

AT32 MCU-based Low Voltage Motor Control Evaluation Board

Introduction

The purpose of this document is to provide users with a guide on how to use the AT32 MCU-based low voltage motor control evaluation board V2.0.

Applicable products:

Product series	AT32F4xx, AT32A4xx, AT32L0xx
----------------	------------------------------

Contents

1	Overview	6
2	Software and hardware requirements	7
3	Getting started	8
4	Hardware layout and configuration	9
4.1	System architecture of evaluation board.....	9
4.2	Jumper and connector positions.....	10
4.3	Jumper settings	11
4.4	Connectors	12
4.4.1	CN1	12
4.4.2	CN2	12
4.4.3	CN3	12
4.4.4	CN4	13
4.4.5	CN2 on MCU	13
4.4.6	Pin header connectors	14
4.5	Test points	15
5	Hardware circuit.....	16
5.1	Incremental encoder circuit	17
5.2	Hall sensor circuit	17
5.3	Current sensing circuit.....	18
5.3.1	Phase current sensing circuit.....	18
5.3.2	DC bus current sensing circuit	18
5.4	OCP sensing circuit	19
5.4.1	Three-phase OCP sensing circuit	19
5.4.2	Bus OCP sensing circuit	19
5.5	Bus voltage sensing circuit	20
5.6	Three-phase output voltage sensing circuit	20
5.7	Power stage circuit	22
5.7.1	Three-phase full-bridge converter circuit	22
5.7.2	Brake circuit.....	22
5.8	Communication circuit	23

5.8.1	UART interface	23
5.8.2	I2C interface	23
5.9	Potentiometer input interface.....	23
5.10	Temperature sensing circuit.....	24
5.11	LED circuit.....	24
5.12	MCU socket.....	25
6	MCU pin map	26
6.1	AT32F421/L021 MCU pin map	26
6.2	AT32F413/F425/F415/F405 MCU pin map.....	27
6.3	AT32F403A/A403A/F435 MCU pin map	28
6.4	AT32F423/F55 MCU pin map	29
7	Schematic diagrams	30
7.1	System power supply	30
7.2	MCU interface	31
7.3	Hall / Encoder circuit diagram.....	32
7.4	Power MOSFET circuit diagram	33
7.5	Voltage feedback circuit diagram.....	34
7.6	Current feedback circuit diagram.....	35
7.7	Others	36
7.8	AT32F421/L021 MCU circuit diagram.....	37
7.9	AT32F413/F425/F415/F405 MCU circuit diagram	38
7.10	AT32F403A/A403A/F435 MCU circuit diagram.....	39
7.11	AT32F423/F455 MCU circuit diagram.....	40
8	Layout	41
8.1	Component positions.....	41
8.2	Top-layer layout	42
8.3	Bottom-layer layout	43
9	Bill of materials	44
10	Revision history	45

List of tables

Table 1. Jumper settings.....	11
Table 2. CN1 description.....	12
Table 3. CN2 description.....	12
Table 4. CN3 description.....	12
Table 5. CN4 description.....	13
Table 6. CN2 (AT-Link) description	13
Table 7. Pin connector description.....	14
Table 8. Summary of test points	15
Table 9. Document revision history.....	45

List of figures

Figure 1. Low voltage motor control evaluation board	6
Figure 2. Board system architecture.....	9
Figure 3. Jumper and connector positions	10
Figure 4. Incremental encoder circuit	17
Figure 5. Hall sensor circuit	17
Figure 6. Phase current sensing feedback circuit	18
Figure 7. DC bus current sensing feedback circuit.....	18
Figure 8. Phase current OCP sensing circuit	19
Figure 9. Bus OCP sensing circuit.....	19
Figure 10. Bus voltage sensing circuit.....	20
Figure 11. Output voltage sensing circuit	21
Figure 12. Virtual neutral point comparator circuit.....	21
Figure 13. V-shunt half-bridge power conversion circuit	22
Figure 14. Brake circuit.....	22
Figure 15. UART serial interface circuit.....	23
Figure 16. UART serial interface circuit.....	23
Figure 17. Potentiometer input interface circuit.....	23
Figure 18. Temperature sensing circuit	24
Figure 19. LED circuit	24
Figure 20. MCU socket circuit.....	25

1 Overview

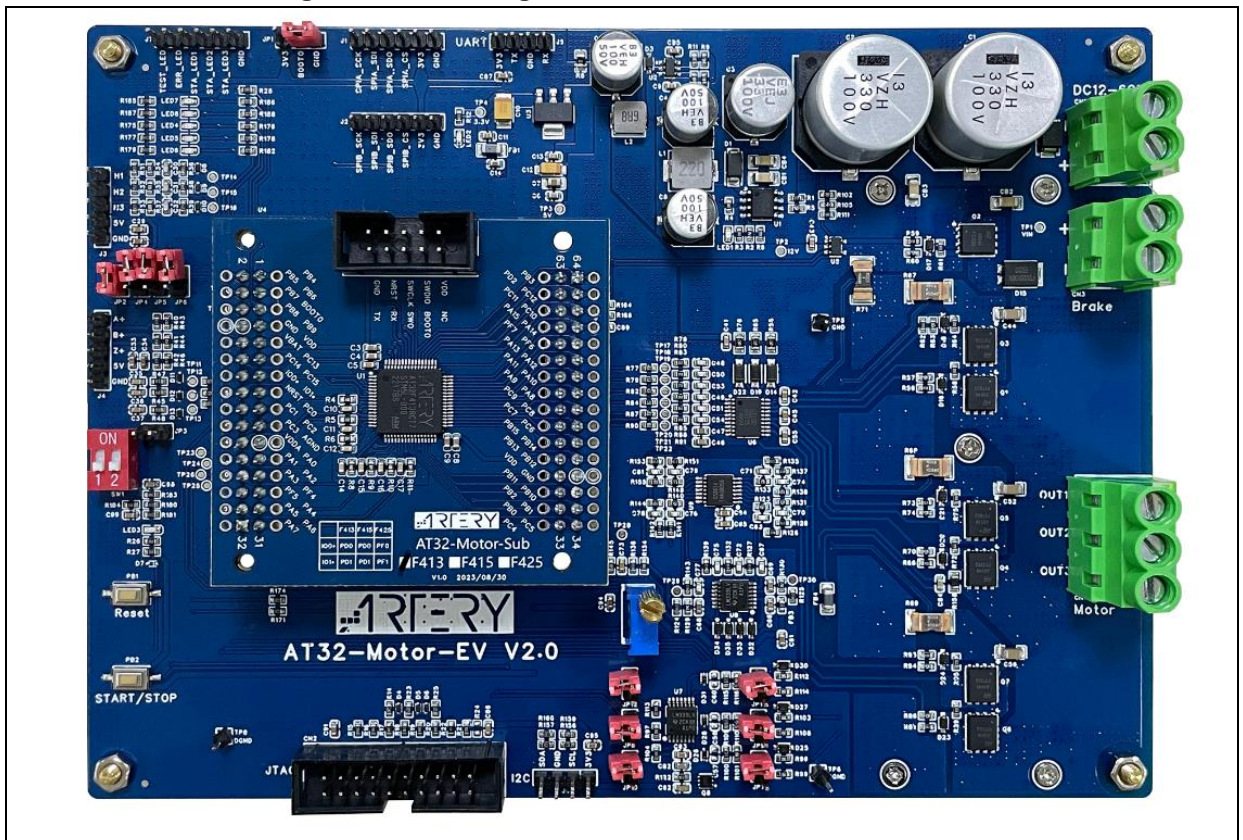
- The motor control evaluation board is a general-purpose low voltage three-phase motor drive based on AT32 MCU and its motor control function library. It can be used to drive BLDC, AC synchronous motor and asynchronous motor
- 1x MCU socket that is suitable to all AT32 MCUs for motor control algorithm execution
- Hall connector and encoder connector for rotor position feedback, to drive sensored motor in FOC vector control or six-step square wave mode
- Brake resistor connector for dynamic braking in high dynamic response control situations
- Three-phase output voltage sensing circuit connected to ADC, virtual neutral point circuit and comparator circuit, suitable for multiple BLDC six-step square wave sensorless applications
- 3x phase current sensing resistors and 1x DC ground bus current sensing resistor, supporting three current sensing modes (3-shunt, 2-shunt and 1-shunt current sensing modes)
- Built-in overcurrent sensing circuits for phase current and bus current
- Support sensored/sensorless FOC vector control algorithm to drive three-phase AC motor
- Support household, commercial and industrial motor control applications
- Input voltage/output current spec

Input voltage: 12V~60V

Maximum output phase current: 30A_{PEAK}

Overcurrent protection point: 45A_{PEAK}

Figure 1. Low voltage motor control evaluation board



2 Software and hardware requirements

- Windows®-based PC (Windows 8/10/11) to install user interface control program
- AT-Link or third-party programmer
- A USB-to-TLL cable (it is needed for third-party programmer) to connect UART onboard to PC for communication
- AT32 motor control demonstration project program
- ArteryMotorMonitor software for user interface control
- 3-phase AC motor
- DC power supply

3 Getting started

Rated specifications for motor control evaluation board

- Input voltage: 12V~60V
- Maximum output phase current: 30A_{PEAK}
- Overcurrent protection point: 45A_{PEAK}

Follow the steps below to start with:

- 1) Check that the Jumper's positions are correct (See Section 4.3)
- 2) Connect AT-Link to CN2 of the MCU daughter board, or connect JTAG to the main board's CN2
- 3) When using a third-party programmer, connect UART pin on the CN2 of MCU daughter board to PC via USB_to_TTL cable
- 4) Connect 3-phase motor cable to CN4, and the U, V, W wires are connected to OUT1, OUT2 and OUT3 respectively
- 5) When using position sensor, connect Hall sensor to J3 of the main board, or connect encoder to J4 of the main board
- 6) When using the comparator mode for zero-crossing detection in sensorless six-step square wave control, it is necessary to short-connect JP8, JP10 and JP12, to connect the compare signals to Hall sensing pin of the MCU
- 7) When using the ADC mode for zero-crossing detection in sensorless six-step square wave control, if DC bus voltage exceeds 34V, it is necessary to short-connect JP7, JP9 and JP11, and reduce output voltage of the motor voltage sensing circuit to avoid it surpassing 3.3V
- 8) Download the AT32 motor control demonstration code to the flash memory of MCU
- 9) Tune DC voltage and current output settings, and connect output to CN1 and then turn on power supply. LED1 (12V power status LED) and LED2 (3.3V power status LED) will be ON
- 10) Set parameters and control motor operation using ArteryMotorMonitor software

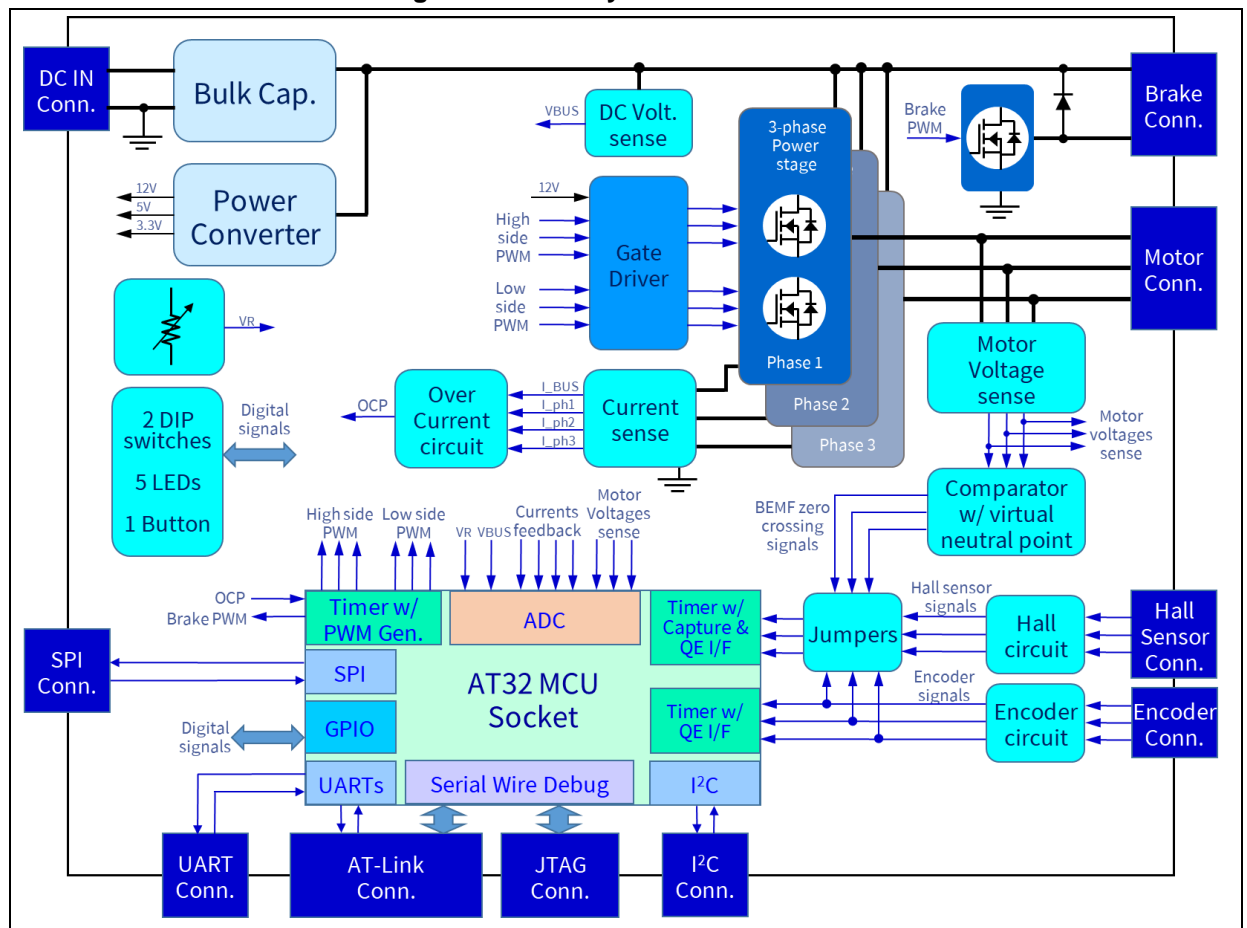
4 Hardware layout and configuration

4.1 System architecture of evaluation board

Figure 2 illustrates the system architecture of the low voltage motor control evaluation board.

The AT32 MCU socket is fit for most AT32 MCUs. The MCU PWM generator is used to control three-phase full-bridge circuit and brake circuit. The output of 3-phase power stage has a voltage divider circuit that can feedback 3 phases output voltages. A comparator circuit with virtual neutral point is able to feedback zero crossing signals of BLDC BEMF. Hall sensor and encoder connectors are used to feedback rotor positions. A rich choice of interfaces such as UART, I²C and SPI are available for communication purposes. A potentiometer analog input interface can be used to adjust resistive voltage divider while its output voltage command is read by ADC. In addition, there are two DIP switches and one button switch for setting control modes. Five color LEDs including an error-status LED are also available on the board.

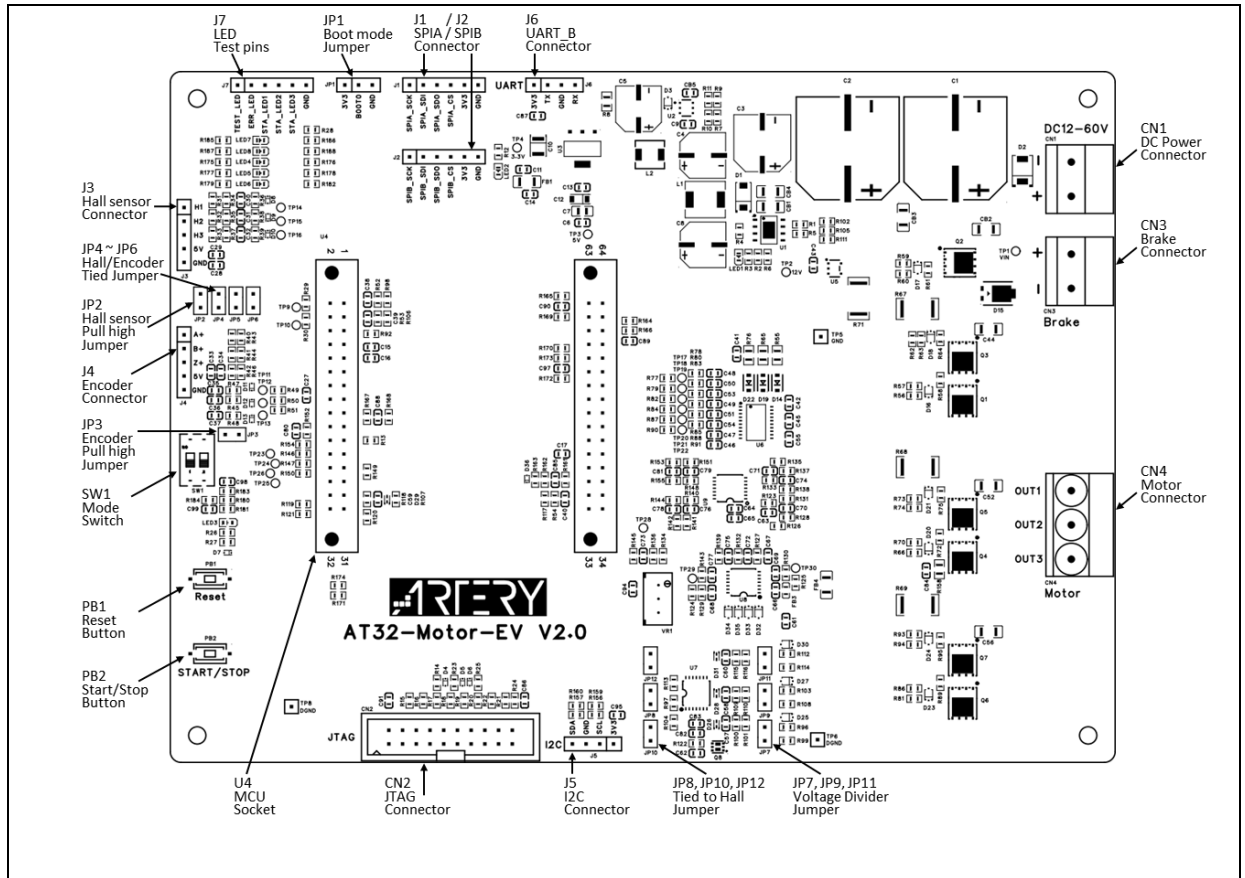
Figure 2. Board system architecture



4.2 Jumper and connector positions

The development board connector and jumper locations are as shown below.

Figure 3. Jumper and connector positions



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 signals to VCC pull-up resistor	CLOSED
JP3	Connect Encoder signals to VCC pull-up resistor	OPEN
JP4	Connect Encoder A signals to H1 (Hall signal) on MCU	OPEN
JP5	Connect Encoder B signals to H2 (Hall signal) on MCU	OPEN
JP6	Connect Encoder Z signals to H3 (Hall signal) on MCU	OPEN
JP7	This is used to connect BEMF1 voltage divider resistors in parallel to reduce divider value	OPEN
JP8	Connect BEMF1 compare signal output to H1 (Hall signal) on MCU	OPEN
JP9	This is used to connect BEMF2 voltage divider resistors in parallel to reduce divider value.	OPEN
JP10	Connect BEMF2 compare signal output to H2 (Hall signal) on MCU	OPEN
JP11	This is used to connect BEMF3 voltage divider resistors in parallel to reduce divider value.	OPEN
JP12	Connect BEMF3 compare signal output to H3 (Hall signal) on MCU	OPEN

4.4 Connectors

4.4.1 CN1

CN1 is used as a 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 for programming and debugging through third-party programmers.

Table 3. CN2 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 used to connect the board to brake resistor. The brake resistance is selected depending on the external voltage value to ensure that brake current must be lower than 40A, for instance, if bus voltage is 60V, then the brake resistance value must not be lower than 1.5Ω .

Table 4. CN3 description

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

4.4.4 CN4

CN4 is used to connect the board to the 3-phase motor power line.

Table 5. CN4 description

Pin	Symbol	Description
1	OUT1	Motor's U phase
3	OUT2	Motor's V phase
5	OUT3	Motor's W phase

4.4.5 CN2 on MCU

MCU's CN2 is a 10-pin AT-Link connector used to connect with AT-Link tool for programming and erasing operation.

Table 6. CN2 (AT-Link) description

Pin No.	Description	Pin No.	Description
1	3.3V supply	2	5.0V supply
3	TMS (SWDIO)	4	BOOT0
5	TCK (SWCLK)	6	TDO (SWO)
7	TMS (SWDIO)	8	UART_RX
9	RESET	10	UART_TX

4.4.6 Pin header connectors

Table 7. Pin connector description

Connector name	Pin No.	Symbol	Description
J1	1	SPIA_SCK	Clock pin (MCU_PA5) for the 1 st SPI, R119 must be removed
	2	SPIA_SDI	Master data input pin ((MCU_PA6)) for the 1 st SPI, R120 must be removed
	3	SPIA_SDO	Master data output pin (MCU_PA7) for the 1 st SPI, R121 must be removed
	4	SPIA_CS	The output pin (MCU_PB3) to enable SPI slave device for 1st SPI
	5	3V3	3.3V power supply
	6	GND	Ground
J2	1	SPIA_SCK	Clock pin ((MCU_PC7)) for the 2 nd SPI
	2	SPIA_SDI	Master data input pin (MCU_PC2) of the 2 nd SPI
	3	SPIA_SDO	Master data output pin (MCU_PC1) of the 2 nd SPI
	4	SPIA_CS	The output pin (MCU_PC6) to enable SPI slave device for 2 nd SPI
	5	3V3	3.3V power supply
	6	GND	Power ground
J3	1	H1	Hall sensor pin 1
	2	H2	Hall sensor pin 2
	3	H3	Hall sensor pin 3
	4	5V	5V power supply
	5	GND	Power ground
J4	1	A+	Encoder phase A pin
	2	B+	Encoder phase B pin
	3	Z+	Encoder phase Z pin
	4	5V	Encoder 5V power supply
	5	GND	Encoder power ground
J5	1	3V3	3.3V power supply
	2	SCL	I2C SCL pin
	3	GND	Power ground
	4	SDA	I2C SDA pin
J6	1	3V3	3.3V power supply
	2	TX	UART TX pin
	3	GND	Power ground
	4	RX	UART RX pin
J7	1	TEST_LED	Blue LED (MCU_PA11)
	2	ERR_LED	Red LED (MCU_PC13)

Connector name	Pin No.	Symbol	Description
	3	STA_LED1	Green LED1 (MCU_PC14)
	4	STA_LED2	Green LED2 (MCU_PC15)
	5	STA_LED3	Green LED3 (MCU_PB9)
	6	GND	Power ground

4.5 Test points

Table 8. 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	UART1_TX signal (PB6)
TP10	UART1_RX signal (PB7)
TP11	Encoder A+ signal
TP12	Encoder B+ signal
TP13	Encoder Z+ signal
TP14	Hall sensor H1 signal
TP15	Hall sensor H2 signal
TP16	Hall sensor H3 signal
TP17	PWM1H signal
TP18	PWM2H signal
TP19	PWM3H signal
TP20	PWM1L signal
TP21	PWM2L signal
TP22	PWM3L signal
TP23	The amplified signal of 1 st phase current sensing resistor
TP24	The amplified signal of 2 nd phase current sensing resistor
TP25	The amplified signal of 3 rd phase current sensing resistor
TP26	The amplified signal of DC BUS current sensing resistor
TP28	Overcurrent emergency stop protection BKIN signal
TP29	Overcurrent setpoint voltage of DC bus current
TP30	Overcurrent setpoint voltage of phase current

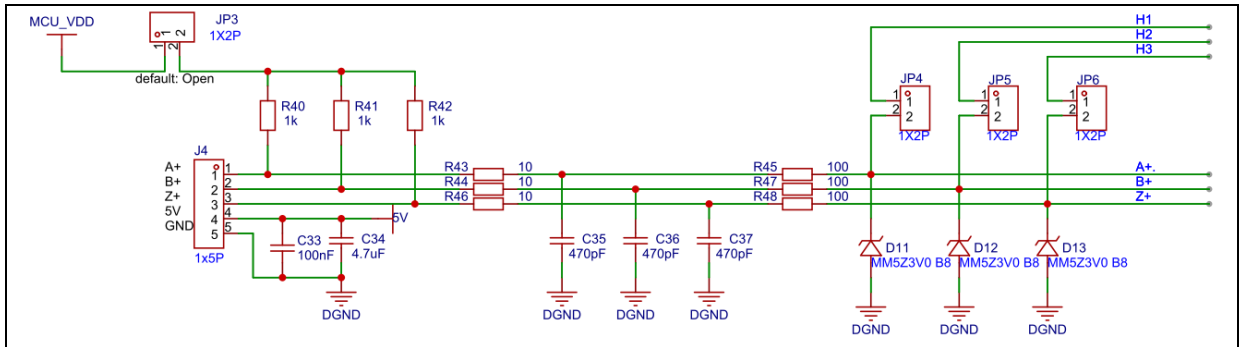
5 Hardware circuit

- A three-phase full-bridge power stage circuit that can drive a three-phase motor, and a brake resistor circuit that can consume regenerative power by applying an external resistor
- Two buck converters: one steps down the input DC voltage to 12 V to supply the gate driver chip, and the other one converts 12 V to 5 V to supply Hall sensor and encoder; with a LDO circuit providing 3.3 V operating voltage
- Encoder and Hall sensor connectors to feedback rotor position
- Three current sensing resistors and current sensing circuit to feedback three-phase current, and one current sensing resistor on DC bus to feedback bus current, supporting single-shunt current sensing control
- OCP (overcurrent protection) circuit, included in the current sensing feedback circuit, is connected to MCU to shut down PWM output upon overcurrent event
- Three-phase terminal voltage divider circuit and feedback signal circuit connected to MCU's ADC pin, virtual neutral point circuit and phase voltage comparator circuit. They can be used in six-step square-wave sensorless control mode
- DC input voltage divider circuit for sensing DC bus voltage, and a temperature sensing circuit composed of a NTC (negative temperature coefficient) resistor to feedback MOSFET temperature
- RESET button, USER button, two custom DIP switches, four status LEDs and one error LED
- A potentiometer circuit that is connected to MCU ADC pin and can be user-defined function
- I2C interface and UART interface
- Provides up to two SPI interfaces, in practice, the number of available interfaces depends on actual MCU peripherals
- AT-Link connector, and the JTAG connector for 3rd-party programmer

5.1 Incremental encoder circuit

Figure 4 illustrates the encoder circuit. When the encoder is open-drain type, the JP3 can be short-connected so that the input pin is connected to the 1kΩ pull-up resistor. The input signals have to go through a RC low-pass filter (consisting of a 10Ω resistor and 470pF capacitor) before being connected to MCU. If the used MCU without the corresponding peripheral pins, it is possible to use other timer peripherals of MCU by connecting JP4~JP6 to Hall sensor output port.

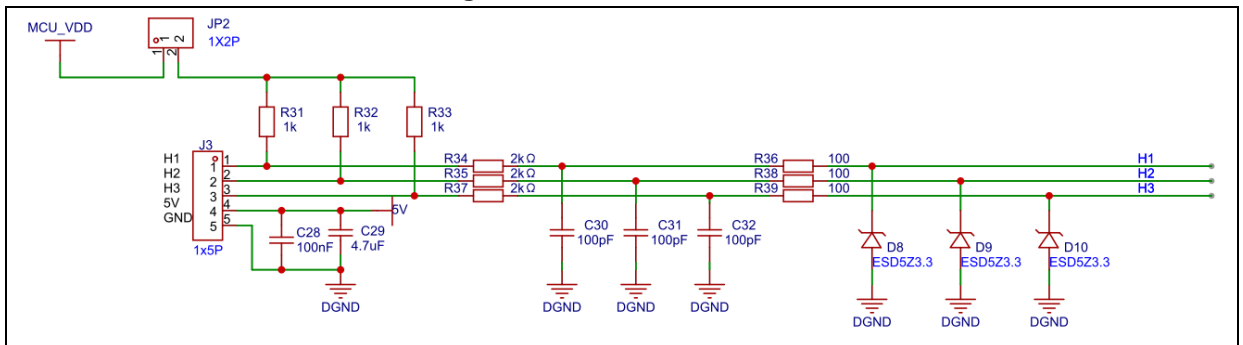
Figure 4. Incremental encoder circuit



5.2 Hall sensor circuit

Figure 5 illustrates the Hall sensor circuit. Typically, the Hall sensor is open-drain type, so JP2 jumper is short-connected by default, and the input pin is then connected to a 1kΩ pull-up resistor. The input signals have to go through a RC low-pass filter (consisting of 2kΩ resistor and 100pF capacitor) before being connected to MCU.

Figure 5. Hall sensor circuit

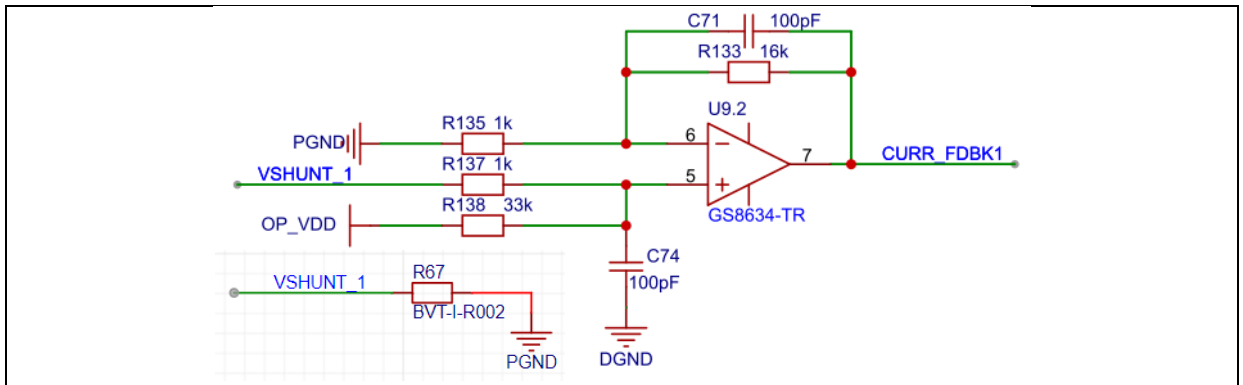


5.3 Current sensing circuit

5.3.1 Phase current sensing circuit

Figure 6 illustrates the phase current sensing circuit diagram. The phase current passes through a 2mΩ current sensing resistor, gets amplified by 16.5 times by an amplifying circuit, and finally pulls the output DC voltage up to 1.65 V. Therefore, the maximum current sensing range is within $\pm 50A_{PEAK}$.

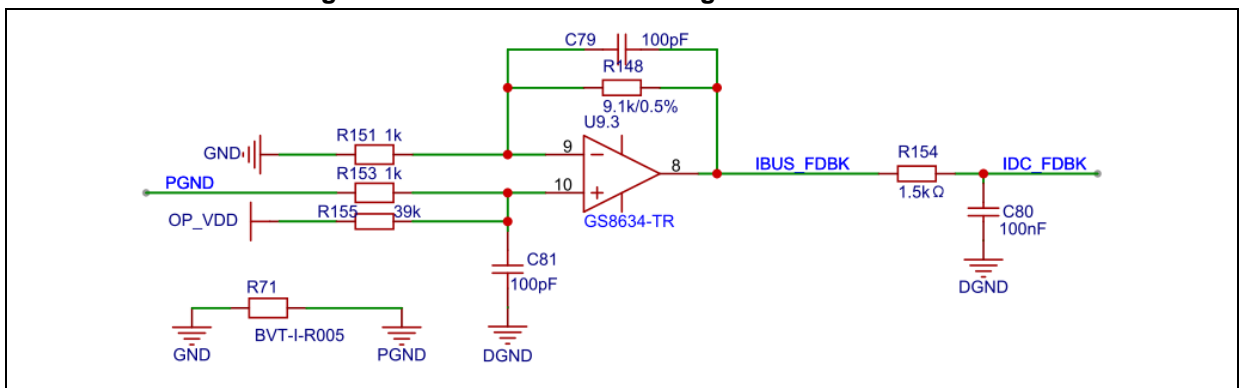
Figure 6. Phase current sensing feedback circuit



5.3.2 DC bus current sensing circuit

Figure 7 illustrates the DC bus current sensing circuit diagram. The bus current passes through a 5 mΩ current sensing resistor, gets amplified by 9.85 times by an amplifying circuit, and finally pulls the output DC voltage up to 0.833 V. Therefore, the maximum current sensing range is between -16.9A_{PEAK} and 50.1A_{PEAK}. Then the output signals go through a RC low-pass filter (consisting of a 1.5kΩ resistor and a 100nF capacitor) and generate IDC_FDBK (average DC bus current signal).

Figure 7. DC bus current sensing feedback circuit



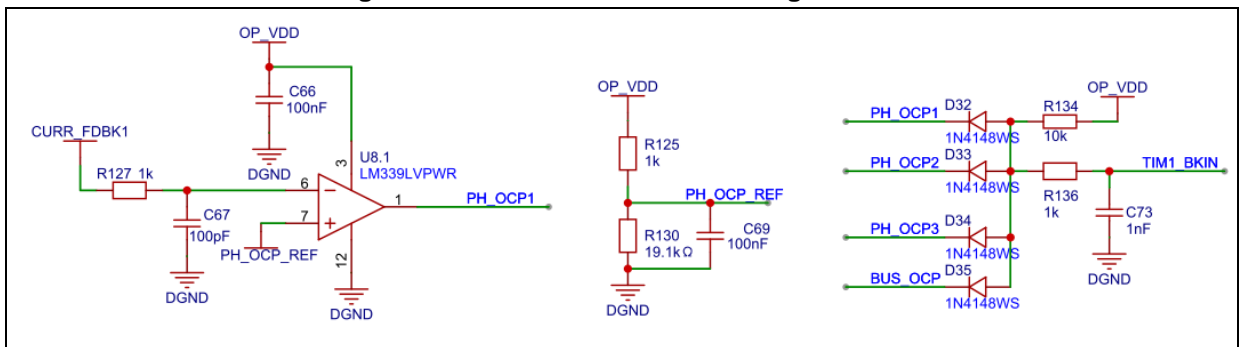
5.4 OCP sensing circuit

5.4.1 Three-phase OCP sensing circuit

The three-phase overcurrent sensing circuit consists of three comparator circuits. Figure 8 takes one of the three-phase overcurrent sensing circuits as an example.

The three-phase overcurrent protection circuit contains an overcurrent reference level divider circuit. The protection circuit compares the amplified three-phase current feedback signals with the overcurrent reference voltage. If the feedback signals are higher than the reference voltage, the comparator outputs low, which is connected 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 the phase current is $45A_{PEAK}$.

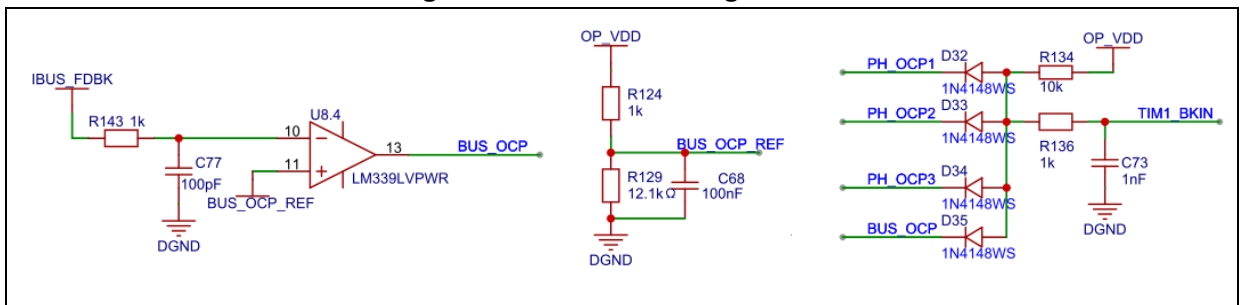
Figure 8. Phase current OCP sensing circuit



5.4.2 Bus OCP sensing circuit

The bus overcurrent sensing circuit is composed of a comparator circuit. Figure 9 shows the bus overcurrent protection circuit, which contains an overcurrent reference level divider circuit. The overcurrent protection circuit compares the amplified bus current feedback signals with the overcurrent reference voltage. If the feedback signals are higher than the reference voltage, the comparator outputs low, which is connected 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 the phase current is $45A_{PEAK}$.

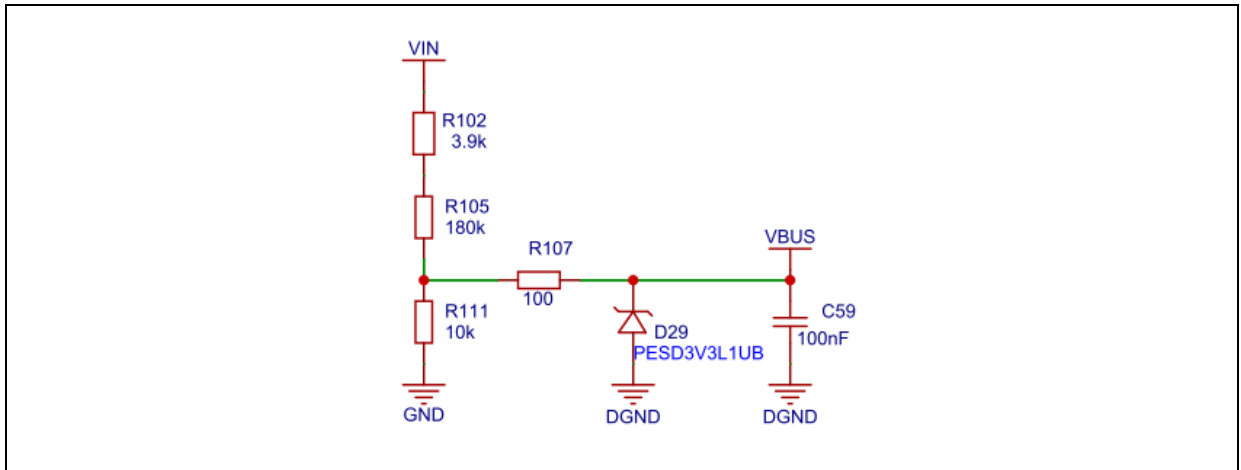
Figure 9. Bus OCP sensing circuit



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. The overvoltage/undervoltage protection functions can be achieved according to the bus voltage feedback. The driver output voltage can be estimated based on three-phase PWM duty cycles, which can then be used for BEMF estimation in sensorless control mode.

Figure 10. Bus voltage sensing circuit

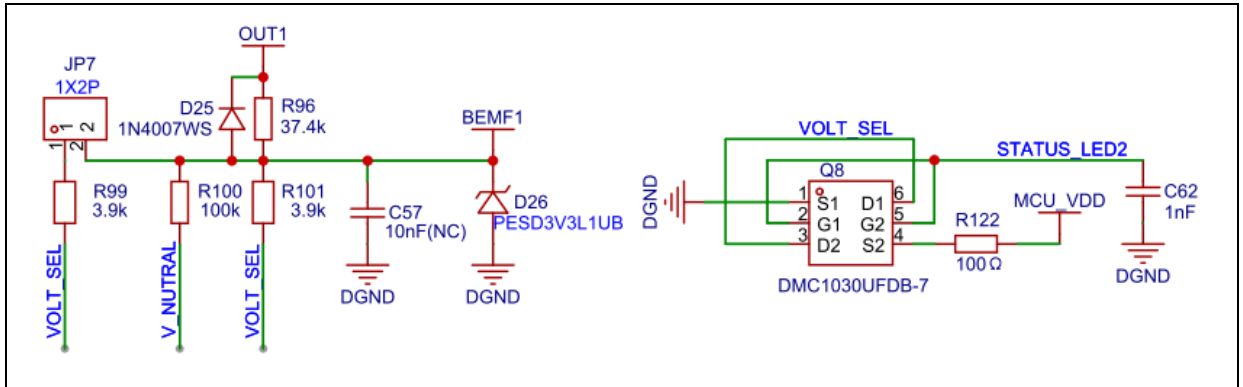


5.6 Three-phase output voltage sensing circuit

Figure 11 uses OUT1 output voltage sensing as an example to illustrate the three-phase voltage sensing circuit. The filtering capacitor after voltage division can be replaced or removed according to the actual needs. This circuit divides the output voltage with R96 and R101. When the DC bus voltage exceeds 34V, it is necessary to short-connect JP9 so that R99 is connected with R101 in parallel to reduce the divided voltage within 3.3V.

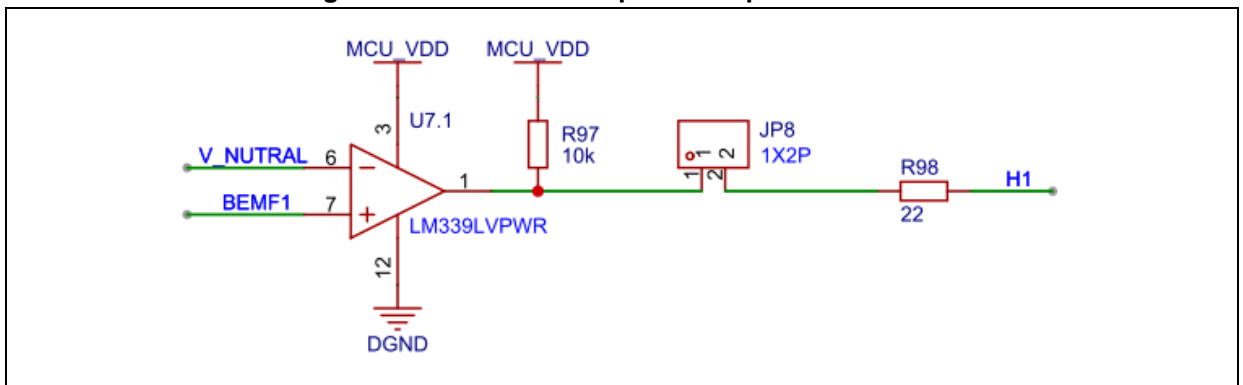
In circuit, the Q8 chip contains a P-channel MOSFET and N-channel MOSFET, forming a push-pull circuit. In most cases, the control signal STATUS_LED2 is at 3.3V high level, which sets the VOLT_SEL signal grounded at low level. Therefore, R99 and R101 are grounded, forming a general voltage division circuit. Such circuit passes through a low-pass RC filtering circuit and gets connected to MCU board, and after a low-pass filtering circuit (1Ω and 1nF capacitor), it is connected to the MCU's ADC input pin. In sine wave drive mode, this circuit can be used to measure the three phases voltages of motor, and then estimate three-phase BEMF accordingly based on motor current data. In six-step square wave sensorless drive mode, this circuit can be used to detect the zero-crossing point of BEMF of the open phase winding. The detection of zero-crossing point takes place during PWM OFF or PWM ON period. During PWM OFF period, it is hard to detect accurately the zero-crossing point because of ADC being unable to sense negative voltage. In response to this issue, ARTERY has developed a patented technology: put a D25 diode in parallel next to R96. When the STATUS_LED2 is grounded at low level, the VOLT_SEL is at 3.3V high level, and thus the D25 turns on and R96 is bypassed, making the BEMF1 output voltage to become the OUT1 voltage plus conductive voltage drop of diode D25. In this way, the OUT1 voltage is not attenuated by voltage division circuit and its base voltage is increased, making it possible to accurately detect BEMF zero-crossing during PWM OFF period.

Figure 11. Output voltage sensing circuit



In addition to detecting zero crossing point of open phase by ADC, the evaluation board also offers a comparator circuit with virtual neutral point as shown in Figure 12. Connect the three divided voltage signals via three 100kΩ resistors to generate virtual neutral point signals. The three-phase voltages are then compared with virtual neutral point signals respectively to judge BEMF zero crossing point based on comparator output level. In the figure below, short connecting jumper can connect the comparator signal to MCU's Hall pin.

Figure 12. Virtual neutral point comparator circuit

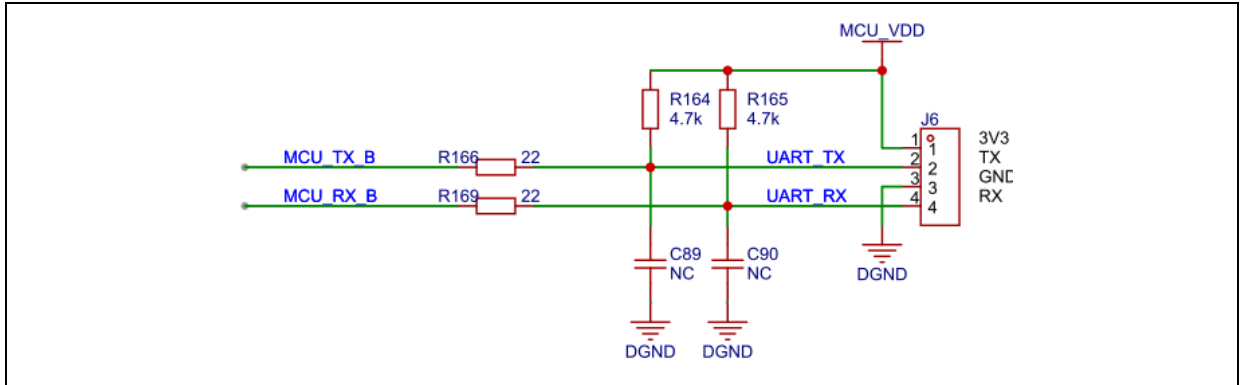


5.8 Communication circuit

5.8.1 UART interface

In addition to directly connecting the MCU's UART1 serial port, the evaluation board offers another serial interface as shown below. The actual usability depends on the available peripherals resource on the MCU. For details, please refer to section 6.

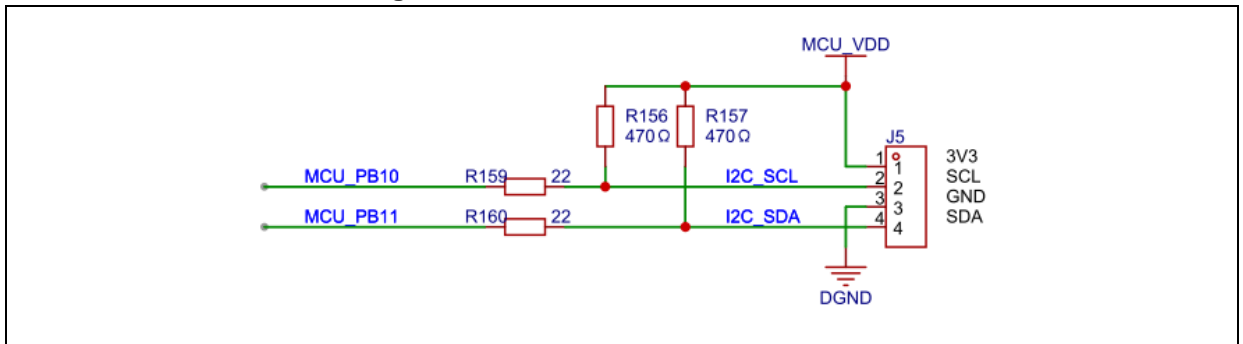
Figure 15. UART serial interface circuit



5.8.2 I2C interface

The I2C interface on the board is shown in Figure 16. The pull-up resistance values are adjustable according to the actual transmission speed requirements.

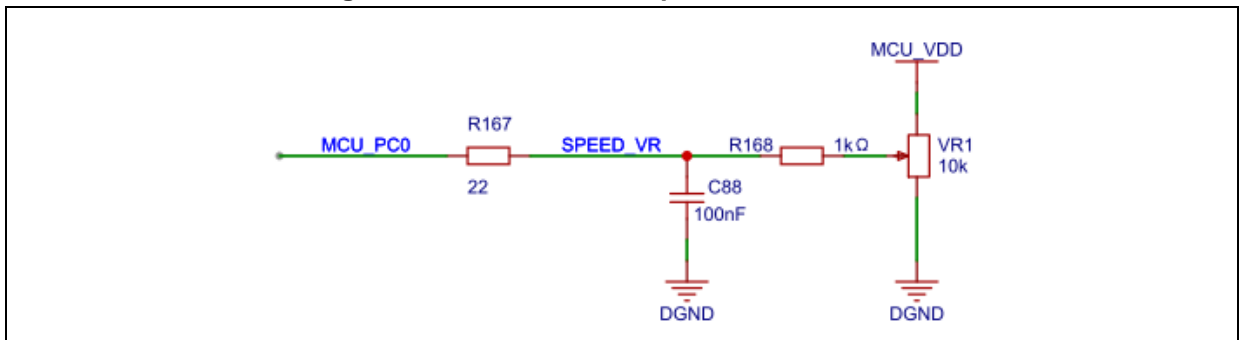
Figure 16. I2C serial interface circuit



5.9 Potentiometer input interface

This circuit contains a 30-to-10 kΩ potentiometer that is connected to MCU ADC channel 10 (PC0).

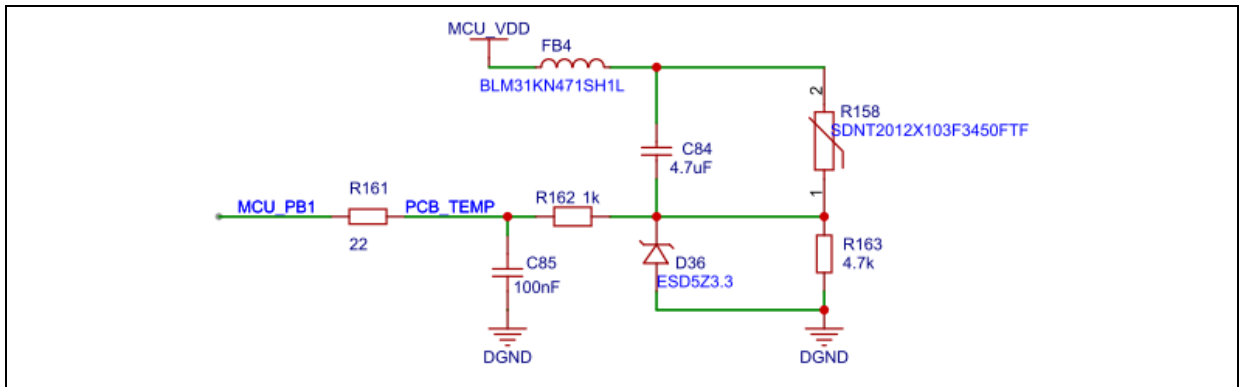
Figure 17. Potentiometer input interface circuit



5.10 Temperature sensing circuit

Figure 18 illustrates the temperature sensing circuit on the board. A 10kΩ NTC resistor at 25°C is placed closely next to Q4 MOSFET to sense MOSFET temperature. When the temperature rises, the NTC resistance decreases, enhancing the voltage of the voltage division circuit. The voltage then passes through a low-pass RC filter and is connected to MCU ADC channel 9 (PB1) to achieve overtemperature protection of the power stage.

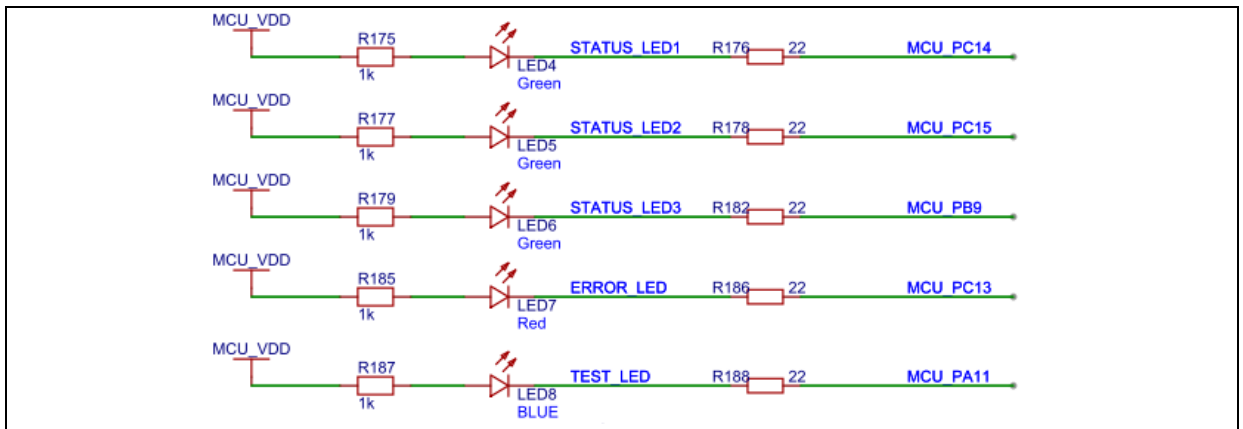
Figure 18. Temperature sensing circuit



5.11 LED circuit

There are three green status LEDs, one red error LED and one blue test LED onboard, as shown below.

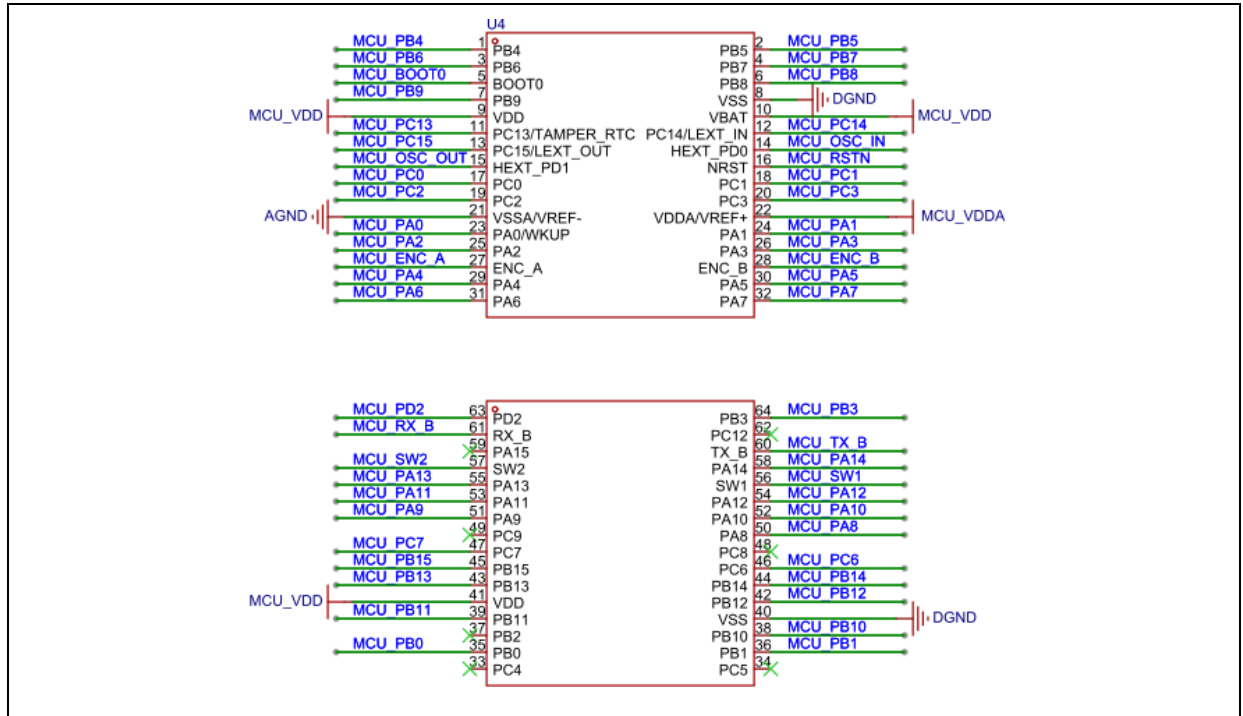
Figure 19. LED circuit



5.12 MCU socket

The MCU socket onboard is shown in Figure 20. This socket is suitable for various AT32 MCUs to implement motor control applications.

Figure 20. MCU socket circuit



6 MCU pin map

6.1 AT32F421/L021 MCU pin map

Socket pin no.	Socket pin name	MCU pin no.	AT32F421/L021	Socket pin no.	Socket pin name	MCU pin no.	AT32F421/L021
1	MCU_PB4	40	TMR3_CH1(PB4)	33	MCU_PC4		
2	MCU_PB5	41	TMR3_CH2(PB5)	34	MCU_PC5		
3	MCU_PB6	42	USART1_TX(PB6)	35	MCU_PB0	18	TMR3_CH3(PB0)
4	MCU_PB7	43	USART1_RX(PB7)	36	MCU_PB1	19	ADC_IN9(PB1)
5	MCU_BOOT0	44	BOOT0	37	MCU_PB2		
6	MCU_PB8	45	TMR16_CH1(PB8)	38	MCU_PB10	21	I2C2_SCL(PB10)
7	MCU_PB9	46	TMR17_CH1(PB9)	39	MCU_PB11	22	I2C2_SDA(PB11)
8	DGND	47	VSS	40	DGND	23	VSS
9	MCU_VDD	48	VDD	41	MCU_VDD	24	VDD
10	MCU_VBAT	1	VDD	42	MCU_PB12	25	TMR1_BKIN(PB12)
11	MCU_PC13	2	PC13	43	MCU_PB13	26	TMR1_CH1N(PB13)
12	MCU_PC14	3	PC14	44	MCU_PB14	27	TMR1_CH2N(PB14)
13	MCU_PC15	4	PC15	45	MCU_PB15	28	TMR1_CH3N(PB15)
14	MCU_OSC_IN	5	HEXT_IN(PF0)	46	MCU_PC6		
15	MCU_OSC_OUT	6	HEXT_OUT(PF1)	47	MCU_PC7		
16	MCU_RSTn	7	NRST	48	MCU_PC8		
17	MCU_PC0	20	ADC_IN10(PB2)	49	MCU_PC9		
18	MCU_PC1			50	MCU_PA8	29	TMR1_CH1(PA8)
19	MCU_PC2			51	MCU_PA9	30	TMR1_CH2(PA9)
20	MCU_PC3			52	MCU_PA10	31	TMR1_CH3(PA10)
21	MCU_AGND	8	VSSA	53	MCU_PA11	32	TMR1_CH4(PA11)
22	MCU_VDDA	9	VDDA	54	MCU_PA12	33	PA12
23	MCU_PA0	10	ADC_IN0(PA0)	55	MCU_PA13	34	SWDIO(PA13)
24	MCU_PA1	11	ADC_IN1(PA1)	56	MCU_SW1	35	PF6
25	MCU_PA2	12	ADC_IN2(PA2)	57	MCU_SW2	36	PF7
26	MCU_PA3	13	ADC_IN3(PA3)	58	MCU_PA14	37	SWCLK(PA14)/USART2_TX
27	MCU_ENCODER_A			59	MCU_PA15	38	USART2_RX(PA15)
28	MCU_ENCODER_B			60	MCU_UART_TX_B		
29	MCU_PA4	14	ADC_IN4(PA4)	61	MCU_UART_RX_B		
30	MCU_PA5	15	ADC_IN5 / SPI1_SCK (PA5)	62	MCU_PC12		
31	MCU_PA6	16	ADC_IN6 / SPI1_MISO (PA6)	63	MCU_PD2		
32	MCU_PA7	17	ADC_IN7 / SPI1_MOSI (PA7)	64	MCU_PB3	39	PB3

6.2 AT32F413/F425/F415/F405 MCU pin map

Socket pin no.	Socket pin name	MCU pin no.	AT32F413/F425/F415/F405	Socket pin no.	Socket pin name	MCU pin no.	AT32F413/F425/F415/F405
1	MCU_PB4	56	TMR3_CH1(PB4)	33	MCU_PC4	24	ADC12_IN14(PC4)
2	MCU_PB5	57	TMR3_CH2(PB5)	34	MCU_PC5	25	ADC_IN15(PC5)
3	MCU_PB6	58	USART1_TX(PB6)	35	MCU_PB0	26	TMR3_CH3(PB0)
4	MCU_PB7	59	USART1_RX(PB7)	36	MCU_PB1	27	ADC_IN9(PB1)
5	MCU_BOOT0	60	BOOT0	37	MCU_PB2	28	PB2 (F413/F415/F405:BOOT1)
6	MCU_PB8	61	TMR10_CH1(PB8)	38	MCU_PB10	29	I2C2_SCL(PB10)
7	MCU_PB9	62	TMR11_CH1(PB9)	39	MCU_PB11	30	I2C2_SDA(PB11)
8	DGND	63	VSS	40	DGND	31	VSS
9	MCU_VDD	64	VDD	41	MCU_VDD	32	VDD
10	MCU_VBAT	1	VDD	42	MCU_PB12	33	TMR1_BKIN(PB12)
11	MCU_PC13	2	PC13	43	MCU_PB13	34	TMR1_CH1N(PB13)
12	MCU_PC14	3	PC14	44	MCU_PB14	35	TMR1_CH2N(PB14)
13	MCU_PC15	4	PC15	45	MCU_PB15	36	TMR1_CH3N(PB15)
14	MCU_OSC_IN	5	HEXT_IN(PD0/F425:PF0)	46	MCU_PC6	37	TMR8_CH1(PC6)
15	MCU_OSC_OUT	6	HEXT_OUT(PD1/F425:PF1)	47	MCU_PC7	38	TMR8_CH2(PC7)
16	MCU_RSTn	7	NRST	48	MCU_PC8	39	TMR8_CH3(PC8)
17	MCU_PC0	8	ADC12_IN10(PC0)	49	MCU_PC9	40	TMR8_CH4(PC9)
18	MCU_PC1	9	ADC12_IN11(PC1)	50	MCU_PA8	41	TMR1_CH1(PA8)
19	MCU_PC2	10	ADC12_IN12(PC2)	51	MCU_PA9	42	TMR1_CH2(PA9)
20	MCU_PC3	11	ADC12_IN13(PC3)	52	MCU_PA10	43	TMR1_CH3(PA10)
21	MCU_AGND	12	VSSA	53	MCU_PA11	44	TMR1_CH4(PA11)
22	MCU_VDDA	13	VDDA	54	MCU_PA12	45	PA12
23	MCU_PA0	14	ADC_IN0(PA0)	55	MCU_PA13	46	TMS-SWDIO(PA13)
24	MCU_PA1	15	ADC_IN1(PA1)	56	MCU_SW1	47	PF6
25	MCU_PA2	16	ADC_IN2(PA2)	57	MCU_SW2	48	PF7
26	MCU_PA3	17	ADC_IN3(PA3)	58	MCU_PA14	49	TCK-SWCLK(PA14)
27	MCU_ENCODER_A	18	TMR5_CH1(PF4)	59	MCU_PA15	50	PA15
28	MCU_ENCODER_B	19	TMR5_CH2(PF5)	60	MCU_UART_TX_B	51	UART3_TX(PC10)
29	MCU_PA4	20	ADC_IN4(PA4)	61	MCU_UART_RX_B	52	UART3_RX(PC11)
30	MCU_PA5	21	ADC_IN5 / SPI1_SCK (PA5)	62	MCU_PC12	53	PC12
31	MCU_PA6	22	ADC_IN6 / SPI1_MISO (PA6)	63	MCU_PD2	54	PD2
32	MCU_PA7	23	ADC_IN7 / SPI1_MOSI (PA7)	64	MCU_PB3	55	PB3(SWO)

6.3 AT32F403A/A403A/F435 MCU pin map

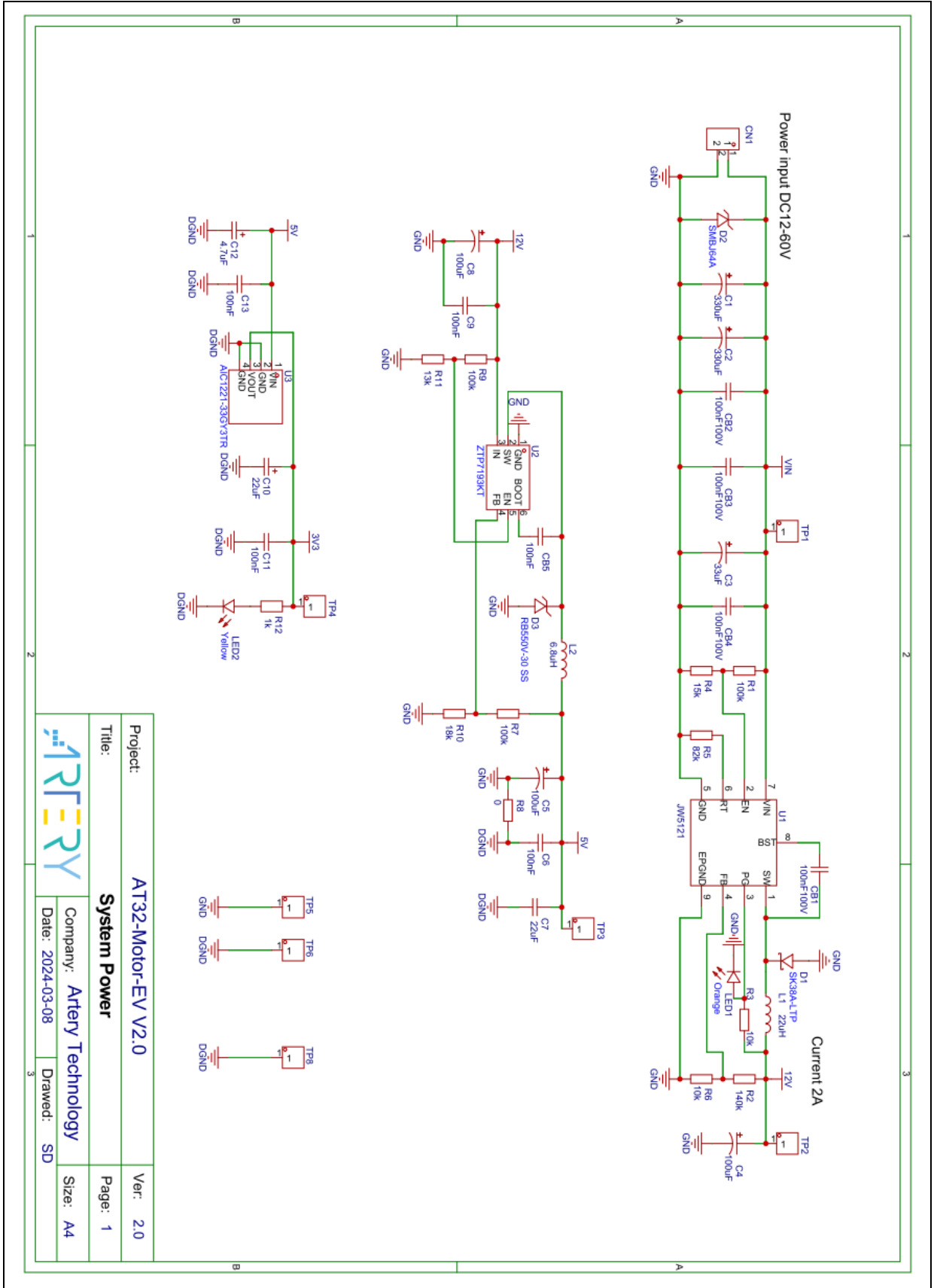
Socket pin no.	Socket pin name	MCU pin no.	AT32F403A/A403A/F435	Socket pin no.	Socket pin name	MCU pin no.	AT32F403A/A403A/F435
1	MCU_PB4	56	TMR3_CH1(PB4)	33	MCU_PC4	24	ADC12_IN14(PC4)
2	MCU_PB5	57	TMR3_CH2(PB5)	34	MCU_PC5	25	ADC_IN15(PC5)
3	MCU_PB6	58	USART1_TX(PB6)	35	MCU_PB0	26	TMR3_CH3(PB0)
4	MCU_PB7	59	USART1_RX(PB7)	36	MCU_PB1	27	ADC_IN9(PB1)
5	MCU_BOOT0	60	BOOT0	37	MCU_PB2	28	PB2/BOOT1
6	MCU_PB8	61	TMR10_CH1(PB8)	38	MCU_PB10	29	I2C2_SCL(PB10)
7	MCU_PB9	62	TMR11_CH1(PB9)	39	MCU_PB11	30	I2C2_SDA(PB11)
8	DGND	63	VSS	40	DGND	31	VSS/ F435:PH3
9	MCU_VDD	64	VDD	41	MCU_VDD	32	VDD
10	MCU_VBAT	1	VDD	42	MCU_PB12	33	TMR1_BKIN(PB12)
11	MCU_PC13	2	PC13	43	MCU_PB13	34	TMR1_CH1N(PB13)
12	MCU_PC14	3	PC14	44	MCU_PB14	35	TMR1_CH2N(PB14)
13	MCU_PC15	4	PC15	45	MCU_PB15	36	TMR1_CH3N(PB15)
14	MCU_OSC_IN	5	HEXT_IN(PD0/F435:PH0)	46	MCU_PC6		
15	MCU_OSC_OUT	6	HEXT_OUT(PD1/F435:PH1)	47	MCU_PC7		
16	MCU_RSTn	7	NRST	48	MCU_PC8		
17	MCU_PC0	8	ADC12_IN10(PC0)	49	MCU_PC9		
18	MCU_PC1	9	ADC12_IN11(PC1)	50	MCU_PA8	41	TMR1_CH1(PA8)
19	MCU_PC2	10	ADC12_IN12(PC2)	51	MCU_PA9	42	TMR1_CH2(PA9)
20	MCU_PC3	11	ADC12_IN13(PC3)	52	MCU_PA10	43	TMR1_CH3(PA10)
21	MCU_AGND	12	VSSA	53	MCU_PA11	44	TMR1_CH4(PA11)
22	MCU_VDDA	13	VDDA	54	MCU_PA12	45	PA12
23	MCU_PA0	14	ADC_IN0(PA0)	55	MCU_PA13	46	TMS-SWDIO(PA13)
24	MCU_PA1	15	ADC_IN1(PA1)	56	MCU_SW1	39	PC8
25	MCU_PA2	16	ADC_IN2(PA2)	57	MCU_SW2	40	PC9
26	MCU_PA3	17	ADC_IN3(PA3)	58	MCU_PA14	49	TCK-SWCLK(PA14)
27	MCU_ENCODER_A	37	TMR8_CH1(PC6)	59	MCU_PA15	50	PA15
28	MCU_ENCODER_B	38	TMR8_CH2(PC7)	60	MCU_UART_TX_B	51	UART3_TX(PC10)
29	MCU_PA4	20	ADC_IN4(PA4)	61	MCU_UART_RX_B	52	UART3_RX(PC11)
30	MCU_PA5	21	ADC_IN5 / SPI1_SCK (PA5)	62	MCU_PC12	53	PC12
31	MCU_PA6	22	ADC_IN6 / SPI1_MISO (PA6)	63	MCU_PD2	54	PD2
32	MCU_PA7	23	ADC_IN7 / SPI1_MOSI (PA7)	64	MCU_PB3	55	PB3(SWO)

6.4 AT32F423/F55 MCU pin map

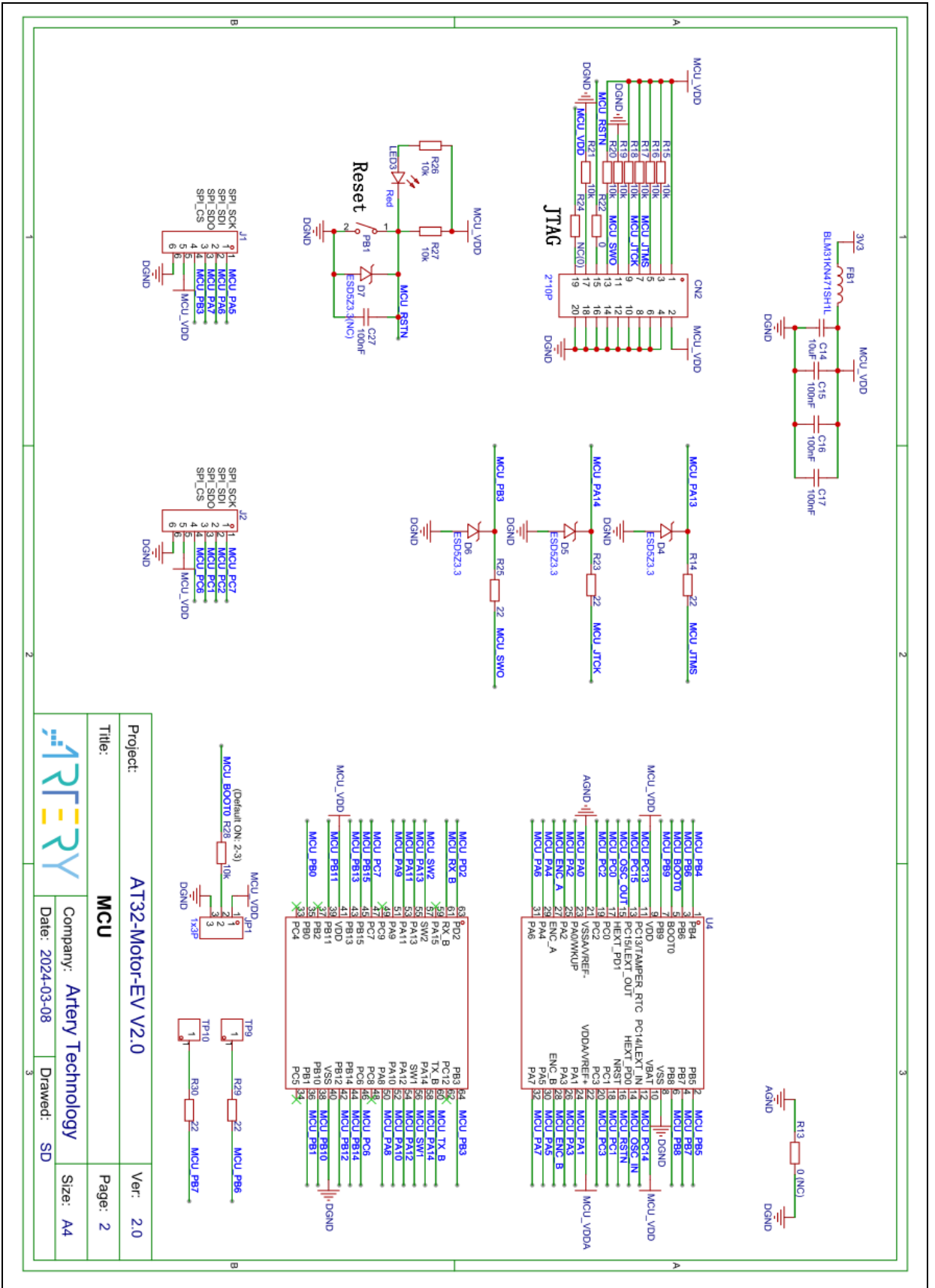
Socket pin no.	Socket pin name	MCU pin no.	AT32F403A/A403A/F435	Socket pin no.	Socket pin name	MCU pin no.	AT32F403A/A403A/F435
1	MCU_PB4	56	TMR3_CH1(PB4)	33	MCU_PC4	24	ADC12_IN14(PC4)
2	MCU_PB5	57	TMR3_CH2(PB5)	34	MCU_PC5	25	ADC_IN15(PC5)
3	MCU_PB6	58	USART1_TX(PB6)	35	MCU_PB0	26	TMR3_CH3(PB0)
4	MCU_PB7	59	USART1_RX(PB7)	36	MCU_PB1	27	ADC_IN9(PB1)
5	MCU_BOOT0	60	BOOT0	37	MCU_PB2	28	PB2 (F455:BOOT1)
6	MCU_PB8	61	TMR10_CH1(PB8)	38	MCU_PB10	29	I2C2_SCL(PB10)
7	MCU_PB9	62	TMR11_CH1(PB9)	39	MCU_PB11	30	I2C2_SDA(PB11)
8	DGND	63	VSS	40	DGND		
9	MCU_VDD	64	VDD	41	MCU_VDD	32	VDD
10	MCU_VBAT	1	VDD	42	MCU_PB12	33	TMR1_BKIN(PB12)
11	MCU_PC13	2	PC13	43	MCU_PB13	34	TMR1_CH1N(PB13)
12	MCU_PC14	3	PC14	44	MCU_PB14	35	TMR1_CH2N(PB14)
13	MCU_PC15	4	PC15	45	MCU_PB15	36	TMR1_CH3N(PB15)
14	MCU_OSC_IN	5	HEXT_IN(PF0/F455:PH0)	46	MCU_PC6	37	PC6
15	MCU_OSC_OUT	6	HEXT_OUT(PF1/F455:PH1)	47	MCU_PC7	38	SPI2_SCK(PC7)
16	MCU_RSTn	7	NRST	48	MCU_PC8	39	
17	MCU_PC0	8	ADC12_IN10(PC0)	49	MCU_PC9	40	
18	MCU_PC1	9	SPI2_MOSI(PC1)	50	MCU_PA8	41	TMR1_CH1(PA8)
19	MCU_PC2	10	SPI2_MISO(PC2)	51	MCU_PA9	42	TMR1_CH2(PA9)
20	MCU_PC3	11	ADC12_IN13(PC3)	52	MCU_PA10	43	TMR1_CH3(PA10)
21	MCU_AGND	12	VSSA	53	MCU_PA11	44	TMR1_CH4(PA11)
22	MCU_VDDA	13	VDDA	54	MCU_PA12	45	PA12
23	MCU_PA0	14	ADC_IN0(PA0)	55	MCU_PA13	46	TMS-SWDIO(PA13)
24	MCU_PA1	15	ADC_IN1(PA1)	56	MCU_SW1	39	PC8
25	MCU_PA2	16	ADC_IN2(PA2)	57	MCU_SW2	40	PC9
26	MCU_PA3	17	ADC_IN3(PA3)	58	MCU_PA14	49	TCK-SWCLK(PA14)
27	MCU_ENCODER_A	47	TMR2_CH1(PF6/F455:PH2)	59	MCU_PA15	50	PA15
28	MCU_ENCODER_B	31	TMR2_CH2(PF8/F455:PH3)	60	MCU_UART_TX_B	51	UART3_TX(PC10)
29	MCU_PA4	20	ADC_IN4(PA4)	61	MCU_UART_RX_B	52	UART3_RX(PC11)
30	MCU_PA5	21	ADC_IN5 / SPI1_SCK (PA5)	62	MCU_PC12	53	PC12
31	MCU_PA6	22	ADC_IN6 / SPI1_MISO (PA6)	63	MCU_PD2	54	PD2
32	MCU_PA7	23	ADC_IN7 / SPI1_MOSI (PA7)	64	MCU_PB3	55	PB3(SWO)

7 Schematic diagrams

7.1 System power supply

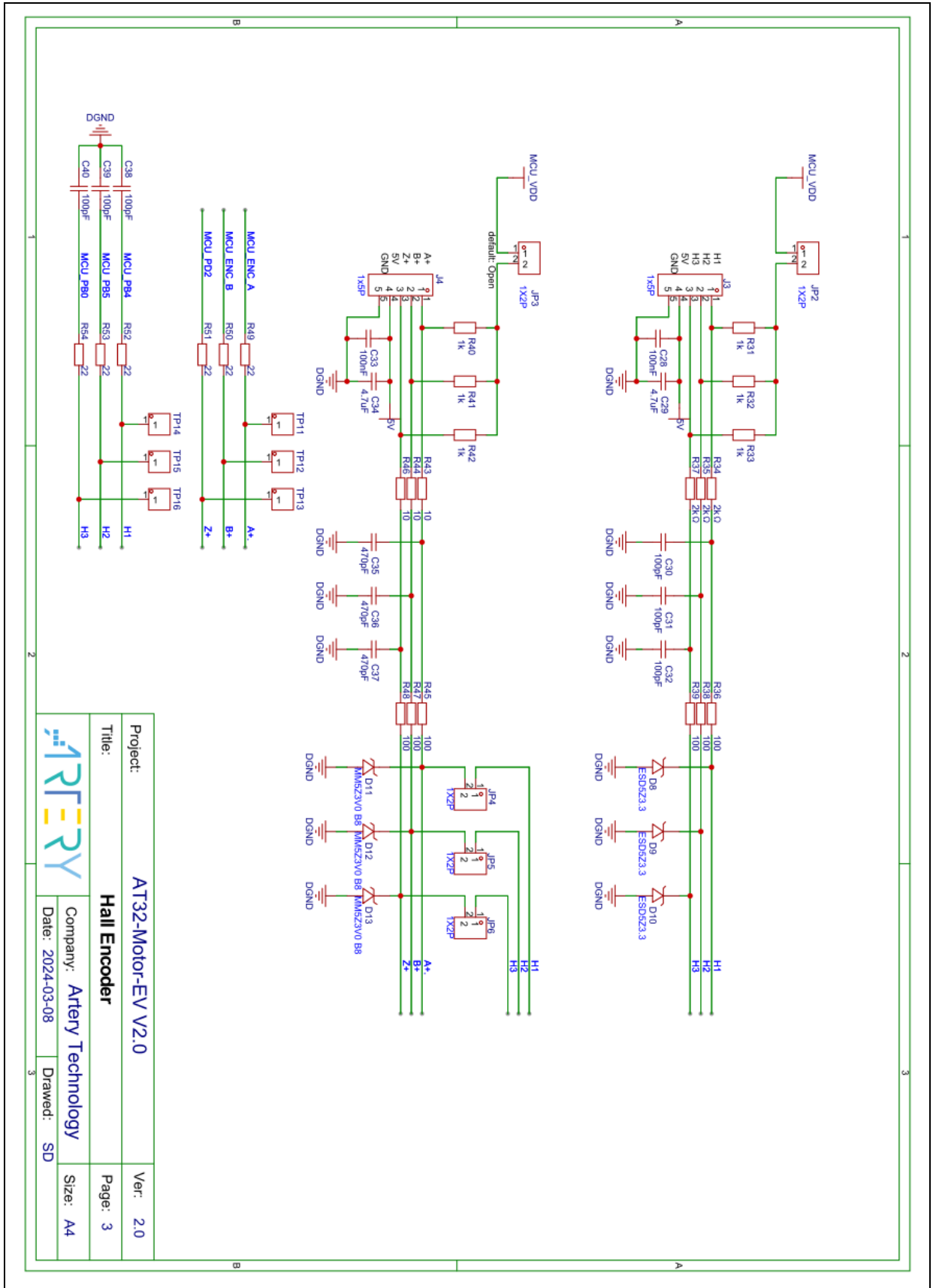


7.2 MCU interface

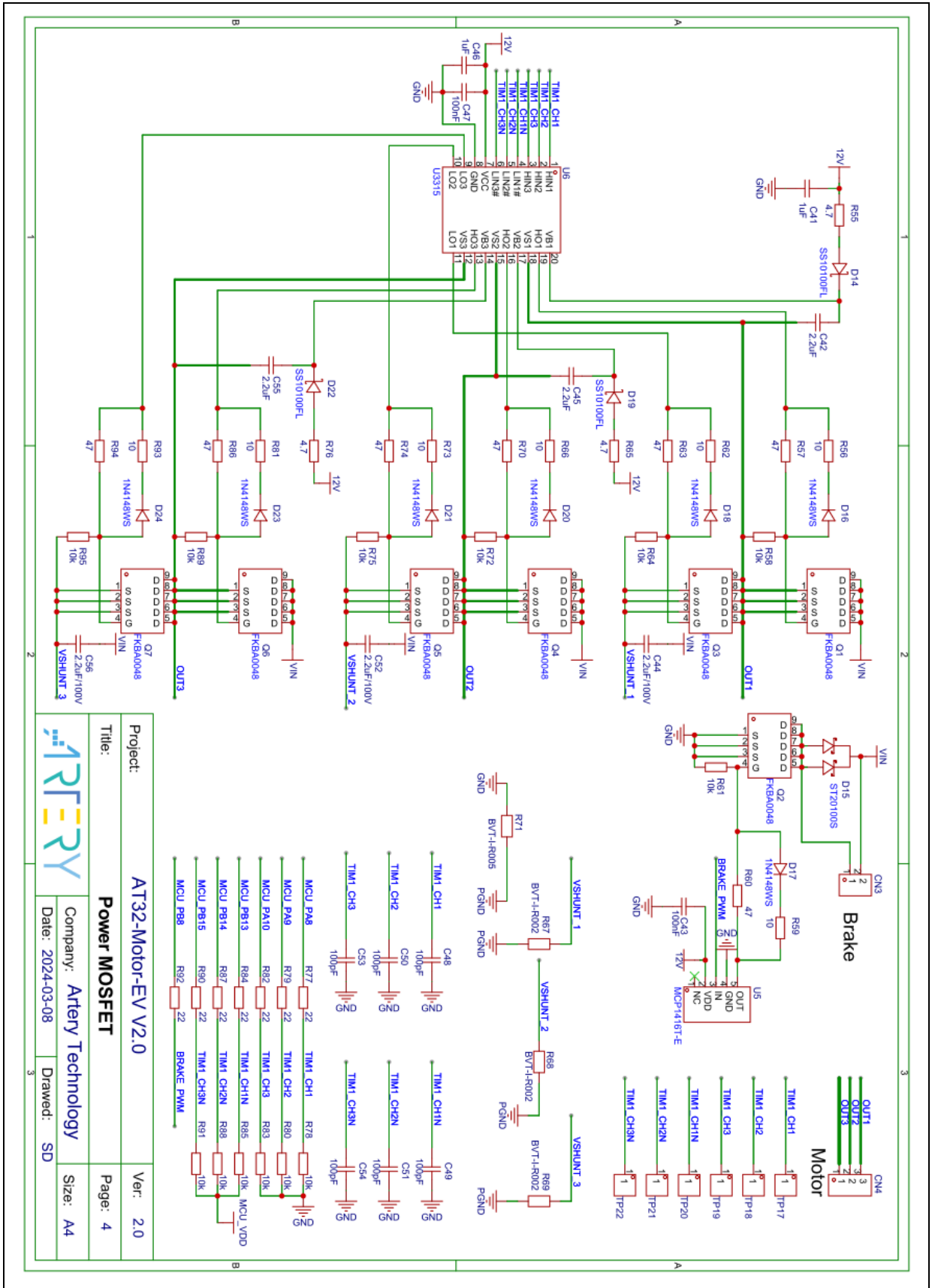


Project: AT32-Motor-EV V2.0		Ver: 2.0
Title: MCU		Page: 2
Company: Artery Technology		Size: A4
Date: 2024-03-08	Drawn: SD	

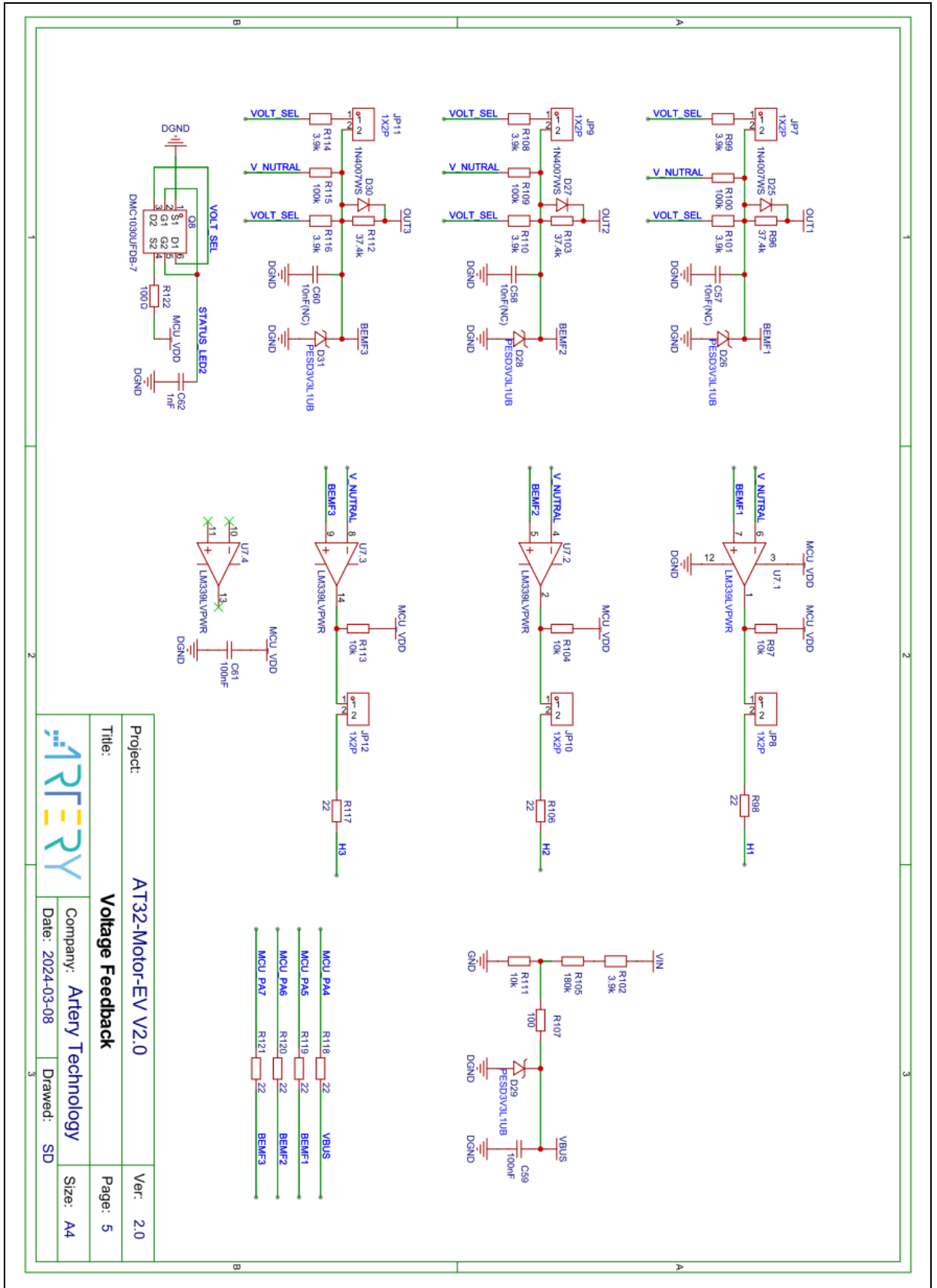
7.3 Hall / Encoder circuit diagram



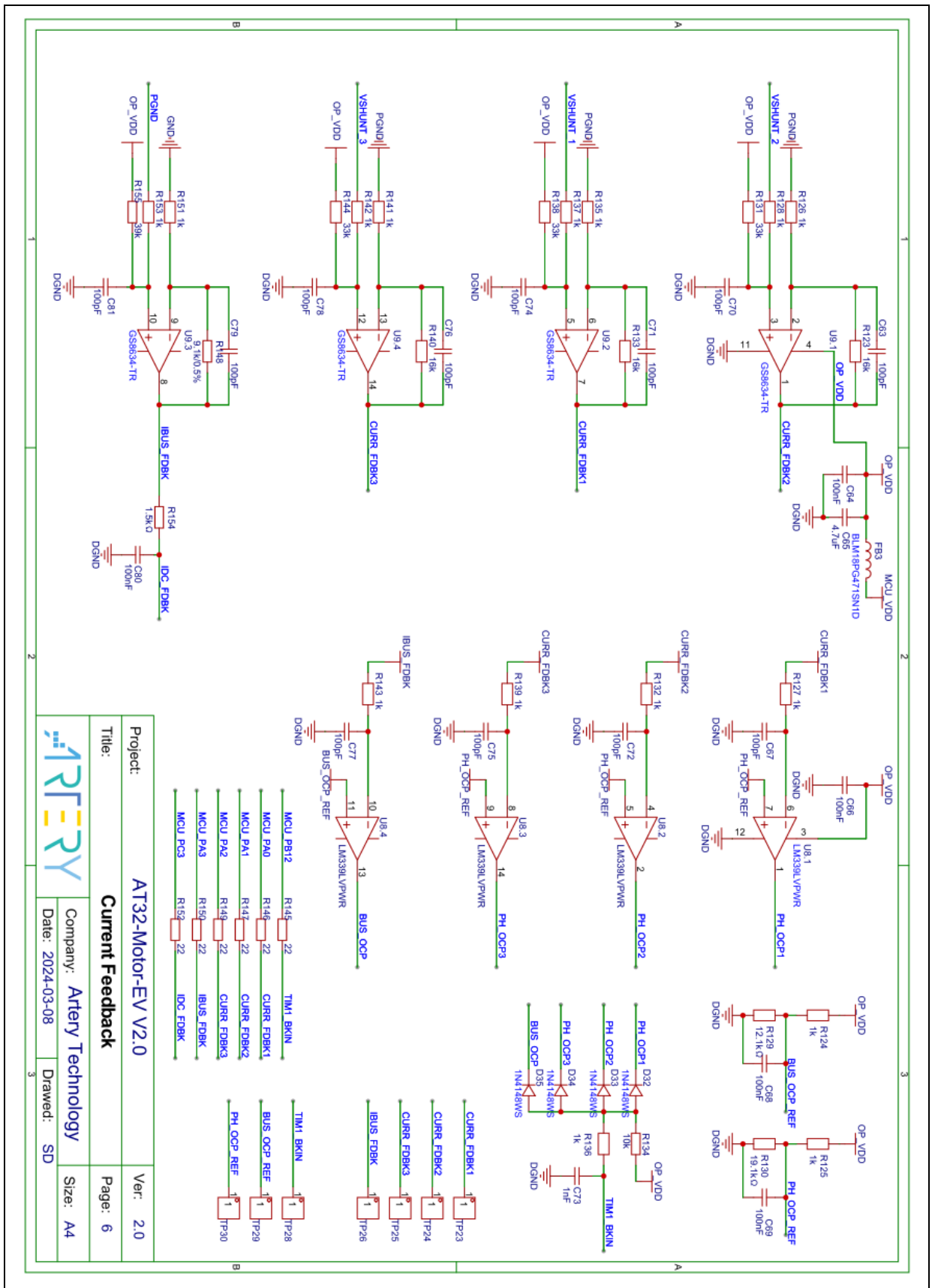
7.4 Power MOSFET circuit diagram



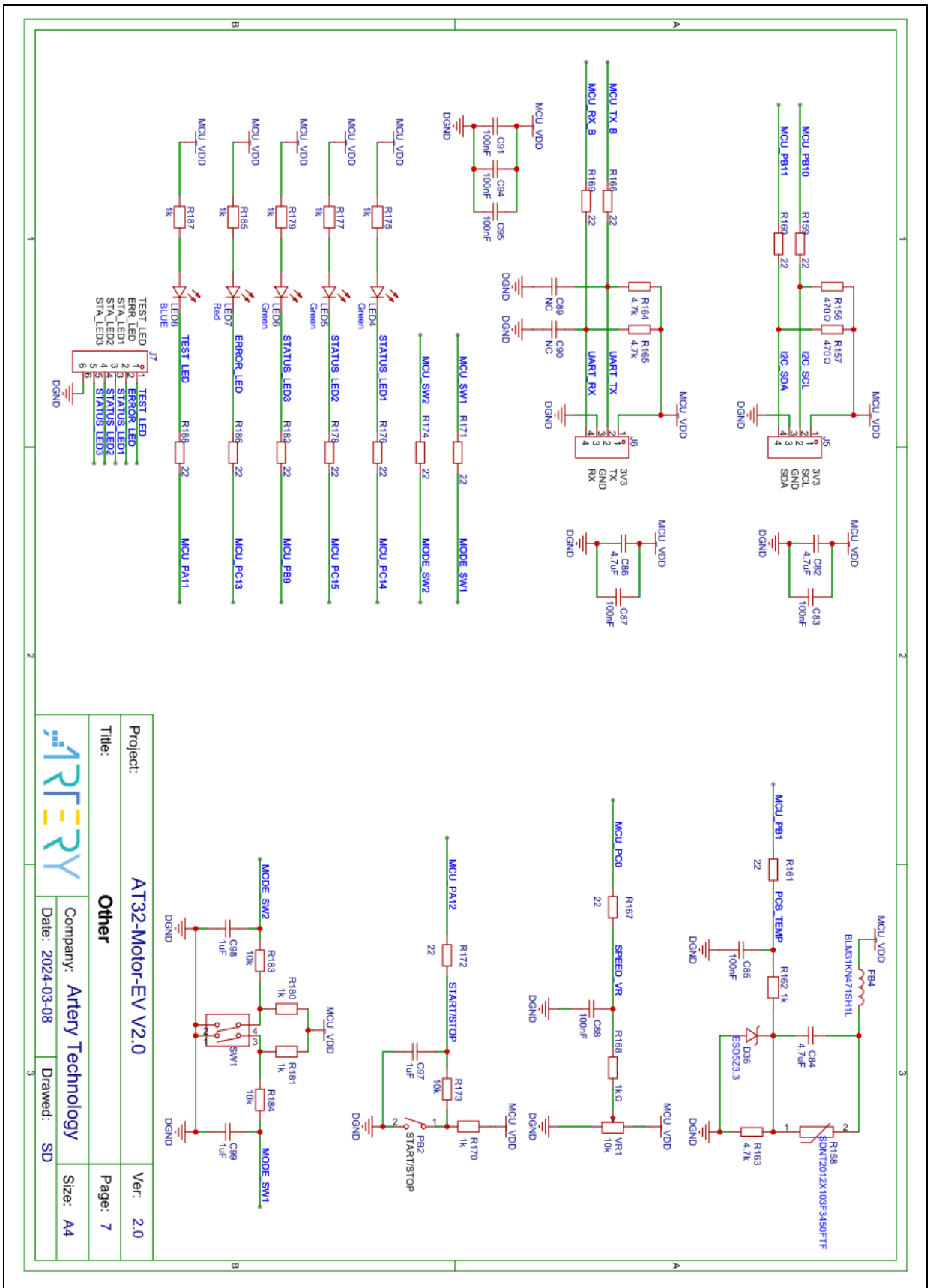
7.5 Voltage feedback circuit diagram



7.6 Current feedback circuit diagram

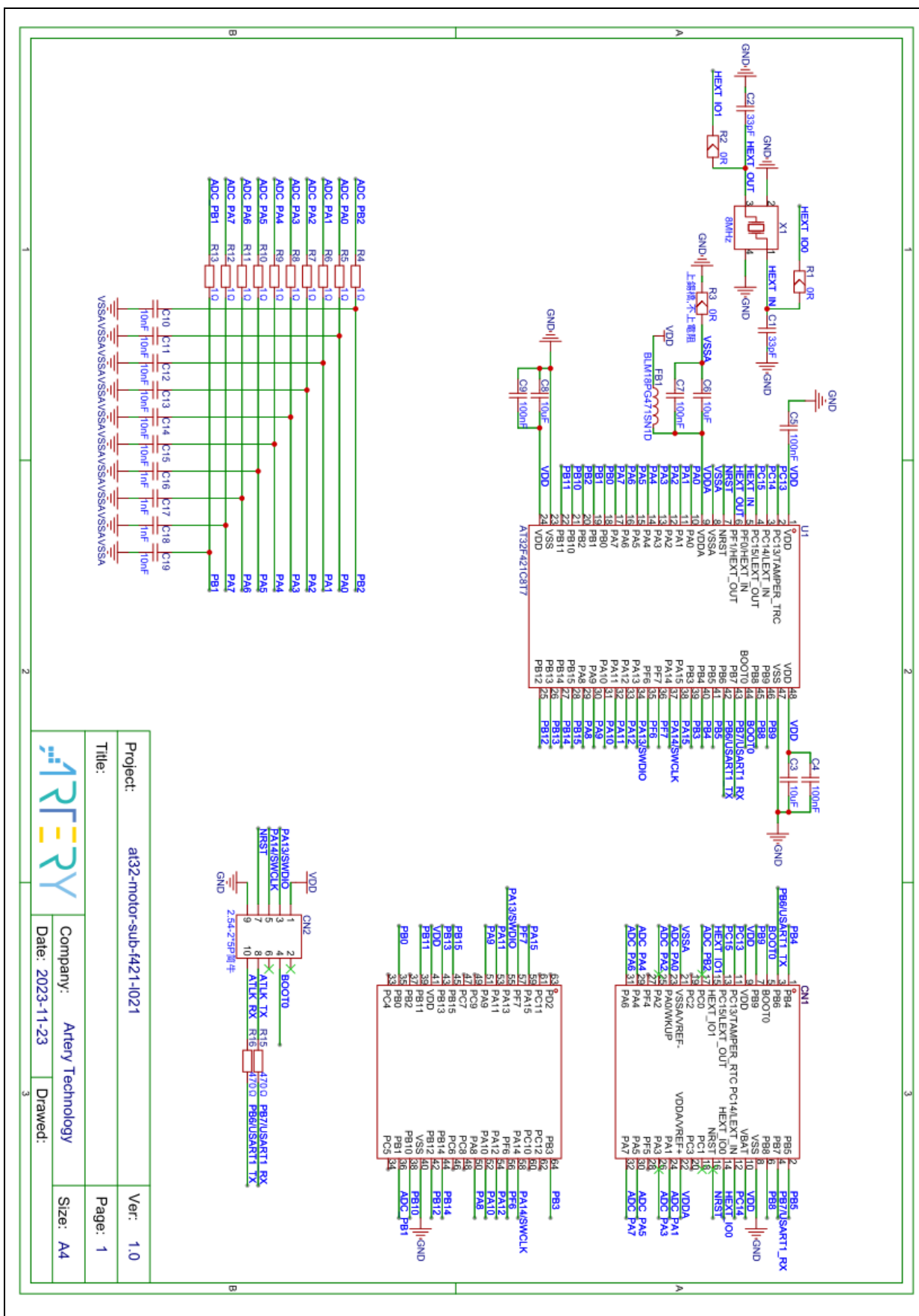


7.7 Others



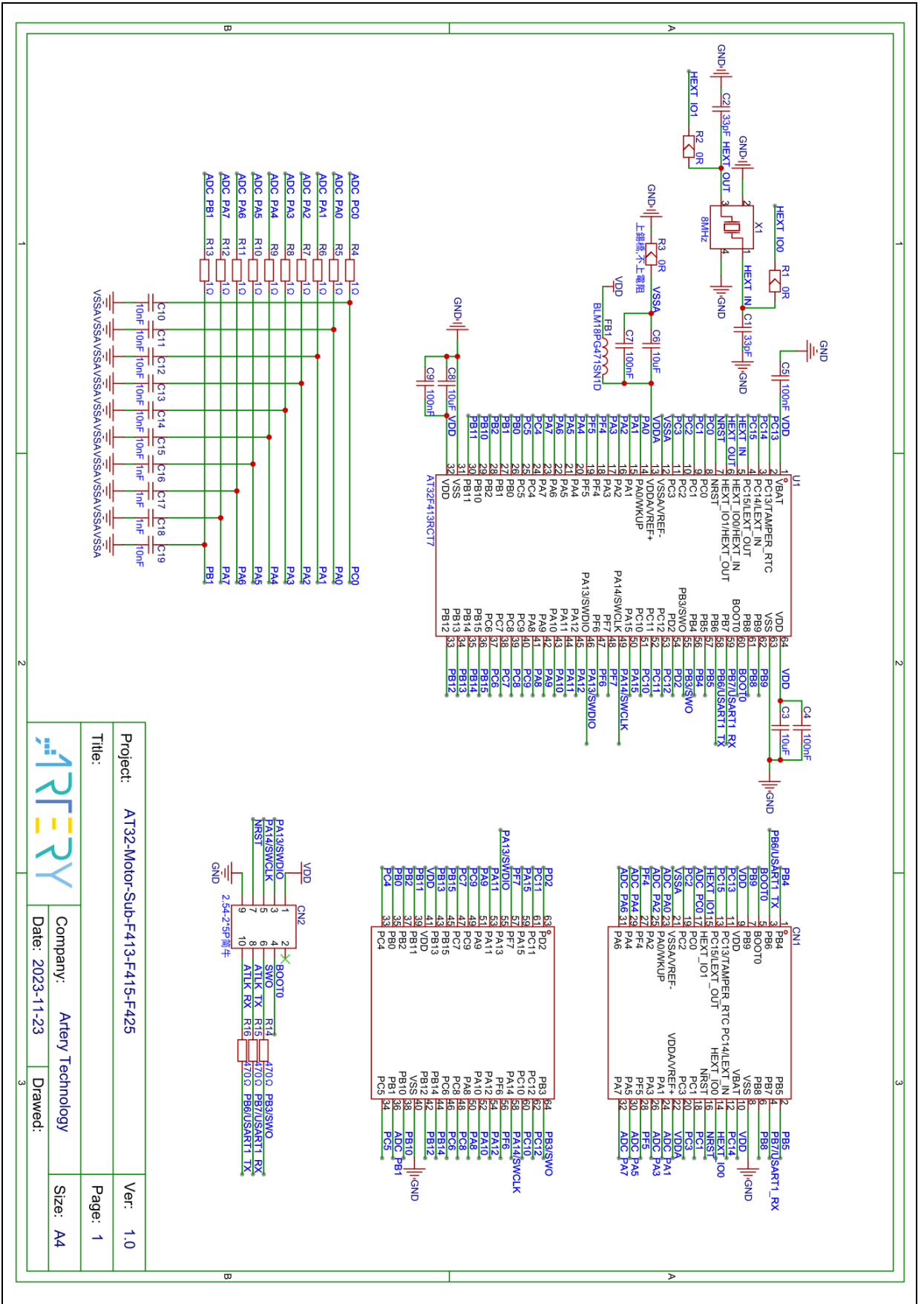
Project:	AT32-Motor-EV V2.0	Ver:	2.0
Title:	Other	Page:	7
Company:	Artery Technology	Drawn:	SD
Date:	2024-03-08	Size:	A4

7.8 AT32F421/L021 MCU circuit diagram



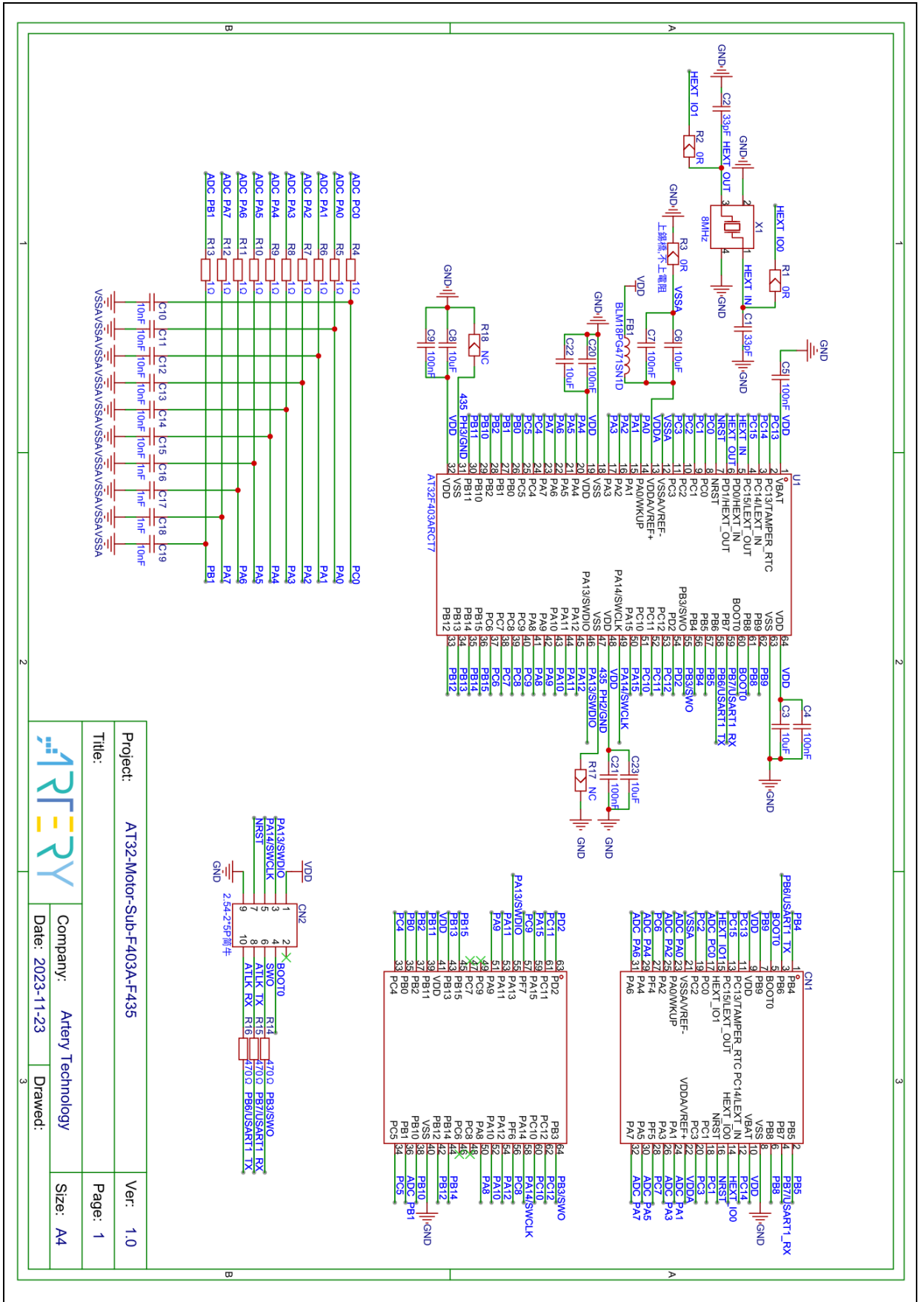
Project:	a132-motor-sub-f421-1021	Ver:	1.0
Title:		Page:	1
Company:	Artery Technology	Size:	A4
Date:	2023-11-23	Drawed:	

7.9 AT32F413/F425/F415/F405 MCU circuit diagram



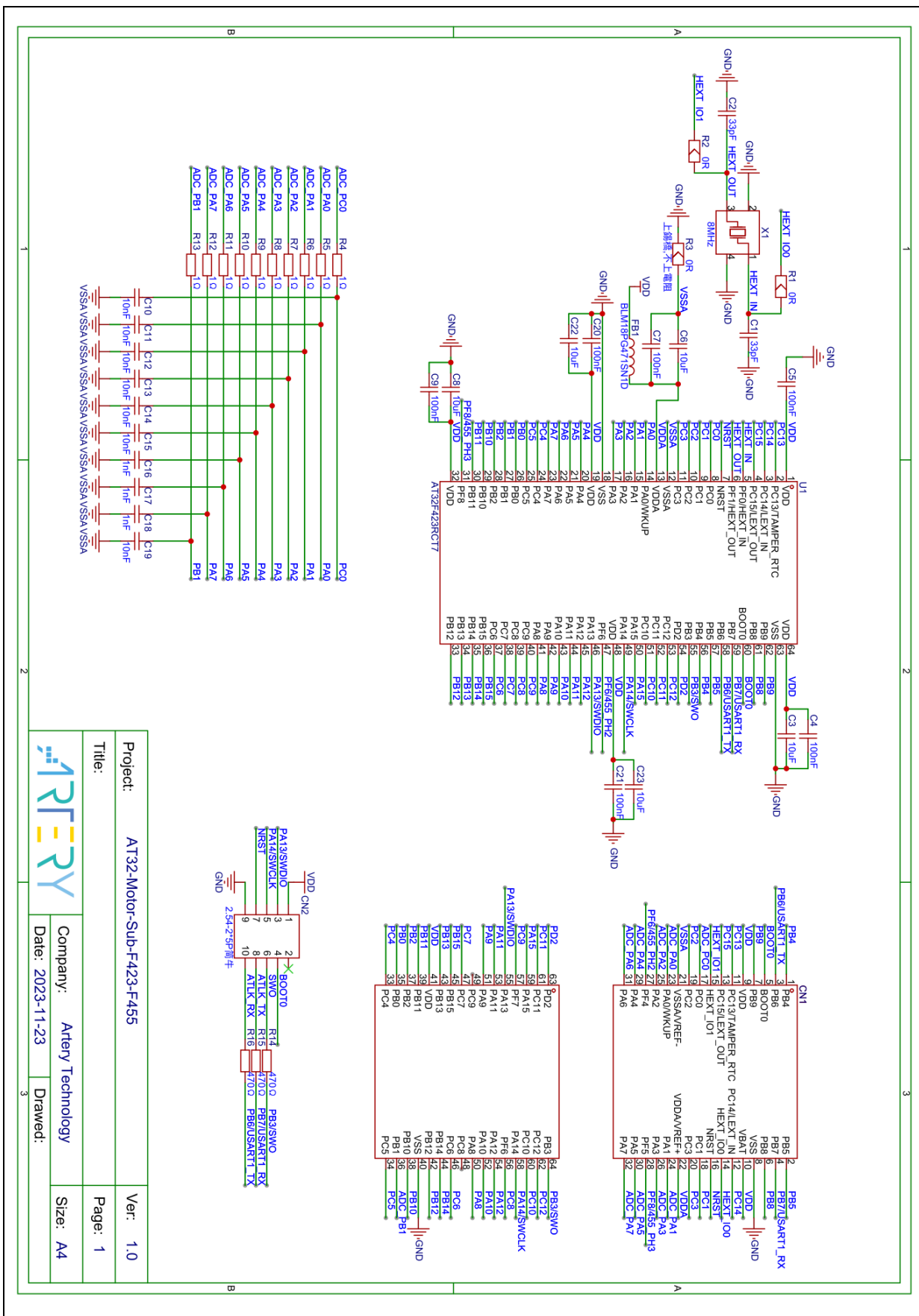
Project:	AT32-Motor-Sub-F413-F415-F425	Ver:	1.0
Title:		Page:	1
Company:	Artery Technology	Size:	A4
Date:	2023-11-23	Drawed:	

7.10 AT32F403A/A403A/F435 MCU circuit diagram

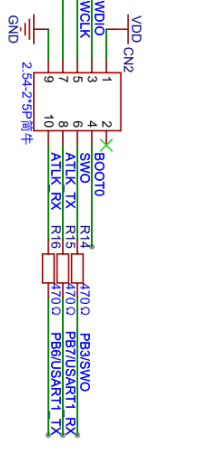


Project:	AT32-Motor-Sub-F403A-F435	Ver:	1.0
Title:		Page:	1
Company:	Artery Technology	Size:	A4
Date:	2023-11-23	Drawed:	

7.11 AT32F423/F455 MCU circuit diagram

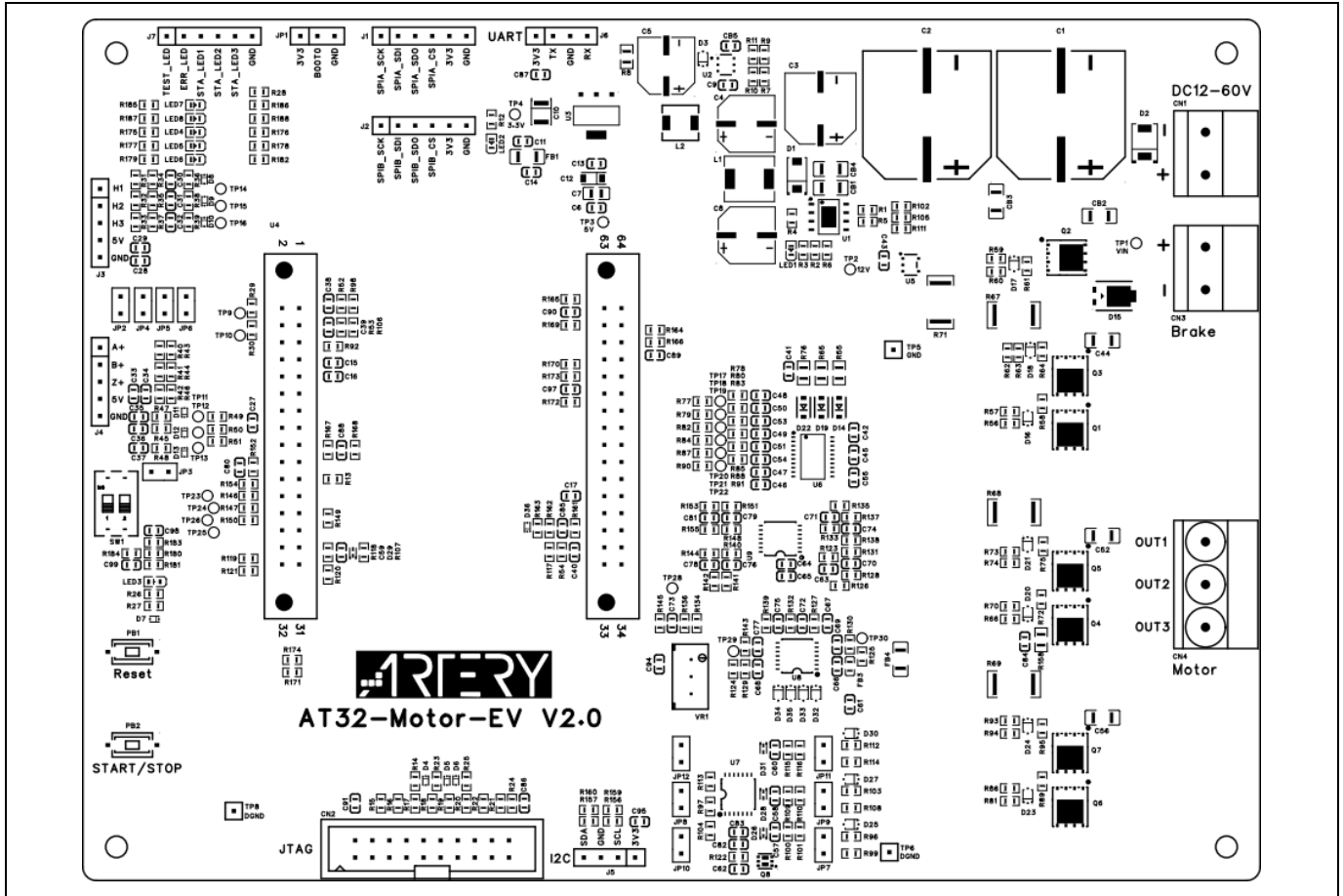


Project: AT32-Motor-Sub-F423-F455		Ver: 1.0	
Title:		Page: 1	
Company: Artery Technology		Size: A4	
Date: 2023-11-23		Drawed:	

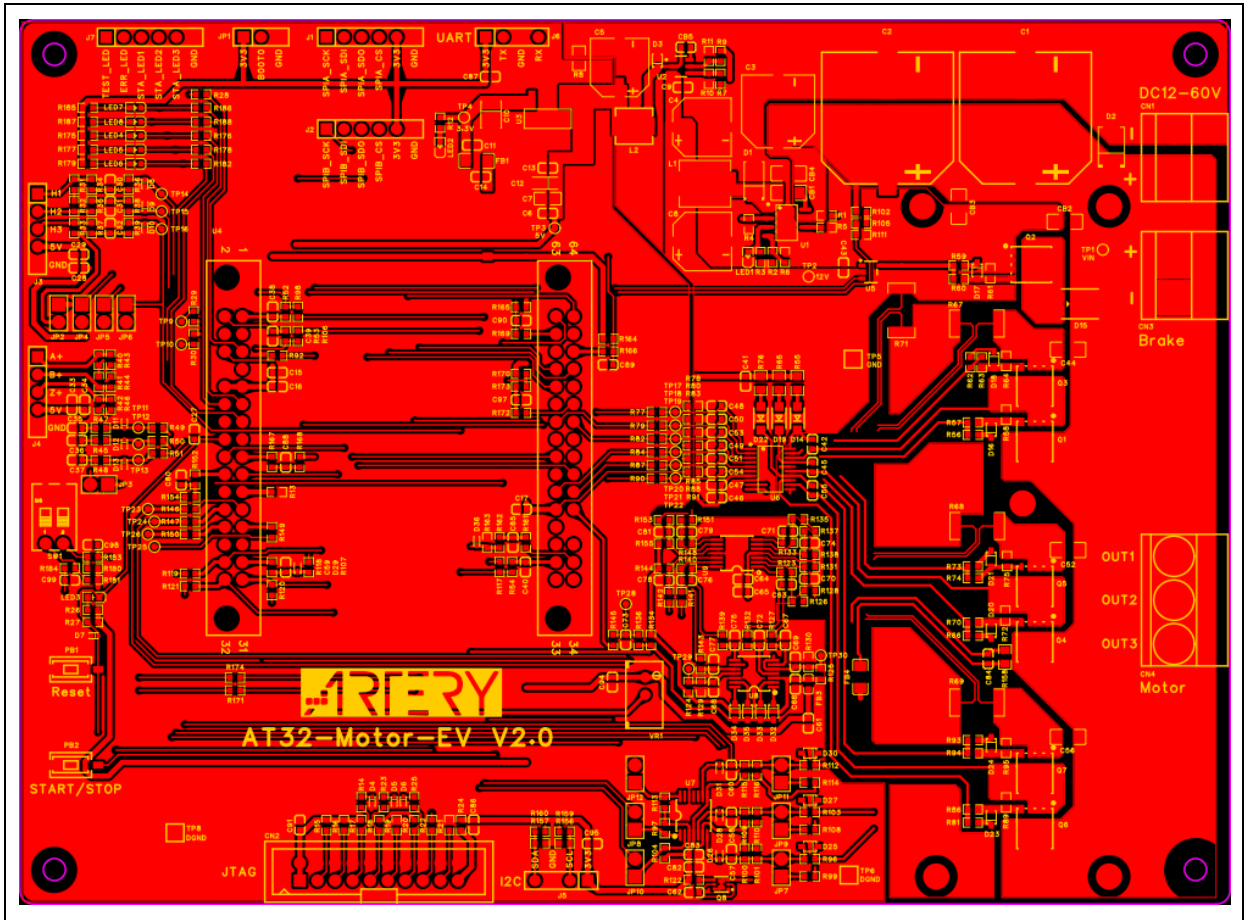


8 Layout

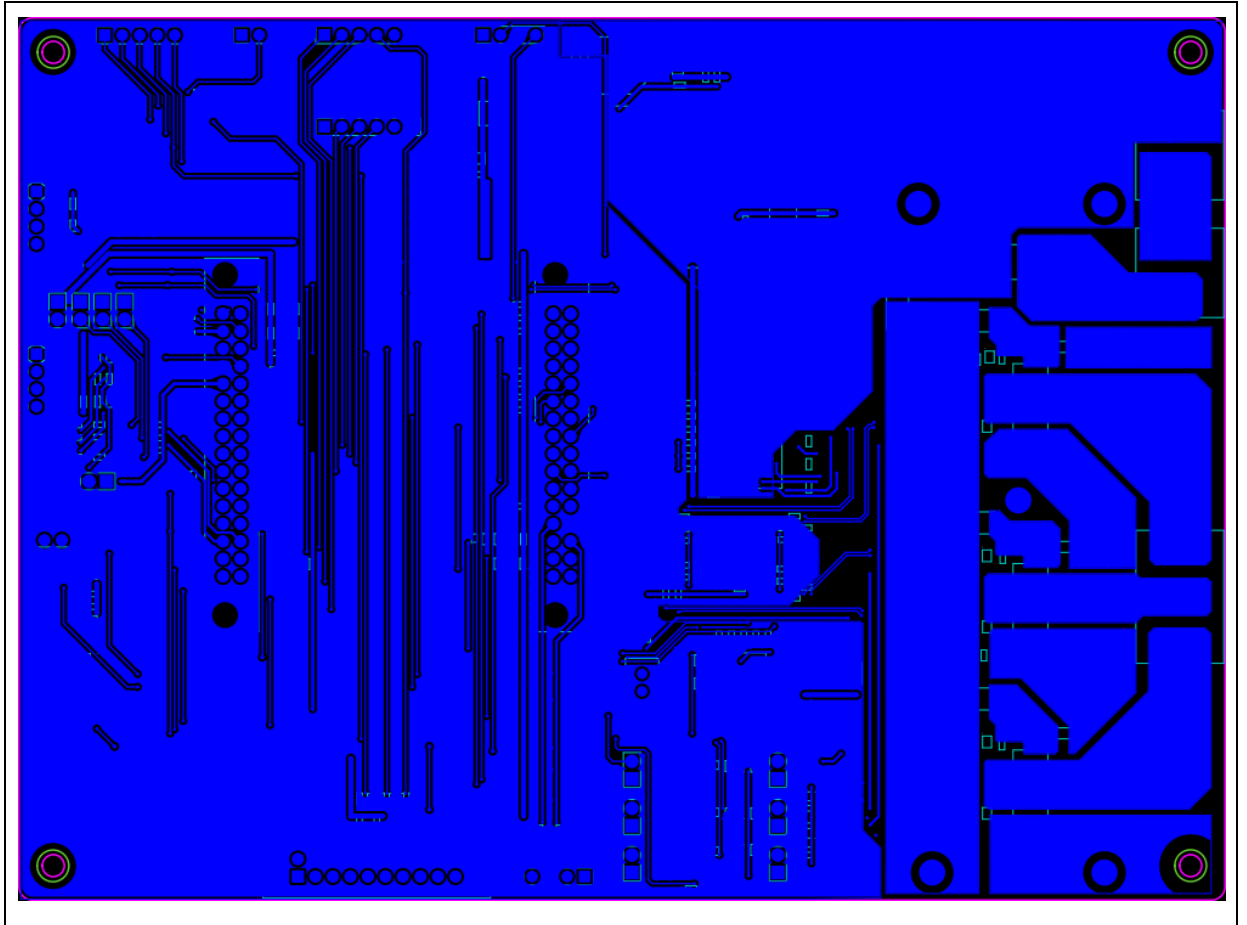
8.1 Component positions



8.2 Top-layer layout



8.3 Bottom-layer layout



9 Bill of materials

Value/Part number	Description	Designator	Footprint	Quantity	Manufacture
330uF	SMD Alum. Elec. Cap. 330uF,100V,20%, D:18mm, H:16.5mm	C1,C2	SMD_BD18.0-L19.0	2	Any
33uF	SMD Alum. Elec. Cap. 100uF,25V,20%, D:10mm, H:10mm	C3	SMD_BD10.0-L10.4	1	Any
100uF	SMD Alum. Elec. Cap.100uF,50V,20%, D:8mm, H:10mm	C4,C5,C8	SMD_BD8.0-L8.3	3	Any
100nF	SMD MLCC 0.1uF,50V,X7R,10%,0603	C6,C9,C11,C13,C15,C16,C17,C27,C28,C33,C43,C47,C59,C61,C64,C66,C68,C69,C83,C85,C87,C88,C91,C94,C95,C B5,C80	C0603	27	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	C0603	1	Any
4.7uF	SMD MLCC 4.7uF,25V,X5R,10%,0603	C29,C34,C65,C82,C84,C86	C0603	6	Any
100pF	SMD MLCC 100pF,50V,X7R,10%,0603	C30,C31,C32,C38,C39,C40,C48,C49,C50,C51,C53,C54,C63,C67,C70,C71,C72,C74,C75,C76,C77,C78,C79,C81	C0603	24	Any
470pF	SMD MLCC 470pF,50V,X7R,10%,0603	C35,C36,C37	C0603	3	Any
2.2uF	SMD MLCC 2.2uF,50V,X5R,10%,0603	C42,C45,C55	C0603	3	Any
2.2uF	SMD MLCC 2.2uF,100V,X7R,10%,1206	C44,C52,C56	C1206	3	Any
1uF	SMD MLCC 1uF,50V,X5R,10%,0603	C41,C46,C62,C73,C97,C98,C99	C0603	7	Any
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,D5,D6,D8,D9,D10,D36	SOD-523	7	Any
MM5Z3V0 B8	MM5Z3V0	D11,D12,D13	SOD-523F	3	Any
SS10100FL	SS10100FL_R1_00001	D14,D19,D22	SOD-123FL	3	Any
FSV20100V	FSV20100V	D15	TO-277B	1	Any
1N4148WS	SMD Switching Diode100V,150mA	D16,D17,D18,D20,D21,D23,D24,D32,D33,D34,D35	SOD-323	11	Any
1N4007WS	SMD Diode 1KV,1A	D25,D27,D30	SOD-323	3	Any
SS10100FL_R1	SMD Schottky Diode100V,1A	D20,D21,D22	SOD-123FL	3	Any
ST20100S	SMD Schottky Diode100V,20A	D24	TO-277B	1	Any
PESD3V3L1UB	PESD3V3L1UB,115	D26,D28,D29,D31	SOD-523	4	Any
BLM31KN471S H1L	SMD Bead 470Ohm@100Mhz 4.0A	FB1,FB4	1206	2	Murata

10 Revision history

Table 9. Document revision history

Date	Version	Revision note
2024.03.14	2.0.0	Initial release.

IMPORTANT NOTICE – PLEASE READ CAREFULLY

Purchasers are solely responsible for the selection and use of ARTERY's products and services, and ARTERY assumes no liability whatsoever relating to the choice, selection or use of the ARTERY products and services described herein

No license, express or implied, to any intellectual property rights is granted under this document. If any part of this document deals with any third party products or services, it shall not be deemed a license granted by ARTERY for the use of such third party products or services, or any intellectual property contained therein, or considered as a warranty regarding the use in any manner of such third party products or services or any intellectual property contained therein.

Unless otherwise specified in ARTERY's terms and conditions of sale, ARTERY provides no warranties, express or implied, regarding the use and/or sale of ARTERY products, including but not limited to any implied warranties of merchantability, fitness for a particular purpose (and their equivalents under the laws of any jurisdiction), or infringement on any patent, copyright or other intellectual property right.

Purchasers hereby agree that ARTERY's products are not designed or authorized for use in: (A) any application with special requirements of safety such as life support and active implantable device, or system with functional safety requirements; (B) any aircraft application; (C) any aerospace application or environment; (D) any weapon application, and/or (E) or other uses where the failure of the device or product could result in personal injury, death, property damage. Purchasers' unauthorized use of them in the aforementioned applications, even if with a written notice, is solely at purchasers' risk, and Purchasers are solely responsible for meeting all legal and regulatory requirements in such use.

Resale of ARTERY products with provisions different from the statements and/or technical characteristics stated in this document shall immediately void any warranty grant by ARTERY for ARTERY's products or services described herein and shall not create or expand any liability of ARTERY in any manner whatsoever.

© 2024 ARTERY Technology – All Rights Reserved