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Improvement, innovation, saving, win-win

Electrocardiogram (ECG) Electronic Circuit Electromagnetic Compatibility Solutions

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1. Industry Standards

1.1 International Industry Standards

International standards for electrocardiograms (ECGs) primarily address information technology applications, covering aspects such as device communications, cabling, and common-mode rejection ratio (CMRR). Regarding device communications, IEEE 11073-10406-2023 specifies specialized standards for basic ECG (1- to 3-lead ECG) devices for personal health device communications. These standards clarify interoperability specifications and ensure compatibility between devices from different manufacturers.

AMI TIR60-2014(2019) focuses on the application of CMRR in ECG monitoring. CMRR directly impacts the ability of ECG monitoring to suppress common-mode interference signals. The development of this standard will help improve ECG monitoring accuracy.

1.2 Domestic Industry Standards

Domestic standards were developed based on practical application scenarios such as health checkups and pediatric examinations.

DB3206/T1078-2024 specifies auxiliary operating requirements for ECG examinations during health checkups, standardizing the operating procedures for the primary examiner and other personnel to ensure the reliability and consistency of examination results, making ECG examinations more standardized and scientific during physical examinations.

DB22/T3266-2021 comprehensively regulates Holter examinations for children, from indications and contraindications to operating procedures and requirements. Taking into account the unique physiological conditions of children, it ensures a safe and effective examination and provides a standardized basis for pediatric heart health examinations.

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2. EMC test related requirements

2.1 Test Items and Standards

01

Medical device EMC testing is based on the latest standard IEC 60601-1-2:2020, which sets strict requirements for radiated emissions, immunity, and electrostatic discharge. Radiated emission testing requires that the device's radiated emission limits be lower within the specified frequency band to avoid electromagnetic interference to surrounding electronic equipment; immunity testing ensures that the device can operate stably in complex electromagnetic environments without malfunction or data loss.

02

The electrostatic discharge immunity test is based on IEC 61000-4-2, with a test voltage of ±8kV contact and ±15kV air, simulating human electrostatic discharge and other conditions to detect whether the electrocardiograph can resist electrostatic interference and ensure normal operation of the equipment. The surge immunity test is carried out in accordance with IEC 61000-4-5 with a 1.2/50 μs voltage waveform to verify the equipment's ability to cope with transient high voltages such as lightning strikes and power grid switching.

2.2 Importance of Testing

For medical devices like electrocardiographs, EMC performance is crucial.

Failure to meet electromagnetic compatibility standards can lead to device malfunction, such as erroneous ECG signal readings, leading to misdiagnosis. It can also cause data loss, hampering patient tracking and diagnosis.

In critical scenarios like surgery, abnormal operation of equipment due to electromagnetic interference can endanger patient safety. Therefore, EMC testing ensures stable and reliable operation of equipment in medical environments.

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3. EMC pain points of electrocardiogram (ECG)

3.1 Disadvantages of contact detection

Traditional ECG monitoring requires the use of contact electrodes to measure changes in surface electrical activity, which can be uncomfortable for patients and make long-term continuous ECG monitoring difficult in daily life.

For example, while a patient is sleeping, the electrodes can cause pressure, disrupting sleep and affecting monitoring continuity.

This inconvenience can easily lead to the loss of fleeting abnormal ECG states, delaying diagnosis and missing the optimal treatment opportunity.

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4. Circuit design solutions for EMC

4.1 Hardware Design

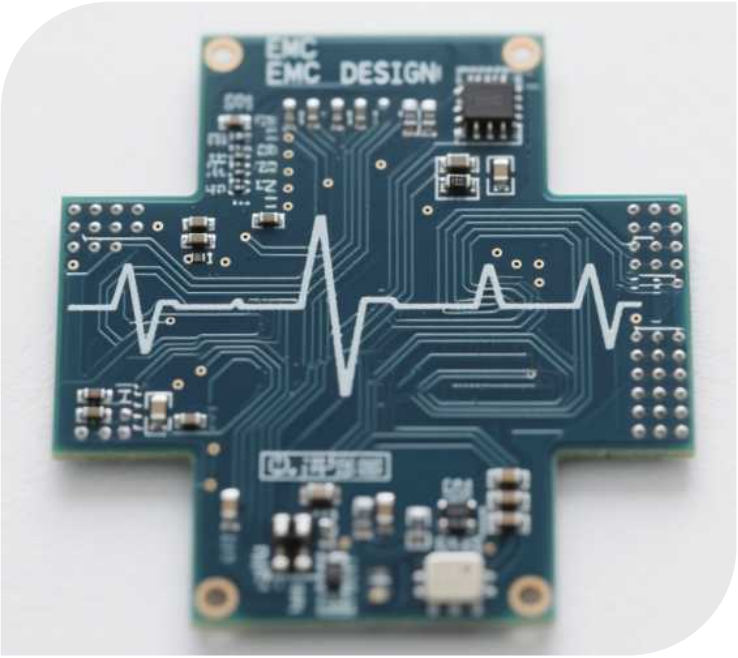
Select low-electromagnetic radiation components to reduce electromagnetic interference at the source. Select low-noise operational amplifiers to reduce their own electromagnetic noise, minimizing contamination of ECG signals and improving signal acquisition purity.

Optimize circuit layout and rationally plan component placement and routing on the circuit board to reduce electromagnetic leakage. Separate sensitive signal lines from interference source lines, avoiding parallel routing to minimize electromagnetic coupling interference.

Use shielding materials, such as metal shielding covers, to shield the internal circuits of the electrocardiograph to prevent internal electromagnetic interference from propagating outwards and external interference from entering, ensuring that the equipment can operate normally in complex electromagnetic environments.

4.2 Filter Circuit Design

Design effective filtering circuits and set appropriate filters for different types of interference. For example, use a low-pass filter to filter out high-frequency noise while retaining the effective low-frequency components of the ECG signal; use a high-pass filter to remove DC bias and low-frequency interference signals.



For common-mode interference, use a common-mode inductor. Its high impedance to common-mode signals suppresses common-mode current and improves the common-mode rejection ratio. For differential-mode interference, use an LC filter circuit consisting of capacitors and inductors. Adjust the capacitor and inductor parameters according to the interference frequency to achieve optimal filtering results.

4.3 EMC Design Strategy

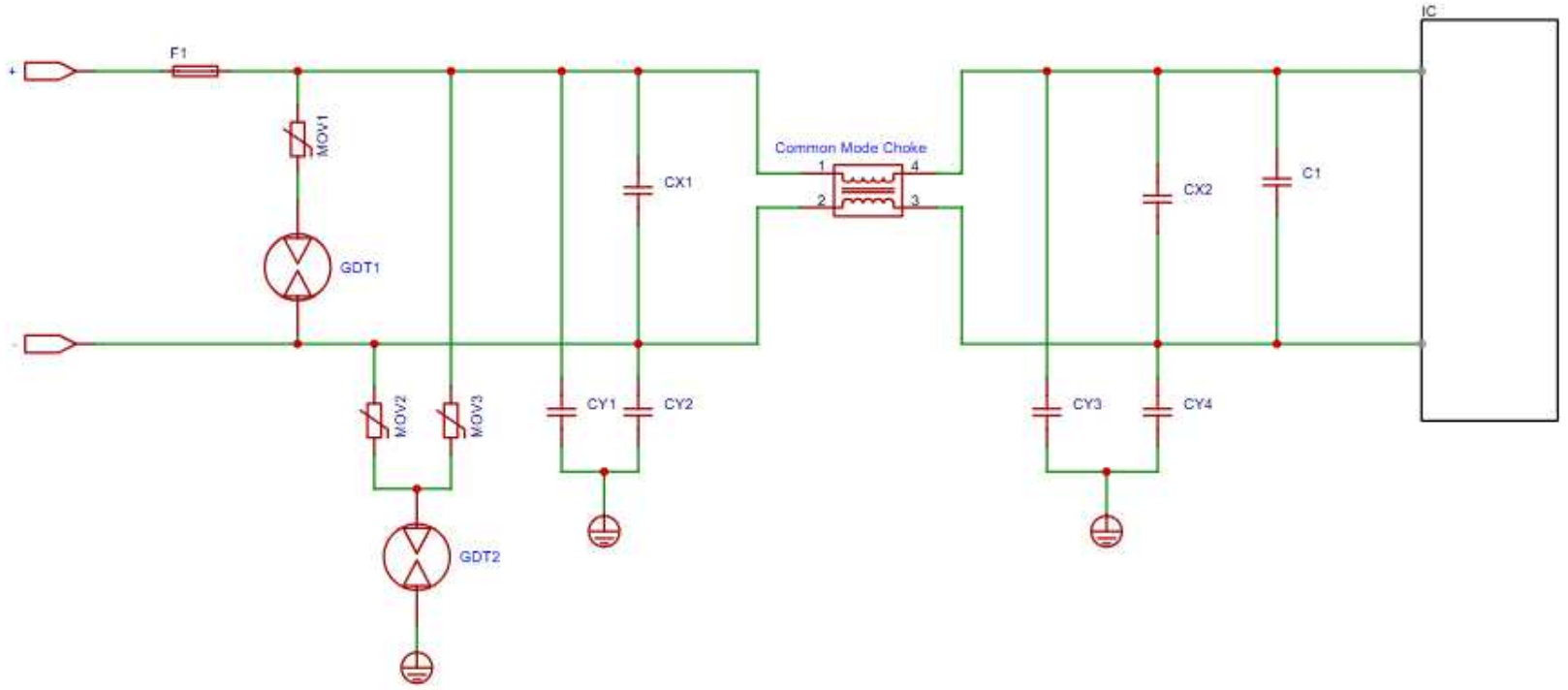
The "**drainage**" strategy, or "unblocking," reduces the impact current entering sensitive circuits by reducing impedance through other channels. Near-ground protection is employed, using the ground plane as the primary path to bypass the impact current. Capacitors are placed between the cable socket and the reference ground or E-plane to shorten the ground path and avoid sensitive areas. Alternatively, additional current diversion methods can be added to circuit areas with strong interference immunity to reduce the impact of affected areas.

The "**blocking**" strategy reduces the impact current by increasing the impedance of the impact path in sensitive areas. At the source of the impact current, isolation measures are implemented for sensitive signals using optocouplers, capacitive couplings, or magnetic couplings. Common-mode inductors, magnetic beads, and other devices are added to power and signal connections to increase impedance and block interfering signals.

The "**treatment**" strategy addresses the overlap of wiring paths with dirty grounds and the impact of wiring itself. Appropriate capacitors are added around signal jacks to reduce current flowing through PCB signal wiring and cables in the high-frequency band. Resistors, inductors, or magnetic beads can also be added in series after the capacitors. Adjusting the parameters based on the actual interference situation can resolve electromagnetic interference issues.

4.4 AC power interface EMC and reliability design

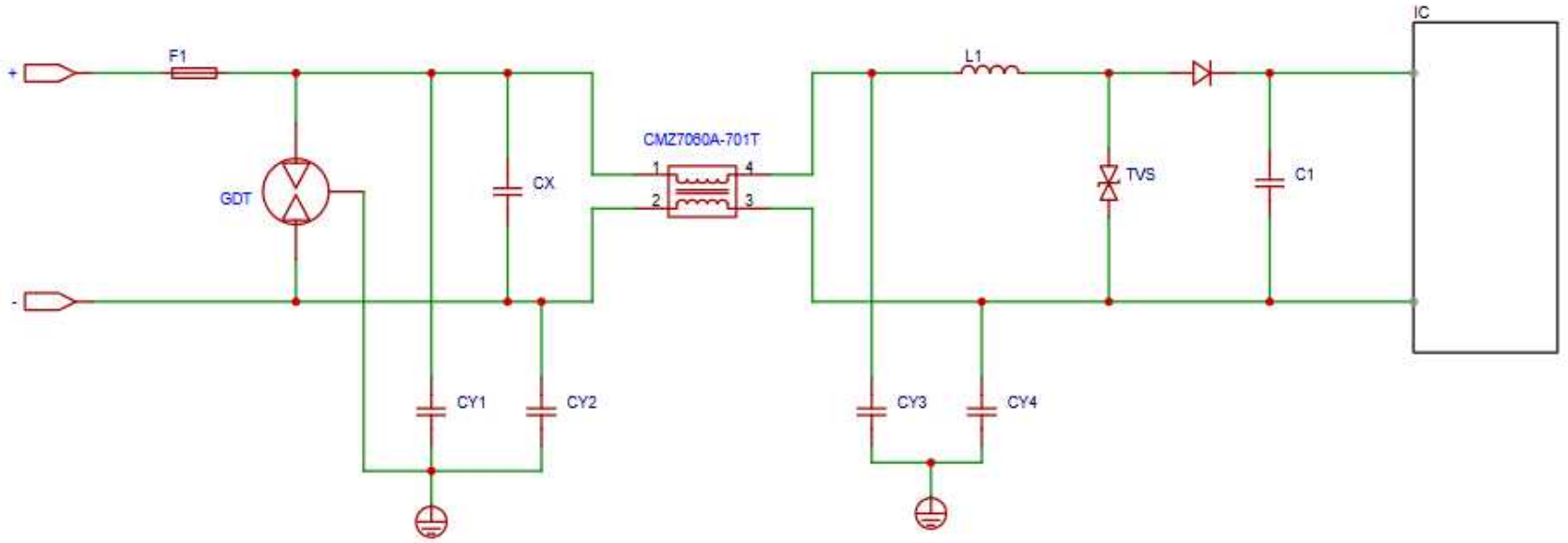
AC power interface: used to connect external 220V AC input



model	Device Type	Use Location	effect	Encapsulation
2R600L	GDT	Power interface	Surge, lightning protection (outdoor products, pay attention to the problem 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

4.5 DC power interface EMC and reliability design

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

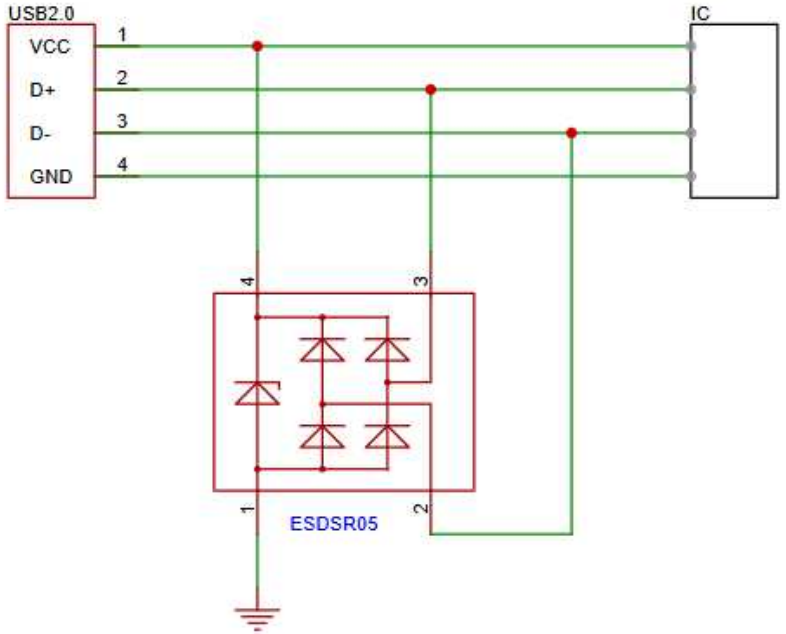


model	Device Type	Use Location	effect	Encapsulation
3R090L	GDT	Power interface	Surge and lightning protection (for outdoor products, pay attention to the issue of continuous current)	3RXXXL
SMBJ6.5CA	TVS Transient Voltage Suppressor Diodes	Power interface	Surge, load dump	SMB/Do-214AA
SMCJ15CA	TVS Transient 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

4.6 USB-2.0 interface EMC and hot-swap reliability design

USB-2.0 interface:

USB 2.0 is designed to provide faster data transfer speeds and better device compatibility; and it has achieved a leap in interface speed, increasing it from the original maximum of 12 Mbps to 480 Mbps; this allows the USB interface to meet the needs of more high-bandwidth devices, such as high-speed printers, scanners, external storage devices, and multimedia devices.

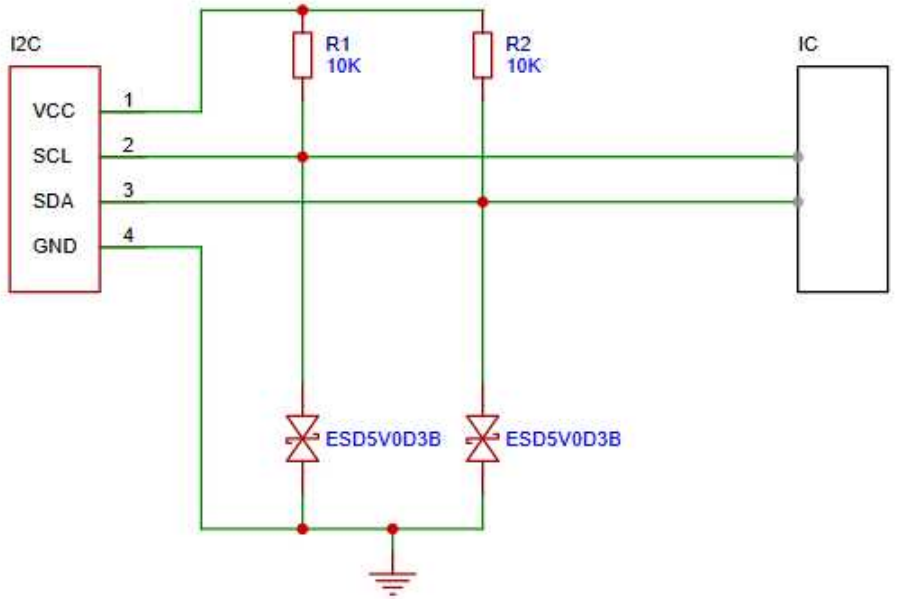


model	Device Type	Use Location	effect	Encapsulation
ESDSR05	ESD	USB interface	Surge, static electricity	SOT143

4.7 I2C General I/O Interface EMC and Reliability Design

I2C interface:

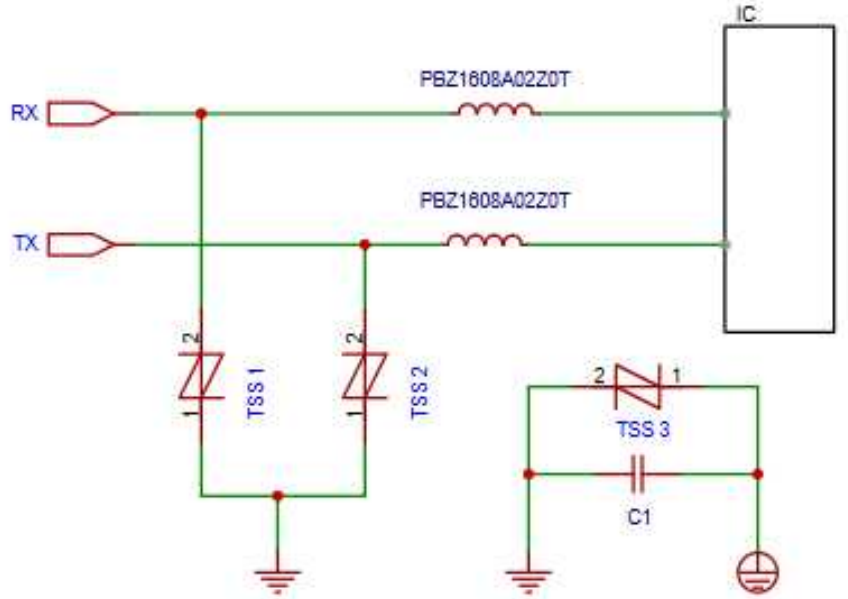
I2C (Inter-Integrated Circuit) interface is a common serial communication protocol, widely used to connect low-speed to medium-speed sensors, memory chips, and other peripheral devices. I2C interface consists of two main signal lines: serial data line (SDA) and serial clock line (SCL).



model	Device Type	Use Location	effect	Encapsulation
ESD5V0D3B	ESD	I2C interface	Surge, static electricity	SOD323

4.8 RS-232 Interface EMC and Reliability Design

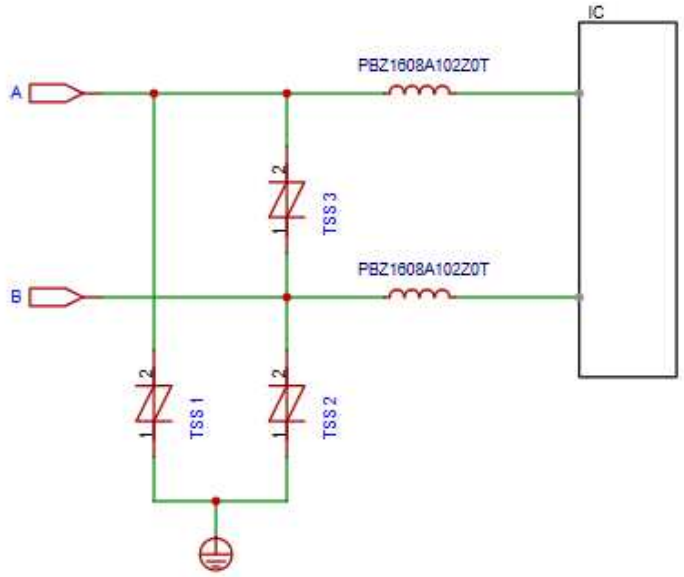
RS232 interface: It is one of the commonly used serial communication interfaces. RS232 is suitable for short-distance device interconnection (such as printers, mice, etc.), but it requires a level conversion chip (such as MAX232) to adapt to different logic levels.



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
PBZ1608A02Z0T	magnetic beads	RS232 interface	Eliminate high-frequency interference	1608

4.9 RS-485 Interface EMC and Reliability Design

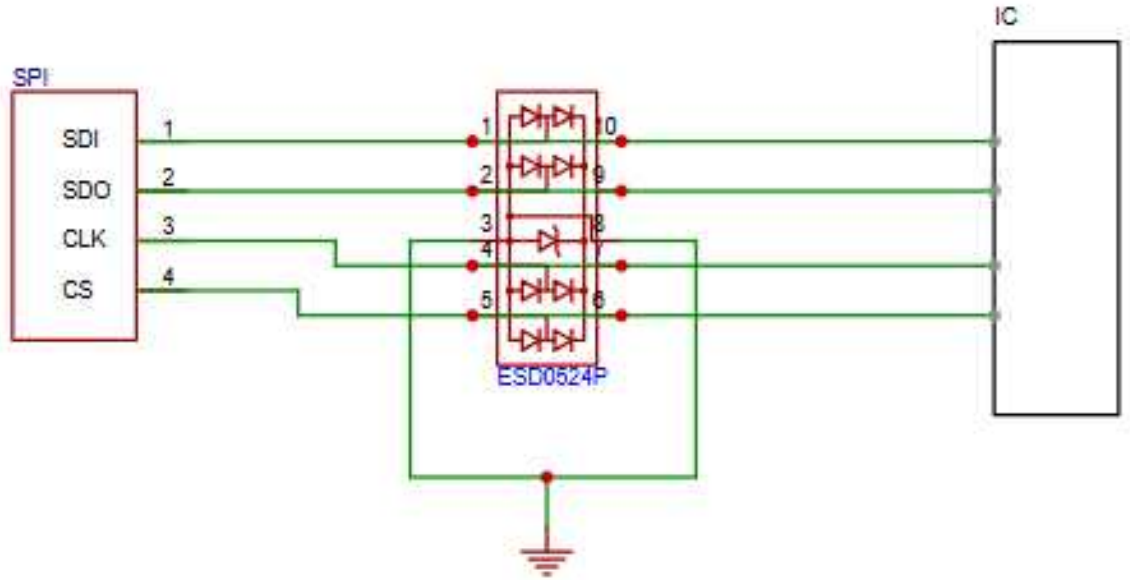
RS485 interface: RS-485 is a serial communication standard that can support multiple devices to communicate through the same serial bus. It is suitable for medium and long distance communication and has good anti-interference ability and data transmission stability.

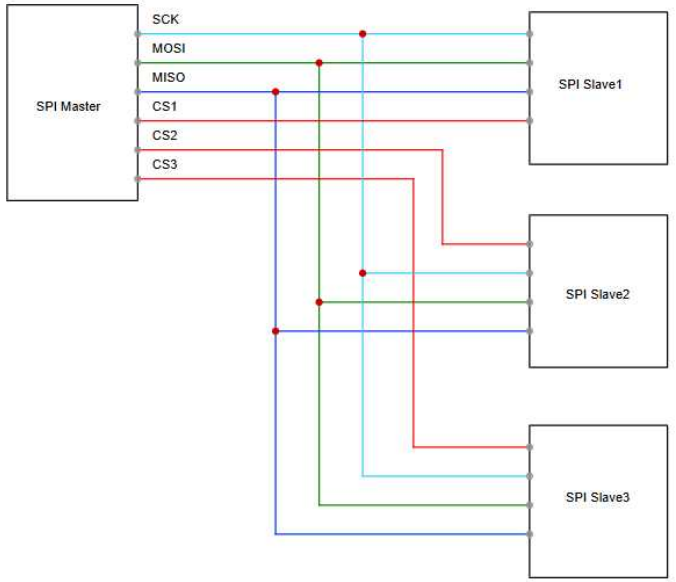


model	Device Type	Use Location	effect	Encapsulation
P0080SCL	TSS	RS485 interface	Surge, static electricity	SMB
PBZ1608A102Z0T	magnetic beads	RS485 interface	Eliminate high-frequency interference	1608

4.9.1 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

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