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PORTABLE SYNTHETIC TESTING SYSTEM FOR SERVOSYSTEM BASED ON INFORMATION FUSION

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ABSTRACT

In view of the disadvantage for sinusoidal machine in naval vessels maintain to quick guarantee goal nowadays, it has designed a protable synthetic testing system for servosystem based on information fusion. The testing system used a portable industrial computer as a core, which uses Windows as operating platform and C++Builder as programmable aid, and Native-XML database technique and dynamic access mechanism, and Win Driver technique and dynamic graphics display for accurate and coarse channels signal. Through developed and designed for hardware and software, it had extended function of conventional sinusoidal machine. It adopts NFE estimator to fusion multi-source information to diagnosis the instrument on-line and database technique for off-line. Application shows it possesses the advantage of simple operate and easy test, high efficiency. It reduces the difficulty of equipment maintenance, conveniences to track and mastery the equipment for long time, and increases the quick guarantee capability. The static position precision of test overland gets 0.1 mil. It has great application value and promotion value.

Keywords: *Portable, Servosystme, Synthetic Testing System, Information Fusion, Design*

1. INTRODUCTION

Sinusoidal machine is indispensable as maintenance equipment for servomechanism in vessels. It provides all kinds of sine signal for detecting state of servomechanism. Traditional sinusoidal machine has only signal output function same as director modeling, has not or partial detection function. In order to master the overall state of equipment, it is necessary to maintain with the help of aided equipments, which raises the cost for maintenance and makes the intensity of maintenance enhanced. So it lacks the ability to rapidly maintenance.

In view of an increasing attention towards winning local wars is the ability to rapidly maintenance in high-tech conditions where the equipment maintenance cycle extends and reduces the work strength, this paper has designed a sine servomechanism test instrument based on information fusion, which has not only signal output function as ordinary sine test, but also has automatic fault diagnosis and detection functions. It cans diagnostic analysis of related equipments on-line and off-line using multi-source information fusion technology, fusion diagnosis provides to workers serving as a rapid equipment support decision making. Also it has database functions such as data storage and query, print, which is convenient for tracing the state of equipments long-term.

This paper will be structured as follows. Section 2 gives a brief overview of a related work. In Section 3 we will introduce the overall design of the system; In Section 4 we will expose the hardware design for testing system; In Section 5 we will describe the data processing and information fusion; In Section 6 we will describe our software design of testing system; In Section 7 we will show servosystem testing.

2. THE RELATED WORK

As important equipment for servomechanism in vessels maintenance, it output all kinds of signal to servomachanism, such as static step signal, constant-velocity signal, and sine signal, small and larger angles turning over signal, which test the servosystem response. Through the servosystem response, we can diagnosis the state of servosystem based on all kinds of technical standard of servosystem. Currently, we often use some devices to observate and measure, analysis and save the

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response data. It is the key to our facing problems which is the larger number of devices required, the scarcity of whole servosystem state, the larger time-consuming for diagnose.

For winning a local wars under modern, especially high-technology conditions, Zhang [2] [3] design a sine machine with some functions. Zhao [1] design an integrated portable synthetic detection and testing instrument. WANG et al. [10] design a test device for flack flowing systems based on virtual instrument technology.

For diagnosis technology and data base design, SHI et al. [5] use fuzzy information fusion in servosystem for naval gun. Lian et al. [6] use SVM-ANN hybrid model to diagnosis fault of servosystem of Naval gun. Guo et al. [9] use prognostics and health management technology for new-generation weapon.

Our work differs from the foregoing in that it fully considers the characteristic of quick maintenance, synthetic diagnosis and equipment maintenance standard and environment conditions. Hence, the proposed testing system is not only portable but also it provides synthetic performance guarantees.

3. THE OVERALL DESIGN OF THE TEST SYSTEM

According to the design requirements, the overall structure of testing servosystem is as shown in Fig.1. Through testing cable, field data is transferred to testing system from servosystem. The testing system outputs data and command to servosystem according to the test requirements. The test system saves the testing data to real time database and history database. Based on information fusion technology, testing data is processed and feature extracted and fused through the decision-making center, in the end, the decision-making is output through database reports as the state of servosystem. The test system can print testing report on-line, and the history database can be used as diagnostic analysis off-line.

The testing system precede kinds of automatic measurement and test functions, such as multistep, constant-velocity, large and small angle arc rotary control. It can perform static error testing, constant-velocity tracing error testing, sine tracing error testing, large and small angle arc rotary tracing error. It can display real-time waveforms for accurate channel and coarse channel, and forward feedback channel, negative feedback channel. Also it can display real-time error voltages, and overshoot, the degree of semi-resonance and reciprocating, the operating time [1]-[3].

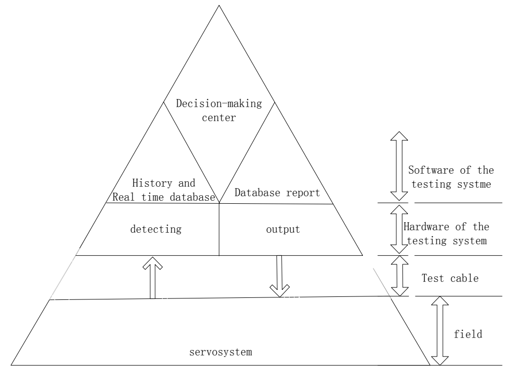

Figure 1. The Structure of Testing System

4. HARDWAER OF SYSTEM DESIGN

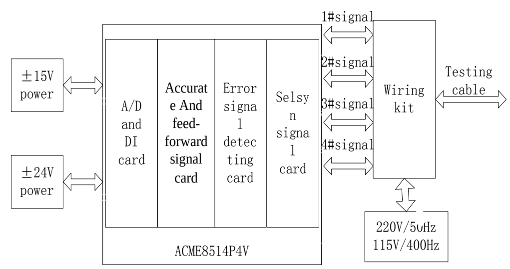

Figure 2. The Hardware Structure of Testing System

The hardware of system is as shown as Fig.2. It include a protable industrial computer such as ACME8514P4V, 3 ISA cards which designed by us, 1 A/D card and 2 DI cards which made by Advantech company, 1#~4# signal wires, 1 wiring kit, and testing cables, accessory power. Except for peripheral cable, the full weight of the testing system is 15.7Kg. All card built in mainboard slot of protable industrial computer. The detailed description of the system configuration is as follows [4 5].

4.1 Host Configuration

Host configuration of ACME8514P4V is as follows: Intel Pentium4 2.4B processor, FSB 533MHz, Intel 845GV chipset, 80G hard disc, 64M display memory, 12 slots passive backplane. The working temperature is from -40^{o}C to $+65^{o}$C.

4.2 A/D and DI Card

A/D card adopts PCL818LA/D which transforms 16 channels single-in or 8 channels differential input analog signals to digital signal, which used as feed-forward output for servosystem. And it adopts PCL733DI card as 32 channels

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digital input, which collect action characteristic of travel switchs for servosystem. Input of travel swithcs is DC24V. The standard pins of A/D card complys with ISA. The vacancy analog input must be grounded.

4.3 Accurate and Feed-forward Signal Card

Accurate and feed-forward signal card output analog accurate voltage and analog feed-forward signal for servosystem. Accurate voltage output <AC12V, and feed-forward voltage output <DC±11.8V. The card include ISA bus interface、adderss decoder、linear solid selsyn signal module、voltage transformer and output interface. It adopts D25 pins as output. The core of card is the single channel digital-to-selsyn convertor and DAC convertor. The card output selsyn signal and feed-forward voltage. And the standard pins of A/D card complys with ISA. The vacancy analog input must be grounded.

4.4 Error Signal Detecting Card

The card is used as detecting card for servosystem output double channel angle error. The error signal ΔU is described by:

$$\Delta U = 57.2 \sin \omega t \quad (1)$$

Where, 57.2V is the maximum of linear rotating transformer output. And ωt is sum of accurate and coarse error angles.

The card includes ISA bus interface、address decoder、XXSZ linear rotate transformer-digital convertor、input interface. ISA bus interface drived by 74HC574. Address decoder adopts 74HC688. The selection signal for output module is generated by 74HC154, and 74HC138 for input module. The core of card is the single channel linear rotates transformer-to-digital convertor, which measure rotate transformer signal. The standard pins of A/D card complys with ISA. The vacancy analog input must be grounded.

4.5 Selsyn Signal Card

Selsyn signal card output mid frequency signal which is simulated as sinusoidal machine output. The mid frequency signal send to vessels servosystem as driving signal. The card includes ISA bus interface、address decoder、selsyn signal output module、output interface. ISA bus interface is driven by 74HC574. The core of card is the single channel digital-selsyn convertor which power is 5W. It output 2 channels selsyn signal that is accurate channel and coarse channel, which voltage is <AC90V. The two channels angle signal transfer is shown in Fig.3. The digital quantity of accurate channel output A_{out} and the digital quantity of coarse channel output R_{out} is described by:

$$A_{out} = \theta \times n \times 2^m / 6000$$
$$R_{out} / A_{out} = 1/n \quad (2)$$

Where, θ is output position angle which is sum of accurate channel output position angle and coarse channel output position angle. m is the module precision. And n is ratio of the signal of accurate and coarse channel, which depends on the specific circumstances.

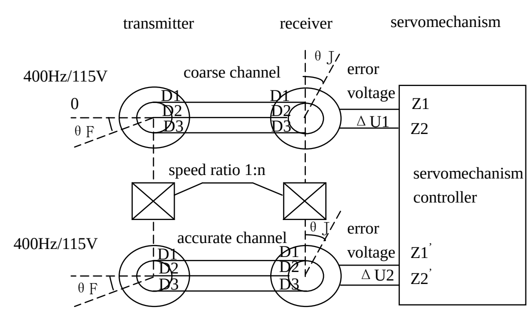

Figure 3. A Principle Diagram of Two Signal Transduction.

4.6 The Wiring Kit and Other Peripheral Devices

Table 1. The Main Signal in Signal Box.

	Card signal input		Servomechanism output	Error input
Accurate / Coarse Signal	S1~ S3	Z1、Z2	CS1~CS3	S1/S2
Max	~90V	~12V	~90V	±90V

Table 2. The Max Voltage of Main Signal in 1#~4#.

	Input signal	Output signal
1#Signal	±90V	90V
2#Signal	18V	±10V
3#Signal	100V	±12V
4#Signal	30V	---

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The card signal and sinusoidal machine output signal and the error signal is pull in wiring kit, which is shown in Tab.1.

1#~ 4 #signals is group of input and output signal for testing system, which max voltage is shown in Tab.2.

Some peripheral devices include ±15V and ±24V power, and some testing cable. During the tests the mid frequency power is supplied by vessels with 220V/50Hz and 115V/400Hz.

4.7 The System Design for Anti-interference

Due to various interferences can enter in servosystem testing system, through space and earth wire, power line and other wire. In the design, we take measures to anti-interference which described as follows.

First, in order to restrain common mode interference, we link the IPC ground and signal ground and the shell ground to form one end line ground.

Second, in order to restrain series mode interference, we adopt filtering technique to restrain interference from servosystem effectively.

Third, we adopt isolation technology to isolate high and low voltage, and shielding technology to anti-electromagnetic, and anti-power interference technology to power interference.

5. THE DATA PROCESSING AND INFORMATION FUSION

It is important to pre-process signals such as estimate the multi-sensor states for data fusion [6]. In this paper, we use neural networks, fuzzy reasoning and expert system as multi-sensor state estimate method, which is NFE estimator. Because multi-source information fusion is a multi-attribute decision, the assessment procedure of evaluation establishes one kind to correspond the multi-sensor information set and the confidence estimation mapping relations. The impact factors of sensor confidence estimate are sensor performance, electronic jamming, clutter intensity and natural environment. The single sensor confidence estimator is shown as Fig.4. The fusion step is as follows: 1) establish the sensor confidence estimate system, fuzzy sensor attributes; 2) define factors weight coefficient affected by sensor performance based on expert knowledge, and unitary processing; 3) modify the attributes using weight coefficient, which is confidence estimator input; 4) choose fuzzy membership function using expert system based on input data; 5) training data using comprehensive evaluation method, and carry through the evaluation using trained confidence estimator [7 8].

NFE confidence estimator fusion algorithm is as shown as Fig.5.

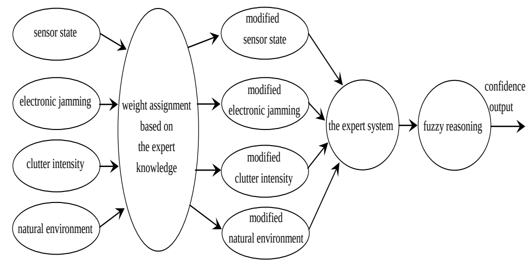

Figure 4. A Single Sensor Confidence Estimator.

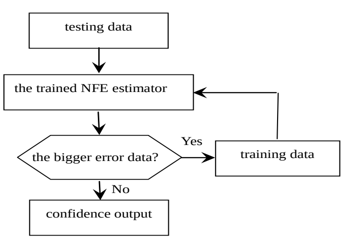

Figure 5. The NFE Estimator Fusion Algorithm.

Expert knowledge and expert system include mainly the technical standard for servosystem which is in common, and each servosystem has its unique characters bucause of different service conditions for each vessel in a long term.

6. SOFTWAER OF SYSTEM DESIGN

The software structure is shown in Fig.6. Edit program with C++ language, it is made up of main program, detection subprogram, testing subprogram, fusion and diagnosis subprogram, database. Because system is multitask operation and fast response with milliseconds, during software development process for testing instrument, it adopts multimedia timer and multiple threads control mechanism, the idea of modular design, Native-XML database techniques and dynamic access mechanism. And the key technologies for the designed cards include Win Driver technique and dynamic graphics display for accurate and coarse channels. With the features of independent to operation systems, system can be transplant to Linux operation system, which ensures the system excellent [9].

In operating software, some key modules is constructed, such as TEngle module, which

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visualized as the servosystem electrical position directly in real-time.

The key to software is database, which includes dynamic database and static database. The static database records vessels administration, equipment's state and maintenance history. The dynamic database records testing project, testing time, testing data and maintenance decision.

Some details will be illustrated in the following.

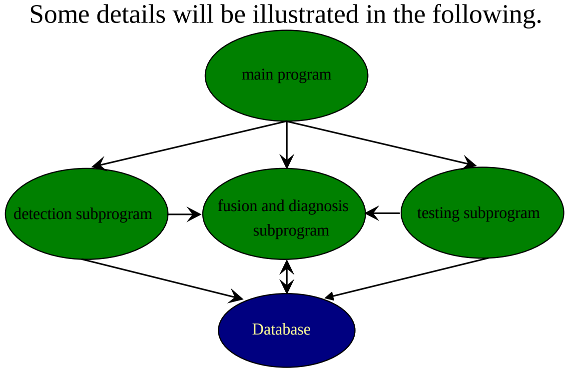

Figure 6. The Software Structure.

6.1 Detecting and Testing Subprogram

A complete testing procedure for azimuth and elevation servo system is as shown as Table 3. All testing include accurate and coarse signal errors and error voltages. Besides, the angles turning over testing include turning over time testing, semi-oscillation testing, and overshoot testing.

As shown in Tab.3, step 1 detects initial state which detect the initial posito and related state. In step2, static step testing defines initial position and amount of step. In step 3, a constant-velocity movement testing defines initial position, finished position, angular velocity, guiding time, feed forward coefficient, and the number of times for reciprocating movement. In step 4, sine movement testing defines initial position, guiding time and cycle and frequence, amplitude also. In step 5 and 6, small and larger angles turning over testing define initial position and turning over angles. A transform formula is described by:

$$1^{o} = \frac{50}{3} mil \quad (3)$$

The main performance index of each testing is left and right extreme position, minimum and maximum velocity and maximum acceleration. Each testing includes accurate and coarse channel static error measure and error voltage measure. In addition to, small angles turning over testing and larger angles turning over testing include tests such as turning over time and semi-oscillation and overshoot, etc.

Table 3. Testing Procedure for Azimuth and Elevation Servosystem.

1	Detect initial state
2	Static step testing
3	A constant-velocity movement testing
4	Sine movement testing
5	Small angles turning over testing
6	Larger angles turning over testing
7	end

There are some established content. Setting for the static testing is initial position and step. Setting for a constant-velocity movement testing is initial position and terminational position and angle velocity, and pilot time, and reciprocal time, positive feedback coefficient also. Setting for sine movement testing is initial position and cycle and amplitude, and the operating time, positive feedback coefficient also. Setting for small angles turning over testing and larger angles turning over testing are initial position and angle.

There are some characteristic of motion for each testing. For a constant-velocity movement testing, it output signal to driving servosystem to achieve established velocity during pilot time. For sine movement testing, it output signal to driving servosystem to achieve established characteristic of motion after n pilot time. And for other testing, it output signal to driving servosystem to achieve the terminational position from initial position during the step time.

The established content of the testing system dynamic save the last setting. And system display the error voltage waveform in real-time.

Some key programs described as follows.

6.2 Sine Signal Output Subprogram

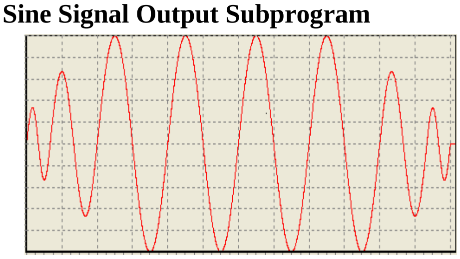

Figure 7. The Wiveform of Sine Signal Output.

According to the design required, given the cycle and the operating time, the testing system output sine signal which amplitude is one-third of the estiblished amplitude in first cycle and two-third of estiblished amplitude in second and next to last cycle, and the others output the estiblished amplitude. Characteristic of sine signal output is shown in Fig.7. The main section of sine signal output subprogram is shown as follows.

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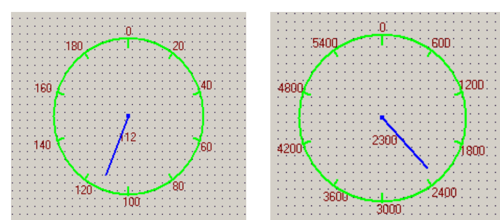
```
void CALLBACK Tfrmsd:: TimeProcfszx (UINT
uID, UINT uMsg, DWORD dwUser,DWORD
dw1,DWORD dw2)
{long izx=proctimei[3];double
t,ty,zqxs;switch(fwgdyxxz)
{case 0:  t=StrToFloat(Edit22->Text);//cycle
ty=StrToFloat(Edit24->Text);//operating time
zqxs=StrToFloat(Edit25->Text);//positive feedback
coefficient
break;…default: break;}
static double y=0,thita;
double zxx0=StrToFloat(Edit20->Text); //initial
position
double A=StrToFloatEdit23->Text); //amplitude
long sum1=(int)(1000/3);long sum2=(int)(2000/3);
long  sum3=(long)(ty*60*1000/t)-2*(sum1+sum2);
long  step0=sum1;long  step1=sum1+sum2;
long  step2=sum1+sum2+sum3;
long  step3=sum1+2*sum2+sum3;
long  step4=2*sum1+2*sum2+sum3;
if (izx<=step0)
{thita=2*M_PI/sum1;
y=zxx0+(A/3)*sinl(izx*thita);}
if((step0<izx)&&(izx<=step1))
{thita=2*M_PI/sum2; y=x0+(A*2/3)*sinl((izx-
step0)*thita);};
if ((step1<izx)&&(izx<=step2))
{thita=2*M_PI/1000; y=zxx0+A*sinl((izx-
step1)*thita);};
if((step2<izx)&&(izx<=step3))
{thita=2*M_PI/sum2; y=zxx0+(A*2/3)*sinl((izx-
step2)*thita);}
if((step3<izx)&&(izx<=step4))
{thita=2*M_PI/sum1; y=zxx0+(A/3)*sinl((izx-
step3)*thita);}
switch(fwgdyxxz)
{case 2:  y=y*200/3;break;default: break;}
Kfz1->Port=0x332;Kfz1-
>Write("0x"+IntToHex((int)(((long)y%6000+y-
(long)y)*4*4096/6000),4));Kfz1->Port=0x334;
Kfz1-
>Write("0x"+IntToHex((int)(((long)y%200+y-
(long)y)*4*4096/200),4));
double qqdy=(int)(zqxs*y)%10+(zqxs*y-
(int)(zqxs*y)); Kfz1->Port=0x338;
if (qqdy>0){Kfz1-
>Write("0x0"+IntToHex(((int)qqdy*0x3ff/6000),3)
);}
else {Kfz1-
>Write("0x0"+IntToHex(((int)qqdy*0x7ff/6000),3)
);}
if(izx%10==0)
Edit53->Text=FormatFloat("###0.##",qqdy);
Engle1->Engle=y;Engle2->Engle=y;
Chart2->Series[0]->AddXY(izx,y);
Chart2->Series[1]->AddXY(izx,(zqxs*y)/1000.0);
if (izx>3000){Chart2->Series[0]->Delete(0);
Chart2->Series[1]->Delete(0);}
proctimei[3]++;}
```

6.3 The Accurate and Coarse Channel Dynamic Output Display Subprogram

In order to dynamic display the accurate and coarse channel error signal which is electrical angle that stand for the servosystem position directly, we construct the TEngle module.



(a) The Accurate Channel *(b) The Coarse Channel*

Figure 8. The TEngle Module.

As shown in Fig.8, it looks like a clock which indicator stand for the actual electrical angle for the accurate and coarse channel. The clock is divided into ten equal parts, which adopts 600 mil as increments for coarse channel and 20 mil as increments for accurate channel.

The main section of the coarse channel TEngle module program is shown as follows, which is similar to the accurate channel TEngle module program. In program, Brush is background colour; Engle is angle; Font is style of the dial; Pen is the colour of round frame and scale; and Ppen is the colour of the indicator.

```
void __fastcall TEngle::Paint( )
{ float rad,dir;float x1,y1,x2,y2;
```

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```
(Width<Height)?Height=Width:Width=Height;
//boundary of square
(Width<Height)?dir=Width:dir=Height;
dir=dir-40;rad=dir/2;Canvas->Pen=FPen;Canvas-
>Brush=FBrush;Canvas->Font=FFont;
if(!JC) //draw dial
{ Canvas-
>TextOutA(10+rad,35+rad,IntToStr(Engle%6000))
; //display the angle
Canvas->Pen=FPen;Canvas-
>Brush=FBrush;Canvas-
>Font=FFont;x1=20+rad;y1=20;x2=20+rad;y2=30;
Canvas->MoveTo(x1,y1); //draw the scale
Canvas->LineTo(x2,y2);Canvas->TextOutA(x1-
3,y1-13,"0");//draw the label
x1=20+(rad+rad*sin(M_PI/5));y1=20+(rad-
rad*cos(M_PI/5));x2=20+(rad+sin(M_PI/5)*rad*0.
9);y2=20+(rad-cos(M_PI/5)*rad*0.9);Canvas-
>MoveTo(x1,y1);Canvas->LineTo(x2,y2);Canvas-
>TextOutA(x1,y1-13,"600");
        .........
x1=20+(rad+rad*sin(9*M_PI/5));y1=20+(rad-
rad*cos(9*M_PI/5));x2=20+(rad+sin(9*M_PI/5)*r
ad*0.9);y2=20+(rad-
cos(9*M_PI/5)*rad*0.9);Canvas-
>MoveTo(x1,y1);Canvas->LineTo(x2,y2);Canvas-
>TextOutA(x1-20,y1-13,"5400");Canvas-
>Ellipse(20,20,dir+20,dir+20);Canvas-
>Pen=FPPen;
x1=20+rad;y1=20+rad;Canvas-
>MoveTo(x1,y1);Canvas->Ellipse(x1-2,y1-
2,x1+2,y1+2);
x2=20+(rad+sin(Engle*0.06*M_PI/180)*rad*0.8);
y2=20+(rad-cos(Engle*0.06*M_PI/180)*rad*0.8);
Canvas->LineTo(x2,y2);}}
```

6.4 Diagnosis Subprogram for Travel Servosystem

According to the characteristic of action for travel servosystem, it divides the travel servosystem into k intervals. $k=(k_1,k_2,\cdots,k_n)$, which $k_i(i=1,2,\cdots n)$ is an interval subset. Each interval subset has some travel switches which is different amount. For example, $k_i=(x_1,x_2,\cdots,x_m)$, $x_j(j=1,2,\cdots,m)$ is detection information of a single travel switch in k_i travel subset. Under the normal conditions, x_j fit the normal distribution. The diagnosis subprgrammer for travel servosystem is described in Tab.4. We use the data having minimum variance as fault feature criterion in the end.

Table 4. Diagnosis Subprogrammer for Travel Servosystem.

1	Testing repeated many times
2	Calculate the approximate unbiased estimation and variance
3	Data process using Kalman Filter
4	Calculate the minimum variance
5	Output

6.5 Design of Database

System database include static database and dynamic database, there are the table of user organiation relationship and the table of administration authority, and table of equipment allocation, table of subservosystem testing, table of testing template, and the synthetic tests table, etc. The static database is used as saving information such as vessel subjection and administrative organzation, and equipment and its state, history of maintenance, etc. It is convenient to master equipment state for the static database in long term. The dynamic database is used as saving information such as vessel code and equipment, testing system, testing item, testing time, testing data, maintenance decision-making, etc.

7. THE SERVOSYSTEM TESTING

The servosystem testing wiring is shown in Fig.9. Power of 220V/50Hz and 115V/400Hz during the tests the mid frequency power is supplied by vessels.

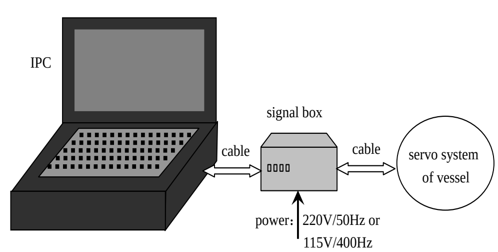

Figure 9. The Servosystem Testing Wiring Diagram.

The main section of calling programmer for PCL818 is shown as follows.

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```
if (DRV_DeviceOpen (0,
&lDriverHandle)!=SUCCESS)
{ShowMessage("Open Error!");return;} //open card
unsigned short x; //define a variable
Di.value=&x;
Di.port=A(0~32); //define a channel
if(DRV_DioReadPortByte(lDriverHandle,&Di)!=S
UCCESS)
{ShowMessage("Read error!") ;return;}; //read data
```

The main section of detecting programmer for static error is shown as follows.

```
void CALLBACK Tfrmsd::TimeProcjsmw(UINT uID,UINT uMsg, DWORD dwUser,DWORD dw1,DWORD dw2)
{int imw=proctimei[7];float mw100ct0=0.0;static long flagmw=0,mwctt=0,mwbzdcs=0;double x1,x2;
double cjcs,jjcs,cjcsdy,jjcsdy,xc,xj,xcdy,xjdy;
frmsd-> Port=0x330;frmsd-> Write("0x0081");
frmsd-> Port=0x33c;cjwcinjt=frmsd-> Read();
if(cjcs!=0&&jjcs==0){jjcs=200;}//if accurate channel error is zero when coarse channel error is not zero
cjcsdy=strtody(cjwcinjt);jjcsdy=strtody(jjwcinjt);
cjcs=strtocjmw(cjcsdy);jjcs=strtojjmw(jjcsdy);
if(imw%10==0)
{frmsd->Edit12->Text=FormatFloat("###0.##",jjcsdy);
frmsd->Edit10->Text=FormatFloat("###0.##",cjcsdy);
frmsd->Edit31->Text=FormatFloat("###0.##",jjcs);}
```

8. CONCLUSION

Through experiments overland, the servosystem has achieved the design requirements. Application shows it possesses the advantage of portable and simple operate and easy test, high efficiency. It reduces the difficulty of equipment maintenance, conveniences to track and mastery the equipment for long time, and increases the quick guarantee capability. The static position precision of test overland gets 0.1 mil. Based on above advangages it has great application value and promotion value.

In this paper, we design the hardware and software design for servosystem testing system, but there are some problems worth considering [10], such as how to qualitative describe characteristics of mechanical and electric of the whole equipment system, etc.

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