Feasibility Study of Point Type Equipment for Detecting Train Transponder System

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Abstract. In the development of railway transportation, safety has always been the most concerned issue. Balise is the core content of high-speed railway train control system, it is one of the most basic unit of information storage and transmission, control and status information necessary for the train. It is affected by many factors in the process of operation, so it is unavoidable to have problems of malfunction. At present, staff are required to operate the transponder to repair or update message information. In order to meet the needs of daily maintenance, the scheme of reading and writing operation of transponder by dynamic train detection is proposed and its feasibility is analyzed. This paper designs the software part of the mobile detection system by analyzing the working status information of different versions of transponders and tests it. The test results show that the dynamic reading and writing operation scheme is feasible.

1. Introduction

Ensuring the safety of train operation is an eternal subject of railway transportation. Especially under the circumstances of increasing axle load, large traffic volume and increasing speed of trunk lines, it is urgent to ensure safety.

In the process of train operation, in order to ensure the safety of driving, it is necessary to obtain correct control information and state information. The CTCs-2 (Chinese Train Control System-2) section is a point-to-link system based on the track circuit of the point transponder to transmit the train operation control information. It indicates that the role of point passive transponder (also known as fixed information transponder[1], this paper is abbreviated as transponder) is crucial for the train to run safely. transponders can send effective data under the action of on-board equipment during the train running, so it should be set up in every block partition of the railway section.

At present, there is no train that can dynamically read and write the transponders so as to update the information and test the related key signals. The current maintenance work of transponder is to update the data read or rewritten by the handheld equipment of railway staff[2]. The staff will not repair the transponder until it is reflected that the ATP on board causes the train to stop. Therefore, the key link of timely discovery of equipment failure hidden danger is missing in daily staff maintenance. It adds uncertainties to safe transportation and disrupts normal transportation order.

For this reason, the work of dynamic detection of transponder is considered to be added to the existing electric test vehicle. Use of electrical test vehicle to meet the safety requirement of daily maintenance of transponder[3]. By means of dynamic detection and data analysis of transponders, it is possible to

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reduce personnel, improve detection accuracy and efficiency. This method can effectively reduce transport accidents caused by transponder faults and provide reliable guarantee for transport safety.
The structure of this paper is as follows: section 2 analyzes the working methods and features of existing balises, providing a basis for the feasibility study of dynamic detection of trains; section 3 carries out the theoretical study of the feasibility of the system; section
4 carries out actual simulation and realization of the theoretical study of feasibility, verifies the practical feasibility of the theory and verifies the function; section 5, conclusions.

2. Transponder System

2.1. Dot Passive Transponder

Transponder is a point device that has a high amount of stored information and can achieve high rate transmission. It has high reliability and can send key information to the vehicle system at high speed. The main functions include: achieve absolute positioning of trains, provide variable train access information, store important information including line profile data, road and bridge locations, long-term or temporary speed limits and assist train control, etc[4]. Moreover, It is an electromagnetic device that uses the principle of electromagnetic coupling to realize communication between vehicles and vehicles. It does not need an external power supply, and its power supply and system operating clock are obtained by sensing the signal antenna sent by the external device.

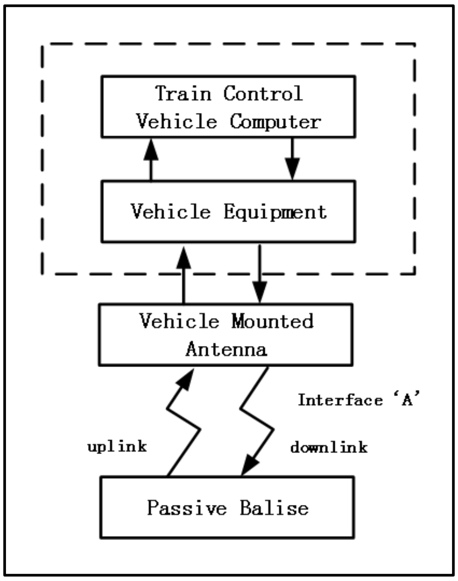

Figure 1. Passive transponder interface diagram.

Figure 1 is an interface diagram of passive transponder. In the transponder system, the communication between passive transponder and the vehicle antenna is performed through A interface, and the A interface can be divided into the following sub- interfaces:
A1 interface: transponder uplink data transmission interface;
A2 interface: vehicle antenna downlink data transmission interface;
A4 interface: vehicle antenna downlink energy supply interface;
In general, we need to perform two operations on the transponder[5]: reading the information mode and writing the information mode. The read operation mode is operated by two interfaces including A1 and A4. During the running of the train, when the vehicle antenna passes over the transponder, the transponder receives the A4 interface signal from the vehicle antenna and converts it into working energy, then continuously transmits the 1023 bits transponder message data through the Al interface. The write operation mode is that the A2 and A4 interfaces work. During the running of the train, when

the vehicle antenna passes over the transponder, the transponder receives the A4 interface signal from the vehicle antenna and transmits 1023 bits of message data to the transponder through the A2 interface cycle.

If the train is to be completed by reading and rewriting the transponder on the section where the ground transponder is distributed, it is required to perform a read- write-read three steps operation. Therefore, it is determined that the transponder is in a normal working state or a programmed state, so its working status is a very important factor. Therefore, the next step is to analyze the actual working condition of the transponder.

2.2. Transponder Working Analysis

The passive transponders arranged on the railway now can be roughly divided into two versions: the European standard transponder and the National standard transponder[6]. During the reading operation, The 4M signals sent by the transponder of the two versions are FSK signals with message information, and there is no difference. The difference between the two versions is that the signal sent by the 4M signal is not the same after the write operation is completed. One is to send a new fsk signal with message information that has been written, and the other is to send a single frequency signal. The performance of the 4M signal of the two versions of the transponder are shown in Figure 2 and Figure 3.

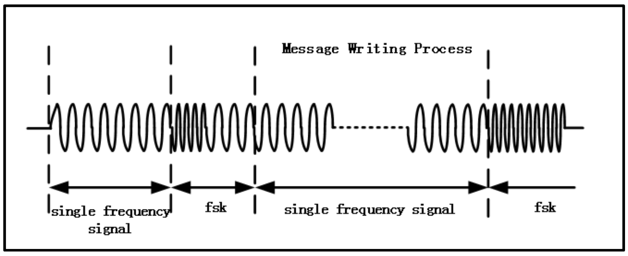

Figure 2. The state of 4M signal of the European standard transponder during write operation.

As shown in figure 2, the European standard transponder will send a signal of 3.951MHz representing the "0" character after the completion of the write operation. The demodulation module of FPGA is also in the working state during the write operation, monitoring the data transmission of the transponder's uplink link.

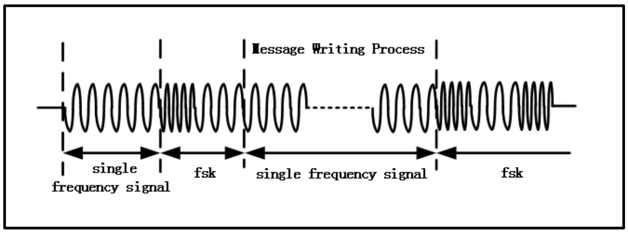

Figure 3. The state of 4M signal of the Nation standard transponder during write operation.

As shown in figure 3, after the write operation, the National standard transponder will automatically send the message of FSK signal modulation which has just write. The demodulation module of FPGA in the write operation is also in working state to monitor the change of the data, when it finds that the single frequency signal is converted into the fsk modulated signal, it means that the transponder's writing process is successful. Because of this feature, the transponder can be directly read for the second time, and the written message can be compared immediately.

Realize the read-write-read operation of the transponder during the running of the train, before using the timer to control the switching between the write operation and the second read operation[7]. After our analysis of the two versions of the transponder, we can directly use the different features of the two versions to reduce the time consuming between operation switching.

3. Feasibility Studies

3.1. Operation Time Analysis

In the previous chapter, the transponder and the analysis of its work were introduced. In our study, while the In other words, the train should be accurate and fast to update the transponder set.

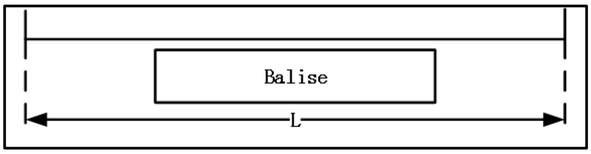

Figure 4. Dynamic read-write transponder system application environment.

The L[8] marked in figure 4 represents the range of action of the train when it passes over the transponder. After measurement,the formula is as follows:

$$L = 0.7\ (m) \tag{1}$$

Here, we assume that T represents the time when the train can transmit data when it passes the scope of action of the transponder, that is, the maximum allowable processing time of read-write-read operation is realized. Then, to guarantee the time of normal operation, the formula should be established.

$$t \ll T \tag{2}$$

We assume that the train is traveling at a speed of Vkm/h, then we can get the value of time at this velocity.

$$\begin{aligned} T &= \frac{L(m)}{V(km/h)} = \frac{0.7(m)}{V(1000(m)/3600(s))} \\ &= \frac{0.7(m)\times 18(s)}{V\times 5(m)} = \frac{12.6}{5V}(s) \end{aligned} \tag{3}$$

Through the above analysis, we have learned that to make the train as fast as possible, we should shorten the processing time of read-write-read operation as much as possible, that is, complete the operation process of the transponder was being read, written and read while running, the train speed should be kept as fast as possible. transponder as soon as possible when passing through the working range of the transponder.

3.2. System Design

The realization of the operation of reading, writing and reading on the transponder during the train running can be described as follows:

1. The upper computer enters the transponder message group information in the driving road before driving, and reads the corresponding message information at the corresponding position when passing each transponder;
2. The upper computer gives the signal of FPGA starting to work (enabling the signal to be pulled down to make FPGA start to work). If the train receives any operation failure or fails to receive successful feedback within a range of 70cm, the upper computer will report error; If the FPGA completes the corresponding operation and gives feedback, the energy signal will be raised;

3. When the upper computer gives the read operation instruction, the FPGA sends 27M signals to supply power;
4. The FSK signal sent by the receiving transponder is demodulated and other operations are performed. After the reading operation, write operation is performed;
5. During the writing operation, the analysis in chapter 2 can monitor the change of 4M signal to determine whether the writing operation is successful or not. After the success, the second reading operation can be performed;
6. The whole operation process ends after the completion of the read back and the second read operation.

The specific working process is shown in figure 5, where above the dotted line is part of the operation mechanism of the upper computer, and below the dotted line is the internal operation mechanism of the lower machine FPGA.

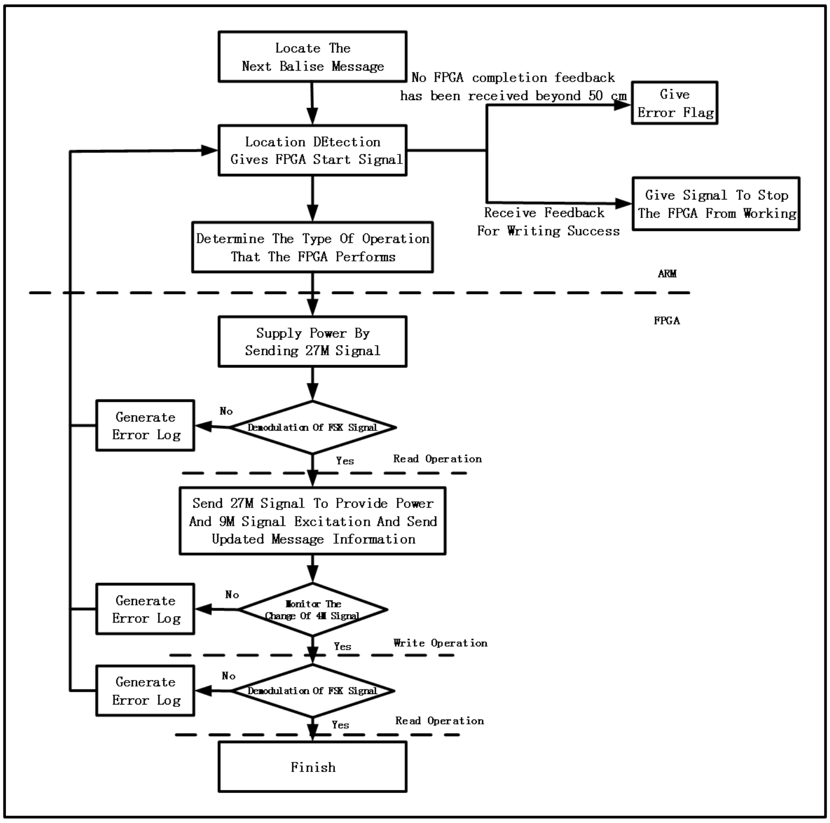

Figure 5. Flow chat of system design.

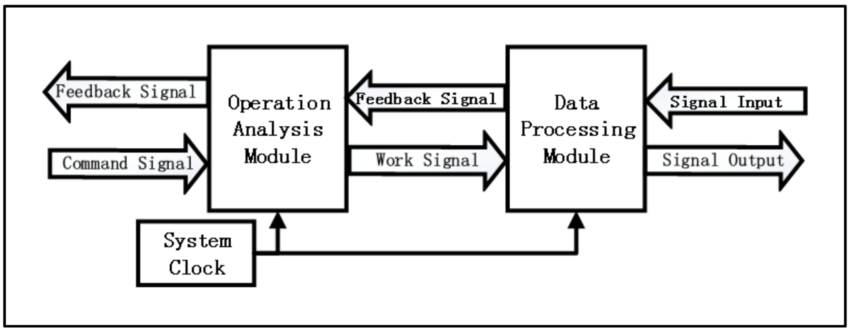

Figure 6. Modular design.

3.3. Modular Design

The software part of the system end is designed to be implemented using the EP3C25F256 chip of Cyclone III series of Altera company, and the wiring layout is conducted on the Quartus II software platform[9].The software part of the system is mainly realized by two parts: operation analysis module and data processing module, as shown in figure 6.

After receiving the data, the data module determines the working state of the system according to the rules of the established operation instructions. According to the corresponding working status, the data processing module sends the corresponding working signal to the data processing module, and the data processing module performs the reading or writing operation. If the module does not get the data feedback information, the working log is automatically generated and the corresponding signal is given to the operation analysis module.

In the process of writing the program code, attention should be paid to distinguish the changes of different control signals in different operation instructions, and avoid the control signal confusion caused by wrong operation. If there is wrong operation, the next instruction can be executed after the operation.

3.4. Software Partial Results

The resource occupancy after the integration of the software part is depicted in figure 7.The logical unit occupied 20%, storage unit utilization 59%. This resource occupancy meets the design requirements.

Flow Status	Successful - Thu Nov 01 15:06:38 2018
Quartus II Version	11.0 Build 157 04/27/2011 SJ Full Version
Revision Name	bept
Top-level Entity Name	bept
Family	Cyclone III
Device	EP3C25F256I7
Timing Models	Final
Total logic elements	8,070 / 24,624 (33 %)
Total combinational functions	6,622 / 24,624 (27 %)
Dedicated logic registers	5,009 / 24,624 (20 %)
Total registers	5009
Total pins	68 / 157 (43 %)
Total virtual pins	0
Total memory bits	359,412 / 608,256 (59 %)
Embedded Multiplier 9-bit elements	28 / 132 (21 %)
Total PLLs	2 / 4 (50 %)

Figure 7. Dynamic read-write transponder system application environment.

4. Performance Test

In order to verify the feasibility of the design and test the performance, a time test is needed. First, the code is downloaded to the existing hardware board platform, and then the operation time is displayed by the interactive display system with the host computer. According to the test time to determine whether the train speed can meet the demand. The structure of display time is tested by the serial assistant on the PC side.

First, the read operation is performed, as shown in figure 8. @ symbol stands for the shortcut key instruction for the read operation, read time 2819 refers to the single reading time of 2.819ms. After several tests, it was found that the values were between 2.8ms-3.8ms.

```
[17:50:04.123] @
[17:50:08.411] read time 2819
[17:50:12.475] Reverse_state  0
[17:50:14.891] CRC Re 427460A6, CRC Cal 427460A6
[17:50:17.092] 90 00 7F 80 00 00 3F A0 0B 96 40 30 02
C0 00 7F FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF FF
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Figure 8. Single read operation test.

Second, perform an integral operation of the system, as shown in figure 9, The system performs two reads and one writes for a total of 73ms.

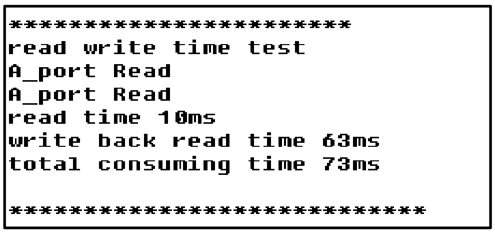

Figure 9. System operation time test.

According to the results of system test in figure 8 and figure 9, combined with our analysis, the running speed of the train can be calculated as 34.5km/h.

5. Conclusion

With the heavy railway transportation tasks, The requirement of safety is getting higher and higher. At the same time, it has been a research topic to reduce personnel access, improve detection accuracy and efficiency of detection, and reduce transportation accidents caused by fault of balise, so as to provide reliable guarantee for transportation safety.

This paper first analyses the working methods and characteristics of the existing version of transponder, and the analysis results provide a basis for the feasibility study of dynamic train detection. Then, through the theoretical study of feasibility, the actual simulation and implementation are carried out. After performance testing, although the train is running slowly, the starting point of considering the equipment is to reduce human costs, basically meet the requirements, and there is room for further improvement.

Acknowledgments

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