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A Complete Analysis of Electromagnetic Compatibility of Electronic Circuits in Medical Molecular Analyzers

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Table of contents

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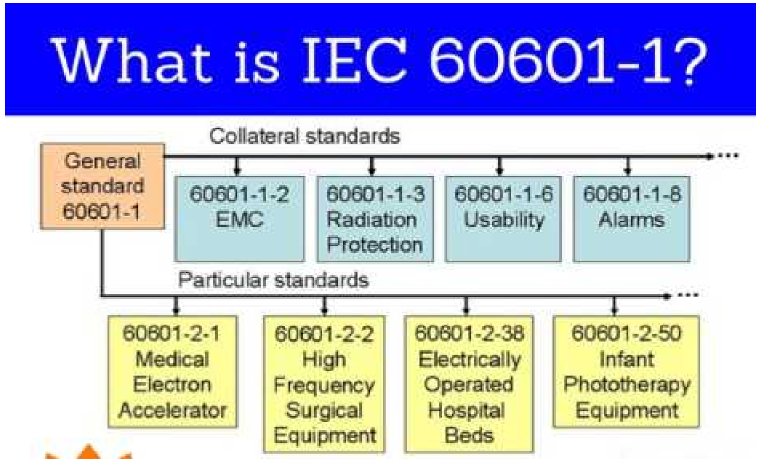
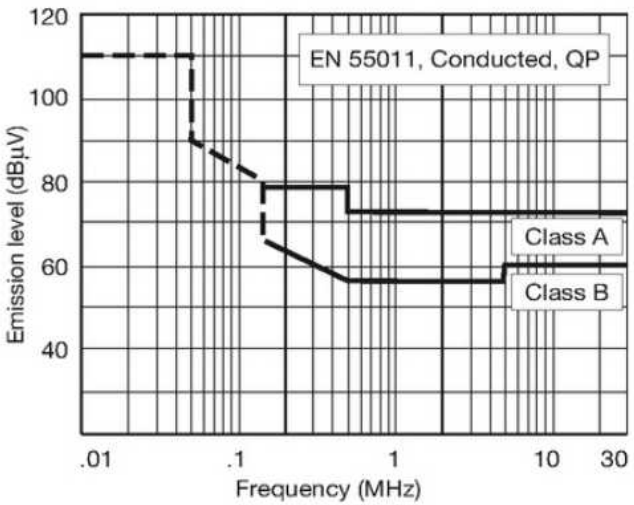
1. Interpretation of industry standards

1.1 International Industry Standards





The main international electromagnetic compatibility standard for medical molecular analyzers is IEC 60601-1-2, the electromagnetic compatibility standard for medical electrical equipment developed by the International Electrotechnical Commission. This standard requires medical devices to function normally in a specified electromagnetic environment while suppressing their own electromagnetic interference within a reasonable range to ensure stable operation and low interference with the surrounding electromagnetic environment.

The EN55011 standard regulates electromagnetic interference for industrial, scientific, and medical equipment, strictly setting limits for radiated and conducted interference, ensuring that medical molecular analyzers do not interfere with other electronic equipment during use.

1.2 Domestic Industry Standards

Safety EMC Quality Management

Medical molecular analysis equipment must meet safety requirements (IEC 60601-1/GB 9706.1)

Electromagnetic compatibility (IEC 60601-1-2/GB 9706.1-2)

Quality management (ISO 13485/YY/T 0287)

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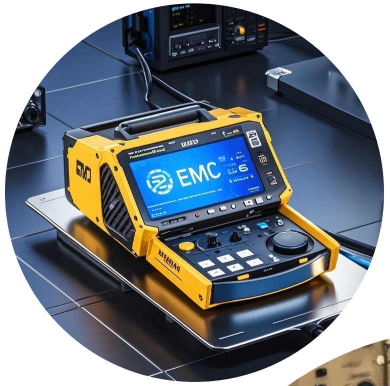
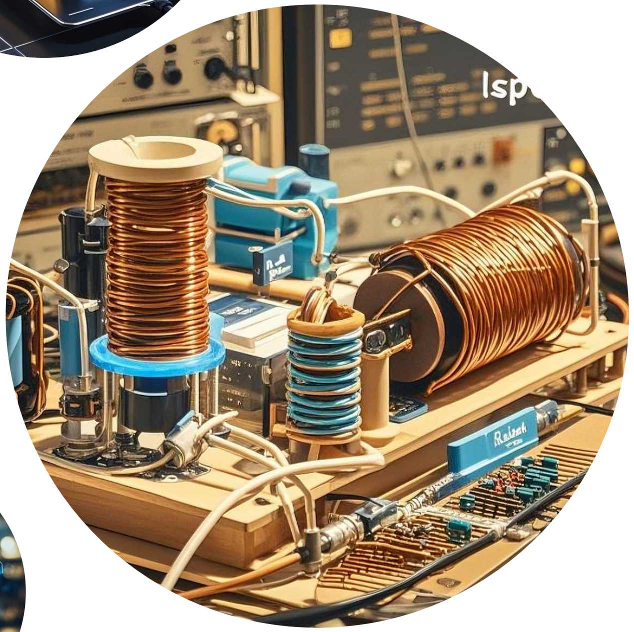
2. EMC test related requirements

2.1 Electromagnetic Interference (EMI) Test Requirements

Conducted Emissions Test:

This test measures the interference transmitted from the medical molecular analyzer to the outside world through the power cord or other conductors. The frequency range is generally 150kHz to 30MHz. This test effectively assesses the device's impact on the power grid and connected equipment, ensuring it does not cause conducted electromagnetic interference to the public power grid or other equipment.





Radiated Emissions Test:

This test primarily measures the electromagnetic waves radiated by the device. The test frequency range is 30MHz to 1GHz. This determines whether the device will interfere with other nearby medical devices and electronic products, preventing interference between devices in the medical environment due to electromagnetic radiation.

2.2 Electromagnetic interference (EMS) test requirements

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01

ESD electrostatic discharge immunity test:

Simulate the electrostatic discharge phenomenon that may occur in daily life and operation to test medical molecular analyzers to ensure that the equipment can still work normally when subjected to electrostatic shock and prevent static electricity from causing equipment failure or data errors

02

CE RF field induced conducted disturbance test:

Evaluate the device's anti-interference capability when subjected to conducted interference induced by RF fields, ensuring that the device operates stably in complex RF electromagnetic environments and does not experience functional abnormalities due to RF interference

03

EFT electrical fast transient burst test:

Test the equipment's resistance to electrical fast transient pulse groups, simulate the fast pulse interference that may occur in the circuit, ensure that the equipment can still operate accurately under such sudden interference, and ensure the continuity and accuracy of the medical process

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3. Analysis of industry pain points

3.1 Equipment failure caused by electromagnetic interference

When used in complex medical environments, medical molecular analyzers are susceptible to electromagnetic interference from surrounding electronic devices, resulting in inaccurate measurement data and compromising doctors' assessment and diagnosis of patients' conditions. For example, strong electromagnetic interference generated by nearby large medical equipment, such as MRI machines and CT scanners, can distort molecular analyzer results.

Electromagnetic interference generated by the analyzer itself can also affect other equipment. In equipment-intensive areas, such as hospital wards, electromagnetic interference from molecular analyzers can disrupt patients' vital signs monitoring equipment, endangering their lives.

3.2 Cost and technical challenges of meeting standards

On the cost side:

To meet stringent EMC standards, companies need to invest heavily in R&D and improving their products' electromagnetic compatibility, including adopting high-quality shielding materials and optimizing circuit design. This undoubtedly increases production costs and reduces a company's market competitiveness.

On a technical level:

Achieving good EMC design requires professional EMC engineers and advanced testing equipment. However, the current shortage of relevant professionals and the high cost of testing equipment present significant challenges for many companies, limiting the industry's overall technological advancement.

4. Circuit design solutions

4.1 Shielding Design

01

Using a metal casing for shielding effectively blocks outward radiation of internal electromagnetic interference and prevents external electromagnetic interference from entering the device.
For example, using an aluminum alloy casing offers excellent conductivity and mechanical strength, ensuring structural stability while providing effective electromagnetic shielding.

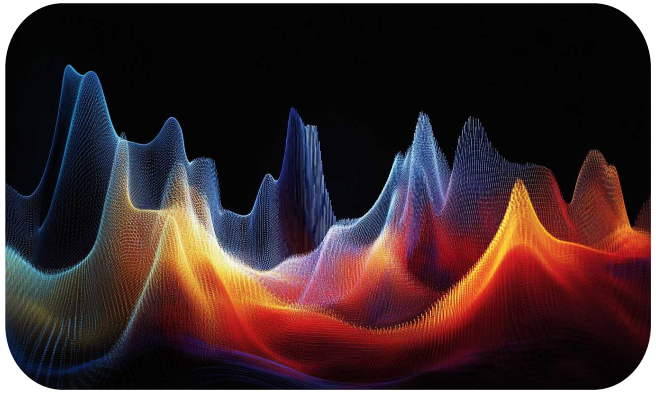
02

Adding a shielding layer to the circuit board. For example, copper foil is laid on the top and bottom layers of the PCB as a shielding layer, and connected to the ground layer through vias to form a complete shielding structure to reduce electromagnetic interference between circuits on the circuit board.

4.2 Filter Design

Adding a power filter to the power input port can effectively suppress the conducted interference on the power line, remove high-frequency noise and clutter in the power supply, provide pure power for the device, and ensure stable operation of the device.

Use signal filters on signal lines, select appropriate filters according to the frequency characteristics of the signal, filter out interference signals mixed in during signal transmission, and ensure the accuracy and integrity of the signal



4.3 Grounding Design

Establish a good grounding system to ensure the equipment's grounding resistance is low enough to allow electromagnetic energy to be smoothly conducted to the earth.

For example, use single-point grounding, connecting all components requiring grounding to the same point to avoid ground loops and reduce ground interference. For multi-layer circuit boards, rationally plan the grounding planes and separate the grounding of different functional modules to avoid mutual interference and improve the equipment's anti-interference capabilities.

4.4 PCB Layou Layout Reference Suggestions

Number of layers	Lay order	Power Supply Design Key Points	Ground design points	Signal design points	Applicable Scenarios
4-layer board	Top: Signal layer	The power layer (L3) is partitioned to avoid excessive segmentation. The distance between adjacent power domains is ⩾ 2m. The decoupling capacitors are close to the IC power pins.	L2 is a complete ground plane to avoid segmentation. Maintain a complete ground plane under key signals and use multiple grounding points to avoid ground loops.	High-speed signals go on the top layer, refer to the L2 ground plane, and sensitive signals (clocks, differential lines) are prioritized close to the ground plane. Follow the 3W rule to reduce crosstalk.	Cost-sensitive, medium- and low-speed circuits (such as MCU control boards and simple digital circuits)
	L2: Ground plane (GND), L3: Power plane (PWR), Bottom: Signal layer				
6-layer board	Top: Signal layer	The power layer (L4) is surrounded by the ground plane (L2/L5) to reduce noise, and high-frequency decoupling capacitors (0.1μF + 1μF combination)	Double ground planes (L2+L5) provide a low-impedance return path. The ground plane should be as complete as possible to avoid cross-splitting of key signals. Via stitching should be arranged along the edge of the board.	High-speed signals (such as DDR, USB) go on the Top layer, reference the L2 ground plane, medium-speed signals go on the L3 layer, bidirectional reference (GND/PWR), differential lines are strictly equal length (±5mil)	High-speed design (such as FPGA, DDR4, and RF circuits)
	L2: Ground plane (GND), L3: Signal layer, L4: Power plane (PWR), L5: Ground plane (GND), Bottom: Signal layer				

Note 1. In a 4-layer board, the power layer (L3) and the ground layer (L2) are adjacent, forming a natural decoupling capacitor.

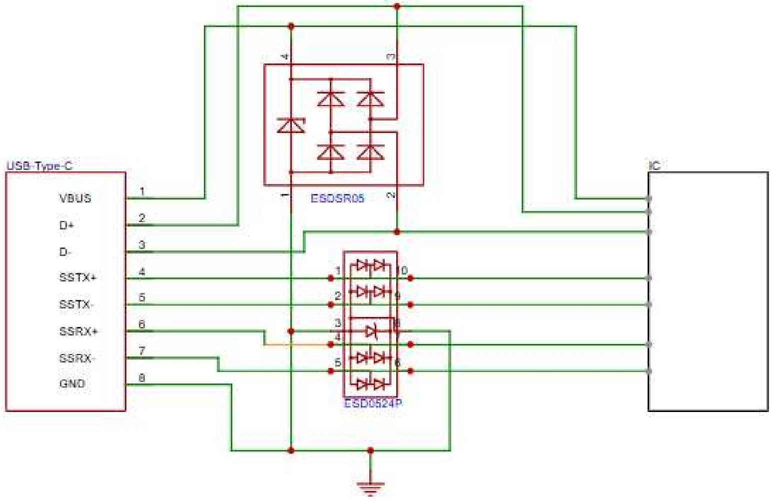
Note 2. In a 6-layer board, the power layer (L4) is sandwiched between two ground planes (L2/L5), further reducing impedance.

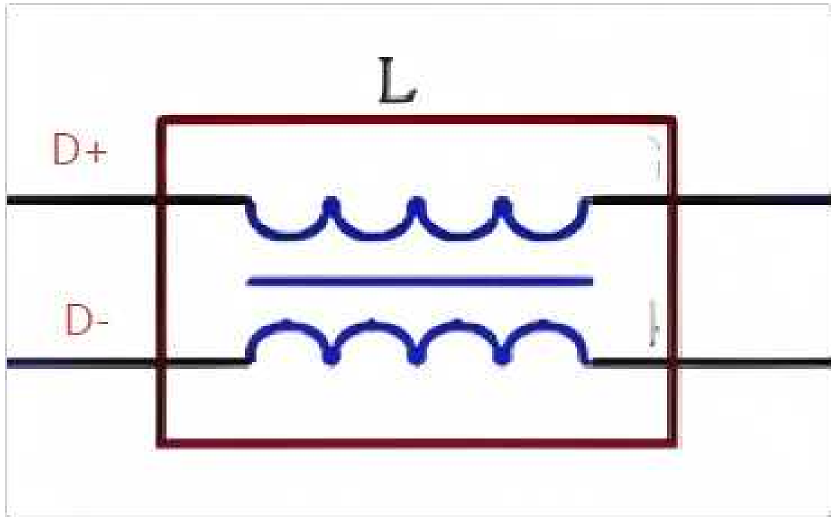
Note 3: The 3W rule is a basic principle used in PCB routing to reduce crosstalk between signals. It requires that the center-to-center spacing between adjacent signal lines be ⩾ 3 times the line width (W).

4.5 USB-Type-C interface EMC and hot-swap reliability design

USB interface

The USB interface has high-speed data transmission capabilities and plug-and-play features, making it easy for users to connect and replace devices at any time, improving the convenience of robot use and playing a key role in various robot application scenarios; high-speed data transmission (such as gene sequence data, mass spectrometry raw data), sequencers, mass spectrometers; all interfaces must pass YY 0505 (EMC standard for medical electrical equipment) testing, so common-mode rejection is very important.





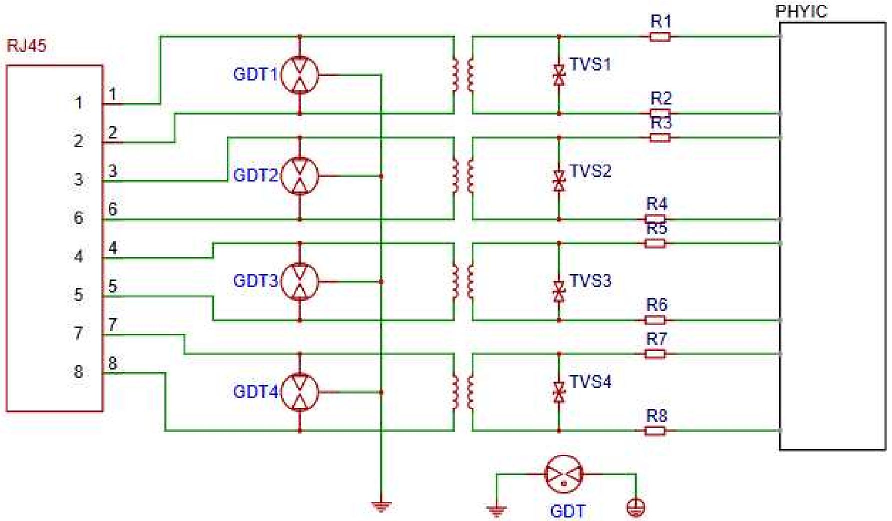
model	Device Type	Use Location	effect	Encapsulation
ESD0524P	ESD	USBinterface	Surge, static electricity	DFN2510
ESDSR05	ESD	USBinterface	Surge, static electricity	SOT143
CMZ2012A-900T	Common choke	USBinterface	EMI	2012 / 3225

Ethernet interface

Ethernet interface (RJ45): Supports wired network connection (commonly found on intelligent robot motherboards).

The Ethernet interface provides a stable network connection for robots, enabling remote control and data exchange. Through Ethernet, robots can upload real-time working data to the cloud, receive remote commands, and achieve intelligent remote operation.

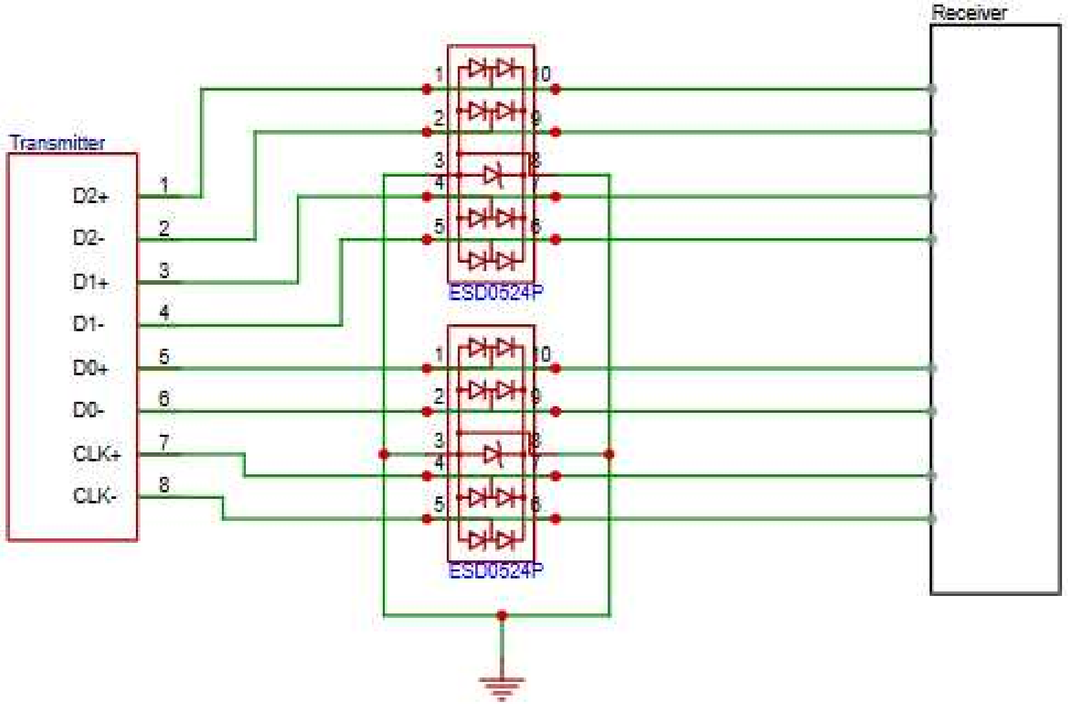
With transmission rates reaching 1000Mbps or higher, it meets the high-speed, stable data transmission requirements of robots in industrial automation, intelligent logistics, and other fields.



model	Device Type	Use Location	effect	Encapsulation
3R090L	GDT	Ethernet interface	surge	3RXXXL
2R090L	GDT	Ethernet interface	surge	2RXXXL
ESDLC3V3D3B	ESD	Ethernet interface	Surge, static electricity	SOD323

4.7 HDMI interface EMC and hot-swap reliability design

HDMI interface High-resolution test result output (such as fluorescence imaging data), digital pathology scanner

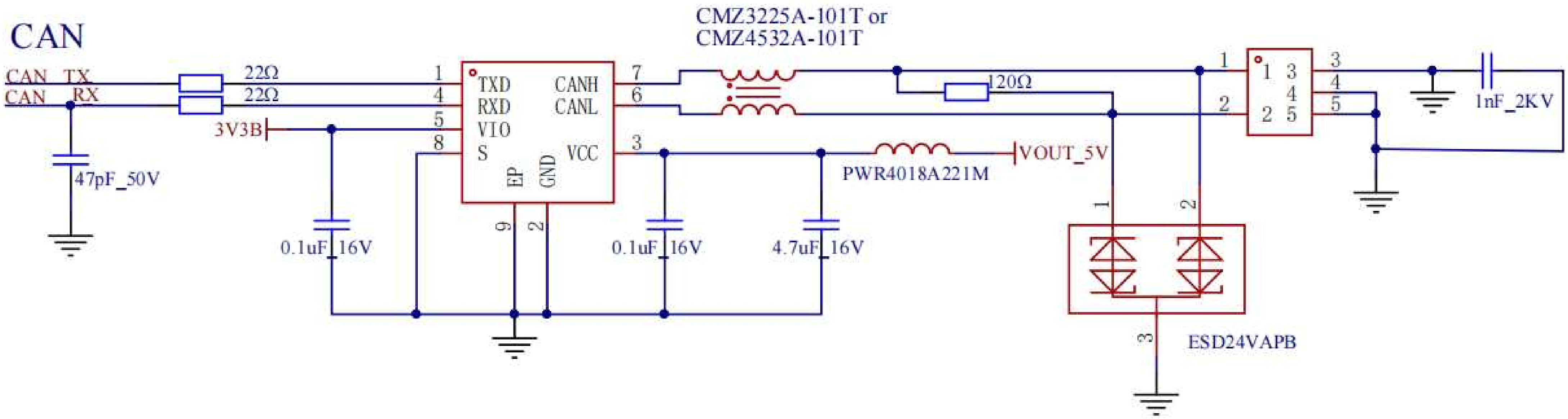


model	Device Type	Use Location	effect	Encapsulation	Features
ESD0524P	ESD	HDMIinterface	Surge, static electricity	DFN2510	Large dosage, high value ratio

4.8 CAN Bus Control Module Solution

For CAN bus multi-module collaborative control (such as temperature control modules and robotic arms), Yinte Electronics has deeply optimized this module to improve data processing capabilities and transmission efficiency, supporting multi-node communication and ensuring efficient system operation.

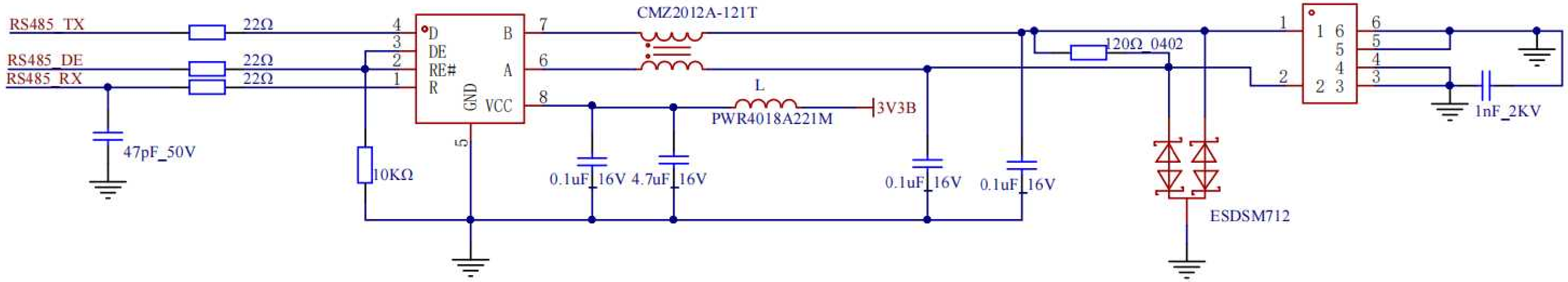
CMZ3225A-101T or CMZ4532A-101T common-mode inductors improve EMI performance.
ESD24VAPB SOT-23 CAN ESD protector.
PWR4018A221M static power supply ripple reduction.



4.9.1 RS485 Communication Module Solution

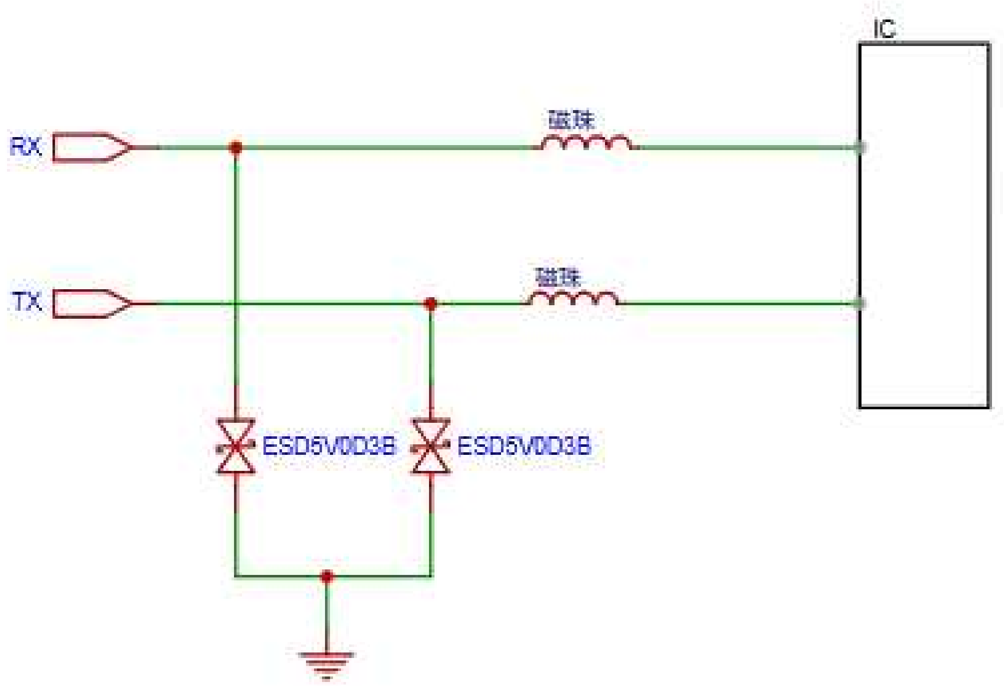
For legacy equipment control (compatible with laboratory automation systems), the RS485 communication module boasts high anti-interference capabilities and utilizes advanced differential signal transmission technology to effectively reduce interference during signal transmission, ensuring accurate and stable data transmission.

CMZ2012-121T common-mode choke improves EMI performance.
PWR4018A221M enhances power supply quality.
ESDSM712 electrostatic protection prevents static interference during installation and removal.



4.9.2 GPIO/UART/I2Cinterface EMC and Hot-Swap Reliability Design

GPIO interface (general purpose input and output): switch control (such as valve and pump start and stop), isolated design to prevent surge



model	Device Type	Use Location	effect	Encapsulation
ESD5V0D3B	ESD	GPIOinterface	Surge, static electricity	SOD323
PBZ1608A02Z0T	EMI	Series Online	Filtering	1608

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