The Design and Implementation of a New Type of Track Test Plate

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Keywords: Phase Difference; Fourier Series Method; Consistent calibration

Abstract. Due to the low efficiency and precision of the traditional way of orbit test plate measuring, a new type of track test plate based on digital signal processing technology was designed. For the 48 track circuits, a modular designment method was proposed to simplify assembly and maintenance; The rail voltage and the local voltage input circuits were designed, so that the signal can be directly obtained by MCU; According to the characteristics of 25 Hz circuit, Fourier series method was selected, which can extract separate extraction under the condition of higher harmonic fundamental component. And the uniformity calibration was used to improve the precision and reduce error. The track plate was tested by the simulation of railway signal, the rail voltage and the local voltage error is less than or equal to ±1%, and the phase angle measurement error is less than or equal to ± 0.5°. Measurement speed goes up to once per second when 48 roads are measured in the same time. The experimental results show that the system measuring accuracy is higher, faster, and has a great practical value.

0 Introduction

25Hz phase sensitive track circuit is the foundation of the railway signal equipment, used for testing if there are trains in stations[1]. Track circuit equipment may have failure[2] affected by factors such as weather, which need to receive real-time monitoring [3]. Test parameters include rail voltage and the phase difference values between every railway signal and a certain local signal.

The traditional orbit test plate need artificially select the orbit to measure data, which has low measuring efficiency and reliability. At present there are several track tests[4], which are based on embedded system. Although some can be measured automatically and circularly, there are still some problems, such as not using modular structure, complex connection relations; Zero-crossing detection and integral method[5][6] are used in phase difference measurement, which need to convert tested signals to the rectangular wave, only utilizing information near zero point, and having large error when the harmonic and noise interference exists.

This paper designed a new kind of test plate, adopting the modular designment, using the method of Fourier series method [7] to measure phase difference. Fourier series method, using all data of sampling sequence, can accurately measure the phase and amplitude of one independent components, therefore it has good anti-interference performance.

1 Design scheme

1.1 circuit configuration

As shown in figure 1, six blocks of the same structure connected to the motherboard MCU via the six plugs, while two local voltage signals are directly connected to MCU. Measurement results are displayed by color dot matrix LCD after round sampling and calculation. System communicate with upper computer via wireless module in order to debug software better and form networks under the control of MCU.
1.2 Fourier series method of phase difference measurement

Rail voltage and local voltage are 25Hz voltage in sinusoidal waveform processed from 50Hz industrial power by electronic crossovers, so there may be interference. Fourier series method can extract the fundamental component under higher harmonic, which is especially suitable for railway 25Hz signal measurement and processing phase.

Continuous periodic signal in time domain \( f(t) \) can be expanded as the sum of triangle basis and orthogonal function department, the \( n \)th degree harmonic expression is:

\[
\begin{align*}
\tilde{f}(t) &= b_0 + \sum_{n=1}^{\infty} \left( a_n \cos \frac{2\pi nt}{T} + b_n \sin \frac{2\pi nt}{T} \right), \\
A_n &= \sqrt{a_n^2 + b_n^2}, \quad \phi_n = -\arctan \frac{b_n}{a_n}
\end{align*}
\]  

(1)

Here \( f \) is the frequency of fundamental wave, and there are:

\[
\begin{align*}
a_0 &= \frac{1}{T} \int_0^T f(t)dt, \\
a_n &= \frac{2}{T} \int_0^T f(t)\cos(2\pi nt/T)dt, \\
b_n &= \frac{2}{T} \int_0^T f(t)\sin(2\pi nt/T)dt
\end{align*}
\]  

(2)

For railway signal measurement, theoretically only 25 Hz single frequency sine signal (actually have second harmonic) is measured. In application, take samples from the signal at a certain interval for \( N \) times in a integer period: \( \{v[n]|n=0,1,2,\cdots,N-1\} \)

Substitute sum for integral:

\[
\begin{align*}
a_i &= \frac{2}{T} \sum_{n=0}^{N-1} v[n]\cos(2\pi n/ N), \\
b_i &= \frac{2}{T} \sum_{n=0}^{N-1} v[n]\sin(2\pi n/ N), \\
\phi_i &= -\arctan \frac{b_i}{a_i}
\end{align*}
\]  

(3)

Then the phase difference can be obtained by subtracting two initial angle values.

1.3 Consistent calibration

The basis of track test plate is the acquisition of 48-road rail voltage with multiplex (8) A/D. Due to the differences in components and circuit performance, the every result calculated differs either, which will be greater than the application requirements.

We investigated the original measurement result of the 48-road rail voltage and the phase differences. Although there are differences when the input voltage equals, the linearity and stability is very good under the scope of the whole measurement. We get consistent results when a linear transformation given and the corresponding parameters found.

2 Hardware circuit design

2.1 structure of the measuring module

In figure 2, the processor chip is with high-performance 8 bit MCU (STC15W4K48S4) and, for the resource, there are WTD, multi-COM, reset circuit, 8-channel 10 bit AD, 4KRAM, 48KFLASH, EEPROM so forth. So there are only circuits of MCU and 485 level switch on the circuit board. TFT touching sreen is connected by high speed serials with processor chip in communication.

![Figure 2. Structure of measuring module.](image)

2.2 Rail voltage input circuit

As shown in figure 3, they are rail voltage receiving circuit and 2.5V voltage reference circuit, where the D31 and D32 are semiconductor of type TSS which will be conducting under the voltage over its threshold and lead the current to the ground to prevent detonator; D33 is the transient
-suppressor diodes of type TVS serving to protect from the biggish different-mode interference. TF31 is the current voltage transformer, where the 25Hz alternating rail voltage input from the terminal is reduced to secondary state and coupled to by resistances.

Figure 4 indicates the designment of analog switch and connector. VG3 in figure 3 is connected with VG4 in figure 4, and the other rail voltage inputs are connected with the base pins corresponding with analog switch.

![Figure 4. Analog switch and connector.](image)

![Figure 5. Local voltage receiving circuit.](image)

### 2.3 Local voltage input circuit

From figure 5, local and rail voltage input circuit have the same configuration with the only exception of the value of thounder prevention discharge tubes and secondary load resistances.

### 3 Software design

Software adopts modular structure. Main loop has two tasks processing upper computer instruction and measure results roundly. The order from upper computer has the priority and the communication use interrupt processing. In the main loop, firstly judge the existence of the order from upper computer, if it's positive, then process the order correspondingly; if it's negative, measure and display values of rail voltage and phase difference circularly.

![Figure 6. Software flow chart.](image)

![Figure 7. Test scheme picture.](image)

### 4 The experiment and analysis

Based on the actual track signal and local signal generation principle and the characteristics of the local signals phase being 90° advance of orbit signal, simulate railway signals shown in figure 7 were designed to test the track test plate.

Prototype debugging result is shown in table 1. The experimental results show that the system measuring accuracy is higher, faster, and has a great practical value.
Table 1. Rail voltage error and phase angle error.

<table>
<thead>
<tr>
<th>number</th>
<th>voltage error</th>
<th>phase measuring error</th>
<th>number</th>
<th>voltage error</th>
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5 Conclusion

The new type of track test device designed in this paper can complete the measurement of 48-road sections at the same time. It adopts the structure of single motherboard and multiple input board, obviously decreasing circuit board size, debug and maintenance. According to the characteristics of the railway signal, Fourier series method is choosed for calculating the phase difference, and we can exclude the interference of second harmonic. Experimental results show that the designed orbit test plate is of low cost, fast speed, and of high precision. It create good conditions for the dispatch of track circuit and has high practical value.

References