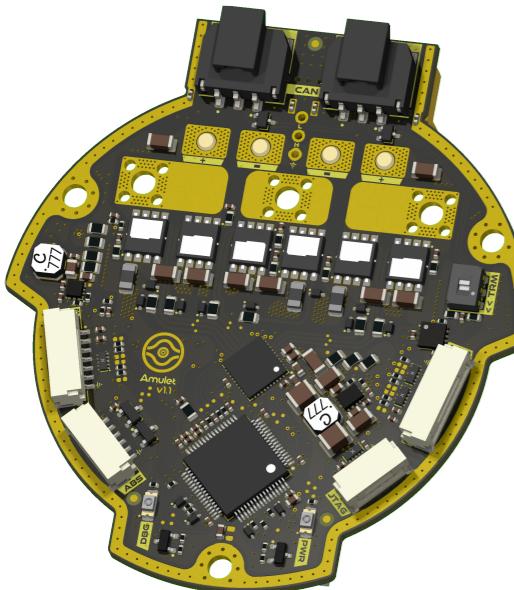
Variant: CHECKED

2024-11-26

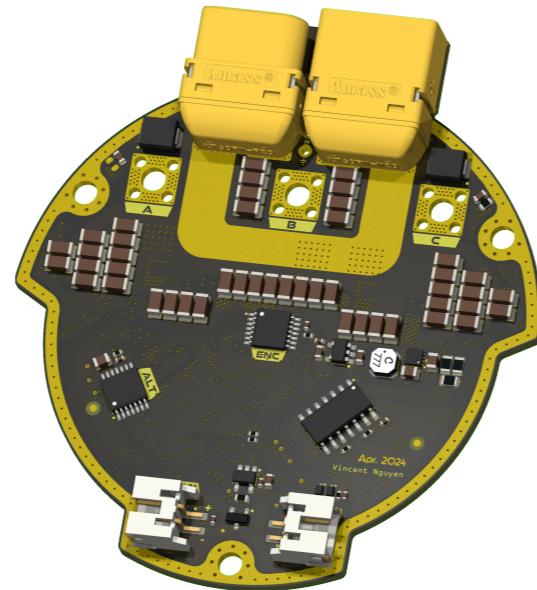
Rev 1.2

| Page | Index                     | Page | Index                     | Page | Index            | Page | Index |
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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.

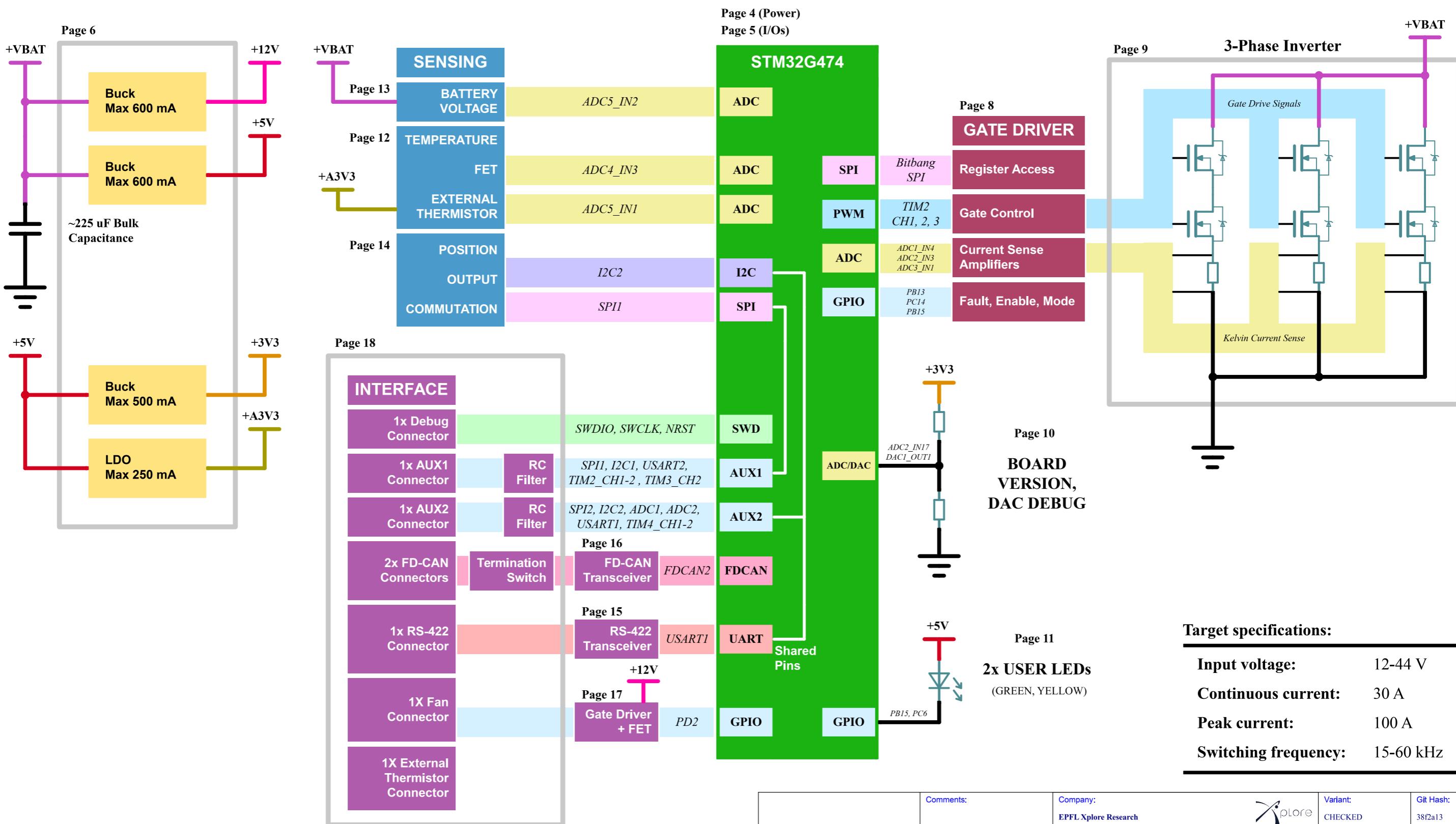
CHECKED - There shouldn't be any mistakes. Contact the engineer if you find any.

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

Date: 26-Nov-2024

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

# [2] Block Diagram

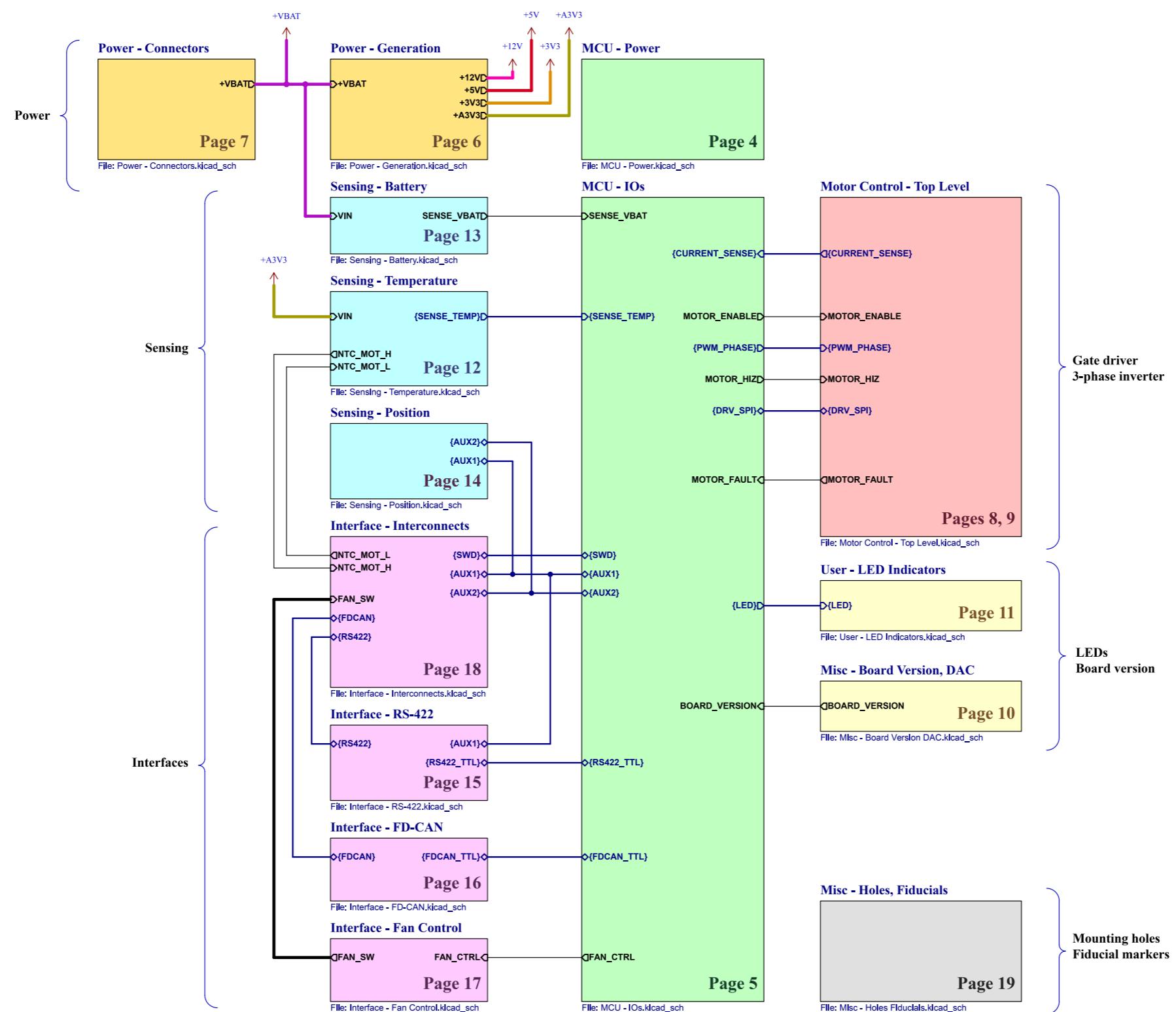


## Target specifications:

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

|                                |  |                                    |                                 |
|--------------------------------|--|------------------------------------|---------------------------------|
| Comments:                      | Company:<br>EPFL Xplore Research               | Variant:<br>CHECKED                | Git Hash:<br>38f2a13            |
|                                | Board Name:<br><b>Amulet Motion Controller</b> | Project Name:<br><b>Chienpanzé</b> |                                 |
| Sheet Title:<br>Block Diagram  | File Name:<br>Block Diagram.kicad_sch          | Designer:<br>Vincent Nguyen        | Date:<br>2024-04-13             |
| Sheet Path:<br>/Block Diagram/ | Reviewer:                                      | Size:<br><b>A3</b>                 | Sheet:<br><b>2</b> of <b>21</b> |

# [3] Project Architecture



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

## [4] MCU - Power



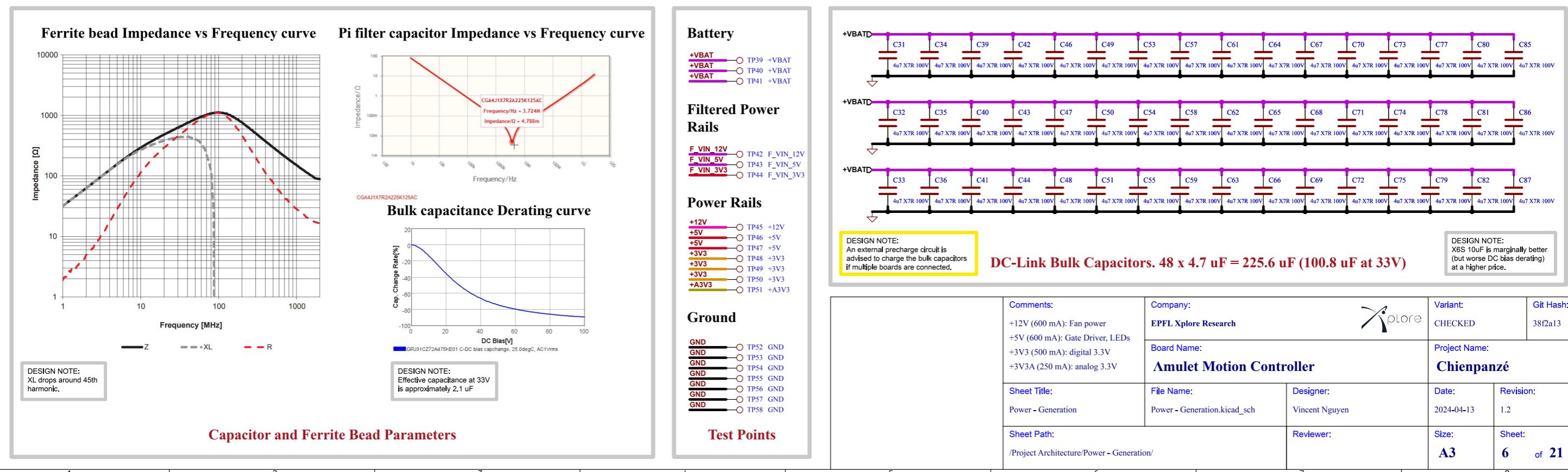
|  |  |                                     |                             |                                    |
|--|--|-------------------------------------|-----------------------------|------------------------------------|
|  | Comments:<br>AN5346<br>STM32G474 Datasheet p.81<br>J. Pieper ADC investigation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

# [5] MCU - I/Os



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

# [6] Power - Generation



# [7] Power - Connectors



A

B

C

D

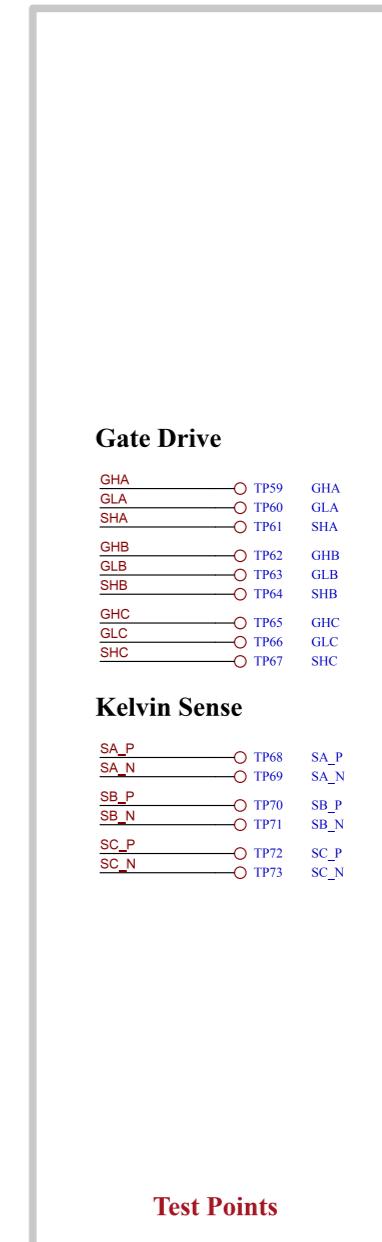
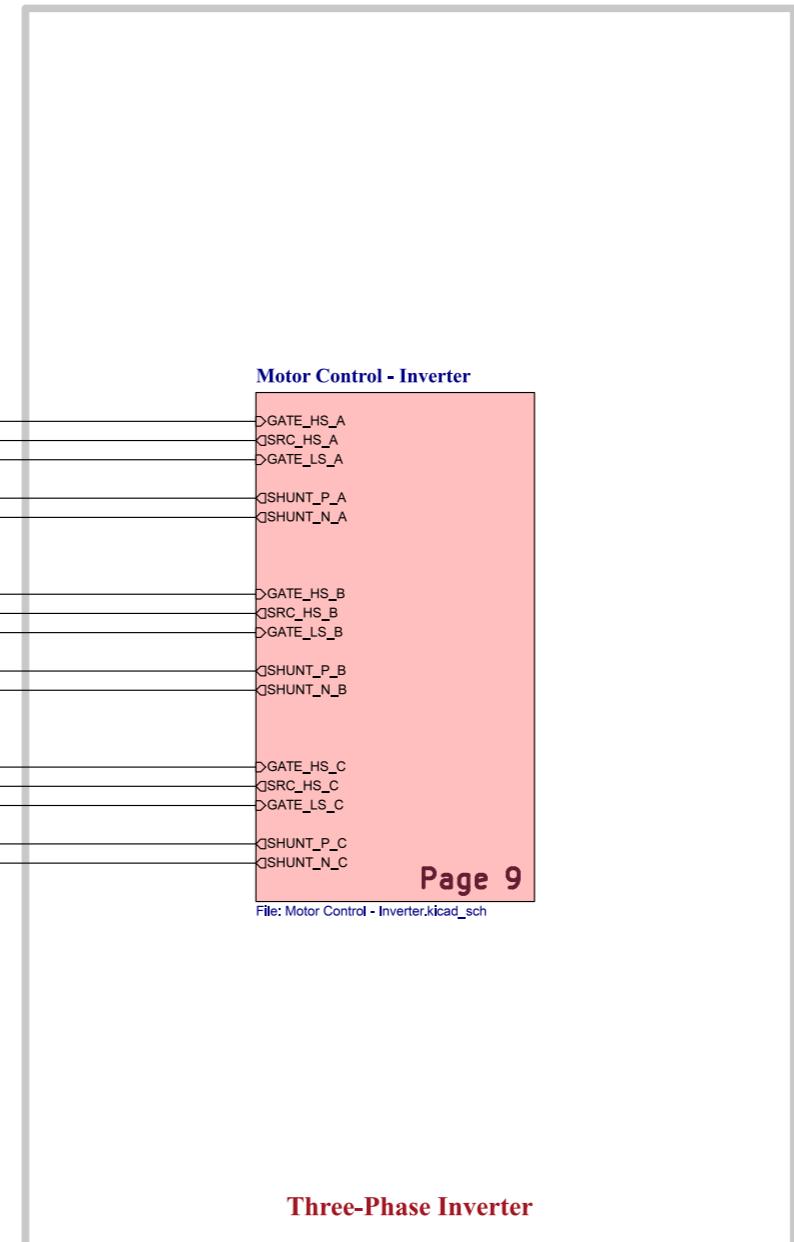
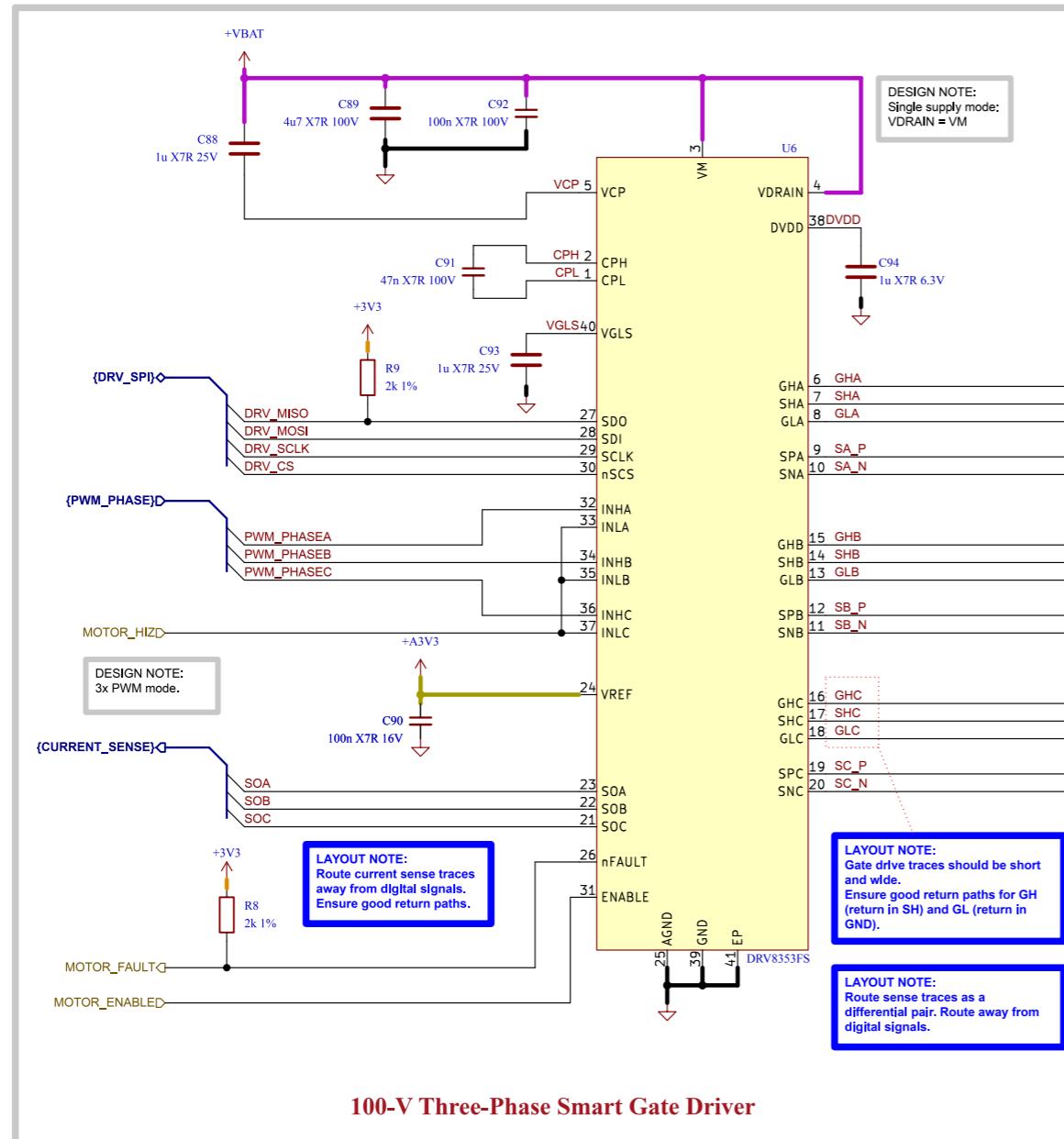
A

B

C

D

# [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:                | Date:         | 1.2       |
|  | /Project Architecture/Motor Control - Top Level/ | Vincent Nguyen                      |                          | 2023-12-20    |           |
|  | Size:  | Sheet:                              | A3                       | Sheet:        | 8 of 21   |
|  | A3   | 8 of 21                             |                          | Sheet:        |           |

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

# [11] User - LED Indicators



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

# [12] Sensing - Temperature

A

B

C

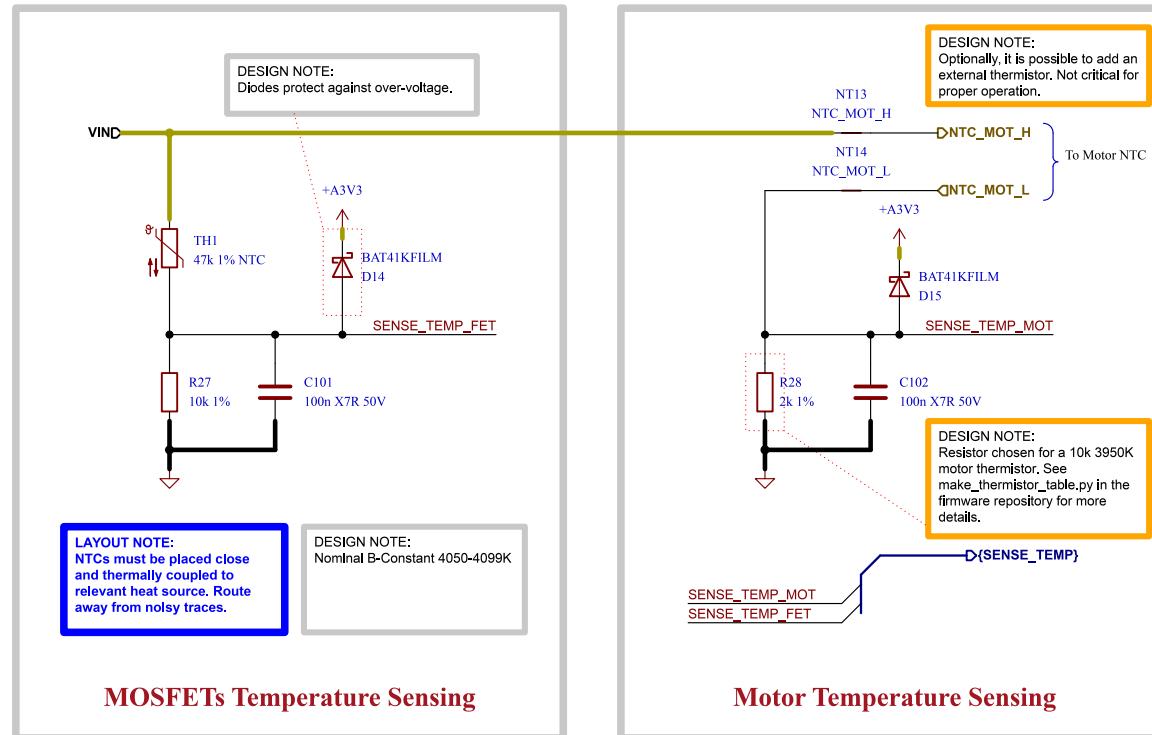
D

A

B

C

D



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

# [13] Sensing - Battery

A

A

B

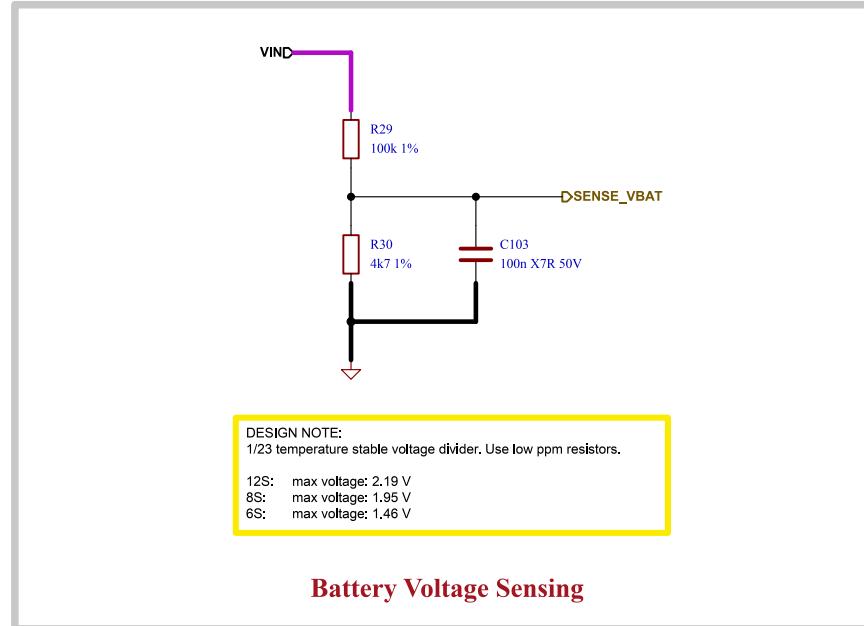
B

C

C

D

D



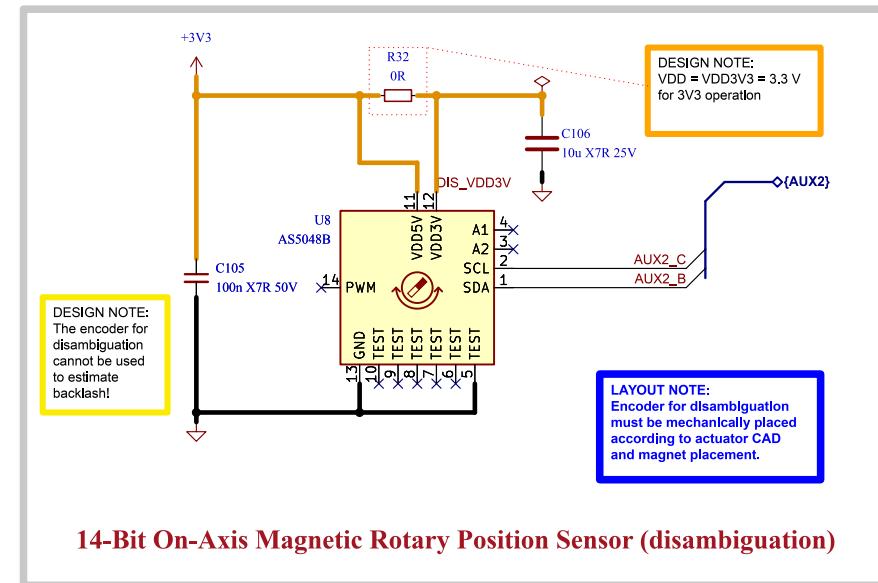
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|  | Board Name:<br><b>Amulet Motion Controller</b>          |   |                             | Project Name:<br><b>Chienpanzé</b>                  |
|  | Sheet Title:<br>Sensing - Battery                       | File Name:<br>Sensing - Battery.kicad_sch | Designer:<br>Vincent Nguyen | Date:<br>2023-10-14                                 |
|  | Sheet Path:<br>/Project Architecture/Sensing - Battery/ |   | Reviewer:                   | Size:<br><b>A4</b> Sheet:<br><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.



C

D

|  |  |  |                             |                                    |
|--|--|--|-----------------------------|------------------------------------|
|  | Comments:  | Company:<br>EPFL Xplore Research           | Variant:<br>CHECKED         | Git Hash:<br>38f2a13               |
|  | Board Name:<br><b>Amulet Motion Controller</b>           |  |                             | Project Name:<br><b>Chienpanzé</b> |
|  | Sheet Title:<br>Sensing - Position                       | File Name:<br>Sensing - Position.kicad_sch | Designer:<br>Vincent Nguyen | Date:<br>2023-10-14                |
|  | Sheet Path:<br>/Project Architecture/Sensing - Position/ |  | Reviewer:                   | Size:<br><b>A4</b>                 |
|  |  |  |                             | Sheet:<br><b>14 of 21</b>          |

# [15] Interface - RS-422



|  |  |   |                             |   |
|--|--|---|-----------------------------|---|
|  | Comments:  | Company:<br>EPFL Xplore Research<br> | Variant:<br>CHECKED         | Git Hash:<br>38f2a13                      |
|  | Board Name:<br><b>Amulette Motion Controller</b>         |   |                             | Project Name:<br><b>Chienpanzé</b>        |
|  | Sheet Title:<br>Interface - RS-422                       | File Name:<br>Interface - RS-422.kicad_sch  | Designer:<br>Vincent Nguyen | Date:<br>2023-10-15      Revision:<br>1.2 |
|  | Sheet Path:<br>/Project Architecture/Interface - RS-422/ | Reviewer:   | Size:<br><b>A4</b>          | Sheet:<br><b>15</b> of <b>21</b>          |

# [16] Interface - FD-CAN



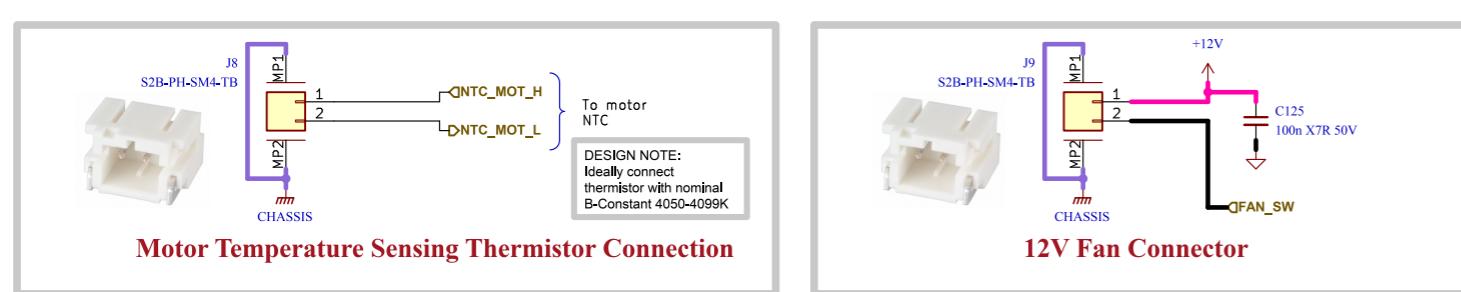
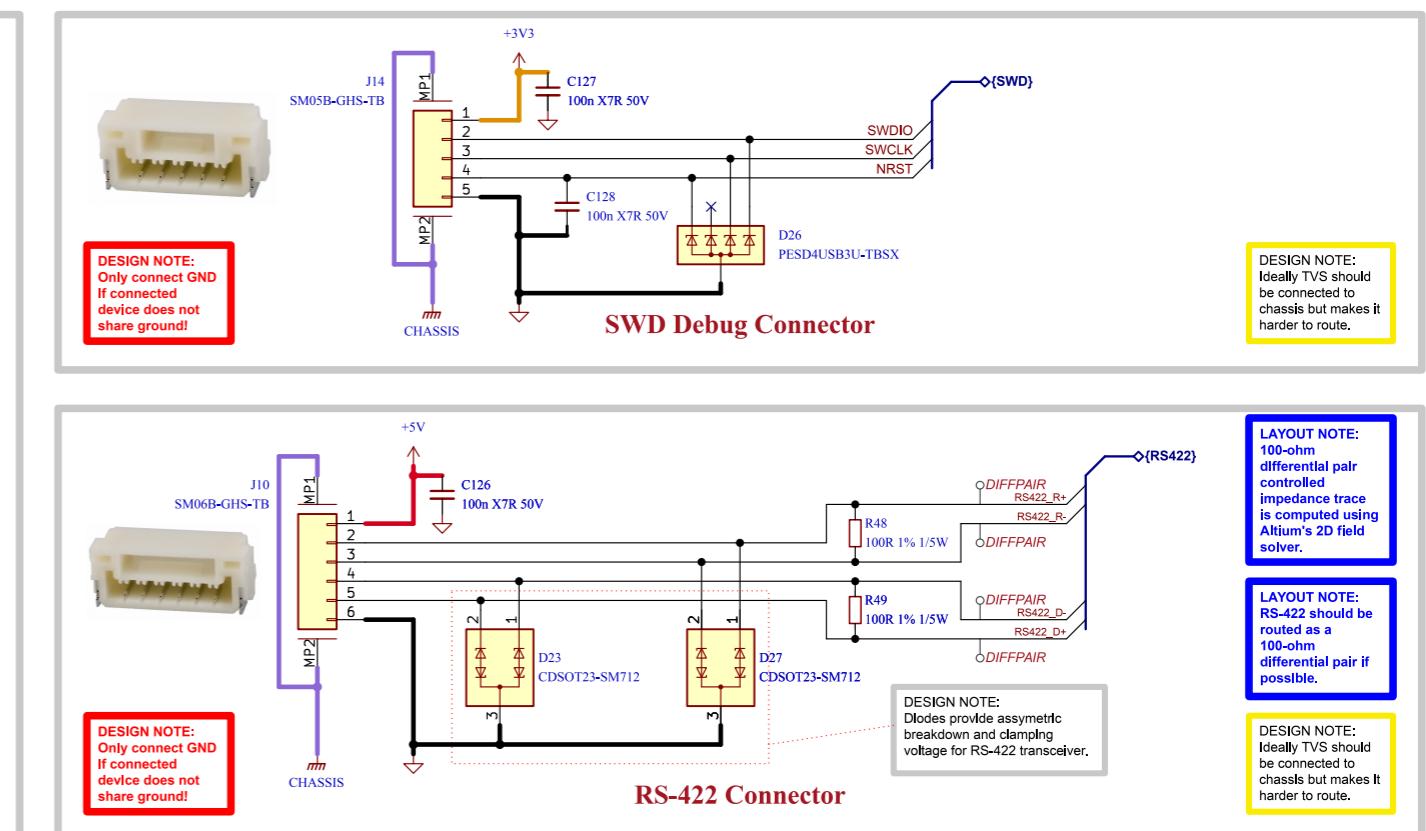
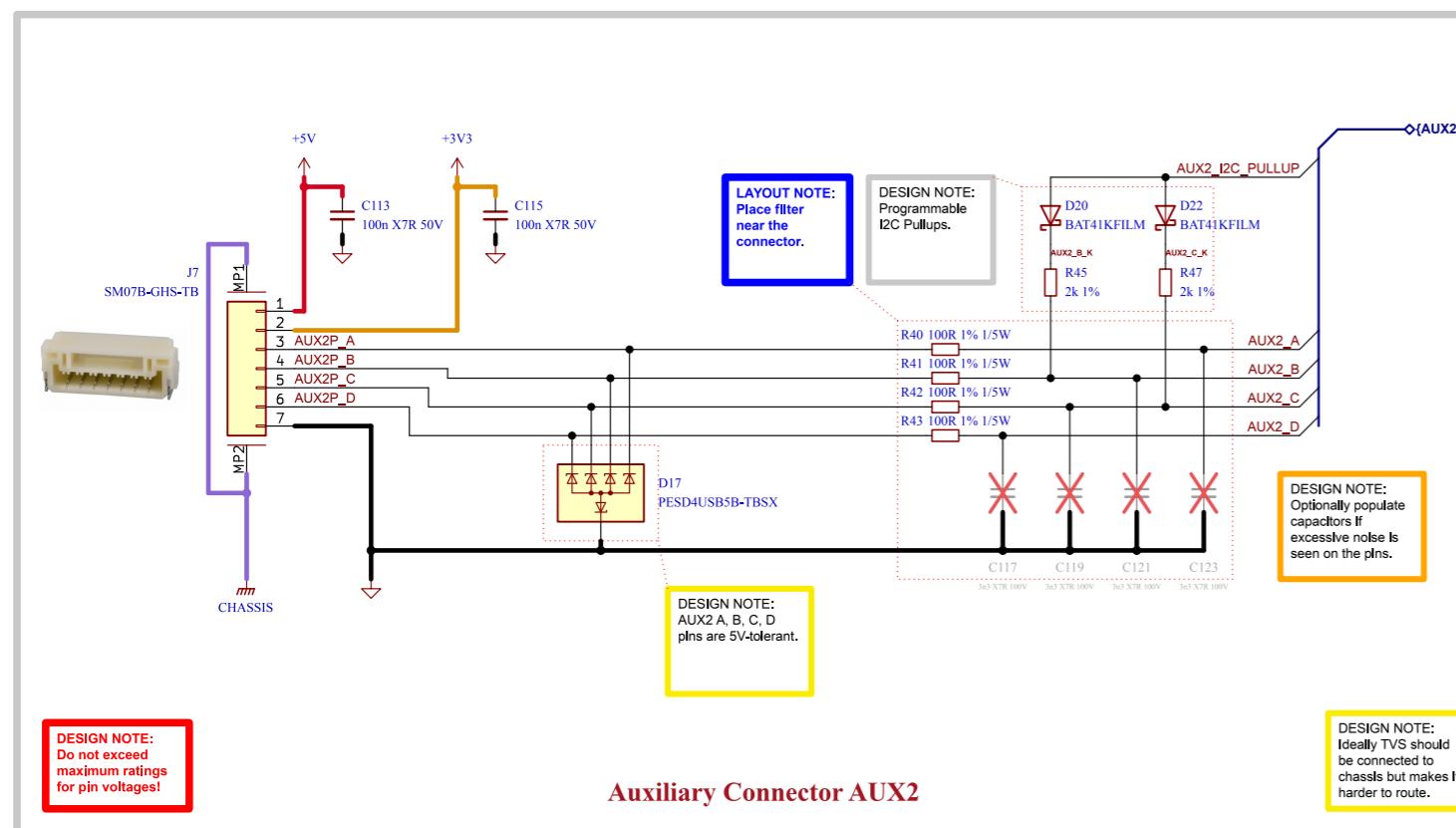
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|  | Comments:  | Company:<br>EPFL Xplore Research           | Variant:<br>CHECKED              | Git Hash:<br>38f2a13               |
|  | Board Name:<br><b>Amulet Motion Controller</b>           |  |                                  | Project Name: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

# [17] Interface - Fan Control



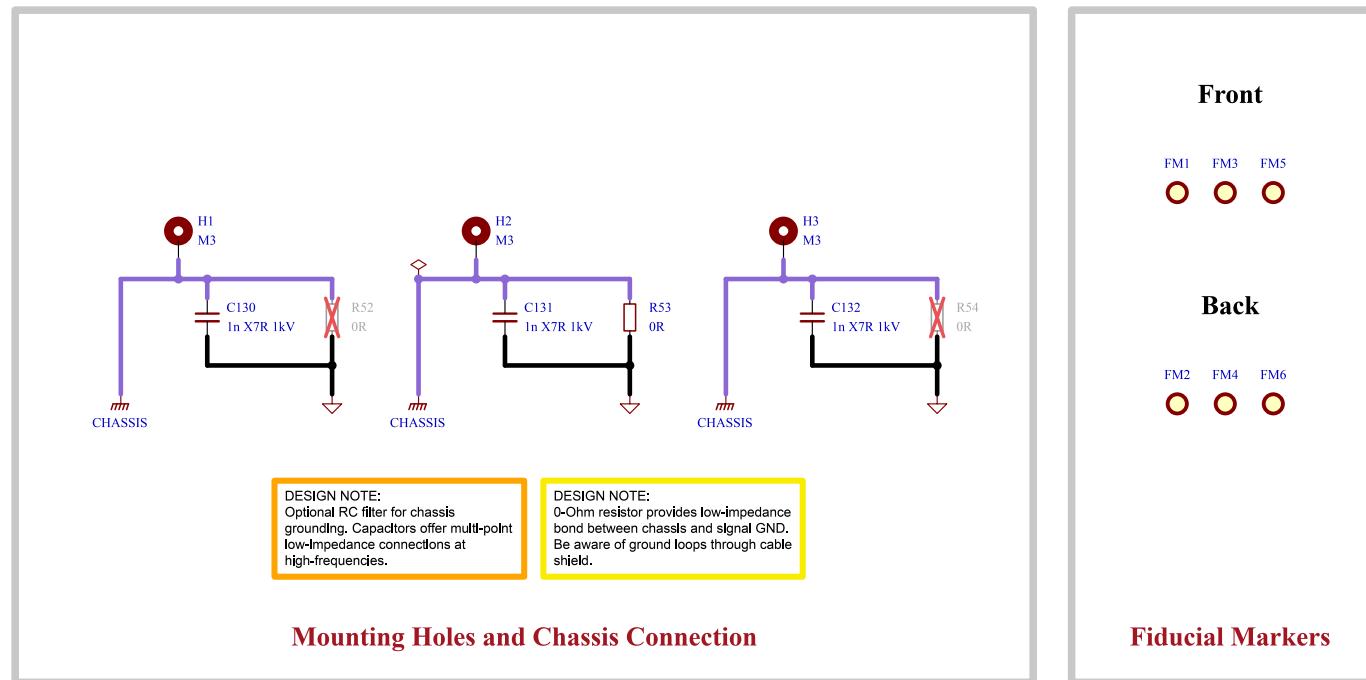
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|--|---|---|-----------------------------|---|
|  | Comments:   | Company:<br>EPFL Xplore Research                | Variant:<br>CHECKED         | Git Hash:<br>38f2a13                                |
|  | Board Name:<br><b>Amulet Motion Controller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

# [18] Interface - Interconnects



|   |   |                             |                                    |                                  |
|---|---|-----------------------------|------------------------------------|----------------------------------|
| Comments:<br>Reference:<br>Flexible I/O worked examples         | Company:<br>EPFL Xplore Research                  |                             | Variant:<br>CHECKED                | Git Hash:<br>38f2a13             |
|   | Board Name:<br><b>Amulet Motion Controller</b>    |                             | Project Name:<br><b>Chienpanzé</b> |                                  |
| Sheet Title:<br>Interface - Interconnects                       | File Name:<br>Interface - Interconnects.kicad_sch | Designer:<br>Vincent Nguyen | Date:<br>2023-12-31                | Revision:<br>1.2                 |
| Sheet Path:<br>/Project Architecture/Interface - Interconnects/ | Reviewer:   |                             | Size:<br><b>A3</b>                 | Sheet:<br><b>18</b> of <b>21</b> |

# [19] Misc - Holes, Fiducials



A

B

C

D

A

B

C

D

|  |   |  |                             |                                    |
|--|---|--|-----------------------------|------------------------------------|
|  | Comments:   | Company:<br>EPFL Xplore Research               | Variant:<br>CHECKED         | Git Hash:<br>38f2a13               |
|  | Board Name:<br><b>Amulet Motion Controller</b>                | Project Name:<br><b>Chienpanzé</b>             |                             |                                    |
|  | Sheet Title:<br>Misc - Holes, Fiducials                       | File Name:<br>Misc - Holes Fiducials.kicad_sch | Designer:<br>Vincent Nguyen | Date: 2023-10-22<br>Revision: 1.2  |
|  | Sheet Path:<br>/Project Architecture/Misc - Holes, Fiducials/ |  | Reviewer:                   | Size: A4<br>Sheet: <b>19</b> of 21 |

# [20] Power - Sequencing

A



B

C

D

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

## [21] Revision History

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