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Study on the Residual Current Protection Device Technology

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Abstract: As an important electrical safety protection device in low voltage distribution system, residual current protection device is to protect the insulation line leakage fault; the electric shock of the people plays an important role in fault. From the protection characteristics of residual current protective device to points, those can be divided into, residual current protection device for residual pulsating direct current and residual dc, according to the residual sinusoidal alternating current.

Keywords: Sidual Current Device (RCD), AC/DC, Waveform.

1. INTRODUCTION

As an important electrical safety protection device in low voltage distribution system, residual current protection device to protect the insulation line leakage fault, the electric shock of the people plays an important role in fault. From the protection characteristics of residual current protective device to points, can be divided into according to the residual sinusoidal alternating current, residual current protection device for residual pulsating direct current and residual dc. The current products to protect against residual sinusoidal AC and residual pulsating direct current mainly, and according to the residual DC less protection [1]. Therefore, at the same time, research on the realization of residual current protective device for the remainder of AC and DC current protection development, can improve the SIEMENS Company in this category blank, improve market competitiveness.

The feasibility study report of feasibility demonstration from technology, device selection, the development environment, cost control on B type residual current protection device project, illustrate the feasibility of the project [2].

2. THE TECHNICAL SCHEME

After the current B type RCD were found by magnetic modulation theory and market research literature retrieval, the difference lies in the concrete implementation method of different. The reason for this situation is available on RCD and sensor technology in the detection of AC / DC and pulsating DC current only magnetic modulation technology, so we decided to adopt this principle, but in the specific implementation of the semi H bridge oscillator scheme innovation combined with 5 order active filters.

2.1. Coil Magnetic Material

According to the characteristics of AC/DC leakage protection, using the principle of magnetic modulation detection, AC and DC leakage current transformer with magnetic material therefore, should have a high permeability and low saturation magnetic induction intensity, the excitation current small under saturated. High magnetic nickel iron alloy [3], it has a very high magnetic permeability, core saturation magnetic induction intensity is very small, consistent with the principles of magnetic modulation requirements, the magnetization curve as shown in Fig. (**1**). Therefore, using the magnetic nickel iron alloy as the detection of magnetic materials AC/DC leakage current.

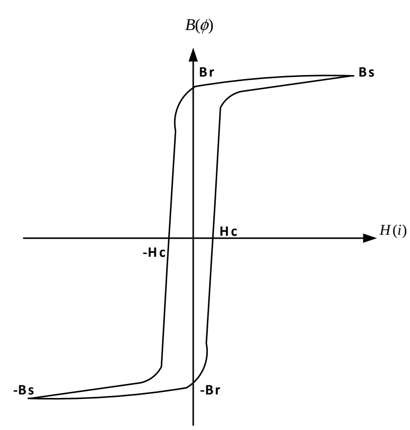


Fig. (1). The magnetization curve.

2.2. The Detection Principle of Half Bridge H

AC/DC leakage current sensor with magnetic modulation principle, the need to impose a certain frequency square wave voltage sensor work, produce the exciting current in voltage, excitation current with different leakage current, will also change [4], to realize the detection of the leakage

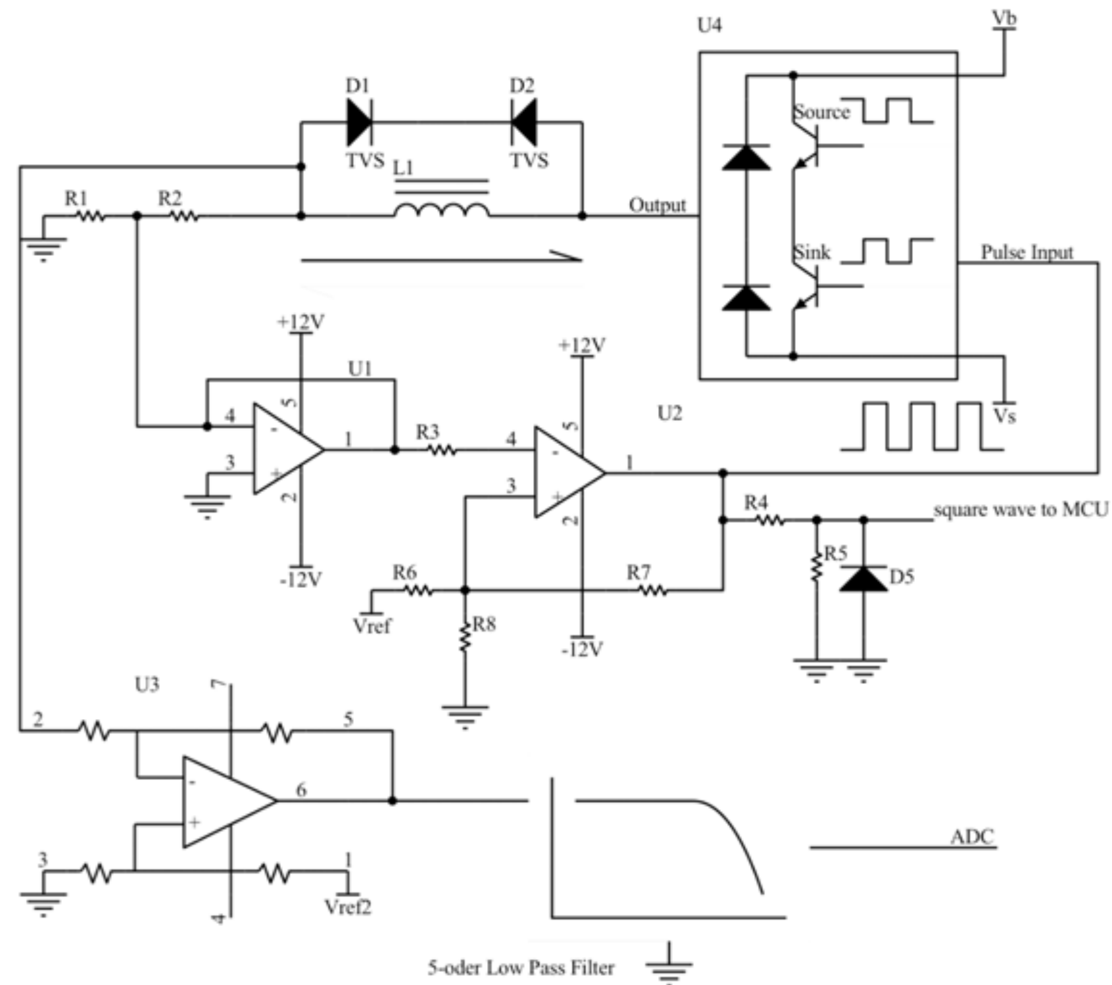


Fig. (2). The magnetic modulated oscillation and modulation principle diagram.

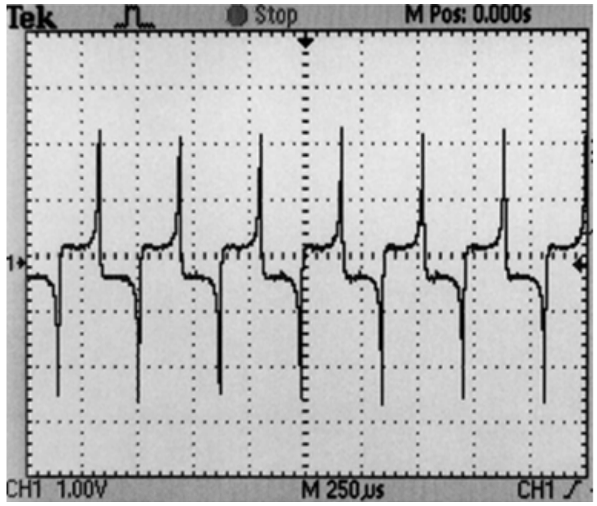
current by detecting the change of magnetizing current. Square wave voltage generating is the detection of a key circuit design, as shown in Fig. (**2**).

This scheme adopts the half bridge driver H as the core to complete the. Following the principle of work: the V-I conversion to R1 through a resistance, a current signal in the coils into voltage signal U to the double limit comparator circuit, when the U exceeds the threshold value (such as positive threshold), the comparator output voltage reversal [5], the magnetization curve of coil and magnetic core is highly rectangular, so the current in the coil is quickly along the exponential reduction and reverse increases, causing U to reverse, when U exceeds the reverse threshold value, the output of the circuit will reverse, then repeat the process of change. This establishes the self feedback oscillations; the oscillation is controlled by the threshold voltage. Note here is how to control the oscillation frequency, according to the preceding analysis, hysteresis loop coil having a rectangular of magnetic flux in the coil saturated current change almost no what influence on the coil magnetic field changes, making it change the threshold voltage of U caused by the oscillation frequency is very small so the work frequency of the circuit depends mainly on the magnetic core coil, through the test also proved this point. Because the magnetic field situation is more complex, so it is difficult to give a precise formula to calculate the oscillation frequency, but we can give an empirical formula, it can also meet the need of practical engineering [6].

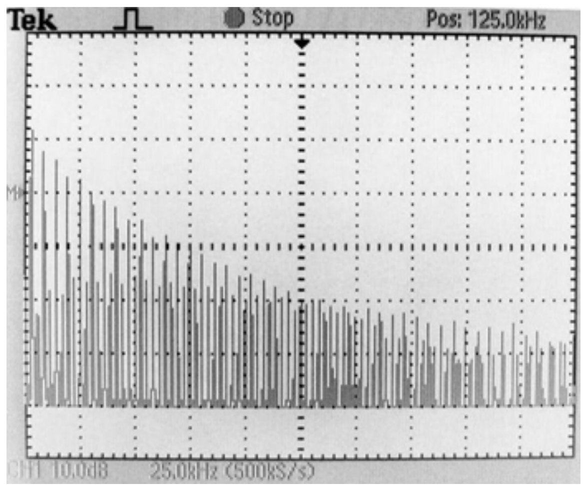
$$f = \frac{k}{N} \tag{1}$$

In the formula, f is the frequency of the oscillation circuit; K is a constant, in determining circuit parameters and magnetic cores in K value also followed to determine, therefore this value can be acquired through test; N is the number of turns of the coil;

Formula (1) meaning is: in determining circuit parameters and magnetic core material, the frequency of the oscillation circuit of F and the number of turns of the coil inversely proportional to N. There is a need to explain, although the influence of circuit parameters on the oscillation frequency is very small, but in order to more appropriate to the actual application we also taking into account of the circuit parameters [7].



(**a**) Carrier signal waveform



(**b**) Carrier signal FFT

Fig. (3). Carrier signal and its FFT.

Signal demodulation process is finished by a low pass filter. Through resistance R (R=R1 = R2) of the V-I conversion, will be the carrier current leakage signal modulation signals into voltage signals, the voltage signal through a low pass filter, it can be taken out and get the carrier signal leakage signal of the real. The core design is to determine the proper filter parameters. We analyze the spectral characteristics in the wave signal and all kinds of leakage signal. The carrier signal waveform and the FFT as shown in Fig. (**3**), you can see the carrier current amplitude at about 2.3V, the harmonic frequencies are mainly distributed in the range of 75kHz (>20dB). In addition to wave signal, the filter order and the cut-off frequency of the impact is the biggest factor is 180° , 90° and 135° waveform signal, the design takes into account the effects to make the carrier signal frequency component decays as quickly as possible and try to maintain the half wave, 90° and 135° wave frequency components (< 500 Hz). Considering we decided to adopt the most flat pass band of the Butterworth low pass filter corner frequency fc and design of the filter is 350Hz, the filter order of 5 order [8].

2.3. Leakage Detection Algorithm and Program

In order to ensure that the leakage of different wave under the protection, the waveform recognition software, and the leakage signal waveform is divided into five types: DC, AC sine waveform, half wave, 90° and 135° waveform. According to the wave, for the conversion of average value and effective value, the leakage protection characteristics consistent in the above five typical waveform, improve performance of the protector [9-11]. According to the requirements of the project and the established program, the overall framework of the software program was developed, the specific planning as follows:

Procedures used in the design of the main program (main) and interrupt (ISP) consisting of foreground/background operation mode. One of the main programs is mainly arranged port initialization, interrupt initialization, gear detection, fault detection, and improve voltage detection subroutine. A variety of detection in a fixed time interval, gear detection and fault detection of each 1s to execute boost voltage detection is executed once per 30s. The main program

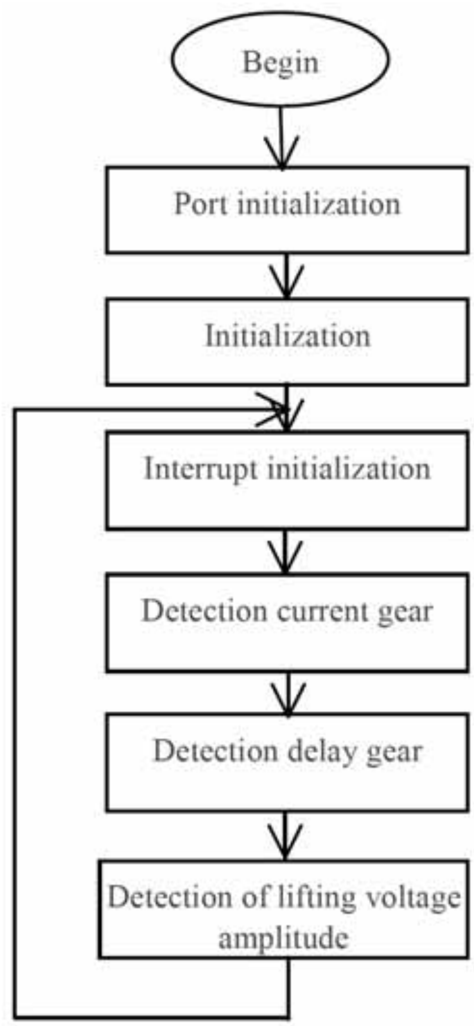


Fig. (4). The flow chart of the main program.

flow has been shown in Fig. (**4**). The interrupt service program is mainly a response from the modulation signal input, the leakage test button to trigger and AD conversion and so on three types of interrupt. Because PIC only provides an interrupt vector, so the three kinds of interrupt arranged in an interrupt service program would be considered by the interrupt flag. Interrupt service program flow chart as shown in Fig. (**5**).

2.4. An Important Parameter in the Procedure

Oscillation frequency:2 kHz

The sampling period:0.25 ms

Sampling window:128×0.25=32 ms

Motion decision value:

Set the Id1, Id2 and Id3 three is used to judge whether the action threshold, the Id1=0.8I_{Δ}n (effective value), Id2=1.5I_{Δ}n (RMS), Delta Id3=3I_{Δ}n (threshold)

The actual detection values are average values for different waveform of the mean and RMS correspondence such as shown in Table **1** [12]:

Table 1. The relationship between the average value and effective value conversion.

Waveform	The Effective Value and Average Value of Relationship
Direct	Iav=Irms
Sine AC	Iav=0.9Irms
Half wave	Iav=0.63Irms=0.707（0.9 Irms）
1/4 wave	Iav=0.45 Irms=0.5（0.9 Irms）
135º wave	Iav=0.2 Irms=0.22（0.9 Irms）

3. SPECIFIC DETERMINATION CONDITIONS

The action time of 0, 0.1, belongs to the category of fast action, taking 32ms as a detecting unit for action judgment:

When more than Id3 (a total of 20 points, the 4 period the following 4 points without judgment) when N1+6 is greater than Id2 N1+3, more than Id1 N1+2, less than Id1 N1-1.

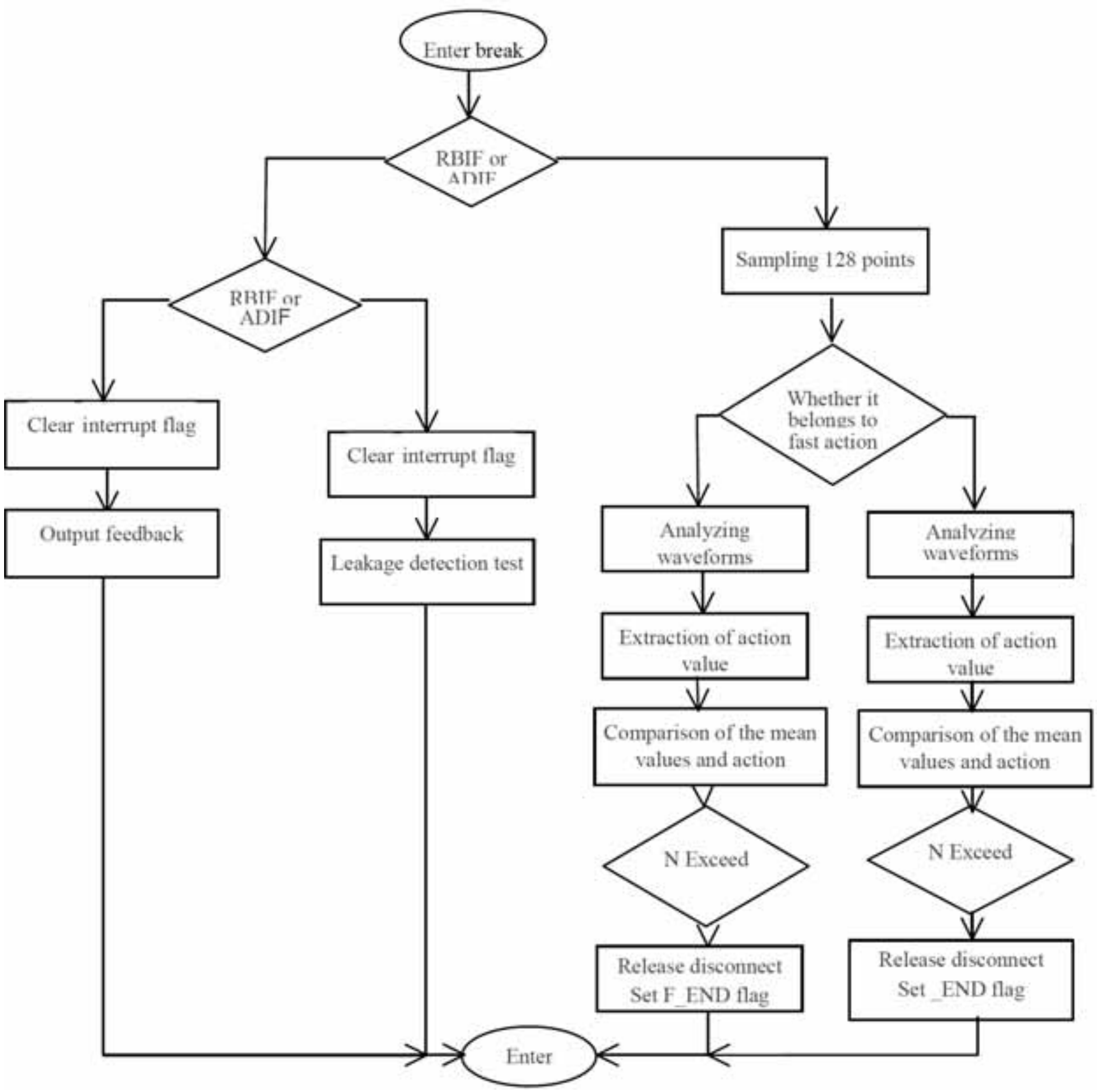


Fig. (5). Interrupt service routine.

t=0, N1>4 action, that is t1=64mS, t2=64ms, t3=32ms

t=0.1, N1>6 action, that is t1=96ms, t2=64ms, t3=32ms

The action time is more than 0.2S, the detection time is Id1 for 32ms×4 as a detection unit (improved critical value accuracy), detection time of Id2 was 32ms for a detection unit:

When more than Id3 (a total of 20 points, the 4 period the following 4 points without judgment) N2+6, more than Id2 N2+3, more than Id1 N2+2, less than Id1 N2-1.

t=0.2, N>4 action, that is t1=128+32=160ms, t2=32×2=64ms, t3=32ms

t=0.3, N>8 action, that is t1=128+32×3=224ms, t2=32×3=96ms, t3=32×2=64ms

t=0.5,N>20 action, that is t1=128+32*9=416ms, t2=32×7=224ms, t3=32×4=128ms

t=1,N>50 action, that is t1=128+32×24=896ms, t2=32×17=544ms, t3=32×9=288ms

t=2,N>100 action, that is t1=128+32×49=1696ms, t2=32×34=1088ms, t3=32×17=544ms

t=3,N>150 action, that is t1=128+32×74=2496ms, t2=32×50=1600ms, t3=32×25=800ms

t=5,N>250 action, that is t1=128+32×124=4096ms, t2=32×84=2688ms, t3=32×42=1344ms

Time interval judgment of 1s gear change, in abnormal (N not equal to 0), do not judge the gear change. The judgment of the boosted voltage time interval has been determined for 30s.

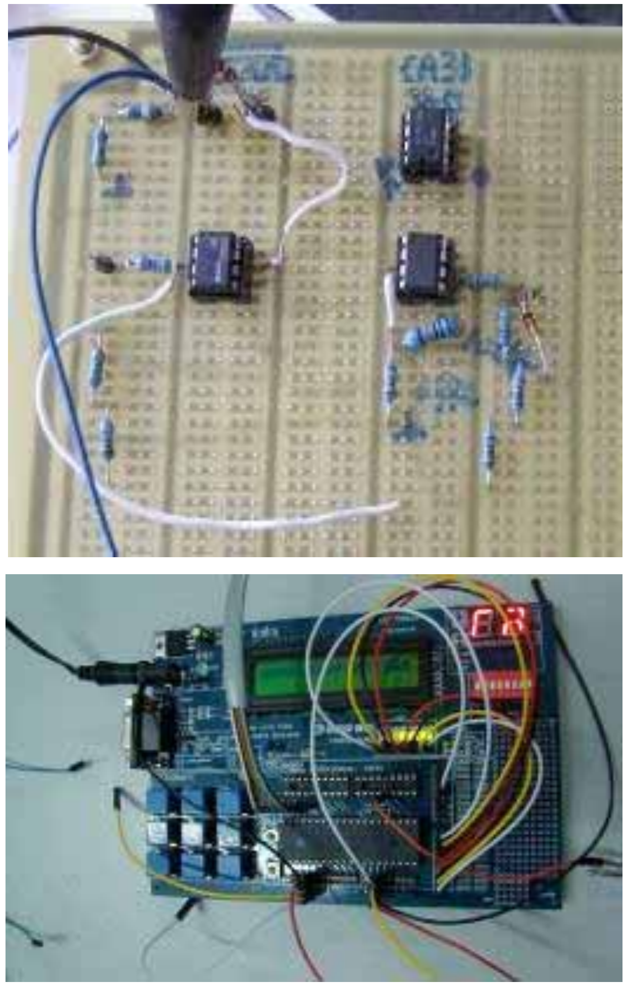


Fig. (6). MCU development board and a half bridge test circuit.

To different current gear in the program, different delay treatment and discrimination of different waveforms, the situation is very complicated, and the program will appear in floating point arithmetic for many times, it will seriously affect the operating speed. In order to solve this problem, setting an action value table, the table according to the different current shift and different waveform consisting of a two-dimensional array, as shown in Table **2** as the threshold of Id1 [13].

Program sampled signal average value and table corresponding discriminant threshold comparison, thus avoiding a large number of operations, improves the response of real-time.

4. EXPERIMENTAL VERIFICATION

The test mainly aims at the new scheme of a half bridge oscillating linear integral measurement linearity and system of two aspects. Test process using a half bridge oscillating circuit and MCU development board line, as shown in Fig. (**6**), the signal demodulation circuit test in the same scheme with full bridge voltage transformer, output point is AN0. In order to study the influence of magnetic core materials on transformer coil, we also selected the same material with different number of turns of the coil and the coil winding with a different number of turns were test Table **3**.

In the case of batch purchasing components, the cost will be greatly reduced. Order the whole disk chip each price generally to order samples each price 60%. At the same time, mass production of PCB plate seihan cost will be greatly reduced [14]. Have an important influence on the circuit work is filtering circuit device, in order to obtain the ideal effect requires filtering capacitors and High Precision Op Amp selection precision resistance, cost may be increased but the performance this relative product is worth. In addition, in order to reduce the power requirements, plans to use the low power design, may also be some increase in cost, but the supply is relatively a high power which is worth [15, 16].

According to the chip selection is different, the cost of the product will be different, to select PIC18F258 as the processing core, the price of about 25 Yuan/ piece (inquiry unit is 10 piece), the whole circuit cost about 150 Yuan (not including the core), if the batch purchase, the cost can be reduced to below 100 Yuan, with costs to products after the completion of the development can draw. The feasibility of the program from the theory and practice prove that is feasible, can complete the task of determining B type RCD.

Table 2. The threshold value table of Id.

In(mA)	6×30=180	6×50=300	6×100=600	300	500	1000
Id1=0.8×In	24	40	80	240	400	800
Direct	24	40	80	38	63	125
Sine	22	36	72	34	56	113
Half wave	15	25	50	24	40	80
1/4 wave	11	18	36	17	28	56
135° wave	5	9	18	8	14	28

Table 3. Coil test results in the same core materials with different number of turns.

The Test Results （n=120）						
The Input Current I (mA)	The Output Voltage Vo（mV）	The Average Effective Value Conversion Vt1(mV)	Waveform to Judge	Vo/I	Vt1/I	Vo/Vt1
10	262	-14.86	n	26.20	-1.49	-17.63
20	331	23.08	n	16.55	1.15	14.34
30	416	109.79	n	13.87	3.66	3.79
39.5	512	207.35	n	12.96	5.25	2.47
52	638	375.37	y	12.27	7.22	1.70
61.5	740	472.93	y	12.03	7.69	1.56
69.6	830	563.96	y	11.93	8.10	1.47
80	938	672.36	y	11.73	8.40	1.40
90	1055	810.07	y	11.72	9.00	1.30
100	1169	923.17	y	11.69	9.23	1.27
109	1265	1057.10	y	11.61	9.70	1.20
119	1376	1194.36	y	11.56	10.04	1.15
140	1617	1525.04	y	11.55	10.89	1.06
149	1705	1623.96	y	11.44	10.90	1.05
159	1823	1726.09	y	11.47	10.86	1.06
174	1993	1934.53	y	11.45	11.12	1.03
192	2194	2150.48	y	11.43	11.20	1.02
209	2380	2370.73	y	11.39	11.34	1.00
220	2501	2479.26	y	11.37	11.27	1.01

Table 3. contd…

The Test Results （n=120）						
The Input Current I (mA)	**The Output Voltage Vo（mV）**	**The Average Effective Value Conversion Vt1(mV)**	**Waveform to Judge**	**Vo/I**	**Vt1/I**	**Vo/Vt1**
242	2746	2751.50	y	11.35	11.37	1.00
259	2937	2958.70	y	11.34	11.42	0.99
270	3054	3096.41	y	11.31	11.47	0.99

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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Declared none.

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