A Web Service and Interface for Remote Electronic Device Characterization

Sumit Dutta, Shreya Prakash, David Estrada, *Student Member, IEEE*, and Eric Pop, *Senior Member, IEEE*

***Abstract*—A lightweight Web Service and a Web site interface have been developed, which enable remote measurements of electronic devices as a "virtual laboratory" for undergraduate engineering classes. Using standard browsers without additional plugins (such as Internet Explorer, Firefox, or even Safari on an iPhone), remote users can control a Keithley source-measurement unit and monitor results in real time from anywhere on the Internet. As an in-class example, students in a solid-state electronics course used the Web site interface to make real-time transistor measurements. Recommendations are made on how to best integrate the interface into electronics classes based on the student assignment responses. The present interface is flexible and could be expanded to many other devices and instruments. The source code has been openly posted online.**

***Index Terms*—Educational technology, engineering education, metal-oxide-semiconductor field-effect transistors (MOSFETs), online services, virtual laboratory.**

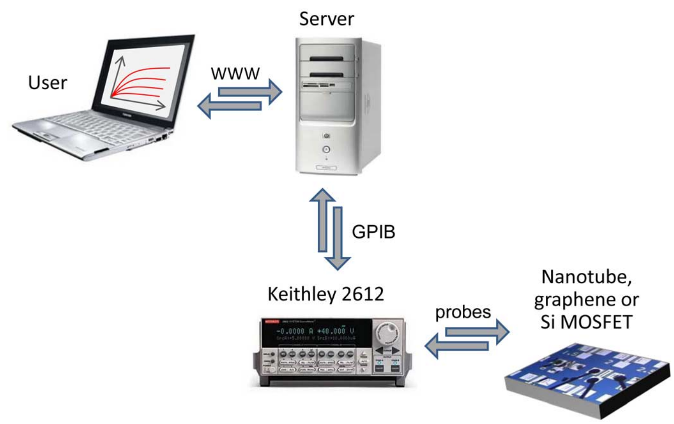


Fig. 1. Schematic of user interaction with remote instrument and test device through the WWW interface.

I. Introduction

MANY contemporary engineering courses are heavily theoretical, particularly for disciplines where setting up experimental labs is costly. One such example is a semiconductor electronics course, where transistor theory is taught without access to experimental data, which is only available in state-of-the-art industrial or research labs. As an alternative, virtual online laboratories can expose students to hands-on learning without incurring the high costs of instructional facilities. Measurement instruments can be connected and controlled by a computer for data capture [1]. This capability has enabled virtual laboratories on the World Wide Web (WWW), allowing many users to access a single instrument. While Web-based remote instrument control has been investigated for over a decade, most implementations have been "heavyweight" approaches relying on Web servers with Java or PHP Hypertext Processor (PHP) scripts [1]–[3]. These often require users to download a ~100-MB LabView or Java browser plugin [4], [5] in addition to having a compliant browser [6]. Other remote laboratories require the measurement software itself, such as LabView [7].

This paper describes the design and development of a lightweight Web Service (WS) for making remote measurements on electronic devices, which operates within standard Web browsers and does not require any downloads. The WS currently allows users to perform typical transistor measurements and has been tested in a classroom environment to gather student feedback. In addition, the WS could be easily extended to different applications, such as remote measurements of bionanotechnology or micromechanical devices. Remote users of this WS control a Keithley 2612 instrument with standard browsers without plugins and monitor their results in *real time* from any computer or Web-browsing mobile device (Fig. 1). The server software successfully places student test requests into a queue, conducts the tests in order, and provides ongoing measurement results to all connected users. Finally, in order to encourage further development of other systems based on this work, the project code has been posted online as open-source [8].

This paper is organized as follows. First, Section II describes the server setup and Web site interface. Section III presents a specific application example of the Web site in an undergraduate electronics course. This section also discusses student feedback and guidelines for future improvements. Finally, Section IV concludes the paper by summarizing the key points.

II. Web Service and Web Site Interface

Web Services provide a standardized means to expose the inputs and outputs of a process to a variety of other remote systems, combining standardized communication over the Hypertext Transfer Protocol (HTTP) with standardized text data in the Extensible Markup Language (XML) [9], [10]. Development with WS has been successfully used for remote instrument control with many possible interfaces for the end-user [10]–[12]. By making use of the recently added WS capabilities in LabView, virtual instrument (VI) control panels can be operated via external computers by connecting to instrument controls through familiar HTTP links. Thus, the

Manuscript received September 14, 2010; accepted December 23, 2010. Date of publication February 07, 2011; date of current version November 02, 2011. This work was supported in part by the National Science Foundation (NSF) under Grants CAREER ECCS-0954423 and CCF-0829907, the NSF-sponsored nanoHUB.org, an Intel Higher Education Grant, the Micron Technology Foundation, NDSEG Graduate Fellowships (D.E.), and the NASA Aeronautics Scholarship (S.D.).

The authors are with the Micro and Nanotechnology Lab, Department of Electrical and Computer Engineering, University of Illinois at Urbana–Champaign, Urbana, IL 61801 USA (e-mail: epop@illinois.edu).

Color versions of one or more of the figures in this paper are available online at http://ieeexplore.ieee.org.

Digital Object Identifier 10.1109/TE.2011.2105488

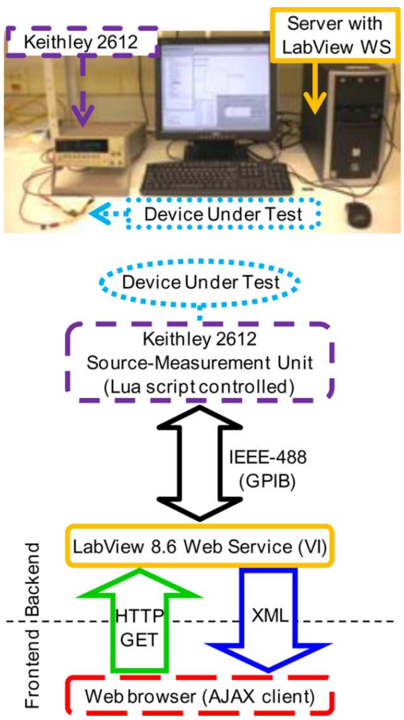


Fig. 2. (*Top*) Photograph of hardware used for the Remote Lab. (*Bottom*) Schematic of the remote instrument WS and Web interface architecture.

WS for the remote-controlled instrument accepts simple HTTP requests and returns XML files with results. This enables any type of client—for example, a Web browser with JavaScript but no additional plugins—to run electronic measurements on a remote server. The server is hosted by the Pop Lab [13] in the Micro and Nanotechnology Laboratory (MNTL) at the University of Illinois at Urbana–Champaign (UIUC), as pictured in Fig. 2.

To enable remote connectivity to the lab instruments, a user-friendly Web site interface was developed with support for on-demand content loading. The Web site works on any Web browser with support for a JavaScript XML HTTP Request, a common feature in most Web browsers on all operating systems including Internet Explorer, Mozilla Firefox, and even Safari running on the iPhone. The Web site avoids the need to load a sequence of pages, as all controls and displays are on a single page (Fig. 3). Real-time plotting in the Web browser is accomplished with Flot, an open-source JavaScript library that uses or emulates the standard $\mathrm{HTML}\langle\mathrm{canvas}\rangle$ tag [14]. The XML requests that must be implemented by the Web site are described in Tables I and II. The authors have made both the WS server and Web site available for download as complete open-source software online [8].

On the current Web site interface, the user chooses to perform either a drain current versus gate-to-source voltage $(I_{\mathrm{D}} - V_{\mathrm{GS}})$ or I_{D} versus drain-to-source voltage $(I_{\mathrm{D}} - V_{\mathrm{DS}})$ transistor measurement using a remotely accessed Keithley 2612 source-measurement unit. Appropriate sourcing parameters are preprogrammed in the LabView VIs, which also set the voltage and current compliances. Information about the requested measurement and associated compliance limits is determined in the Initial Request, an initiating request made by the client, as shown in Table I. While determining the information for requesting a test, data currently being collected by the remote lab instrument are displayed to all active sessions. This feature allows students to collaborate as well as view the results of other users in order to develop a better intuition about the measurements. Users can choose whether to acquire and display data for the ongoing test, whether it is their own test or of another user. Nevertheless, the test requests made by all connected users execute in the chronological order in which they were received.

As the test data is acquired by the instrument, it is made available to the client in real time. Every second, a New Data Request with no data other than the standard HTTP headers is sent, for which an XML data response is provided with the newest data points recently acquired by the lab instrument. These data are just over 500 B in size, which highlights the low bandwidth of the requests, due to data being sent in small packets rather than in a high-overhead Web page. The delay in transporting data over the HTTP protocol is typically $\sim$100 ms, which is usually fast enough to receive data in real time, at a rate below $\sim$10 Hz. This delay is largely determined by server performance.

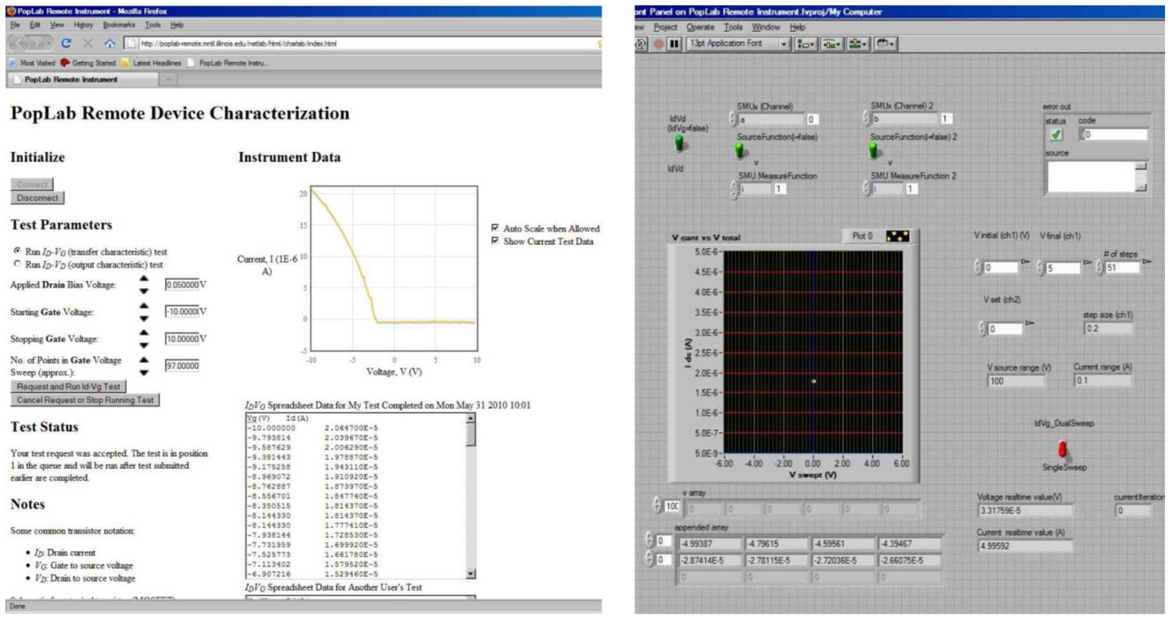
Users view data in a separate text box for each test run while connected. The text box provides a mechanism for the data to be easily copied and pasted into a spreadsheet and subsequently analyzed. The Web site data plot is also updated in real time. A screen capture (by $\mathrm{Alt} + \mathrm{PrintScreen}$ for instance) can copy the plot for use elsewhere. Only a basic keyboard and mouse are needed to operate the Web site because the controls are all buttons and numerical input fields.

The WS server software consists of 11 VIs in LabView, as shown in Fig. 4. The three categories of VIs are: 1) software and hardware control options; 2) VIs invoked by client requests such as the queue handler; and 3) internal processes that consist of the instrument control VI and queue manager VI. Client requests such as test input selections are sent to the unique URL for a particular VI in category 2. The VI checks the request inputs against the options in category 1 and accordingly takes action by verifying or correcting the test inputs and then queuing the test using the queue manager VI in category 3. The queue manager VI runs the instrument control VI for every dequeued test, dequeuing tests in the order they entered the queue.

The technologies used for the WS and interface are remarkably stable and secure. An analysis of previous technologies for remote laboratories shows that the AJAX development paradigm used here has the highest ranking in security, the second highest ranking next to HTML in universality, the third highest ranking in power and flexibility, and the highest ranking in development facilities [11]. In addition, the WS enables a flexible interface and the dynamic use of various resources [10].

III. Example Application in Solid-State Electronics Class

The Remote Lab interface is now an experimental component used by students in the undergraduate Solid-State Electronic Devices course (ECE 440) in the Department of Electrical and Computer Engineering (ECE) at UIUC. This course focuses on semiconductor physics in electronic devices including p–n junctions, metal-semiconductor devices, bipolar transistors, optoelectronic devices, and metal-oxide-semiconductor field-effect transistors (MOSFETs).



(a) (b)

Fig. 3. Screenshots illustrating (a) the Web interface of the remote instrument seen by the user and (b) the LabView VI that runs on the Web server.

TABLE I
USER SESSION AND DATA ACQUISITION EVENTS

Event	HTTP Request	XML Response
Initial Request Establishes identification and session	Browser request: • `HTTP GET /dataprovider` • `formName=initialRequest` • User-identifying HTTP headers	XML text response contains: • Available names of tests • Numerical voltage control limits • Plot/axes options (name, range) Browser interpretation: • Provide list of tests and inputs • Apply limits to input controls • Set plot/axes name and range
New Data Request Retrieves latest unseen data points from server	Browser request: • `HTTP GET /dataprovider` • `formName=newDataRequest` • User-identifying HTTP headers	XML text response contains: • Name of ongoing test • Whether new test • New data points Browser interpretation: • Update data displayed (plot, text box table) with new points, refreshing if data from a new test • Hold/identify current/past tests

Theoretical studies alone cannot provide students with a complete understanding of the course material, and some lab experience would be much welcomed. However, with ~150 students in ECE 440 every semester, providing individual lab access would be prohibitively expensive. Instead, students are provided with a small lab component in which they use the Remote Lab interface to measure transistor devices. In addition to providing a more complete understanding of the ECE 440 course material, this brief exposure to experiments could also encourage students to take the follow-up undergraduate elective course, Theory and Fabrication of Integrated Circuits (ECE 444).

When introducing the Remote Lab interface to ECE 440 students, the MOSFET was chosen as the main example because of its many applications. Traditional MOSFETs fabricated in-house in ECE 444 (Fig. 5) and cutting edge research devices (e.g., carbon nanotubes) fabricated at the Micro and Nanotechnology Laboratory (where the Pop Lab is located) were available for measurement. This gave ECE 440 students a glimpse of ECE 444 and connected their theory with practical electronic devices, promoting an overall understanding of the subject.

A. Online Student Exercise

Near the end of the Spring 2010 semester, ECE 440 students were invited to use the Remote Lab interface hosted online at the time of writing [15]. They were given a measurement and analysis assignment that they could complete for extra credit.

One example is the extraction of threshold voltage (V_T) in a standard MOSFET, an important metric describing the voltage at which a MOSFET "turns on." The measurement involves monitoring the drain current (I_D) of the device as a function of gate voltage (V_{GS}) under a small and fixed drain voltage $(V_{DS} \sim 50 \text{ mV})$. Post-measurement analysis is typically performed using the linear extrapolation method, that is, by taking the derivative of I_D with respect to V_{GS} to find the inflection point, and then identifying the x-intercept of the tangent line at that point [16]. Once V_T is known, the effective mobility (μ_{eff})

TABLE II
TEST QUEUE MANAGER EVENTS

Event	HTTP Request	XML Response
Test Request Submits request for a user-defined test to be validated and entered into server queue	Browser request: • `HTTP GET /queuehandler` • `formName=testRequest` • User-identifying HTTP headers • Test name • Voltage range/bias • Number of points	XML text response contains: • Test name • Corrected voltage range/bias • Number of points Browser interpretation: • Notify user of successful test request, showing modifications
Stop Request Cancels running/queued test	Browser request: • `HTTP GET /queuehandler` • `formName=stopRequest` • User-identifying HTTP headers	XML text response contains: • Whether test stopped, why Browser interpretation: • Notify if error

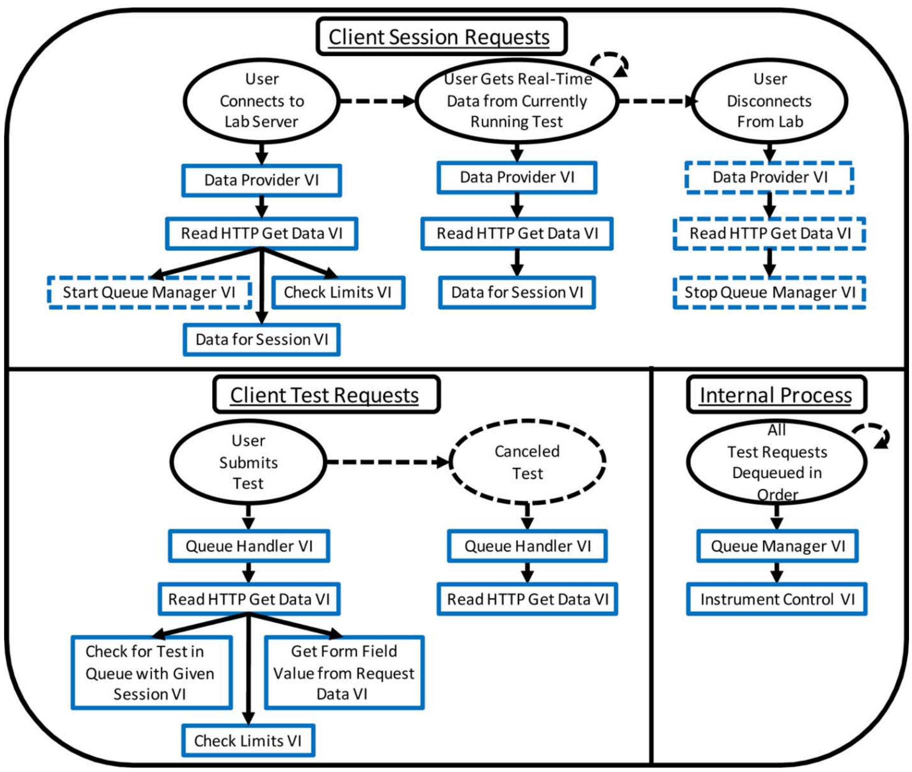


Fig. 4. Diagram of client interaction with LabView server VIs.

of the MOSFET can also be extracted with the MOSFET current equation

$$|I_\mathrm{D}| = \mu_\mathrm{eff} C_\mathrm{ox} \frac{W}{L} \left(|V_\mathrm{GS}| - |V_\mathrm{T}| - \frac{|V_\mathrm{DS}|}{2} \right) |V_\mathrm{DS}| \quad (1)$$

where W and L are the width and length of the device, and C_ox is the capacitance per unit area of the gate oxide (typically SiO_2). As shown in Fig. 6, these methods are applied on data measured remotely with the Web site as well as on data taken by the instrument locally in the lab.

For the local measurement, $V_\mathrm{T} = -1.92$ V and $\mu_\mathrm{eff} = 105$ $\mathrm{cm^2V^{-1}s^{-1}}$, whereas for the remote measurement, $V_\mathrm{T} = -2.18$ V and $\mu_\mathrm{eff} = 112$ $\mathrm{cm^2V^{-1}s^{-1}}$. The slight difference between local and remote tests is attributable to differences in hardware control. Although these numerical methods were not given to the students up front, they showed their conceptual understanding since the average V_T reported was -1.19 V. However, the students had difficulty in extracting μ_eff, reporting values from 10^{-3} to 10^{6} $\mathrm{cm^2V^{-1}s^{-1}}$. This difficulty was probably due to unit conversion issues (microns to centimeters, and so on). Nevertheless, even in its first classroom use, the instrument provided a valuable learning experience for students who would otherwise not be exposed to realistic measurements until taking more advanced courses such as ECE 444.

B. *Student Feedback and Improvement Suggestions*

Student feedback from the aforementioned assignment was used to assess the effectiveness of such an interface in the classroom. Typical student feedback included the following.

- "I was impressed by this Remote Lab. Everything is easy to use and understand."
- "I think measuring parameters of a device that someone else made is more realistic than just taking industry/textbook-standard values."
- "In an actual lab, we would have to pay more attention to what is going on."

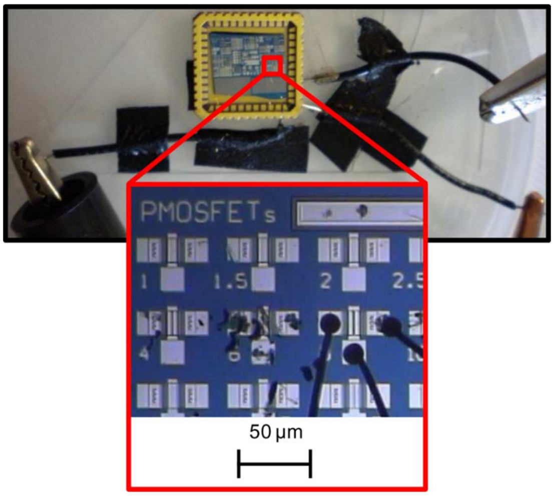


Fig. 5. Photograph and close-up of wirebonded transistors fabricated by undergraduates in the UIUC "Theory and Fabrication of Integrated Circuits" course (ECE 444). In the enlarged image, an individual transistor is wirebonded to the chip carrier, which is then connected to the Keithley 2612 for initial testing of the Remote Lab setup.

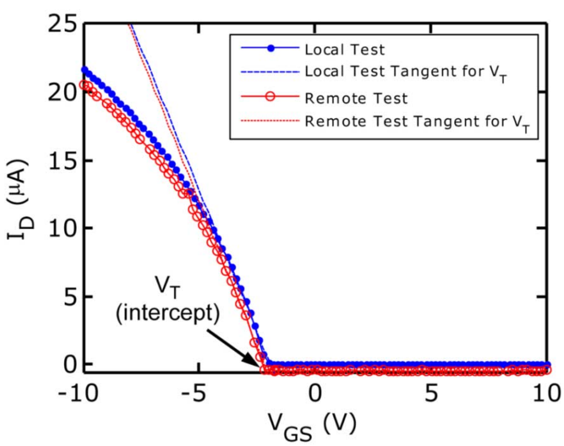


Fig. 6. Comparison of data taken locally in the lab and remotely using the WS shows nearly identical results, validating the WS technique. Here, the drain current (I_{D}) versus the gate voltage (V_{GS}) of a p-type MOSFET is measured. The threshold voltage (V_{T}) is extracted using the linear extrapolation method (see text).

- "I'm glad to see this implemented. I think that it would be neat to have one of these accompanying each new device introduced."
- "The Web site is by far the best way to take measurements remotely."

Overall, students were impressed by the features and flexibility of the Remote Lab interface. Some recounted taking measurements online from their dorm room or even from an airport. When asked about other useful potential features, students provided these representative responses.

- "Video would be cool, but I suppose much higher bandwidth."
- "I think more of an explanation on how these measurements were obtained would help me to understand why we are doing the lab."
- "It should be expanded to cover, if possible, all the graphs used in the class."

Considering that many of these features cannot be implemented in a plain HTML page, the development of additional

TABLE III
COUNTS OF STUDENT RESPONSES TO QUANTITATIVE FEEDBACK QUESTIONS

Question	Strongly Disagreeing	Disagreeing	Neutral	Agreeing	Strongly Agreeing
1	N/A	11	N/A	8	N/A
2	N/A	3	N/A	16	N/A
3	N/A	8	N/A	11	N/A
4	0	0	3	10	9
5	0	0	6	10	3

interfaces to the Remote Lab WS such as Java applets is suggested. However, this must be weighed against the desire to have a simple lightweight interface (that can run even on an iPhone browser), as was the original intention. Additional instruments such as capacitance–voltage (C–V) meters could also be connected to the interface to provide students other meaningful tests [17].

Quantitative feedback questions were included in the assignment to provide relative rankings for the Remote Lab interface and to characterize its fit to the course. The following questions have these possible answers: Yes = Agree or No = Disagree.

- Question 1: "Would you prefer taking lab measurements using this software instead of using real instruments during an assigned lab time?"
- Question 2: "Would you use this Web site interface if you already had access to the actual lab, but had to learn how to use the instruments?"
- Question 3: "Would you use this Web site interface if you already had access to the actual lab and knew how to use the instruments?"

The following feedback questions have these possible answers: 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, or 5 = Strongly Agree.

- Question 4: "Intuitiveness: Was the Web site interface easy to use?"
- Question 5: "Real Time Data: How valuable is real time (live) data acquisition to improving your understanding of MOSFETs?"

Table III summarizes the responses to these questions [18], [19]. The use of a WS and Remote Lab interface provides the benefit of a low cost per student because the components shown in Fig. 2 may already be present in many school labs. Thus, the only investment is the time spent to write and post a meaningful lab assignment. The initial gains of exposing ECE 440 students to lab tests were high, but the assignments could evolve into a click-and-complete nuisance if the WS and interface are overused in the curriculum. Thus, a WS and interface should be used as a concise, complementary tool to the in-class curriculum [20].

IV. CONCLUSION

In summary, a remote electronic device measurement setup has been developed that can run on any modern Web browser without requiring additional plugins or downloads. The WS server software places test requests into a queue, conducts the tests in order, and displays ongoing measurements to all connected users. The desired resolution of measured data is achieved with an adjustable real-time data transfer rate between the WS and the Web site interface. In order to encourage further development of other systems based on this work, the project code has been posted online as open-source [8]. The authors also plan to make their own Remote Lab interface available publicly through the WWW [15], giving a worldwide audience access to cutting-edge measurements on, for example, carbon nanotubes or state-of-the-art MOSFET devices.

The remote instrument setup has been tested in a large undergraduate classroom, and students provided valuable feedback to guide future extensions and applications. Due to the modular design of the software, other instruments with a LabView driver or GPIB interface can be connected to conduct a variety of remote tests, including AC measurements [21]. The flexibility of the WS also permits the development of various Web site interfaces for use in different courses. Such remote laboratories are valuable to expose students in engineering and science classes to realistic experiments and devices.

Acknowledgment

The authors thank M. Bohr and Intel Corporation for assistance and support, J. C. Lee for initial LabView help, D. Sievers for ECE 444 wafers, and J. Potts and J. Bird for IT support.

References

[1] J. Santos, J. Mendonca, and J. C. Martins, "Instrumentation remote control through Internet with PHP," in *Proc. IEEE VECIMS*, Istanbul, Turkey, 2008, pp. 41–44.

[2] D. Grimaldi, L. Nigro, and F. Pupo, "Java-based distributed measurement systems," *IEEE Trans. Instrum. Meas.*, vol. 47, no. 1, pp. 100–103, Feb. 1998.

[3] W. Winiecki and M. Karkowski, "A new Java-based software environment for distributed measuring systems design," *IEEE Trans. Instrum. Meas.*, vol. 51, no. 6, pp. 1340–1346, Dec. 2002.

[4] H. A. Basher and S. A. Isa, "On-campus and online virtual laboratory experiments with LabVIEW," in *Proc. IEEE SoutheastCon*, Memphis, TN, 2006, pp. 325–330.

[5] L. Costas-Pérez, D. Lago, J. Farina, and J. J. Rodriguez-Andina, "Optimization of an industrial sensor and data acquisition laboratory through time sharing and remote access," *IEEE Trans. Ind. Electron.*, vol. 55, no. 6, pp. 2397–2404, Jun. 2008.

[6] S. Rapuano and F. Zoino, "A learning management system including laboratory experiments on measurement instrumentation," *IEEE Trans. Instrum. Meas.*, vol. 55, no. 5, pp. 1757–1766, Oct. 2006.

[7] M. A. Stegawaki and R. Schaumann, "A new virtual-instrumentation-based experimenting environment for undergraduate laboratories with application in research and manufacturing," *IEEE Trans. Instrum. Meas.*, vol. 47, no. 6, pp. 1503–1506, Dec. 1998.

[8] S. Dutta, "Remote Lab Web Service," 2010 [Online]. Available: http://remotelab.sourceforge.net

[9] H. Vargas, J. Sánchez-Moreno, S. Dormido, C. Salzmann, D. Gillet, and F. Esquembre, "Web-enabled remote scientific environments," *Comput. Sci. Eng.*, vol. 11, pp. 36–46, May–Jun. 2009.

[10] A. Bagnasco, A. Boccardo, P. Buschiazzo, A. Poggi, and A. M. Scapolia, "A service-oriented educational laboratory for electronics," *IEEE Trans. Ind. Electron.*, vol. 56, no. 12, pp. 4768–4775, Dec. 2009.

[11] J. García-Zubia, P. Orduna, D. Lopez-de-Ipina, and G. R. Alves, "Addressing software impact in the design of remote laboratories," *IEEE Trans. Ind. Electron.*, vol. 56, no. 12, pp. 4757–4767, Dec. 2009.

[12] V. J. Harward, J. A. del Alamo, S. R. Lerman, P. H. Bailey, J. Carpenter, K. DeLong, C. Felknor, J. Hardison, B. Harrison, I. Jabbour, P. D. Long, T. Mao, L. Naamani, J. Northridge, M. Schulz, D. Talavera, C. Varadharajan, S. Wang, K. Yehia, R. Zbib, and D. Zych, "The iLab shared architecture: A Web services infrastructure to build communities of Internet accessible laboratories," *Proc. IEEE*, vol. 96, no. 6, pp. 931–950, Jun. 2008.

[13] E. Pop, "Pop Lab at UIUC," Univ. Illinois Urbana–Champaign, Urbana, IL, 2010 [Online]. Available: http://poplab.ece.illinois.edu

[14] IOLA, "Flot," Aalborg, Denmark, 2010 [Online]. Available: http://code.google.com/p/flot

[15] S. Dutta, "Pop Lab remote device characterization," Univ. Illinois Urbana–Champaign, Urbana, IL, 2010 [Online]. Available: http://poplab-remote.mntl.illinois.edu

[16] D. K. Schroder, *Semiconductor Material and Device Characterization*. Hoboken, NJ: Wiley-Interscience, 2006.

[17] P. Arpaia, A. Baccigalupi, F. Cennamo, and P. Daponte, "A measurement laboratory on geographic network for remote test experiments," *IEEE Trans. Instrum. Meas.*, vol. 49, no. 5, pp. 992–997, Oct. 2000.

[18] M. C. Plummer, C. Bittle, and V. Karani, "A circuits II laboratory accessible by Internet," in *Proc. ASEE Annu. Conf. Expos.*, Montréal, QC, Canada, 2002, pp. 767–774.

[19] M. Vaidyanathan, "Electronics from the bottom up: Strategies for teaching nanoelectronics at the undergraduate level," *IEEE Trans. Educ.*, vol. 54, no. 1, pp. 77–86, Feb. 2010.

[20] J. Fischer, R. Mitchell, and J. del Alamo, "Inquiry-learning with WebLab: Undergraduate attitudes and experiences," *J. Sci. Educ. Technol.*, vol. 16, p. 337, 2007.

[21] N. Lewis, M. Billaud, D. Geoffroy, P. Cazenave, and T. Zimmer, "A distance measurement platform dedicated to electrical engineering," *IEEE Trans. Learn. Technol.*, vol. 2, no. 4, pp. 312–319, Oct.–Dec. 2009.

Sumit Dutta is pursuing the B.S. degree in electrical engineering at the University of Illinois at Urbana–Champaign (UIUC), expected to graduate in 2011.

In 2010, he was a Product Development Co-op Engineer with AMD, Austin, TX. He held prior internships with State Farm Insurance, Champaign, IL; the U.S. Naval Observatory, Washington, DC; and NASA, Greenbelt, MD. His research interests are in integrated circuits and nanotechnology.

Mr. Dutta is a Member of Tau Beta Pi, Engineers Without Borders, and Etta Kappa Nu (HKN) and is an Edmund J. James Scholar. He received the NASA Aeronautics Scholarship for 2009 to 2011, the Raytheon U.S. FIRST Robotics Scholarship for 2007 to 2009, and the Robert M. Janowiak Scholarship in 2010.

Shreya Prakash is pursuing the B.S. degree in electrical engineering at the University of Illinois at Urbana–Champaign (UIUC), expected to graduate in 2012.

Her research interests are in biomedical imaging and nanotechnology. She interned at Riverbed Technology, Champaign, IL.

Ms. Prakash is a Member of Women in Electrical and Computer Engineering (WECE), the International Association for the Exchange of Students for Technical Experience (IAESTE), and Etta Kappa Nu (HKN) and is an Edmund J. James Scholar. She is a recipient of the IEEE/ECE Alumni Outstanding Sophomore Award, the Rockwell Collins Scholarship, and the Oakley Foundation Scholarship.

David Estrada (S'07) received the B.S. degree in electrical engineering (EE) from Boise State University, Boise, ID, in 2007, the M.S. degree in EE from the University of Illinois at Urbana–Champaign (UIUC) in 2009, and is currently pursuing the Ph.D. degree in EE at UIUC.

From 1998 to 2004, he served in the U.S. Navy as an Electronics Warfare Technician, achieving the rank of First Class Petty Officer before an honorable discharge in 2004.

Mr. Estrada is a Member of Tau Beta Pi, the Materials Research Society (MRS), and the American Physical Society (APS). He is a recipient of the Micron, National Defense Science and Engineering Graduate (NDSEG), and National Science Foundation (NSF) Fellowships. He has received Best Poster Awards at the 2009 Society of Hispanic Professional Engineers (SHPE) National Conference and at the 2010 Hispanic Engineer National Achievement Awards Corporation (HENAAC) National Competition and the John Bardeen Graduate Research Award from UIUC.

Eric Pop (M'99–SM'11) received the B.S. and M.Eng. degrees in electrical engineering (EE) and the B.S. degree in physics from the Massachusetts Institute of Technology (MIT), Cambridge, in 1999, and the Ph.D. degree in EE from Stanford University, Stanford, CA, in 2005.

Since 2007, he has been a faculty member with the Department of Electrical and Computer Engineering, University of Illinois at Urbana–Champaign (UIUC). His group studies energy-efficient electronics with focus on carbon nanotube and graphene devices, phase-change memory, and nanoscale energy transport. Between 2005 and 2007, he worked at Intel, Santa Clara, CA, on nonvolatile memory and performed post-doctoral work with Stanford University.

Prof. Pop currently serves on the program committees of the IEDM, DRC, and ISDRS conferences, and is the faculty advisor to the Etta Kappa Nu (HKN) Alpha Chapter at UIUC. In 2010, he was named a Presidential Early Career (PECASE) award winner by the White House, the highest honor given by the U.S. Government to scientists and engineers in early stages of their independent careers. He is also a recipient of the 2010 National Science Foundation (NSF) CAREER Award and Young Investigators awards from the Office of Naval Research (ONR) in 2010, the Air Force Office of Scientific Research (AFOSR) in 2010, and the Defense Advanced Research Projects Agency (DARPA) in 2008.