CONTROLLING THE LABORATORY USING LABVIEW™

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1. Abstract

The efficient design of computer control software for measurement systems is a common problem in many laboratories. Requirements vary from fully automated customer calibration systems to one-off type measurements. Usually the measurement systems are composed of a range of instruments with different types of computer interfaces, some standard, some not. When requirements change even slightly, much code has to be rewritten which, under a quality system, can be a tedious process that is costly and time consuming. In this paper we discuss the development of a universal measurement program that is capable of controlling all the experiments in our laboratory. The program is based on the National Instruments graphical programming language LabVIEW™.

2. Introduction

The development of software under a quality system is a costly and time consuming process, in particular for calibration systems where in most cases, software at NPL is developed to an integrity level of 3 out of 4. Quite often more time is spent developing the software and writing the manuals and specifications than is spend developing the measurement system itself. The idea of a universal measurement program is not new and an earlier version has been written in Turbo Pascal. However, this software was developed more than 10 years ago before the advent of Windows and is becoming increasingly incompatible with current systems. In particular, it does not make the best use of Ethernet capabilities and modern graphical user interfaces. Also, as the people who have developed the original code move on to other jobs, the software becomes more difficult to maintain.

Integrating the Ethernet in a measurement program has several advantages. The control of the measurement system can be spread over more computers allowing for more complex systems and processes running in parallel. For example time critical operations can be separated and run under a real time system. Obviously, the Ethernet allows remote control of the measurement system which can be a useful tool for monitoring continuous processes or for performing diagnostics on customer systems all over the world.

An added benefit of a single measurement program is a universal user interface which reduces the amount of training to be given to operators and minimizes the risk of operator errors. In addition, a universal data format is obtained which allows for recycling of analysis software and database software across many different measurement systems.

3. Program design

The central part of the program is an interpreter that can take commands either from the keyboard or mouse or from a predefined list of instructions in a plain ASCII file, thus allowing automated control. Simple control structures such as, *loop for* and *procedures*, are included. The measurement configuration, that is, which instruments comprise the measurement system, is also listed in a separate ASCII file. Changing the measurement or configuration of instruments in the measurement system only involves making changes to the ASCII files. The two ASCII files are automatically recorded with the data file, ensuring traceability of the results and allowing exactly the same experiment to be performed at a later stage by re-running the instruction file.

The instrument commands are listed in the instrument command files, one for each type of instrument. Each instrument is characterised by its own specific set of instructions, for some complex instruments this list can be very large. However, all the possible functions of a particular instrument are rarely used and only the most frequently used ones need to be included in the instrument command file with further commands added as required. This command file is also used by the interpreter to generate a menu bar on the user screen. Each instrument in the configuration file appears as a separate item on the menu bar with all its commands available as sub menus. The menus are also used by the interpreter to store the values or status of the instruments and are updated when an instruction file is running. Menus are updated after successful completion of a command. This has the benefit that the complete status of the measurement system is known and always up to date.

The principle of the interpreter is that any instrument can be accommodated without changing the code. However, there is a problem with user-specific instruments, such as those with the NPL optical ring interface, which do not use one of the industry standard bus systems. To tackle this problem, user-specific instruments are controlled via separate server programs. The interpreter communicates with these server programs via LabVIEW datasocket technology [1]. The server constantly listens on the network for commands. On receiving a command it performs the task and sends a reply back to the interpreter. In this way the user-specific instrument is made to behave in exactly the same way as stanadard instruments with the ethernet as communication medium. The server program can run on any machine connected to the network or on the local machine running the interpreter or on a real time single board computer if speed or timing are an issue.

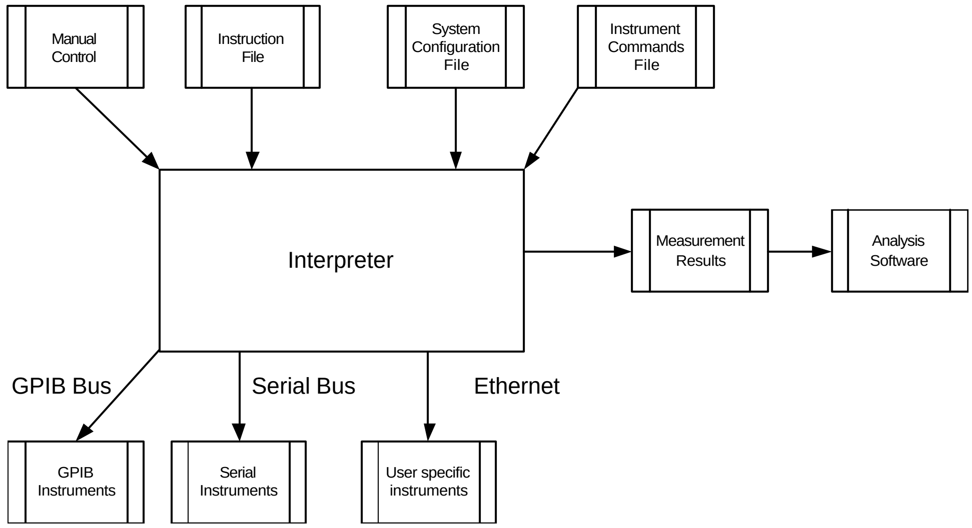

Figure 1: Block diagram of general measurement system

The interpreter controls the acquisition of data from the instruments. All the data is in the form of ASCII characters and saved as ASCII characters. No conversions are performed by the interpreter as these can lead to rounding errors. The analysis of the data is handled by separate measurement system specific software.

4. Example measurement system: Josephson Voltage Calibration

In this section the application of this measurement software to a real measurement system in a laboratory is discussed. The calibration of voltage standards at NPL is a routine task with many standards measured each year. Each voltage standard is measured a minimum of 8 times against the primary voltage standard which is a Josephson junction array [2]. An individual measurement consists of approximately 10 forward and reverse voltage measurements. Many thousands of individual voltage readings are therefore taken in the course of a year so this system is therefore ideally suited to a high level of automation.

Figure 2 shows a schematic diagram of the measurement system. The control is divided over three computers. One PC is used for running the interpreter program and the control of the NPL designed Josephson bias source. The second PC is used for controlling the reversing switches and scanners and the measurument of the voltage standards temperatures. Finally, the third PC is located in the office and is used by the operator to monitor the measurements in progress and for the analysis of the measurment results. Data is stored by the interpreter on the site server system which is maintained and backed up by the IT department. The same measurement system can also be used for calibration of digital voltmeters or for development work by simply loading a different configuration and instruction file.

The tuning procedure for the Josephson array to different voltage levels is programmed into the instruction file. When standards are to be measured the operator only has to load the instruction file and start the measurements which can then be left to run. Preferably this is done overnight when ambient noise levels are lower.

The flexibility of the interpreter allows changes to the measurement system to be made and the systematic behaviour of the system and measurement uncertainties over a large number of measurements to be investigated in a short space of time. The high level of automation and the direct measurement of the voltage standards against the Josephson array has lead to a reduction in the uncertainty budgets as can be seen from Table 1.

Voltage standard	Old system (ppm)	New system (ppm)
1.018V Weston cell	0.21	0.08
1V/1.018V electronic standards	0.21	0.14
10V electronic standards	0.08	0.02

Table 1 Combined uncertainties for the Josephson measurement system

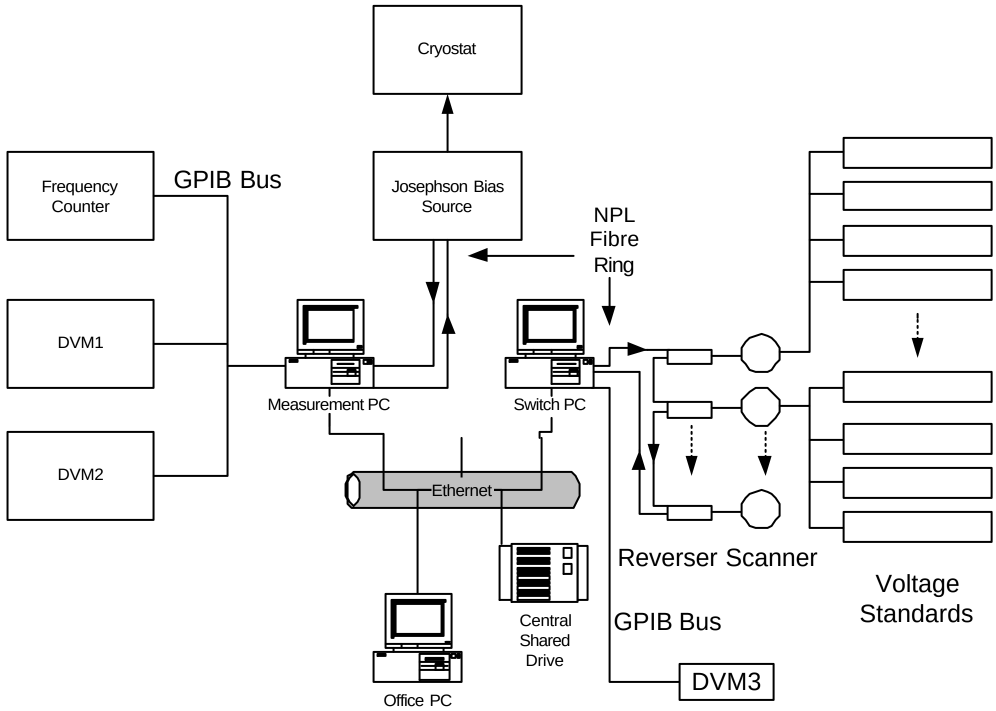

Figure 2 Block diagram of Josephson measurement system

Conclusion

A measurement program has been developed which is capable of controlling many experiments in our laboratory. Amongst others than the one highlighted above are the the quantum Hall system described in [3] and development work on SETSAW devices described in [4] in this conference. In our case the use of this software has significantly reduced the number of programs to be maintained in the laboratory and reduced the software development time. In particular when using this software for development work, much time can be saved writing software for a constantly changing measurement system.

Reference

1 National Instruments™ LabVIEW™ user manual, chapter 17.

2 L. C. A. Henderson, R. G. Jones, “The NPL Josephson junction array system and its use for voltage ratio measurements”, Meas. Sci. Technol. **1** No 10 (October 1990) 993-999.

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