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Design of Wireless Measuring Terminal for Absolute Position and Displacement of Railway Track Based on PSD Position Sensor

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Abstract: *With the large-scale application of seamless rail in China, the workload of front-line railway maintenance workers has also greatly increased, and the traditional manual "two times measurement method" has been unable to meet the requirements of the rapid operation of patrol workers. In this context, in order to realize the accurate and rapid measurement of the absolute position and slight creeping displacement of motion direction of seamless railway track, a wireless position measuring device based on PSD position sensor for railway track absolute position and displacement is presented. The device consists of three parts, such as a wireless sensor terminal, a mobile handheld terminal and a PC host computer. The functions of railway track absolute position and the micro creeping displacement of seamless railway track in the direction of train running measurement, data acquisition and statistics, over limit warning and quality evaluation of patrolling workers can be realized. The utility model has the advantages of high observation precision, long time work in the field, high efficiency, small volume, low power consumption, automatic data statistics and analysis, etc. The utility model has wide application prospect and great economic and social benefits.*

Keywords: *PSD position sensor, seamless rail, track absolute position, micro creeping displacement of track, data processing*

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I. Introduction

In recent years, the rapid development of high-speed railway in China, according to data released by the relevant departments, by the end of 2016, China's high-speed railway mileage will exceed 22 thousand km, high speed rail operations also rose steadily, to further facilitate people's travel. The vigorous development of high iron industry in our country, at the technical level, in addition to break traction drive technology, braking technology, operation control technology, comprehensive application of seamless rail also played an important role in the development of high-speed rail , The so-called seamless rail is the standard length of rail welded rail hundreds to thousands of meters long through certain technical means, the application of seamless rail for damping and noise reduction, solve the steel, speed, running stability plays an important role in the improvement of performance[1]. At present, the main city in China Metro, high-speed rail line, most of the passenger lines are seamless rail, new lines in the future, also adopts the seamless rail [2].

Generally speaking, the temperature stress of rail is related to the cross sectional area of rail and the range of temperature change, and has nothing to do with the length of the rail, it is further found that if the rail is fully constrained, the seamless rail can be extended indefinitely, but the temperature force remains constant, which is also the basis for seamless rail applications. But the large-scale application of seamless rail also greatly increased the maintenance of rail work, due to the jointless track has no rail joint, apart from the telescopic areas at both ends, other parts are restrained, when the rail temperature rises, the rail has a tendency to become longer and constrained, so there is a temperature stress. When the temperature stress is too large or the constraints of the rail are not strong enough, it may cause derailment, causing serious accidents. Therefore, the absolute position and displacement measurement of seamless rail lines is a key inspection and measurement project for railway maintenance, and the observation value directly influences the establishment of maintenance and maintenance tasks [3].

The traditional observation method uses the "Secondary measurement Method", By pasting the displacement label at the test point, after a fixed period and artificial displacement observation, the whole measurement process wastes a lot of manpower and material resources, measurement method is not accurate, artificial observation errors and measurement irregularities can easily lead to initial label zero misalignment or observation displacement readings are not accurate and the straight ruler measurement is not accurate also led to lower measurement efficiency[4]. At the same time, China's orbital position measurement from the 80s of last century gradually changed from the relative position measurement into absolute position measurement, the domestic and international practice is by attaching to the absolute position of the track fixed point reference

coordinate system to achieve absolute position measurement, this Method of practical operation need to combine the prism work, low efficiency and measurement results by the environment and measurement of the technical level of a greater impact. In this context, the subject presents and develops a railway track absolute position and displacement wireless measuring device based on PSD position sensor, can achieve the absolute position of the railway track and the train running direction of the track crawling displacement measurement, data acquisition and statistics, overrun warning and other functions, it has the advantages of high observation precision, high efficiency, small volume, automatic data statistics and analysis, and has great economic and social benefits[5].

II. System structure design

The development of the railway track absolute position and displacement of the wireless measurement device is mainly composed of three parts, among them, The wireless sensor terminal attached to the rail is based on a two-dimensional PSD position sensor that converts the displacement of the light spot into a change in the electrical signal with high sensitivity, high resolution and fast response speed, which can detect the railway track with high accuracy Position (the default location of the first installation of the rail position for the original absolute position) and displacement; Handheld terminal is mainly distributed to the line inspection workers, can collect and temporarily store the railway track absolute position and displacement data, when the inspection line approaching the sensor, the device will automatically collect the sensor data up, and sound and light alarm. Inspectors can almost complete the railway track absolute position and displacement data acquisition without affecting the operation at all. The handheld terminal saves every data collected and adds time information to the data. And then stored in their own Nandflash, the design can be compatible with the storage of millions of data; PC terminal host computer is mainly installed on the host of the observation station, which can further analyze the absolute position and displacement data of the railway track collected by the handheld terminal, and then adopt the clustering algorithm to obtain the change law of the rail displacement and give the warning information. Assess the quality of inspection staff, if necessary, you can also achieve the relevant data for a long time to save [6].

The project is based on Si1000 wireless on chip system, and the system operates in 470M frequency rang. The communication system has longer communication distance and stronger penetrating power; The handheld terminal adopts modularization and integration design, the micro ceramic antenna with good performance can be used for real-time and accurate data receiving and transmitting; PC host computer is developed with C++ language in VS2012 environment. It can realize fast data statistics and classification, data mining and cluster analysis, rule summarization and visual alarm. As shown in figure 1, the absolute position and displacement of the railway track based on the PSD position sensor are reasonable, the internal data transfer logic is clear, the working sequence is ordered, the miniaturization of the measuring device and the actual assembly line tour Line workers lay the foundation for practicality.

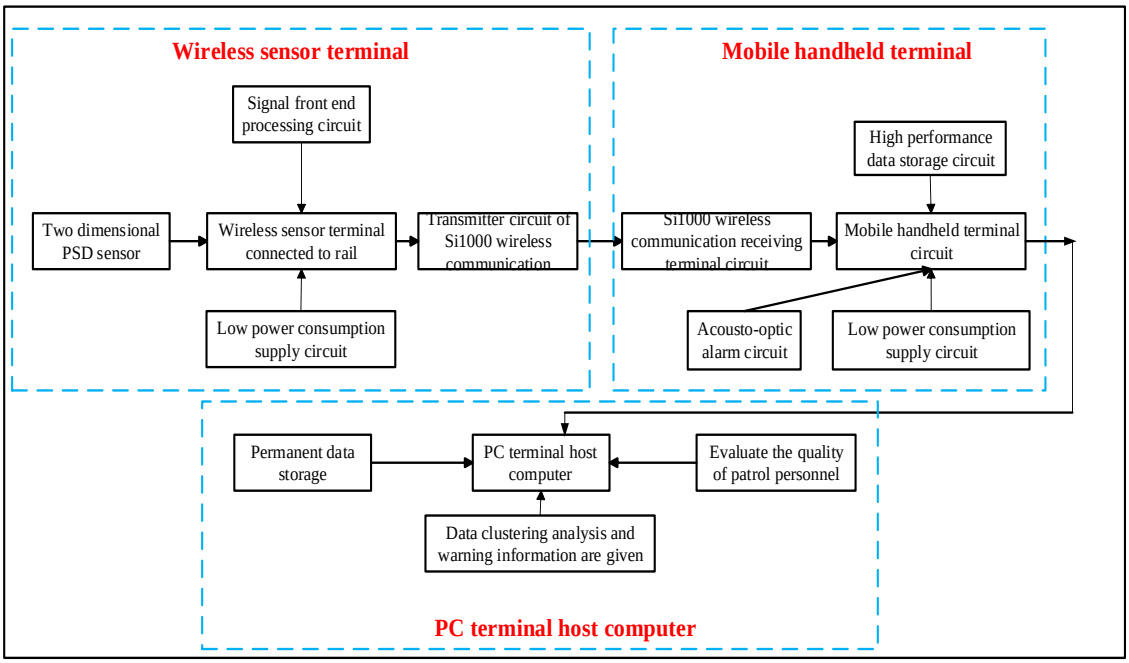

Figure 1: Overall function diagram of wireless measurement device for absolute position and displacement of railway track

III. Design of Wireless Sensor Terminals Connected to Rail

Wireless sensor terminal design of the basic requirements of low power consumption, can work for a long time in the wild, the data is accurate and easy to transfer, Based on the above requirements, the wireless sensor terminal uses the two-dimensional semiconductor photoelectric position sensor (PSD) to realize the accurate measurement of the railway track absolute position and the train running direction rail crawling displacement, The two-dimensional semiconductor photoelectric position sensor is attached to the side end of the rail, which can better perceive the change of the crawling position of the absolute position and the moving direction of the rail. Using high-performance small lithium battery for the sensor power supply, under normal circumstances, can be continuously powered more than two years, you can achieve two years of sensor maintenance-free; In order to achieve absolute position and creep displacement signal accurate and stable, wireless sensor terminal with signal front-end processing circuit, the signal can be amplified and denoised processing; Wireless sensor terminal using Si1000 wireless system-on-chip system with handheld mobile terminal communication and data transmission[7]. The installation of a two-dimensional semiconductor photoelectric position sensor connected to the rail is shown in figure 2.

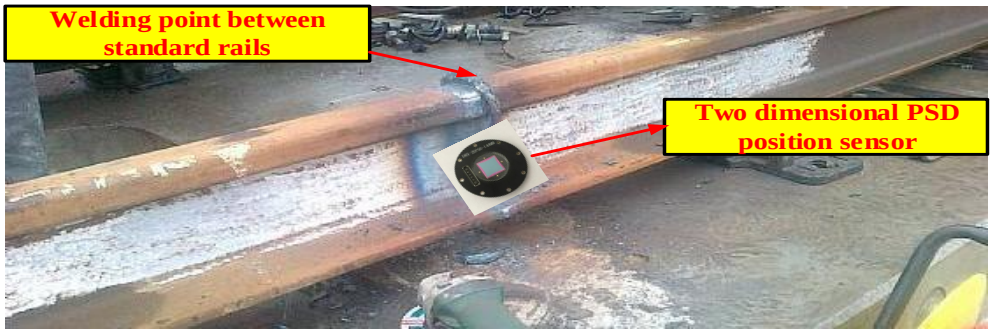

Figure 2: Installation diagram of two dimensional semiconductor photoelectric position sensor connected to rail

In order to achieve long-term wireless maintenance terminal maintenance-free work, In the sensor power supply should be used to stabilize, can be a long time to maintain a constant voltage regulator circuit, It is necessary to set the optical isolation circuit to ensure the current stability of the power supply circuit, taking into account the price factors and the actual use of the results, the subject selection of the power supply circuit to ensure that the power supply circuit current stability, taking into account the price factors and the actual use of the results, the subject selection Japan produced TLP124 to achieve optical coupling; At the same time, in order to prevent the voltage drop caused by the wireless sensor terminal work exception, the subject design of the switching regulator circuit, using TPS61175PWP constitute the boost converter circuit; For the further stability and amplification of the circuit, the subject set up two levels by the ADTL082 composed of two-stage amplifier circuit, you can achieve universal amplification, sampling and other functions. The schematic diagram of the power supply circuit of the wireless sensor terminal is shown in figure 3.

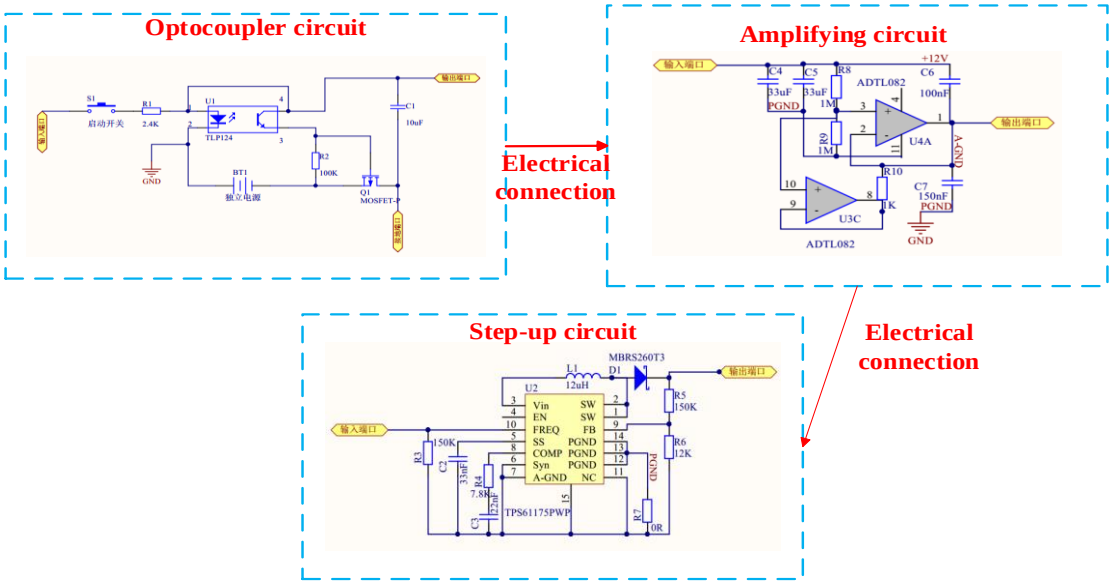

Figure 3: Schematic diagram of power supply circuit for wireless sensor terminal

In order to achieve the railway track absolute position and the direction of the crawl shift signal accurate and stable, the subject set the signal front-end processing circuit, Signal front-end processing circuit mainly includes signal amplification circuit, signal filter circuit, signal conditioning circuit and other three parts, Can achieve the absolute position of the railway track and the direction of the crawl shift signal amplification and de-noising, signal quality conditioning, signal amplitude restrictions. Based on the above considerations, the LM741 operational amplifier is used to form the pre-subtractive circuit to realize the positive and negative symmetry of the voltage [8]. Then the voltage reference chip ADR01BRZ is used to realize the voltage precision fixed and adjustable voltage reference design. The voltage reference chip is placed in two-Semiconductor optoelectronic position sensor (PSD), can be a long time for the stability of the sensor to provide precision fixed voltage, wireless sensor terminal for a long time maintenance-free work is essential. In order to improve the efficiency of signal processing, the subject uses four ADTL082 low cost, JFET input dual channel operational amplifier to form signal processing and transmission dual channel, It has been proven that this design improves signal processing and transmission speed by nearly 1.5 times. Based on the transmission speed and transmission distance considerations, the Si1000 wireless system-on-chip system is used to communicate and communicate with handheld mobile terminals, The transfer circuit is placed after the entire signal front-end processing circuit. The schematic diagram of the signal processing and data transmission circuit of the wireless sensor terminal is shown in figure 4.

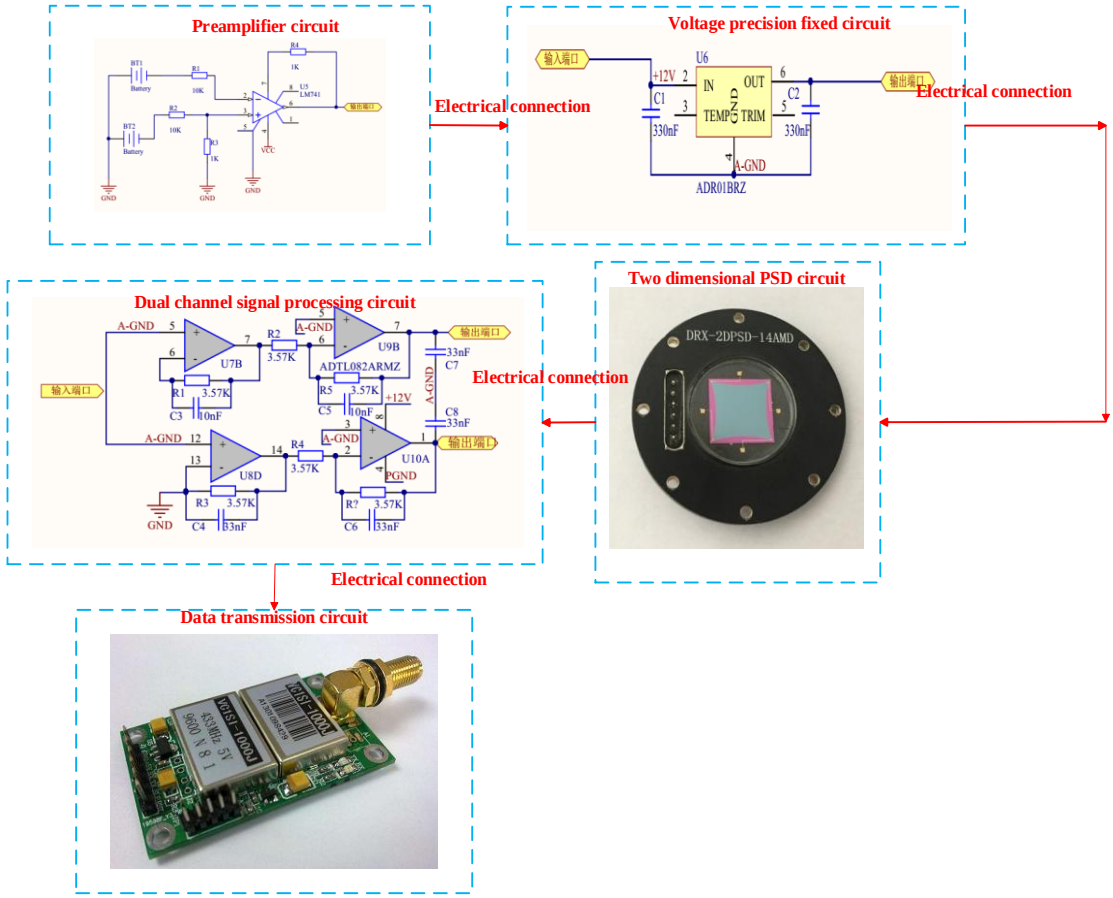

Figure 4: Schematic diagram of signal processing and data transmission circuit of wireless sensor terminal

After the installation of wireless sensor terminal attached to the rail, The system enters into the normal working state, the power supply circuit to work, into the self-state system, the system self-test after entering the absolute position of railway track and train running direction of rail creeping displacement detection, start at the same time the data transmission mechanism, uninterrupted search for handheld terminal data corresponding to the received signal. The position of the two-dimensional semiconductor photoelectric position sensor (PSD) is first installed as the reference absolute position of the seamless rail, When the absolute position of the seamless rail changes relative to each other, The subject only collects the relative displacement between the absolute position and the absolute position of the reference, And uploads the data to the hand-held terminal when the corresponding hand-held terminal data reception signal is detected. Meanwhile， Subject through the two-dimensional semiconductor photoelectric position sensor (PSD) accurate collection of train running direction

rail crawling displacement, in order to ensure the smooth transmission of the signal and no distortion and improve the data transmission speed, the dual channel signal processing and transmission circuit is set up behind the two-dimensional semiconductor photoelectric position sensor (PSD), Through double processing and double input mechanism, the signal conditioning time can be saved, the signal conditioning efficiency can be improved, and the data transmission speed can be improved. After the signal processing is completed, long distance and high fidelity data transmission is realized through the Si1000 wireless on-chip system. The working diagram of the wireless sensor terminal connected to the rail is shown in figure 5.

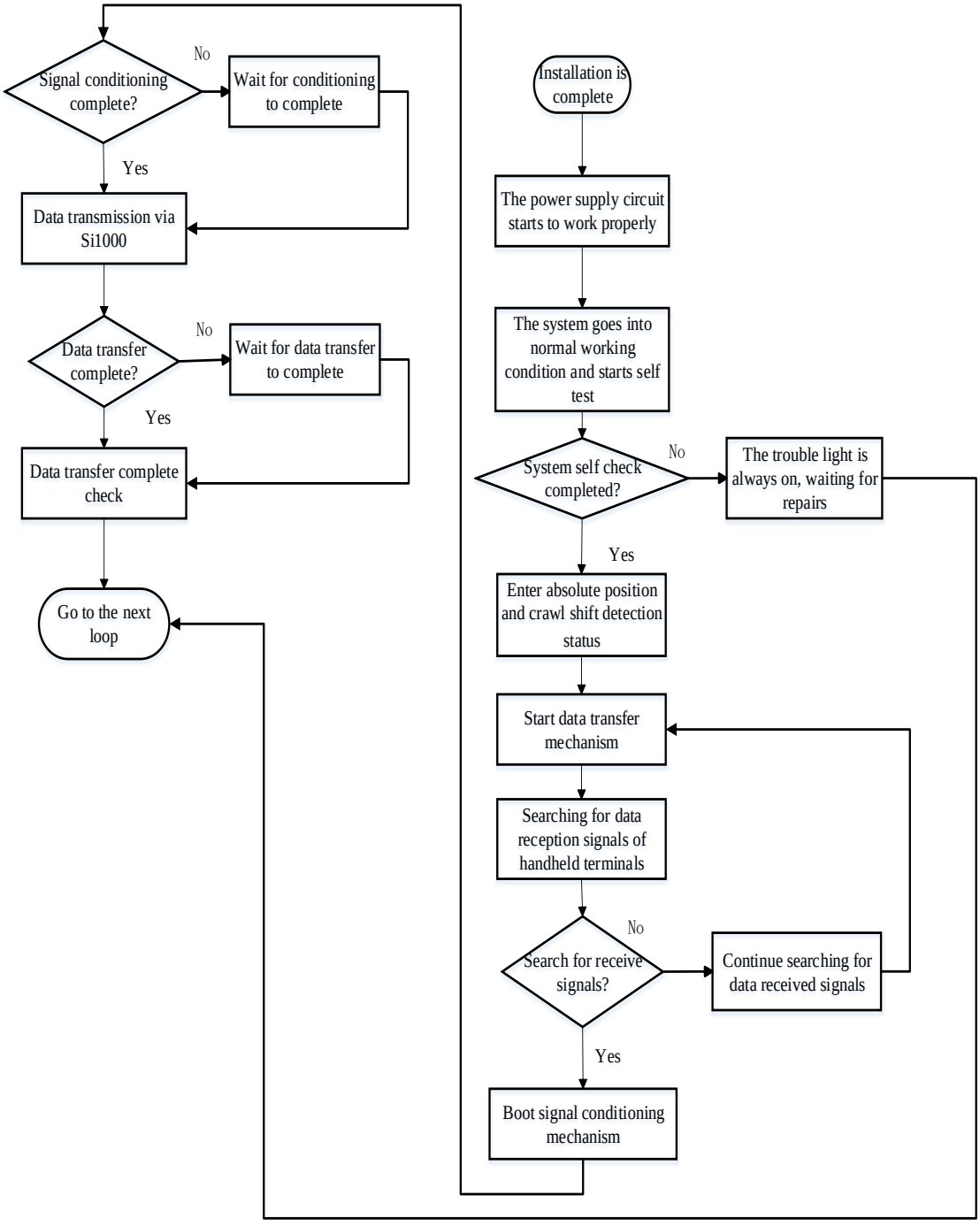

Figure 5: Working flow diagram of wireless sensor terminal connected with rail

IV. Handheld terminal design

Handheld mobile terminals are mainly distributed to front-line patrol workers, mainly used to meet the frontline patrol worker cyclical collection of orbital crawling displacement of the absolute position of the rail and the direction of the train. Handheld mobile terminals are designed with integrated integration, built in

miniature ceramic antenna, compact size and high sensitivity, When the frontline patrol workers to carry out periodic maintenance of seamless rail, when the handheld mobile terminal approaches the wireless sensor terminal, receiver and transmitter Si1000 wireless on-chip system automatically channel matching, after the channel matching is successful, the wireless sensor terminal starts the data transmission of the crawling displacement of the absolute position of the rail and the running direction of the train. At the same time, the handheld mobile terminal opens the data reception mechanism and activates the built-in Nandflash memory and temporary storage of data [9]. The handheld mobile terminal is provided with a data threshold comparator, when the data collected is greater than the value set by the data threshold comparator, handheld mobile terminal sound and light alarm, to remind maintenance personnel in time for the maintenance of railway lines. Based on the above, handheld mobile terminal circuit including the clock circuit, the receiver Si1000 wireless on-chip system circuit, Nandflash storage circuit, power supply and charging circuit, sound and light alarm circuit and so on. The handheld mobile terminal circuit diagram is shown in figure 6.

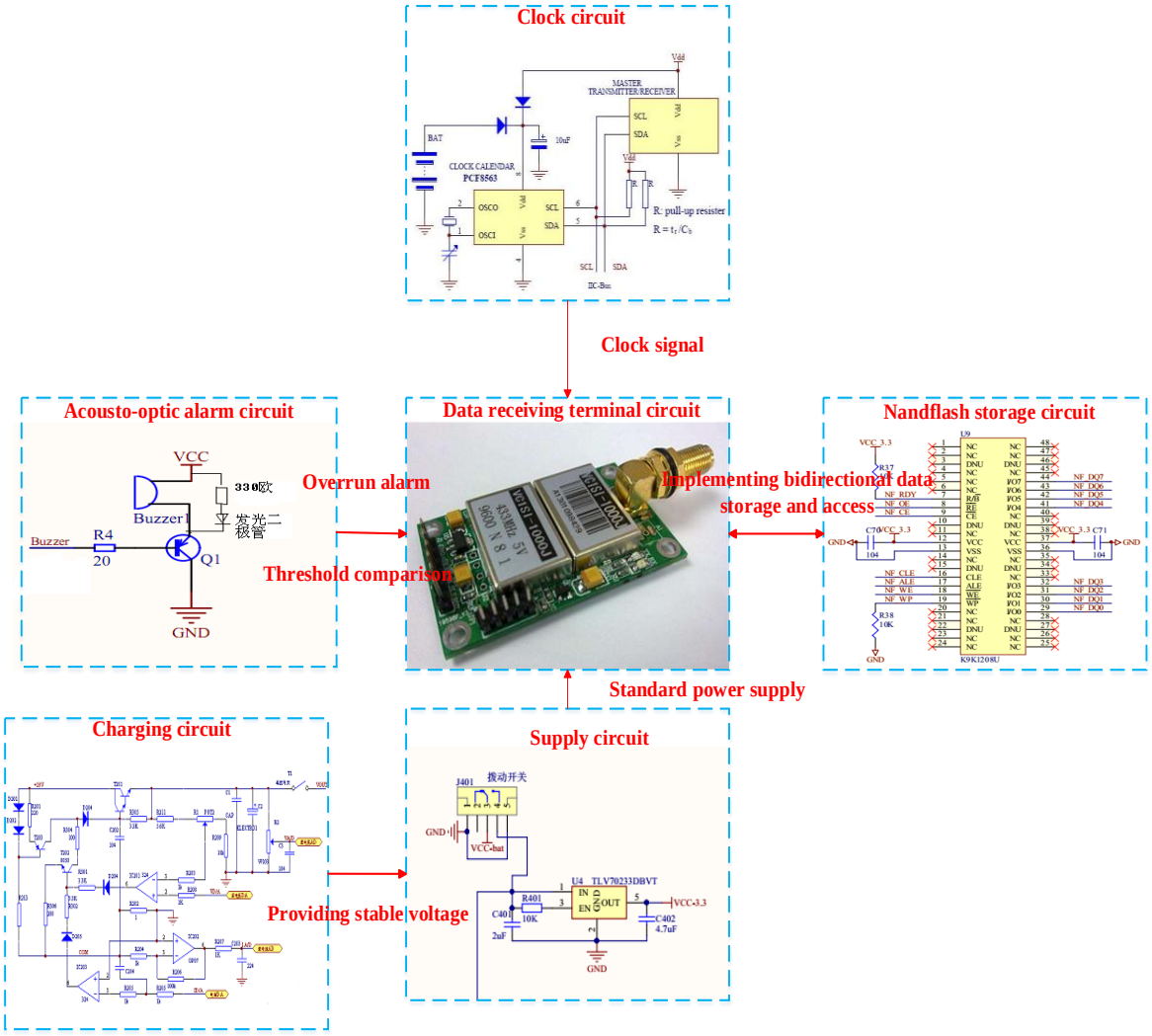

Figure 6: Handheld mobile terminal circuit diagram

After the handheld mobile terminal is charged, the power supply circuit starts to work properly and enters the normal working state, the system into the self-test state, after the system self-test and enter the railway track absolute position and train running direction rail crawling displacement detection state, while starting the data receiving mechanism, continuously searching data transmission signals corresponding to wireless sensing terminals. When the wireless sensor terminal data transmission signal is searched, handheld mobile terminal and wireless sensor terminal channel negotiation and data transmission mechanism to establish, after the data transmission mechanism has been successfully established, it enters the data transmission state, Firstly, the time information is added to the acquired sensor data, then, the data format is checked and stored into the Nandflash memory after verification, finally, the data transfer is ended and the next loop is received after the data transmission stop bit is received[10]. The schematic diagram of the handheld mobile terminal workflow is shown in figure 7.

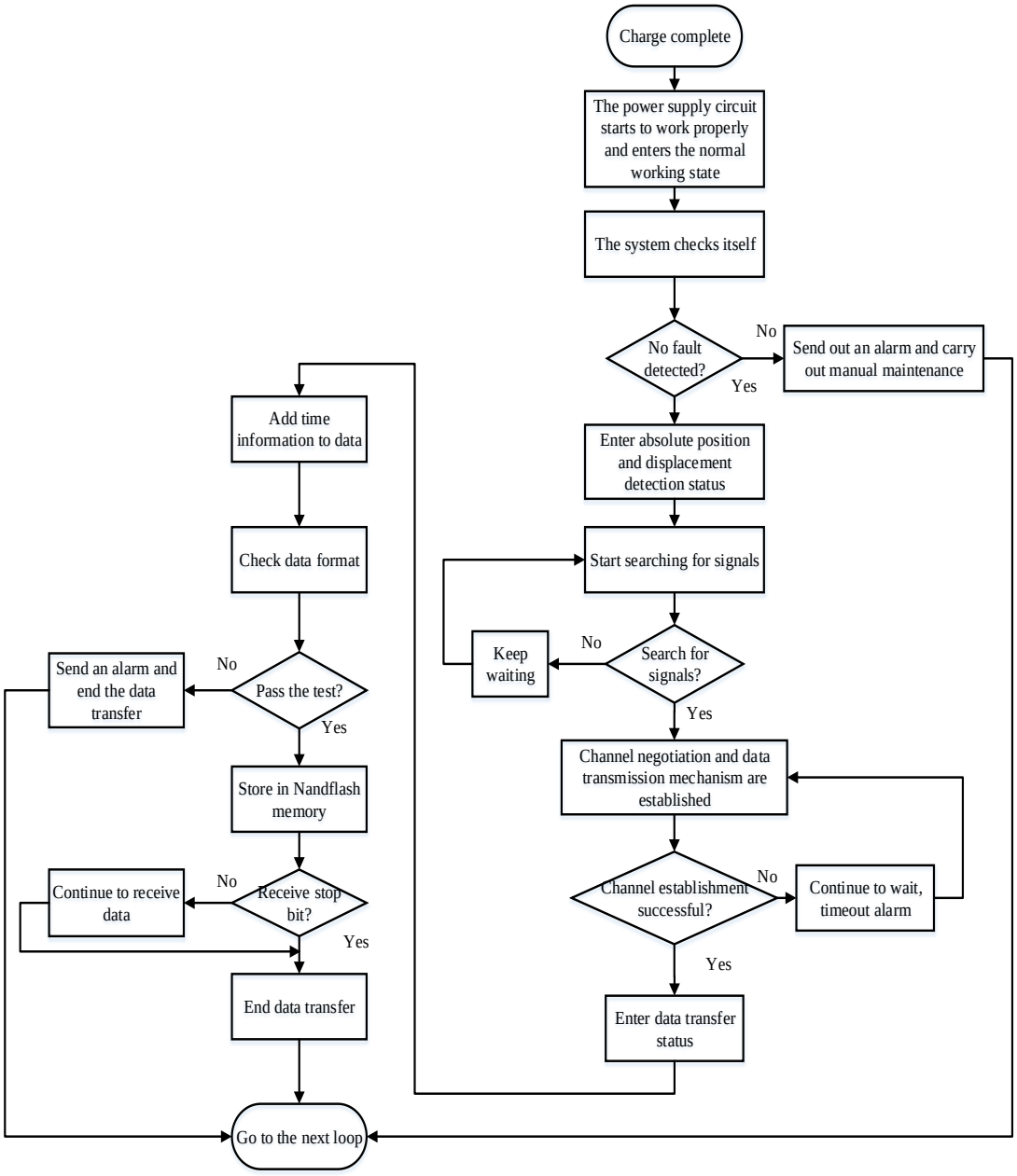

Figure 7: Handheld mobile terminal workflow diagram

V. System upper computer design

The project adopts C++ language, and develops the corresponding upper computer under the VS2008 environment, when the patrol worker returns to the workstation, through the serial port or USB interface to the handheld mobile terminal storage of the absolute location of the railway track and the train running direction of the seamless rail track small creep displacement data uploaded to the PC side of the host computer, furthermore, the functions of fast data statistics and classification, data mining and cluster analysis, regular summarization and visual alarm can be realized[11]. Each time you open the host computer should be channel matching, data analysis format settings, otherwise there will be data upload failed. The schematic diagram of the interface of the upper computer is shown in figure 8(Note: taking into account the special nature of the seamless rail track, the data shown on the upper computer interface are obtained through the simulation environment in Dalian laodong park of china).

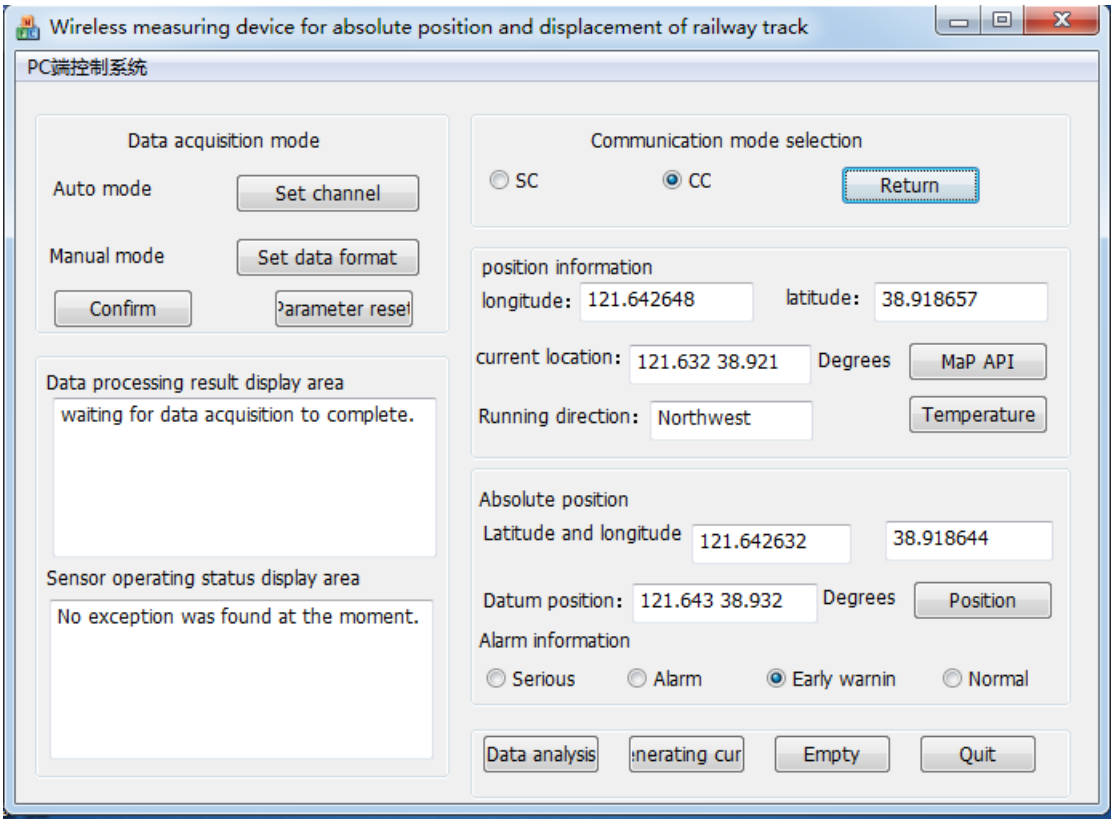

Figure 8: Schematic diagram of working interface of system upper computer

VI. Experimental verification

After completion of the system design, functional testing, considering the particularity of the railway industry and the security of the testing environment, the function, stability and accuracy of the device are tested under the simulated environment. The test environment is chosen in Dalian Labour Park in Liaoning province of china (the benchmark location is: 121.643211, 38.932431), in the testing experiments, paper adopts a plurality of glued bamboo chopsticks (chopsticks pick is the tensile strength of steel is 5 to 6 times) to simulate the seamless rail, apply a fixed tensile force at one end of the bamboo chopsticks, so that bamboo chopsticks produce lateral deformation, used to simulate micro displacements of seamless rails. The simulation test results are shown in table 1 (Note: the actual test results in the table are obtained with high precision vernier caliper), The schematic diagram of the simulated test environment is shown in figure 9, the schematic diagram of the test circuit is shown in figure 10.

Table 1: Simulation test result table

PJ / SN	Test absolute position (latitude and longitude)	Task test result (unit: micron)	Actual test results (unit: micron)	Error size (percentage)
1	121.642432 38.919234	7.810000	7.68000	1.692708
2	121.642432 38.919234	9.150000	8.980000	1.893095
3	121.642433 38.919232	5.320000	5.460000	2.564102
4	121.642433 38.919232	8.330000	8.170000	1.958384
Remarks	Datum position is：121.643211 38.932431			

According to table 1, within a certain range of error, the absolute position and displacement of the railway track based on the PSD position sensor can accurately locate the absolute position of the seamless rail (under the fixed position of the reference position) and quickly and accurately measure the small displacement of the seamless steel track in the direction of the train[12]. The actual test shows that the wireless sensor terminal, mobile handheld terminal, PC side of the host computer three parts of the work of coordination, fast and accurate data transmission, data integrity, data processing and scientific and reasonable, better completed the scheduled design tasks.

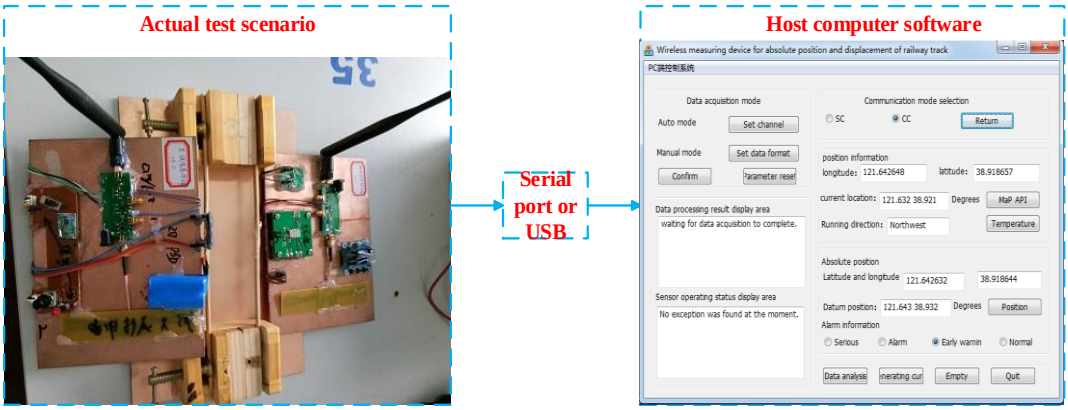

Figure 9: Schematic diagram of simulation test environment

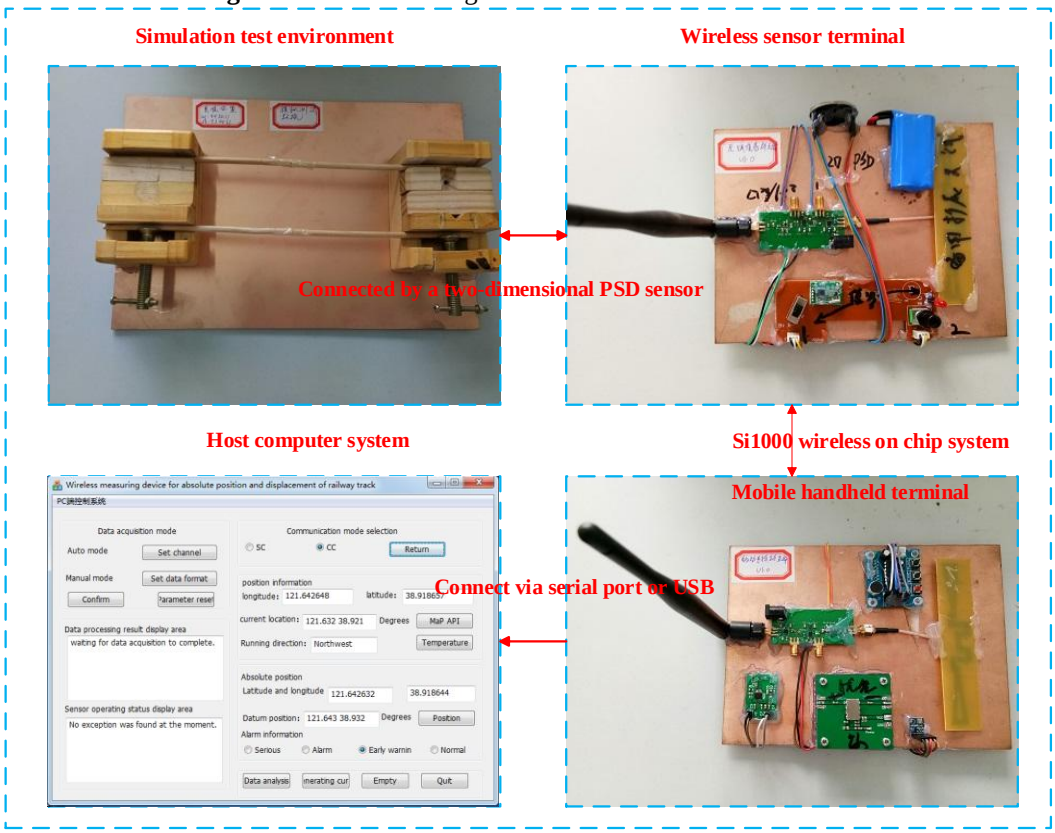

Figure 10: Schematic diagram of subject test circuit

VII. Conclusion

According to the simulation experiment in the simulation environment, Aiming at the absolute location of seamless rail and comparison and analysis of the measurement of micro displacement of seamless rail in the direction of train movement, the test results show that the absolute position and displacement of the railway track based on the PSD position sensor can accurately locate the absolute position of the seamless rail and allow precise measurement of the small displacement of the seamless steel track in the range of permissible error. The promotion of this device will greatly improve the frontline patrol work efficiency, greatly liberating manpower, the safe operation of the sustainable development and the protection of China's high speed railway of seamless rail.

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