

# Design of Visual Monitoring Software for Micro-Drive Debugging in Electromechanical System

Qian Wang, Yuqing Zhao\*, Hongjun Shi

*Department of Mechanical and Electrical Engineering, Xingtai Polytechnic College, Xingtai 054035, China*

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## Abstract

Aiming at the problems of low monitoring accuracy and large memory consumption of traditional monitoring software, a visual monitoring software for MEMS micro-drive debugging is designed in this paper. According to the characteristics of MEMS system and the driving principle of micro actuator, the functional module of visual monitoring software for micro actuator debugging is designed. It includes monitoring pause button module program, visual display module program, monitoring quadrature signal module program and monitoring signal communication module program. Improve the monitoring accuracy through the connection between various modules. Select the material of the micro-drive and set its structural parameters, connect and debug the hardware of the drive, and test the performance of the designed software. The experimental results show that the software designed in this paper has high accuracy and low memory loss, the average accuracy is more than 90%, and the memory consumption is only 156 kb. It shows that this method can effectively monitor MEMS micro actuator, and the monitoring results are reliable.

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**Keywords:** MEMS; Micro actuator; Function module; Connect and debug; Visual monitoring.

## 1. Introduction

So-called MEMS (Micro company Mechanical Systems, MEMS), refers to the micro structure of the sensors, actuators and signal processing of small and integration in the integration of control circuit and other components, which can give and send the order information or information acquisition and processing according to the obtained information to work independently or in accordance with the outside world commands a micro computer electric parts, gear, or the micro system [1]. The devices developed by using MEMS technology can be applied in the fields of aerospace, aviation, military, biomedical, environmental monitoring and electronic consumption, etc., with a very broad prospect [2]. MEMS technology is gradually developing into a huge industrial cluster, and at the same time is pregnant with a very profound technological change, which will bring a new round of impact on human production and life [3, 4]. As a key part of MEMS, micro-drives have been studied in many countries since the 1980s, and some achievements have been made in China.

Yu and Tan designed a laser processing system monitoring software based on DEA control module [5]. The system is divided into different modules, mainly: identity verification module, monitoring module, data management module, etc. It is built on the basis of OEF graphics algorithm DEA control model, adding DEA control model to the laser processing system can better control the system. The operator uses the above modules to complete the monitoring, data management and other

functions of the laser processing system, and the interface of each module is very clear, which provides a guarantee for the smooth operation of the system. The monitoring software in the system mainly includes: port settings, converter configuration, motor status request, user request response, etc. These software have data collection, processing, analysis and other functions, which can ensure the stable operation of the laser processing system monitoring function. The software processes the program hierarchically, but ignores the overall function of the software, which has the problem of low accuracy of monitoring results. Li and Liu designed an upper computer monitoring software in the hydrological monitoring system [6]. The monitoring software is a software system that can be built on the hardware of the Internet of things, which will be a software innovation on the application layer of the Internet of things. Experiments show that the monitoring software designed on the host computer can not only complete the basic collection and management of hydrological information, but also continue the secondary development, and realize the advanced applications, such as statistical analysis of basic data, data mining and decision support. The functional design of the software is comprehensive, but there is a problem of large memory consumption.

In order to solve the problems of low monitoring accuracy and large memory consumption of traditional monitoring software, a MEMS micro drive debugging visual monitoring software is designed in this paper. The following is the main research content of this paper:

(1) According to the characteristics of MEMS system and the driving principle of micro actuator, the functional

\* Corresponding author e-mail: hbxtzhaoyuqing@163.com

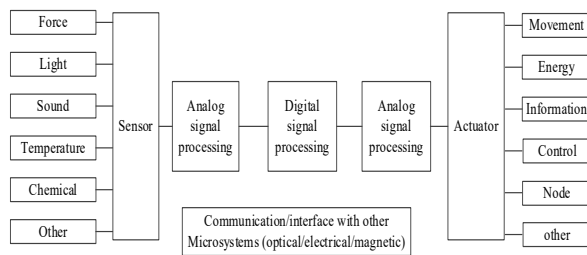
module of micro actuator debugging visual monitoring software is designed.

(2) Select the material of the micro drive and set its structural parameters, connect and debug the hardware of the drive.

(3) The monitoring results of the designed software verify that the visual monitoring software designed in this paper has ideal application effect.

## 2. Micro-Drive Debugging of Electromechanical System

The composition of the MEMS system in this paper is shown in Figure 1.



**Figure 1.** The composition of the MEMS system

In the debugging process of the micro-drive, the axial length of the internal micro beam is larger than the inner wall length of the external frame of the drive [7, 8], which is intended to provide certain axial extrusion pressure to the micro beam [9]; The drive structure also includes sixteen adjusting electrode pairs and a pair of driving electrode pairs. The adjusting electrode pair is realized to control both ends of the micro beam synchronously by adjusting the external adjusting circuit. The axial force on the micro beam is regulated, and the voltage provided by the external regulating circuit is driven laterally by the driving electrode to the micro beam. Thus, the micro-drive produces transverse displacement [10]. In MEMS, the micro-drive is a very important component. Micro actuator has the advantages of small size, high precision and low energy consumption. At present, compared with foreign countries, domestic researches on micro-drives are still in the laboratory stage, with only a small part of micro-drives products. But these products can only be used in some special fields, has not formed a complete industry group. So now, our country urgent problems for micro-drive is to keep up with the pace of the international as soon as possible, shorten the gap, improve research level, and then let the micro-drive to realize industrialization. Micro-drive refers to the micro electrical parts that enable micro devices to realize movement. It is a very important component of MEMS [11]. Electromagnetic drive When the electromagnetic coil and magnetic medium (permanent magnet or soft magnet) interact with each other will produce mutual attraction or mutual repulsion force. Under the action of this force, a certain displacement will be generated, so as to realize the electromagnetic drive of MEMS drive. The drive consists of a movable silicon film, a permanent magnet, and an electromagnetic coil, where the permanent magnet is above the movable silicon film and the electromagnetic coil. When ac voltage is applied to both ends of the coil, an electromagnetic field is generated

under the action of ac voltage. The permanent magnet is driven by the electromagnetic coil to do up and down vibration, so the silicon film is also driven to do up and down vibration.

The advantages of electromagnetic drive include simple structure, sensitive action, easy to control, high reliability, low price, etc., but it also has shortcomings, such as high energy consumption, large volume, large noise, high manufacturing difficulty and so on. The S120 drive control system adopted in this paper adopts modular structure design [12]. In terms of hardware structure, it can be divided into two parts: power module and motor module, which are connected by DC bus, and each motor module shares the power source module. The S120 integrates a new communication interface DRIVE-CLiQ, through which the S120 can be connected to motors and encoder and other components. Each component has an electronic nameplate, and all components can be automatically identified by the DRIVE-CLiQ cable.

The power module converts three-phase ALTERNATING current into direct current, and supplies power to subsequent motor modules through DC bus. There are two types of power supply modules: Active Line Module (ALM) and Smart Line Module (SLM). ALM is equipped with DRIVE-CLiQ interface (X200-X202). The DRIVE cable derived from the DRIVE-CLiQ interface of the NUMERICAL control system is connected to the X200 interface of ALM, and the X201 interface of ALM is connected to the adjacent motor module. SLM does not have DRIVE-CLiQ interface. The DRIVE cable derived from the DRIVE-CLiQ interface of the CNC system is connected to the X200 interface of the first motor module. First, connect the motor module X201 to the next adjacent motor module, and so on. It should be noted that the more powerful motor module should be installed adjacent to the power module.

Use one SLM power module and two biaxial motor modules. The communication cable derived from the X1 interface of the CNC system is connected to the X200 (DRIVE-CLiQ) interface of the first biaxial motor module. The X201 (DRIVE-CLiQ) interface of the first biaxial motor module is connected to the X200 (DRIVE-CLiQ) interface of the second biaxial motor module. The X202 and X203 (DRIVE-CLiQ) interfaces of the two motor modules are used to connect the encoder on the servo motor.

After the hardware wiring is connected, the CNC system needs to be debuggable first, and then the S120 drive can be debuggable.

The debugging process consists of the following main steps:

(1) Check CNC system before power on

The inspection before electrification includes four aspects: 1) Check whether the power module of the drive and the 24 V DC power supply of the motor module are connected correctly. 2) Check that the power module of the drive and the DC bus of the motor module are connected correctly. 3) Check whether the DRIVE-CLiQ cable is connected correctly. 4) Check whether the PROFIBUS cable is connected correctly and whether the terminal resistance is set correctly.

(2) Numerical control system electrification

If no errors are checked before energizing, the system can be energized. Close the system main power switch, 802Dsl host, PP72/48, and drive are powered on. The two green lights on PP72/48 marked "POWER" and "EXCHANGE" indicate that the PP72/48 module is ready and data is exchanged by the bus. The indicator light on the power module and motor module of the drive. The READY light if it is color means that the drive has not set parameters, and if it is red, it is faulty. DC LINK lamp if it is orange means normal, if it is red means incoming power failure. If there is no indicator light, it means there is no DC 24V power supply.

#### (3) Nc system initialization

After the 802Dsl is powered on, the system initialization should be performed first, and the required initialization files should be passed into the 802Dsl system using Siemens tooling software RCS802 or CF card. After the components of the 802Dsl are properly connected, the PLC control logic should be designed and debugged. The drive and 802Dsl parameters can only be debugged after all the safety functions of the PLC are correct.

#### (4) S120 drive debugging

Only after the PLC application program is correct, the drive can then be debugged. In order to simplify the debugging of the S120 drive, Siemens 802Dsl has specially designed a graphical drive debugging wizard, which can easily realize the fast debugging of the drive. The process is as follows: 1) Load S120 drive firmware. Ensure that all components of the drive have the same firmware version. 2) Load S120 drive factory settings. Activate the factory parameters of each drive component. 3) Topology identification and confirmation. Read the structure of the drive connection and the control parameters of the actual motor, and set the topological structure comparison level.

Complete the debugging of the micro-drive through the above steps. Based on this, the debugging result monitoring software is designed below.

The debugging process of S120 drive is shown in Figure 2.

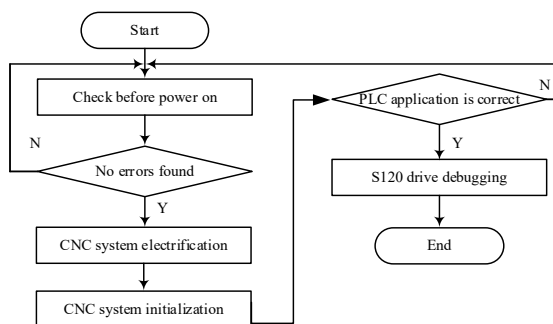


Figure 2. S120 drive debugging flow chart

### 3. The Design of the Function Module of the Visual Monitoring Software for Micro-Drive Debugging

Introduction to Software Development Environment Code Warrior (CW) is a software integrated development environment developed by Metrowerks. It provides a series of tools for software development, including the Integrated Development Environment (IDE), compiler,

connector, Debugger etc. [13]. Processor Expert (PE) is an internal sub-module of CW, which encapsulates embedded internal function modules and peripheral function modules into independent modules. With the support of hardware circuits, you only need to configure the corresponding modules to use its functions without writing the underlying program. PE mainly completes the initialization of modules, and CW completes project integration, editing, compilation and downloading, etc. The cooperation of PE and CW effectively improves the development speed based on Freescale chip systems. CW has cutting-edge debugging technology and a sound development environment, that brings embedded development to a new level of development [14, 15], and also provides developers with a highly visual and automated framework. It greatly improves the speed of project development, and creates applications for users of various development levels that are simple and convenient. The powerful compiling function of CW can check out obvious syntax format errors in the code. After the compiling software is passed, use USB TAP to burn the program, and it can be debugged online. The development environment of CW is shown in Figure 3.

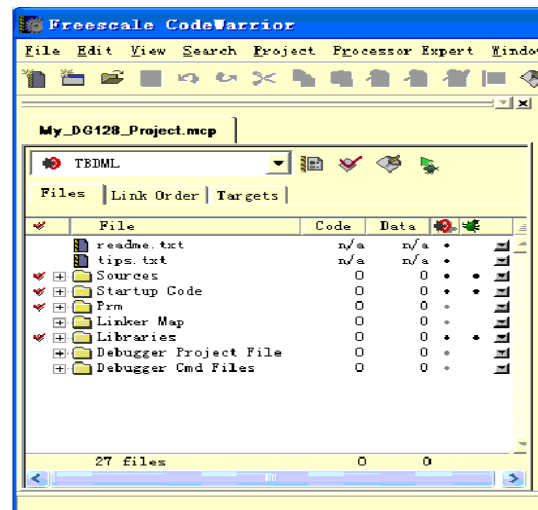


Figure 3 Code Warrior development environment

The main program of the system completes the initialization of the program and the selection of function modules. The initialization program is the operation of the MC56F84789 register after the terminal is powered on. It is an indispensable part of the program. In the terminal, it mainly initializes the ADC module, PWM module, IO status, timer module, etc. To ensure the normal operation of the system program. The terminal is divided into three functional modules: signal source, signal monitoring and digital signal. The signal source includes PWM, CLK, monitor quadrature signal, analog voltage signal and single-ended voltage signal; Signal monitoring includes CLK signal monitoring and encoder signal monitoring; digital commands are issued under RS232 and CAN communication respectively. After power-on, the system first initializes and enters the main menu interface. After the effective button is monitored, enter the corresponding secondary menu according to the button value. When the effective button is pressed again, the program jumps to the function module to work. The person presses the return

key, the program returns to the previous menu, and waits for the next key command [16, 17].

### 3.1. Monitoring pause button module program

In the process of debugging and monitoring the micro-drive, if an abnormal situation occurs, it must be paused in time to check the specific fault. This section designs the program of the monitoring pause button module. The button is used to realize the human-computer interaction function of the debugging terminal, and the corresponding function is entered through the button selection and parameter setting. The stability of the button program is the basic guarantee for the stable operation of the terminal. In the key hardware circuit, the debugging terminal uses the CH455 chip, which is connected to the I2C (Inter-Integrated Circuit) interface of MC56F84789, with an external interrupt IO port. In the process of software writing, configure the Internal I2C module and EINT module in the PE, and write the program in conjunction with the CH455 chip data manual. First, MC56F84789 sends a work start instruction to CH455 chip according to the instruction code of the data manual. CH455 chip starts to work according to the received digital instruction, and continuously scans the keyboard. The internal part of CH455 chip is divided into row scan and column scan to prevent misjudgment of keystrokes. In this case, CH455 chip uses double discrimination to be valid. When the two keyboard scan results are the same, the key is confirmed to be valid. Each key corresponds to a unique key code. The key code is determined by judging the position of the key pressed. When a key is pressed, MC56F84789 detects the interrupt signal and generates an effective low-level keyboard interrupt, and then reads the key code through the serial port. The key program flowchart is shown in Figure 4.

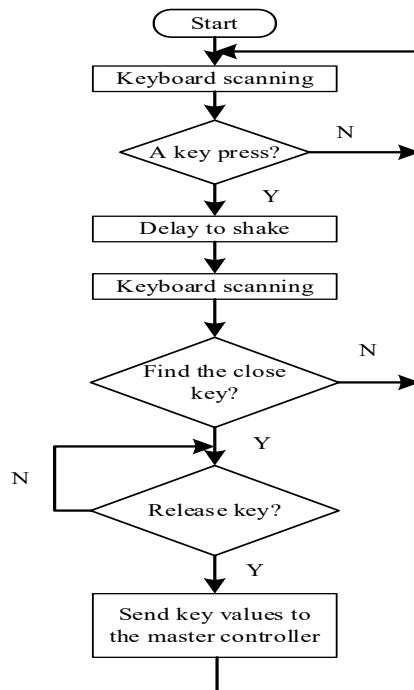


Figure 4. Keystroke program flowchart

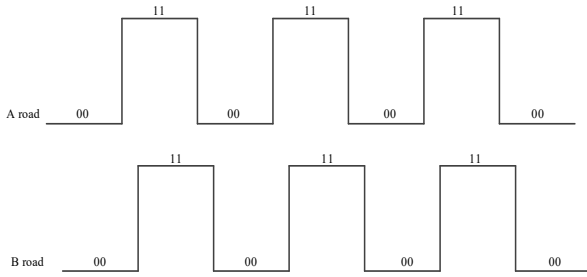
### 3.2. Visual display module program

The LCD visual display screen visually displays the running status of the system in real time, and cooperates with the button function to realize the human-computer interaction function. The visual display module uses Jinpeng OCMJ44X8C-15 LCD visual display, and uses only 4 wires with MC56F84789 to realize data serial transmission, and combines the OCMJ44X8C-15 data manual for programming. The LCD screen of OCMJ44X8C-15 is a  $128 \times 64$  dot matrix with an integrated font library chip, which can visually display 8192 Chinese characters and 126 symbol fonts, and users can also visually display drawings. OCMJ44X8C-15 provides basic and extended instruction set to meet the needs of developers, such as clear visual display, function setting, setting DDRAM address and other practical functions. Write and send a data function module according to the serial timing diagram of the data manual. First, set the PSB signal low to set the transmission mode to serial mode, set the chip select CS high, start transmitting the start byte, and receive 5 consecutive "1". As the starting byte, the transmission count is reset and the serial is synchronized to the serial transmission. The three bits received later are used as the transmission direction bit (RW), and the register selection is (RS) and "0". After receiving the start byte, each eight-bit instruction is divided into two parts. The upper four bits (DB7~DB4) are received in the LSB part of the first byte, and the lower four bits (DB3~DB0) are in the LSB part of the first byte. The LSB part of the second byte is received. The remaining bits of the first and second bytes are 0. In the LCD visual display function module, first write the sending data module according to the set time sequence, initialize the LCD screen with data manual instructions, set the visual display row and column position, and finally use the pointer to transfer the characters that need to be visualized to LCD module.

### 3.3. Monitor quadrature signal module program

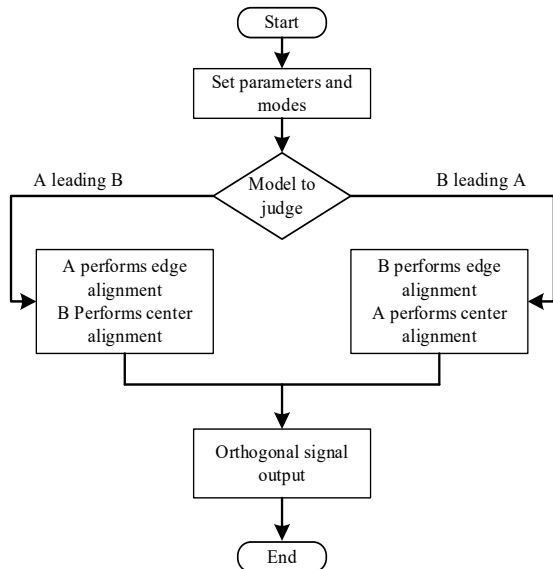
The monitor quadrature signal is two rectangular waves with the same frequency, duty cycle, and amplitude, and a phase difference of  $90^\circ$ . Among the many signal sources of the micro-drive, the monitor quadrature signal is one of them. The micro-drive debugging terminal uses MC56F84789 internal integration.

The PWM module realizes the function of monitoring the quadrature signal. On the hardware circuit, only one output signal circuit is configured on the PWMA and PWMB ports, which can be realized by software programming. The PWM module is divided into center-aligned mode trigger and edge-aligned mode trigger. Using the different trigger mode characteristics of the PWM module, when channel A is  $90^\circ$  ahead of channel B, set PWMA module to edge-aligned mode trigger and PWMB module to configure center-aligned Mode trigger; vice versa. Figure 5 is the timing diagram of channel A ahead of channel B by  $90^\circ$ .



**Figure 5.** Timing diagram of channel A ahead of channel B by 90°

After the Code Warrior IDE compiler has configured the PWMMC module, the PE function automatically generates the underlying program. When the PWMMC module is configured in the center-edge alignment mode and the edge-aligned mode, the value written to the register will change, because the micro-drive debugging terminal In monitoring the quadrature signal source, it is required that the A and B signals can choose any one to lead the other. Therefore, both PWMA and PWMB can execute center-aligned mode programs and edge-aligned mode programs, but only one mode can be selected in the configuration. In the process of programming, it is found that the center-aligned mode program and the edge-aligned mode program are considered to be written in PWMMC In the bottom layer, and the PWMMC module is frozen to ensure that the bottom layer program does not change when the PWMMC module is changed next time. This method can solve the single use of center-aligned mode and edge-aligned mode. The program flow chart of monitoring quadrature signals is shown in Figure 6.



**Figure 6.** Program flow chart of monitoring orthogonal signal

**3.4. Monitoring signal communication module program**

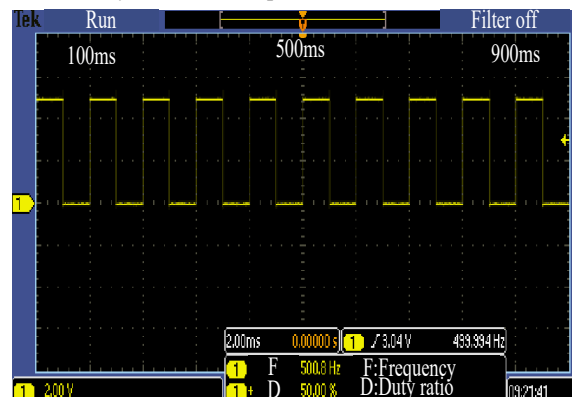
RS232 communication and CAN communication are two widely used communication methods at present. The monitoring signal communication module program of the micro-drive debugging terminal uses a reasonable structure. When the function module program is written,

RS232 communication and CAN communication are written together, through the flag bit Determine the communication method currently in use. The internal Asynchro Serial module and Freescale CAN module of MC56F84789 provide great convenience for the programming of monitoring signal communication module. Through the configuration of RS232 and CAN function module, PE generates such function functions as Send Char (), Recv Char (), Send Block (), Recv Blck (), etc., which are convenient for users to call. In this program preparation, three important parameters, namely flag bit, function code and value, are required to send a setting instruction. The communication mode at this time is determined by the flag bit, and then the function code and value are written into the corresponding buffer.

**4. Software Performance Test**

(1) Operational validity test of the designed monitoring software

In order to test the effectiveness of the visual monitoring software for micro-drive debugging, this experiment introduces a duty cycle indicator. The duty cycle of the signal is the ratio of the time occupied by the pulse to the total time during a period of continuous working time. The higher the duty cycle, the higher the effectiveness of the software. The monitoring signal is tested by connecting to an oscilloscope. The main test content is monitoring frequency and duty cycle. According to the comparison between the measurement and the setting value, it can be concluded whether the monitoring signal performance meets the standard. This project is designed to monitor if the frequency error range of 0.1% within 200K is qualified. Since the initial frequency is set to 500 Hz, the prescaler coefficient is automatically set to divide by 4, so operate the divider function to change the prescaler coefficient in different frequency ranges. Figure 7 shows the real-time waveform of the 500Hz oscilloscope measured by the oscilloscope.



**Figure 7.** Monitoring signal waveform

The test of the monitoring waveform mainly focuses on the change of the duty cycle at different frequencies. Therefore, the design of the test data during the test is shown in Table 1. Each set frequency corresponds to three sets of duty cycle values, which can be clearly seen as high the error of the duty cycle increases under the frequency condition, which is consistent with the setting.

Table 1 Monitoring signal waveform data

Set monitoring frequency (Hz)	Read monitoring frequency (Hz)	Set monitoring duty cycle (%)	Read monitoring duty cycle (%)
12	12	20.00, 50.00, 70.00	20.00, 50.00, 70.00
500	500	20.00, 50.00, 70.00	19.99, 49.99, 69.00
1000	1000	20.00, 50.00, 70.00	19.98, 49.98, 69.97
5000	4999	20.00, 50.00, 70.00	19.97, 49.88, 69.99
10000	9996	20.00, 50.00, 70.00	19.98, 49.98, 69.97
20000	19980	20.00, 50.00, 70.00	19.33, 49.34, 69.75
30000	29970	20.00, 50.00, 70.00	19.05, 49.58, 69.99
40000	399300	20.00, 50.00, 70.00	19.90, 49.08, 69.17
50000	499000	20.00, 50.00, 70.00	18.76, 49.75, 69.73

(2) Comparison of accuracy of different monitoring software

The monitoring software is difficult to ensure that no errors will occur during the running process. In order to verify the effectiveness of the designed electromechanical system micro-drive debugging and visual monitoring software, the designed software is compared with the design in Reference [5] and Reference [6]. The monitoring accuracy rate of the micro-drive debugging monitoring software is compared, and the comparison result is shown in Figure 8.

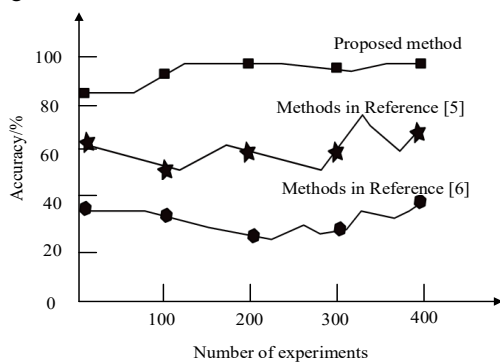


Figure 8 Comparison of monitoring accuracy of different methods

It can be seen from Figure 8 that the monitoring accuracy of different monitoring software is different. When the number of experiments is 100 times, the accuracy of the designed monitoring software is 88.29%, and the monitoring accuracy of the system designed in [5] is 65.27%. The monitoring accuracy rate of the system designed in [6] is 60.12%. Through data comparison, it can be seen that the monitoring accuracy of the designed monitoring software is much higher than other methods, and the average accuracy of the designed monitoring software is above 90%. It can be seen that the designed monitoring software has certain superior performance. Therefore, according to the characteristics of MEMS system and the driving principle of micro actuator, this paper designs the functional module of visual monitoring software for micro actuator debugging. It includes monitoring pause button module program, visual display

module program, monitoring quadrature signal module program and monitoring signal communication module program. Through the connection between each module, the monitoring accuracy is improved.

(3) Comparison of memory loss between different monitoring software

Memory consumption (KB) was compared with the monitoring software designed in References [5] and [6], and the analysis results were shown in Table 2.

Table 2 Compares the memory consumption of different monitoring software

Software	Memory cost/kb
Software in this paper	156
Software in Reference [5]	3608
Software in Reference [6]	895

It can be seen from Table 2 that the memory consumption in the monitoring process using the designed system is relatively low. The memory consumption generated by software in Reference [5] is the highest, followed by that in Reference [6]. The experimental results show that the difference between the memory cost of Reference [5] and the memory cost of the designed software is 3456 kb. The difference between the memory cost of Reference [6] and that of the designed software is 739 kb. The lower memory loss effectively increases the applicability of the visual monitoring software for micro-drive debugging, and the application scope is wider. The data obtained from the experiment show that the applicability of the designed software is better than the other three traditional electromechanical system micro-drive debugging visual monitoring software.

(4) Test the packet loss rate of different monitoring software with or without queuing

Packet loss rate refers to the ratio of the number of monitoring packets lost in the monitoring test to the sent data group. In this experiment, it is divided into queued and non-queued cases. In the case of queuing for debugging of multiple micro-drives, queueing is required. In this case, visual monitoring requires better monitoring ordering. If there is no queuing, there is only one micro-drive debugging. The method in Reference [5] and the method in Reference [6] were compared with the proposed method, and the test results were shown in Figure 9.

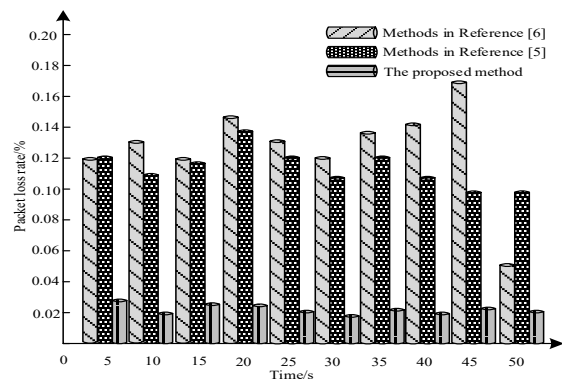
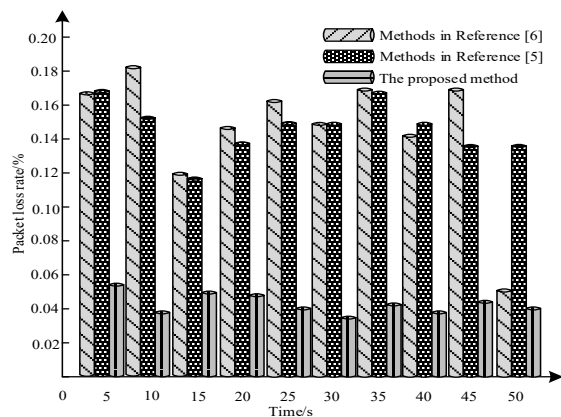


Figure 9 Comparison of packet loss rate of different software without queuing

In the case of queueing, three methods are adopted to visually monitor the packet loss rate of micro-drive

debugging. The comparison results are shown in Figure 10.



**Figure 10.** Comparison of packet loss rate of different software under queued conditions

Packet loss rate can effectively evaluate the micro actuators debugging visual monitor performance. It can be seen through Figure 9 and Figure 10 that the experimental results shown using this software to monitor the micro actuators debugging packet loss rate were significantly lower than the method of Reference [5] and the method of Reference [6], the experiment of using this software in the 50 s in the packet loss rate lower than 0.02%, and in the absence of any queue in case, having queued packet loss rate is kept below 0.16%. The packet loss rate meets the current technical requirements in this field, and ensures the data integrity of the visual monitoring process of micro-drive debugging, and verifies the monitoring reliability of the software designed in this paper. The reliability in this paper is the design software of the monitoring.

## 5. Conclusion

1. Electromechanical system drives are mainly debuted by computers as upper computers, and multiple signal sources need to be connected. Due to the uncertain on-site environment, it is difficult to visually monitor their operation status. Therefore, this paper designs a new visual monitoring software for micro-drive debugging.
2. The Design of the functional modules of the visual monitoring software for the micro-drive debugging, includes the monitoring pause button module program, the visual display module program, the monitoring orthogonal signal module program, and the monitoring signal communication module program.
3. Design software testing scheme. Select the material of the micro-drive and set its structural parameters. The designed software is used to monitor the debugging results visually.
4. Test results show that the designed software has higher accuracy, lower memory loss, ideal monitoring effect, and can be widely used.

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