AC 2010-250: PREPARING FOR ENGINEERING 2020: A NEW COURSE IN ELECTRONIC MANUFACTURING FOR ELECTRICAL AND COMPUTER ENGINEERING MAJORS.

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Preparing for Engineering 2020: A New Course in Electronic Manufacturing for Electrical and Computer Engineering Majors.

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ABSTRACT
A new course in electronic manufacturing for senior electrical and computer engineering was developed at Indiana University Purdue University Indianapolis (IUPUI) to incorporate importance of information technology and processes in engineering. The course covers elements from engineering 2020 objectives. This includes new technology with industrial involvement towards the application specific integrated circuits, printed circuit board design, and micro electro motion (MEMS). A layout editor, Catapult software and L-Edit, software from Tanner research Inc have been utilized for the custom ASIC design.

The course was offered before at IUPUI with the two components ASIC &FPGA, and PCB technologies, and then modified to feature MEMS technology. The paper details the contents and the CAD tools used in the design. The course was three credit hour delivered in one semester (16 weeks) in three separate modules, one credit hour each. Students can register for one or more module within a semester period. The industrial partner at the Indiana Life Sciences Inc. was part of the teaching team for the PCB and MEMS sections.

I. INTRODUCTION
With the continued and rapid increase of technology, electronic manufacturing has become a significant sector in manufacturing industry. Electronic production world wide is undergoing a revolutionary change at both component and system levels, utilizing chip and board technologies. The new technologies have reduced component size and costs and have improved reliability and safety of the electronic products. Electrical and computer engineering education recently has been following changes to integrate new technologies into curricula and keep up with the fast pace leading to prepared engineers who can contribute to improvement of quality life incorporating business, social, and ethical issues.

The field of electronic manufacturing is a multidisciplinary area that encompasses several technologies from electrical, materials, industrial, chemical, and computer engineering. For example, circuit analysis, digital and analog electronics, software, CAD/CAM, automation, and production planning are necessary for students to learn the latest microchip and PCB technologies. We believe that the growing electronic manufacturing industry will demand increasingly of this multidisciplinary area.

Microchip ASIC and FPGA based components require innovative changes in computer and board design algorithms, testing, and inspection. The sophisticated automation systems of the future will require planners, designers, and operators who possess a higher degree of knowledge and technical skills. This makes it mandatory that institutions develop state-of-the-art programs to equip their graduates with the latest information for a rapidly changing domestic industry.

Engineering 2020 concerns designing an engineering curriculum that grows to meet or exceed current and future demands. This is based on vision, values, variability, knowledge and awareness of the inherent worth of people [1]. In this work, we describe a state-of-the-art, multidisciplinary undergraduate course in electronic manufacturing that satisfy elements from engineering 2020 objectives. The course integrates knowledge from different technologies with application in life sciences. The course incorporates four technology processes: ASIC, PCB, FPGA, and MEMS into engineering application. Indiana Life Sciences Inc. located at Indianapolis, Indiana, will be hosting the manufacturing facility of PCB surface mount based boards. MOSIS services are utilized for the manufacture of ASIC microchip. L-Edit, a lay out editor from Tanner Research Inc is used for the ASIC part of the course. The course is a collaborative effort from the ECE faculty at IUPUI and the Indiana life Sciences Inc, Indianapolis Indiana.

II. DESCRIPTION OF THE COURSE:

The new developed electronic manufacturing course consists of material that includes ASIC design, PCB, FPGA, and MEMS. The course in its first phase was taught by two instructors for the first two components: ASIC and PCB design, while the other two components are added and will be taught in Fall 2011. The course in its first phase exposes students to electronic manufacturing aspects of the design of integrated circuits and printed circuit boards. ASIC part of the course is described as:

Part I: ASIC Design

In this part of the course, students are introduced to the device aspects from layout point of view. The MOS device is modeled to include the secondary effects of short channels. Simulation results utilizing the model are generally in agreement with those of actual digital systems. In five weeks, students are required to design and generate the artwork file for manufacture. The material covered in this period is:

- Historical background on IC design that started with the invention of the point transistor, until recent technology of 2000s.
- Difference between CMOS and BJT technologies in all aspects: integration, power, N.I. (noise immunity), drivability, speed, etc
- Short channel considerations: mobility degradation, hot electrons, electromigration, aluminum spiking, etc.

- Introduction to IC CMOS fabrication, layout, design rules, and CAD tools.
- Layouts for logic gates and memories using L-Edit Software [2] (PC based lay out tools)
- Lab components with Catapult [3]: Catapult work flow, getting an algorithm ready for synthesis, understanding interface synthesis, streaming, integrated system C verification flow, using memories in catapult C, Loop pipelining.
- Project samples:
    - DCT
    - Matrix manipulation
    - Sequential circuit
    - FIR filter
    - IIR filter

Lab Component Using Catapult C:

1. Catapult C Workflow and setup design and generating the RTL
2. Getting an Algorithm ready for Synthesis
3. Understanding the Interface Synthesis
4. Understanding the Interface Synthesis-streaming
5. Integrated System C Verification Flow
6. Using Memories in Catapult C
7. Loop Unrolling and Loop Pipelining
8. Interactive and Iterative Analysis and Optimization Process

Flexibility with the ASIC Design

The course project gives the opportunity to students to implement their design with FPGA utilizing Xilinx tools. With the FPGA background that students receive from the pre-requisite course, students can choose to do the FPGA design using Xilinx tools. In this new course, they may write the VHDL code and download it to generate the FPGA circuit. The VHDL code is also covered in a pre-requisite course. As per our experience, we have seen varieties of students are using L-Edit for ASIC project, Xilinix for FPGA, or Mentor Graphics (Unix based tools) for top down design approach.

Part II: Printed Circuit Board Assembly

The basic challenge in five weeks of the course is to teach students enough about manufacturing technology, circuit board layout design practices, and a design automation tool to provide them with an overview of the electronic manufacturing process. Emphasis is placed on learning surface mount component package styles, and their placement on top and bottom sides of 2 to 6 layer fiberglass-epoxy boards. The common manufacturing processes for these boards are studied, and students will have a first hand opportunity to practice some of these processes as described below:

- Familiarization with CAD tools
- Component placement

- Automatic component placement
- Routing
- CAM files for routed boards
- Design Project: Typical projects: Burglar alarm, traffic light controllers, elevator control circuit, or in general sequential circuit design.

Figures 1 shows the manufacturing process of a PCB design, while figures 2& 3 show the auto placement and the autorouting tools of the CAD of the PCB CAD

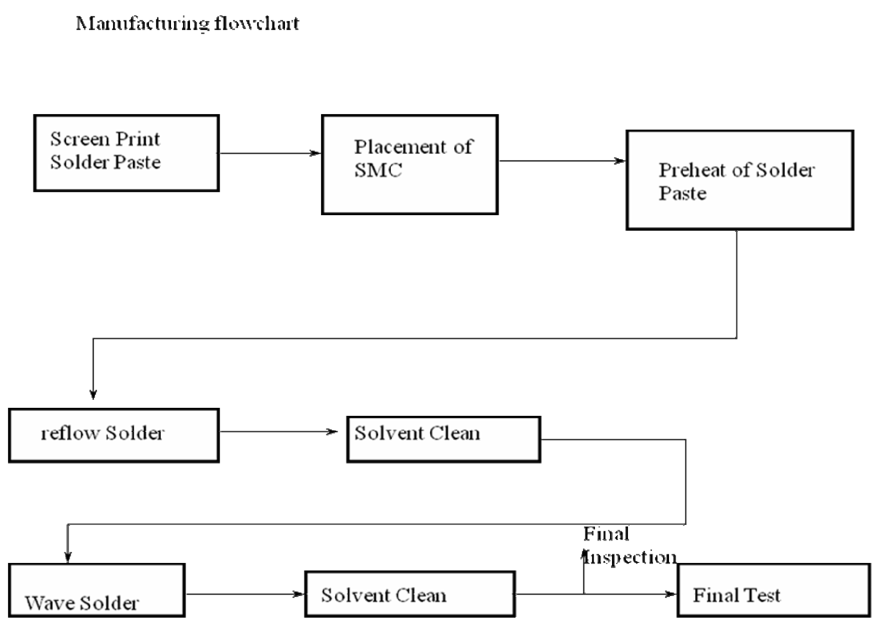

Figure : The manufacturing Process

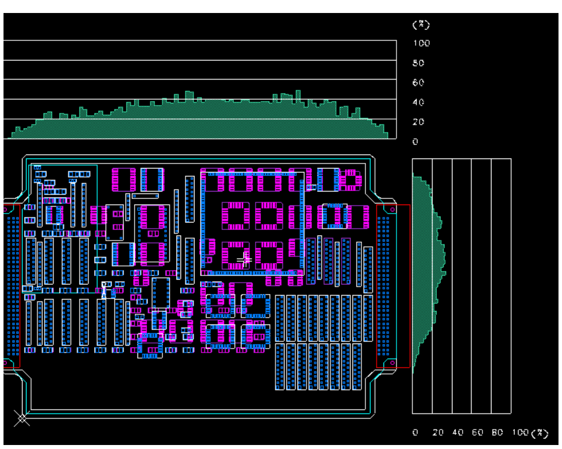

Fig 2: Component placement by auto placement

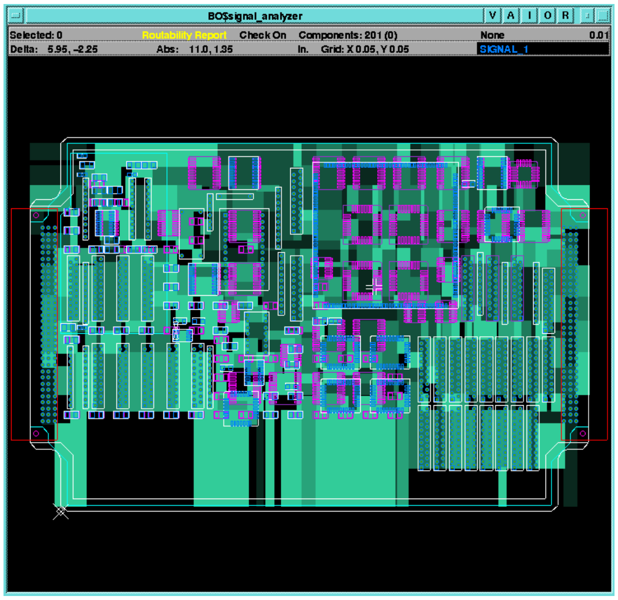

Figure 3: The PCB layout as laid by the auto router

Part III: MEMS

This part of this course is presented to explore the world of MEMS by understanding its design and fabrication aspects. More specifically, students learn that MEMS are sensors and actuators that are designed using different areas of engineering disciplines and they are constructed using a microlithographically-based manufacturing process in conjunction with both semiconductor and micromachining microfabrication technologies. Different examples of MEMS designs and fabrication technologies would be studied that are currently employed in a wide range of devices, including microaccelerometers for crash detection in vehicles, and pressure sensors for implantable medical devices. The results of case studies and course project will prove the benefits of MEMS devices, which include small size, low power consumption, ease of integration into arrays, potential for monolithic integration with electronics, and low cost in high volume. The material covered in this part is:

- An overview of MEMS devices and technologies.
- Material properties and fabrication methods
- Sensing of position and strain
- Pressure sensors and accelerometers
- MEMS system design
- Design Project: Design a pressure sensor

III. Sample of a Multidisciplinary Project:

RF CMOS Voltage Controlled Oscillator (VCO) that is capable of generating an output frequency near 5GHz for monitoring neural and cardiac activities. The circuit topology has been chosen to achieve such high frequency with high Q-factor. The team project works on the transmitter circuit and its layout with L-Edit software is given. This includes the prescribed inductances and capacitances required to achieve the design specifications. Figures 4 and 5 show the schematics of an rf amplifier that was simulated with PSpice, and the result is given in figure 6. The results provide the 5 GHz VCO that meets the design specifications. The effect of L and C values in the oscillation frequency is given in figure 7. Figure 8 shows the Layout of the circuit. It is noticeable the circuit function sensitivity to the inductance and capacitance values. The specifications of the layout are given based on the device dimensions as reported in table 1. The oxide capacitance and junction resistances are given also in table 1. The circuit was designed to

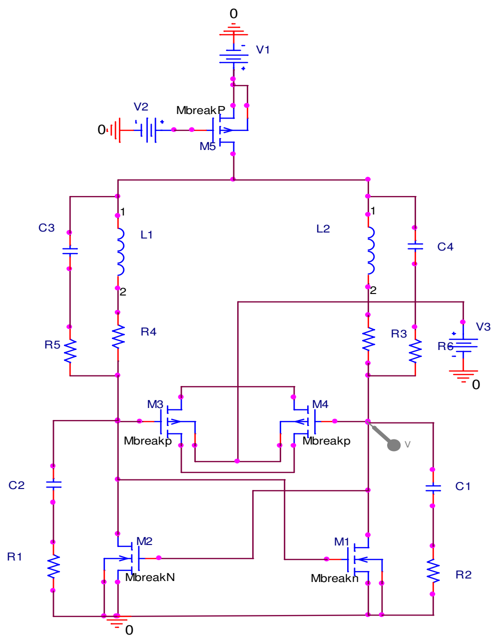

Figure 4: VCO topology used

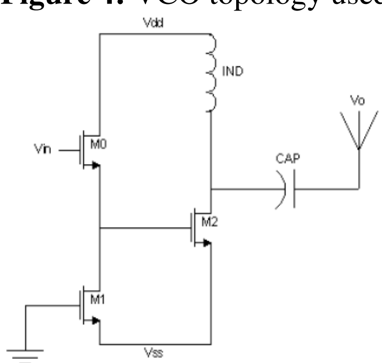

Figure 5: Class-C Power Amplifier: Used to increase the amplitude of the signal. It is required because a higher resistance, needed to increase the Q-factor, can decrease output amplitude.

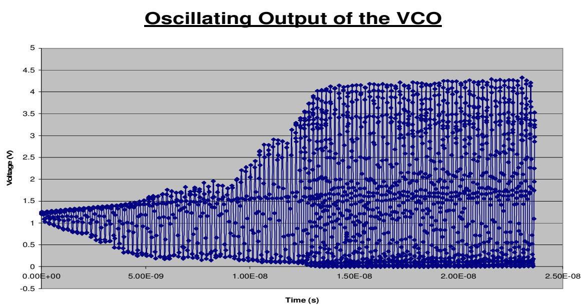

Figure 6: Oscillations in the VCO Output

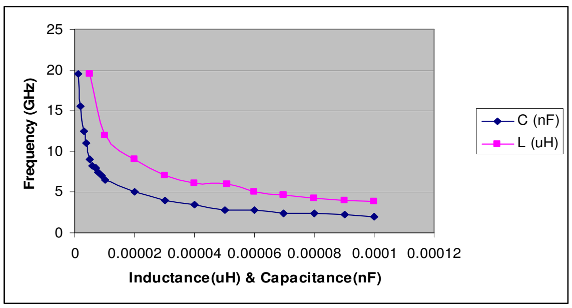

Figure 7: Variation in frequency w.r.t Inductance (L) and Capacitance© values

Table 1: Table showing parameters used in MOSFET modeling

Model Parameters	NMOS	PMOS
Level	1	1
W	176um	176u
L	350nm	0.35n
Kp	69ua	34.5 ua
Cgdo	40pf	40 pf
Cgso	40pf	40 pf
Cj	200uf	200 uf
Rd	1	1
Rs	1	1
lambda	0.06	0.06
Tox	0.04u	0.04u
gamma	0.37um	0.37

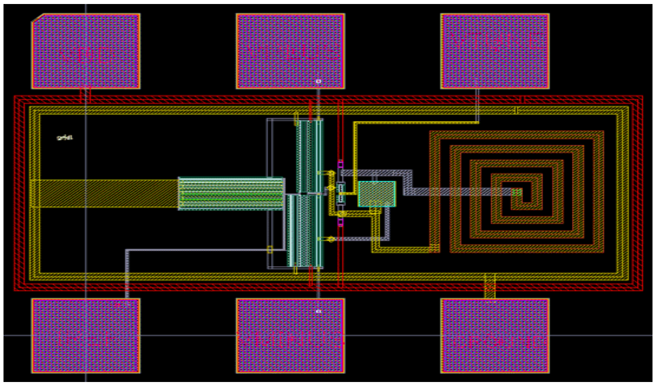

Figure 8: The IC layout of the VCO with Guard rings to avoid "crosstalk." Using L-Edit software

Note: The above sample project combines applications related to health sciences and has elements in communications, electronics, and analog integrated circuits. This project was partially funded by MURI program at IUPUI

IV. Results and Discussions

This course as a three one credit modules (total 3 credits) was offered for the first time in Fall 2007. The three modules were ASIC design, PCB design, and MEMS. The following survey was taken for 21 students who attended both ASIC and PCB design. Highest score was 5.0 and lowest is 1.

1. I intend to pursue a career in electronic manufacturing or a closely related area 3.77
2. I enjoyed Catapult software used in this ASIC design course 3.77
3. I found computer laboratories with ASIC design easy to follow and helpful for the project 4.05
4. I feel like I' m gaining confidence to do hardware design with ASIC or PCB 4.17
5. I am interested to pursue an engineering job in related areas (PCB or ASIC) 3.62
6. this course has given me a better understanding of hardware design 3.47
7. Courses like this one motivate me to put effort into my studies 4.09
8. I would like to do projects with L-Edit custom design software 4.25
9. I would love to take another course in DSP where Catapult is used in the hardware design of processors 4.41
10. Topics covered in this course met my expectations 3.80
11. Working with groups in both ASIC with Catapult and PCB with OrCad was important 4.50
12. If I were to take technical electives, I would like to take another course in this area such as VLSI design and DSP processors. 4.45
13. The hands-on aspects of the course made it interesting 3.66

14. The computer facilities added to the quality of my experiences in this course 3.93
15. I enjoyed the interdisciplinary nature of this course (elements of PCB and ASIC design) 4.27
16. The ASIC design was appropriate since it uses C programming rather than VHDL 4.60
17. As compared to other elective hardware courses you have seen in the curriculum, this course is ranked 4.34
18. overall, taking this course was enjoyable experience 4.40

Conclusion:

The design of the course was motivated by the local industry in the area of Indianapolis, and by the student interests in microelectronics and CAD tools. The course was developed and taught under team efforts from industry and academia. The ECE department at IUPUI has provided the release time for the development of the course.

The approach followed here for the ASIC design utilizing Catapult C allows electrical engineering undergraduate students who do not have UNIX based program to use Mentor or Cadence tools, to write C code that can be converted by Catapult C to generate the VHDL code. Students at the junior level were able to achieve good size projects using both Catapult and L-Edit software.

The course is multidisciplinary in nature, where electrical engineering and computer engineering can work together. The course can be open to mechanical engineering students since they had the digital electronics background in their (ECE204 course: Electrical and Electronics Circuits).

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