

### AT32 MCU-based Low Voltage Motor Control Development Board

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## Overview

This document mainly introduces the basic functions, hardware features and hardware circuits, aimed at helping developers to easily develop motor control applications with AT32 MCU on this board.

Applicable products:

Part number	AT32F4xx, AT32L0xx
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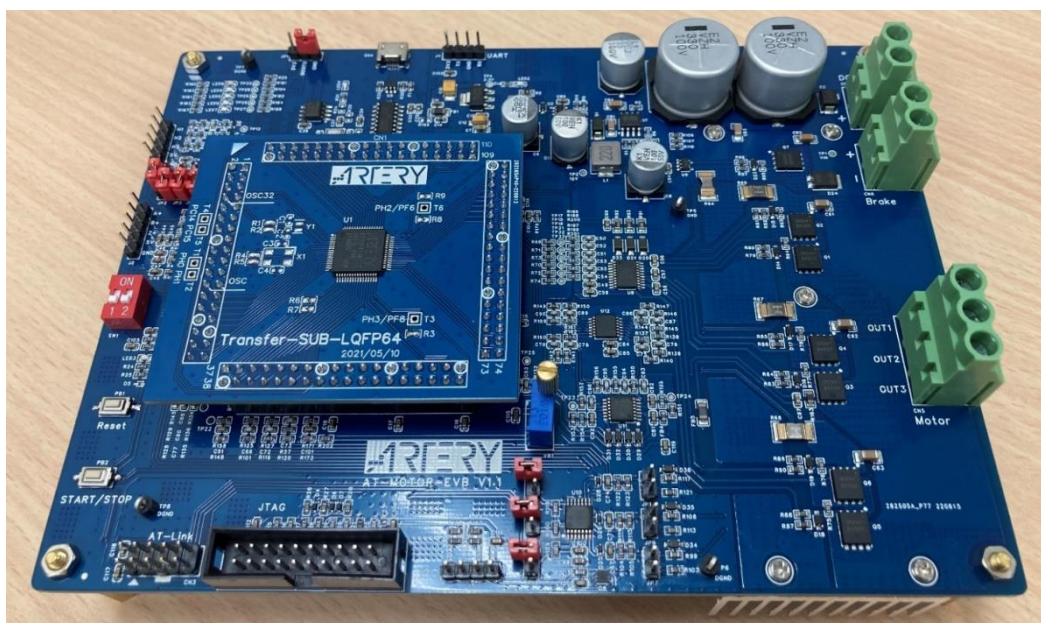
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# 1 Board description

- The motor development board serves as a general-purpose low voltage three-phase motor driver based on ARTERY AT32 MCU and mo/fu tor control function library. It can be used to drive BLDC, AC synchronous and induction motors
- A MCU socket applied to all AT32 MCU for motor control algorithm execution
- Hall connector and encoder connector for rotor position feedback, to drive motor with sensor in FOC vector control or six-step square wave mode
- Regenerative brake resistor connector for dynamic braking in high dynamic response control mode
- 3-phase output terminal voltage sensing circuit connected to ADC, virtual neutral point circuit and comparator circuit, suitable for multiple BLDC six-step square wave sensorless applications
- 3 phase current sensing resistors and a DC ground bus current sensing resistor, supporting three current-sensing modes (3-shunt, 2-shunt and 1-shunt current sensing modes)
- Built-in overcurrent compare circuits for phase currents and bus current
- Support sensor/sensorless field-oriented vector control algorithm to drive three-phase AC motors
- Support household, commercial and industrial motor control application technologies
- Input voltage/output current specs
  - Input voltage: 12V~60V
  - Maximum output phase current: 30A<sub>PEAK</sub>
  - Overcurrent protection point: 45A<sub>PEAK</sub>

Figure 1. Low voltage motor control development board



## 2 Software and hardware requirements

- Windows®-based PC (Windows 8, Windows 10, Windows 11) to install user interface control program
- Micro-B USB cable to connect the board with PC for communication
- ARTERY AT-Link or third-party programmer
- ARTERY AT32 motor control demonstration project program
- 3-phase AC motor with 12V~60V rated voltage, and below 30A rated current
- DC power supply

### 3 Getting started

- Rated specifications for motor development board
  - Input voltage: 12V~60V
  - Maximum output phase current: 30A<sub>PEAK</sub>
  - Overcurrent protection point: 45A<sub>PEAK</sub>
- Getting started with the steps below:
  - Step 1: Check that the jumper settings are correct (See Section 3.1)
  - Step 2: Connect AT-Link to CN3, or JTAG to CN2
  - Step 3: Program ARTEYR AT32 motor control demonstration program
  - Step 4: Connect 3-phase motor cable to CN5, and connect U, V, and W wires to OUT1, OUT2 and OUT3 respectively
  - Step 5: Adjust voltage and current of DC power supply, connect output to CN1 before turning on power supply, and then LED1 (12 V power indicator) and LED2 (3.3V power indicator) will be ON
  - Step 6: Setup parameters and control motor operation using the Artery motor monitor software



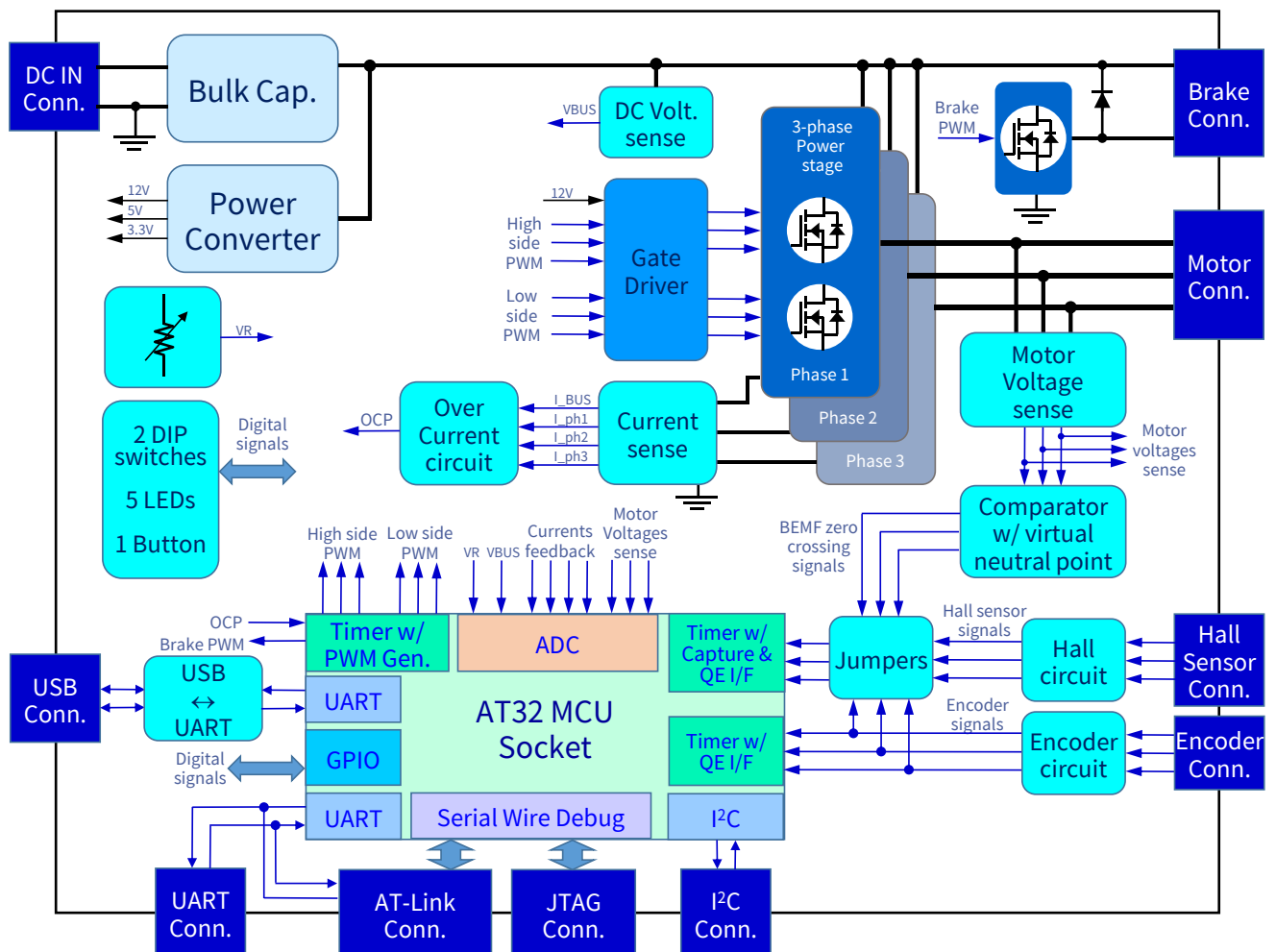
## 4 Hardware configuration

### 4.1 System architecture

Figure 2 presents the system architecture of low voltage motor control development board.

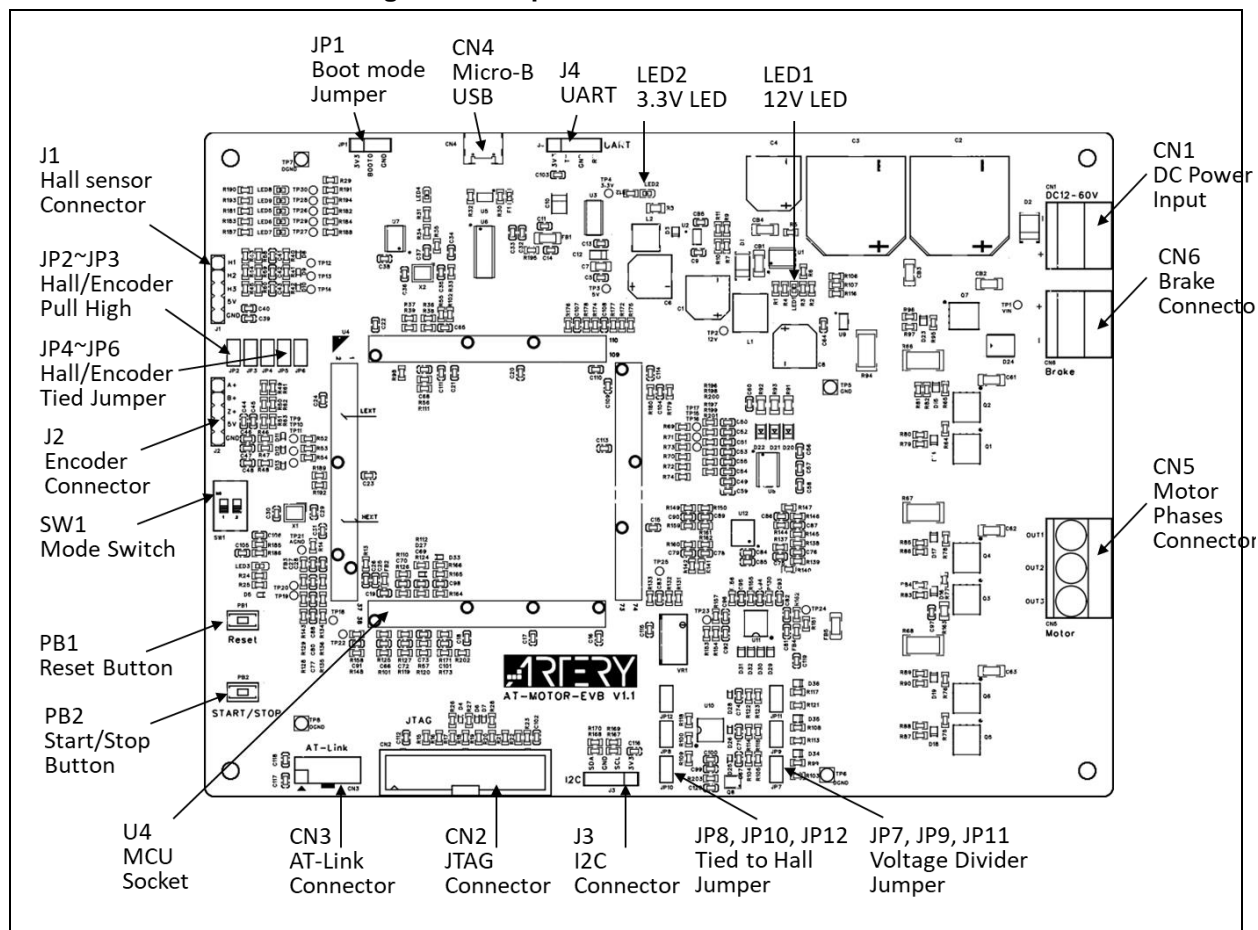
As illustrated in Figure 2, AT32 MCU socket is available to be connected with most AT32 MCUs. The MCU PWM generator is used to control three-phase full-bridge circuit and regenerative brake circuit. The output of 3-phase power stage has a voltage divider circuit for 3-phase output voltages feedback. The board also includes a comparator circuit with virtual neutral point, which is able to feedback the zero crossing signals of BLDC BEMF. Besides, there are on-board Hall sensor and encoder connectors designed to feedback rotor positions. In terms of command input interfaces, the board incorporates USB-to-USART, UART, I2C, and a potentiometer analog input interface. By adjusting this potentiometer to change the output voltage command and read by ADC. In addition, the board offers two DIP switches and one button switch that can be used to configure control modes. Also, five LEDs including an error LED are available on the board.

**Figure 2. Board system architecture**



## 4.2 Jumper and connector location

Figure 3. Jumper and connector location



## 4.3 Jumper settings

Table 1. Jumper settings

Jumper No.	Description	Pre-configured state
JP1	Connect Boot0 to either VCC(1-2) or GND(2-3)	2-3
JP2	Connect Hall sensor signal to VCC pull-up resistor	CLOSED
JP3	Connect Encoder signal to VCC pull-up resistor	OPEN
JP4	Connect Encoder A signal to Hall signal H1 on MCU side	OPEN
JP5	Connect Encoder B signal to Hall signal H2 on MCU side	OPEN
JP6	Connect Encoder Z signal to Hall signal H3 on MCU side	OPEN
JP7	This is used to connect BEMF1 voltage divider resistors in parallel to reduce the divider value	OPEN
JP8	Connect BEMF1 compare signal output to Hall signal H1 on MCU side	OPEN
JP9	This is used to connect BEMF2 voltage divider resistors in parallel to reduce the divider value	OPEN
JP10	Connect BEMF2 compare signal output to Hall signal H2 on MCU side	OPEN
JP11	This is used to connect BEMF3 voltage divider resistors in parallel to reduce the divider value	OPEN
JP12	Connect BEMF3 compare signal output to Hall signal H3 on MCU side	OPEN

## 4.4 Connectors

### 4.4.1 CN1

CN1 is DC power supply input, in the range of 12V~60V.

Table 2. CN1 description

Pin	Symbol	Description
1	-	Negative power input
2	+	Positive power input

#### 4.4.2 CN2

CN2 is a 20-pin JTAG connector that can be used for programming and debugging through third-party programmers.

**Table 3. CN2 (JTAG) description**

Pin	Description	Pin	Description
1	Volt Target ref	2	Volt supply
3	nTRST	4	GND
5	TDI	6	GND
7	TMS (SWDIO)	8	GND
9	TCK (SWCLK)	10	GND
11	RTCK	12	GND
13	TDO (SWO)	14	GND
15	nSRST	16	GND
17	NC	18	GND
19	NC	20	GND

#### 4.4.3 CN3

CN3 is a 10-pin AT-Link connector that can be used for programming and debugging through ARTERY's AT-Link tool.

**Table 4. CN3 (AT-Link) description**

Pin	Description	Pin	Description
1	3.3V supply	2	5.0V supply
3	TMS (SWDIO)	4	BOOT0
5	TCK (SWCLK)	6	TDO (SWO)
7	NRST	8	UART_RX
9	GND	10	UART_TX

#### 4.4.4 CN4

CN4 is a Micro-B connector. It is used for serial communication between the on-board UART-to-USB circuit and external USB interface.

**Table 5. CN4 USB description**

Pin	Description	Pin	Description
1	5V	2	D-
3	D+	4	ID
5	GND		

#### 4.4.5 CN5

CN5 serves as a connector linking the board to the motor three-phase power lines.

**Table 6. CN5 description**

Pin	Symbol	Description
1	OUT1	Motor phase U connection
2	OUT2	Motor phase V connection
3	OUT3	Motor phase W connection

#### 4.4.6 CN6

CN6 connector is used to connect the board to a brake resistor. The selection of the value of the brake resistor should take into consideration the applied voltage in order to make sure that the maximum brake current is below 40A.

For example, for a 40V DC power (applied voltage), the value of the resistor must be greater than  $1\Omega$ .

**Table 7. CN6 description**

Pin	Symbol	Description
1	+	Brake interface on power supply side
2	-	Brake interface on transistor side

## 4.4.7 Pin header connectors

Table 8. Pin connector description

Connector	Pin	Symbol	Description
J1	1	H1	Hall sensor signal pin 1
	2	H2	Hall sensor signal pin 2
	3	H3	Hall sensor signal pin 3
	4	5V	Hall sensor 5V power pin
	5	GND	Hall sensor power ground
J2	1	A+	Incremental encoder phase A signal pin
	2	B+	Incremental encoder phase B signal pin
	3	Z+	Incremental encoder phase Z signal pin
	4	5V	Incremental encoder 5V power pin
	5	GND	Incremental encoder power ground
J3	1	3V3	I2C 3.3V power pin
	2	SCL	I2C SCL signal pin
	3	GND	I2C power ground
	4	SDA	I2C SDA signal pin
J4	1	3V3	UART 3.3V power pin
	2	TX	UART TX signal pin
	3	GND	UART power ground
	4	RX	UART RX signal pin

## 4.5 Test points

**Table 9. Summary of test points**

Test point No.	Description
TP1	Input voltage
TP2	12V voltage
TP3	5V voltage
TP4	3.3V voltage
TP5	GND
TP6,TP7,TP8	DGND digital ground
TP9	Encoder A+ signal
TP10	Encoder B+ signal
TP11	Encoder Z+ signal
TP12	Hall sensor H1 signal
TP13	Hall sensor H2 signal
TP14	Hall sensor H3 signal
TP15	PWM2H signal
TP16	PWM3H signal
TP17	PWM1H signal
TP18	Feedback signal of 2 <sup>nd</sup> phase current after going through current sensing resistor and being amplified
TP19	Feedback signal of the 3 <sup>rd</sup> phase current after going through current sensing resistor and being amplified
TP20	Feedback signal of the 1 <sup>st</sup> phase current after going through current sensing resistor and being amplified
TP21	AGND analog ground
TP22	Feedback signal of DC bus current after going through current sensing resistor and being amplified
TP23	Overcurrent setpoint voltage of DC bus current
TP24	Overcurrent setpoint voltage of phase current
TP25	Overcurrent emergency stop protection BKIN signal
TP26	LED1 status indicator
TP27	LED3 status indicator
TP28	Digital output test point signal
TP29	LED2 status indicator
TP30	LED error status indicator
TP31	PWM1L signal
TP32	PWM2L signal
TP33	PWM3L signal

## 5 Hardware circuit

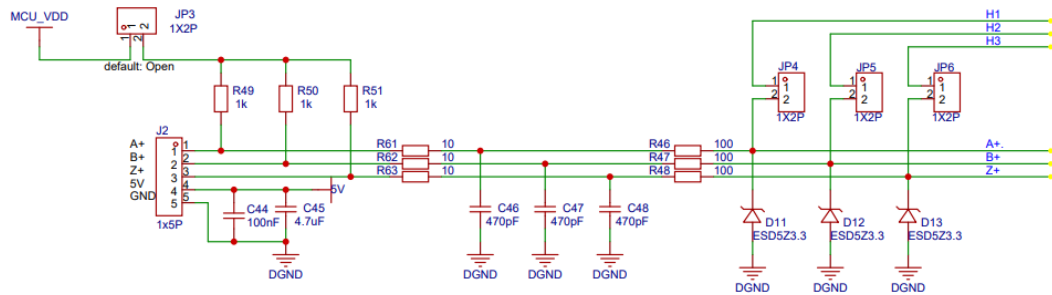
- Contains a three-phase full-bridge power stage circuit that can drive three-phase motors, and includes a regenerative resistor brake circuit that can consume regenerative power by applying an external resistor;
- Designed with two buck converters: one steps down the input DC voltage to 12 V to provide gate driver chip control voltage, and the other one converts 12 V to 5 V to provide power for the Hall sensor and incremental encoder; with a LDO circuit that provides 3.3 V working power;
- Provides input interface of incremental encoder and Hall sensor, which can be used to feedback rotor position;
- Designed with three current sensing resistors and circuit to feedback three-phase current, and one current sensing resistor on DC bus to feedback bus current, which can be used to realize single-shunt current sensing control;
- The aforementioned current sensing feedback circuits contain OCP (overcurrent protection) circuits, and connect the output to MCU to shutdown PWM output and realize the overcurrent protection mechanism;
- Contains three-phase terminal voltage divider circuit and its feedback signals are connected to MCU ADC pins, virtual neutral point circuit and phase voltage polarity judgment circuit. They can be used in six-step square-wave sensorless control mode;
- Contains a DC input voltage divider circuit that is used for sensing DC bus voltage, and a temperature sensing circuit composed of a NTC (negative temperature coefficient) resistor to feedback MOSFET temperature;
- Contains a RESET button, a USER button, two custom DIP switches, four status LEDs and one error LED;
- Designed with one potentiometer circuit that is connected to MCU ADC pin and can be customized by the user;
- Provides a serial-Micro-B USB interface for the convenience of communication with external devices, and one USB power LED;
- Provides one I2C interface and one UART serial interface;
- Designed with AT-Link connector and the JTAG connector for a 3rd party programmer.



## 5.1 Incremental encoder circuit

As shown in Figure 4, for the open-drain encoder, JP3 can be short-connected to connect the input pin to a 1 k $\Omega$  pull-up resistor, and the input signal is connected to MCU through an RC low-pass filter composed of 10  $\Omega$  resistor and 470pF capacitor. If the applied MCU does not have the corresponding peripheral pins of the circuit, the output signal can be connected to Hall sensor circuit output end through JP4~JP6 jumpers and use another timer peripherals of MCU.

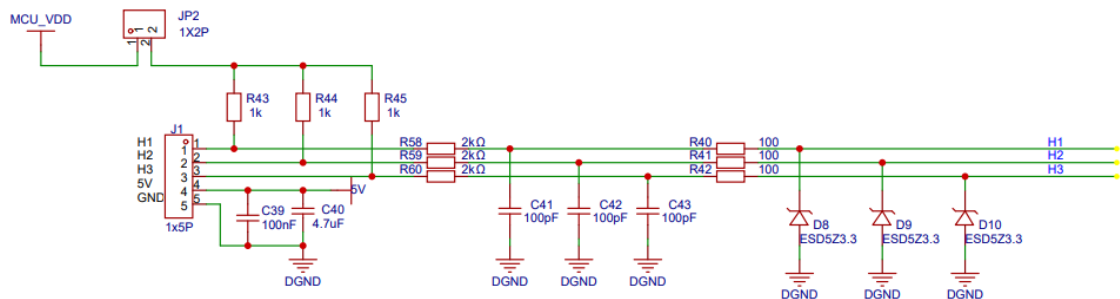
**Figure 4. Incremental encoder circuit**



## 5.2 Hall sensor circuit

As shown in Figure 5, the Hall sensor is generally open-drain type, so that JP2 jumper is short-connected by default and connects the input pin to 1 k $\Omega$  pull-up resistor. The input signal is connected to MCU through an RC low-pass filter composed of 2 k $\Omega$  resistor and 100pF capacitor.

**Figure 5. Hall sensor circuit**

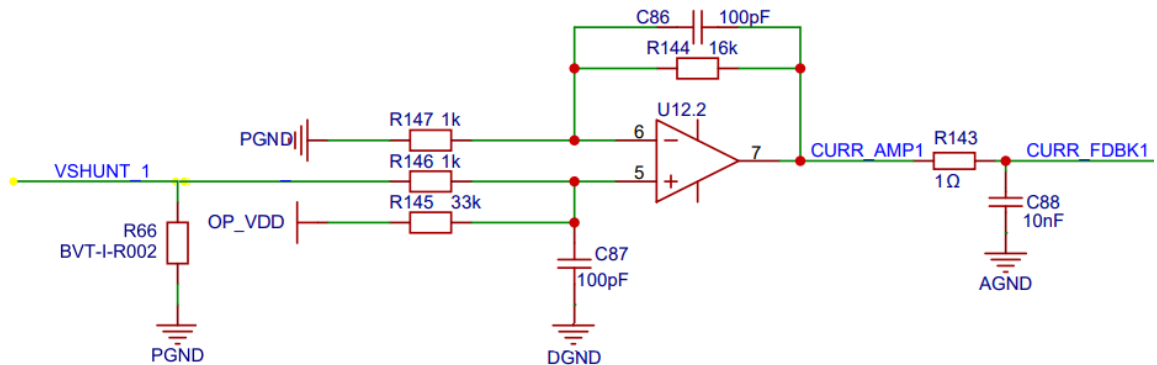


## 5.3 Current sensing circuit

### 5.3.1 Phase current sensing circuit

As shown in Figure 6, the phase current passes through a 2 mΩ current sensing resistor, and then it is amplified 16.5 times by an amplifying circuit and the output DC voltage level is also pulled up to 1.65 V; therefore, the maximum current sensing range is  $\pm 50A_{PEAK}$ .

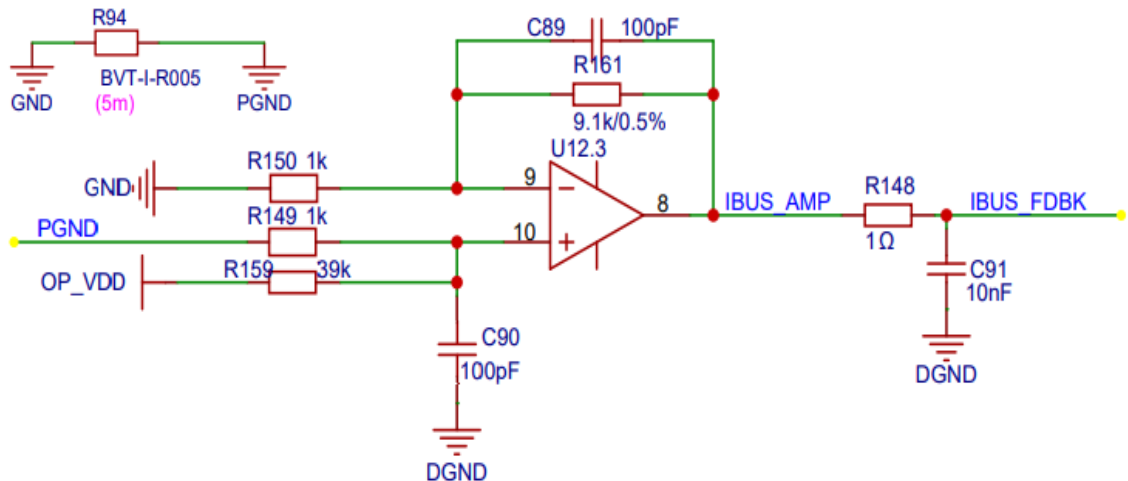
Figure 6. Phase current sensing feedback circuit



### 5.3.2 DC bus current sensing circuit

As shown in Figure 7, the bus current passes through a 5 mΩ current sensing resistor, and then it is amplified 9.85 times by an amplifying circuit and the output DC voltage level is increased to 0.833 V; therefore, the maximum current sensing range is  $-16.9A_{PEAK} \sim 50.1A_{PEAK}$ .

Figure 7. DC bus current sensing feedback circuit

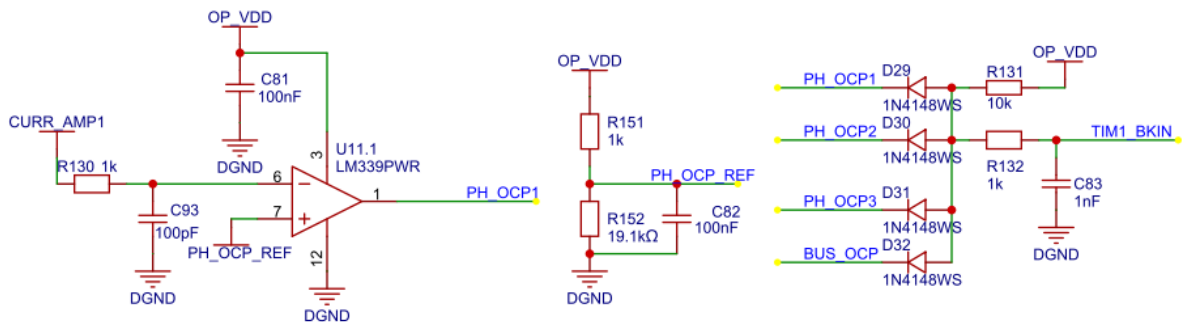


## 5.4 OCP sensing circuit

### 5.4.1 Three-phase OCP sensing circuit

The three-phase OCP sensing circuit consists of three comparator circuits (one-phase protection circuit is shown in Figure 8), and the three-phase OCP circuit contains one overcurrent reference level divider circuit. The protection circuit compares the amplified three-phase current feedback signal with the overcurrent reference voltage. If the feedback signal is higher than the reference voltage, the comparator outputs low level, and connects to the MCU timer BKIN pin to stop PWM output. Based on the voltage division level as shown in the figure below, the overcurrent protection point of phase current is  $45A_{PEAK}$ .

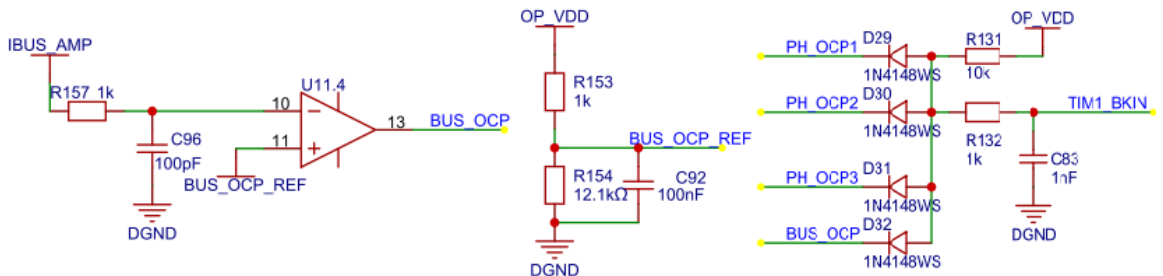
**Figure 8. Phase current OCP sensing circuit**



### 5.4.2 Bus OCP sensing circuit

The bus overcurrent sensing circuit is composed of a comparator, and its OCP sensing circuit is shown in Figure 9, which contains an overcurrent reference level divider circuit. The OCP circuit compares the amplified bus current feedback signal with the overcurrent reference voltage. If the feedback signal is higher than the reference voltage, the comparator outputs low level, and connects to MCU timer BKIN pin to stop PWM output. Based on the voltage division level as shown in the figure below, the overcurrent protection point of phase current is  $45A_{PEAK}$ .

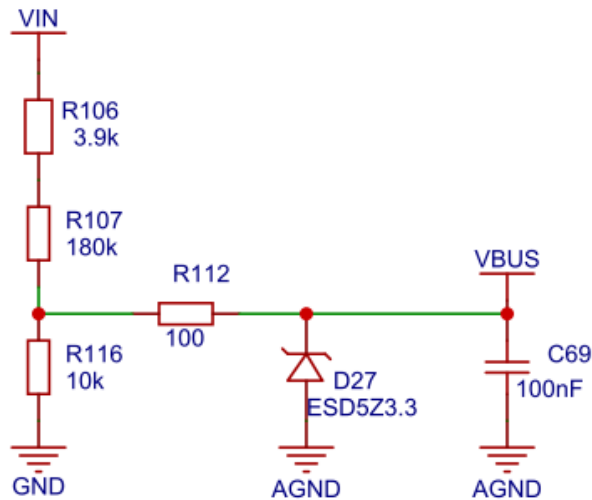
**Figure 9. Bus OCP sensing circuit**



## 5.5 Bus voltage sensing circuit

The bus voltage sensing circuit is composed of a divider circuit as shown in Figure 10. The maximum voltage value that can be measured by the circuit is 64 V, and the overvoltage/undervoltage protection function can be realized according to the bus voltage feedback. Calculating with three-phase PWM duty cycles, the driver output voltage can be estimated, which can be used to estimate the BEMF in sensorless control.

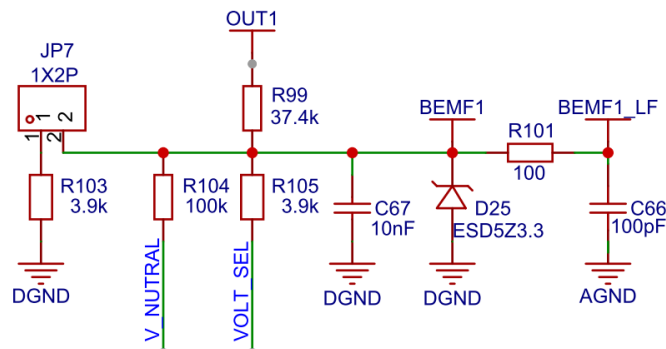
Figure 10. Bus voltage sensing circuit



## 5.6 Three-phase output voltage sensing circuit

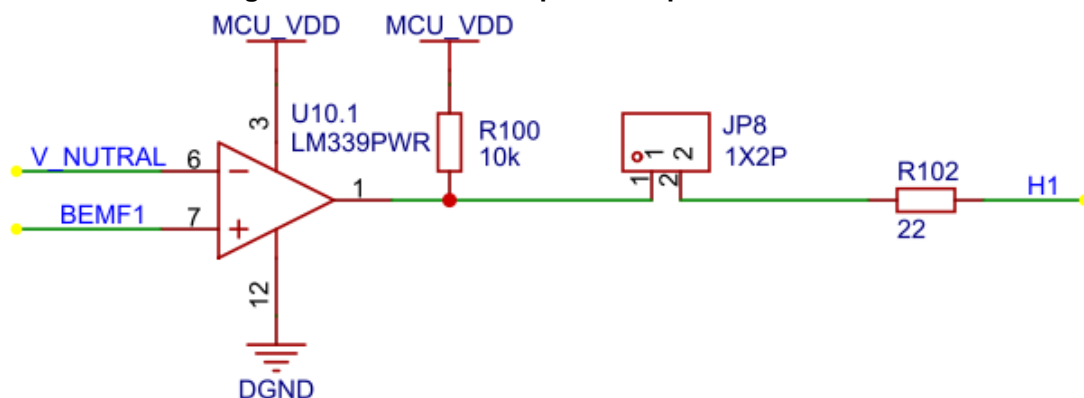
One of the three-phase output voltage sensing circuit is shown in Figure 11, which passes through a low-pass RC filter and connects to MCU ADC input pin. In sine wave driving mode, it can feedback the motor terminal voltage, and then integrate with the feedback currents to estimate the motor three-phase BEMF. In case of six-step square-wave drive control, it can be used to measure the BEMF zero crossing point of open phase. Based on the PWM duty cycle, it is possible to measure the zero crossing point during PWM OFF or PWM ON. If the PWM duty cycle is low, measure the zero crossing point in PWM OFF; otherwise, measure in PWM ON. The filter capacitor after voltage division can be changed or removed according to the actual demand.

Figure 11. Output voltage sensing circuit



In addition to measuring open-phase zero crossing point in ADC manner, a virtual neutral point comparator circuit (as shown in Figure 12) is also provided by the evaluation board. Connect the voltage signals after three-phase voltage division through three 100 kΩ resistors to get a virtual neutral point signal; then the comparator compares the three-phase terminal voltages with the virtual neutral point signal, so as to judge the BEMF zero-crossing point according to the comparator output level. As shown in the figure below, short the jumper to connect comparator signal to MCU Hall sensor pin.

**Figure 12. Virtual neutral point comparator circuit**

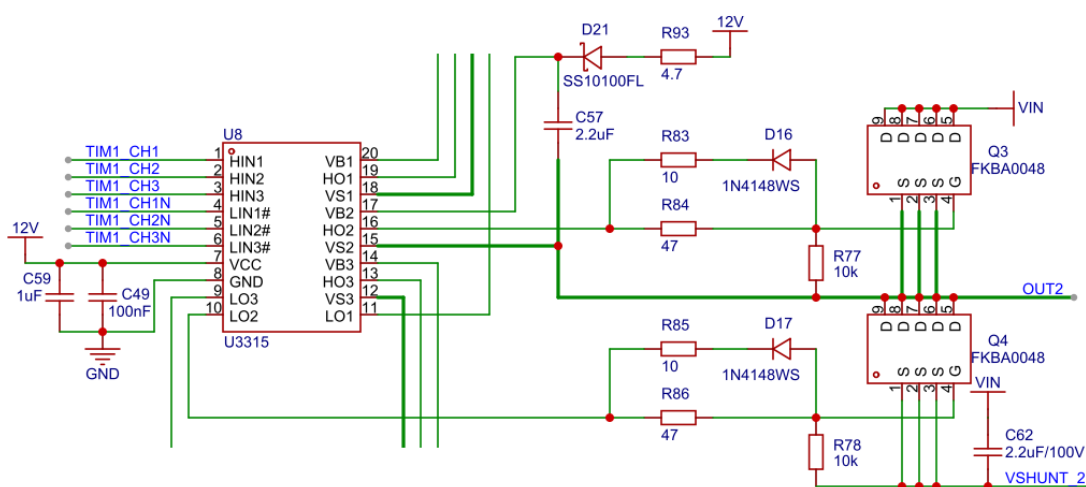


## 5.7 Power stage circuit

### 5.7.1 Three-phase full-bridge converter circuit

The three-phase full-bridge converter circuit is composed of an integrated three-phase full-bridge gate driver chip, six 100 V/78 A/8 mΩ MOSFETs (package: DFN5×6-8) and relevant circuits. Figure 13 shows the phase V half-bridge power conversion circuit, where OUT2 is connected to phase V output of CN5 connector to connect the motor phase V wire. The Q4 MOSFET source output V\_SHUNT2 passes through the current sensing resistor to feedback phase V current.

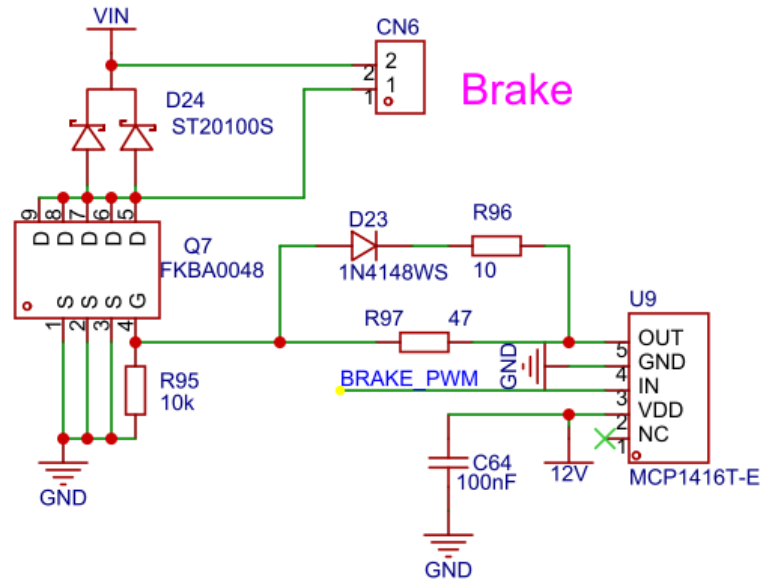
**Figure 13. V-shunt half-bridge power conversion circuit**



## 5.7.2 Regenerative brake circuit

The regenerative brake circuit is shown in Figure 14. CN6 is connected to an external brake resistor, and the driving signal drives Q7 MOSFET via U9 gate driver, so as to connect the brake resistor across the DC bus to dissipate motor regenerative energy. Note that a proper brake resistor should be used to ensure that the maximum current is below 40 A. For example, if the bus voltage is 60 V, the brake resistor should not be less than 1.5  $\Omega$ .

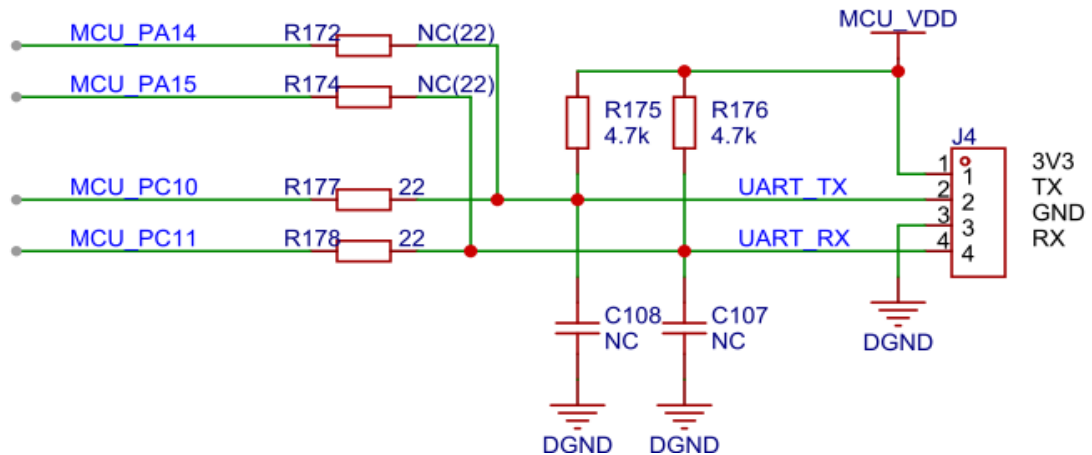
**Figure 14. Regenerative brake circuit**



## 5.8 Communication circuit

The evaluation board has one serial-Micro-B USB interface, one I2C interface and one UART serial interface. The signal pins of UART serial interface can be adjusted for different MCUs, as shown in Figure 15.

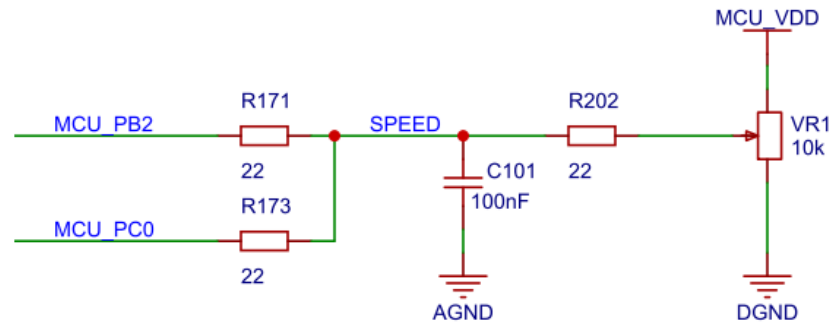
**Figure 15. UART serial interface circuit**



## 5.9 Potentiometer input interface

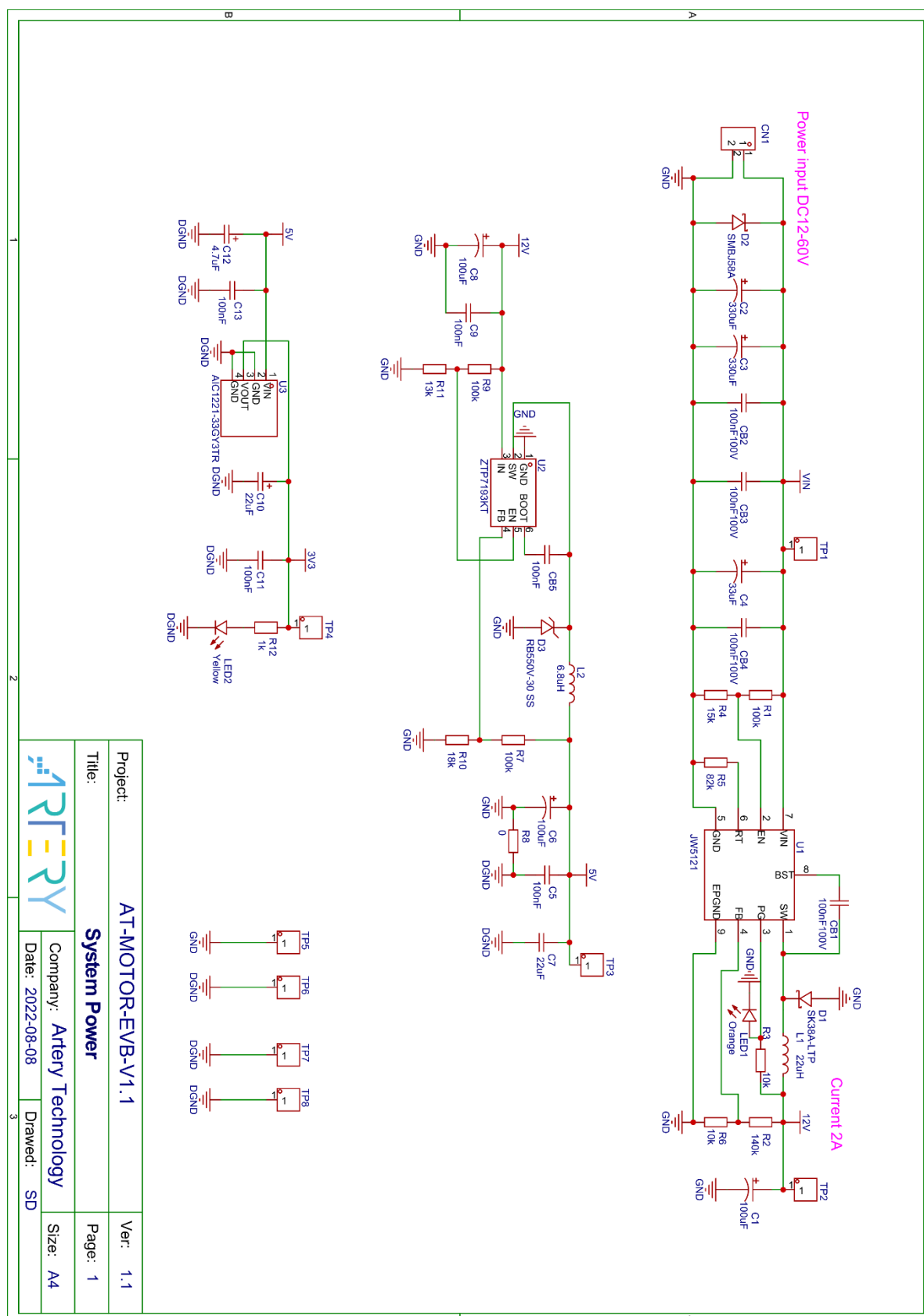
This circuit contains a 30-turn 10 k $\Omega$  potentiometer that can be connected to MCU ADC pins according to different MCUs. The potentiometer input interface circuit is shown in Figure 16 below.

Figure 16. Potentiometer input interface circuit



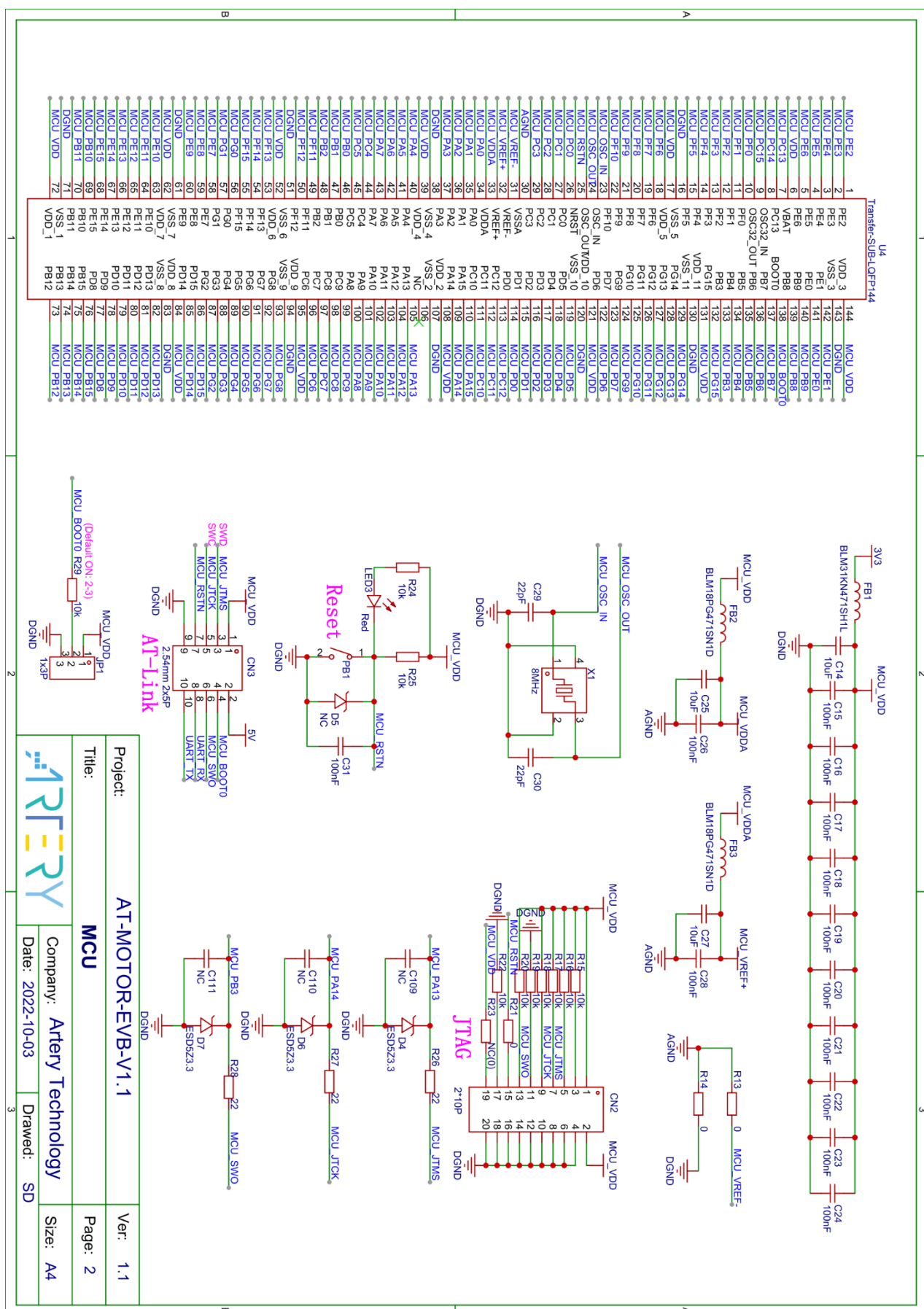
## 6 Schematic diagrams

### 6.1 System power supply

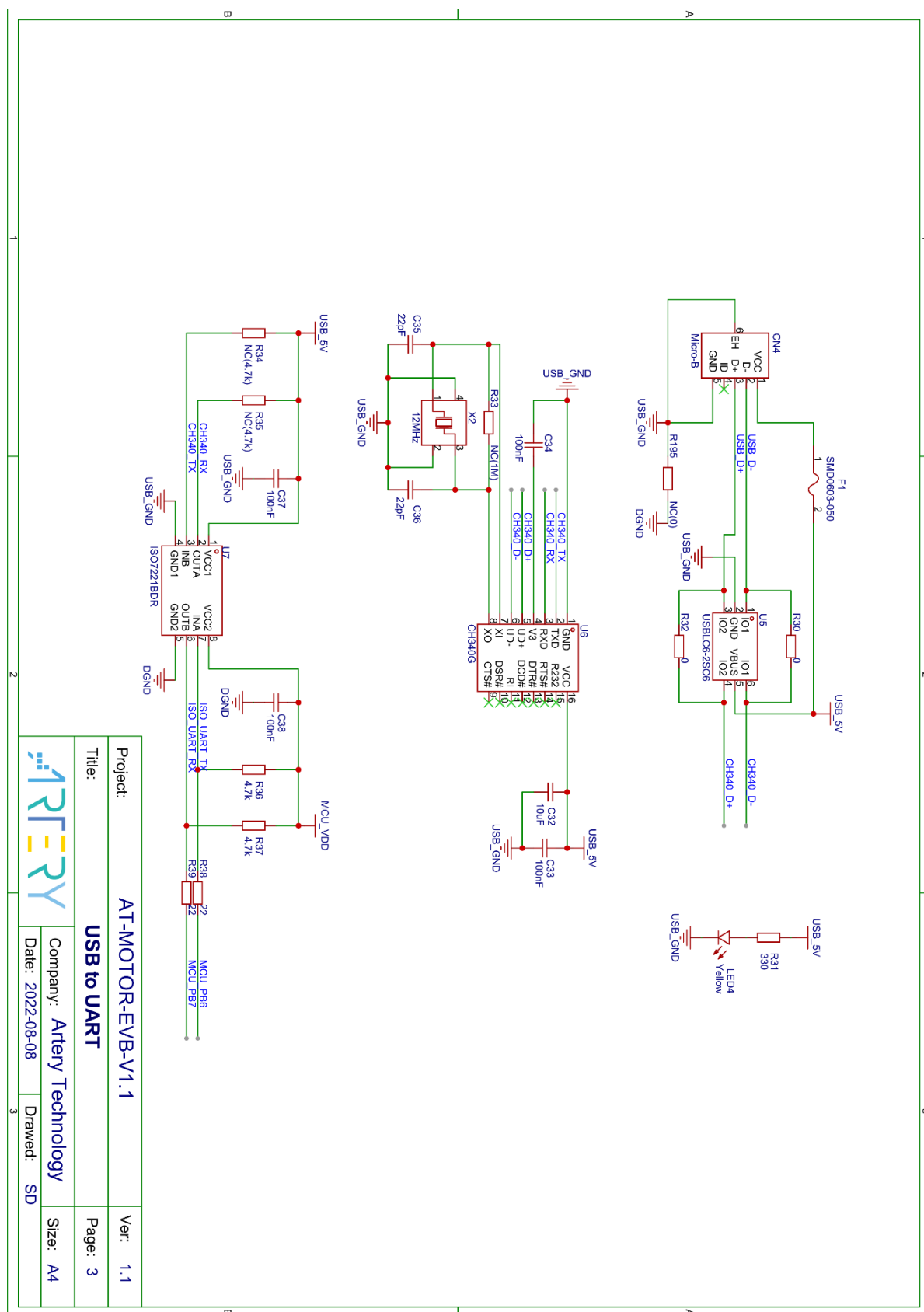




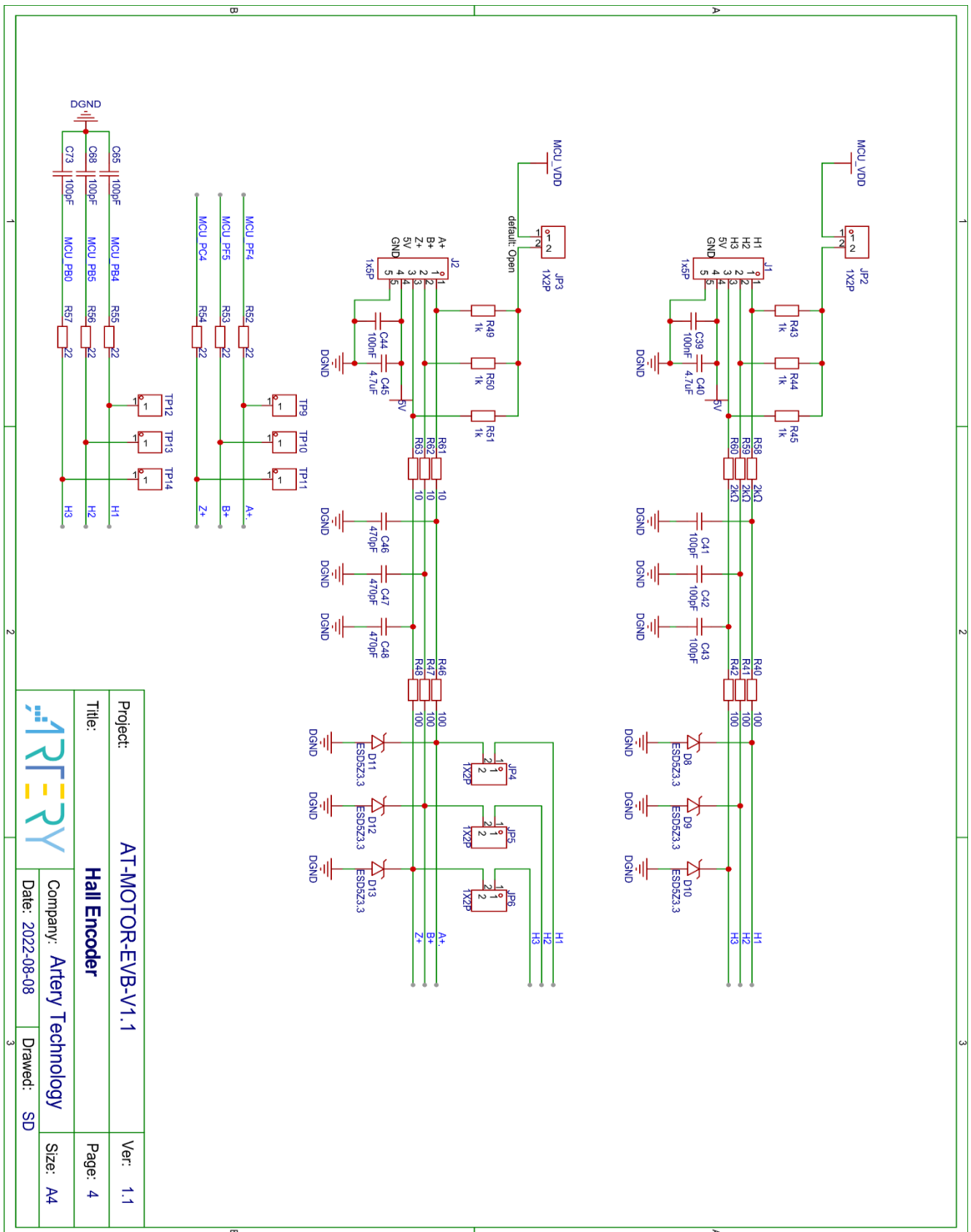
## 6.2 MCU interface



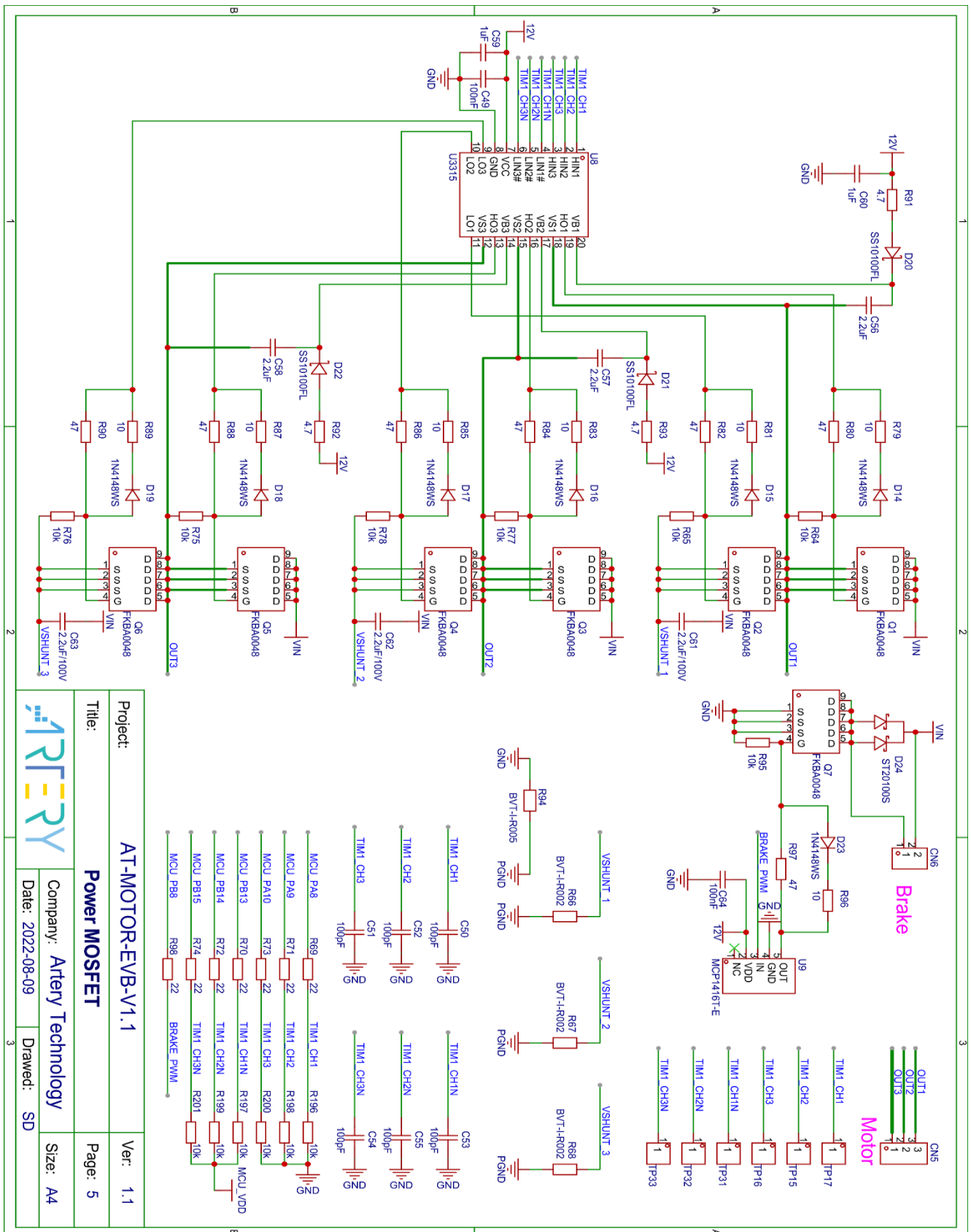
## 6.3 USB-to-UART interface



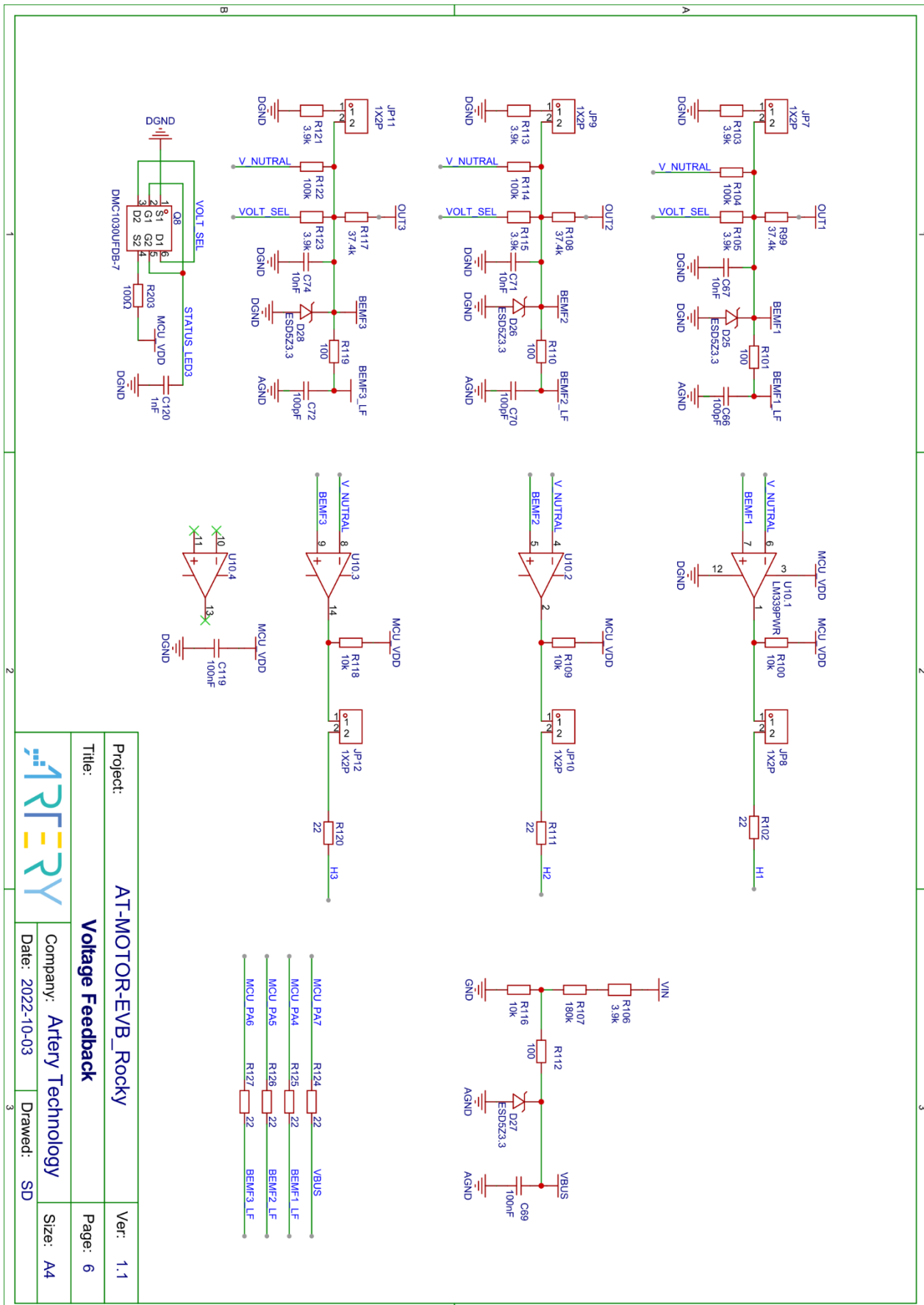
## 6.4 Hal encoder schematic



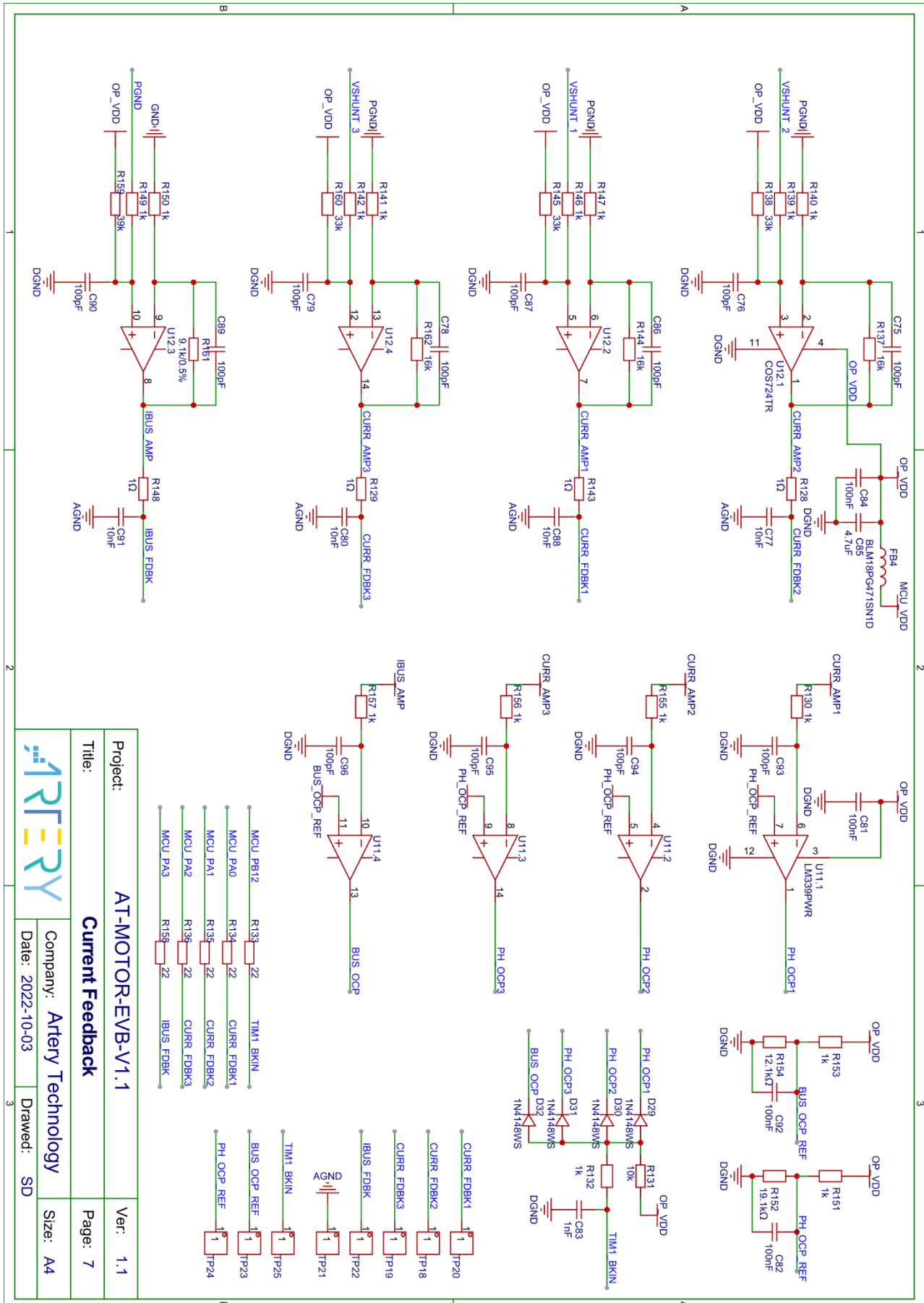
## 6.5 Power MOSFET schematic



## 6.6 Voltage feedback schematic



## 6.7 Current feedback schematic

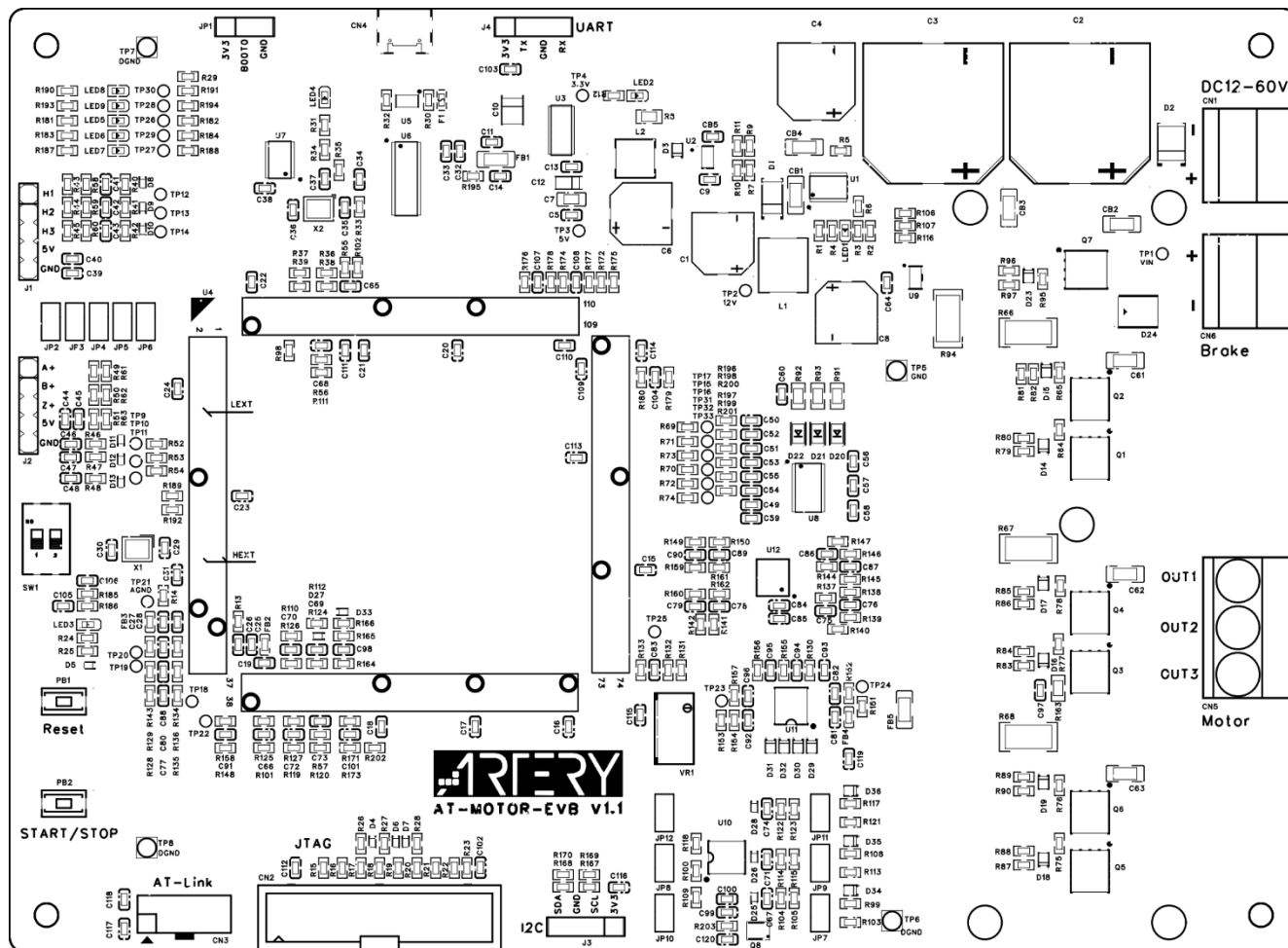


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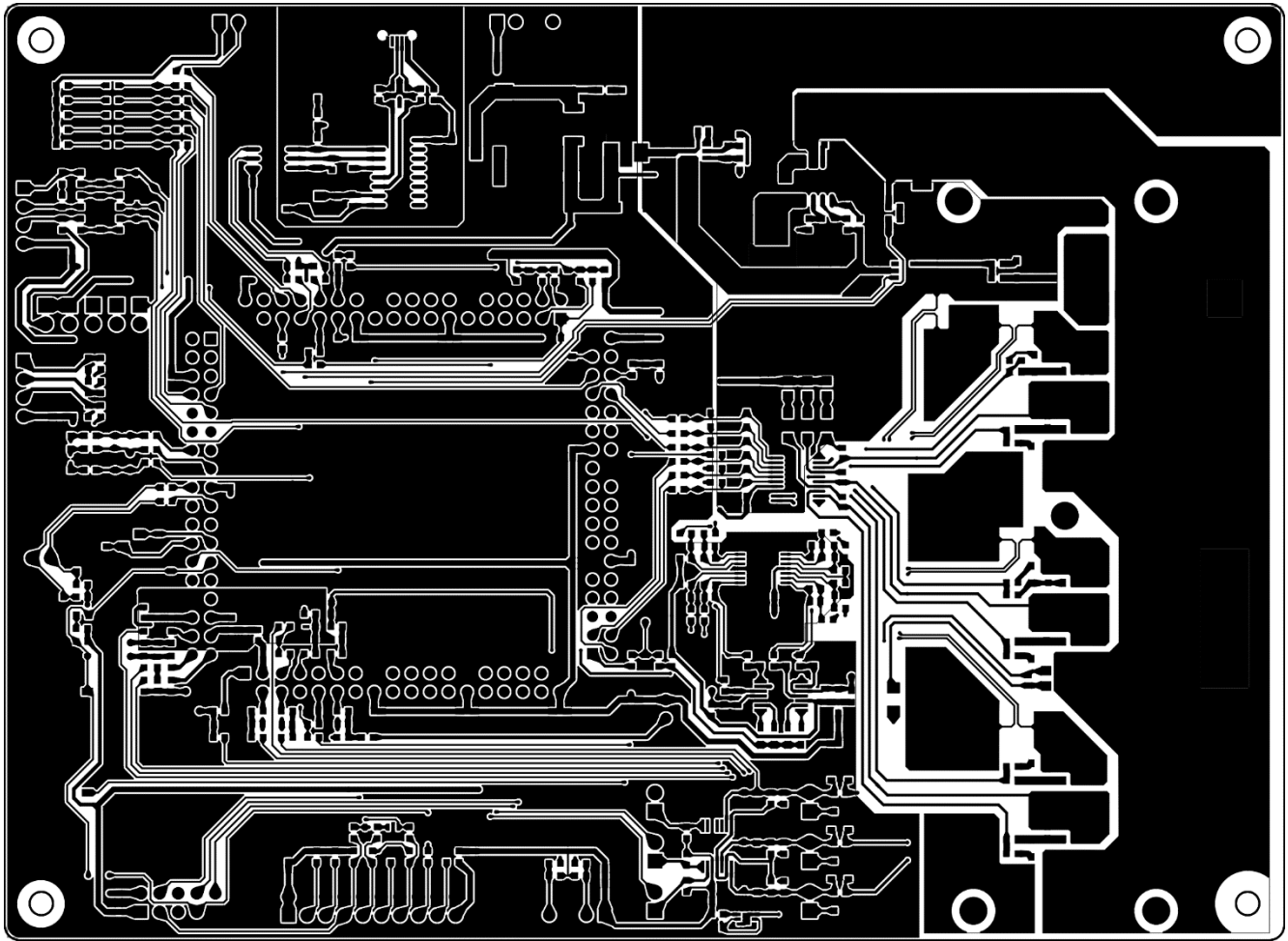
## 7 PCB Layouts

### 7.1 Component location diagram

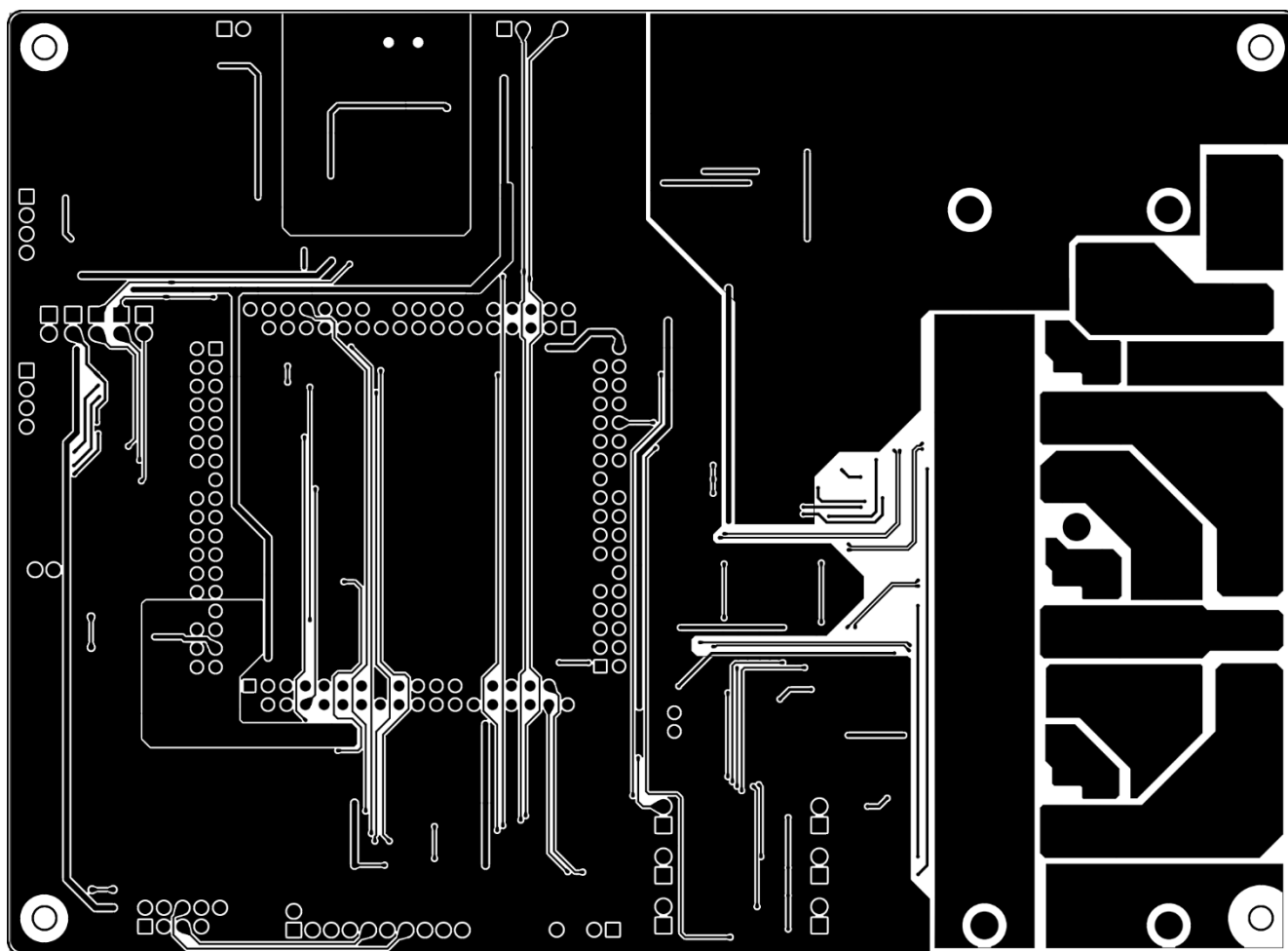




## 7.2 Top layer layout



### 7.3 Bottom layer layout



## 8 Bill of materials

Value/Part number	Description	Designator	Footprint	Quantity	Manufacturer
100uF	SMD Alum. Elec. Cap.100uF,50V,20%, D:8mm, H:10mm	C1,C6,C8	SMD_BD8.0-L8.3	3	Any
330uF	SMD Alum. Elec. Cap. 330uF,100V,20%, D:18mm, H:16.5mm	C2,C3	SMD_BD18.0-L19.0	2	Any
33uF	SMD Alum. Elec. Cap. 100uF,25V,20%, D:10mm, H:10mm	C4	SMD_BD10.0-L10.4	1	Any
100nF	SMD MLCC 0.1uF,50V,X7R,10%,0603	C5,C9,C11,C13,C15,C16,C17,C18,C19,C20,C21,C22,C23,C24,C26,C28,C31,C33,C34,C37,C38,C39,C44,C49,C64,C69,C81,C82,C84,C92,C98,C100,C101,C103,C112,C113,C114,C115,C116,C117,C118,C119,C120	C0603	43	Any
22uF	SMD MLCC 22uF,25V,X5R,20%,0805	C7	C0805	1	Any
22uF	SMDTantalum Elec. Cap. 22uF,16V,10%CASE-B 3528	C10	CASE-B 3528	1	Any
4.7uF	SMDTantalum Elec. Cap. 4.7uF,16V,20%CASE-A 3216	C12	CASE-A 3216	1	Any
10uF	SMD MLCC 10uF,16V,X5R,20%,0603	C14,C25,C27,C32	C0603	4	Any
22pF	SMD MLCC 22pF,50V,COG,5%,0603	C29,C30,C35,C36	C0603	4	Any
4.7uF	SMD MLCC 4.7uF,25V,X5R,10%,0603	C40,C45,C85,C97,C99,C102	C0603	6	Any
100pF	SMD MLCC 100pF,50V,X7R,10%,0603	C41,C42,C43,C50,C51,C52,C53,C54,C55,C65,C66,C68,C70,C72,C73,C75,C76,C78,C79,C86,C87,C89,C90,C93,C94,C95,C96	C0603	27	Any
470pF	SMD MLCC 470pF,50V,X7R,10%,0603	C46,C47,C48	C0603	3	Any
2.2uF	SMD MLCC 2.2uF,50V,X5R,10%,0603	C56,C57,C58	C0603	3	Any
1uF	SMD MLCC 1uF,50V,X5R,10%,0603	C59,C60,C104,C105,C106	C0603	5	Any
2.2uF	SMD MLCC 2.2uF,100V,X7R,10%,1206	C61,C62,C63	C1206	3	Any
10nF	SMD MLCC 10nF,50V,X7R,10%,0603	C67,C71,C74,C77,C80,C88,C91	C0603	7	Any
1nF	SMD MLCC 1nF,50V,X7R,10%,0603	C83,C120	C0603	2	Any
0.1uF/100nF	SMD MLCC 0.1uF,100V,X7R,10%,1206	CB1,CB2,CB3,CB4	C1206	4	Any
SK38A-LTP	SMD Schottky Diode 80V,3A	D1	SMA(DO-214AC)	1	Any
SMBJ58A	SMD TVS SMBJ58A	D2	SMB(DO-214AA)	1	Any
RB550V-30 SS	SMD Schottky Diode 30V,1A	D3	SOD-323	1	Any
ESD5Z3.3	SMD ESD Diode ESD5Z3.3	D4,D6,D7,D8,D9,D10,D11,D12,D13,D25,D26,D27,D28,D33	SOD-523	14	Any
1N4148WS	SMD Switching Diode100V,150mA	D14,D15,D16,D17,D18,D19,D23,D29,D30,D31,D32	SOD-323	11	Any
SS10100FL_R1	SMD Schottky Diode100V,1A	D20,D21,D22	SOD-123FL	3	Any
ST20100S	SMD Schottky Diode100V,20A	D24	TO-277B	1	Any
1N4007WS	SMD Diode 1KV,1A	D34,D35,D36	SOD-323	3	Any
SMD0603-050	Resettable Fuses 6V, hold: 0.5A, trip: 1A	F1	0603	1	LCSC Electronics
BLM31KN471SH1L	SMD Bead 120Ohm@100Mhz 4.0A	FB1,FB5	1206	2	Murata

Value/Part number	Description	Designator	Footprint	Quantity	Manufacturer
BLM18PG471SN1D	SMD Bead 470Ohm@100Mhz 1.0A	FB2,FB3,FB4	0603	3	Murata
22uH	Inductor 22uH,3A,20%,Part no.MHCI06030-220M-R8	L1	SMD 6.6x7.3x3	1	Chilisin
6.8uH	Inductor 6.8uH,3.5A,20%,Part no.MWSA0503S-6R8MT	L2	SMD 5.2x5.4x3.0	1	Sunlord
Orange	SMD LED Orange 0603	LED1	LED0603	1	Any
Yellow	SMD LED Yellow 0603	LED2,LED4	LED0603	2	Any
RED	SMD LED Red 0603	LED3,LED8	LED0603	2	Any
GREEN	SMD LED Green 0603	LED5,LED6,LED7	LED0603	3	Any
BLUE	SMD LED Blue 0603	LED9	LED0603	1	Any
UK-B0240-W-250	SMD SPST Button L3.5*W6*H2.5mm	PB1,PB2	SMD	2	Any
FKBA0048	N-MOSFET100V/78A, SMD 5mmx6mm	Q1,Q2,Q3,Q4,Q5,Q6,Q7	PRPAK5X6	7	FETek
DMC1030UFDB-7	P-N-MOSFET 12V/3.9A SMD 2mmx2mm	Q8	U-DFN2020-6D	1	Diodes
100K	SMD Resistor 100K,1/10W,1%,0603	R1,R7,R9,R104,R114,R122	R0603	6	Any
140K	SMD Resistor 140K,1/10W,1%,0603	R2	R0603	1	Any
10K	SMD Resistor 10K,1/10W,1%,0603	R3,R6,R15,R16,R17,R18,R19,R20,R22,R24,R25,R29,R64,R65,R75,R76,R77,R78,R95,R100,R109,R116,R118,R131,R179,R185,R186,R196,R197,R198,R199,R200,R201	R0603	33	Any
15K	SMD Resistor 15K,1/10W,1%,0603	R4	R0603	1	Any
82K	SMD Resistor 82K,1/10W,1%,0603	R5	R0603	1	Any
0R	SMD Resistor 0R,1/10W,1%,0805	R8	R0805	1	Any
18K	SMD Resistor 18K,1/10W,1%,0603	R10	R0603	1	Any
13K	SMD Resistor 13K,1/10W,1%,0603	R11	R0603	1	Any
1K	SMD Resistor 1K,1/10W,1%,0603	R12,R43,R44,R45,R49,R50,R51,R130,R132,R139,R140,R141,R142,R146,R147,R149,R150,R151,R153,R155,R156,R157,R165,R181,R183,R187,R190,R193	R0603	28	Any
0R	SMD Resistor 0R,1/10W,1%,0603	R13,R14,R21,R30,R32	R0603	5	Any
22R	SMD Resistor 22R,1/10W,1%,0603	R26,R27,R28,R38,R39,R52,R53,R54,R55,R56,R57,R69,R70,R71,R72,R73,R74,R98,R102,R111,R120,R124,R125,R126,R127,R133,R134,R135,R136,R158,R164,R169,R170,R171,R173,R177,R178,R180,R182,R184,R188,R189,R191,R192,R194,R202	R0603	46	Any
330R	SMD Resistor 330R,1/10W,1%,0603	R31	R0603	1	Any
4.7K	SMD Resistor 4.7K,1/10W,1%,0603	R36,R37,R166,R167,R168,R175,R176	R0603	7	Any
100R	SMD Resistor 100R,1/10W,1%,0603	R40,R41,R42,R46,R47,R48,R101,R110,R112,R119, R203	R0603	11	Any
2K	SMD Resistor 2K,1/10W,1%,0603	R58,R59,R60	R0603	3	Any
10R	SMD Resistor 10R,1/10W,1%,0603	R61,R62,R63,R79,R81,R83,R85,R87,R89,R96	R0603	10	Any
BVT-I-R002	SMD Shunt Resistor 2mW BVS-A-R002	R66,R67,R68	R2512	3	Isabellenhütte
BVT-I-R005	SMD Shunt Resistor 5mW BVS-A-R005	R94	R2512	1	Isabellenhütte

Value/Part number	Description	Designator	Footprint	Quantity	Manufacturer
47R	SMD Resistor 47R, 1/10W, 1%, 0603	R80, R82, R84, R86, R88, R90, R97	R0603	7	Any
4.7K	SMD Resistor 4.7K, 1/10W, 1%, 0805	R91, R92, R93	R0805	3	Any
37.4K	SMD Resistor 37.4K, 1/10W, 1%, 0603	R99, R108, R117	R0603	3	Any
3.9K	SMD Resistor 3.9K, 1/10W, 1%, 0603	R103, R105, R106, R113, R115, R121, R123	R0603	7	Any
180K	SMD Resistor 180K, 1/10W, 1%, 0603	R107	R0603	1	Any
1R	SMD Resistor 1R, 1/10W, 1%, 0603	R128, R129, R143, R148	R0603	4	Any
16K	SMD Resistor 16K, 1/10W, 1%, 0603	R137, R144, R162	R0603	3	Any
33K	SMD Resistor 33K, 1/10W, 1%, 0603	R138, R145, R160	R0603	3	Any
19.1K	SMD Resistor 19.1K, 1/10W, 1%, 0603	R152	R0603	1	Any
12.1K	SMD Resistor 12.1K, 1/10W, 1%, 0603	R154	R0603	1	Any
39K	SMD Resistor 39K, 1/10W, 1%, 0603	R159	R0603	1	Any
9.1K	SMD Resistor 9.1K, 1/10W, 1%, 0603	R161	R0603	1	Any
SDNT2012X103F3 450FTF	SMD NTC Resistor 10K, 1%, 3450K	R163	R0805	1	Sunlord
DSWB02LHGET	2POS DIP Switches 2.54mm, Red	SW1	DIP 6.64x9.6mm	1	Any
TP Ring	PCB Test Point Ring pin, BLACK5001	TP5, TP6, TP7, TP8	DIP	4	Any
JW5121	DC/DC Step-Down Converter 60V, 2A	U1	ESOP-8	1	JoulWatt
ZTP7193KT	DC/DC Step-Down Converter 18V, 3A	U2	TSOT-23-6	1	ZILLTEK
AIC1221- 33GY3TR	LDO 6V, Vo:3.3V, 2A	U3	SOT-223	1	AIC
USBL6-2SC6	USB ESD Protect, USBL6- 2SC6	U5	SOT-23-6	1	MSKSEMI
CH340G	USB to Serial Port Chip, USB2.0, 2Mbps	U6	SOP-16_150MIL	1	WCH
ISO7221BDR	Digital 2CH Isolator, 5Mbps	U7	SOIC-8_150MIL	1	TI
U3315	3-Phase Bridge Gate-driver	U8	TSSOP-20	1	UNI-SEMI
MCP1416T-E/OT	Low side Gate-driver, 1-CH, 1.5A	U9	SOT-23-5	1	Microchip
LM339PW	Quad Differential Comparators	U10, U11	TSSOP-14	2	TI
COS724TR	Quad low noise OP Amp	U12	TSSOP-14	1	COSINE
3296W-1-103	Potentiometer 10K, 10%	VR1	DIP	1	BOCHEN
X32258MSB4SI	8MHz SMD Crystal 20PF, 10ppm	X1	SMD-3225	1	YXC
X322512MSB4SI	12MHz SMD Crystal 20PF, 10ppm	X2	SMD-3225	1	YXC
Connector	PCB Screw Terminal, 2P, 6.35mm, 30A, XY636-6.35-2P	CN1, CN6	DIP	2	Any
Connector	PCB Screw Terminal, 3P, 6.35mm, 30A, XY636-6.35-3P	CN5	DIP	1	Any
IDC Connector	Box Header 2x10P, 2.54mm, Black	CN2	HDR2X10	1	Any
Header 2X5	Pin Header 2x5P, 2.54mm, Black	CN3	HDR2X5	1	Any
Micro-B Female	Micro-B USB Female	CN4	DIP	1	Any
Header 1X5	Pin Header 1x5P 2.54mm, Black	J1, J2	HDR1X5	2	Any

Value/Part number	Description	Designator	Footprint	Quantity	Manufacturer
Header 1X4	Pin Header 1x4P 2.54mm, Black	J3,J4	HDR1X4	2	Any
Header 1X3	Pin Header 1x3P 2.54mm, Black	JP1	HDR1X3	1	Any
Header 1X2	Pin Header 1x2P 2.54mm, Black	JP2,JP3,JP4,JP5,JP6,JP7,JP8,JP9,JP10,JP11,JP12	HDR1X2	11	Any
Header 2X18	Female Haeder Connector 2x18P, 2.54mm, Black	U4 Connector	HDR2X18	4	Any



## 9 Revision history

Date Version	Date	Date Version Revision Note
2022.11.18	2.0.0	Initial release.
2023.03.02	2.0.1	Revised Table 4. CN3 (AT-Link) description