

Mixed Signal IC Design

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Abstract

This paper describes an undergraduate subject in the design of analog and digital CMOS integrated-circuits. This subject is offered for the students of Electronics in their 5th semester of the 10-semester master-programme. The emphasis is given on the mixed signal aspects of the IC design.

1. INTRODUCTION

The subject is a one-semester introductory subject in analog and digital CMOS integrated circuit design. During the semester the students learn to design analog and digital integrated circuits based on CMOS technology, and how to integrate the analog and digital blocks into a top level system.

Originally this subject covered only digital design, and the students did not have any parallel analog subjects. The first introduction to analog design was one full year later, with another more advanced digital course in between.

2. THE SUBJECT

A. Subject description

This description is from [1].

- Semiconductor physics, CMOS technology.
- P-N junction, The MOS transistor: Function and characteristic properties.
- Static and dynamic analysis of logical functions.
- Fundamental analog building blocks.
- CMOS processing and layout.
- Synthesis and design of digital modules.
- Design for testability.
- Introduction to CAD tools.
- Guest lecturers from the electronic industry.
- Mandatory project: Design and verification of a medium complex analog/digital circuit.
- The final grade is given from the exam (60 %) and the project assignment (40 %).

B. Subject goals

The subject shall give the students knowledge and experience in the design of analog and digital integrated circuits in CMOS-technology with emphasis on integration of analog and digital blocks into a top level system.

In the beginning, the subject introduces the students to CMOS technology. Followed by this, analog and digital fundamental blocks are introduced. The analog and digital components are covered separately, but they are at the same time presented in a setting where they interact and are mutually dependent on each other. To get the hands on experience in the IC design for the students, a semester project, designing the readout and control circuit for a four pixel digital camera is introduced in this subject [2].

Figure 1 shows a typical, modern electronic system with inputs from the analog world, conversion to digital signals and digital control. The subject covers all these aspects ex-

cept from the Analog to digital conversion.

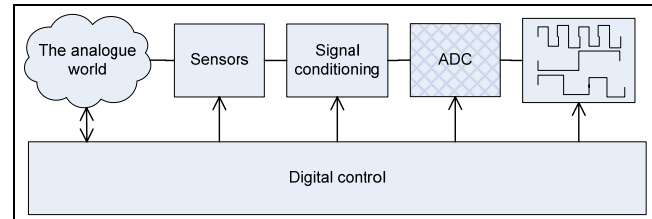


Figure 1 A typical electronic system

3. PEDAGOGY

The semester starts with a motivational lecture given by one of our former students, who is also the R & D manager of Atmel Norway. This R & D group is responsible for the AVR® microcontroller which is a very good example for our case. Figure 2 is a block diagram of a typical AVR® processor. (AVR® is the registered trademark Atmel Corporation.) This is mainly a digital design, but it also contains some vital analog parts. The success of this processor is due to precision analog components on the same die as the digital components. This serves as a credible example that it is worth spending time on all parts of the subject.

Following this introductory lecture, analog design is introduced by focussing on the transistor modelling and layout issues. Basic current mirrors and single-stage amplifiers are thoroughly covered. Some lectures are spent in simulating the circuits with SPICE [3].

This analog part is taught by faculty from the analog staff.

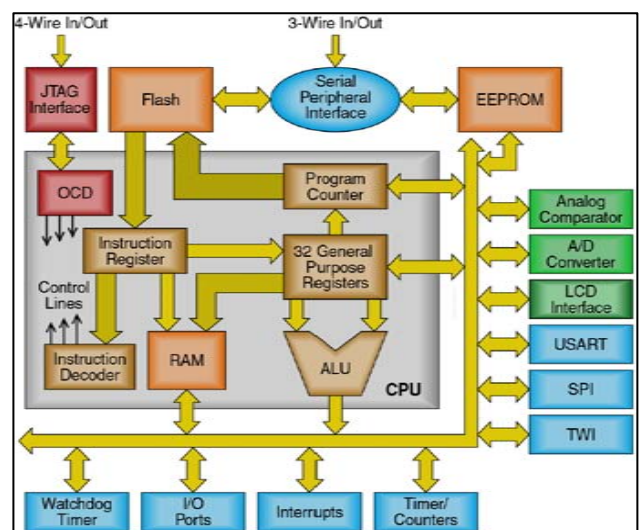


Figure 2 A typical AVR® microcontroller

After covering the analog IC design fundamentals, digital IC design is started by one of the teachers with digital background. This part starts by emphasising the analog features of the CMOS transistor. The logic gates are presented

as real CMOS circuits and simulated using aim-spice.net in the same way as for analog functions. The students learn to find the switching characteristics of and the time-delay through a logic gate. They may also use aim-spice.net to extract the average current and thus calculate the power dissipation of the block.

When simple transistor based logic designs have been covered, Verilog® is presented and used for system design. The students use aimspice.net to find timing parameters for the Verilog model.

The digital designs are simulated and verified by the students by the provided Verilog test-benches.

For this subject, there is no combined analog/digital simulator available. This is a deliberate choice to let the students stay close to the integration of the analog and digital parts and not hide the problems.

During the semester the students design a combined analog and digital circuit. This is the readout and control circuits for a digital camera [2]. All students have some knowledge of a digital camera, and this has proved to be a good example and project circuit.

4. TOOLS

Analog simulations are performed using aim-spice.net [3]. This is available on the web and the students get access by logging in to the server using their normal user/password for the university intranet. Any web-browser may be used.

The plots from aimspice.net are shown as graphic pictures, and the results may also be downloaded as xml or html. The students may download ngl-chart, a postprocessor to plot the simulation results and have significantly better graphic resolution [4]. Using ngl-chart the students may scale their plot better and may copy it as bitmap or vectors.

Figure 3 shows the standard plot from aimspice.net while Figure 4 shows the plot of the same simulation using ngl-chart as a post processor. This simulation is to verify a 1-bit full-adder. The standard plot is in colour while the plot from the post processor may be formatted in different ways. For this example Figure 4 is formatted with the theme Black_white.

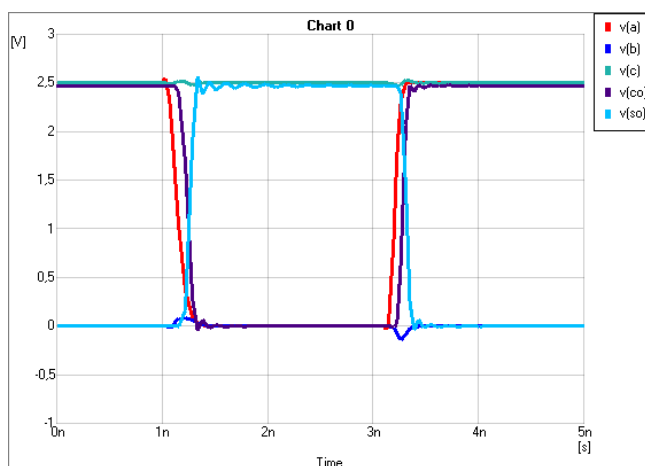


Figure 3 Adder verification from aimspice.net.

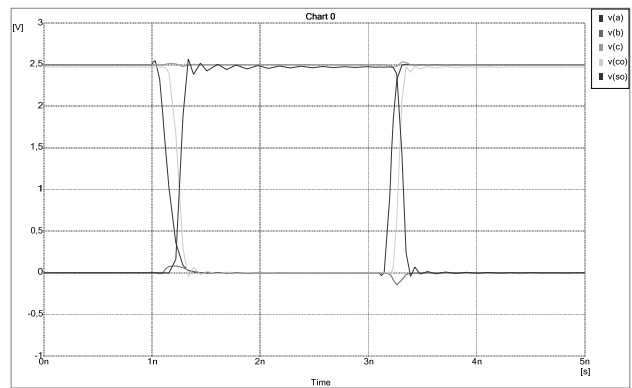


Figure 4 The same simulation as in Figure 3 using nglchart with the theme Black_white

Active-HDL from Aldec is used for digital simulation. This is a very convenient simulator for universities. It has an intuitive user interface and the students are very happy with it [5].

5. EXPERIENCE

The change of this subject from a pure digital to a combined analog and digital subject has made the students more aware of the close connection between the analog and the digital world. Also the introduction of an analog professional to cover the transistor modelling and simulations has made the transistor more accessible to the students.

The students express that they are very satisfied that the subject shows the close connection between the analog and digital realms and also the transistors inside the combinatorial functions. This is also the case for the use of a digital camera as a case for the semester project

6. CONCLUSIONS

A combined subject for analog and digital CMOS-design has been successful in giving the students a better understanding of the digital building blocks. They also claim that they see the relationship between the analog and digital realms. An important part of this is that the analog part is taught as analog CMOS and not as an introduction from a digital designer.

References

- [1] *Studiehåndbok for teknologi (sivilingeniør)-studiet ved NTNU 2006-2007* (in Norwegian) "The study handbook for the master of technology studies at NTNU 2006-2007". Available in English from http://www.ntnu.no/portal/page/portal/ntnuen/all_courses?selectedItemId=31010&rootItemId=29569&emnekode=TFE4151
- [2] Bjørn B Larsen, Linga Reddy Cenkeramaddi, and Jukka Typpö, *Readout and Control Circuit for a Four Pixel Digital Camera as Semester Project*, 2007 IEEE International Conference on Microelectronic Systems Education, pp 99-100.
- [3] <http://ngl.iet.ntnu.no/> Next generation lab at NTNU.
- [4] <https://ngl.iet.ntnu.no/aimspice/nglchart.aspx> to download ngl-chart.
- [5] <http://www.aldec.com/> for information on Active-HDL.