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Design of High-speed ATE Calibration Equipment

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***Abstract* –The calibration of Automated Test Equipment(ATE) is an important part of microelectronics measurement. To achieve full calibration of high-speed ATE, each high-speed digital channel should be traced to the calibration equipment. Calibrating each channel individually with an instrument will pose a great challenge to the calibration of ATE, and channel switching will increase a large amount of calibration time. This paper puts forward a design solution of calibration equipment of high-speed ATE, which can realize the versatility and portability of calibration equipment, and realize multichannel automatic calibration progress.**

I. INTRODUCTION

The calibration of Automated Test Equipment(ATE) is an important part of microelectronics metrology[1~7]. Only the calibrated ATE can ensure that the measurement value can be traced to the reference value through a traceability chain with known uncertainty. There are many technical indicators for high-speed ATE, but the most important dynamic indicators are eye height, eye width, rise time, time interval and jitter injection[8~11]. Usually there are 16 channels or even more than dozens of high-speed digital channels in the high-speed ATE. To complete the calibration of all high-speed channels, the dynamic parameters of each channel need to be measured. The disadvantage of the existing calibration methods is that calibrating each channel individually with an instrument will pose a great challenge to the calibration of ATE, and channel switching will increase a large amount of calibration time. Therefore, this paper puts forward a design solution of calibration equipment of high-speed ATE, which can realize the versatility and portability of calibration equipment, and realize multichannel automatic calibration progress.

This paper is organized as follows. In section 2 we describe the calibration principle of high-speed ATE. In section 3 we present the architecture design of calibration equipment. In section 4 we present the design of high-speed channel switching system. In section 5 we present the design of calibration software. In section 6 we draw conclusions.

II. CALIBRATION PRINCIPLE OF HIGH-SPEED ATE

There are many technical indicators for high-speed ATE, but the most important dynamic indicators are eye height, eye width, rise time, time interval and jitter injection.

1. The calibration principle of time interval

The time interval is the difference between the measured signal edge timing and the predetermined signal edge timing. Figure 1 shows the calibration principle of time interval.

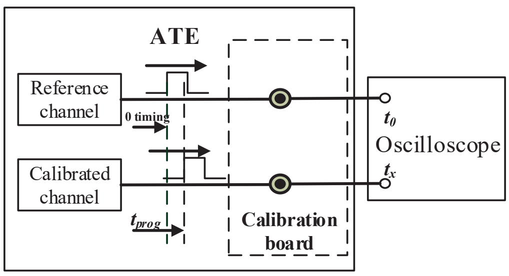

Fig.1. The calibration principle of time interval

After selecting a stable signal source synchronized with the timing of ATE as the reference signal, or selecting a special channel of ATE as the reference signal, we connect both the calibrated channel and the reference channel to the oscilloscope. A test program is written to make the calibrated channel generate a rising edge from 0 to 1 at t_{prog}, while make the reference channel generate a rising edge from 0 to 1 at t_0 with the same magnitude. Then the oscilloscope is used to synchronously measure the rising edge t_x from the calibrated channel and the rising edge t_0 from the reference channel. The time interval is calculated according to the following formula:

$$\Delta t = t_x - t_{prog} - t_0$$

2. The calibration principle of eye height

The eye height is the size of eye chart on the vertical axis, which is the signal-to-noise ratio measurement. Figure 2 shows the definition of eye height.

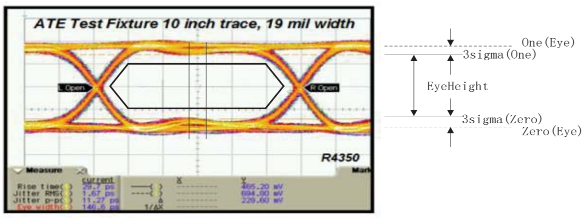

Fig.2. The definition of eye height

Figure 3 shows the calibration principle of eye height. A test program is written to set a pseudo-random pattern with corresponding level V_0 and timing t_0. Then the oscilloscope collects the output waveform in real time to measure the eye height V_x through the eye graph measurement mode.

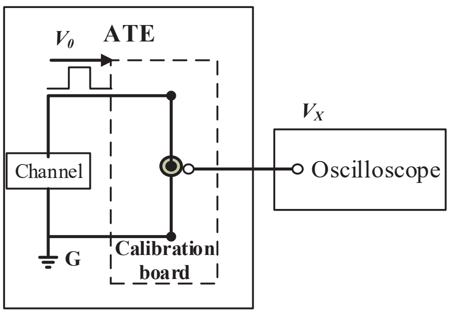

Fig.3. The calibration principle of eye height

3. The calibration principle of eye width

The eye width reflects the total jitter of the signal, that is, the size of the eye chart on the horizontal axis, which is defined as the time difference between the intersection points of the two upper and lower edges. Figure 4 shows the definition of eye width.

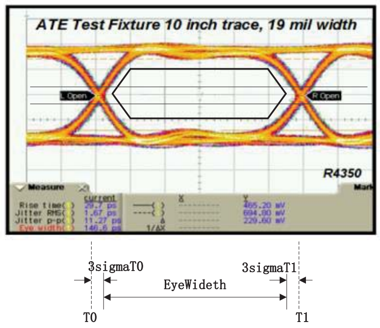

Fig.4. The definition of eye width

Figure 5 shows the calibration principle of eye width. A test program is written to set a pseudo-random pattern with corresponding level V_0 and timing t_0. Then the oscilloscope collects the output waveform in real time to measure the eye width t_x through the eye graph measurement mode.

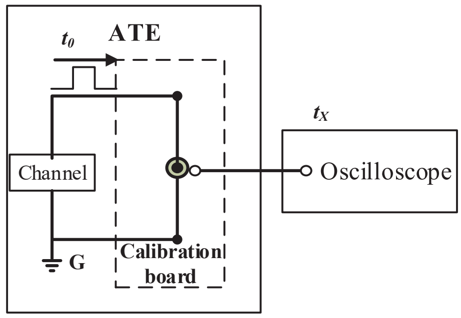

Fig.5. The calibration principle of eye height and eye width

4. The calibration principle of rise time

The rise time refers to the interval between the two transients when the pulse instantaneous value first reaches the specified lower limit and the specified upper limit. Figure 6 shows the calibration principle of rise time.

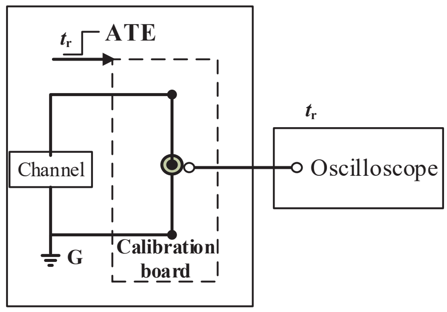

Fig.6. The calibration principle of rise time

A test program is written to set a square wave pattern with corresponding level and period. Then the oscilloscope collects the output waveform in real time to measure the rise time t_r.

5. The calibration principle of jitter injection

The jitter injection is a kind of redundancy test to measure high-speed digital signal. It is to insert a fixed periodic jitter into an ideal high-speed digital signal, which is used to measure its tolerance to bad signals.. Figure 7 shows the calibration principle of jitter injection.

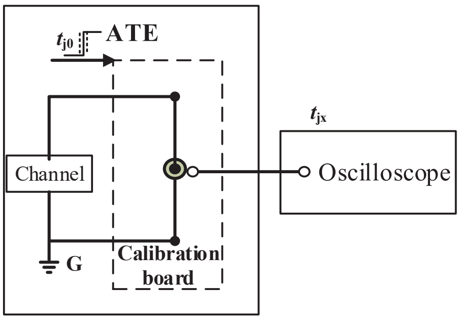

Fig.7. The calibration principle of jitter injection

A test program is written to set a pseudo-random pattern with corresponding level V_0 and jitter injection t_{j0}. Then the oscilloscope collects the output waveform in real time to measure the total jitter t_j, which is separated from random jitter and deterministic jitter by some fitting method. After the random jitter and deterministic jitter are separated, the components of deterministic jitter are further decomposed until the jitter injection is t_{jx} calculated.

III. THE ARCHITECTURE DESIGN OF CALIBRATION EQUIPMENT

Fig 8 shows the structure of calibration equipment, which consists of controller, oscilloscope, high-speed channel switching system, and calibration board. Through the calibration board, a group of calibrated high-speed channels of ATE are connected to the high-speed switching system, which can designate any channel to connect to the oscilloscope. The oscilloscope analyzes and calculates the pseudo-random code output from ATE. The controller sends corresponding control instructions to the high-speed channel switching system, oscilloscope, ATE, and calibrates the parameters of all high-speed channels in turn.

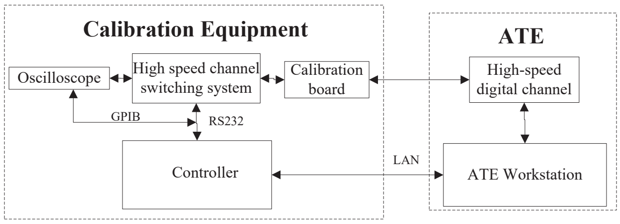

Fig.8. The structure of calibration equipment

The oscilloscope and high speed channel switching system adopted by the calibration equipment meet the performance requirements, and the specific indicators are shown in Table 1.

Table.1. The indicators of calibration equipment

Instrument	Model	Indicators
oscilloscope	MSO73304DX	Bandwidth: 33GHz Sampling rate: 100GS/s Rise time: 14ps DC accuracy: 2%
High speed switching system	Custom-made	Topology: 2×16 Bandwidth: 26.5GHz EPA: 20ps Insertion loss: 1dB

The quantity traceability diagram of high-speed ATE calibration equipment is shown in Fig 9. The ATE is traced to the high-speed ATE calibration equipment, which is traced to the highest calibration equipment.

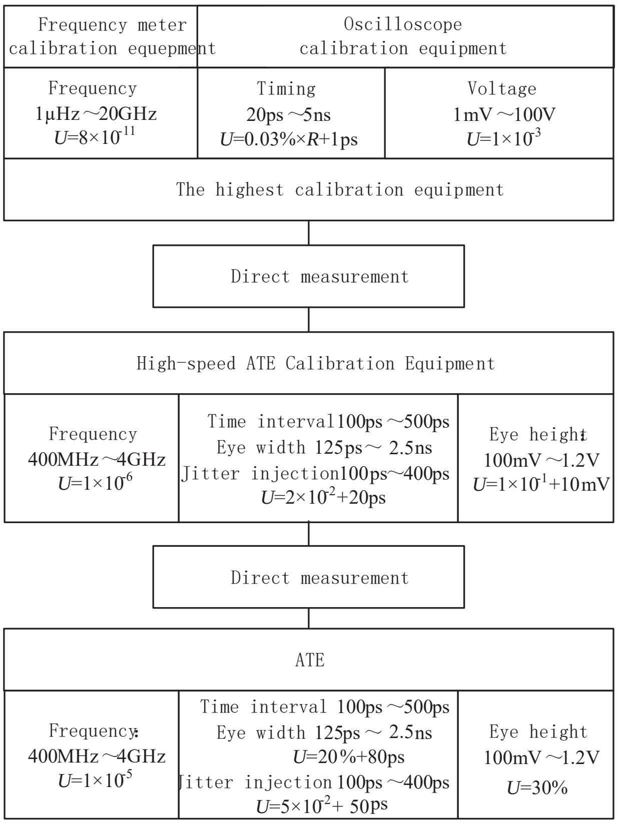

Fig.9. The quantity traceability diagram

IV. THE DESIGN OF HIGH-SPEED CHANNEL SWITCHING SYSTEM

The high-speed channel switching system is the core component of the calibration equipment, and the key to the lossless transmission of multi-channel high-speed signal to the measuring instrument. Fig 10 shows the structure of high-speed switching system, which consists of power module, digital control module and high-speed signal path.

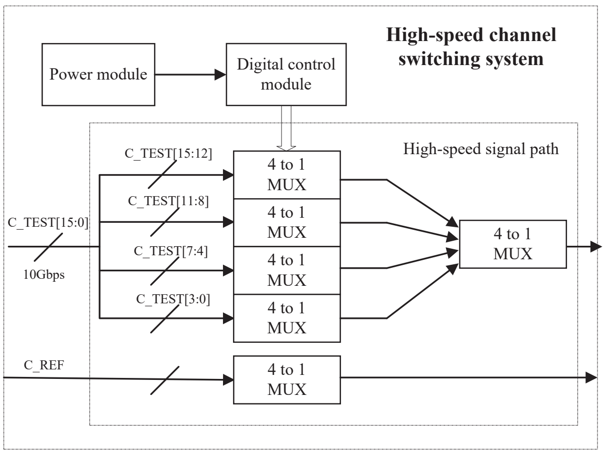

Fig.10. The structure of high-speed channel swtiching system

The digital control module is used to communicate with the controller and control the RF switchs.

The power module is used to provide the stable working voltage required by the digital control module and RF switchs.

The high-speed signal path is the core component of the channel switching system, which is composed of high-performance RF switch, high-performance RF cable and connector. The high-speed signal does not need to be routed through PCB, which can avoid the signal integrity problems such as additional crosstalk, insertion loss and return loss caused by the discontinuity of signal path impedance through PCB. The RF switch adopts keysight's L7204C high-speed switch with a bandwidth of 26.5GHz, and the bandwidth of RF cable and connector are both 26.5GHz. Considering the requirement of high-speed test, a simple topology connection is adopted to avoid the use of power divider with lossy signal. In order to ensure the signal stability and no distortion, the total length of RF cable in each signal path shall not exceed 1m.

V. THE DESIGN OF CALIBRATION SOFTWARE

The calibration software has many functions such as instrument control, signal processing, real-time control and display, data processing and storage[12~13]. Meanwhile, high-speed ATE need to be calibrated with the help of special test program, which is used to control ATE to send required high-speed signal.

The structure of calibration software is shown in Fig11. The calibration software adopted LabView as program language consists of instrument control, channel switching, communication, data processing, and error correction.

(1)The instrument control module performs automatic control of selected instruments to complete specific sunctions, including insturment self-calibration and configuration.

(2)The main function of channel switching module is high-speed switch control, which can automatically switch any one of the sixteen channels.

(3)The communication module is used for network connunication and data interacation between the calibtration equipment and ATE. Normally, the test program is in the TCP waiting state. If the connection is fail, the module will prompt the user to check the network configuration and connection.

(4)The main functions of data processing module are data analysis and processing, uncertainty calculation , repeatability and stability checking of the calibration equipment.

(5)The error correction moudle can compensate the error in the measuring loop. By means of the technique of error correction, the accuracy of calibration equipment has been improved.

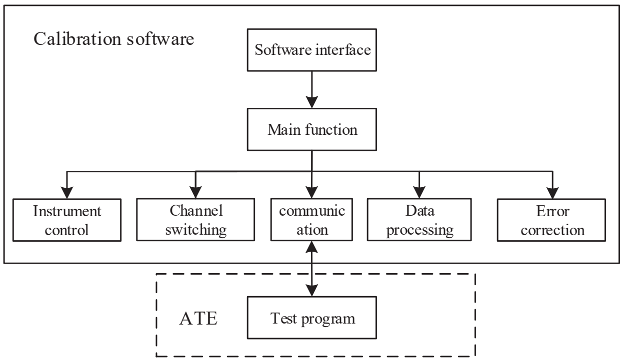

Fig.11. The flow chart of calibration software

The flow chart of calibration software is show in Fig 12. After the calibration equipment is started, it should be initialized first. If the self-test is abnormal, it will go in for fault troubleshooting and re-test after troubleshooting. The calibration software selects channels and items to be calibrated and configure the channel switching system. After the communication connection between the calibration equipment and ATE is established, the test program is issued to execute the corresponding subroutine. Then the calibration software controls the oscilloscope for measurement, synchronously processing the calibration data during the calibration process, and displaying the process and results in real time. The uncertainty analysis of calibration data is carried out after the whole calibration process is completed.

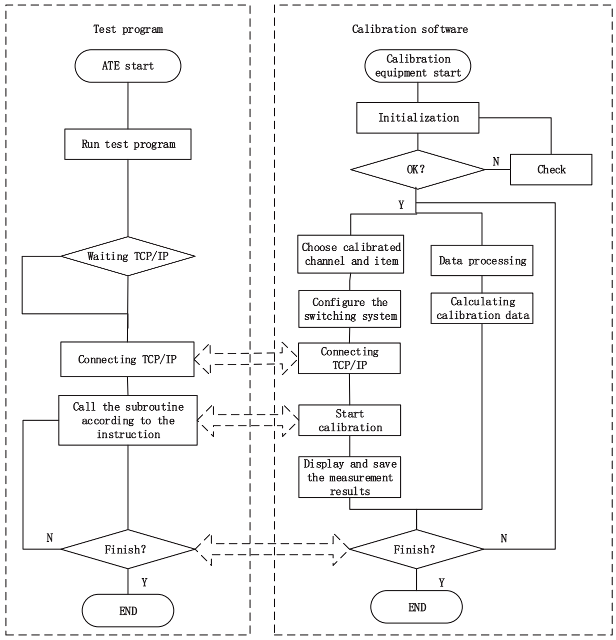

Fig.12. The flow chart of calibration software

VI. CONCLUSIONS

This paper provides a design method of high-speed ATE calibration equipment. By controlling the high-speed channel switching system to switch different channels in turn, and sending instructions to ATE to output required high-speed signals through the designated channel, and controlling the oscilloscope to measure the main dynamic parameters(eye height, eye width, rise time, time interval and jitter injection) on the designated channels at the same time, the calibration of high-speed ATE is realized. It breaks through the limitation of the traditional qualitative verification method, realizes the quantitative measurement of multi-channel dynamic parameters of high-speed ATE, and can accurately evaluate the high-speed dynamic performance of ATE. The high-speed ATE calibration equipment can be used to calibrate all kinds of high-speed ATE, which can greatly improve the calibration coverage of ATE.

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