Design of Software for Digital Multimeter Calibration Based on Labwindows/CVI

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Abstract. The digital multimeter is a common instrument in the metrology department calibration. In order to improve the efficiency of verification and calibration, the automatic calibration software is developed based on the Labwindows/CVI platform, by using the SCPI programming method under the VISA architecture, and by means of the instrument driver programming. It realizes the automatic calibration of different types of digital multimeters, and transforms the work done by the original manual operation instrument into the software control instrument automatically, which greatly improves the work efficiency.

1. Introduction
Digital multimeters are one of the most widely used instruments in electromagnetic meters, and they are also the most common type of instruments in electromagnetic metering. The mainstream digital watch manufacturers currently on the market include Fluke, Keysight (formerly known as Agilent), National Instruments, Keithley, Yokogawa, and Rigol, including traditional benchtop instruments and board-based instruments based on virtual instrument technology.

Some high-end digital meters are generally equipped with a programmable interface, including GPIB interface, RS232 interface, USB interface or LAN interface. The program-controlled interface provides a way for the PC to control and read and write the data of the meter, so that the test and measurement can be automatically performed according to the established process under the control of the computer.

With the continuous improvement of the level of electronic technology and manufacturing technology and the actual needs of scientific research and production, the performance of digital multimeters has been continuously improved, and the functions have become increasingly rich and perfect. There are more than a dozen main functions, but the calibration and calibration are generally only for the most basic five functions, including DC voltage measurement, AC voltage measurement, DC current measurement, AC current measurement and resistance measurement. Other functions are generally based on this. Extending, so no calibration or calibration is required, and the various multimeter calibration software is generally designed around these five functions.

At present, the verification and calibration of the digital multimeter is generally carried out by means of manual operation of the instrument or by Fluke's automated measurement management software MET/CAL-Plus. The manual operation of the instrument is flexible and convenient, but the efficiency is very low. In today's increasingly automated, this method is obviously not suitable for
social development; the calibration using MET/CAL-Plus also has the following drawbacks: (1) The software is expensive. The cost of purchasing a set of software is often higher than the cost of purchasing a standard set of instruments. (2) When the MET/CAL-Plus verification process is implemented, the programmer must learn the programming language of MET/CAL-Plus. (3) Due to commercial competition, in the hardware construction of the automatic verification system, hardware produced by certain companies must be used, and the hardware versatility is somewhat lacking. Therefore, it is necessary to design a digital multimeter calibration software based on Labwindows/CVI.

2. Hardware composition
When manually calibrating the digital multimeter, only one multi-function calibration source is required to complete all calibration items. After the automatic calibration, only one ordinary PC, one USB-GPIB adapter card, and two GPIB cables are needed. Can. Figure 1 shows the hardware connection when the digital multimeter is automatically calibrated.

![Figure 1. Hardware composition and connection diagram](image)

The computer is the core of the whole system. It is both a control center and a platform for human-computer interaction. It can replace the manual control of the instrument action, and can collect the test data and display it in real time. The calibrator no longer performs any operation on the instrument, and the simple operation of the computer mouse and keyboard can complete the cumbersome calibration work. The printer is used to print calibration reports. The multi-function calibration source is the standard source used by the calibration software to provide a standard signal for the calibration table.

Since the GPIB bus is not a standard interface of the PC, communication between the computer and the standard instrument can be realized by means of a GPIB expansion card. Considering that the most common interface on the computer is a USB interface, and the USB interface is very convenient to use, the system is Use the USB-GPIB riser card to resolve communication problems between the computer and the instrument.

The Agilent 82357B is a USB-GPIB riser card for Agilent (now renamed Keysight) that is designed for general PC and GPIB communication. It has the advantage of plug and play and can be used with USB 2.0 interface (compatible with USB 1.1). standard GPIB interface, the maximum transmission speed is up to 1.15MB/s [1].

The 82357B can be easily installed on a computer using the I/O program suite provided by Keysight, but it should be noted that if the installed I/O repository is a version of the Agilent IO Libraries Suite prior to 14.2 (including version 14.2), it will need to be separate. Install the driver. If
the installed I/O repository is Agilent IO Libraries Suite 14.2 or later, you do not need to install the driver. The USB-GPIB driver is already included in the I/O repository. After the driver is successfully installed, restart the machine and plug in the USB-GPIB card. Windows will recognize and install the hardware by itself. At this time, you can view the hardware in the device manager. After installation, the ordinary PC can access the GPIB system through the USB interface, and the 82357B supports hot plugging, which can be easily connected and disconnected without turning off the computer, which is very convenient to use.

3. **Software design**
   
   In the whole calibration system, the software is the core of the system, whether the system can work normally, complete the calibration task and automatically issue the report, it depends on whether the software can achieve the corresponding function [2].

3.1. **LabWindows/CVI and multi-threading technology**
   
   In the field of measurement and control, LabWindows/CVI and LabVIEW have been the two most active virtual instrument development platforms. Compared with LabVIEW, LabWindows/CVI has more flexible functions, higher efficiency and better stability. It is suitable for medium and large-scale measurement and control software. Development, mainly used in areas with high requirements for stability and reliability, such as the military industry [3] [4], so this paper selects LabWindows/CVI development software.

   LabWindows/CVI is a complete ANSI C programming environment with a simple and intuitive graphical user interface, using input function parameters on the function panel, and using event-driven and callback function programming techniques to make engineering design efficient and stable. It is object-oriented programming ideas, rich controls and buttons, and powerful libraries such as signal processing libraries, interface libraries, and the Windows SDK (Software Development Kit) make it ideal for instrument control, automatic detection, and data processing. It is widely used, in addition to it, it also adds a lot of toolkits. The SQL (Structured Query Language) Toolkit toolkit used in this article enables LabWindows/CVI to access and manipulate the database.

   Multi-threading technology is a technology that allows a computer to execute multiple tasks concurrently. Compared with single-threading, multi-threading is not as fast as single-thread processing. However, proper multi-threading in measurement and control software can not only improve software efficiency. It can also make the software more humane. Implementing multithreading in LabWindows/CVI is very simple. It provides an advanced mechanism for creating asynchronous timers and thread pools. Thread pools are generally used for cyclic execution tasks, while asynchronous timers are generally used for tasks that are executed periodically. In this article, the thread pool function CmtScheduleThreadPoolFunction () is used to implement multithreading.

3.2. **Instrument control**
   
   To achieve automatic calibration of the digital multimeter, the first problem to be solved in software design is the control of many instruments [5].

   Instrument control is based on VISA (Virtual Instrument Software Architecture). VISA is called virtual instrument software architecture. It is a software specification developed for the development of virtual instruments [6]. VISA is unified in the instrument I/O interface layer, making measurement and control the program is no longer written for a specific interface, and the measurement and control program written based on VISA can be applied to almost all interfaces. SCPI (Standard Commands for Programmable Instrumentation) is a specialized language for instrument control that tells the instrument which operation to perform in the form of a string. This programming method encapsulates the underlying operations associated with instrument operation, allowing programmers to program the instrument without having to know the instrument's hardware [7].
The appearance of SCPI is conducive to the unification and standardization of instrument control methods. The program written by SCPI statement has good versatility. Therefore, the control of the digital multimeter in the software is programmed by SCPI language, no matter which manufacturer produces it. A multimeter, as long as it supports SCPI command programming, it can be controlled by the same SCPI instruction.

The instrument driver is a library of functions that can be used directly to control the instrument and can be called directly in the CVI. The instrument driver encapsulates a wide range of underlying operations, including communication links (via VISA) and SCPI programming. The packaged advanced functions are used to control the function of a particular instrument or classes of instruments. The instrument driver is used to write the measurement and control program without paying attention to the cumbersome underlying programming protocol. It only needs to provide the appropriate interface parameters for the modified driver function. This programming method makes the instrument control become a general function call problem, which reduces the programmer. The burden. Instrument drivers generally support the same series of devices from the same manufacturer, which has a certain degree of versatility, but it does not allow interchange between instruments from different manufacturers. Compared with SCPI programming, the program versatility is much lower.

Since the calibration standard source is generally fixed to Fluke's 5xxxA series of multi-function calibration sources, there is no high versatility requirement, so the instrument driver is used to control the calibration source.

3.3. Calibration steps and key procedures

When the digital multimeter is calibrated, a standard signal is provided by the multi-function calibration source for measurement by the calibration table. The computer controls the multi-function calibration source through the GPIB bus to send a signal to the calibration table according to the software setting process, and the calibration table is in the computer. The measurement properties are configured under control to measure the standard signal. The measurement results are processed by the computer and the uncertainty is given. The calibration process is shown in Figure 2.

![Figure 2. Number table calibration flow chart](image)

The software adopts multi-thread design. During the measurement process, the main thread is mainly used for the operation of the software interface. A single thread is used for the calibration of the device, so that the operation of the main thread is not interrupted, and human-computer interaction can be performed well at any time. Information type and output display). Data storage and report
generation are long-lived. If you use multiple threads, there will be a long wait time, which will affect the operation of the interface. Therefore, it also opens up a separate thread, making the whole software run more smoothly.

The control of the calibration source is carried out by the manufacturer's VPP driver. These instrument drivers are written by professional programmers and have been rigorously tested and very reliable. Controlling the calibration source by calling the VPP driver function can reduce development difficulty and shorten development time.

The calibration of the multimeter is implemented by SCPI programming under the VISA architecture. Because the digital multimeter is equipped with many different types of instruments from different manufacturers, there is no suitable instrument driver to control all types of multimeters. In order to ensure the versatility of the program, SCPI program control instructions are used for programming.

Taking the calibration of the 6V point of the DC voltage 10V range as an example, the relevant code for implementing the automatic calibration is as follows.

Connect and initialize each instrument:

```
ViSession defRM;  // Resource manager handle
ViSession MCHandle;  // Multi-function calibration source handle
ViSession DmmHandle;  // Digital multimeter handle
ViOpenDefaultRM (defRM);  // Open the resource manager
Err=fl5xmcal_init(device.address, VI_TRUE, VI_TRUE, & MCHandle) // Initialize the calibration source
Err=viOpen (defRM, InstrDesc, VI_TRUE, VI_TRUE, iv);  // Initial number table
```

Configure the instrument for automatic calibration:

```
Err=fl5xmcal_setOutputValues(MCHandle, FL5XMCAL_VOLT, 6, 0, 0);  // Configure the calibration source output 6V
Delay (1);  // delay 1 second
Err=viPrintf(DmmHandle, "MEASurement:%s?\n", val[i]);  // Configure the measured digital multimeter to measure
```

Close all resources:
```
viClose (MCHandle);
viClose (DmmHandle);
viClose (defRM);
```

4. Calibration test

Figure 3.

Figure 3 shows the physical connection diagram for calibrating the digital multimeter Agilent 34401A using the Fluke 5500A multifunction calibration source. After the verification test, the software operation is smooth, the functions are normal, and no errors occur after running for a long time. The test data is saved and viewed smoothly, and the report is automatically generated to achieve the
expected goal. Compared to manual manual calibration, the calibration results are equally accurate and more efficient.

5. Conclusion
Based on the automatic test technology, this paper designs a set of digital multimeter automatic calibration software based on LabWindows/CVI, which can realize the calibration of different types of digital multimeters, and transform the work done by the original manual operation instrument into software control instrument automatically. get on. Compared with the traditional manual manual calibration, the calibration efficiency is greatly improved, the human resources are saved, and the utility model has good practical significance and application value.

6. References
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