Pertanika J. Sci. & Technol. 22 (1): 105 - 112 (2014)

SCIENCE & TECHNOLOGY

Journal homepage: http://www.pertanika.upm.edu.my/

Development of Internet-Based Instrumentation for the Study of Hall Effect

Ariffin Abas[1]*, Abdul Halim Shaari[1,2], Zainal Abidin Talib[1] and Zaidan Abdul Wahab[1]

[1]*Department of Physics, Faculty of Science, Universiti Putra Malysia, 43400 Serdang, Selangor, Malaysia*
[2]*Institute of Mathematical Research (INSPEM), Universiti Putra Malysia, 43400 Serdang, Selangor, Malaysia*

ABSTRACT

The computer, together with Lab View software, can be used as an automatic data acquisition system. This project deals with the development of a computer interfacing technique for the study of Hall Effect and converting the existing automation system into a Web-based automation system. The drive board RS 217-3611 with PCI 6025E card and stepper motor RS191-8340 with a resolution of 0.1mm, was used to move a pair of permanent magnets backward and forward against the sample. The General Interface Bus (GPIB) card interfaces, together with digital nano voltmeter and Tesla meter using serial port RS232 interface, are used for measuring the potential difference and magnetic field strength respectively. Hall Effect measurement on copper (Cu) and tantalum (Ta) showed negative and positive sign Hall coefficient. Therefore, the system has electron and hole charge carriers respectively at room temperature. The parameters such as drift velocity, conductivity, mobility, Hall Coefficient and charge carrier concentration were also automatically displayed on the front panel of Lab View programming and compared with standard value. The Web-based automation system can be remotely controlled and monitored by users in remote locations using only their web browsers. In addition, video conferencing through Net Meeting has been used to provide audio and video feedback to the client.

Keywords: Interface, Hall Effect, Web-based automation system

INTRODUCTION

The Hall effect V_H is observed when a magnetic field (B) is applied at right angles to a sample of material carrying an electric current (I). Hall Effect (or Hall voltage) that appears across the sample is due to an electric

Article history:
Received: 1 July 2011
Accepted: 1 December 2012

E-mail addresses:
ariffa70@yahoo.com (Ariffin Abas),
ahalim@upm.edu.my (Abdul Halim Shaari),
zainalat@upm.edu.my (Zainal Abidin Talib),
zaidan@upm.edu.my (Zaidan Abdul Wahab)
*Corresponding Author

ISSN: 0128-7680

field which is at right angles to both the current and the applied magnetic field (Edward, 2006). Hall voltage can then be expressed as:

$$V_H = \frac{BI}{nqd} = \frac{R_H BI}{d} \tag{1}$$

where d= thickness of the sample, q= charge and n = charge carrier density

The quantity $R_H = \frac{1}{nq}$ is called Hall Coefficient (2)

The Hall voltage is directly related to the magnetic field and the drift current, and it is inversely related to the thickness of the sample. The samples used for the measurement are in the form of thin strips. A plot of Hall voltage (V_H) as a function of magnetic field (B) at constant current will have a slope given by the following equation:

$$Slope = \frac{IR_H}{d} \tag{3}$$

From equation (3), the slope of dependency V_H vs. B is defined, in particular, by the Hall coefficient R_H. This R_H carries information about majority electron or holes concentration. The conductivity σ is given as:

$$\sigma = \frac{IL}{VA} \tag{4}$$

where, L= Length and A= Cross sectional of the sample.

The mobility μ, is given as:

$$\mu = \sigma R_H \tag{5}$$

and also the drift velocity v_x of the sample is given as:

$$v_x = \frac{I}{nqA} \tag{6}$$

INSTRUMENTATION AND SOFTWARE

The Hirst Tesla meter model GM08 was used to calibrate the magnetic field and connected to a personal computer (PC) via Serial Port (Kai Qian, 2009). A current supply of 1.0A through the sample was provided by Keithley current source model 224. Keithley nano voltmeter model 2182 was connected to a PC via General Purpose interface Bus (Sumathi, 2007) to measure the Hall Effect potential. The drive board RS217-3611 (RS Component, 2001) with PCI 6025E (Basil, 2011) card through opto isolator circuit and stepper motor (Takashi, 1985; Kalman, 1995) with a resolution of 0.1mm were used to move a pair of permanent magnets, Neodymium-Iron-

Boron (Nd-Fe-B), backward and forward against the sample. The opto isolator circuit is used to amplify 5 volt to 12 volt from DAQ Card PCI 6025E to make the stepper motor work and also served as a protection circuit for any excess current, which could backflow into the PC in any case of short circuit or current spikes. The Web designs are based on the client-server concept. The term client-server refers to a relationship between two systems or processes. The client-server is a computer architecture that divides functions into client (requestor) and server (provider) subsystems, with standard communication methods such as Transmission Control Protocol (TCP) or Internet Protocol (IP) to facilitate the sharing of information between them (Carl, 1994). A web camera also connected to a server computer running NetMeeting enables the provision of audio and video feedback to the client, on the happenings during Hall Effect experiment, as shown in Fig.1.

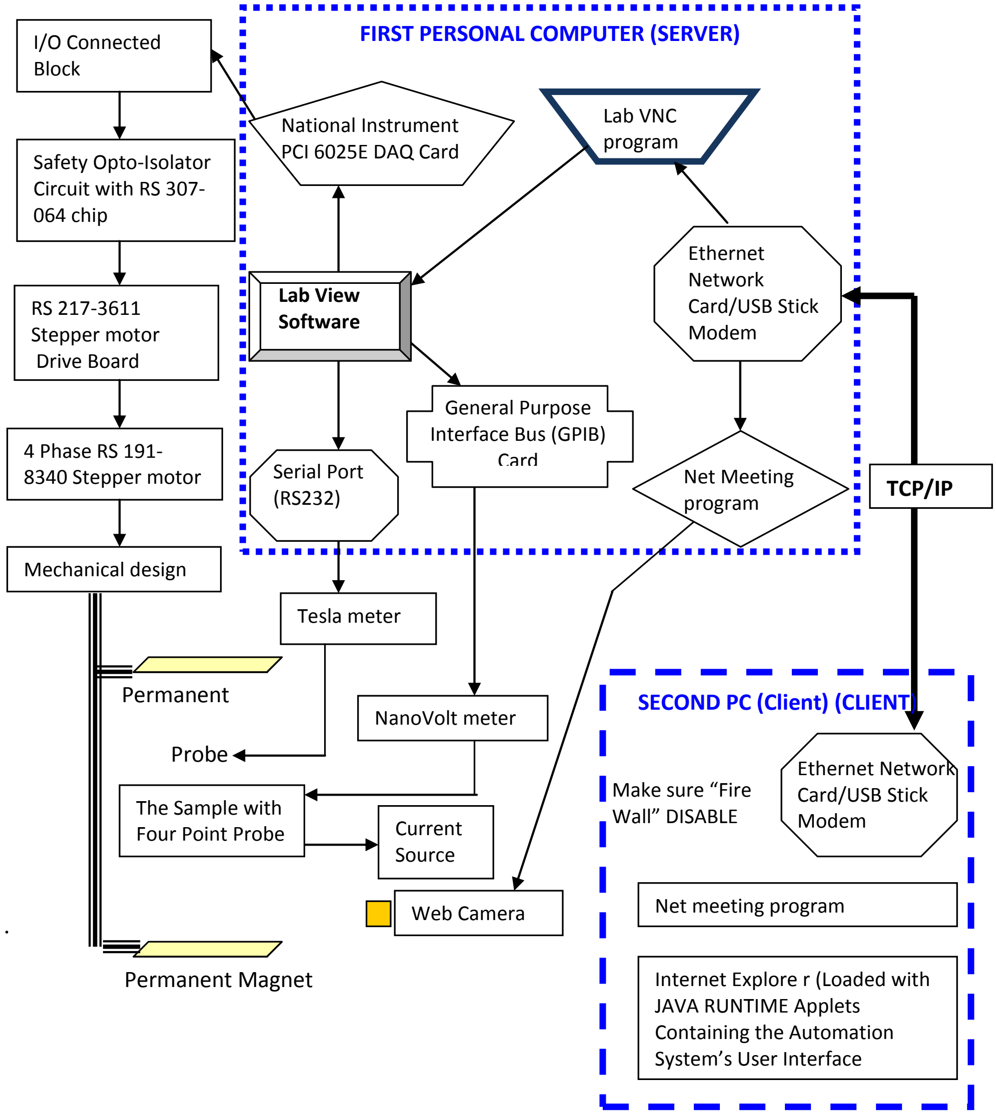

Fig.1: A Full Schematic Illustration of Web-based Automation system

Lab VNC or Lab View Virtual Network Control, a powerful third party freeware, is installed in the server computer and then configured to be a Lab View server (Travis, 2000). The server's Lab VNC will then load the user interface in the form of Java Applets into the client's web browser software such as Internet Explorer. These Lab VNC programmes run simultaneously with the automation system and enables client to control and monitor the automation system through the Internet. To achieve web-based control, the user at the server PC must NOT configure the user interface, but instead allow the user at the remote client PC to figure the user interface. Operating the automation system through web-based control involves configuring both the server and client PC as shown the flowchart in Fig.2.

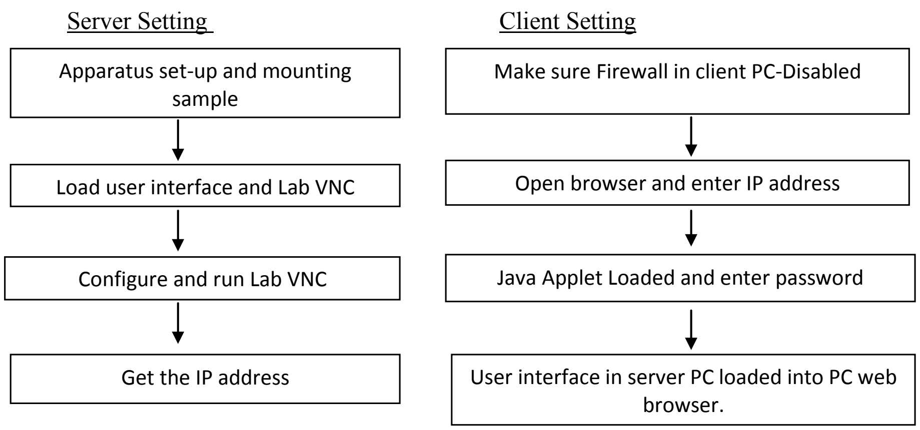

Fig.2: Flowchart Web-based control of the automation system

The sample with four point probes set up is shown in Fig.3, where two wires are connected to a current source 1.0A and the other wires are connected to a nano voltmeter. In order to have good electrical contacts, the sample surface was thoroughly cleaned, using alcohol.

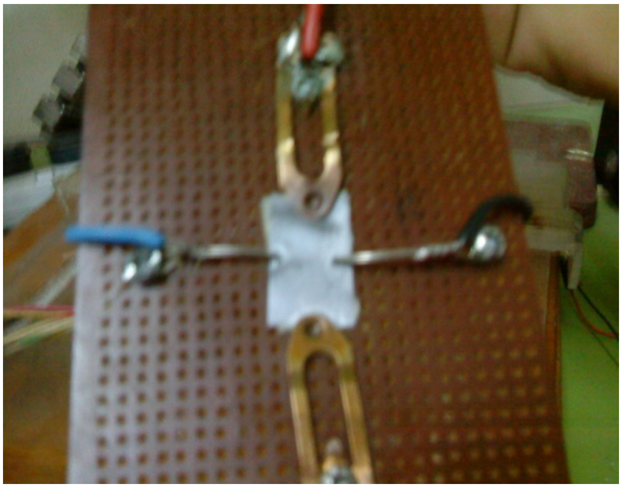

Fig.3: Sample holder with four point probes for metal sample

All the apparatus were controlled by LABVIEW programming (Wells & Travis, 1997) to acquire the data. The user interface of the LABVIEW programming containing Java Applet through Internet web is shown in Fig.4. The user interface is divided into three parts as follows:

a. The pre-setup system consisting of four features are: Test selection menu for the user to select either to choose Hall Effect experiment or to move stepper motor; Offset voltage (Brandley, 2007) for the user to provide initial voltage so that the LABVIEW programming will automatically fix this voltage as offset voltage; Dimension of the sample for providing the length, thickness and width of the sample; File selection tool that permits a user to store the acquired data.

b. The monitoring systems are a motor indicator and web camera, each one to indicate the distance between two permanent magnets and provide video and audio feedback to the client, respectively.

The data acquisition consists of parameters of the experiment that display specific values: the drift velocity, conductivity, mobility, Hall coefficient and charge carrier concentration; magnetic field and voltage reading that display the magnetic field strength and Hall voltage reading respectively; graph to display the Hall voltage as a function of the magnetic field.

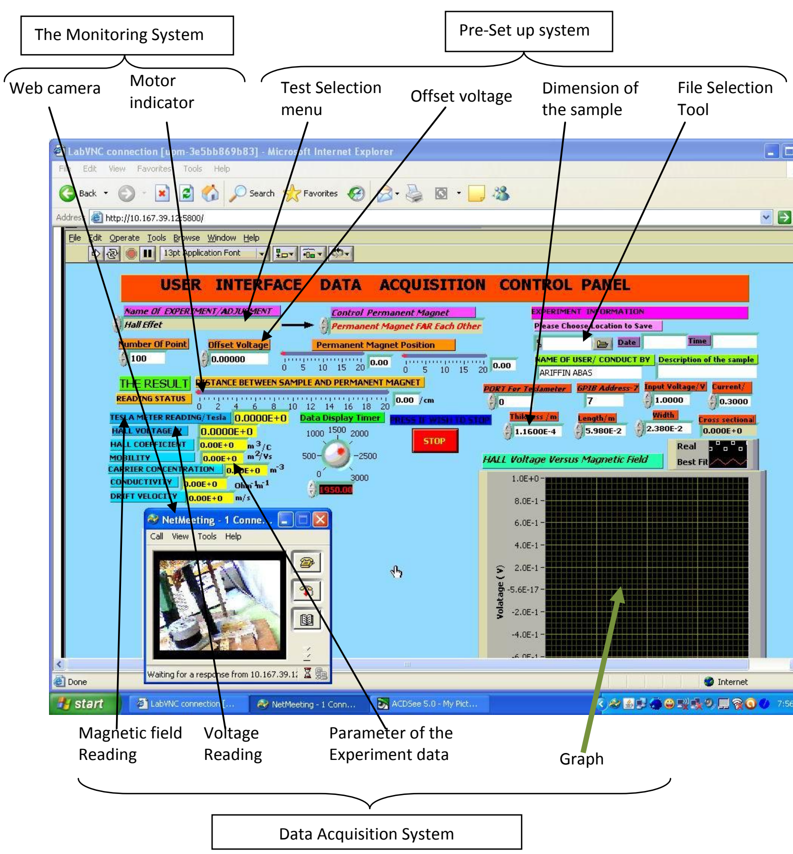

Fig.4: User Interface containing Java Applet through Internet web

The standard apparatus for Hall effect measurement, as used in the teaching laboratory and acquired from LEYBOLD, costs approximately RM36,000 per set. However, there is no facility for remote control through web-based and the data are recorded manually. An estimate of the current set-up of the whole system is approximately RM16,000.

RESULTS AND DISCUSSION

The web-based automation system - written using Lab View programming - has been successfully developed to give instructions to the computer. The data from Tesla meter and nano voltmeter, via serial port and GPIB respectively, are automatically saved to the hard drive for further analysis and automatically plotted in real time. The Hall voltage increased linearly with increasing magnetic field strength as shown in Fig.5.

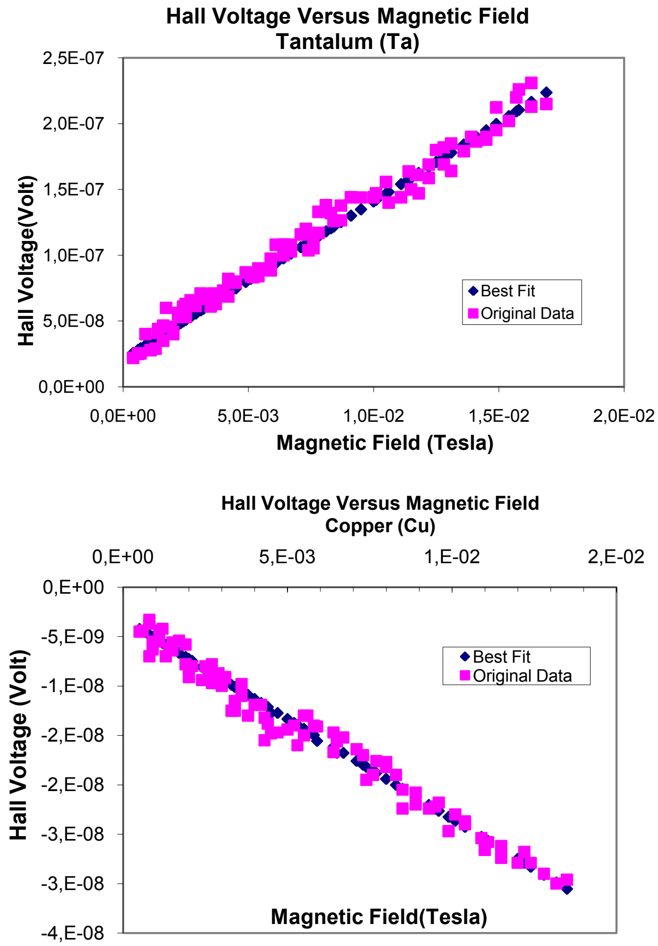

Fig.5: Hall Voltage as a function of magnetic field for tantalum and copper

Table 1 shows the results which were automatically calculated and displayed in the front panel user interface through Lab View programming and obtained by using equations 1-6.

TABLE 1
The Hall Effect result for selected materials

Material	Thickness d±0.001 x10^{-3}m	Width W±0.001 x10^{-3}m	Length L±0.001 x10^{-3}m	Hall Coefficient R_H x10^{-10} m^3/C	Charge carrier n x10^{28} m^{-3}	Conduction σ x10^6 $ohm^{-1}m^{-1}$	Mobility μ x10^{-3} m^2/Vs	Drift velocity V_d x10^{-3} m/s
Copper (Cu) - 99.5%	0.039	12.800	23.810	-0.78 ±0.05 (-0.55) (41.8)*	8.01±0.52 (11.40) (29.7)*	47.70±2.30 (58.80) (18.8)*	3.72±0.29 (3.23) (15.1)*	0.15±0.02
Tantalum (Ta) - 99.4%	0.023	13.800	23.800	+1.14±0.02 (+1.01) (12.8)*	5.48±0.09 (6.19) (11.4)*	7.50±0.06 (7.80) (3.8)*	0.88±0.02 (0.78) (12.8)*	0.35±0.04

(   ) Theoretical value (Hurd, 1972; Kittel, 1971)
(   )*%accuracy

Hall coefficient for copper showed that the charge carriers have a negative sign. In this case, the conduction band is dominated by electron charge carriers moving through the material and hence, making copper dominated by electrons as charge carrier. For tantalum, the Hall potential difference shows that the charge carriers have a positive sign, which means the conduction is dominated by holes, unoccupied energy levels in the valence band. The holes correspond to the absence of an electron and thus, behave like positive charge carriers moving through the material. The experimental values of Hall Effect coefficient, conductivity, mobility and charge carrier for the sample are compared to the theoretical values. The differences between the two values may be due to disturbing secondary effect particularly at the contact points or impurities in the test sample. The drift velocities for both copper and tantalum are very small. However, the drift velocity of copper is smaller than that of tantalum due to the fact that copper has a higher value of charge carrier since the drift velocity is inversely proportional to the charge carrier $V_d \propto \frac{1}{n}$.

CONCLUSION

In this paper, the apparatus used in the experiment to measure Hall Effect are simple, cheap and easy to handle. The results obtained are in the same order of magnitude when compared to theoretical values. The Web-based automation system can be remotely controlled and monitored by users in remote locations by using only their web browsers. The advantage offered by this system is in the field of education since it can be a key component of e-learning. Students are able to view and control physics experiments carried out 'live' over the Internet and also participate over conventional web browsers in real time. Hence, the system that was developed can also be used as an affective teaching aid.

ACKNOWLEDGEMENTS

This work was supported by Research University Grants (RUGS), Universiti Putra Malaysia, Serdang Selangor, Malaysia. A special mention and thanks are accorded to the Malaysian Ministry of Education for granting study leave to the author, thus giving the opportunity to carry out this project successfully.

REFERENCES

Basil, H. (2011). A mimicking human arm with 5 DOF controlled by Lab View. IACSIT *International Journal of Engineering and Tech., 3*(1), 9-15.

Brandley, A. (2007). *Hall Effect Experiment*. Department of Physics and Astronomy publication. Tennessee USA.

Carl, L. H. (1994). *Technical Foundations of Client/Server Systems.* New York: John Wiley & Sons, pp. 1-20.

Edward, R. (2006). *Hall-Effect Sensors Theory and Application*. Elsevier Science (2nd Edn.) Newnes Texas USA.

Hurd, C. M. (1972). *The Hall Effect in Metals and Alloys*. New York: Plenum Press.

Kai Qian. (2009). *Embedded software development with C*. New York: Springer Dordrecht Heidelberg London New York, pp. 179-190.

Kalman, C. J. (1995). Lab View: A software for data Acquisition, Data analysis and Instrument Control. *Journal of Clinical Monitoring, 11*(1), 51-58.

Kittel, C. (1971). *Introduction to Solid State Physics* (4th Edn.). New York: John Wiley & Sons.

Wells, L. K., & Travis, J. (1997). *Lab VIEW For Everyone, Graphical Programming Made Even Easier*. Prentice Hall Virtual Instrumentation Series, New Jersey USA. Pp. 19-21.

R. S. Components (Malaysia) Sdn Bhd (1999). *Technical Manual for RS 217-3611 4 Phase Unipolar Stepper Motor Drive Board*. Issued by RS Components.

Sumathi, S. (2007). *Lab View based advanced Instrumentation system*. Springer Dordrecht Heidelberg London New York. Pp. 239-279.

Takashi Kenjo (1985). *Stepping Motors and Their Microprocessor Controls.* Monographs in Electrical and Electronic Engineering 16, Clarendon Press, Oxford. 1-3, 21, 25, 34.

Travis, J. (2000). *Internet Application in Lab View*. Upper Saddle River NJ USA Prentice Hall. pp. 350-357.