A Web Service and Interface for Electronic Device Characterization

Sumit Dutta, Shreya Prakash, David Estrada, and Eric Pop

Department of Electrical and Computer Engineering, Micro and Nanotechnology Laboratory, University of Illinois at Urbana-Champaign

2010 ASEE Annual Conference & Exposition Session 2232
Labs for Everyone

Specialized Lab Software

Universal Web Software
The Theory Course Dilemma

• Large enrollment often
• Lab course challenging to set up
  - Facilities $\rightarrow$ expensive (> $100k)
  - Instructors $\rightarrow$ limited
• Consequence: exclusive focus on theory
• Solution:
  - “Lightweight” web interfaces for lab instruments
  - Use existing instructional or research lab
Outline and Objectives

• Goal: Lab exposure in theory classes
• Enabling virtual test and measurement with Web Services
• Creating Web interfaces for students
• Suggestions based on application in solid-state electronics course
Outline and Objectives

- Goal: Lab exposure in theory classes
- Enabling virtual test and measurement with Web Services
- Creating Web interfaces for students
- Suggestions based on application in solid-state electronics course
Web Service and Interface

**Backend**
- Device Under Test (DUT)
- Keithley 2612 Source-Measurement Unit
- GPIB, IEEE-488 (GPIB)
- LabView 8.6 Web Service Server

**Frontend**
- Website (AJAX client)
- HTTP GET
- XML

Web-based Learning in ECE

Dutta
Lab Setup

Keithley 2612

Server with LabView WS

Device Under Test

50 µm
LabView Web Service Requests

- Client-activated session management
  - Data Provider (connect/disconnect)

- Client-activated test queue
  - Queue Handler (test submission/canceling)

- Internal process
  - Queue Manager (dequeue tests)
  - Instrument Control (driver)
Outline and Objectives

• Goal: Lab exposure in theory classes
• Enabling virtual test and measurement with Web Services
• Creating Web interfaces for students
• Suggestions based on application in solid-state electronics course
Lightweight Messaging & Interface

• Consume ReSTful Web Service
  - User requests by HTTP GET
  - LabView response in XML

• AJAX used for underlying messaging
  - All tasks accomplished with mouse clicks
  - Plot continuously refreshes itself with data from instrument’s currently running test
Stability of Technologies

• Web Service
  - XML understood on virtually all platforms
• Website interface
  - AJAX conducive to Web Services support
• Many other possible interfaces
  - Java applets
  - iPhone app
  - Application extensions
PopLab Remote Device Characterization

Test Parameters

- Run $I_d-V_G$ (transfer characteristic) test
- Run $I_d-V_D$ (output characteristic) test

- Applied Drain Bias Voltage: $0.050000$ V
- Starting Gate Voltage: $-10.0000$ V
- Stopping Gate Voltage: $10.0000$ V
- No. of Points in Gate Voltage Sweep (approx.): $97.0000$

Test Status

Your test request was accepted. The test is in position 1 in the queue and will be run after tests submitted earlier are completed.

Notes

Some common transistor notation:

- $I_D$: Drain current
- $V_G$: Gate to source voltage
- $V_D$: Drain to source voltage

Dutta
Data Quality

- 500+ bytes per data packet
- Data acquisition rate within 10 Hz
- Rate adjustable for desired measurement sensitivity

Local test $V_T = -1.92$ V
Remote test $V_T = -2.18$ V
Outline and Objectives

• Goal: Lab exposure in theory classes
• Enabling virtual test and measurement with Web Services
• Creating Web interfaces for students
• Suggestions based on application in solid-state electronics course
Online Real Time MOSFET Measurements in ECE 440

Websites Used

1. PopLab Remote Instrument
2. Answer Submission Survey

Instructions

You will perform measurements on a MOSFET located in the Pop Lab.

1. If you are off-campus, first connect to the U of I network using VPN.
2. Open the PopLab Remote Instrument (opens in a new window).
3. Click "Connect."
5. Set $V_D = 0.05 \text{ V}$ and $V_G$ to go between $-10 \text{ V}$ to $10 \text{ V}$.
6. Ask for about 30-60 data points (you may get fewer).
7. Once ready, click to "Request and Run" the test (test will take ~30 seconds).
8. Copy/paste the raw data output to a spreadsheet or text file for further analysis.
9. Click "Disconnect."
10. Please fill out the answer survey (opens in a new window).

Notes on using the interface:

- You will only see data if you are connected (be sure to click "Connect"). If another user is connected, you will see his or her test running and then your test will run. Your tests will generally be labeled as "My Test," though in some browsers your test might get misidentified as someone else’s, in which case you should identify your test based on when the results appear.
- If $I_D$ goes below zero, you may take those values to be zero.
- On rare occasions the first point in the test will actually be from the previous test due to a glitch in the instrument. Please disregard any unusual first points.
- You may receive fewer points back than requested depending on the latency of your connection. Try requesting at least double the points you really need to get all data.
- If you have questions please contact sdutta3@illinois.edu.
Online Real Time MOSFET Measurements in ECE 440

1. Is this MOSFET an n-channel (nMOS) or p-channel (pMOS) device?
   - nMOS
   - pMOS

   You may extrapolate the threshold voltage from the point where the transistor current reaches nearly 0 A.

2. What is the threshold voltage, $V_T$, in volts?

   You may extract the mobility by using the MOSFET current equation for operation in linear mode:
   $$|I_D| = \mu C_{ox} (\frac{W}{L}) (|V_G| - |V_T|) (|V_D|/2)^2 |V_D|$$

   Important parameters that will be useful for your calculation include:
   - Width, $W = 36 \mu m$
   - Length, $L = 8 \mu m$
   - Oxide type: Silicon dioxide
   - Oxide thickness: 20.7 nm

3. What is the effective mobility, $\mu$, in cm$^2$/V-s?
Feedback & Integration into Courses

• Highest impact in theoretical classes
  – Complements curriculum, does not replace it
  – Instructional lab classes still valuable

• Different instruments/tests in Web Service

• Different interface for each audience

• Assign a test and data analysis problem for each topic, before exam
Conclusions and Direction

• Low-bandwidth, real-time lab measurements with Web Services
• Introduce as ancillary, new aspect of theoretical classes
• Flexible and reusable
• Could further standardize
  - Web Services Resource Framework
Download It!

- Remote Lab Web Services
  http://remotelab.sourceforge.net

Our Implementation Uses:
- LabView 8.6 software
- Keithley 2612 hardware
Acknowledgments

- Mark Bohr at Intel for hardware donation
- Dr. J. C. Lee for LabView assistance
- Josh Potts and Jeremy Bird for IT support
- NSF CCF-0829907 and CAREER ECCS-0954423
Web Technology Illustrated

Test Parameters

- Run $I_D-V_G$ (transfer characteristic) test
- Run $I_D-V_D$ (channel) test

Applied Drain Bias Voltage: 0.05 V
Starting Gate Voltage: -10.00 V
Stopping Gate Voltage: 10.00 V
Incremental Steps of Gate Voltage: 32

Request and Run Id-Vg Test

Response Sent to Client, Interpreted by Client
Web-based Learning in ECE

Dutta