EDUCATIONAL ACTIVITIES

Integration of Online Microelectronic Device Characterization and Simulation

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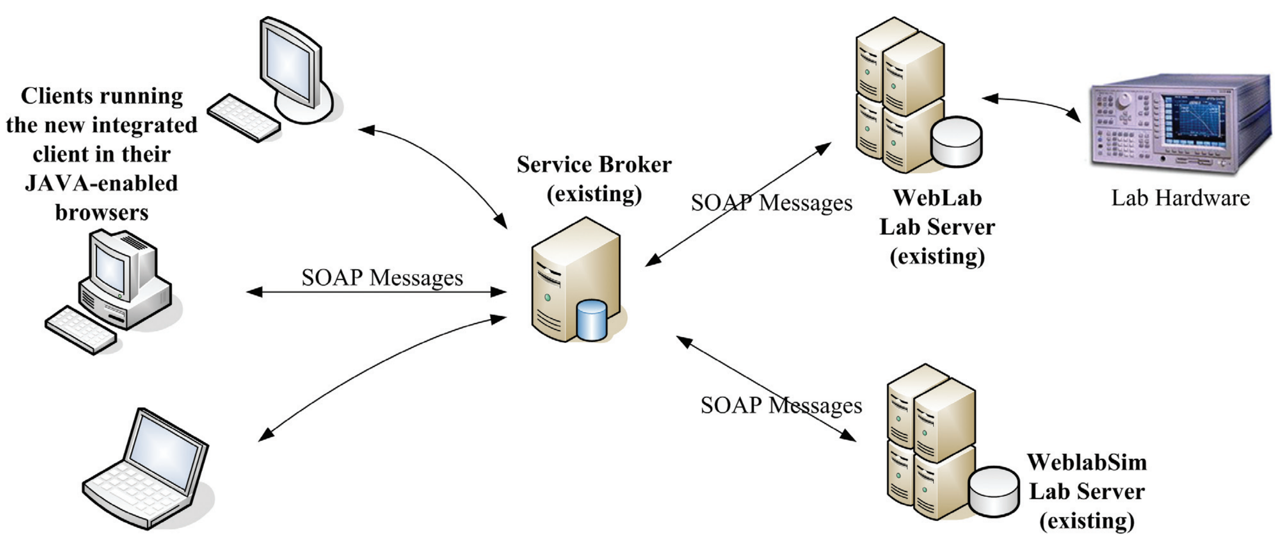
Sponsorship: iCampus (MIT-Microsoft Alliance)

In this project we created a new online laboratory that combines and significantly upgrades the capabilities of our two existing online microelectronics labs: WebLab, a device characterization lab [1], and WebLabSim, a device simulation lab [2]. The new integrated tool allows users to run, simultaneously, experiments on real devices and simulations on the virtual ones, as well as to compare the results of the two. Our hope is that this tool will enrich microelectronics teaching and learning by allowing students to compare the real-life behavior of devices with theoretical expectations.

Both WebLab and WebLabSim were built based on the iLab Shared Architecture. This means that they are both three-tier systems, consisting of a client Java applet that lets users set up the experiments/simulations, a laboratory server that runs them, and a generic service broker that mediates between the two, through SOAP-based web services. The modular infrastructure and common interfaces allowed us to integrate the two labs simply by developing a new lab front-end (Figure 1). The development was a very smooth task owing to the facts that the clients of WebLab and WebLabSim share much of their codebase and that this existing software core has been gradually perfected in the eight years of operational history of WebLab.

In addition to integrating the labs, we significantly extended the capabilities of the original clients. Two of the most interesting features we added are: 1) the ability to graph the results of multiple experiments/simulations simultaneously, on top of each other, which allows for much easier comparison and 2) the ability to load and display results of experiments/simulations that ran at any point in the past. These improvements will be made part of the main client codebase and, thus, be featured in all new releases of our online microelectronics laboratories.



▲ Figure 1: Schematic diagram of the new integrated lab as implemented on top of the existing modules and architecture.

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The ELVIS iLab: a Flexible Platform for Online Laboratory Experiments in Electrical Engineering

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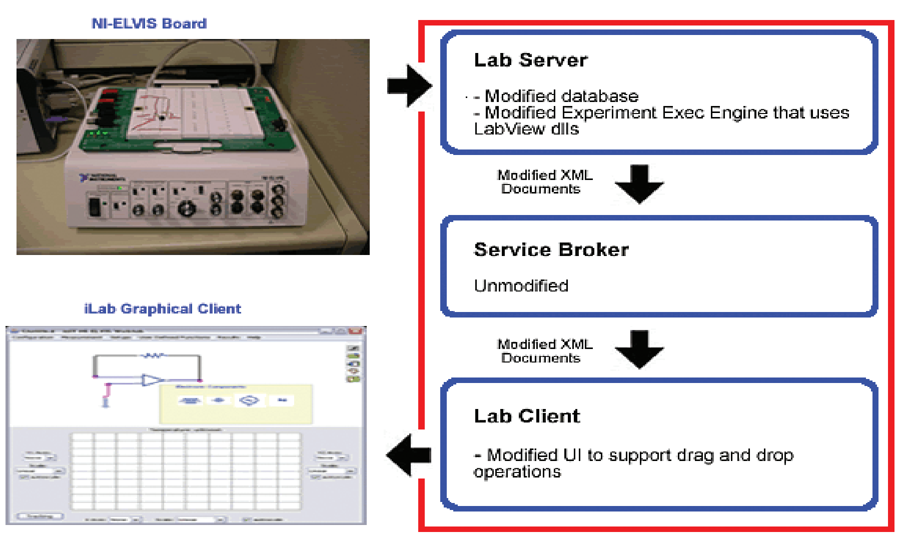
Sponsorship: Carnegie Corporation of New York, Microsoft

This project is part of the collaboration between MIT and universities in sub-Sahara Africa to exploit the value of iLabs in the developing world [1]. The main goal of this project is to develop software that will integrate the National Instruments Educational Laboratory Virtual Instrumentation Suite (ELVIS) into the iLabs shared architecture. The project takes into consideration the special circumstances surrounding the deployment of iLabs in Africa such as bandwidth limitations, limited access to networked computers, and lack of computer skills on the part of students. Integrating ELVIS into iLabs will facilitate the rapid deployment of new online labs to augment the physics and electrical engineering curricula in these universities.

The iLab development efforts for this project are being made in parallel with developers at the Obafemi Awolowo University (OAU) in Nigeria. One of the main goals of the new system is to fill the gap of laboratory experiences in introductory level electronics and physics classes, which are hardest hit by the lack of equipment due to their typically large enrollment. Our goal is to support the development of electronic circuit building skills by providing an environment where students can easily try different circuit configurations before submitting experiments for execution. We are therefore investigating new iLab client-user interface designs that will enable students to create and edit circuit schematics from provided electronic components.

Our ELVIS iLab design will also formalize and simplify the process of creating and administering such labs for instructors, thereby speeding up the deployment of new labs in an environment where software development skills are not at a premium. This will be achieved by recycling many of the components that currently lie behind the success of the microelectronics weblab [2]; these components have been adapted before for new iLabs [3]. Besides reusing existing software, the project aims to make a major contribution towards enhancing students' experiences with iLabs through its new interactive client design.



▲ Figure 1: This diagram shows how many of the microelectronics weblab components can be adapted to create software for developing new iLabs that communicate with the ELVIS board.

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[2] J. Hardison, D. Zych, J.A. del Alamo, V.J. Harward, S.R. Lerman, *et al.*, "The Microelectronics WebLab 6.0 – An implementation using web services and the iLab shared architecture," presented at ICEER, Tainan, Taiwan, 2005.

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Increasing Reliability, Reusability, and Measurement Flexibility in the MIT Microelectronics WebLab

J. Hardison, A. Haldar, J.A. del Alamo
Sponsorship: Microsoft

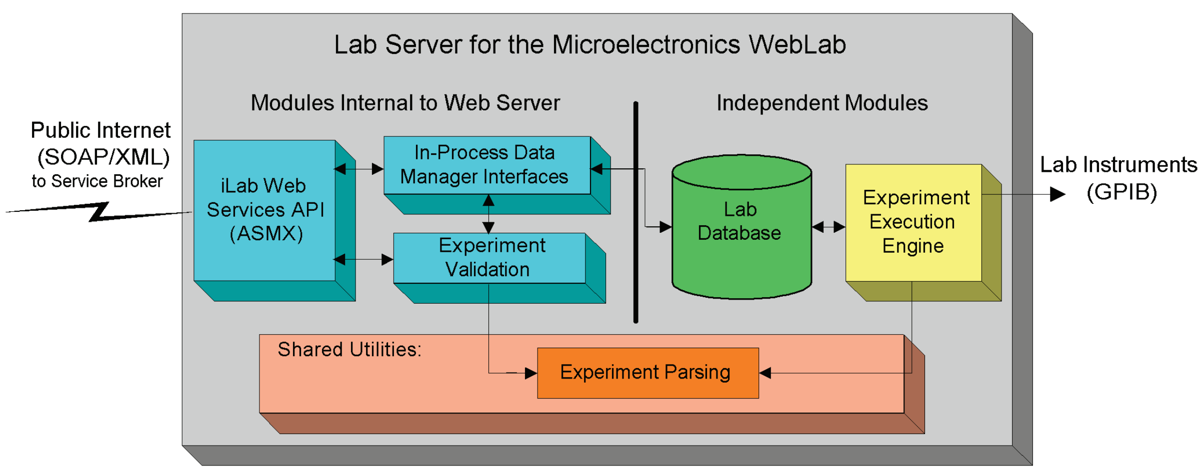
A number of updates have recently been made to the MIT Microelectronics WebLab, an online semiconductor device characterization laboratory. The most recent major release came in the Spring of 2004 with WebLab 6.0; the first lab built on the iLab Shared Architecture and an exemplar for lab development using that architecture [1]. These latest revisions focus on increasing the functionality and reliability of the lab as well as its efficacy as a reference implementation for other developers.

The functionality of WebLab has been expanded with the integration of an Agilent 41501B SMU & Pulse Generator Expander. This addition increases the measurement capacity from 100 volts and 100 milliamps to 200 volts and 1 amp, allowing the characterization of high power devices. The result is a lab with broader utility that can be used in a greater range of courses.

Revisions have also been made to the WebLab Lab Server software (Figure 1). A stand-alone utility now performs the parsing of XML-encoded experiment specification documents. Previously, this functionality was duplicated in a number of other components. The Experiment Validation module has been re-written in an effort to streamline its operation and make it easier to modify validation criteria. Finally, the WebLab Experiment Execution Engine, which governs the execution of experiments on the lab instrumentation, has been similarly streamlined and deployed as a Windows service. All of these revisions contribute to the reliability of the lab by reducing the complexity of the code base, increasing modularity, enabling easier modification, and improving the integration of the lab server software with the host server.

Additionally, these revisions benefit lab developers using WebLab as a reference. Clearly written modular components can be more easily co-opted into other labs or used as models for original components. Further, thorough documentation details the specific functionality and reusability of these revised components.

WebLab continues to be used for credited lab assignments in undergraduate and graduate level courses both at MIT and at other institutions. It is also made publicly available through MIT's OpenCourseWare initiative [2]. The WebLab source continues to be released a model for other lab developers and has been used as the basis for other online labs. The MIT Microelectronics WebLab can be accessed for in-course use at http://ilab.mit.edu or at http://openilabs.mit.edu for unrestricted guest use.



▲ Figure 1: Schematic of the Microelectronics WebLab Lab Server detailing the relationships between the revised components.

REFERENCES:

[1] J. Hardison, D. Zych, J.A. del Alamo, V.J. Harward, S.R. Lerman, et al., "The Microelectronics WebLab 6.0 – An implementation using web services and the iLab shared architecture," presented at ICEER, Tainan, Taiwan, 2005.

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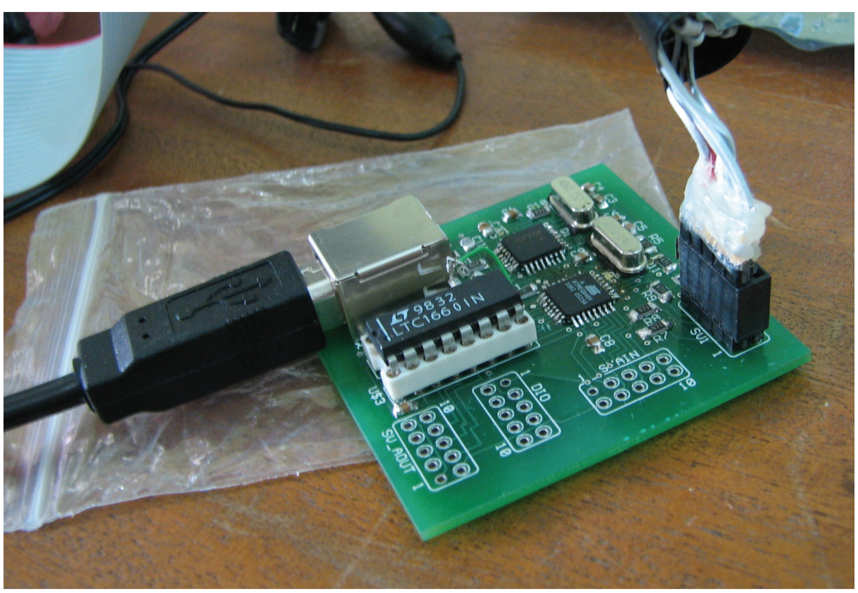
A Low-cost Platform for Online Experiments

P. Mitros, J.A. del Alamo
Sponsorship: Carnegie Corporation of New York

The goal of the iLab project is to connect laboratory instruments to the web, allowing students to perform experiments from anywhere at anytime. We are developing a low-cost platform for the development of online electronics experiments for use under the iLab architecture. With this board, instructors in the developed world will be able to quickly, cheaply, and easily deploy online laboratories relevant to specific problem sets. In addition, it will dramatically facilitate the creation of iLabs in the developing world, where students would otherwise have extremely limited practical experience, due to equipment costs.

The initial version of the platform consists of a USB-powered board with eight analog inputs, eight analog outputs, and a number of digital general purpose IO ports. This board can be used to deploy basic electronic experiments for under $30. It can be used for static and low-speed experiments, such as characterizing the input/output relationship of a logic gate or plotting the response of an integrator to a variety of waveforms. In addition, in conjunction with a daughterboard being developed, the system can function as a basic, low-precision parameter analyzer for around $40. This daughterboard can convert each set of 2 analog input ports, 1 analog output ports, and 1 digital port into one SMU port capable of outputting either a controlled voltage or a controlled current and capable of measuring both the current and the voltage (for a total of 4 SMU).

We currently have a working prototype PCB of the main board, shown in Figure 1. We have developed and tested the parameter analyzer daughterboard on a protoboard. We have manufactured, but not yet tested, a prototype PCB version of the parameter analyzer daughterboard, as well as of a candidate final version of the main board. In addition, we are working on integrating the system into the iLab Shared Architecture. We are doing a preliminary investigation of the possibility of developing similar low-cost equipment for other types of experiments, e.g., higher-speed circuits.



▲ Figure 1: The prototype iLab Mini PCB board.

Low-cost Atomic Force Microscopy for the Bioinstrumentation Teaching Laboratory

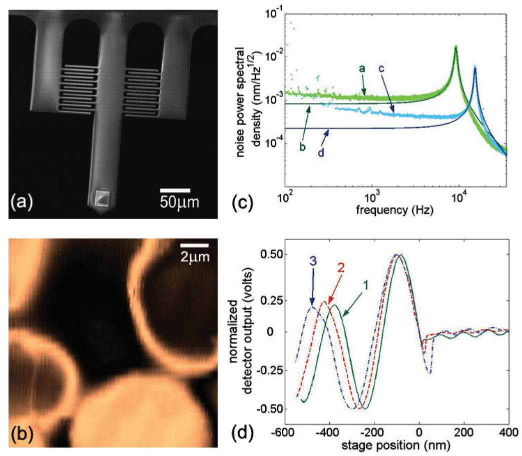
M. Shusteff, T.P. Burg, S.R. Manalis

Sponsorship: Cambridge-MIT Institute educational grant

We present a low-cost atomic force microscopy (AFM) apparatus that we have designed and built for use in an undergraduate teaching laboratory. The tool gives students hands-on access to nano-Newton force measurements, and sub-angstrom position measurements. The apparatus relies mainly on off-the-shelf components and utilizes an interferometric position sensor known as the interdigitated (ID) cantilever to obtain high resolution. The mechanical properties of the ID readout enable a robust and open design that makes it possible for students to learn about and directly control any part of it. Its instructional advantage is that students interact with a complete measurement system, and learn measurement principles in context.

This AFM enables several experiments in biomechanics and thermodynamics. Students have used it for imaging, measuring the elastic modulus of a surface, and measuring Boltzmann's constant k_B by recording the thermo-mechanical noise of the probe cantilever and applying the equipartition theorem. Further experiments for measuring molecular forces and elastic moduli of live cells are in development. In addition to gaining an appreciation of the lower limits of position and force measurement, students learn to apply numerous classroom concepts such as digital sampling, Fourier-domain analysis, noise sources, and error propagation.

The complete design details are available online at http://web.mit.edu/be/teachAFM/ .



▲ Figure 1: (a) A scanning electron micrograph (SEM) image of the cantilever probe used for imaging. The short side-levers are used as fixed reference beams and do not contact the sample. (b) A 15 μm square image of human red blood cells taken with our AFM, imaged in air after the cells were dried on a glass substrate (32 lines of data × 250 points per line, up-sampled to 400 × 400 pixels). (c) Power spectral density data of cantilever vibrations driven by ambient thermal energy (curves "a" and "c") and corresponding fits (curves "b" and "d") for 350 μm and 275 μm long cantilevers, respectively. Fitting a second-order model harmonic oscillator function to the data yields key system parameters like quality factor Q and resonant frequency f0, which allow the calculation of kB by equipartition. (d) Normalized data collected for an experiment to measure elastic modulus. The period of the oscillating section of the force curves is larger for softer samples. Force curve 1 was taken on a hard sample (silicon nitride), whereas curves 2 and 3 were taken on PDMS of variable hardness (Dow Corning Sylgard 184 mixed in ratios of 10:1 and 25:1, respectively).

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Microfabrication Project Laboratory (6.151)

Technical Instructor, L. Wang

This laboratory course is offered in the spring semester for students that have already completed 6.152J. The course is designed to teach experimental microfabrication process design. The students of this subject are given a broad process goal, namely to build a device, and they are challenged to design and develop a process sequence. Typically, the entire class (4-6 students) works on one device, and they partition the integrated process into a set of unit process sequences. Work proceeds first, on the development of the unit processes, and then, on the integrated process. In recent years, the students have succeeded in microfabricating micromachined contactors for integrated circuit testing, flexible electrode arrays for retinal implants, and microcantilevers for AFM applications.

Micro/Nano Processing Technology (3.155J/6.152J)

Technical Instructor, L. Wang

This combination laboratory and lecture course is offered and taught jointly by the Department of Electrical Engineering and Computer Science and the Materials Science and Engineering Department. The course includes weekly lectures on all aspects of micro/nano processing technology with design problems to teach process design. Additionally, the course includes weekly laboratory sessions conducted in the MTL. During these sessions, each student fabricates a wafer of poly-silicon gate MOS devices, silicon nitride nano-mechanical devices, and a plastic microfluidic mixer. All the devices and structures are tested and laboratory reports correlating the test results with theoretical expectations culminates the education experience. The course is offered every semester, and a laboratory-only version of the course is offered 3-4 times/year.