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A Complete Analysis of Electromagnetic Compatibility in Blood Pressure Monitor Electronic Circuits: From Pain Points to Solutions

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1. International industry standards

1.1 Main International Standards for Blood Pressure Monitoring Equipment

01

The main standards for blood pressure monitoring equipment include the IEC 60601 series. IEC 60601-1-2 is a key standard for electromagnetic compatibility of medical electrical equipment, clearly defining the ability of devices to function properly in an electromagnetic environment and not interfere with other devices.

02

The ISO 11073-10407 standard focuses on the specialized equipment requirements for blood pressure monitors within the context of personal health device communications in health informatics. It ensures compatibility and stability between different blood pressure monitoring devices, facilitating the accurate transmission and sharing of medical data.

03

The IEEE 11073-10407 standard, developed by the Institute of Electrical and Electronics Engineers (IEEE), also plays a significant role in the specialized field of blood pressure monitors within the context of personal health device communications in health informatics, providing a basis for the technical implementation and functional specifications of blood pressure monitors.

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2. Domestic industry standards

2.1 Standards and specifications followed by domestic blood pressure monitors

Domestic blood pressure monitor standards are aligned with international standards while also taking into account actual domestic needs and the specific characteristics of the medical environment.

YY9706.234-2021, "Medical Electrical Equipment - Part 2-34: Particular Requirements for the Basic Safety and Essential Performance of Invasive Blood Pressure Monitoring Equipment," strictly stipulates the basic safety and essential performance requirements for invasive blood pressure monitoring equipment, ensuring their safety and effectiveness in clinical use.

YY0505, China's EMC standard for medical electrical equipment, is largely consistent with the internationally accepted IEC60601-1-2. It covers several key test items, including electrostatic discharge immunity, radio frequency radiation immunity, and electrical fast transient/burst immunity. This ensures that the equipment operates stably in complex electromagnetic environments while not interfering with surrounding equipment.

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3. EMC test related requirements involved in industry standards

3.1 EMC test items and their importance

静电放电抗扰度测试

The test requires that the blood pressure monitor can still maintain normal working state when subjected to electrostatic discharge, without abnormal phenomena such as data errors, freezing, and restarting. In daily life, electrostatic discharge may be generated when the human body comes into contact with the equipment. If the monitor does not meet this test requirement, it may lead to inaccurate measurement data and affect the doctor's judgment of the patient's condition.

射频辐射抗扰度测试

The test is designed to verify the device's ability to resist interference in a radio frequency radiation environment. Hospitals are equipped with various wireless communication devices, such as Wi-Fi and Bluetooth devices, which may interfere with the normal operation of blood pressure monitors. This test ensures that the monitor can operate stably in such an environment and accurately measure the patient's blood pressure data.

电快速瞬变脉冲群抗扰度测试

The test requires that the equipment does not malfunction when subjected to electrical fast transient pulse group interference. In the electrical environment of the hospital, the starting of the motor, the opening and closing of the switch, etc. may generate electrical fast transient pulse groups. The monitor that meets the test requirements can effectively resist these interferences and ensure the accuracy and stability of the measurement.

传导发射测试

The test is used to limit the intensity of electromagnetic interference conducted by the blood pressure monitor to the outside through the power line or signal line. If the conducted emission of the device exceeds the limit, it may affect the normal operation of other devices in the same electrical network. Therefore, this test can ensure that the monitor will not cause conducted interference to surrounding medical equipment, electrical systems, etc.

辐射发射测试

The test specifies the limit of electromagnetic energy radiated by the device into the surrounding space. Blood pressure monitors generate a certain amount of electromagnetic radiation when working. If the radiation emission exceeds the standard limit, it may interfere with other nearby electronic devices and even have potential effects on the health of patients and medical staff. Therefore, this test can ensure the electromagnetic compatibility of the medical environment.

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4. Industry pain points of blood pressure monitors

4.1 Pain Point 1: Insufficient Immunity (RF)

◆ Pain Points:

In medical environments, the device is susceptible to interference from other high-frequency devices (such as mobile phones, Wi-Fi, and surgical electrosurgical units), resulting in measurement errors, screen flickering, or freezing.

When the device is in an MRI room or near a large transformer, the pressure sensor output drifts (e.g., the indication error exceeds ±5 mmHg).

◆ Typical Scenario:

In the ICU or operating room, the monitor displays abnormal blood pressure values due to interference from the electrosurgical unit.

◆ Cause: RF immunity (e.g., failure of the RF field immunity test in the YY0505/IEC60601-1-2 standard).

Magnetic shielding measures are not implemented for the Hall effect element or analog signal chain.

IEC60601-1-2:2014 (corresponding to YY0505-2012), Section 6.8.3.3.

Testing compliant with: IEC61000-4-6 (frequency range 150 kHz–80 MHz).

IEC 60601-1-2, Section 6.8.3.2 (references IEC 61000-4-8).

4.2 Pain Point 2: Conducted Emissions Exceeding Standards

◆ **Pain Points:**

Excessive electromagnetic noise transmitted through device power or signal lines can affect other devices on the same power grid (such as electrocardiographs and infusion pumps).

◆ **Typical Scenario:**

When multiple devices are used in parallel, a blood pressure monitor can trigger false alarms. Screen distortion and blood pressure fluctuations can occur when the device is near Wi-Fi (2.4GHz), mobile phones (900MHz/1.8GHz), or medical RF equipment (such as electrosurgery).

◆ **Cause:** Inadequate power supply filtering or poor grounding.

4.3 Pain Point 3: Electrostatic Discharge (ESD) Failure

◆ Pain Points:

Contacting device buttons or interfaces can cause static electricity to cause program crashes or hardware damage.

◆ Typical Scenario:

Discharge triggered by medical personnel during operation, resulting in device reboots or data loss.

◆ Cause:

Enclosure insulation design defects or failure to pass IEC 61000-4-2 testing (e.g., failure of ±8kV air discharge).

IEC 60601-1-2, Section 6.8.3.1 (According to IEC 61000-4-2, ±6kV contact discharge/±8kV air discharge).

4.4 Pain Point 4: Excessive Radiation Emissions

◆ **Pain Points:**

The device's own electromagnetic radiation interferes with other devices, or fails regulatory testing (such as FDA or CE certification).

◆ **Typical Scenario:**

Radiated frequency bands (e.g., 30MHz-1GHz) exceed limits, resulting in device certification failure.

◆ **Cause:** Improper PCB layout or inadequate shielding (e.g., lack of isolation for motor drive circuits).

IEC 60601-1-2:2014, Section 6.8.3.4 (corresponding to Section 36.202.4 of YY 0505).

Testing Principle: IEC 61000-4-3 (frequency range 80MHz–2.7GHz, severity level 3V/m; critical care equipment requires 10V/m).

4.5 Pain Point 5: Poor Tolerance to Fast Transients (EFT/Burst)

Pain Points:

Power grid fluctuations (such as equipment startup and shutdown) can cause false triggering or measurement interruptions in blood pressure monitors.

Typical Scenario:

Frequent device restarts when central air conditioning is started in a hospital.

Causes:

No transient suppression in the power supply circuit or signal line (failed IEC61000-4-4 testing).

The power module lacks a transient suppression circuit (missing a varistor and TVS).

Standard Clause: IEC60601-1-2, Section 6.8.3.5 (according to IEC61000-4-4, ±2kV for power lines/±1kV for signal lines).

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5. Circuit design solutions for EMC

5.1 Critical Limit Requirements in the Standard

Test items	Standard basis	Frequency/severity level	Pass conditions
Conducted RF immunity	IEC 61000-4-6	150kHz–80MHz, 3Vrms	Functions normally without performance degradation
Radiated RF immunity	IEC 61000-4-3	80MHz–2.7GHz, 10V/m (critical care equipment)	No misoperation is allowed
Power frequency magnetic field immunity	IEC 61000-4-8	50/60Hz, 30A/m	The measurement error is within the clinical allowable range
Electrostatic Discharge (ESD)	IEC 61000-4-2	±8kV (air discharge)	Automatic recovery after testing, no hardware damage
Fast transient burst	IEC 61000-4-4	±2kV (power line)	Does not trigger the safety protection mechanism

5.2 Shielding Design

The blood pressure monitor's housing design utilizes metal or composite materials with shielding properties to create an effective electromagnetic shielding layer, preventing internal electromagnetic radiation from leaking into the external environment while also preventing external electromagnetic interference from entering the device. For example, an aluminum alloy housing not only provides excellent shielding performance but also ensures the device's structural strength.

Partially shield the internal circuit boards. Critical circuit modules prone to electromagnetic interference, such as the power module and RF module, are isolated with metal shielding covers to reduce electromagnetic coupling interference between modules.

5.3 Filter Circuit Design

Design appropriate filters at the power input and signal input terminals, such as low-pass filters, high-pass filters, and band-pass filters, to filter out high-frequency interference from the power supply and signal, ensuring the purity of the power and signal input to the device.

5.4 Circuit Nodes

1. AC/DC power supply (flyback) outputs 12V

2. Buck converter (3.3V/5V) inputs 12V and outputs 5V

3. MCU (STM32, etc.) inputs 5V, outputs control signals (GPIO), and receives ADC signals

4. Pressure sensor (Wheatstone bridge) outputs a differential signal

5. Instrumentation amplifier (INA128) inputs a differential signal and outputs an amplified signal

6. Filter circuit inputs the amplified signal and outputs a filtered signal to the ADC

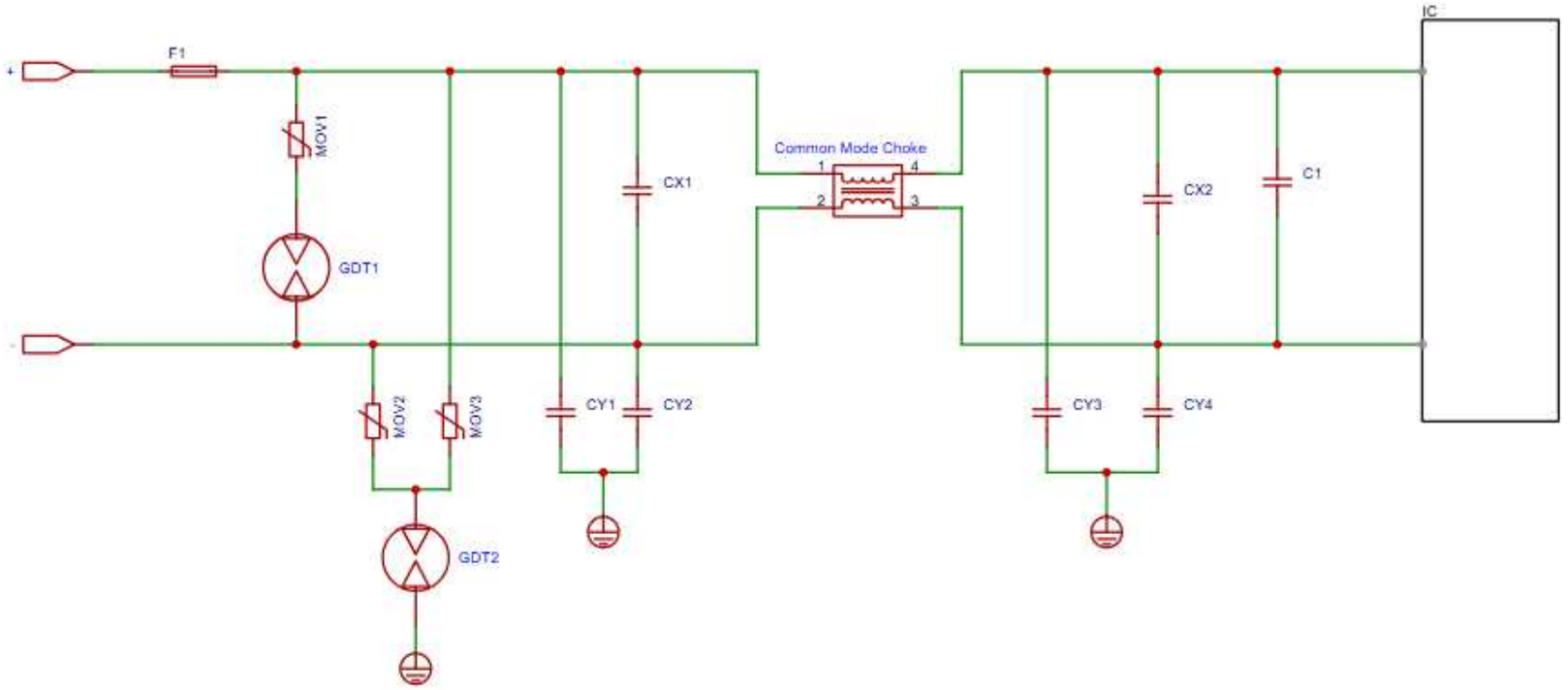
7. ADC (16/24-bit) inputs the filtered signal and outputs a digital signal to the MCU

8. H-bridge driver (DRV8871) inputs a GPIO (PWM) signal from the MCU and outputs a signal to drive the air pump

9. The air pump (DC motor) is driven by the H-bridge driver

5.5 AC power interface EMC and reliability design

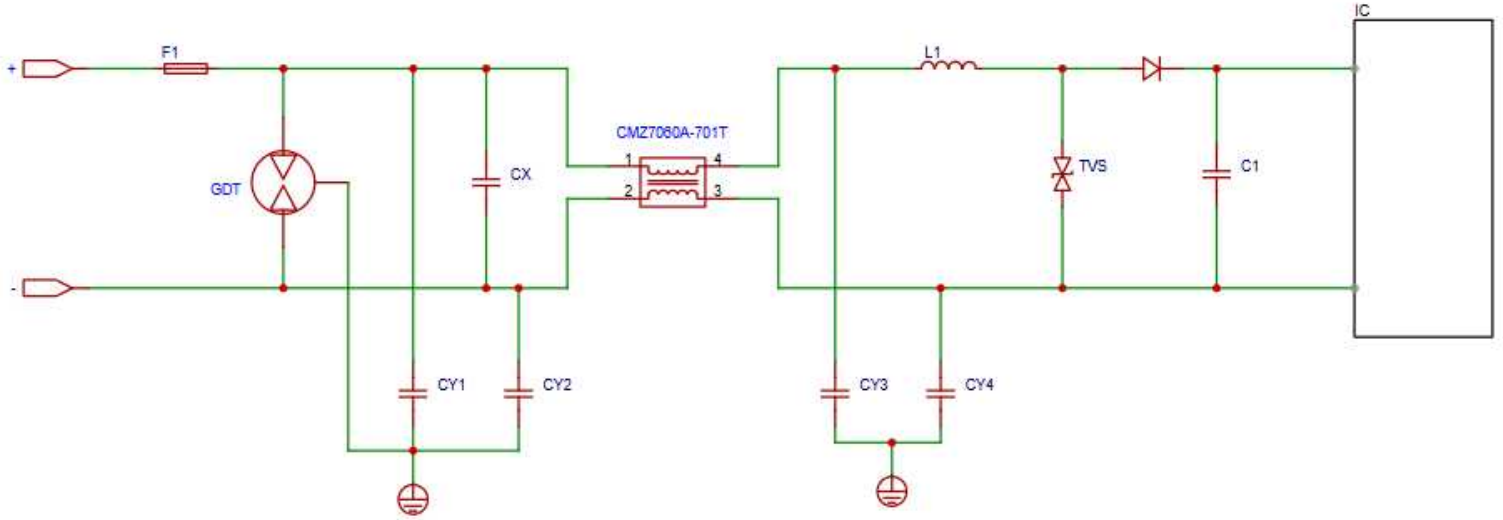
AC power interface: used to connect external 220V AC input



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

5.6 DC Power Supply Interface EMC and Reliability Design

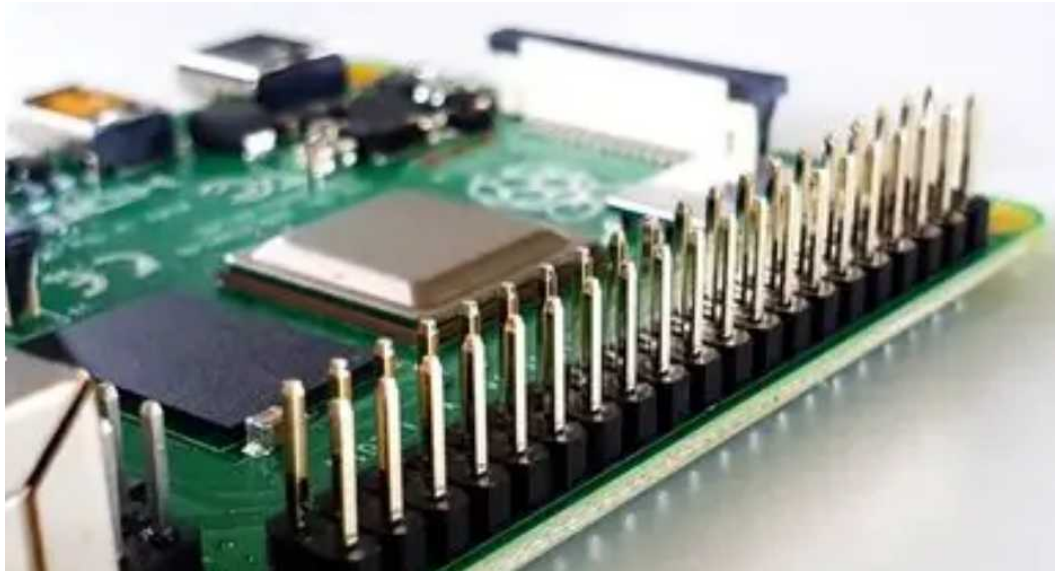
DC power interface: used to connect an external power adapter (such as 5V/12V DC input). Some motherboard chips support power supply via USB.

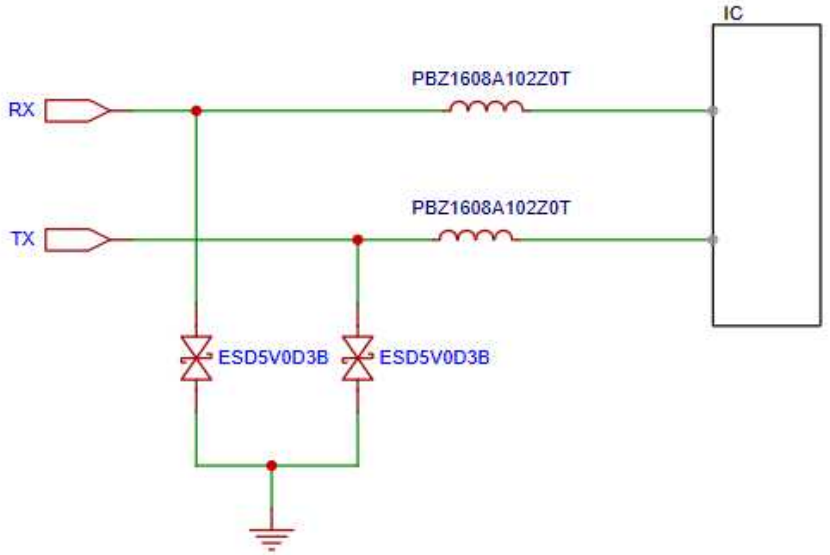


model	Device Type	Use Location	effect	Encapsulation
3R090L	GDT	Power interface	Surge and lightning protection (for outdoor products, pay attention to the issue of continuous current)	3RXXXL
SMBJ6.5CA	TVS Transient Voltage Suppressor Diodes	Power interface	Surge, load dump	SMB/Do-214AA
SMCJ15CA	TVS Transient Voltage Suppressor Diodes	Power interface	Surge, load dump	SMC/Do-214AB
CMZ7060A-701T	EMI common-mode suppressors	Power interface	CE conduction, common mode suppression, smaller current, consider small encapsulation	7060

5.7 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



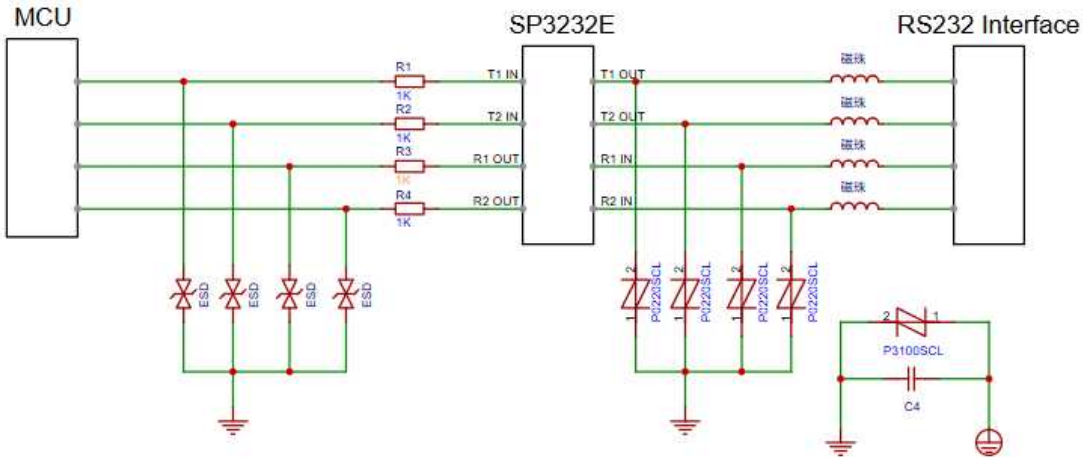


model	Device Type	Use Location	effect	Encapsulation
ESD5V0D3B	ESD	GPIO interface	Surge, static electricity	SOD323
PBZ1608A102Z0T	magnetic beads	GPIO interface	Eliminate high-frequency interference	1608

5.8 RS232 to TTL (SP3232E) Interface EMC and Hot-Swap Reliability Design

RS232 interface:

One of the commonly used serial communication interfaces, RS232 is suitable for short-distance device interconnection (such as printers, mice, etc.), and requires a level conversion chip (such as SP3232E) to adapt to different logic levels. It is used here to connect to an old medical printer, with a general rate of 115.2kbps.

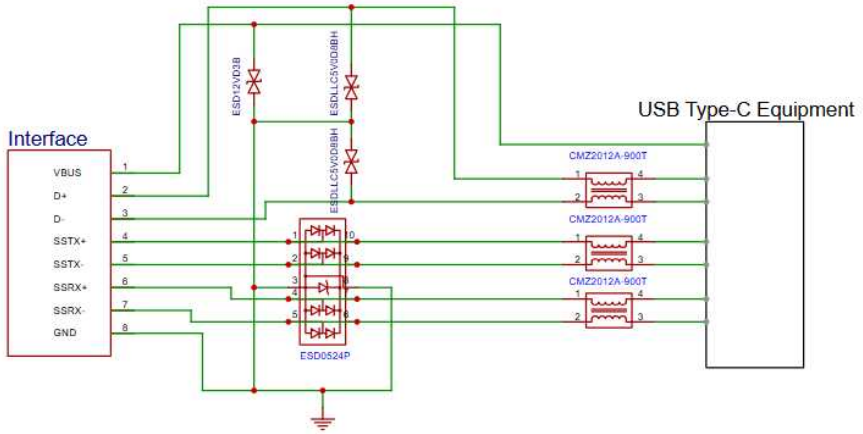


model	Device Type	Use Location	effect	Encapsulation
P0220SCL	TSS	RS232 interface	Surge, static electricity	SMB
P3100SCL	TSS	RS232 interface	Lightning strike、Surge, static electricity	SMB
ESD5V0D3B	ESD	MCU interface	Surge, static electricity	SOD323
PBZ1608A102Z0T	magnetic beads	RS232 interface	Eliminate high-frequency interference	1608

5.9.1 USB-TYPE-C PD (Supporting 9V/2A Fast Charging) EMC and Hot-Swap Reliability Design

USB-Type-C 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 machine use, and playing a key role in various machine application scenarios; such as high-speed data transmission (such as gene sequence data, mass spectrometry raw data), sequencers, and mass spectrometers; and all interfaces must pass the YY 0505 (EMC standard for medical electrical equipment) test, so common mode rejection is very important.

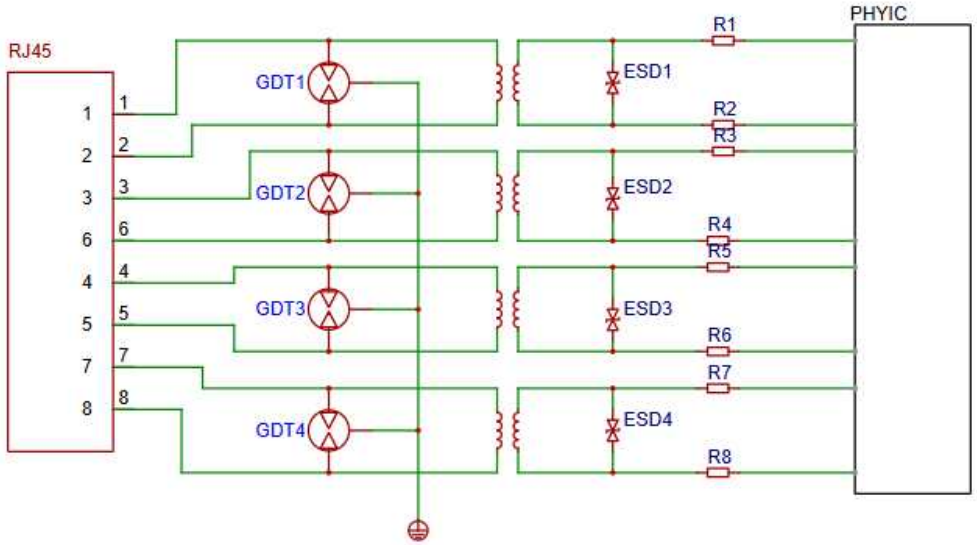


model	Device Type	Use Location	effect	Encapsulation
ESD0524P	ESD	USBinterface	Surge, static electricity	DFN2510
ESD5V0D8BH	ESD	USBinterface	Surge, static electricity	DFN1006
CMZ2012A-900T	EMI common-mode suppressors	USBinterface	Common-mode rejection	2012
ESD12VD3B	ESD	USBinterface	Surge, static electricity	SOD323

5.9.2 Ethernet Interface EMC and Hot-Swap Reliability Design

Ethernet interface

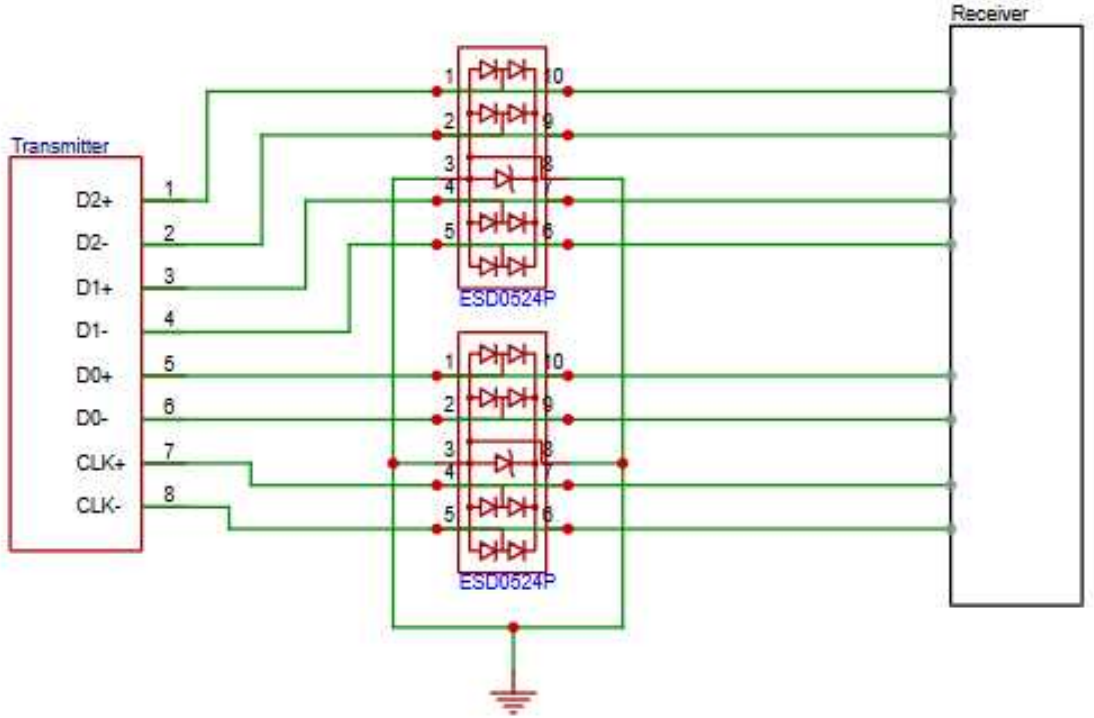
Supports wired network connection; Ethernet interface provides stable network connection for the machine, supporting remote control and data interaction. Through Ethernet, the machine can upload working data to the cloud in real time, receive remote commands, and realize intelligent remote operation;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



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

5.9.3 HDMI interface EMC and hot-swap reliability design

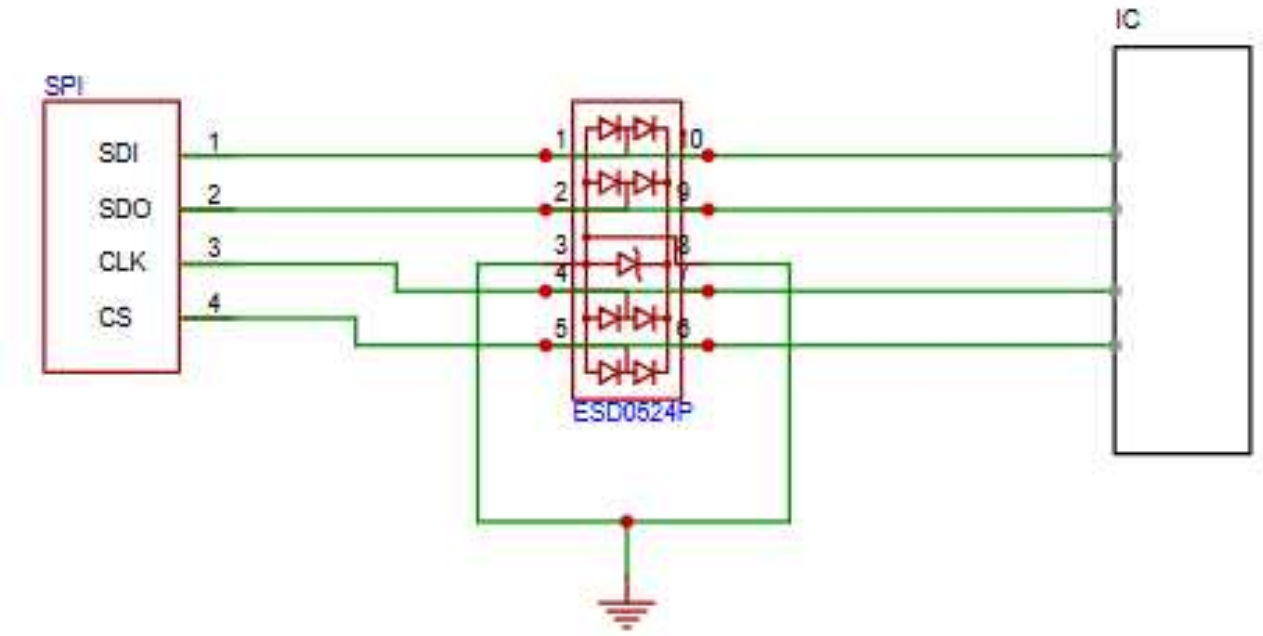
HDMI interface: used to connect to a monitor to output video signals

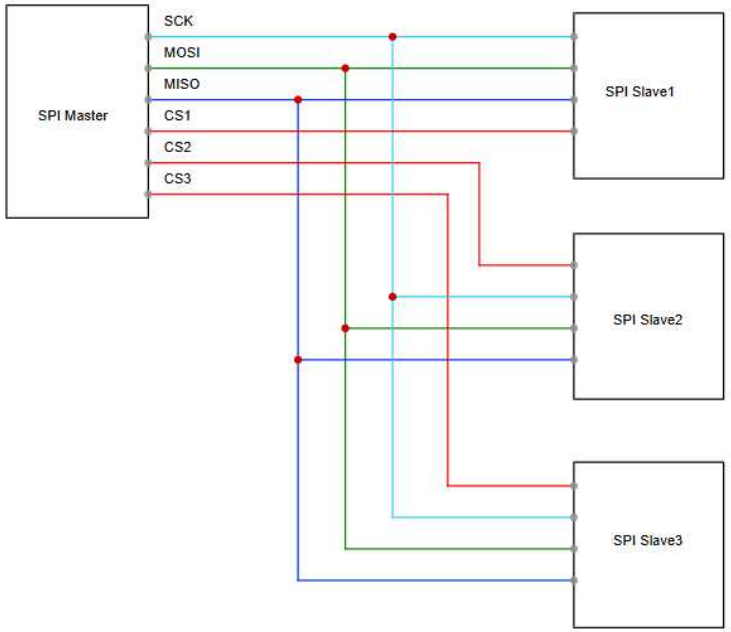


model	Device Type	Use Location	effect	Encapsulation	Features
ESD0524P	ESD	HDMI interface	Surge, static electricity	DFN2510	Large dosage, high value ratio

5.9.4 SPI Interface EMC and Hot-Swap Reliability Design

SPI interface: high-speed serial communication interface, used to connect to display screens, etc.

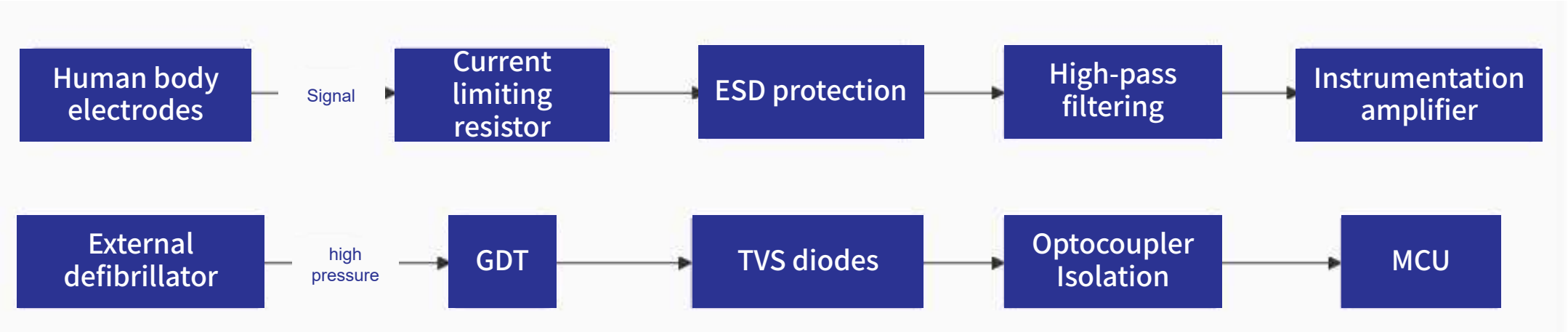




model	Device Type	Use Location	effect	Encapsulation
ESD0524P	ESD	SPI interface	Surge, static electricity	DFN2510

5.9.5 ECG lead socket

Electrocardiogram, ECG: The key interface for connecting human electrodes to collect ECG signals. IEC60601-2-25: ECG equipment standard.



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