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## Interference Effects of Multiple Pulses on Microcontroller

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### Abstract

In order to investigate the interference effect of multiple pulses on modern microelectronic devices, a test module based on CAN (Controller Area Network) bus technique for distributed control is designed. More than a hundred modules are prepared for statistic test. Pulse injection test is carried out to measure the variation of interference threshold under electromagnetic pulse (EMP). The threshold voltage under two situations, multiple pulses with different number and with different time interval are considered. Accumulative effects of multiple pulses are observed and discussed.

### 1. Introduction

With the rapid development of microelectronics technology, microcontrollers are widely used in both industry control and civil engineering, such as production line and intelligent buildings. In the same time of improving control efficiency, the application of microcontrollers also raises the sensitivity to electromagnetic interference (EMI) [1]. Interference threshold is one of the key parameters for describing the sensitivity of electronic devices. Many researchers have reported the test methods and experiment results in this area. M. Camp and H. Gerth proposed a concept of failure rate to describe the interference effect of the integrated circuit under EMP and ultra-wide band (UWB) pulses [2]. L. H. Shi, X. Y. Chen and A. B. Zhai also reported their experimental results on the EMP sensitivity of single-chip systems [3-5]. However, most of the conclusions were derived from a very limited number of test samples. The variation of threshold versus different samples needs to be further investigated.

CAN bus communication system is a typical microcontroller used in the distributed control system. The interference induced in the communication lines is the main threat to it. Therefore we choose to use pulse injection to the communication port to simulate the interference cause by electromagnetic pulse environment. In this paper, a test module based on CAN bus technique is designed and a large number of test modules are prepared. The influence of pulse number and time interval between repeated pulses are studied. Ten test modules are used in each test situation and the variation of threshold for different samples is also summarized.

### 2. CAN Bus Module Used in Experiment

CAN is a kind of communications network that supports the distributed and real-time controlling. Because of its fully compatibility, high speed, short-circuit proof to battery and ground and low networking cost, CAN bus has been widely used in harsh environment and industrial automation field [6]. To control the experiment cost, a simplified CAN module with typical function is designed in our research. The designed test module consists of the CPU circuit, power supply circuit, debug interface circuit, reset circuit and CAN bus interface circuit, as is shown in Fig. 1.

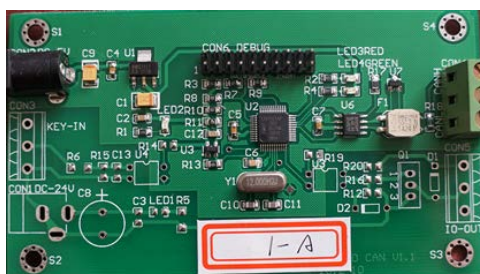


Fig. 1. Picture of the CAN module

The PCA82C250 is used as CAN controller interface, which is located between the CAN protocol controller and the physical bus. It provides differential transmitting capability to the bus and differential receiving capability to the CAN controller. Usually, it is used for high-speed applications (up to 1 Mbit/s). The protocol controller is connected to PCA82C250 via the data output line CAN\_TXD and data input line CAN\_RXD. With two bus terminal CANH and CANL, PCA82C250 and the bus cable are connected. In order to avoid the electrostatic discharge (ESD) and the surge pulse damage, TVS is connected between CANH and CANL. The ESD protection level is up to 23kV. A retardation coil is also used to prevent the circuit from EMI. As an example, Fig. 2(a) and Fig. 2(b) show the voltage waveform of a single cycle and three repeated cycle. The transmitted data is 55AA data by 8 bytes, the high level is 2V and low level is 0V. The width of each pulse train is 200 $\mu$ s and the width of a cycle is 235 $\mu$ s. It is obvious that any disturbance in the communication line may cause the mistake in transferred data or damage the sensitive device. We use a monitoring program to verify the transferred data and then to find the interference effect.

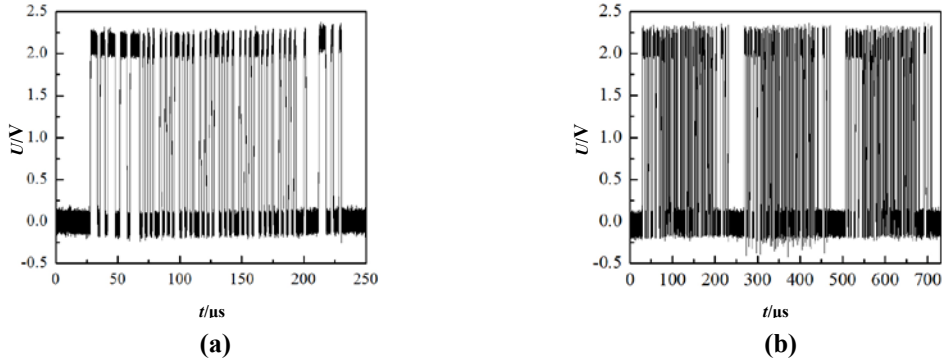


Fig. 2. (a) Single cycle of pulse voltage waveform. (b) Multiple cycles of pulses voltage waveform

### 3. Test Setup for Pulse Injection

The experimental setup is shown in Fig. 3. Pulse injection to the module is performed by EFT61004B pulse generator. Its output waveform is double exponential wave with adjustable voltage, number and time interval. The voltage ranges is from 100V to 4500V on a matching loads of 50  $\Omega$ , and the raising time is 2.5ns  $\pm$  30%. The data is transmitted by two parallel cables with length of 3m between the two modules. The positive electrode of pulse generator is connected with CANH data line, and the negative electrode is connected to ground of the testing circuit. A voltage probe is used to measure the input voltage on CANH data line in vicinity of the receiving port, and a current probe is used to measure the coupling current on CANH data line.

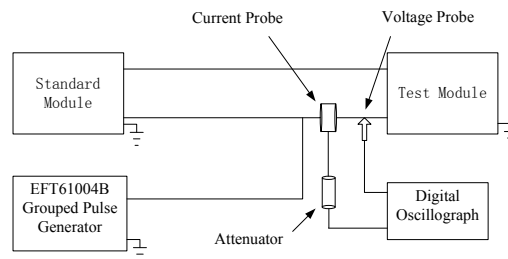


Fig. 3. Experimental configuration

Before the formal test, the level of interference threshold is decided from preliminary test of 5 sample module. During the form test, this level is used to define the injection pulse voltage. The main aim of our test is to observe the influence of pulse numbers and intervals. Therefore, a relative lower voltage than this threshold is selected as the actual input voltage. The test is divided into two classes: (1) Influence of pulse numbers. The number of pulse is selected as 1, 5, 10 and 20, and for each pulse number we use 10 modules to observe the variation of threshold versus different samples. The time interval between each pulse is 30s. If the module does not show any interference effect after the defined number of pulse is applied, the test module is removed from our data records and a new module will be selected. (2) Influence of time intervals. Three kinds of intervals are used, which is 1s, 10s and 1min, with the upper limit of pulse number being 10. The tested module is removed from our data records if it shown any interference effect when the applied pulse number is less than 6, or if the module was not disturbed after 10 pulses are applied. This 'removing' process ensures that the test data are obtained under the same condition and prevents additional accumulative effects.

The judgment of the interference phenomenon is performed automatically by the embedded program in the tested module. A known test data string is sent and received repeatedly. This program monitors the abnormalities of the received data and gives a LED indication when the received data is not exactly the same as the known one.

The normal monitored voltage waveform on the data line is shown in Fig. 2(a). When we apply a pulse voltage, the LED flashes, the monitored waveform is shown in Fig. 4. In this case the received data is not the same as before but the module is not damaged. We can obviously find that some data is lost, but when the next cycle comes, the data is back to normal again. This means the communication is disturbed.

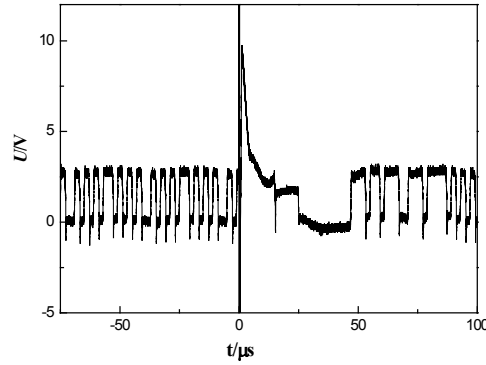


Fig. 4. Voltage waveform when the communication is disturbed

## 4 Test Results and Analysis

### 4.1 The effect of pulse numbers

Fig. 5(a) shows the distribution of interference threshold under different pulse numbers. In the figure the horizontal axis is the serial number of the test module, their sequence is of no meaning. The number on  $x$  axis just show different sample. The vertical axis is the threshold voltage. As an example, ‘5 times’ in the figure means there are 5 pulses applied to the module and the time interval remains 30s. Each dot represents a separate sample module. From Fig. 5(a) we can see that all lines are without intersection and they are distributed in different voltage levels. The accumulative effect is reflected clearly. The average of threshold voltage for each group of data (10 samples) under different pulse number is shown in Fig. 5(b), where the variation of threshold with applied pulse number can be obviously found. The more the pulse number, the smaller the threshold. The average difference between each group is about 20V.

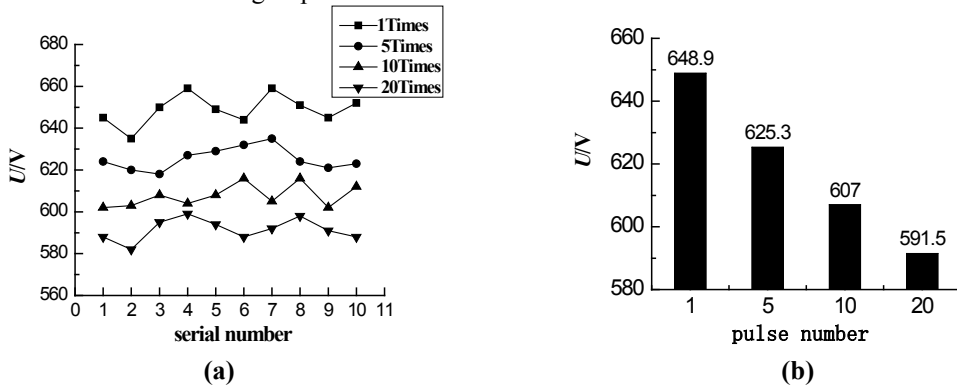


Fig. 5. (a) Distribution of threshold with applied pulse number and test sample. (b) Average of threshold voltage with different pulse number.

### 4.2 The effect of time interval

Fig. 6(a) shows the distribution of interference threshold voltage with pulse interval and test samples. Three kinds of intervals are used, which is 1s, 10s and 1min, with the upper limit of pulse number being 10. We can see from Fig. 6(a) that the threshold voltage of three cases is different, there are obvious boundaries and no intersections among these three lines. This indicates that we can find the accumulative effect of time intervals in

this test. Fig. 6(b) is the average threshold of each case. We can also see that the longer the time interval, the larger the average threshold voltage, with difference about 30V.

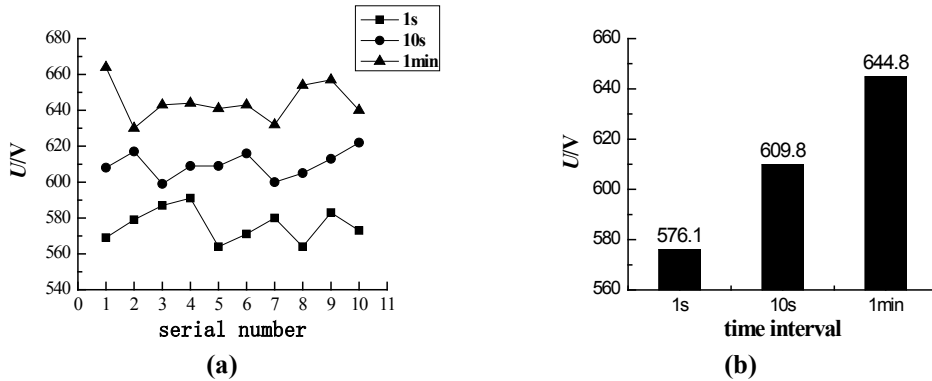


Fig. 6. (a) Distribution of threshold voltage with time intervals. (b) Average of threshold voltage with different time intervals.

## 5. Conclusion

Pulse injection test is carried out to measure the variation of interference threshold under electromagnetic pulse. The threshold voltages under two situations, multiple pulses with different number and with different time interval are measured from a relative large number of test samples. Accumulative effects of multiple pulses are observed and discussed. The results show that the accumulative effects are obvious on pulse numbers and time intervals situation in our test setup.

## 6. Acknowledgments

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