Massive Open Online Courses for Educating Circuit Designers: What Works and What Doesn't

I was invited to write up a short overview of my experiences with massive online open courses (MOOCs, pronounced *mooks*) [1] via the Web site CMOSedu.com. As I draft the article, I'll start out by asking the readers of *IEEE Solid-State Circuits Magazine* who also have online education experience—either as users or creators of online courses—to write to the editor-in-chief, Mary Lanzerotti, and share their experiences, including what they like and what they don't like about MOOCs.

My initial use of the Internet focused on enhancing the traditional university lecture experience (see Figure 1) and providing tutorials, especially tutorials on using software tools (e.g., Cadence, Electric, LTspice, and so on). When I started posting course information online, my goal was simply to enhance the on-campus lecture experience by letting the students go back and review a lecture on their own time or revisit a concept that wasn't clear to them. The students could even review a previous year's lecture (see Figure 2) to get another perspective. In addition, I lecture using a document camera [2] (see bottom document camera image in Figure 2) and scan my notes to post as PDFs along with the videos (see Figure 3). I then recommend that my students *not take notes* while I lecture but rather pay attention—and think about—the lecture's content. As an unintended side benefit to the engineering community, thousands of students and engineers from all over the world have used the posted lectures and tutorial videos at CMOSedu.com to study circuit design (I base this estimate on reports from Google Analytics, e-mail, and personal interactions during lecture tours).

So with this approach, what works? Posting lecture videos and notes helps the on-campus students master the material and get more out of a course. In a dozen semesters of posting videos, I haven't received a single negative course evaluation comment related to providing these learning aids. Rather, the students feel they get more out of a course when they have videos of—and notes from—the lectures. It's important to note, however, that the on-campus students are provided feedback via graded homework, quizzes, exams, and projects. More on why this feedback is important in a moment.

Before I talk about what doesn't work—and at the risk of stating the obvious—note that it's more labor for the instructor to transport the recording equipment to the lecture hall, set up and take down the recording equipment, convert the videos, post the videos (a 1.25-hour lecture is around 250 MB, which can take a while to upload), scan the notes, post the notes, and edit the Web pages so they link everything together. Hiring a student to facilitate this effort is useful if extra funds are available; I, however, would put a priority on hiring a student grader.

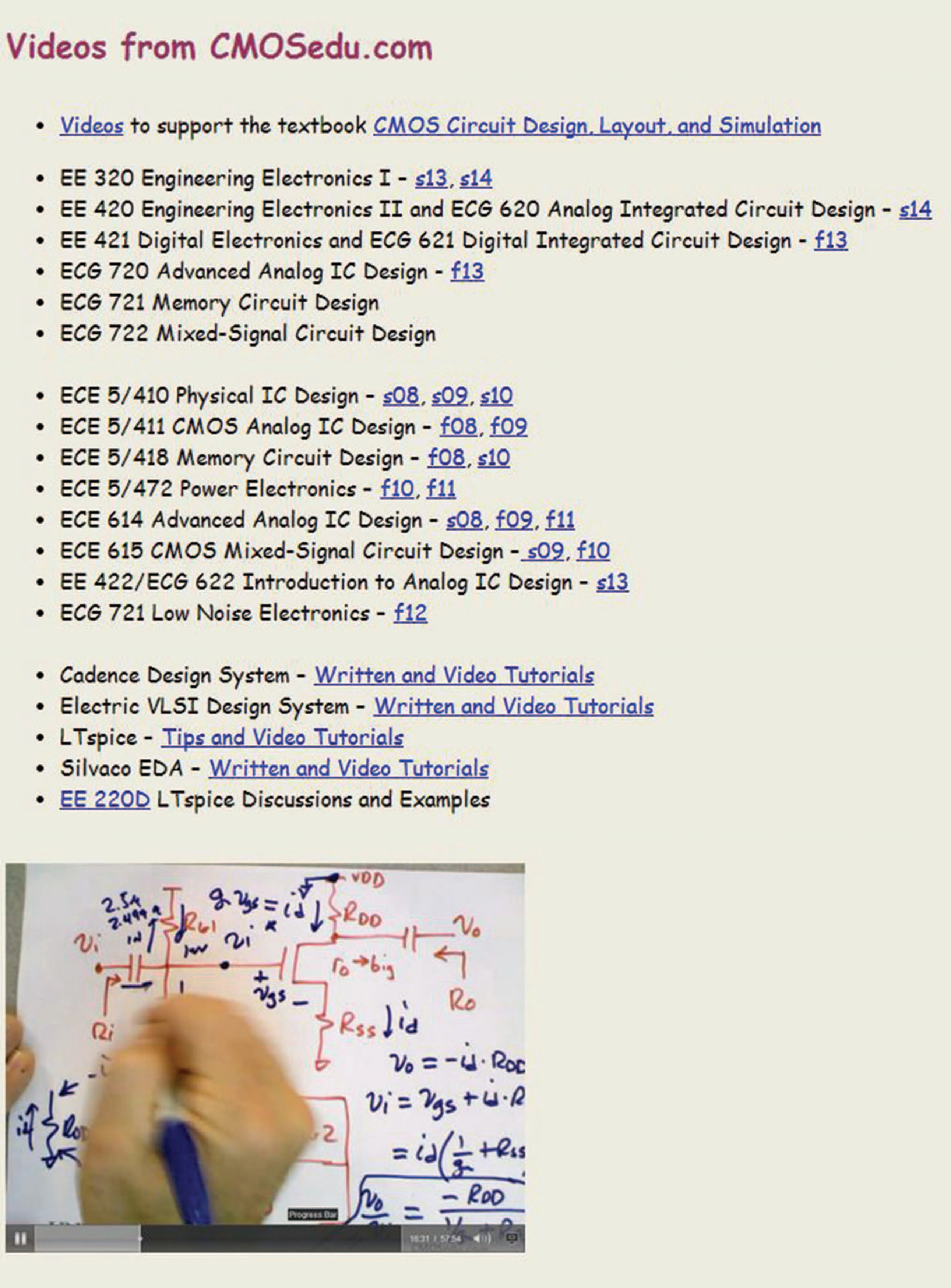
Next, it's been my experience that if a significant online effort is going to be made, then one should invest in one's own Web hosting. For example, the CMOSedu.com site has about 120 GB of information and costs, roughly, US$7 per month for hosting services from bluehost.com, though there are many other Web hosting services. Without providing support for this position, let me simply say that it is worthwhile to pay this fee to have 100% control and commercial reliability for one's online educational activities.

What about the learning curve for creating online courses? For some, one of the issues with starting to generate online material is learning about creating and editing Web pages. Someone new to editing Web pages can use a word processor such as Microsoft Word or one of many free tools [3] to create the online content. Maintaining and creating basic Web pages, like those found at CMOSedu.com, is a very simple task.

Now, what doesn't work in a MOOC? The quick answer is not giving students timely, frequent, and relevant feedback on assessed work to guide their study efforts. Lecture videos and notes are wonderful, but they aren't sufficient by themselves to provide a quality learning experience. If a course is to be offered to a large number of off-campus students, then some method of providing feedback to these students, such as online automated testing, must be developed. This development can take considerably more effort than creating videos and notes.

FIGURE 1: The author giving and recording a lecture in circuit design to post online.

Digital Object Identifier 10.1109/MSSC.2014.2316075
Date of publication: 24 June 2014



Videos from CMOSedu.com

- Videos to support the textbook CMOS Circuit Design, Layout, and Simulation

- EE 320 Engineering Electronics I - s13, s14
- EE 420 Engineering Electronics II and ECG 620 Analog Integrated Circuit Design - s14
- EE 421 Digital Electronics and ECG 621 Digital Integrated Circuit Design - f13
- ECG 720 Advanced Analog IC Design - f13
- ECG 721 Memory Circuit Design
- ECG 722 Mixed-Signal Circuit Design

- ECE 5/410 Physical IC Design - s08, s09, s10
- ECE 5/411 CMOS Analog IC Design - f08, f09
- ECE 5/418 Memory Circuit Design - f08, s10
- ECE 5/472 Power Electronics - f10, f11
- ECE 614 Advanced Analog IC Design - s08, f09, f11
- ECE 615 CMOS Mixed-Signal Circuit Design - s09, f10
- EE 422/ECG 622 Introduction to Analog IC Design - s13
- ECG 721 Low Noise Electronics - f12

- Cadence Design System - Written and Video Tutorials
- Electric VLSI Design System - Written and Video Tutorials
- LTspice - Tips and Video Tutorials
- Silvaco EDA - Written and Video Tutorials
- EE 220D LTspice Discussions and Examples

FIGURE 2: A Web page from CMOSedu.com, at http://cmosedu.com/videos/videos.htm, showing current and archived online courses. Note the document camera image at the bottom.

Lecture notes and videos for EE 320 Engineering Electronics I, Spring 2013

May 15 - final exam (comprehensive), 3:10 to 5:10 PM
May 8 - lec27_ee320.pdf and lec27_ee320_video - review for the final exam
May 6 - lec26_ee320.pdf and lec26_ee320_video - more amplifier design using the BJT
May 1 - lec25_ee320.pdf and lec25_ee320_video - common-emitter (CE) amplifiers, derivation of g_m, r_{be}, and r_e
April 29 - lec24_ee320.pdf and lec24_ee320_video - start discussing bipolar junction transistors (BJTs)
April 24 - lec23_ee320.pdf and lec23_ee320_video - work the exam
April 22 - midterm2
April 17 - lec22_ee320.pdf and lec22_ee320_video - review for midterm2
April 15 - lec21_ee320.pdf and lec21_ee320_video - the source-follower (SF, aka common-drain) and common-gate (CG) amplifiers
April 10 - lec20_ee320.pdf and lec20_ee320_video - work homework problems including simulations, selecting coupling capacitors
April 8 - lec19_ee320.pdf and lec19_ee320_video - review CS amplifier, simulating input and output resistance
April 3 - lec18_ee320.pdf and lec18_ee320_video - even more CS amplifiers, PMOS flavor
April 1 - lec17_ee320.pdf and lec17_ee320_video - Q-point, common-source (CS) amplifier
March 20 - lec16_ee320.pdf and lec16_ee320_video - biasing the MOSFET, four-resistor biasing, MOSFET amplifiers
March 18 - lec15_ee320.pdf and lec15_ee320_video - channel-length modulation, body effect, depletion devices
March 15 - lec14_ee320.pdf and lec14_ee320_video - MOSFET operation, current-voltage equations, channel resistance in triode, transconductance, gm
March 13 - lec13_ee320.pdf and lec13_ee320_video - work homework problems, start on Ch. 4, characteristics of the MOS capacitor
March 11 - lec12_ee320.pdf and lec12_ee320_video - review the exam, introduce transistors
March 6 - hw_help1.pdf and hw_help1_video - help with Ch. 3 homework problems from HW#8 and HW#9
March 4 - midterm1
March 1 - lec11_ee320.pdf and lec11_ee320_video - full-wave rectifiers and review for midterm1
February 25 - lec10_ee320.pdf and lec10_ee320_video - diode small-signal resistance and rectifiers
February 22 - lec9_ee320.pdf and lec9_ee320_video - Schottky diodes, diode circuit analysis, ideal diodes, half-wave rectifiers
February 15 - lec8_ee320.pdf and lec8_ee320_video - diode temperature behavior, built-in potential, energy band diagrams, Zener diodes, breakdown voltage, examples
February 13 - lec7_ee320.pdf and lec7_ee320_video - the diode equation, forward and reverse bias, saturation current, breakdown
February 11 - lec6_ee320.pdf and lec6_ee320_video - overview of the diode, pn junction physics, Sec. 3.1
February 6 - lec5_ee320.pdf and lec5_ee320_video - resistivity of Si, doping, mobility, diffusion and drift currents
February 4 - lec4_ee320.pdf and lec4_ee320_video - finish op-amp gain-bandwidth, start Ch. 2, Solid-State Electronics
January 30 - lec3_ee320.pdf and lec3_ee320_video - op-amp imperfections, finite gain, offset, gain-bandwidth, and examples
January 28 - lec2_ee320.pdf and lec2_ee320_video - more op-amp circuits, the integrator, frequency response, making an ideal op-amp symbol in LTspice
January 23 - lec1_ee320.pdf and lec1_ee320_video - course overview, review of op-amp circuits, introduction to LTspice

FIGURE 3: A sample Web page showing how course notes and videos are posted for anyone to view at any time.

To be fair, a quality learning experience is possible without giving the student feedback, that is, using only video lectures and notes, as long as relevant problems and corresponding solutions are available. The student does, of course, have to be self-motivated, since there aren't any homework, quiz, or test deadlines. I have seen this approach work very well, for example, when a well-established semiconductor company moves into a country with very little or dated circuit design expertise in the universities. To gain employment, the students need to gain the knowledge and skills needed by the employer, so they are extremely motivated. They study the online videos and notes, work problems backwards and forwards, and then go to the job interview prepared to demonstrate their knowledge and get a job. And many do!

Let's discuss this last item—a MOOC lacking feedback—in greater detail. Imagine that a student studies for an exam by looking at the solutions manual to a course's textbook. He or she looks at a problem and the corresponding solution and thinks, *Yup, I know how to do that one.* Then the student moves on to read the next solution and problem. This process is repeated until the student has read every problem and the corresponding solution in the solutions manual. In other words, the student is not actually working on any problems or thinking critically about the steps in the solutions to the problems. The exam comes, and the student, of course, does poorly. A similar scenario can be imagined for the student who only reviews lecture videos or notes. To be successful, a student has to try to solve a problem without looking at the solution. Then when the student either gets stuck or thinks the problem has been solved, it's time to look up the solution. If it doesn't match the student's own answer, asking "Which solution is right?" is better than merely saying to oneself, "I am wrong."

The bottom line is that the usefulness of a MOOC is largely determined by the person using it. MOOCs aren't a magical learning tool that enables someone to gain knowledge without any effort. On the other hand—and I've witnessed this firsthand—online courses can enable motivated students to gain significant skills that can change their lives and those of their families. Be excited about MOOCs, yes, but temper your enthusiasm with the realization that with these learning aids comes more work. That means more work for both the person creating the material and—perhaps more important—the person attending the MOOC.

References

[1] Wikipedia. (2014). The massive open online course (MOOC; provides a good overview of the recent developments of MOOCs for distance education). [Online]. Available: http://en.wikipedia.org/wiki/Massive_open_online_course

[2] R. J. Baker. Information on setting up a laptop with a document camera to record a lecture. [Online]. Available: http://cmosedu.com/jbaker/recording/recording.htm

[3] R. J. Baker. Example information, including a "how to" video, on editing Web pages. [Online]. Available: http://cmosedu.com/jbaker/webpages/webpages.htm

—R. Jacob Baker