The Design of ATE Calibration Equipment Based on Microelectric Reference Materials

Yong Hu, Qian Liu and Houping Zhou

ABSTRACT

Microelectronic Reference Materials (RMs) are a good way to achieve microelectronic traceability. To achieve full calibration of Automated Test Equipment (ATE), each test channel should be traced to calibration equipment of ATE based on RMs. This paper puts forward a design solution of calibration equipment of ATE based on RMs, which can realize the versatility and portability of calibration equipment, and realize automatic calibration progress.

INTRODUCTION

Microelectronic reference materials called as RMs for short, is a special circuit as a standard of dissemination, of which one or several parameters are certified. RMs has three notable characters. Firstly, it is for measurement. Secondly, it has the accurate certified values. Lastly, its value could be traced to the source[1~8].

RMs are widely used in parameter alignment and calibration of Automated Test Equipment (ATE), which has many benefits such as simplification on ATE calibration, easy to take, adaptive for on-site calibration. Recently, development and application of RMs has become one of the main direction of microelectronics measurement. However, the pins of RMs are limited, which can’t achieve full calibration of all channels of ATE. Therefore, in order to achieve the full calibration of ATE, it is necessary to design a calibration equipment of ATE based on RMs, which can disseminate the value of RMs to each channel of ATE.

Yong Hu, Qian Liu, Houping Zhou, Wuhan Digital Engineering Institute, Wuhan, China, 430074
This paper is organized as follows. In section 1 we describe the calibration principle of ATE with RMs. In section 2 we present the architecture design of calibration equipment. In section 3 we present the hardware composition of calibration equipment. In section 4 we draw conclusions.

THE CALIBRATION PRINCIPLE OF ATE WITH RM

ATE employs a number of stimulus and measurement instruments such as the Drivers, Comparators, Precision Measurement Unit (PMU), Device Power Supplies(DPS), AC subsection. Because of the complexity of ATE, which employs many instruments, and each instrument can have many ranges and modes, RMs used for ATE calibration should be a kind of integrated circuit (IC) with many programmable parameters, which can verify ATE and disseminate the value of quantity to ATE. Therefore, we choose the following parameters as the properties of RMs: Minimum Input high voltage (VIH), Maximal Input low voltage (VIL), Output high voltage (VOH), Output low voltage (VOL), Output high current (IOH), Output low current (IOL), Power Supply current (IDD), Propagation delay L to H (tPLH), Propagation delay H to L (tPHL). The calibration principle of ATE with these parameters of RMs are as follows[9].

The Calibration Principle of $V_{IL}/V_{IH}$

Figure 1 shows the calibration principle of $V_{IL}/V_{IH}$. To perform a $V_{IL}/V_{IH}$ calibration, the Driver is connected to the input pin under test, and the Comparator is connected to the output pin corresponding to the input pin. The voltage of the input is gradually increased from VSS. Meanwhile execute functional test pattern and monitor the output signal. When the output state is changed, the input voltage is $V_{ILX}$, which is the measurement value of ATE. Calculate the error of $V_{ILX}$ and $V_{ILS}$ (standard value of RMs) by equation(1).
\[ \Delta U = V_{ILX} - V_{ILS} \] (1)

The calibration principle of VIH is similar.

**The Calibration Principle of \( V_{OL}/V_{OH} \)**

Figure 2. The calibration principle of \( V_{OL}/V_{OH} \).

Figure 2 shows the calibration principle of \( V_{OL}/V_{OH} \). To perform a \( V_{OL} \) measurement, the device is preconditioned to set the output into the logic 0 state, the PMU is connected to the pin under test. The IOL current is forced and the resultant voltage \( V_{OLX} \) is measured. Calculate the error of \( V_{OLX} \) and \( V_{OLS} \) (standard value of RMs) by equation(2).

\[ \Delta U = V_{OLX} - V_{OLS} \] (2)

The calibration principle of \( V_{OH} \) is similar.

**The Calibration Principle of \( I_{OL}/I_{OH} \)**

Figure 3. The calibration principle of \( I_{OL}/I_{OH} \).
Figure 3 shows the calibration principle of IOL/IOH. To perform an IOL measurement, the device is preconditioned to set the output into the logic 0 state, the PMU is connected to the pin under test. The VOL voltage is forced and the resultant current IOL is measured. Calculate the error of IOLX and IOLS (standard value of RMs) by equation (3).

\[ \Delta I = I_{OXL} - I_{OLS} \]  

The calibration principle of IOH is similar.

**The Calibration Principle of I\textsubscript{DD}**

![Calibration board diagram](image)

Figure 4. The calibration principle of I\textsubscript{DD}.

Figure 4 shows the calibration principle of IDD. To perform a IDD measurement, the device is held in a static condition state and the amount of current IDDX flowing into the VDD pin is measured. Calculate the error of IDDX and IDDS (standard value of RMs) by equation (4).

\[ \Delta I = I_{DDX} - I_{DDS} \]  

**The Calibration Principle of t\textsubscript{PLH}/t\textsubscript{PHL}**

Figure 5 shows the calibration principle of tPLH/tPHL. The tPLHX measurement is made from an input signal to an output signal. This will fix the input signal and require a search on the output signal to find and measure their relative position. Calculate the error of tPLHX and tPLHS (standard value of RMs) by equation (5).

\[ \Delta t = t_{PLHX} - t_{PLHS} \]
The calibration principle of tPHL is similar.

![Figure 5. The calibration principle of tPLH/tPHL.](image)

**THE ARCHITECTURE DESIGN OF CALIBRATION EQUIPMENT**

Through the use of virtual instrument technology, the calibration equipment of ATE based on RMs consists of RMs, PXI instruments, calibration software and calibration board. Compared to conventional special calibration equipment, which can’t be used for calibrating different ATE due to the different hardware structure and programming language, the calibration equipment based on RMs has many benefits such as simplification and complete automatization on ATE calibration, easy to take, adaptive for on-site calibration.

**The Calibration Model of ATE Based on RMs**

![Figure 6. The structure of calibration equipment.](image)

Figure 6 shows the structure of calibration equipment based on RMs, which consists of RMs, PXI instruments, controller, special cables, calibration software and calibration board.
PXI instruments consist of SMU (Source Measure Unit), High Density Matrix Modules, RF Matrix Modules. SMU is used for supplying power to RMs. High Density Matrix Modules are used for the connection of RMs to ATE channels when DC parameters are calibrated. RF Matrix Modules are used for the connection of RMs to ATE channels when AC parameters are calibrated. All PXI instruments are interconnected to the controller via the bus, which establishes TCP/IP connection through the workstation of ATE to achieve the control signal synchronization and data transmission.

RMs are placed on the calibration board, which is placed on the test head of ATE during calibration of ATE. Matrix Modules are connected to the tested pins of RMs and digital channel interface via special cables. Through the switch of matrix RMs can be connected to each channel of ATE.

The working principle of calibration equipment is as follows. Through calibration board the connection is physically built between ATE and calibration equipment. Through the TCP/IP network protocol control signal and calibration data are successfully transmitted between ATE and calibration equipment. Finally, with the help of ATE program and calibration software, ATE can be fully calibrated after nine parameters of RMs (VIH, VIL, VOH, VOL, IOH, IOL, IDD, tPLH, tPHL) are tested.

**The Design of Calibration Software Based on Virtual Instrument**

Virtual instrument technology is the new advanced technology in the field of test and measurement. With virtual instrument technology, it is easy to control different instruments, achieve signal acquisition and data processing, complete real-time process control and display. Virtual instrument that can greatly improve the flexibility and dynamic reconfiguration of the instrument, not only can achieve the test and measurement functions of traditional instrument, but also has lower price and the same measurement accuracy. Therefore, virtual instrument will gradually become the mainstream of test and measurement technology[10~13].

Figure 7 shows the function of calibration software, which consists of instrument control, signal processing, real-time control and display, data processing and storage. Meanwhile, ATE needs to be calibrated with the help of special test program, which can control input and output signal to test RMs.
THE HARDWARE COMPOSITION OF CALIBRATION EQUIPMENT

Figure 8 shows the hardware composition of calibration equipment. The connection of hardwares are as follows, SMU supplies power to RMs, High Density Matrix Modules are connected to ATE channels and RMs with the interface of IDC50, RF Matrix Modules are connected to ATE channels and RMs with the interface of SMA.

Figure 9 shows the composition of calibration board, which totally has four kinds of interfaces, including test fixture of RMs, test interface of RMs, interface of dc parameter, interface of ac parameter. IDC10 interface is adopted as test interface of RMs, one end of which is connected to the RMs via calibration board, the other end of which is connected to X end of High Density Matrix Modules via special cables. IDC50 interface is adopted as interface of dc parameters, one end
of which is connected to test channels via calibration board, the other end of which is connected to Y end of High Density Matrix Modules via special cables. Every 32 test channels are connected to each IDC50 interface, numbers of which can fully connected to ATE. SMA interface is adopted as interface of ac parameters, which is connected to test channel and pins of RMs via RF cables.

![Calibration board](image)

Figure 9. The composition of calibration board.

The measurement loop between RMs and test channels of ATE will have a significant impact on the overall performance of calibration equipment. We will take the following approach to solve the problem. Firstly, the test channels are connected to IDC50 interface directly by all equal length lines. Secondly, in order to reduce the measurement error, we set the measurement interface to measure the loop resistance of any channel to RMs pins by calculating the compensation to the result. Finally, calibration board is guaranteed impedance matching of measurement loop. We measure the loop delays of any channel to RMs pins by calculating the compensation to the result.

**CONCLUSIONS**

ATE calibration with RMs is a new way, which have many benefits such as simplification on ATE calibration, easy to take, adaptive for on-site calibration. Based on the measurement characters of ATE, this paper proposes a calibration technique with microelectric reference materials, which adopts the virtual instruments technique and develops an universal calibration equipment consists of PXI instruments modules, universal calibration software, special program for given ATE, RMs, as well as the calibration board. The calibration equipment based on RMs can be used to fully calibrate all kinds of ATE, which can greatly improve the calibration coverage of ATE.
REFERENCES