Remote Lab in Instrumentation and Control Engineering Using LabVIEW

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Abstract-Remote enabled Laboratory implementation of Instrumentation and Control Lab is shown in this work. Many principles related with Instrumentation can be demonstrated by means of Remote enabled laboratory and it is the advancement in Instrumentation course teaching. The characteristic of LM35. LDR and Photodiode is shown in this work. One application of RPM measurement and control of PMDC motor is also shown in this work. By using LabVIEW developing software investigator has developed the remote laboratory for engineering students. The circuits as well as the combination of real and virtual are novel. The remote laboratories were developed using LabVIEW virtual instrumentation and they enable web control and monitoring of the laboratory equipment, allowing engineering students to perform the experiments in real time, at their own computers, from anywhere and whenever is suitable for them and also at reduced cost.

Index Terms—remote laboratory, instrumentation and control, RPM of PMDC motor

I. INTRODUCTION

Laboratories, which are found in all engineering and science programs, are an essential part of the education experience. Not only do laboratories demonstrate course concepts and ideas, but they also bring the course theory alive so students can see how unexpected events and natural phenomena affect real-world measurements and control algorithms. However, equipping a laboratory is a major expense and its maintenance can be difficult. Teaching assistants are required to set up the laboratory, instruct in the laboratory and grade laboratory reports. These time-consuming and costly tasks result in relatively low laboratories are available only when equipment and teaching assistants are both available [1]-[12].

All of these and many more exciting applications are now easily achievable with the new technology available with National Instruments LabVIEW remote panels. With this standard feature of LabVIEW, a user can quickly and effortlessly publish the front panel of a LabVIEW program for use in a standard web browser. Once published, anyone on the web with the proper permissions can access and control the experiment from the local server. If the LabVIEW program controls a realworld experiment, demonstration, calculation, etc., LabVIEW remote panels turns the application into a remote laboratory with no additional programming or development time [13]-[15].

II. BLOCK DIAGRAM OF THE SYSTEM

The data is taken from different sensors and after signal conditioning and ADC it is send to microcontroller .The microcontroller then manipulate the data and send it to the PC using USB protocol. The LabVIEW program uploads the required data to the internet. To perform the experiment one can open the Labview based front end software installed in the user PC. It will display the experiment in online mode. To perform the experiment online on can click on the online tab and the online page of the selected experiment is displayed on the screen. The block diagram of the system is shown in Fig. 1. For example if one want to perform the experiment of LM35 sensor, then in online mode the request to get the data is send to the microcontroller via internet through USB interface and the then microcontroller get the required data from the experimental setup and then upload it on the web page [16].



Figure 1. Block diagram of the system

III. HARDWARE

The hardware is based on PIC18F4550 microcontroller. It consist of PIC 18F4550 microcontroller, alpha numeric

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LCD, relay, USB connector and different sensors connectors etc. The circuit diagram is developed using Orcad Capture software. The microcontroller has in built 10 bit ADC, which converts the output voltages of the sensors into digital data. The voltages from sensors are readied through the ADC channel of the microcontroller. It is then processed and converted into a format to be displayed on the LCD and is sending to host computer using USB protocol. At computer side LabVIEW firmware receive this data. The power supply to the hardware is provided by the host computer through USB port and 12V dc SMPS. The hardware is simple, reliable and very cost effective. The LCD is used to monitor the hardware of experiment and for debugging purpose. First card circuit diagram in Orcad Capture is shown in Fig. 2, the signal conditioning of sensors to microcontroller is shown in Fig. 3.



Figure 2. Circuit diagram of DAQ card

The circuit is made using PIC18F4550 microcontroller. It consists of the USB port and 10 bit ADC which is the basic requirement of the required system. The microcontroller is operated at 20Mhz frequency. The 16*2 smart LCD is used to display the concern experiment data to be visualized at the remote end of the experiment. LM7805 is used to provide the 5V dc supply for the system. J6 is the programming connector for ISP programming of the microcontroller. Power transistor is used for PMDC motor control. 12 V dc Relays are used for the bulb control. Different connectors are used to connect the PCB with the experimental setup.

The diagram of DAQ card and the experimental setup is shown in Fig. 4 and Fig. 5 respectively.



Figure 3. Circuit diagram of signal conditioning of DAQ card



Figure 4. Photo of DAQ card



Figure 5. Photo of experimental setup

A. Experiment: Characteristic of LM35

The data of LM35 is taken through con3 connector. This analog voltage is sent to analog PortRA3 which has in built ADC on this port and convert the analog signal into 10 bit digital signal. This signal is converted into voltage and sends temperature and voltage readings to the host PC using LabVIEW software. The experimental setup of this experiment is shown in Fig. 6.



Figure 6. Experimental setup of LM35 experiment

It consists of the AC bulb, LM35 sensor and DC fan. When the student starts the experiment by opening the LabVIEW program the microcontroller gets the address for the experiment and on the bulb. As soon as the bulb is ON the chamber temperature of the experiment increases thereby increasing the temperature of the LM35 and the output voltage of LM35 increases which is proportional to the chamber temperature. This data is then sent to student laptop through microcontroller via USB port. The LabVIEW plot the graph. After completing the experiment the LabVIEW stops the experiment. Then the microcontroller of the bulb and ON the dc fan for cooling the experimental chamber for some duration .After then the dc fan is also stopped and the system is ready for next experiment [17].

B. Experiment: Characteristic of Light Dependent Resistor

The data of LDR is taken through LDR_CON connector. This analog voltage is sent to analog Port RA3 which has in built ADC on this port and convert the analog signal into 10 bit digital signal. This signal is converted into light intensity and resistance and then sends this data to the host PC using LabVIEW software. The experimental setup of this experiment is shown in Fig. 7. It consists of the white LED's and LDR sensor. When the student starts the experiment on his laptop and run the LabVIEW program the microcontroller gets the address for the experiment and on the LED's. As soon as the LED's are ON the resistance of LDR changes. This data is then sent to student laptop through microcontroller via USB port. The LabVIEW plot the graph. After completing the experiment the LabVIEW stops the experiment. After then the system is ready for next round of experiment.



Figure 7. Experimental setup of LDR experiment

C. Experiment: Characteristic of Photodiode

The data of photodiode is taken through J12 and J14 connector. This analog voltage is sent to analog Port RA1 which has in built ADC on this port and convert the analog signal into 10 bit digital signal. This signal is converted into irradiance and photodiode current and then sends this data to the host PC using LabVIEW software. The experimental setup of this experiment is shown in Fig. 8. It consists of trans-receiver pair of photodiode. When the student starts the experiment on his laptop and run the LabVIEW program the microcontroller gets the address for the experiment and on the trans-receiver photodiode. As soon as the trans-receiver photodiode is ON the photodiode irradiance changes the photodiode current changes. This data is then sent to student laptop through microcontroller via USB port. The LabVIEW plot the graph. After completing the experiment the LabVIEW stops the experiment. After then the system is ready for next round of experiment.



Figure 8. Experimental setup of photodiode experiment

D. Application: Hardware Setup of RPM Measurement and Control of PMDC Motor

The data of RPM measurement is taken through J20 and J21 connector and the dc motor is controlled through J17 connector. The digital pulse received from photodiode is sent to digital Port RD1. This signal is converted into RPM and then sends the data to the host PC using LabVIEW software. The setup of this application is shown in Fig. 9. When the user starts the application on his laptop and run the LabVIEW program the microcontroller gets the address for the experiment and switches ON the trans-receiver photodiode. As soon as the trans-receiver photodiode is switched ON and the RMP of the dc motor changes the photodiode signal changes. This data is then sent to student laptop through microcontroller via USB port. The LabVIEW displays the RPM of PMDC motor. After completing the application the LabVIEW stops the setup. After that the system is ready for next round [18].



Figure 9. Setup of RPM measurement and control of PMDC motor

IV. SOFTWARE

Software for front end software for remote terminals is designed in LabVIEW. The block diagrams of the different experiments are shown here.

A. Block Diagram for LM35 Experiment

The LM35 series are precision integrated-circuit temperature sensors, with an output voltage linearly proportional to the Centigrade temperature. It has got three terminals. First is supply voltage, second is output voltage and third is ground terminal. The suitable dc voltage is applied at terminal one and we get the output voltage proportional to temperature of the sensor environment.

In this experiment investigator has designed the LabVIEW software to study the characteristic of LM35. The X-Y graph is plotted between output voltage of LM35 and temperature of the experiment chamber. The block diagram of the LM35 characteristic is shown in Fig. 10.



Figure 10. Block diagram of LM35 characteristic

The program consists of the four steps:

- Acquire data: The block diagram consists of the VISA functions for reading and writing the data through USB port. When the program is executed the program sends the channel number for the experiment to the microcontroller.
- **Data manipulations:** The address and the data sent by the microcontroller are separated using index array functions. The signal is then manipulated as per the requirement of the experiment variable to be displayed on the graph.
- **Data representation:** The acquired data is checked for the address of the experiment using formula node. If address matches then the manipulated signal is send to the XY graph to be plotted.
- **Termination of Loop:** The loop is terminated using stop button or if the while loop count is completed as specified in the block diagram.

B. Block Diagram for LDR Experiment

A light dependent resistor (LDR) is a semiconductor product either cadmium sulphide or cadmium selenide arranged in a zigzag pattern. The resistance of the material varies with incident light. When it is connected to an external battery current flow depending on the light intensity, the current is controlled by incident light. It is a surface phenomenon. The suitable dc voltage is applied at terminal one and we get the output voltage proportional to resistance.

In this experiment investigator has designed the LabVIEW software to study the characteristic of LDR. The logarithmic X-Y graph is plotted between Illumination of LDR and the resistance of the LDR. The block diagram of the LDR characteristic is shown in Fig. 11.



Figure 11. Block diagram of LDR characteristic

The program consists of the four steps:

• Acquire data: The block diagram consists of the VISA functions for reading and writing the data through USB port. When the program is executed the program sends the channel number for the experiment to the microcontroller.

- **Data manipulations:** The address and the data sent by the microcontroller are separated using index array functions. The signal is then manipulated as per the requirement of the experiment variable to be displayed on the graph.
- Data representation: The acquired data is checked for the address of the experiment using formula node. If address matches then the manipulated signal is send to the XY graph to be plotted.
- **Termination of Loop:** The loop is terminated using stop button or if the while loop count is completed as specified in the block diagram.

C. Block Diagram for Photodiode Experiment

An Infrared Photodiode is a semiconductor product which is based on the principle of photodiode effect- the generation of a voltage across the PN junction of the semiconductor when the junction is exposed to infrared light. The low C_j planer diffusion type photodiode is used for the manufacturing of Infrared Photodiode.

In this experiment investigator has designed the LabVIEW software to study the characteristic of Infrared Photodiode. The logarithmic X-Y graph is plotted between Illumination of Infrared Photodiode and the shunt current of the Infrared Photodiode.

The block diagram of the Photodiode characteristic is shown in Fig. 12.



Figure 12. Block diagram of photodiode characteristic

The program consists of the four steps:

- Acquire data: The block diagram consists of the VISA functions for reading and writing the data through USB port. When the program is executed the program sends the channel number for the experiment to the microcontroller.
- **Data manipulations**: The address and the data sent by the microcontroller are separated using index array functions. The signal is then manipulated as per the requirement of the experiment variable to be displayed on the graph.
- **Data representation:** The acquired data is checked for the address of the experiment using formula node. If address matches then the manipulated signal is send to the XY graph to be plotted.

• **Termination of Loop:** The loop is terminated using stop button or if the while loop count is completed as specified in the block diagram.

D. Block Diagram for RPM Measurement and Control of PMDC Motor

In this experiment investigator has designed the LabVIEW software to control and measure the RPM of the dc motor.

The block diagram of the RPM Measurement of dc Motor is shown in Fig. 13.



Figure 13. Block diagram of RPM measurement of dc motor

The program consists of the four steps:

- Acquire data: The block diagram consists of the VISA functions for reading and writing the data through USB port. When the program is executed the program sends the channel number for the experiment to the microcontroller.
- **Data manipulations:** The address and the data sent by the microcontroller are separated using index array functions. The signal is then manipulated as per the requirement of the application variable to be displayed.
- **Data representation:** The acquired data is checked for the address of the application using formula node. If address matches then the manipulated signal is send to the front panel to be displayed.
- **Termination of loop:** The loop is terminated using stop button or if the while loop count is completed as specified in the block diagram.

V. EXPERIMENTAL RESULTS

A. Real Time Remote Plotting of LM35 Characteristic

First open the HTML page as shown in Fig. 14 opens. When the HTML page opens right click on the window the window ask for the Request control of vi and select it. The control is now transferred to the remote HTML page. The response of the output voltage of LM35 and the temperature is shown in Fig. 14. This graph is obtained after the online experiment is completed and the student can save the X-Y graph into the bitmap image and later on paste it on the practical file for later use. The readings of the sensor are shown in Table I. This table can be saved into the working computer for future reference.



Figure 14. Response of the output voltage and temperature of LM35

TABLE I. VOLTAGE VERSUS TEMPERATURE READINGS OF LM35

| S. NO | Voltage (volts) | Temperature (⁰ C) |
|-------|-----------------|-------------------------------|
| 1 | 0.156 | 16 |
| 2 | 1.11 | 114 |
| 3 | 1.12 | 115 |
| 4 | 1.14 | 117 |
| 5 | 1.20 | 123 |

B. Real Time Remote Plotting of LDR Characteristic

First open the HTML page as shown in Fig. 15 opens. When the HTML page opens right click on the window the window ask for the Request control of vi and select it. The control is now transferred to the remote HTML page. Now the student can run the vi program and LDR resistance change to Illumination is shown in Fig. 15 is plotted. This graph is obtained after the online experiment is completed and the student can save the X-Y graph into the bitmap image and later on paste it on the practical file for later use.

The readings of the sensor are shown in Table II. This table can be saved into the working computer for future reference.



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Figure 15. Response of LDR resistance change to illumination

| S. NO | Resistance (ohms) | Illumination (Lux) |
|-------|-------------------|--------------------|
| 1 | 4000 | 1.581 |
| 2 | 2300 | 2.085 |
| 3 | 1700 | 2.425 |
| 4 | 1400 | 2.672 |
| 5 | 1200 | 2.886 |

TABLE II. RESISTANCE VERSES ILLUMINATION READINGS OF LDR

C. Real Time Remote Plotting of Photo Doide Characteristic

First open the HTML page as shown in Fig. 16 opens. When the HTML page opens right click on the window the window ask for the Request control of vi and select it. The control is now transferred to the remote HTML page. Now the student can run the vi program and Photo Diode reverse current change to Irradiance graph is shown in Fig. 16 is plotted. This graph is obtained after the online experiment is completed and the student can save the X-Y graph into the bitmap image and later on paste it on the practical file for later use.

The readings of the sensor are shown in Table III. This table can be saved into the working computer for future reference.



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Figure 16. Response of photo diode reverses current change to Irradiance

TABLE III. REVERSE PHOTO DIODE CURRENT VERSES IRRADIANCE READINGS OF PHOTO DIODE

| S. NO | Reverse Current (µA) | Irradiance (mW/cm ²) |
|-------|----------------------|----------------------------------|
| 1 | 77 | 0.76 |
| 2 | 74 | 0.73 |
| 3 | 66 | 0.65 |
| 4 | 41 | 0.40 |
| 5 | 40 | 0 39 |

D. Real Time Remote RPM Measurement and Control of PMDC Motor

First open the HTML page as shown in Fig. 17. When the HTML page opens right click on the window the window ask for the Request control of vi and select it. The control is now transferred to the remote HTML page. Now the student can run the vi program and speed control of PMDC motor and RPM measurement is shown in Fig. 17.



Figure 17. Response of RPM measurement and control of dc motor

VI. CONCLUSIONS

In the present work, author has developed DAQ card, and three experimental setups and one application for Instrumentation and Control Engineering experiments. The experimental results have been compared with the datasheets of the sensors and the encouraging resuls have been found. This shows that LabVIEW is very good front end design tool. Futhermore this method of online experimentation can complement traditional laboratory experiments.

The features of the package developed by the investigator are mentioned below:

- i. A user friendly web enabled virtual instrumentation laboratory package developed is proved very suitable tool in learning and experimental process.
- ii. The package is developed using LabVIEW, Dreamweaver, Orcad and Mikro C compiler.
- The characteristics of different sensors are being plotted and stored on remote computers.
- The cost effective DAQ card is developed for performing the experiments online.
- v. The cost of the system developed is very less as compared to ELVIS II, used by other authors as mentioned in the references [19].

REFERENCES

- [1] M. T. Restivo, *et al.*, "A remote laboratory in engineering measurement," *IEEE Transactions on Industrial Electronics*, vol. 56, no. 12, pp. 4836-4843, Dec. 2009.
- [2] B. Kanmani, "An alternate approach to the laboratory implementation of communication experiments," in *Proc. Digital Signal Processing Workshop and IEEE Signal Processing Education Workshop (DSP/SPE)*, Sedona, Jan. 2011, pp. 517-522.
- [3] Y. Bao and X. Jiang, "Application of virtual instrumentation which based on labview in electronic measurement technology course," in *Proc. International Conference on Electronics and Optoelectronics*, Dalian, Jul. 2011, pp. 215-218.
- [4] C. K. Maiti, S. Mahata, and Ananda Maiti, "Design and development of a cost effective online electronic circuits laboratory," in *Proc. IEEE International Conference on Technology for Education*, Chennai, Jul. 2011, pp. 221-224.

- [5] H. Vargas, et al., "A network of automatic control web-based laboratories," *IEEE Transactions on Learning Technologies*, vol. 4, no. 3, pp. 197-208, 2011.
- [6] A. Maiti and S. Mahata, "A study of switching mechanisms in remote electronics laboratories for engineering education," in *Proc. IEEE International Conference on Teaching, Assessment, and Learning for Engineering (TALE)*, Hong Kong, Aug. 2012, pp. W2B-4 - W2B-6.
- [7] K. M. Moudgalya and I. Arora, "A virtual laboratory for distance education," in *Proc. IEEE International Conference on Technology for Education (T4E)*, Mumbai, Jul. 2010, pp. 190-193.
- [8] N. Sousa, G. R. Alves, and M. G. Gericota, "An integrated reusable remote laboratory to complement electronics teaching," *IEEE Transactions on Learning Technologies*, vol. 3, no. 3, pp. 265-271, 2010.
- [9] C. Y. Nie, S. S. Xu and S. J. Ji, "Data acquisition and realization of communication transmission based on LabVIEW," in *Proc. International Conference on Computer Science and Electronics Engineering*, Hangzhou, Mar. 2012, pp. 215-218.
- [10] E. G. Guimaraes, E. Cardozo, D. H. Moraes, and P. R. Coelho, "Design and implementation issues for modern remote laboratories," *IEEE Transactions on Learning Technologies*, vol. 4, no. 2, pp. 149-161, 2011.
- [11] G. A. Meneses, "Design of an electronic instrumentation virtual laboratory based on free-open resources," in *Proc. IEEE 6th Colombian Conference on Computing Congress (CCC)*, Manizales, May 2011, pp. 1-6.
- [12] A. V. Szarka, "Development of remote controlled virtual laboratory," in *Proc. XIX IMEKO World Congress Fundamental* and Applied Metrology, Lisbon, Sep. 6-11, 2009, pp. 49-53.
- [13] S. Sumathi and P. Surekha, LabVIEW Based Advanced Instrumentation System, Springer Publication, 2007.
- [14] R. Bitter, T. Mohuddin, and M. Nawrocki, *LabVIEW Advanced Programming Techniques*, New York: CRC Press, 2001.
- [15] LabVIEW Tutorial Manual, National Instruments Corporation, 1996.
- [16] J. Jing, L. Nie, B. Wang, and J. Li, "Remote laboratory data management system based on LabVIEW," in *Proc. International Conference on Measuring Technology and Mechatronics Automation*, Changsha City, Mar. 2010, pp. 1016-1019.
- [17] I. Arora, K. M. Moudgalya, and S. Malewar, "A low cost open source single board heater system," in *Proc. 4th IEEE International Conference on E-Learning in Industrial Electronics* (*ICELIE*), Glendale, Nov. 2010, pp. 7-12.
- [18] A. P. J. Chandra and C. R. Venugopal, "Novel design solutions for remote access, acquire and control of laboratory experiments on dc machines," *IEEE Transactions on Instrumentation and Measurement*, vol. 61, no. 2, pp. 349-357, Feb. 2012.
- [19] S. Mahata, A. Maiti, and C. K. Maiti, "Cost-Effective web-based electronics laboratory using NI MultiSim, LabVIEW and ELVIS II," in *Proc. IEEE International Conference on Technology for Education (T4E)*, Mumbai, Jul. 2010, pp. 242-243.



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