MICROELECTRONICS EDUCATION AT FACHHOCHSCHULEN IN BADEN-WUERTTEMBERG

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The paper describes the Multi Project Chip Group at Fachhochschulen in Baden-Wuerttemberg, Germany. The activities of this group focus on microelectronics education. Project examples are given, covering digital and analog VLSI design, cell layout and PCB design.

1 Overview on MPC Activities

The Multi Project Chip Group (MPC Group) has been founded in 1987, following an initiative by Fachhochschule (FH) Furtwangen. The promotion was authorized and funded by the Ministry of Science Baden-Wuerttemberg (BW). One of the promoters is the Institute for Microelectronics Stuttgart (IMS), a silicon foundry. Now about 30 scientists from twelve institutes of different FHs of BW, concerned with education and development in VLSI design, are members of the MPC Group. Most of them are members of EUROPRACTICE, being former EUROCHIP members.

The basic idea of the MPC Group is to provide an environment in which mutual cooperation leads faster to new knowledge in VLSI design, enforces the progress in teaching and supports the members by exchange of lecture notes and examples for students projects. Furthermore the organizational overhead is minimized for running the equipment and a cheap way is organized to get circuits on silicon.

The MPC Group meets at a workshop at the end of each semester. In addition training courses are organized for MPC Group members, covering new methods and tools in VLSI design. All FHs use HP7xx workstations and Mentor Graphics software, thus mutual help is possible in trouble shooting and developing course material. The group acts as one partner in negotiations with the ministry,with IMS and with tool suppliers. It participates at regional exhibitions and international workshops.

Each year 500 students are trained and 50 final projects are done. Contacts to industry have been enhanced, mainly to small and medium size enterprises.

2 Project Examples

To show some aspects of microelectronics education methods within the MPC Group, examples of various areas are presented in the following.

2.1 Digital Microprocessor Kernel

The purpose of this project is to give students insight into microprocessors, "learning by doing". The "First Homemade Operational Processor" (FHOP) was designed by a small team of students in their final project, lasting only 4 month. Intended application areas are small systems completely integrated on a chip, e.g. smart cards.

Development of such a complicated integrated circuit in such a short time is only possible by using advanced design tools, e.g. VHDL-compiler and logic-synthesis.

The choosen 16-bit architecture has some similarity with existing microprocessors (8088) but there was no attempt to be compatible. The clock can be rised up to 33 Mhz in the 1 μm version, and up to 50 Mhz for the actual 0.7 μm design, giving better performance than 8051-series processors. There is a 64KB-address-space and an isolated I/O-space of 256B. 115, mostly1 Byte, operations are possible. The address/data-bus is multiplexed, Byte oriented, with Ready and Hold.

The microprocessor-kernel was tested successfully in a chip fabricated via EUROCHIP. A redesigned version in 0.7μm technology needs 4 mm^2. Students have designed several additional modules for the kernel, e.g. serial interface, power management (Information via "http:/www.fh-offenburg.de"). A comfortable "Integrated Development Enviroment" with simulator running under windows, programmed also by students, allows to implement the kernel in "Intelligent ASICs".

2.2 Analog Design Methodology

This IC design teaching methodology is shown by an integrated biquadratic filter with bipolar transistors.

Firstly, the physical models of transistors, resistors and capacitors are explained to the students, which become familiar with these elements by designing and simulating simple circuits. Then the basic function of the filter is investigated, using ideal macro blocks as e.g. transconductance amplifiers. The transfer function is derived by the students by means of mathematical software (Mathematica, Maple).

Next the first order parasitics are included: The macro model is expanded by the amplifier phase delay, being studied within the mathematical model. Then the students recognize, that in the real circuit this phase delay should be kept small. Some further refinements can be included as e.g output resistance of the unity gain buffer.

Now the students design, by use of pencil, paper and books, but without computer, the desired function using transistors, resistors and capacitors described by their physical model. Afterwards the schematic entry is done with Mentor Graphics. Some signal and power sources are added and a bias point analysis is performed to check that all elements are in a reasonable operating point. The frequency response and the large signal behaviour of the circuit are simulated and optimized. Furthermore Monte Carlo-analysis and temperature analysis are performed.

The method described above is successful in teaching IC design in a way, that the designer is not a slave of the simulator. Rather the designer should know before the simulation starts what results he has to expect from the simulation.

2.3 Cell Layout

IC design education does not end at the boundary of cell libraries. No doubt, bearing a high industrial significance, an important aspect of circuit integration is the layout of leaf cells according to design rules and electrical rules down to the transistor level as smallest entity. Designing own cells teaches hands-on knowledge and trains e.g. in area usage and abutment, safe and testable design, minimizing of parasitics, intracellular place and route problems. However, even an expert adheres wisely to a set of strategies of proven success. It is the symbolic layouting in matrix oriented layout that has become very effective and was even CAE enhanced by "incremental verification" and "local layout generation".

Layout synthesis assistance efforts are found in the analog and digital field. In general, it can be said that there are to be followed Layout Structure Rules implying the methodical approach chosen. The advantage in teaching these as prerequisites is the short "time to student". Furthermore the granularity of layout elements is coarse enough, thus suitable, for cell designs of larger circuits during the lab session.

Within a Microsystems Engineering course "IC Design and Layout" is taught in the 5th term. The lab tackles three leaf cells, two in digital and one in analog design (digital comparator, flipflop counter/register, differential amplifier). The work includes the circuit design, simulation, layout, extraction, verification and postlayout simulation specification of the cell (info from FH Furtwangen on request).

2.4 PCB Design

PCB design is described here by an audio frequency sampler with RS232 port for communication with a PC. This is a design with an analog frontend, a sample-and-hold circuit to sample an audio frequency signal from a shortwave receiver or a telephone line, and some digital components including gate array logic as a controller. Auto-placement and auto-routing are only used for the digital parts. The analog frontend has to be designed interactively to avoid crosstalk and interference with the digital components.

The PCB layout system is integrated into the complete design process from Schematic Entry to Simulation and PCB Design. All downstream applications use the same database so that forward and back annotation is possible. PCB design is taught with Mentor Graphics PCB Tools. PCB design systems on PC's are simpler to learn and operate, but often limited in some respect.

The students learn the following design steps: create symbols for components for a hierarchically structured schematic, create geometries and mapping files for these components, place and route interactively as well as automatically regarding the given constraints, create manufacturing data and a documentation. Finally, the different designs are compared and evaluated with respect to the electrical function.

3 Outlook

Knowledge in VLSI design technics which has been very important for electronic engineers in the past has even got more importance now. Especially VHDL design and synthesis, hardware-software codesign and VLSI for signal processing play a dominant role for todays electrical engineers. This has to be noticed in the further development of curricula. Correct description of electronic systems on a behavioural level and its fast and comprehensive verification has to be taught. Right use and appropriate control of synthesis tools with the target technology in mind are skills students have to learn now. Design for testability is a very important aspect in the development of integrated systems, too. The students have to be instructed and supervised to use them. In the future, the fabrication of selected chip design should become even more popular, to better close the design loop and emphasize on test aspects as well.

The mutual cooperation in the MPC Group has shown its advantages since the beginning. Cooperation with institutions abroad can be a stimulus. The MPC Group is an encouraging example for combined industry-government-university efforts in microelectronics education.