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Improvement, innovation, saving, win-win

Electromagnetic compatibility solution for electronic circuits of medical electric chairs

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1. Medical Electric Chair Industry Standard

1.1 International Industry Standards

Electric wheelchairs sold in international markets, particularly in the EU, must meet strict standards. For example, EU CE certification classifies them as Class II medical devices and is subject to the EU Medical Device Regulation (MDR) 2017/745, the Low Voltage Directive (LVD) 2014/35/EU (if applicable), the Electromagnetic Compatibility Directive (EMC) 2014/30/EU (generally applicable), and the Batteries and Accumulators Directive (if using lithium batteries).

Key harmonized standards include:

EN ISO 13485 Quality Management Systems for Medical Devices

EN ISO 14971 Risk Management for Medical Devices

EN 12184 General Safety Requirements for Electric Wheelchairs, which specifies performance, safety, and test methods

EN 60601-1 General Requirements for Medical Electrical Equipment, which covers electrical safety and essential performance

EN 60601-1-2 Electromagnetic Compatibility Requirements, which conducts EMC compatibility testing

EN 62366 Usability Engineering for Medical Devices, which ensures user-friendliness and prevents misuse

EN ISO 10993 series Biocompatibility testing, biological safety assessment of materials that come into contact with the skin

1.2 Domestic Industry Standards

China has established specific standards for electric wheelchairs, such as YY9706.102-2021, to ensure the safety and performance stability of electric wheelchairs during use. Verification testing requirements include static and dynamic load tests to verify stability under different loads; electrical safety tests to ensure circuit design complies with safety regulations; and long-term durability tests to prevent device failure after prolonged use.

Design requirements include ergonomics and ease of operation to meet the needs of different users; waterproofing to adapt to diverse operating environments; and materials that meet environmental and recyclable standards to minimize environmental impact. For user safety, they must be equipped with a braking system, emergency stop button, and overload protection.

GB18268.1 is China's national standard for electromagnetic compatibility of medical devices, applicable to electric wheelchairs.

It requires electromagnetic interference (EMI) control to ensure that no excessive interference is generated in the electromagnetic environment and does not affect surrounding medical equipment; electromagnetic immunity (EMS) to ensure that electric wheelchairs can withstand external electromagnetic interference and ensure safe use. Testing includes electrostatic discharge immunity and electromagnetic field radiation immunity testing; and compatibility testing to ensure safe and effective operation in various electromagnetic environments.

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2. EMC test related requirements in industry standards

2.1 EMC test items and requirements ESD

Electrostatic Discharge (ESD) Immunity GB/T17626.2/IEC61000-4-2

The EMC standard for medical electrical equipment specifies ESD immunity specifications for medical equipment of ±2 kV, ±4 kV, and ±6 kV for air discharge. During testing, an electrostatic generator is used to simulate actual ESD.

Contact discharge involves placing the discharge electrode of the electrostatic generator in direct contact with the metal housing of the device. Air discharge involves placing the discharge electrode close to the device under test to cause a spark discharge. Indirect discharge also involves discharging through a 0.5 m x 0.5 m metal plate placed vertically 10 cm from the device housing. Compliance with the requirements during the test is determined based on the medical device immunity compliance criteria.

General level: ±6 kV for contact discharge, ±8 kV for air discharge (per 60601-1-2)

2.2 EMC test items and requirements EFT

Fast Transient Burst Immunity (GB/T17626.4/IEC61000-4-4)

Generation Mechanism: When the AC power supply used by medical electrical equipment is connected to the public power grid, the discontinuous discharge generated by the closing of high-power inductive loads or relay contacts can generate fast transient bursts in the power supply line, potentially interfering with medical equipment connected to the power grid.

The standard specifies that fast transient bursts of ±0.5 kV, ±1 kV, and ±2 kV should be applied to AC and DC power lines. During testing, a fast transient burst generator capable of generating specific waveforms is used to inject transient bursts into the power line or other signal cables and interconnecting cables through a coupling device. Compliance with the requirements is then determined based on the medical device immunity compliance criteria.

General Level: ±2 kV for power ports, ±1 kV for signal ports

2.3 EMC test items and requirements Surge

Lightning Surge Immunity (GB/T17626.5/IEC61000-4-5)

Natural lightning, high-power load switching, or power system faults can generate lightning surges. These surges can be transmitted through power lines or communication lines, disrupting equipment operation and even causing damage.

The standard requires applying ±0.5 kV, ±1 kV, and ±2 kV line-to-ground to AC power lines; and ±0.5 kV and ±1 kV line-to-line.

During the test, surge voltages are injected into the power lines through a coupling device.

General level: ±1 kV line-to-ground, ±0.5 kV line-to-line

2.4 EMC test items and requirements

Immunity to Voltage Dips, Short Interruptions, and Voltage Variations (GB/T17626.11/IEC61000-4-11)

Power system failures or drastic load changes can cause power interruptions or voltage sags. A voltage sag is a brief drop in voltage at a point in an electrical system followed by a return to normal; a short interruption is a period of interruption (generally no more than one minute) when the power supply voltage is lost.

The standard requires that power supplies be subjected to voltage sags, short interruptions, and voltage variations as specified. Voltage sags and short interruptions are tested using voltage-regulating transformers and switches according to specified requirements. Equipment must withstand these variations and maintain normal functionality or return to normal operation after the short interruption. The test method complies with national standards.

General Level: Voltage sag of 50% (0.5 cycle), short interruption recovers after 5 seconds

2.5 EMC test items and requirements CE and RE test

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Conducted Emissions (CE)

Standard: CISPR 11/EN 55011 Class B (domestic use) or Class A (non-domestic use)

Limits: 150 kHz to 30 MHz, with Class B limits being more stringent (e.g., peak value ⩽ 60 dBμV).

Radiated Emissions (RE)

Standard: CISPR 11/EN 55011 Class B (recommended)

Limits: 30 MHz to 1 GHz, with Class B limits (e.g., ⩽ 40 dBμV/m at a distance of 3 m).

Radiated RF Immunity

Standard: IEC 61000-4-3

Level: 3 V/m (80 MHz to 2.7 GHz, required for normal operation)

3. EMC pain points of medical electric chairs

3.1 Pain points related to electromagnetic compatibility

Interference Causes Equipment Failure

Intelligent, networked medical systems, such as medical power chairs, operate in complex electromagnetic environments and are susceptible to electromagnetic interference from surrounding equipment.

In hospitals, strong electromagnetic signals generated by surrounding medical equipment, such as MRI machines and high-frequency electrosurgical units, can infiltrate the power chair's electronic circuits, causing the microprocessor to malfunction and incorrect control commands. This can lead to dangerous situations such as sudden acceleration, deceleration, or loss of control, seriously compromising user safety and the normal operation of the equipment.

Self-electromagnetic radiation can affect other equipment.

When a medical power chair is in operation, its internal motor and drive circuits generate electromagnetic radiation. In medical equipment-intensive environments, such as hospitals, this electromagnetic radiation can interfere with other nearby electromagnetically sensitive medical equipment. For example, electrocardiogram (ECG) machines can cause inaccurate data from these devices, affecting doctors' assessments of patients' conditions and potentially leading to serious consequences such as misdiagnosis.

3.2 Five core pain points and solutions

Pain points	Problem Description	Influence	Related test standards	Solution
1. Motor drive interference	Motor start-stop and PWM speed regulation generate high-frequency noise, and conducted and radiated emissions are likely to exceed standards.	Interference with other medical equipment (such as monitors), causing test failure (CISPR 11 Class B)	CISPR 11 EN 55011	Optimize PWM circuit, add RC buffer; shield the motor housing; add magnetic ring filter to the power line
2. Power supply conducted emissions exceed the standard	Switching power supplies have excessive noise conduction in the 150kHz to 30MHz frequency range, especially low-cost non-medical-grade power supplies.	Failure to pass CE/FCC certification affects market access	IEC61000-6-4 CISPR 11	Use medical-grade power modules; optimize PCB layout; add common-mode chokes and X/Y capacitors for filtering
3. Insufficient immunity and malfunction	During RF radiation (3V/m) or fast transient pulse (EFT) testing, the MCU or sensor is disturbed and the seat moves unexpectedly	Patient safety risks (e.g., falls), violation of IEC 60601-1-2 performance criteria (Class B/C)	IEC61000-4-3 IEC61000-4-4	Shield key signal lines; add a watchdog timer in the software; select a high-interference-resistant MCU (such as the STM32 series)
4. ESD causes system crash	When the human body touches metal parts (buttons, handrails), electrostatic discharge (±8kV) may cause the system to freeze or reset.	Poor user experience and potential safety risks (such as motor loss of control)	IEC61000-4-2 (Level 4)	Interface circuit plus TVS diode; non-metallic housing design; ESD protection chip (such as USBLC6-4SC6)
5. Cable radiated emissions	Long cables such as power cables and motor cables act as antennas, causing radiation exceeding standards in the 30MHz to 1GHz frequency band.	RE test failure (e.g., exceeding 40dBμV/m @3m)	CISPR 11 FCC Part 15	Shorten cable length; use shielded cables and ensure good grounding; optimize PCB layout for high-frequency loops

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4. Circuit design EMC solution

4.1 Hardware Circuit Design Strategy

Grounding design

Use reasonable grounding methods, such as single-point grounding, multi-point grounding, or mixed grounding. For the electronic circuits of medical electric chairs, the high-power drive circuit part can adopt single-point grounding to reduce the interference current in the ground loop; while the signal processing circuit part, due to the high signal accuracy requirements, can adopt multi-point grounding to reduce the grounding resistance, improve the anti-interference ability, and ensure the stable operation of the equipment in complex electromagnetic environments.

Shielding technology

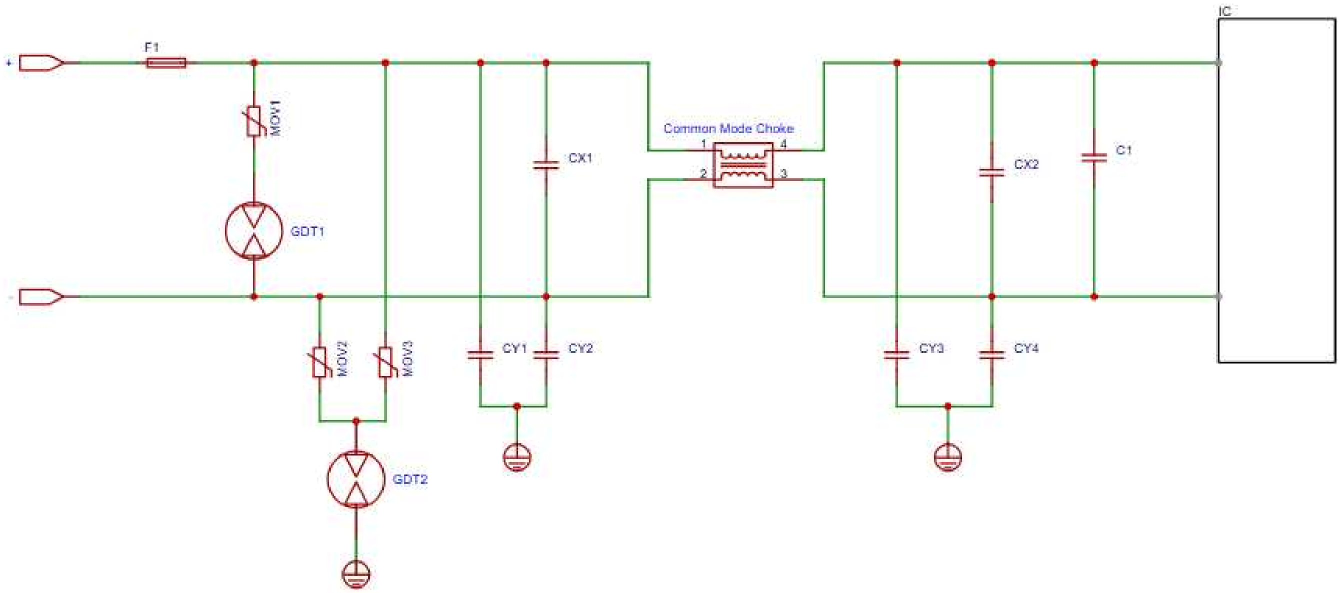
Use metal shielding to shield circuit modules that are susceptible to interference or generate interference. For example, wrap the motor of an electric chair with a metal shielding to prevent the electromagnetic radiation generated by the motor from spreading outward and interfering with other circuits. At the same time, use shielded wires for sensitive signal transmission lines to prevent external electromagnetic interference signals from coupling into the transmission lines, ensuring the accuracy of signal transmission.

Filter circuit design

Set up filtering circuits at the power input and output ends and signal transmission lines. Add a low-pass filter to the power input end to filter out high-frequency interference signals on the power line to ensure that pure DC power is provided to the equipment; on the signal transmission line, design appropriate filters according to the signal frequency characteristics, such as band-pass filters, to allow useful signals to pass smoothly and block interference signals in other frequency bands, thereby improving the circuit's anti-interference performance.

4.2 AC power interface EMC and reliability design

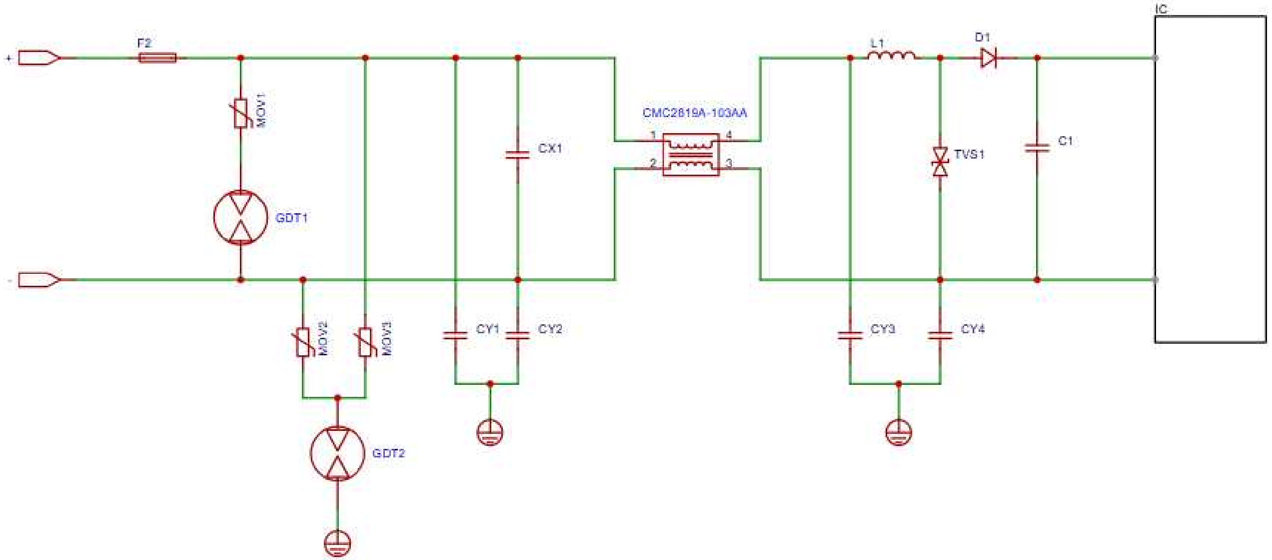
AC power interface: used to connect external 220V AC input



model	Device Type	Use Location	effect	Encapsulation
2R600L	GDT	Power interface	surge, lightning protection (outdoor products, focus on the issue of continuous current)	2RXXXL
14D561K/14D511K	MOV	Power interface	surge, lightning protection	14D
CMZ/CML	EMI common-mode suppressors	Power interface	Common-mode rejection	SMD

4.3 12V/24V vehicle power supply interface EMC and reliability design

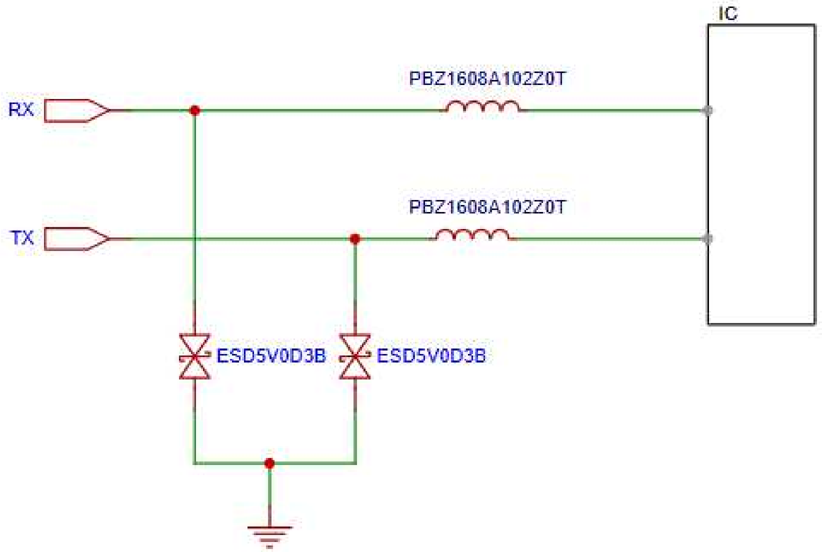
DC power interface: used to connect to external 12V/24V vehicle power input, supports offline use (such as when the patient is moving))



model	Device Type	Use Location	effect	Encapsulation
2R600L	GDT	Power interface	surge, lightning protection (outdoor products, focus on the issue of continuous current)	2RXXXL
14D561K/14D511K	MOV	Power interface	surge, lightning protection	14D
CMZ/CML	EMI common-mode suppressors	Power interface	Common-mode rejection	SMD
SMBJ24CA/SMBJ33CA	TVS	Power interface	surge, load dump	SMB

4.4 GPIO/UART/I2Cinterface EMC and hot-swap reliability design

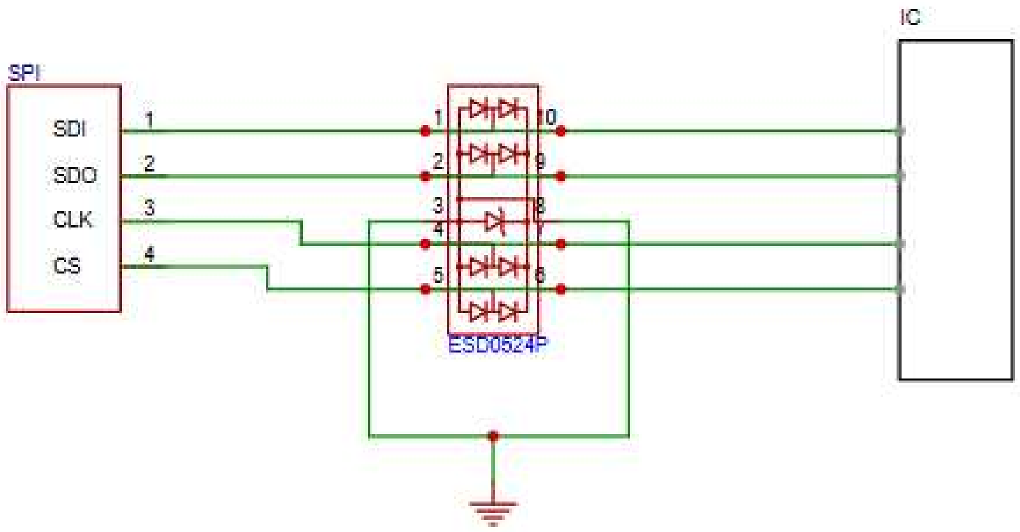
GPIO interface (general purpose input and output): used to connect sensors, actuators and other peripherals, supporting custom programming control

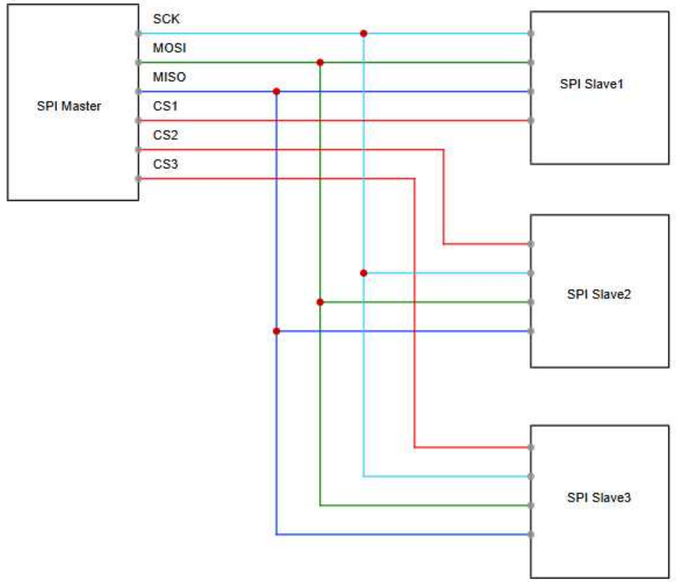


model	Device Type	Use Location	effect	Encapsulation
ESD5V0D3B	ESD	GPIO interface	Surge, static electricity	SOD323
PBZ1608A102Z0T	magnetic beads	GPIO interface	Eliminate high-frequency interference	1608

4.5 SPI interface EMC and hot-swap reliability design

SPI interface: high-speed serial communication interface, used to connect memory chips, displays, etc.

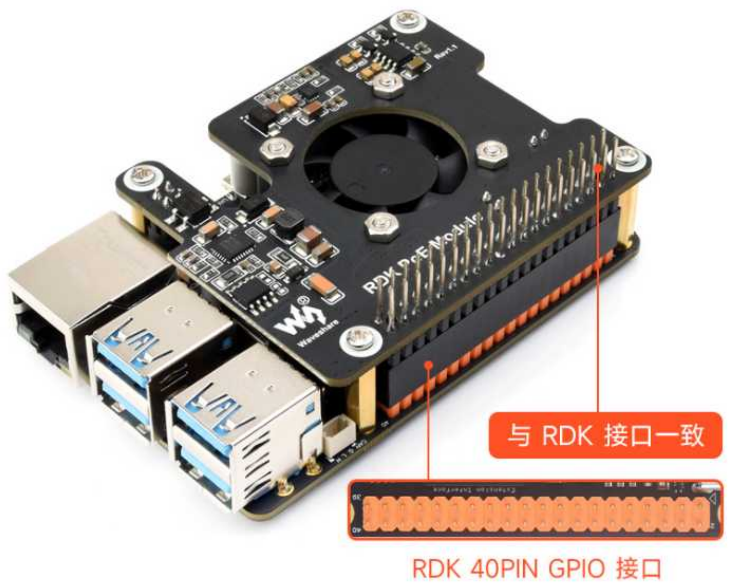


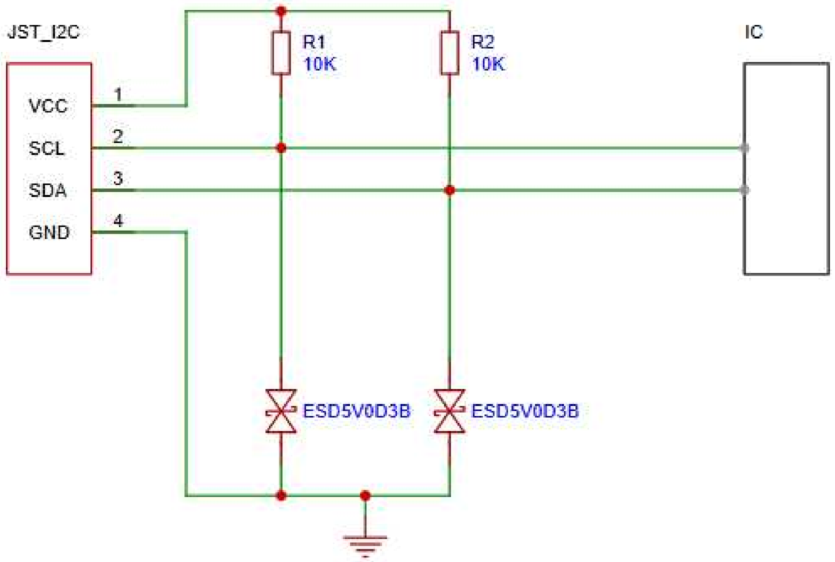


model	Device Type	Use Location	effect	Encapsulation
ESD0524P	ESD	SPI interface	Surge, static electricity	DFN2510

4.6 JSTinterface EMC and hot-swap reliability design

JST interface： Dedicated interface for connecting sensors and other devices

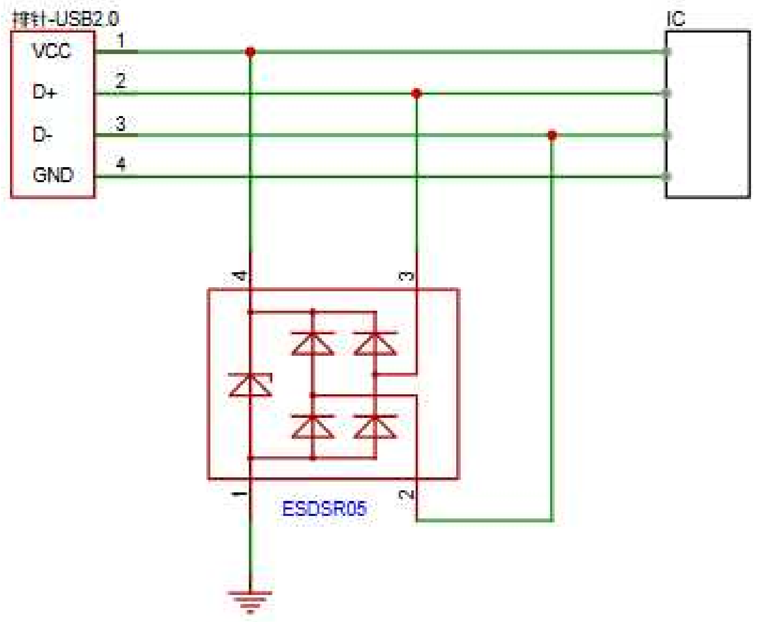




model	Device Type	Use Location	effect	Encapsulation
ESD5V0D3B	ESD	I2Cinterface	Surge, static electricity	SOD323

4.7 Pin header interface EMC and hot-swap reliability design

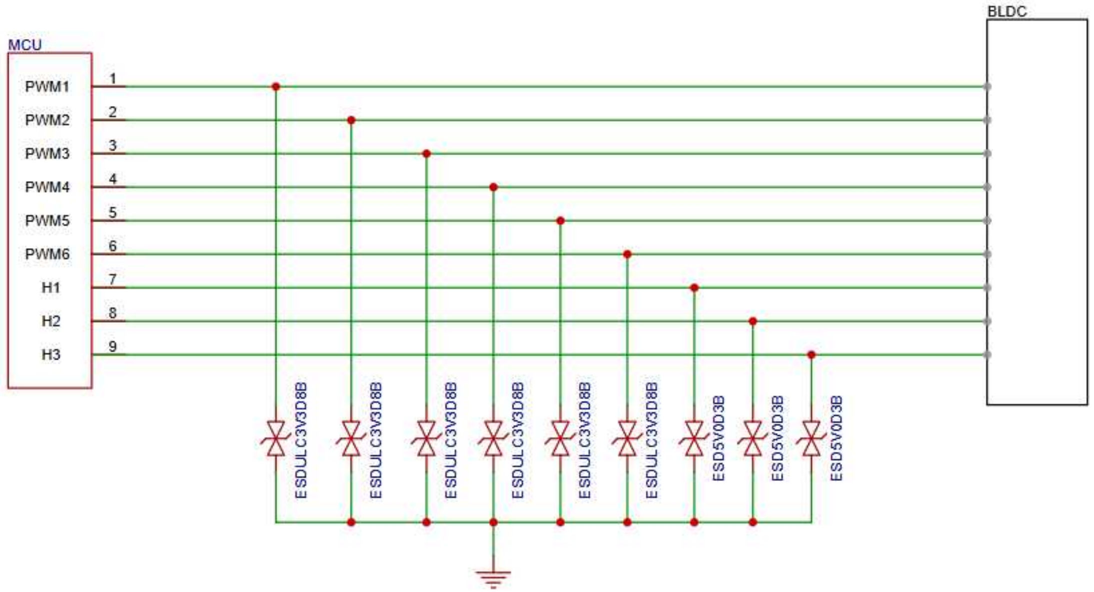
Pin header interface: used to connect cables or expansion boards to achieve functional expansion



model	Device Type	Use Location	effect	Encapsulation
ESDSR05	ESD	USBinterface	Surge, static electricity	SOT143

4.8 MCU drives BLDC motor module

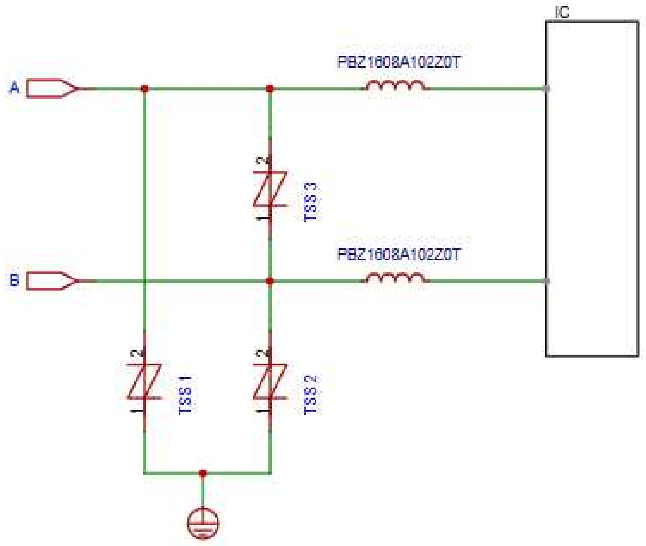
MCU interface: MCU control of a BLDC (brushless DC) motor typically involves multiple interfaces, including PWM outputs and Hall sensor inputs.
Pin Definition: The MCU outputs six PWM signals for controlling the upper and lower arms of the three-phase bridge. Additionally, three inputs receive Hall sensor signals to obtain rotor position information for proper commutation.



model	Device Type	Use Location	effect	Encapsulation
ESDULC3V3D8B	ESD	MCU interface	Surge, static electricity	SOD882
ESD5V0D3B	ESD	MCU interface	Surge, static electricity	SOD323

4.9.1 RS485 interface EMC and hot-swap reliability design

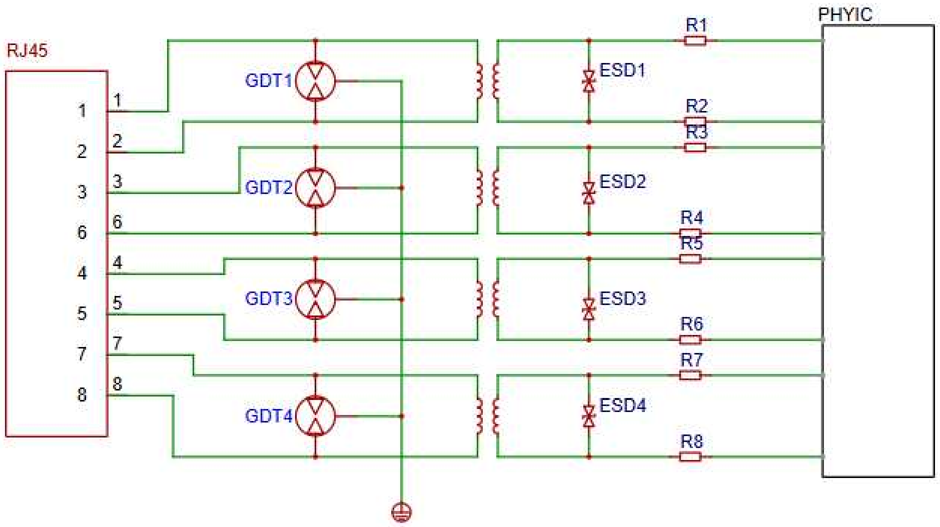
RS485 interface: RS-485 is a serial communication standard that can support multiple devices to communicate through the same serial bus. It is suitable for medium and long distance communication and has good anti-interference ability and data transmission stability.



model	Device Type	Use Location	effect	Encapsulation
P0080SCL	TSS	RS485interface	Surge, static electricity	SMB
PBZ1608A102Z0T	magnetic beads	RS485interface	Eliminate high-frequency interference	1608

Ethernet interface

Supports wired network connection, provides stable network connection for the machine, supports remote control and data interaction. Through Ethernet, the machine can upload working data to the cloud in real time, receive remote commands, and realize intelligent remote operation; its transmission rate can reach 1000Mbps or even higher, meeting the machine's demand for high-speed and stable data transmission.



model	Device Type	Use Location	effect	Encapsulation
3R090L	GDT	Ethernet interface	surge	3RXXXL
ESDLC3V3D3B	ESD	Ethernet interface	Surge, static electricity	SOD323

4.9.3 Software Algorithm Optimization Assistance

Anti-interference programming

Anti-interference algorithms are incorporated into software programming. For example, digital filtering algorithms are used to process collected sensor signals, removing noise and improving signal reliability. Checksums and CRC (cyclic redundancy check) are used during the transmission and reception of control commands to ensure data transmission accuracy and avoid data errors caused by electromagnetic interference, thereby ensuring the control accuracy and safety of the power chair.

Fault diagnosis and self-recovery

Develop a fault diagnosis program to monitor the operating status of the power chair's electronic circuits in real time. When an abnormality caused by electromagnetic interference or other factors is detected, the program can quickly locate the fault point and take appropriate self-recovery measures, such as reinitializing the circuit and adjusting control parameters, to restore the equipment to normal operation as quickly as possible, minimizing the inconvenience and danger to users caused by the fault.

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