

## Teaching Statement

Ajay Joshi

Boston University

Department of ECE, 8 Saint Mary's Street, Boston MA 02215

April 2, 2015

---

Since starting as an Assistant Professor at Boston University in Fall 2009, I have taught 4 different courses: 1) EK131/132 (Introduction to Engineering - Electronic Control of Robots); 2) EC311 (Introduction to Logic Design); 3) EC571 (Digital VLSI Circuit Design); and 4) EC772 (VLSI Graduate Design Project). EK131/132 is primarily a Freshman course, EC311 is a Sophomore/Junior course, EC571 is a Senior/Graduate course and EC772 is an advanced graduate course. I strongly believe in coupling theory with practice, and hence ensure that students get the experience of putting into practice the knowledge gained in lecture. Hence, in all my courses students get hands-on experience through labs and projects. **Overall my courses have been well received, and for that I was awarded the Boston University ECE Department Award for Excellence in Teaching in 2014.** A more detailed description of the courses is provided in Section 1

In addition to formal classroom teaching, I have also actively mentored undergraduate and graduate students in a research setting. In addition, I host high-school students every summer through the BU Research Internship in Science and Engineering (RISE) program, which provides an opportunity to high-school students to perform research in University labs. I was also guest lecturer for BU's Upward Bound Math Science Vacation week. A more detailed discussion about my outreach and mentoring activities is given in Section 2 Section 3.

Moving forward, I would like to adopt the 'Flipped class' approach while teaching EC571 and EC311. I would also like to offer a course on advanced topics in digital circuit design. This course will serve as an intermediate course between EC571 and EC772. Section 4 discusses the rationale for adopting the 'Flipped Class' approach and the new course on digital circuit design.

## 1 Courses

### **EK131/132 (Introduction to Engineering - Electronic Control of Robots) - *Fall 2011, Fall 2012, Spring 2014, Spring 2015***

EK131/132 is a Freshman course, and I developed a new section on 'Electronic Control of Robots' for this course in Fall 2011. Since 2011, this section has been offered in each academic year. The goal of this section is to expose students to electrical devices, circuit design, digital logic design and programming of embedded computer systems. Using robotics as an underlying theme, students get hands-on experience working on one circuit design lab, one digital logic design lab and two programming labs. In the last week of the course, the students complete a project on programming the iRobot Create to trace the alphabets B and U or programming the iRobot Create to find its way out of the maze.

Coming straight out of high school, this course can be very challenging for Freshman students. However, I have seen students rise up to the challenge and excel in the course. The course enrollment has always been close to full capacity every time I taught this course. Some of the students comments (from BU course evaluations) are as follows:

- "Actually learned about engineering compared to others in EK"
- "Labs were pertinent and relevant as they helped me problem solve and pushed me to think like an engineer.... "
- "Great job at presenting everything. I really learned a lot and am excited for higher level courses about the material."

- “I enjoyed the course, the materials covered, and the difficulty of the course. It was challenging while allowing me to learn.”
- “Course gave me a good idea of applications of eng. Although it was challenging, I felt this class was a good introduction to many practical and valuable skills.”

In addition, I have also received valuable feedback in terms of how I can improve the course. One primary criticism was the amount of work required to complete the labs. Based on this feedback, I have made modifications to the lab components of the course such that students are able to complete the labs in a timely manner and at the same time get plenty of experience with solving engineering problems.

### **EC311 (Introduction to Logic Design) - *Fall 2010, Spring 2012***

The class covers the theory and practice of digital hardware design. Students learn to formulate real world tasks using Boolean algebra and FSM theory, and to apply manual and computer-aided techniques to solve the problems. I believe that the best way to learn digital logic design is through hands-on experience. Hence, my course has several lab assignments where students learn the fundamentals of logic design and verification skills using Verilog HDL and FPGAs. In addition, the course also has project assignment. The various student projects (completed by students during the two semesters that I taught the course) include designing a digital clock using FPGA, implementing a two-player 3x3 tic-tac-toe game on the FPGA, using an FPGA to program an iRobot to traverse the shape of ‘8’, image processing (median filtering and intensity thresholding) using FPGA and designing a 5x5 router using an FPGA. Some of the students comments (from BU course evaluations) are as follows:

- “The course is interesting. Labs are challenging but really helpful in terms of learning course material.”
- “Examples were really good for different topics, and clearly understands what he’s talking about. Emphasized the practical use in professional settings.”
- “Joshi is a great professor. He presents the material well and is flexible when responding to class difficulty.”
- “The instructors presentation of the material was very clear and very well organized. The instructor was very open to students questions and very responsive in helping students understand the material.”
- “Good professor, cared about the students.”

One common feedback that I got from many students was that they would have liked extra formal lectures on Verilog programming. I am scheduled to teach this course in Spring 2016. I plan to schedule weekly formal ‘Recitation Sessions’ for students where either me or the Teaching Assistant would teach Verilog coding. This would not only prepare them well to tackle the EC311 labs and projects but also the labs and projects in EC413 (Computer Organization), EC513 (Computer Architecture) and EC551 (Advanced Digital Design with Verilog and FPGA).

### **EC571 (Digital VLSI Circuit Design) - *Spring 2010, Spring 2013, Fall 2013, Fall 2014***

The goal of this course is to expose students to various concepts of digital CMOS design. Starting with MOSFET basics, the course covers the design of combinational/sequential logic using static and dynamic CMOS design, the design of different types of CMOS-based memory arrays and the design of on-chip RLC interconnects. The theoretical concepts covered in class are consolidated through

extensive CAD laboratory sessions. By the end of the course, the student are able to design a digital CMOS circuit for a given area, power and performance specifications.

One of the critical aspect of this course is the use of Cadence tools for designing and evaluating circuits. Students find this part quite challenging. To make it easier for students to learn the Cadence tools, my Lab Assistant and I developed videos that the students could view and learn the Cadence tools at their own pace. Students really appreciated these videos. Moreover, these videos were adopted by Prof. Hubbard to teach Cadence tools when he taught the EC571 course.

As part of the class project, I ask students to pair up and ask them to review papers from the top circuit conference. This provides students with an opportunity to familiarize themselves with the current state-of-the-art in digital circuit design. Moreover, my research group focuses on developing novel circuits for low-power, high-performance and robust VLSI systems. I ask my PhD students to present their PhD research to class. This gives an opportunity to the EC571 students to know about the circuits research at BU and at the same time, it also provides my PhD students with a forum to publicly discuss their work and receive feedback.

This course is taken by both graduate and undergraduate students. I have received excellent feedback from students about this course. Some of the students comments (from BU course evaluations) are as follows:

- “This was a fabulous course. My favorite part was that Prof. Joshi did not rely on Power Point slides which are hard to learn from in my opinion but did a lot of chalk board notes...”
- “Strong style of teaching, notes preparation, presenting style & interaction with students, good homework set, detail workout on lab (Cadence + HSPICE), tools...”
- “Prof. Joshi is great professor. Teaching methods effective and he is very approachable with questions...”
- “Lots of practical material covered. Learned tools and theory.”

One feedback that I got when I taught this course in 2013 was that students would like to get more practice with solving circuit design problems. Hence in 2014, I scheduled weekly formal ‘Recitation Sessions’ that were dedicated to solving circuit design problems based on the topic covered in the lectures during that week. These recitation sessions were well received and I plan to continue having these sessions moving forward.

### **EC772 (VLSI Graduate Design Project) - *Spring 2011***

The goal of this course is to give students hands-on experience with designing digital CMOS chips. The design process includes design specifications, circuit/micro-architecture design, Verilog programming, chip floorplanning, placement and routing, parasitic extraction and validation. Students work in groups, and successful projects have the option of fabricating and testing their digital CMOS chips.

In Spring 2011, I completely revamped the teaching material that was used for teaching this course. The Cadence Encounter toolflow (Verilog to PAR) for designing digital ASICs was used for the first time in this course. This toolflow used the 45 nm Nangate Open Cell library. The adoption of this toolflow made it easier for students to design the chip. Moreover, given that the toolflow was already set up, they did not have to spend time setting up the tools and could devote more time focusing on micro-architecture design and circuit design. The updated course material and Cadence toolflow was adopted by Prof. Hubbard who taught the course in Spring 2013 and Spring 2014. Some of the students comments (from BU course evaluations) are as follows:

- “The projects were very interesting, and did present an opportunity to explore in greater detail subject matter that was taught in previous courses.”

- “Instructor was very accessible and helpful after class.”
- “Good course in learning how to write code and build chip to execute algorithm.”

Based on the student’s feedback, one change that I would like to make when I teach the course next time is that I would hand out the project assignments a little early so that the students will have sufficient time to work on the project. In addition, when students form their project groups I would ensure that each group has at least one member who is proficient in each of the following areas Verilog coding, Digital Circuit Design and Microarchitecture Design.

## 2 Mentoring

Currently, I have 5 PhD students, 3 MS/MEng students and 3 BS students conducting research as part of my group. To maintain the research productivity of my group, my long-term goal is to maintain a critical mass of students at a similar level during my academic career. I have 1:1 meetings with all my students every week. I believe that PhD students need the most mentoring in their first 1-2 years of their PhD program. This is when they learn good research practices. Hence, I work very closely with my PhD students in their first 1-2 years. By the end of their 2nd year, they are more independent and I adopt a ‘hands-off’ approach. I allow them to drive their own research, but at the same time ensure that they are not going astray. I also pair the senior PhD students with Master’s students and/or Undergraduate students. This gives the senior PhD students mentoring experience and at the same time the Master’s student and/or Undergraduate student is closely mentored. Moreover, this was there is always a team of 2-3 students working on a project which make the sub-group very productive.

I send my students to attend the top conferences in the area of circuits and architecture every year. This gives the student an opportunity to interact with experts in their respective research areas as well as with their peers. Moreover, this motivates the students to work hard on their respective research projects. In addition to attending conferences, I encourage my students to do atleast 1 summer internship during their PhD program. This internship experience provides students with an industry perspective and makes them more pragmatic about their research. It keeps them ‘grounded’ and motivates them to develop practical solutions to research problems. My students have interned at Intel, Analog Devices, Mediatek and NASA JPL. Graduates from my group have also managed to secure full-time positions in a broad range (startups to well-established) of companies including Intel, Freescale Semiconductor, HP Labs, MIT Lincoln Labs, Atlas Wristband and Netronome Systems.

## 3 Outreach

Boston University has an Upward Bound Math Science (UBMS) Program that provides high-school students from Brighton, Chelsea and Charlestown High Schools an opportunity to perform joint academic activities with Boston University students. As part of the UBMS Science Vacation Week (from 2/19/13 to 2/21/13), I conducted a hands-on tutorial on programming iRobot Create for 15 high school students. I first presented an overview of the area of robotics. This was followed by a discussion of the programming of the iRobot using toy examples. Finally, the students programmed the iRobot to trace the alphabets B and U. The key driver for this activity was to encourage these high-school students to pursue careers in STEM areas.

BU has a 6-week Research Internship in Science and Engineering (RISE) Program for motivated rising high-school seniors to conduct university-level research. In Summers of 2011, 2012, 2013 and 2014, I hosted high school students through this program. The students have worked on a variety of design projects including an obstacle avoidance module for iRobot Create, novel layouts for photonic NoC to reduce laser power, the use to memristors to design RF circuits, performance analysis of Parallela

board with 16-core Epiphany co-processor and algorithmic learning and training with Convolutional neural networks. These students are now undergraduate students at MIT, U C Berkeley, USC and UCSD.

## 4 Future Plans

Moving forward, I would like to explore the ‘Flipped Class’ approach for teaching EC311 and EC571 courses. This move to the Flipped Class approach is driven by that fact that over the years (based on my personal experiences while teaching the above listed courses and student feedback) I have noticed that students are able to easily grasp a topic and get a deeper insight into the topic if I solve several related practice problems in class. The ‘Flipped Class’ approach would enable me to do that. Moreover, I think both EC311 and EC571 courses are suitable for the ‘Flipped Class’ approach as both these courses involve extensive design of digital circuits and digital logic, respectively. To enable me to spend more time solving design problems in class, I will record 2-3 short videos covering the theory of each lecture topic in detail. Students will be expected to watch these videos before coming to class. The lecture would then be devoted to solving design problems based on the topics covered in the videos. This way the students will get extensive in-class experience in the design of circuits and logic. To make the process of solving design problems more interactive, the design problems will be formulated such that students can solve some problems individually, students will pair up to solve some problems and some problems will need students to form a small group. The formulation of such a variety of problems will be challenging, but I am confident that this interactive approach will pay rich dividends in the long run.

In terms of new course development, I would like to offer a new course on Advanced Digital Circuit Design Techniques. One of the motivations for offering this course is that students normally take EC571 followed by EC772. The EC772 course can be a significant step up from EC571 course as students need to know the advanced concepts in digital chip design for EC772, but the EC571 course is not able to cover all the advanced concepts. The Advanced Digital Circuit Design Techniques course that I would like to offer could serve as an intermediate course that covers various advanced topics including design of ultra-low power circuits, design of high-speed on-chip communication circuits, design of peripheral test circuits, design of memory blocks using both CMOS and emerging technologies, and noise analysis and control. Students interested in the area of digital circuit design could then potentially take EC571, followed by the proposed Advanced Digital Circuit Design Techniques course and then take EC772. By taking these three courses, students would gain an in-depth understanding and experience in the design of digital VLSI circuits, which would prepare them well to tackle the design problems that they will face as part of their PhD research and/or full-time jobs.