Enhancing Student Learning Through State-of-the-Art Systems
Level Design and Implementation: The Development of a Lower Division Learning Module

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Lower Division Printed Circuit Board (PCB) Design Experience

- Background for project
- Curricular requirements for two modules
- Development of tutorial module
- Development of laboratory experiment
- Status and plans for project
- Conclusions
Background

• Few engineering colleges have PCB electronic manufacturing
  – 300 engineering colleges
  – 24 ABET manufacturing engineering programs
  – 35 ABET manufacturing technology programs
• Cal Poly has manufacturing engineering program and laboratories
  – History of use of PCB in senior project

Background

• Recent history of electronic manufacturing
  – 1990’s proposed incorporation into curricula without manufacturing
    • Development of new laboratories
  – New manufacturing engineering programs
• Now, development of web-based PCB fabrication services
  – Tutorials for PCB design tools
• Recognition that PCB technology is available to all lower division engineering students
  – Possible to extend to K-12 schools also
Curricular Requirements

- Purpose: Integrate design, fabrication, assembly and testing of PCB electronic systems into curriculum of all lower division engineering students
- Development of two learning modules
  - Tutorial learning module: hands-on PCB technology
  - Laboratory learning module: replace standard op-amp experiments in lower division EE course/lab

Curricular Requirements

- Integrate modules into lower division EE service course for all engineering students
- Replace two lab experiments taken during a five week period
- Lecture before first lab on principles of electronic manufacturing
- First lab: tutorial on PCB
  - Produce basic continuity tester
  - Design PCB and assemble
Curricular Requirements

• First lab to second lab: op-amp project
  PCB design and experiment
  – Students design PCB, submit to web vendor
  – Students order parts over web
  – Student assemble op-amp PCB
• Second lab: students use their op-amp
  PCB to perform standard lower division
  experiment

Curricular Requirements

• Summary of requirements for engineering
  program
  – Acquire two learning modules (free on web)
  – Soldering station (est. $50/workstation)
  – PCB tutorial and parts (est. $10/student)
  – Substitute laboratory learning module for
    existing op-amp experiments (est. $40/
    student)
  – Note: lab fees could be used to cover costs
Tutorial Module Development

- Survey on existing PCB Computer-Aided-Design tools completed
  - DipTrace chosen as PCB design tool
  - Free evaluation copy without Gerber file output (students can use)
  - Gerber file available for $125/seat for academic institutions (one or more seats for students to access)

Tutorial Module Development

- Continuity tester is hands-on project
  - Tutorial module to design PCB

Figure 2 Top View of Continuity Tester
Tutorial Module Development

Table 1: Bill of Materials of the Continuity Tester

<table>
<thead>
<tr>
<th>ITEM</th>
<th>QTY</th>
<th>REF</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>601</td>
<td>Model: VC600A, 1000 V, 20 mA, 100 mA, 1000 mA</td>
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<tr>
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<td>1</td>
<td>602</td>
<td>RS-150-50, 15 µF, 50 V, Panasonic 10±5% Tolerance</td>
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<tr>
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<td>1</td>
<td>603</td>
<td>1.8 A, 12 V, 1/2 W, Fushan</td>
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<td>4</td>
<td>1</td>
<td>604</td>
<td>3A, 12 V, 1/2 W, Fushan</td>
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<td>605</td>
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<td>6</td>
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<td>606</td>
<td>Screw, 5/32&quot; x 1/8&quot;, Phillips</td>
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<td>7</td>
<td>1</td>
<td>607</td>
<td>Switch, 10 A, 1,000 V, 90% tolerance</td>
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<tr>
<td>8</td>
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<tr>
<td>12</td>
<td>1</td>
<td>612</td>
<td>C-1200-12</td>
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</table>

Laboratory Module Development

- **EE service course usually covers circuits, electronics and electrical energy conversion**
  - Concurrent laboratories
  - Lower division courses

- **Standard topic is theory and application of op-amps**

- **Op-amp laboratory experience usually two labs**
Laboratory Module Development

- Rearrange two op-amp labs
  - First lab for PCB tutorial
  - Second lab op-amp experiment
    - Three weeks between first and second lab
      - Design PCB, fabrication on web
      - Order parts on web
      - Assemble PCB before lab
    - Students perform op-amp experiments
      - With PCB, less overhead to use more circuits
      - Goal is same op-amp learning objectives met

- Uses PCB design to perform experiments

Laboratory Module Development

Figure 3 Prototype op-amp PCB for Laboratory Learning Module
Status and Plans

- Preliminary testing with 13 Allan Hancock students Spring 2008
- Performed tutorial module
  - DipTrace tutorial
  - Continuity tester using tutorial
    - Parts provided
- Students successful in completing assignment
Status and Plans

- Performed modified laboratory module
  - Chose one of four op-amp circuits
  - Instructor integrated four designs on one PCB
    - Submitted integrated PCB for fabrication
    - Using student input ordered parts
  - Students assembled PCB and tested
    - Four examples to be viewed

- Preliminary assessment performed
  - Parts difficult to identify, especially switch
  - Time was an issue
Status and Plans

- Time an issue
- 21 hours to complete

<table>
<thead>
<tr>
<th>Task</th>
<th>Average time (hrs)</th>
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<tbody>
<tr>
<td>DipTrace tutorial</td>
<td>5:40</td>
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<tr>
<td>Continuity tutorial</td>
<td>3:23</td>
</tr>
<tr>
<td>Soldering video</td>
<td>0:44</td>
</tr>
<tr>
<td>First lab/write up</td>
<td>2:50</td>
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<tr>
<td>Design op-amp</td>
<td>5:53</td>
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<tr>
<td>Design approval</td>
<td>0:30</td>
</tr>
<tr>
<td>Second lab session</td>
<td>2:02</td>
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<tr>
<td>Total Time</td>
<td>21:02</td>
</tr>
</tbody>
</table>

Status and Plans

- Issues to resolve
  - Time to complete too long: 21 hours
    - Expect around 10 hours including 6 hours of labs
  - More effort required for instructor
    - Ordering parts, consolidating PCB designs and submitting for fabrication
  - Op-amp pedagogy/PCB time tradeoff
  - Requirement for more material to support instructor
Conclusions

- Tutorial material has been developed
- Students have tested the materials
  - Modified original plan to meet time constraints
- Issues have been identified
- Address the issues in the next year and one-half of the project
- Students liked the PCB project
  - “Took circuits to the next level”

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  **3453: Innovations in Manufacturing Education**
  Wed 7:00-8 18 a.m. David L. Lawrence Convention Center, 323
  
  **AC 4005: A PROJECT-BASED ELECTRONICS MANUFACTURING LABORATORY COURSE FOR LOWER-LEVEL ENGINEERING STUDENTS**

  **3432: Project-Based Learning in ECE Education**
  Wed 12:30-2:45 p.m. David L. Lawrence Convention Center, 315
  
  **AC 2088-2186: CURRICULAR ENHANCEMENT TO SUPPORT PROJECT-BASED LEARNING IN COMPUTER AND ELECTRICAL ENGINEERING**

  **0232: Embedded System Design using the FPGA Workshop**
  All day workshop on Sunday