Design and Implementation of Mechanical Instrument for Flight Simulator

LI Huiru[a]

Simulation Training Center , Civil Aviation Flight University of China, GuangHan 618307, China

Abstract . The mechanical simulation instrument of flight simulator can meet the display visual error specified by the new regulations. By studying the working principle of the flight simulator mechanical simulation instrument, it can be seen that the mechanical simulation instrument can be quickly converted into other instruments of the same series by changing the dial. Taking the oxygen pressure indicating instrument of flight simulator as an example, this paper introduces the design principle, design circuit diagram, design angle calculation and software architecture of the instrument. It was installed on the CJ1 flight simulator for transmission delay testing. Test results show that the simulation instrument can fully meet the regulatory requirements

1 Introduction

The instrument system on the flight simulator is exactly the same as the indicator on the real aircraft instrument system. The simulator instrument can be the real part of the aircraft or the simulation part (simulation instrument). The actual parts of the aircraft are generally expensive[1-2], and special repairs are needed in case of failure. The organization performs maintenance [3-5]. The simulation instrument simulates the principle of the aircraft instrument and relies on built-in software algorithms and parameter settings to simulate the display of the real instrument [6-7].

The simulation instrument can be divided into a graphical instrument and a mechanical instrument. Simulated instruments,such as electronic flight instruments, straight Connected to the corresponding computer through the connection line HPMI/VGA/DVI, the information displayed by the computer control instrument; mechanical instruments, such as the leveling instrument, voltmeter, ammeter, displayed by the motor-driven instrument, complete the indication of the instrument.

The new regulations stipulate that the electronic display image of a three-dimensional instrument (such as an electromechanical instrument) should have the same three-dimensional depth of field as the aircraft instrument. When observing the simulator instrument from the position of the main operator, the same appearance should be reproduced when observing the aircraft instrument. . The image displayed by the simulator meter should reproduce the inaccuracy of the meter reading due to the viewing angle and parallax. The viewing angle error and parallax on the shared meter should be minimized, such as engine displays and alternate indicators.

Therefore, the graphical instrument cannot display visual errors because it is a complete virtual instrument. In the future, in order to meet the regulatory requirements, the visual error of the display instrument will be replaced by a mechanical instrument.

Analog instruments, also known as virtual meters, are widely used in the manufacture of simulators. The simulation instrument is applied to the simulator to display all the data information on the simulated real aircraft instrument. According to the driving method of the simulation instrument, it can be divided into a graphical instrument and a mechanical instrument. The simulation instrument, such as the electronic flight instrument, is directly connected to the corresponding computer through the connection line HPMI/VGA/DVI, and the information display of the instrument is controlled by the computer; the mechanical instrument, such as the leveling instrument, the voltmeter, the ammeter, is displayed by the motor driven instrument, Complete the instructions of the meter. However, for more complicated mechanical instruments such as horizons, aircraft real parts are often used on the simulator, and the ARINC429 interface used for the real parts needs to be converted into a serial connection.

The simulation instrument has the advantage that the cost of the aircraft is incomparable and the cost is low. In addition, the development of the simulation instrument is relatively easy. The simulation instrument is applied to the simulator, which has the characteristics of easy maintenance and simple maintenance procedures for routine maintenance. In addition, the simulation instrument has powerful scalability, which can be quickly simulated by software and hardware migration, and can be quickly

[a] Corresponding author: 825987996@qq.com

simulated into similar simulation parts. In addition, the simulation instrument can be modified and used in VPT (Virtual Program Trainer) virtual program trainer.

2 Page layout Mechanical simulation of aviation instrument working principle

Mechanical simulation instruments generally refer to aerospace instruments that require mechanical devices to drive. The mechanical aviation simulation instrument adopts digital signal processor, stepping motor and peripheral circuit to realize the simulation display of the instrument. Mechanical aviation instruments are usually divided into two categories, one is non-pointing instruments, such as leveling instruments, horizontal status indicators, and the other is pointer instruments, such as airspeed meters, voltmeters, and so on.

Pointer-type aviation instruments are the most widely used and have a large number. And the pointer meter can be quickly modified into other instruments of the same series by changing the dial [8]. The key components in mechanical instrument design are stepper motors (classified according to the purpose of the motor, divided into control and drive types, stepper motors belong to the control category), stepper motors can convert electrical pulse signals into angular displacement or line Displacement output, used to drive the connected actuator [9] (eg, meter pointer). Control the angle of rotation of the stepper motor to control the angular displacement output value [10]. When the frequency of the pulse signal is too fast, the stepping motor will produce a "lost step" phenomenon, which requires the motor driver to control. The motor driver sends a direction command and a pulsation command to the motor to drive the actuator pointer. In addition, the actuator feeds back the signal to the motor drive, which in turn presents the desired output value. Stepper motor type indicator needs to return to zero. For the 360 degree rotation meter, the method of detecting the zero position by photoelectric sensor can be adopted; for the instrument with the rotation angle lower than 360 degrees, the drive pointer can be used to return to the zero position, and the collision blocking pointer can be used. The method of stopping the card pin returns to zero.

3 Mechanical simulation of aviation instrument working principle Simulation design of oxygen pressure gauge

Since the oxygen pressure indicator on the real aircraft is displayed according to the supply of the oxygen system on the real aircraft. The actual parts of the oxygen pressure indicating instrument cannot be used directly on the simulator. The oxygen pressure indicator on the simulator must be a dummy.

3.1 Oxygen pressure indicating instrument design block diagram

Analyze the working status of the oxygen indicating instrument of a certain aircraft. The instrument indicates that it rotates within the range of 0~300°, the minimum scale is 1°, and there is yellow light in the meter.

The principle of instrument design, the design of the simulation instrument uses a micro stepper motor to drive the instrument, and obtain appropriate instructions. Since the stepping motor is rotated under the action of a pulse, the inverter is used for continuous operation. The working current of the stepping motor is large, and the front stage is connected to the driving circuit. The digital signal processor is used for signal acquisition and processing, and is connected to the flight control host computer through the interface circuit. Photoelectric sensors are used for resetting and zero detection of the meter. The working principle is shown in Figure 1.

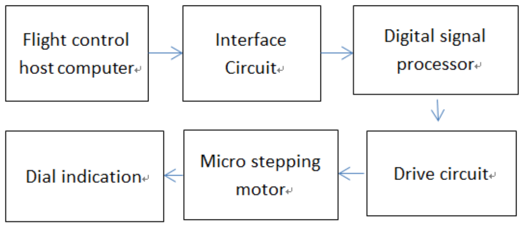

Figure 1. Driver circuit and software implementation of meter indicator

3.2 Oxygen pressure indicator instrument design circuit diagram

The specific implementation of the simulation circuit is shown in Figure 1. The internal drive circuit of the instrument is driven by a motor with two coils. The indicator is driven by a ±15 VDC power supply. The amplifier amplifies the signal and drives the stepper motor. The motor drives the pointer of the indicator to rotate. When the sinusoidal signal is zero and the cosine signal is at a maximum of 10 volts, the meter is at the indicated zero position. Diodes and capacitors form a protection circuit to prevent inadvertent erroneous connection of the supply voltage and possible damage to the instrument.

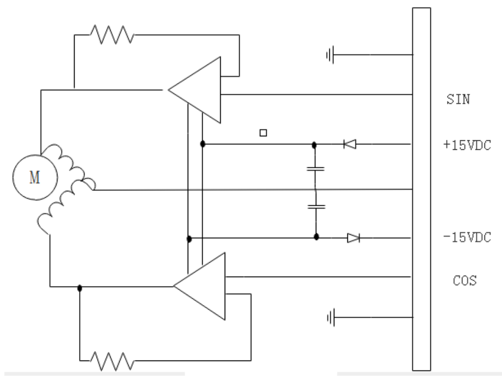

Figure 2. Simulation instrument working principle diagram

3.3 Oxygen pressure indicating instrument design angle calculation

Due to the non-linear distribution of the scale of the meter, the dial is non-linearly distributed, and the voltage input value needs to be converted into the analog value of D/A for output, so that the meter pointer is displayed to the appropriate scale. In the instrument design process, the 10-bit data is analyzed, and the display accuracy of the 12-data meter is displayed. Generally, thedisplay accuracy of the 12-bit data can meet the display requirements of the vast majority of meters. For 10-bit data, the range is from 0 to 1023, and for 12-bit data, the range is from 0 to 4095 [11-13]. This example uses 12 bits.Table 1 shows the correspondence between the calculated rotation angle and the input voltage value and the D/A input amount.

Table 1. Correspondence between rotation angle and input voltage value and D/A input.

Instrument pointer Rotation angle (degrees)	Sinusoidal sin input Voltage value (volts)	Cosine cos input Voltage value (volts)
0	0	10
30	5	8.6
60	8.6	5
90	10	0
120	8.6	-5
150	5	-8.6
180	0	-10
210	-5	-8.6
240	-8.6	-5
270	-10	0
300	-8.6	5
330	-5	8.6
360	0	10

3.4 Oxygen pressure indicator instrument design software framework

When the emulation instrument has external power input, the system starts self-test, the pointer indicates to the initial position [14], waits for the data transmitted by the interface circuit, and judges whether there is rotation according to the transmitted data. If the number of steps is greater than one, the motor starts. Rotate, after completing one rotation, the motor waits for the next serial port data, and so on[14].

When the flight simulator is powered up, the simulator pointer emulation indicator starts working. The indicator starts the power-on self-test, and the indicator double pointer returns to zero at the same time after the system is initialized. At this time, the digital signal processor performs signal acquisition and analog-to-digital conversion; compares the converted values, and calculates the number of steps of the motor rotation; sets the direction in which the motor rotates, and then drives the motor to rotate, one step per step, stepping Decrement the number by one until the number of steps is 0, the motor stops moving and the pointer stabilizes. When the acquired signal changes, the motor starts to rotate again. This way, the loop is working continuously, and the pointer can be instructed to the correct position at any time. This is how the built-in firmware works[15-17].

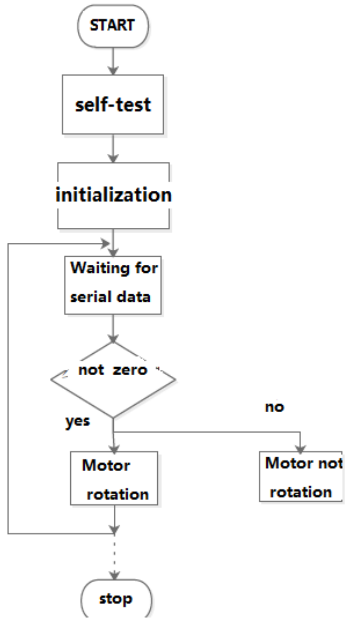

Figure 3. Simulation instrument working principle diagram

3.5 Oxygen pressure indicator meter calibration

The simulator maintenance personnel calibrate the meter and generally implement it in the calibration document. Change the value in the calibration document to change the indication of the meter pointer. The principle of meter calibration follows: one is to calibrate the point of abnormal change on the calibration curve; the other is to observe the indication range of the meter, and the maximum and minimum values indicated by the meter must be within the range indicated by the meter.

The mechanical simulation instrument is calibrated every 12 months as required in the simulator maintenance manual. In addition, calibration must be performed when there is an error in the indication [18-19]. There are several reasons for the error of the mechanical instrument. For example, gravity acts, the pointer is affected by gravity, and the indication error is generated. During the rotation, the torque of each point is different, and the indication error is also generated; the coil of the synthetic motor is not Uniformity also causes errors when the motor drives the meter pointer.

4 Meter transmission delay test

According to the CCAR-60 regulations of civil aviation, the instrument display delay time of the flight trainer should be less than 300ms, and the full-motion flight simulation instrument should display the delay time less than 150ms (the latest consultation notice is 100ms) [20]. The meter's transmission delay is measured by a photosensor connected to one or more virtual instrument displays. Figure 4 is a recording of the meter response using the photoelectric sensor to detect changes in meter brightness during the test. For the test mechanical

 https://doi.org/10.1051/matecconf/201929101007

simulation instrument, the photoelectric sensor can be removed, and the mechanical instrument position feedback potentiometer output is connected to the photoelectric sensor end of the circuit. Figure 5 is a meter transmission delay test box.

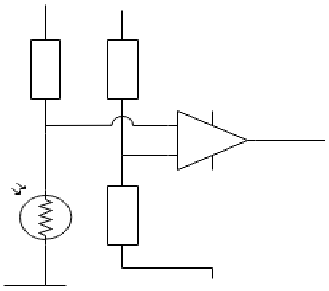

Figure 4. Photoelectric sensor work

Figure 5. Photoelectric sensor kit

The designed pointer indicator is connected to the CJ1 flight simulator for testing. The test result is the same as expected, indicating that the repeatability is good, the indicator pointer rotates smoothly, and there is no jumping phenomenon. The test results show that the CJ1 flight simulator pointer simulation indicator meets the design requirements of the CJ1 simulator flight indicator, which can successfully replace the indicator on the existing simulator. Thus, the design study of the CJ1 flight simulator simulation indicator was successfully completed.

CJ1 flight simulator pointer simulation indicator main features are as follows[21]:

1 The indicator structure is simple, and the price is lower than that of the imported simulator indicator;

2 using high-performance stepper motor, high precision;

3 Using digital signal processor, the sampling precision is high, the work is stable and reliable, and the anti-interference ability is strong;

4 can meet different aircraft simulators, flight exercises

Demand for the device;

5 plug and play, do not worry about the indicator burned;

6 provides self-test and zero return function;

7 The pointer rotates smoothly without bounce.

Figure 6 shows the transmission delay test results for the rudder input of the CJ1 flight simulator. The response time of the instrument is 118ms. The result meets the requirements of the original CCAR-60, but is lower than the latest flight simulator consultation notice.

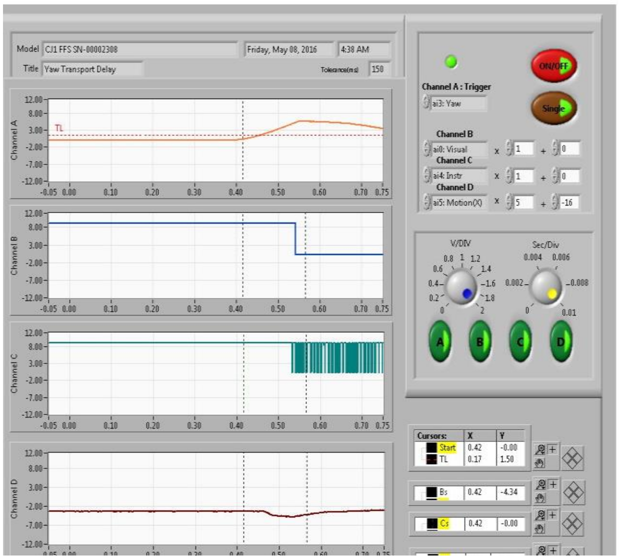

Figure 6. YAW response transmission delay test result

5 In conclusion

Mechanical simulation instruments have the advantage of being incomparably cheap and cost-effective, and the development of mechanical simulation instruments is relatively easy. It is applied to the simulator and has the characteristics of easy maintenance and simple maintenance procedures for routine maintenance. In addition, the simulation instrument has powerful scalability, which can be quickly simulated by software and hardware migration, and can be quickly simulated into similar simulation parts. In addition, the simulation instrument can be modified and used in VPT (Virtual Program Trainer) virtual program trainer. .

References

1. Yan Zhiwu, Li Chenggui. Overview of the development of aircraft cockpit instrument display [J]. Modern displayShow, 2005 (1): 22 - 25.
2. Su Bin, Chen Hongying, Liu Duhui. Automatic Flight System Modeling Party in Flight SimulatorLaw [J]. Journal of Civil Aviation Flight University of China, 2007, 18(5): 9 - 13.
3. Wu Dong yan. Flight Simulator Cockpit Instrumentation Design and Application [D]. Changchun: JiLin University, 2006.
4. Chen Youjun. Development of Pointer Instrument for Flight Simulator[J]. Science & Technology Information. 2011，21，31-33
5. Chen Youjun. Simulation of aircraft safety warning system based on OpenGL [D]. Chengdu: University of Electronic Science and Technology of China. 2009
6. Xu Qiang, Gu Hongbin, Research on Instrument Communication Technology of Flight Simulator Cockpit[J].InformationTechnology,2012(1): 1- 3

7. Wang Xing ren. Flight real-time simulation system and technology [M]. Beijing: Beijing Aerospace University Academic Press, 1998: 44-53.
8. Zhang Huizhen, Zhang Peng. Integrated design of electronic products based on Altium Designer [J].Radio communication Technology, 2008, 34(6): 56-58.
9. Cheng Hao. Application and Research of Altium Designer in Virtual Simulation in Electrical and Electronic Teaching Research [J]. Journal of Shazhou Vocational and Technical College, 2009, 12(3): 28-31.
10. Li Yinhua, Yang Cunxiang, Bao Air Force. Based on dsPIC30F3014 refrigerant filling device control System design [J]. Electronic Devices, 2007, 30(3): 931-933.
11. Chen Youjun. Overview of modern flight simulator technology development [J].Journal of Civil Aviation Flight University of China, 2011，22(2) : 25-27
12. Pu Kun, Chen Youjun. Simulation implementation of CJ1 flight simulator cockpit equipment and common faults In addition to [J]. Aviation Maintenance and Engineering, 2011(2) : 66 - 68.
13. Xiao Zhijian. Design of Simulation Simulator for Flight Simulator[J]. Wit Motor. 2013，41（9），33-34
14. Liu Guoqing, Li Zheyi. Research on virtual instrument system of a certain aircraft simulation trainer [J].Microcomputer Information, 2010, 26(6 - 1): 110 -111.
15. Liu Heping, Zheng Qunying, Jiang Wei. dsPIC general digital signal controller principle and application [M].Beijing: Beijing Aerospace University Press, 2007: 77-97.
16. Wang Liwen, Zhou Haibo. Simulation design of flight simulator precision approach channel indicator [J]. Electricity Light and Control, 2010(5): 70-73.
17. Wu Sentang, Fei Yuhua. Flight control system [M]. Beijing: Beijing University of Aeronautics and Astronautics Society, 2005.
18. Ma Chao, Xu Yan. Research on Multi-stepping Motor Linkage Control Based on DSP [J].Information Technology.2010，5，109-114
19. Maintenance manual CJ1 FFT for CAFUC. Metronix . 2013
20. China Civil Aviation Administration，Identification and use rules for flight simulation equipment ，CCAR-60（141）.Beijing，2005
21. Xiao Zhijian. Design of double pointer indicator for Boeing 737-NG simulator[J]. Automation Instrumentation. 2012，33（12），74-76