Microelectronic Education by Doing

The MPC-Group of Baden Württemberg

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In 1989, the Multi Project Chip Group (MPC) was founded by 13 Engineering Schools, now Universities of Applied Sciences of Baden Württemberg, which have electronics design in their curriculum. Emphasis of the MPC organization was to provide the Universities with software, computer equipment for microelectronic design and a path to real silicon prototypes. In the beginning there were own contracts to companies as there have been Telefunken and the IMS Stuttgart and first silicon chips were developed by students. Later the European project of EUROCHIP and the successor Europractice managed this path to prototyping, but cooperation of the UAS were established and concentrated on information exchange, software acquisition and know how in ASIC design. The MPC group, which is still active and organizes an own workshop two times a year (now we will have the 43rd WS in February 2010) developed more than 80 silicon chips, most of them designed by students, fabricated and tested since then. The range of these designs cover all actual topics of microelectronic design including processor cores, SOC designs, high level system designs, telecommunication chips, analog- and mixed signal chips, full custom design of small cores and other applications.

The presentation will give an overlook over the concept of the MPC group, their activities and achieved results in education. Typical project chips will be presented and the impact of industrial cooperation demonstrated.

I. INTRODUCTION

Electronic design today is more or less assembly of industrial designed integrated circuits on printed circuit boards. Successful design requires careful reading and understanding of complex data sheets, interfacing between different standards and adaption of programmable devices to protocol requirements. There is few circuit design left, may be a small space in high quality analog electronics with high performance requirements or with special power or environmental requirements. Assembling predefined ICs is not a very satisfying job for a creative electronic engineer, there is no real area for own concepts and improvements. Even for industry using existing chips is not enough because everybody can do it and there is no differentiation in product, performance or behavior, may be only in some software running on the system.

Real new things require the ability to design own ICs, which allow to have the required originality in performance, advantages in price, size or power consumption, which the competing company does not have, with other words: ASICs (Application Specific Integrated Circuits) are a must to differentiate and to stay in a fast moving high competitive market. It's about the same as if a car manufacturer uses only DIN-Parts to assemble a roadster. He will never sell it!
ASICs can be designed in house or under contract by a design house. Who has the knowledge and experience, what is possible with ASIC design and where are the technological and financial limits? Modern electronic education has to answer these questions during a course in modern electronics in every engineering school or university.

II. GOALS OF MICROELECTRONIC EDUCATION

A. Modern electronics teaching

Electronics is one of the fastest changing subjects in all engineering professions. To keep track teachers have to do own work in this field, by the best they should actively work in industrial design projects or work closely together with design houses. Link to industry is a must, but there are complex fields that have to be covered today:

- Analog Design on transistor level
- Digital Design on System and HDL-Level,
- Digital design on CPLD, FPGA and ASIC
- Cell based ASIC design
- Hardware/Software-co-design
- Busses and Network interfacing
- Embedded Processors, IPs, memory

There are more subjects of importance; complexity is even faster growing than the doubling of transistor numbers every two years, called the famous rule of Gordon Moore.
Classical analog circuit design is one course, same for fundamental logics, processor architectures, VHDL as a design language, may be with already first training on FPGA devices.
But teaching microelectronics must be much more. You can not be a gardener without putting your hand into the soil. So there must be a direct contact to silicon also for students, CAE

and EDA is nice and important, but without the feedback from real things build up it stays theory. You cannot teach swimming without water!

B. Learning by doing, founding the MPC-Group

Since Mead and Convey [1] in the 80th we have the concept of educational test designs on silicon, teaching students by defining a project, one student or a team of students, designing their own chip in an actual technology.
In USA the MOSIS was started in 1981, a manufacturing site, later more a broker site, to give low cost or even no cost access to silicon for universities.
In Europe, with the European Program of EUROCHIP, started in 1988, a similar approach was made. Main difference to MOSIS was that there were no own manufacturing intended; instead standard processes are offered from IC Fabs in a multi-project wafer fashion. This program is still ongoing now with Europractice, which offers several international available production processes from UMC to AMS, from AMI to very special RF-Processes, covering the actual technology scenery with a standardized administration process and reduced and affordable prices for university designs.
I have to mention the competing broker site of CMP, run by TIMA, Grenoble, also available for European universities with alternative processes down to 60 nm and below, founded at about the same time as Eurochip. CMP is now main supplier of French and non European universities, even customer from USA are common.
In this scenery, the 13 German Engineering Schools (Fachhochschulen) of Baden-Württemberg which educate in electronics formed an own organization in 1986, called the

MPC – Group

MPC stands for **M**ulti **P**roject **C**hip, Fig. 1. Our idea has been similar to the later Eurochip/Europractice-Program, but in a much smaller scale. The name was taken from the original Mead Conway MIT courses and ideas under the same acronym. We made contracts to German fabs at that time like TELEFUNKEN, AEG and other (they are all gone, why?), working in close cooperation with the Institute of Microelectronics (IMS) in Stuttgart, which was founded about the same time.
Main interest of the MPC group is until today:

- Education in Microelectronics and IC Design
- Paving away to Silicon, real ICs, real problems
- Way to actual processes and device libraries
- Working and teaching on industrial CAE Equipment
- Using actual high level Tools
- Keeping and developing technical knowledge and intercommunicating this in the group by organizing and conducting courses on IC design.
- Mutual assistance and help in running soft- and hardware
- Workshops in regular intervals, two times a year to give a forum for students for presentations.
- Proceedings of the workshop as a publication journal with official ISN registration and peer reviewed papers.

Fig.1: Logo of the MPC-Group of Universities of Applied Sciences, Baden-Württemberg founded in 1986.

III. Design Software and Computer Equipment

A. Design Software

From the beginning it was decided to use industrial grade software for IC design, although there were several no cost university programs available. At that time many teaching institutions worked on their own equipment, some even in their own technology kitchen. Because of the small time available to train the students in microelectronic subjects, it was decided, to go “fab-less”, to use the same programs which industry use, and to use the same fabs for manufacturing, which are used by industry.
This was very challenging! Not for technology, but for the amount of equipment and money which has to be acquired. The coming up of “university-programs” by companies who are interested that students are trained in their software helped a lot. A common DFG-Application with significant volume in money allowed the group in 1990, to acquire a first set of Apollo-Workstations for each school and related software Licenses from MENTOR-Graphics. This software covered

- Analog simulation with SPICE,
- Analog and full custom IC-Design with the IC-Station
- Digital design with Simulation, later also with a VHDL Compiler and Synthesis.

Further Software allowed plotting the designs, DRC and LVS and all what is needed to make a real chip.
In later years many MPC members are still going with MENTOR in education, even when there some Cadence – and Synopsys Tools are available and used.
Since Europractice started in 1996, all MPC – members are also members of europractice and most of them are using the tools which are provided from there. I have to mention that we use still about the same set of software, acquired with MPC resources and contracts. Now the europractice portfolio is

The Author is elected speaker of the MPC Group since 1998 much larger, complete and actual, which make it easier to keep actual and updated. On the other site, nearly 50% of the available resources are spent for membership fees and license costs, but it is worth while having the access to big packages of tools.

B. Computer Equipment

The decision to use commercial design software required from the beginning high level (UNIX) hardware and computer equipment, mainly so called workstations, which were very expensive at that early time (before the PC arrived). The MPC Group managed to be equipped with three generations of Hardware, starting with about 3 … 5 graphical workstations of Apollo Type per School. Later we got HP-Workstations with up to 8 places, 5 years ago the last hardware update with a modern concept of SUN-Ray graphical sites, organized around a central SUN-Server-Cluster with network based connection and more than 24 places connected. These acquisitions were possible by three DFG- reviewed projects, the last one 5 years ago with a volume of about 1.3 Million € for all the 13 now called Universities of Applied Sciences.

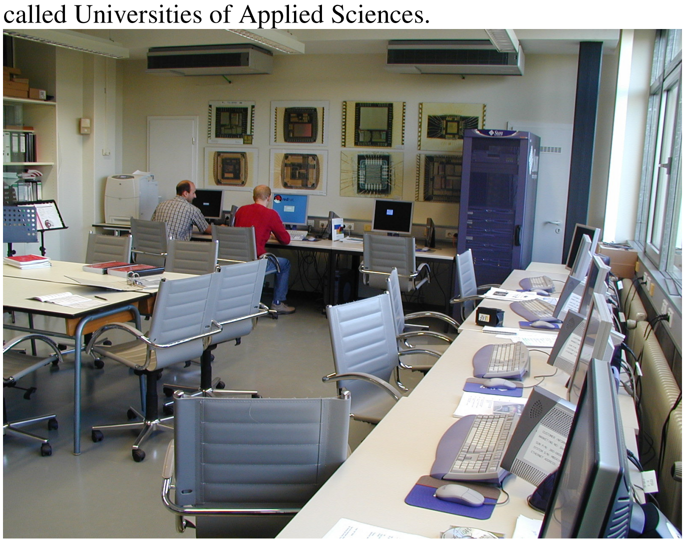


Fig 2: SUN Cluster with SUN-Ray – Terminals (Offenburg)

In addition, several high performance PCs were added and connected to the central cluster, because more and more of the commercial software is running now better on a PC than on a UNIX-Solaris system, especially the FPGA design software, often used in the training of students. So the tendency is to expand the X86 server side, which will be done soon, without scrapping the Solaris which is still good for special programs, not yet available on PC. May be there will be some way to virtualization.
Running these complex clusters, all members have grown to experts in UNIX and CAE/EDA administration. This has been a severe bottle neck in the past, because these software tools were extreme complex and required a lot of administration.

IV. Cooperation with Industry

Although all members signed license agreements which reserved the use of the software for educational use, several industry projects as well as research work have been performed in the group. Fig 3 shows a map of Baden-Württemberg with the member- Universities well distributed over the region, being a natural addressee for IC related issues.

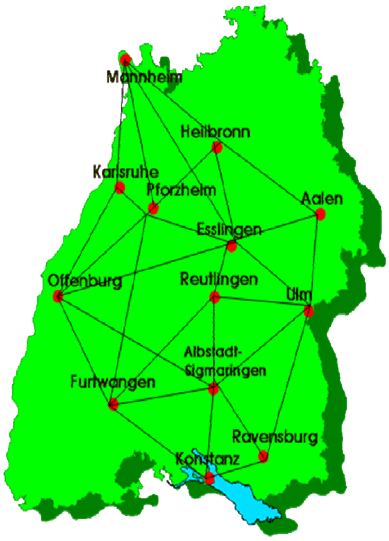


Fig 3: Map of Baden-Württemberg with MPC sites.

There is even more: depending on the personal history of the member and interest, there has been a specialization on certain subjects. So there are sites with emphasis on digital design, other sites are more full custom design or system design related. We have experts on nearly all important subjects in our MPC Group, if we our self are not able to respond, we have many connections to Universities, Fraunhofer Institutes or even international sites, where we are known and where we can ask. So every MPC site can offer the whole spectrum as a local representative. See our website

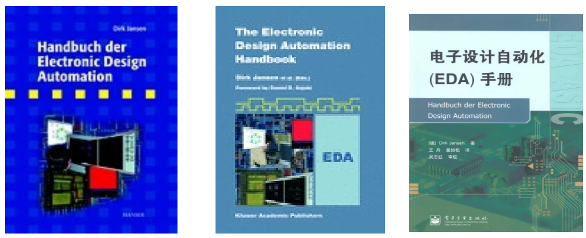
www.mpc.belwue.de

These industrial contacts are very important for teaching and the actuality of our microelectronic courses, many students found jobs in the corresponding companies, after being engaged in cooperation projects or performing Master/Bachelor thesis in these companies.

V. Projects and Results

There are more than 100 Chip designs done in the MPC group since 1989, starting with analog arrays on a Telefunken Master up to now high performance CMOS ICs with processors on in a 0.18 UMC Technology.
In 2000, the educational knowledge of the group was condensed in the 744 pages book:

“Electronic Design Automation Handbook”[3]



by the author of this paper with contribution of 16 authors, mostly from the MPC group and associated partners and a foreword by Professor Gajski, UCI. The book, first edition in German language [3], was translated to English 2005 and is available until now from Springer [4]. A Chinese edition was added in 2005 and is successful sold by Publishing House of the Electronics Industry, Peking as a paperback version [5]. The book is still used in the microelectronic courses and allows an easy insight into basics of modern microelectronics, even when there are many new developments since than done.

The MPC group will have its

43. Workshop on Microelectronics

on 9th of July this year in UAS Reutlingen, with a non interrupted rhythm of twice workshops a year, from the beginning. There are no similar networks active and successful over more than 20 years as far as I know in this field.
On the 40th workshop 2008 in Constance there was a "Best Paper Edition" of papers from our proceedings journal, taken from the past 20 years [2].
Nearly every year the group organizes special courses on IC design, so "Net to Chip" in 2002 and 2006, "Analog Design with Cadence" in 2009 and this year again a SystemC-Course. These courses were taken from educational material, produced by the members and distributed in the group, as well as there are course scripts distributed, text books written by members and so on.
But the main thing is silicon, not only talking on chip design, but doing it. Here are some examples from ICs, made by students in Labs of the MPC group.

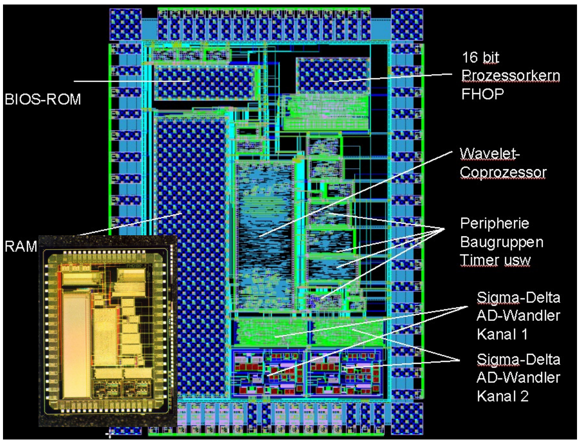


Fig. 4: DSWPC-Chip for 24 hr ECG recorder with 2 channel sigma-delta converter, 16 bit processor, wavelet coprocessor, FIR signal processing and data compression, in ES 2, 0..5µm CMOS Technology. Chip photo in the corner. The chip has a dimension of 4.9x 6.6 mm^2, designed by Wolfgang Vollmer, UAS Offenburg, 1998.

The *DSWPC Chip* was designed in 1998 for a one-chip 24 hr ECG recorder, which was later produced in series and sold with CE from 2002 on (it is still on the market). The chip contains a 16 bit processor core, already developed in Offenburg in the 90th , related RAM and ROM structures, a wavelet unit with 3 FIR Filter for data compression and the related A/D converter using the sigma/delta concept. The chip is able to process the 2..3 mV heart electrode signals directly, compress the data and store it on SD-Card or send it via a small bandwidth telephone link. The chip was used in several other medical and industrial applications and is still used in these systems.
Fig. 5 shows a 0.35 AMI CMOS design for the project ePille®, containing a 32 bit processor, PLL, temperature cell, special medical telemetry blocks and further periphery blocks forming a complete system on chip (SOC)[4-8]. The soft processor SIRIUS, developed in Offenburg in 2005 and used in several applications, is a 1 instruction per clock cycle low power design with about 120µW/MHz and an area in silicon below 1 mm^2 in 0.35 Technology. The chip photo is shown in the corner.

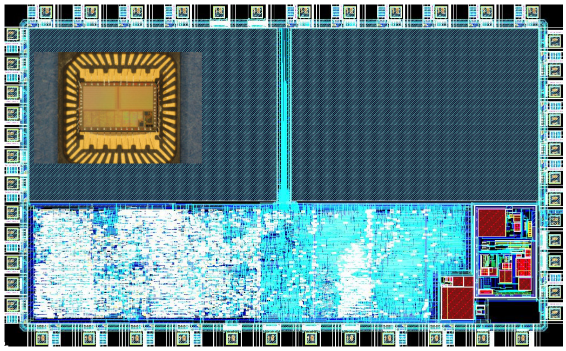


Fig. 5: Design and chip photo of the ePille® -processsor chip for a medical application. AMI 0.35 A/D Tchnology, contains a 32 bit processor, peripherie, temperature cell, PLL, wake-up and power down electronics (design NidalFawaz, Daniel Bau, UAS Offenburg 2008)

The last example is a 0.18µm Design in UMC technology, showing a 32 bit processor and related periphery for a student-PDA called studPod, with interface for external memory, an OLED display and an USB interface. This design, made in 2009 by Daniel Bau, is only 1.6 by 3.4 mm2 in size and represents a more than 4 times higher integration in comparison to the above chips. All these designs were published on international conferences and papers and are part of cooperating dissertation thesis [9].

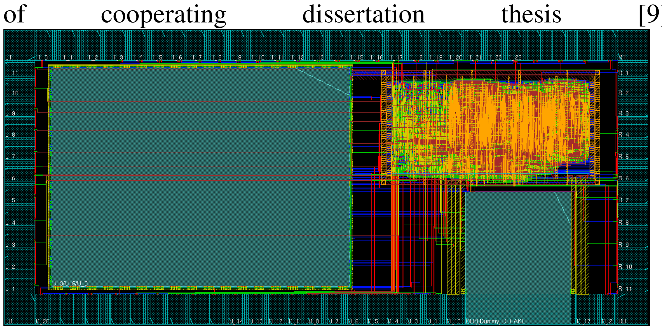


Fig. 6: 32 bit processor SIRIUS and periphery for a PDA in a 0.18 µm 6M1P A/D-CMOS technology. Chipsize is 1.6 x 3.4 mm^2. Designed by Daniel Bau, 2009, Offenburg.

There are of course many other designs from other UAS of the group, which emphasis on analog, RF-Frontend, signal processing or whatsoever. Many publications are made; some of them research papers in conjunction with PHD processes.

VI. Conclusion

Microelectronics education has a 22 year history and experience in the Universities of Applied Sciences of Baden-Württemberg, organized in the MPC-Group. With an average of 150 students a year, more than 3300 Students were educated and trained on IC design, with more than 80 ICs designed in student projects (52 since europractice, see annual report 2009). Complexity of actual designs covers all flavors from RF to high level SOC chips in a research adequate level. Success was gained from available full commercial tools and a paved way to silicon, using Eurochip, later Europractice as a broker. In all 13 Universities, basic IC design is part of the curriculum. All concepts are fab-less, IC-technology development is not in the focus and is not regarded as a subject of training.

Acknowledgment

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