Educator's Corner

A Flexible Virtual Instrument for Hall Effect Measurements

Doru Ursutiu, Cornel Samoila – "Transilvania" University of Brasov
Doru Popescu – Agilent Technologies

Application Note

Abstract

This paper introduces a new and flexible Virtual Instrument (VI) developed using the remote access capabilities of off-the-shelf test and measurement instruments used to take fixed magnetic field Hall Effect measurements. Transylvania University of Brasov (UTBv) has developed a flexible instrumentation system with the ability to measure for the new materials electrical and magnetic (Hall parameters) properties. This application was created using a new class of Agilent modular instruments accessed remotely. Key advantages include flexibility and remote access.

This implementation greatly benefits university research laboratories which are in need of flexible test systems that can be configured easily, in accordance to their specific testing needs. The Hall Measurement System can be remotely controlled using MIT's iLab Shared Architecture, for example, providing a uniquely modern, web-controlled educational instrument. This is a valuable tool especially for university physical engineering programs. This paper will briefly summarize the objectives of the electric and magnetic measurements and discuss the hardware and software configurations used to set up a robust and flexible remote engineering test environment.

Agilent Technologies

Introduction

In the last 15 years, the Center for Valorization and Transfer of Competences (CVTC) has continuously promoted new measurement technologies and software in middle region of Romania.

In our experience in training of engineers we noticed that, in any situation, there is a necessary interface between the academic world and the industrial world. There are a lot of problems which we didn't touch during training (due to limited time, due to the conservative character of training system, etc.) but are needed in engineering careers, or other problems which appeared when companies wanted to improve their technical capacity and needed lifelong learning for employees.

CVTC was developed and a strong team of specialists joined. In recent years this team was involved in a high number of National and International projects (TEMPUS, Socrates, Minerva, NATO, World Bank, Comenius, CNCS, MATNANTEC, etc.) and presented papers in well known conferences and publications mainly based on new DAQ systems and especially those controlled by sophisticated LabVIEW and VEE-Pro applications.

In the last couple of years we founded one new CVTC Laboratory the "Radu Grigorovici" Thin Films and Nanosystems Laboratory, much like part of the Creativity Center. Our goal was to try to implement all the new devices, sensors, systems and concepts in order to be able to develop new and valuable remote laboratory technologies based on the real physical instruments (devices) and also to implement creatively new virtual instruments and create flexible Remote Engineering (RE) technologies.

Generally speaking, the school doesn't teach creativity as main preoccupation. For a long time, creativity was considered a natural gift, which one has or not. Serious studies regarding creativity have contradicted this opinion, but not entirely. The main reason of this ambiguity was the impossibility to measure the human creativity. It can be estimated based on its effects and results, but it cannot be anticipated and determined.

There have been several attempts to stimulate creativity in schools. There is discussion regarding that research which is referred to as divergent thinking, in comparison with convergent thinking. The latter dominating quite exclusively the teaching/learning systems. But exaggerated cultivation of the convergent thinking which conducts to unique answers, used for hundreds of years in schools, didn't succeed to "kill" human creativity, the evidence being the permanent progress in knowledge and in inventiveness of the mankind.

The new teaching/learning technology called "remote laboratory and virtual instrumentation" is, from the pedagogical point of view, a part of the classic teaching system. It means that convergent thinking is dominating the concept of laboratory works. It means that all of the student's efforts are concentrated towards a unique answer, the only one existing and to which is arriving by using the gradual elimination of all of the other answers. Many times the convergent thinking is confounded with the human intelligence.

For which reason, do we consider that "remote laboratory" well sustained by "virtual Instrumentation" will encourage the creativity? This is due to the fact that the remote teaching system contains a group of creativity factors such as fluency, flexibility and originality which belong to divergent thinking. Divergent thinking provides the production, from an information group, not of a unique answer but of many solutions (many outputs) which will provide the appearance of some original answers and solutions.

In this paper we introduce a new and flexible Multifunction Virtual Instrument based on Agilent Technologies' Modular USB technology and developed using LabVIEW Graphical Programming (from National Instruments) and/or VEE-Pro (from Agilent Technologies). This system (Figure 1) was integrated using i-Lab MIT technology and can be remotely controlled (Figure 2).

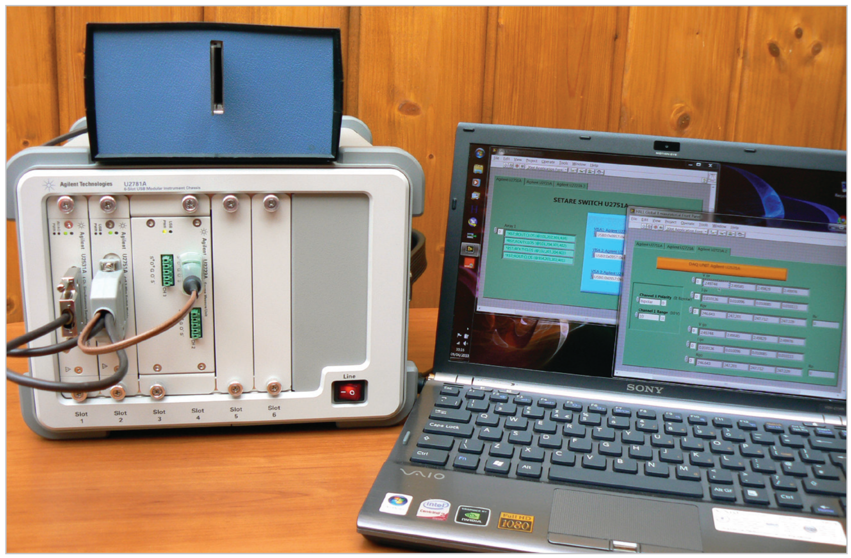

Figure 1. Hall Effects Measurement System

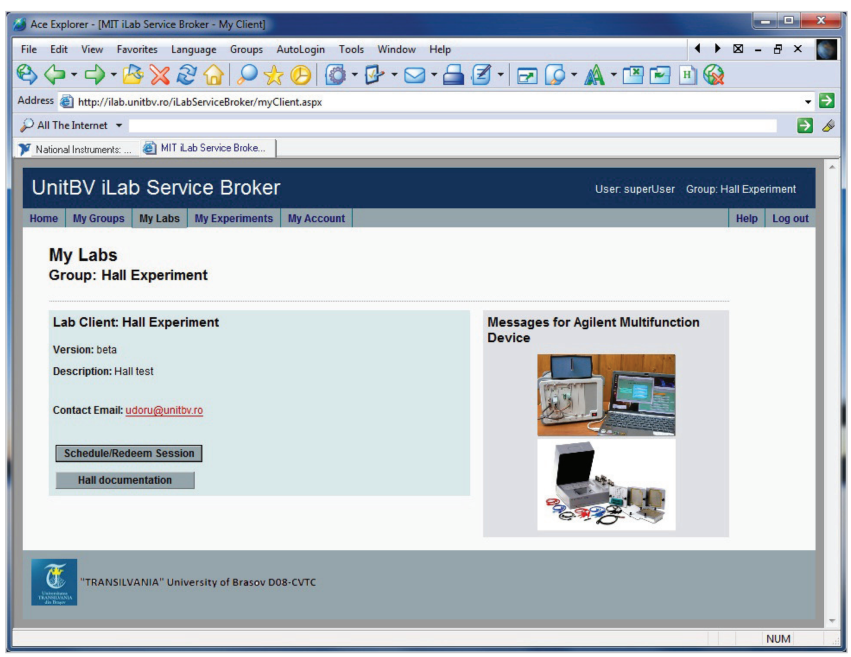

Figure 2. iLab Hall Experiment Interface

System Development

Many engineers, researchers, and educators are continually looking for testing instruments that offer flexible configurations, a quick setup, and affordability. The ability to operate these instruments as space-saving solutions will be another huge benefit to all users alike.

The general idea was to develop a flexible system which offers to the teachers and generally speaking to the university and research labs (like "Radu Grigorovici" laboratory) one easy to use and reconfigurable system. For the development of such a system we selected the Agilent U2781A USB Modular Products Chassis with the following Agilent modules: U2531 A four channels simultaneous sampling DAQ (or U2353A 16Ch. Multifunction DAQ), U2751A 4x8 2-wire Switch Matrix and a U2723A Source Measure Unit. The U2781A rack offers the advantage for the user to accommodate and control six USB modular instruments using only one PC USB communication port.

For this system we developed in the "Transilvania" University Creativity Laboratory some special heads and sample holding systems:

- HALL measurement head (with 1.8 T fixed magnetic field)
- Special sample holder with field measurement sensor (we used the Analog Devices AD22151 HALL sensor)
- Sample holders (HALL samples, four probe conductivity, heating system, etc.)
- Helmholtz coils (for low and variable magnetic field measurements)
- Adapters and sample holders for the Agilent U2941A parametric test fixture (designed for semiconductor device testing)
  The preliminary test of this system was done with:

- LabVIEW 2010 using the National Instruments developed drivers for the Agilent Technologies Modular instruments (like rapid and flexible tools for LabVIEW users)
- Agilent Measurement Manager AMM 2.0 which offer the possibility to quickly and easily test the systems and control the modular devices selected for the six slot U2781A Agilent rack
- VEE-Pro 9.2 easily developed applications using Instrument Manager and IVI drivers

The Van der Pauw Method [1] is a commonly used technique to measure the sheet resistance of a material but it is often used to measure the Hall Effect [2], which characterizes a sample of a semiconductor material and can be successfully completed with a current source, voltmeter, and a magnet.

The Fixed Magnetic Field HALL experiment setup is shown in Figure 1, with the HALL measurement head and the LabVIEW Virtual Instrument that controls the U2715A Matrix switch and, based on the selected instruments, can measure HALL parameters using the Van der Pauw Method. With the special sample holder we can control sample temperature and measure the temperature variations in HALL parameters.

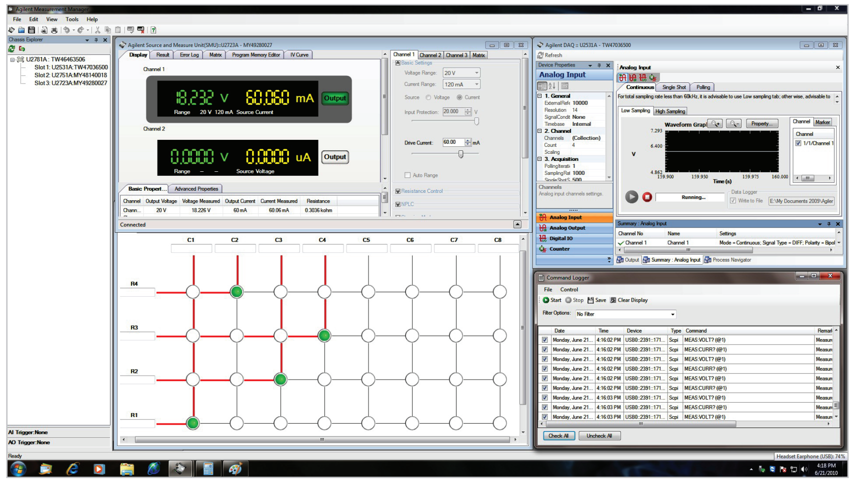

Figure 3. Command Logger

Agilent Measurement Manager AMM 2.0 can be used to do preliminary testing or to easy control the systems. For students and researchers, our selection of software (LabVIEW, AMM, VEE-Pro etc.) offers a deep flexibility to change the system structure and measure different parameters. In some cases, like the case of Agilent AMM software, they can conduct important measurements without the necessity to do special software development [3]. AMM software offers a special facility: the researcher can start the “Command Logger” (see Figure 3) and without special VEE-Pro programming knowledge, can to easy convert his or her AMM test in a real VEE-Pro application.

For small and variable magnetic fields we developed two Helmholtz coils (see Figure 4). These coils can be controlled using the second channel of the U2723A Source Measure Unit (the first channel was used in the HALL measurements; but the matrix switch offers the flexibility to use it in other measurements as well) and the resulting magnetic field was captured (see Figure 5) [4].

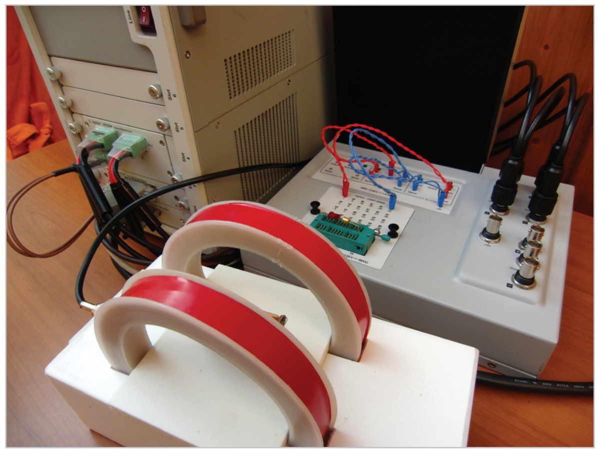

Figure 4. Head with Helmholtz coils

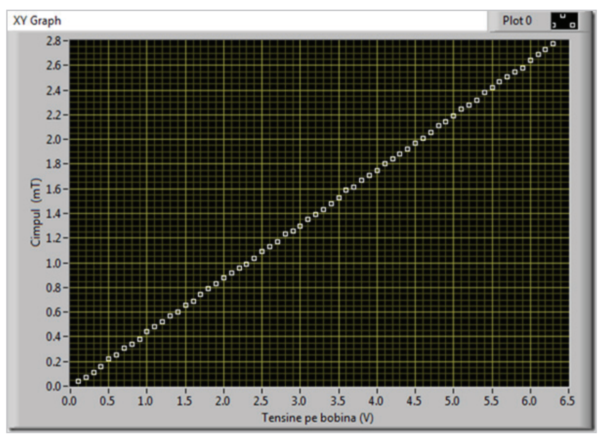

Figure 5. Helmoltz field

Adding to our system, the Agilent U2941A parametric test fixture was designed to complement the usage of the source measure unit in the testing of semiconductor components including SMT and DIP ICs. This unit came bundled with the Agilent Parametric Measurement Manager (PMM) software, which helps the user to kick start tasks sooner with these features: out-of-box configuration of instruments for easy set-up, user friendly graphical user interface, IV curve plotting with various graph tools (including auto-scale, zoom and markers), save data in text and JPEG formats, and print graph functions.

Light-emitting diodes (LED's) are gaining significance in many important applications such as automotive, street lights, and general lighting thanks to their energy saving, long operative life, and ease of integration. Improvements in LED structure and the use of new materials in recent years have permitted new developments in terms of device efficiency and color availability. One of the LEDs' most important advantages is the longer life with respect to other light sources such as incandescent bulbs. But this characteristic depends on many manufacturing factors, for instance, thermal resistance between chip and air, plastic encapsulation, semiconductor defects, etc.

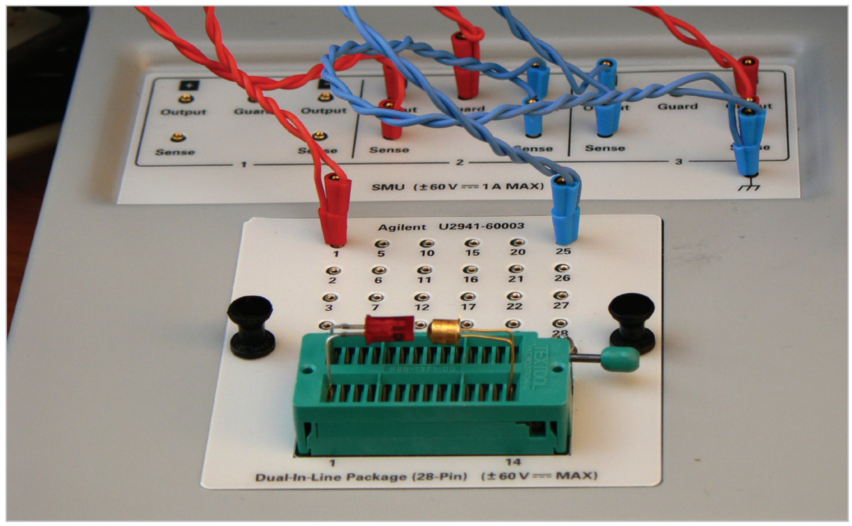

Figure 6. Measurement hardware setup

As shown in Figure 6, we developed the necessary hardware and software components and we proved the possibility to use this flexible system in reliability measurements of LEDs. For these measurements we stress the LED devices with "high power pulses" and we measure the degradation of the LED noise and optical induced noise (in normal polarization of the tested LED). The LED initial noise and the increase of noise (electrical and optical noise) after applying a high number of stress pulses, was proved to be related to the reliability of semiconductor devices and is one of the recognized "reliability indicators".

A wide range of experiments were developed at the CVTC Center including different conductivity measurements, Hall measurements, magnetic parameters, sensor characterization, current-tension characteristics, variation of the different parameters with temperature, noise and reliability, optical properties. These test systems were based on Agilent USB Modular Instruments which offer a good measurement platform, especially in nano-materials and device characterization. At the same time, this measurement platform can be remotely controlled using MIT's iLab Shared Architecture and is providing a uniquely modern, Web-controlled collaborative platform in research and education.

The iLab Shared Architecture is a software architecture that offers Online Laboratory developers and users a common framework to use and share Online Laboratories [5]. Overall, this architecture divides an online laboratory into three distinct parts: the Lab Client, the Service Broker and the Lab Server. The Lab Client is the user's interface to the iLab while the Lab Server connects to the laboratory hardware and manages the execution of user submitted experiments. MIT's iLabs Shared Architecture (ISA) specifies that Lab clients and Lab Servers contain lab specific functionality. The Service Broker is responsible for providing functionality that is generic and useful to all iLabs applications. The ISA provides a framework for the deployment of iLabs in a distributed fashion using web services. This allows online laboratories developed on the ISA to be made available to users worldwide using standard network protocols [6]. The first implementation of the iLab Shared Architecture at Transylvania University of Brasov was made in August 2010 in an interactive laboratory developed in cooperation between "Transilvania" University of Brasov from Romania and Carinthia University of Applied Sciences from Austria. It is presented as an attempt to enable students to perform multiple distinct experiments remotely and in real time.

Conclusions

The setup presented in this paper can be used in both laboratory work and for developing research areas to measure thin layers and nano-system's electrical and magnetic properties. The system was tested with different samples and the measurement result was found to be in good agreement with scientific publications.

It is proven that this modular system can be easily developed in university and research laboratories and can be adapted to the different needs of measurements using virtual instruments. This measurement system can be reconfigured for other applications using LabVIEW Virtual Instrumentation and/or VEE-Pro applications with the selection of Agilent USB Modular Instruments presented here or by adding other components to the system. This family of USB-based modular instruments offers the flexibility to arrange and rearrange configurations to fit changing measurement needs – efficiently and affordably. In addition, the concept of virtual instrumentation and remote control are powerful methodologies for use in an engineering education environment.

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