EMC Guidelines for HT8

Introduction

Electromagnetic compatibility (EMC) means that the equipment or system must continue to operate correctly when facing the demands of its electromagnetic environment. It also means that it must not generate electromagnetic interference which will affect other equipment in its surrounding environment. Therefore EMC has two requirements. One is to have a certain degree of protection against electromagnetic interference existing in its own environment, which is EMS. The other is that any electromagnetic interference generated by the equipment during normal operation cannot exceed a certain limit, which is EMI.

EMS test items include an electrostatic discharge test (ESD), an electrical fast transient test (EFT), injected current immunity test (CS), surge (Shock) immunity test (Surge), voltage drop test (DIP) and radio frequency electromagnetic field immunity test (RS). EMI test items include conducted interference test (CE) and radiated interference test (RE).

EMS Management

The most important item for the above mentioned EMS test is to enhance the product’s anti-interference capabilities. Although Holtek 8-bit MCUs have all undergone systematic EMC considerations during the design phase, variances will result from the differences in different MCUs applications. Here, the following suggestions are summarised based on the internal structure of Holtek 8-bit MCUs.

ESD Protection

- Series Impedance

Generally, impedance components such as series resistances or magnetic beads can be used to limit ESD discharge currents and reduce the effects due to anti-static, as shown in the following figure. For example, an input I/O pin can be protected with a 1K ohm resistor, such as for an ADC input, a logic input, or other pins.
Parallel Discharge Components

Commonly used discharge components are TVS, Zener diodes and filter capacitors as shown in the accompanying figure.

EFT Protection

The majority of EFT interference signals come from the power supply, therefore processing them at the power supply end offers the most effective protection. Measures to do this include voltage-sensitive varistors, transient voltage suppressors (TVS), common mode chokes, ferrite magnetic rings, capacitor filters and using twisted-pair power cables at the power supply end. Managing this on the MCU side of things includes the following suggestions.

MCU VDD/VSS Parallel Capacitor

It is recommended to connect a 100nF capacitor in parallel with the VDD and VSS pins on the MCU. This capacitor has two functions. First is a bypass function, which enables the capacitor to provide the large current required during the instantaneous MCU switching operations. There is also a decoupling function. Due to the high-speed running of the logic circuits inside the MCU there will be high-frequency noise generated during operation. In order to prevent this noise from being transmitted onto the power supply or the ground layer, the capacitor should be located as close as possible to the MCU’s VDD and VSS pins as shown in the figure.
Communication Interface Serial Connection Resistance

Many products will communicate with multiple ICs during design using PCB traces or communication lines, however these communication lines are susceptible to EFT interference. Connecting resistors in series with the communication lines can effectively reduce the interference energy, thereby protecting the MCU as shown in the figure. The resistance selected should be chosen to match the communication speed.

![Fig. 4](image)

Surge Protection

A surge test is commonly known as a lightning strike test. Surge interference is caused by lightning strikes in nature, short circuit faults in power supplies and during heavy load switching. Surge protection should be handled from the AC power input end.

The use of varistors (MOV) is the most common protection method. Usually a varistor is connected in parallel between the live and neutral lines of the AC input after the fuse.

A gas discharge tube (GDT) can be used, when connected between the live and neutral lines of the AC input. When a surge interference appears, the discharge voltage between the two poles drops to 20V~50V to protect the back-end circuit.

Software Recommendations

Much of the software processing is used for protection or prevention during EMC testing to improve the product stability and the ability of the product to resist EMS interference. A correct and effective use of a reset source has the following two important functions, one is to improve the stability of the product and the other is to help remedy or shut down the operating condition when the product experiences an EMC failure to protect both the operator and the product.

Reset Function

It is extremely important to detect and manage reset-related functions as this is the most common method of dealing with EMC problems in the MCU software. The Holtek microcontroller reset sources include internal and external events which will trigger a reset, the most commonly used are listed as follows:

- Power-on Reset
  
  This is the most basic and unavoidable reset which occurs after the microcontroller is powered on. In addition to ensuring that the program memory is executed from its initial address, the power-on reset forces the other registers to be reset to their initial conditions. All I/O control
registers are reset to a high state to ensure that all logic I/O pins are setup in a high-impedance input state after power-on.

\[ \text{V}_{\text{DD}} \]

\[ \text{Power-on Reset} \]

\[ \text{SST Time-out} \]

\[ t_{\text{RSTD}} \]

Note: \( t_{\text{RSTD}} \) is the power-on delay time, with a typical value of 50ms

**Fig. 5 Power-on Reset Timing**

- **Low Voltage Reset – LVR**

  The microcontroller’s low voltage reset circuit monitors its power supply voltage. The low voltage reset function is always enabled at a fixed voltage value, known as \( V_{\text{LVR}} \). For example, during power supply battery replacement, if the power supply voltage to the microcontroller falls to a value between 0.9V and \( V_{\text{LVR}} \), then the LVR will automatically reset the microcontroller and the LVRF bit in the CTRL register will be set high. However for the LVR to be effective it must meet with certain conditions. The effective LVR signal, which is the time when the 0.9V~\( V_{\text{LVR}} \) low voltage state exists, must exceed the value of the \( t_{\text{LVR}} \) parameter in the LVD/LVR electrical characteristics. If the low voltage does not exceed the value of the \( t_{\text{LVR}} \) parameter, it will be ignored by the LVR circuit and a reset function will not be executed. The LVR function will be automatically disabled when the microcontroller enters the IDLE or SLEEP mode.

  LVRC register self-check function: Any LVRC register content other than a defined value will cause the microcontroller to reset. The reset action will be effective after 2~3 \( f_{\text{LIRC}} \) clock cycles. Here the contents of the register will be reset to the POR value.

\[ \text{LVR} \]

\[ \text{Internal Reset} \]

\[ t_{\text{RSTD}} \]

\[ t_{\text{LST}} \]

Note: \( t_{\text{RSTD}} \) is the power-on delay time, with a typical value of 50ms

**Fig. 6 Low Voltage Reset Timing**

- **Normal Operation Watchdog Overflow Reset**

  Except for the fact that the watchdog overflow flag bit TO is set high, this watchdog overflow reset is the same as the LVR reset during normal operation.

  WDTC register self-check function: Any setting other than a fixed defined register value will cause the microcontroller to reset. This function can cause a reset to occur should the WDTC register value be changed due to EMC.

\[ \text{WDTC Time-out} \]

\[ \text{Internal Reset} \]

\[ t_{\text{RSTD}} \]

Note: \( t_{\text{RSTD}} \) power-up delay time, the typical value is 16.7ms

**Fig. 7 Normal Operation Watchdog Overflow Reset Timing**
Idle or Sleep Mode Watchdog Overflow Reset

A watchdog overflow reset during sleep or idle mode is different from other types of reset. Except for clearing the program counter and stack pointer to "0" and the TO bit set to "1", most of the other conditions remain unchanged. For a detailed description of tSSR in the figure, refer to the A.C. electrical characteristics in each MCU datasheet.

![Fig. 8 Sleep or Idle Mode Watchdog Time-out Reset Sequence](image)

MCU Self-Check Mechanism

When an MCU abnormality occurs, measures should be taken to prevent injury to operators and also damage to the product.

For example, when referring to the UL / IEC60730 standard for self-checking the internal resources of the MCU, the self-check items are determined by the MCU resources used by the product. The common self-check items are shown in the following table.

For more software protection measures, refer to the AN0530EN <Anti-electromagnetic Noise Interference Software Strategies >

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Item</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>ADC self check</td>
<td>During self-checking, when the MCU discovers an abnormality, it will execute appropriate error handling, by switching off the product or implementing a reset depending upon the specific product operating conditions.</td>
</tr>
<tr>
<td>2</td>
<td>Clock self check</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>MCU Registers self check</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>ROM self check</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>RAM self check</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>PC self check</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Stack self check</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Interrupt self check</td>
<td></td>
</tr>
</tbody>
</table>

Table 1

For details on the UL/IEC60730 content, consult the AN0377E~AN0387E <HT8 UL60730 Safety Library -- xxx>.

EMI Management

PCB Layout Recommendations

The PCB board is an important factor with regard to receiving and transmitting interference, especially in connection with the tracks close to the MCU. Therefore, in order to reduce interference problems, the PCB wiring and power line design are especially critical. PCB traces can act like antennas with each loop and trace having a parasitic inductance and capacitance. As long as currents, voltages or electromagnetic flux changes, these traces will both radiate and absorb energy. It is recommended to ensure that loops are as small as possible to reduce noise problems.
Recommendations for high speed signal lines
If products use high speed communication interface lines, LED scanning or key scanning control peripherals, it is recommended to keep lines as short as possible to reduce high-frequency interference.

Reduce signal rise and fall times
When using the MCU to drive MOS and IGBT transistors and other peripheral devices, the sudden change of voltage and current (high dv/dt and di/dt) can be the main reason for generating EMI. It is therefore recommended to reduce the signal rise and fall times to reduce the energy in the interference signals.

Oscillator Circuit
Holtek 8-bit MCU oscillators have many different options, the most commonly used ones are shown in the accompanying table.

<table>
<thead>
<tr>
<th>Type</th>
<th>Name</th>
<th>Frequency</th>
<th>Pins</th>
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<tbody>
<tr>
<td>External High Frequency Oscillator</td>
<td>HXT</td>
<td>400kHz~20MHz</td>
<td>OSC1/OSC2</td>
</tr>
<tr>
<td>Internal High Frequency RC Oscillator</td>
<td>HIRC</td>
<td>8/12/16MHz</td>
<td>—</td>
</tr>
<tr>
<td>External Low Frequency Oscillator</td>
<td>LXT</td>
<td>32.768kHz</td>
<td>XT1/XT2</td>
</tr>
<tr>
<td>Internal Low Frequency RC Oscillator</td>
<td>LIRC</td>
<td>32kHz</td>
<td>—</td>
</tr>
</tbody>
</table>

Table 2
As the HIRC and LIRC oscillators are fully internal to the MCU there is no need to consider PCB routing. However, when the application uses the HXT and LXT oscillators, special care has to be taken with PCB routing for which the following are some suggestions.

- It is recommended to ground the external metallic casing of the crystal to prevent the oscillator emanating radiation and to shield the external interference.
- It is recommended to pour copper below the oscillator to prevent interference with other PCB layers or to prevent interference from affecting normal oscillator operation.
- The oscillator traces should be as short as possible and the oscillator and associated capacitors should be as close as possible to the MCU pins. Higher oscillator frequency will result in higher levels of interference. The oscillator circuit wiring is shown in the figure below.
Software Recommendations

- Reduce the Output Frequency
  During production operation, higher frequency control signals in the circuit loop will generate higher electromagnetic radiation in the same circuits, resulting in greater EMI radiation interference. Therefore, in practical applications such as for driving MOS and IGBT drive transistors, it is recommended to reduce the control frequency.

- Spread Spectrum Techniques
  A spread-spectrum technique will take a narrow band of frequency energy and spread it over a wider frequency range. The frequency spectrum is therefore distributed over a wider bandwidth which reduces the peak emission of radiation. See Fig 10 for a graphical diagram.
  Here the total energy contained in the signal remains unchanged however it is distributed over a broader frequency range. As the frequency band becomes wider, the peak energy is reduced. This technique is implemented using software and therefore results in no increase to hardware costs. Spread-spectrum techniques can also be applied to PWM peripheral drive products.

![Fig. 10]
PCB Design Principles

To minimise the effects of EMC, PCB Layout is very important for which the following suggestions are made for HT8 applications.

1. Logic and analog ground lines should be separated. If there are both logic and analog circuits on the board they should be separated as much as possible. The ground of any low-frequency circuits should use a single-point ground as much as possible. The high-frequency circuits should be grounded in series with multiple points. Ground lines should be as short and thick as possible. If possibly, poured ground areas should be spread around any high-frequency components.

2. It is recommended that three times the size for the current rating for the ground track is used.

3. Ground lines can form ground loop. Printed boards composed only of digital circuits, whose ground circuits are grouped into loops, will generally have improved anti-noise capability.

4. The capacitor lead connections must be kept short, especially high-frequency bypass capacitors which can cause antenna effects.

5. When the printed boards contain components such as relays, fans, coils and other inductive components, switching will result in back EMF voltages being generated. For this reason it is recommended to connect diodes in the circuit or use filter capacitors to absorb this energy.

Conclusion

EMC testing is a key but difficult aspect to consider during product development. In order to speed up the product development process, EMC countermeasures should be taken into consideration at the beginning of product design. This application note has explained some hardware and software measures for the Holtek HT8 MCUs.

Reference Material

AN0377T~AN0387T < HT8 UL60730 Safety Library -- xxx>.

AN0530EN <Anti-electromagnetic Noise Interference Software Strategies >.

For more information see the Holtek website www.holtek.com.

Revision and Modification Information

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<th>Date</th>
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<th>Issue Release and Modification</th>
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<td>鴻毅韜</td>
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