System LSI education strategy at Waseda University

Jan. 26, 2004

Takeshi Ikenaga

The Graduate School of Information, Production and Systems

Waseda University

Outline

- Introduction of the Grad. School of IPS Waseda University
- System LSI educational curriculum
  - Regular and invited lectures
- Subject: “System LSI design”
  - Actual LSI through lectures and exercises

Outline

- Introduction of the Grad. School of IPS Waseda University

- System LSI educational curriculum
  - Regular and invited lectures

- Subject: “System LSI design”
  - Actual LSI through lectures and exercises

Graduate School of Information, Production and Systems (IPS)

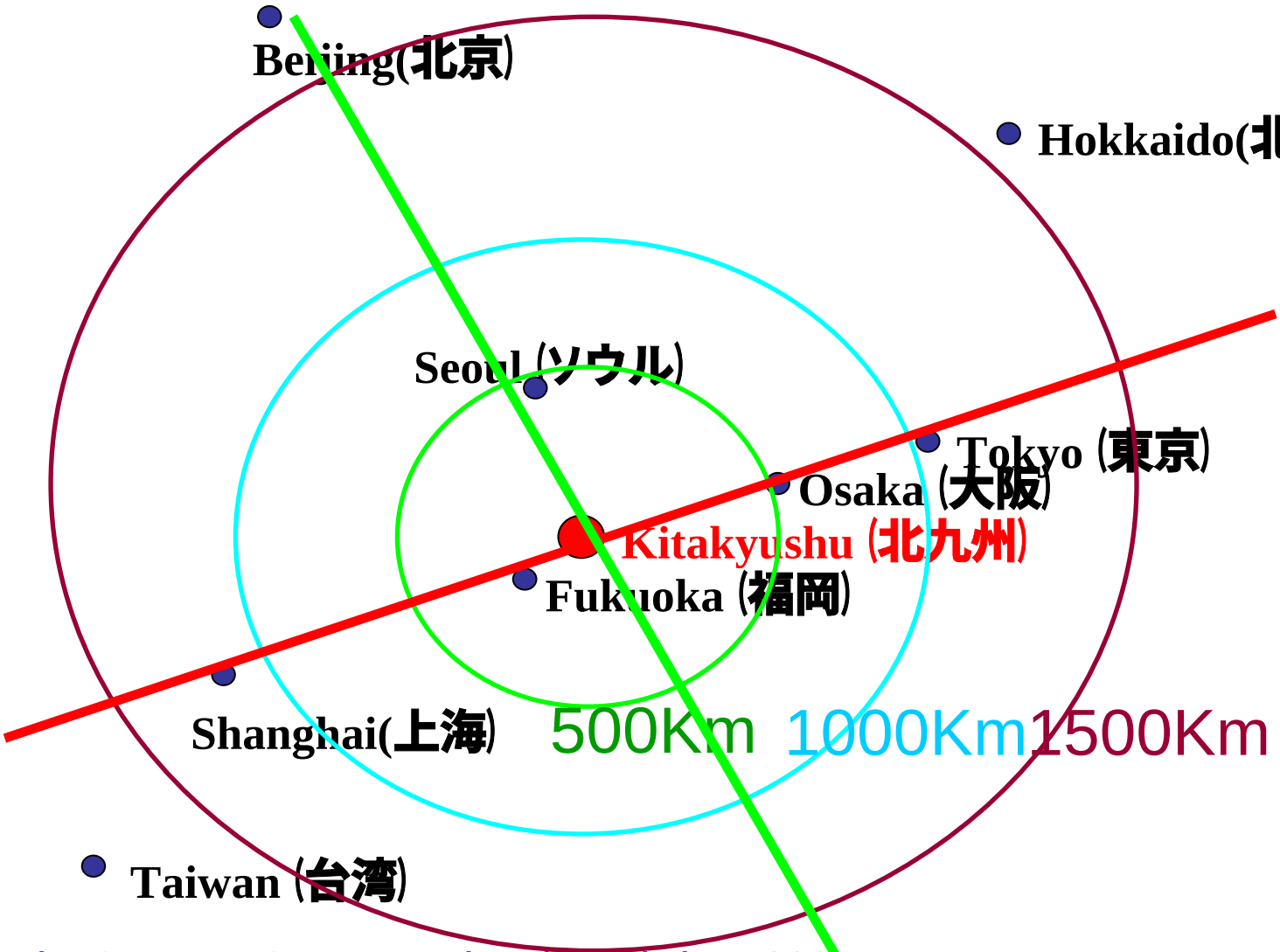
Current status

31 professors / associate professors

181 master's or doctoral course students

- 55 students are from overseas and 53 students belong to Ph. D course -

Why Waseda in Kitakyushu?

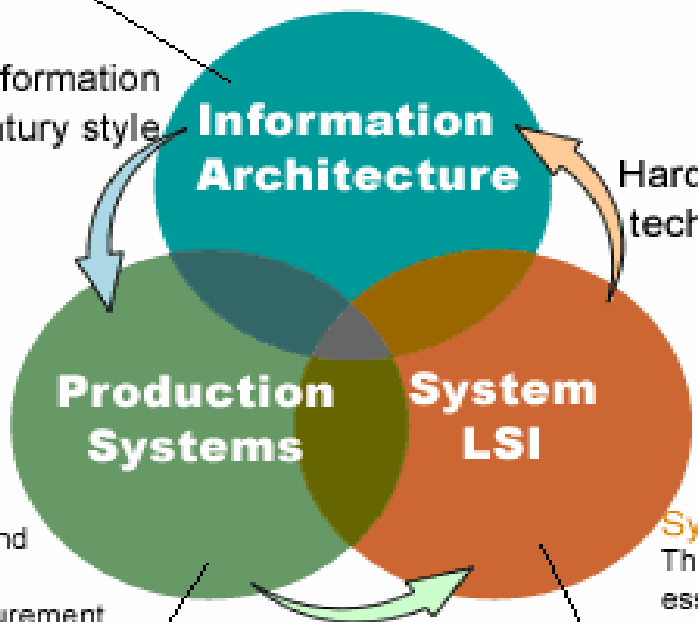


Three program fields

Information Architecture Field

This field covers the various application of information technology including information representation means through multimedia, information processing means focused on its algorithms, networks for transmitting and processing information, and applications of information process into business management.

Production systems utilizing information technology toward 21st century style



Hardware supporting information technology

Production Systems Field

This field encompasses 21st century oriented production systems that incorporate information technology and covers process engineering and FA system engineering as well as measurement and control engineering being recognized as common technology, and the issue of energy engineering as infrastructure research.

An example of an important production system in the 21st century

System LSI Field

This fields covers system LSI design; an essential hardware means for supporting the progress of information technology. System LSI applications and its design and verification methodologies are key subjects.

System LSI field

- **Advanced education and research for System LSI**

  Largest and best stuffs in System LSI in Japan.
  Most of all professors have industry background and experience in System LSI.

- **10 professors cover almost all area of system LSI**
  - Vision：Market research and product design
  - Strategy：Architecture design and implementation
  - Design：Methodologies and design tools
  - Tactics：Verification, test and marketing strategy

Faculties and research area

Satoshi Goto

Application Area

Multimedia, Mobile, Ubiquitous

Takaaki Baba

High Level Design and Verification

Takeshi Ikenaga

On-chip Memory and CAM

Takeshi Yoshimura

Shinji Kimura

Tsutomu Yoshihara

Logic Design Partitioning and Layout

Takahiro Watanabe

Yasuaki Inoue

Analog Circuit Design and Simulation

Integration of Digital / Analog, MEMS, Sensors and Micro Energy

Toshihiko Yoshimasu

Noriyoshi Yamauchi

Background of faculties

Satoshi Goto

NEC

High Lev… V…

Takeshi Yoshimura

NEC …n

…and Layout

Takahiro Watanabe

Appl… Multimedi…s

NTT ブロードバンドで、未知の自由へ。

Takeshi Ikenaga

NAIST

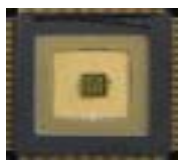
…chip Memory and CAM

Shinji Kimura

Tsutomu Yoshihara

TOSHIBA

Digital …rs and …



Yasuaki Inoue

SANYO 人と・地球が大好きです

Toshihiko Yoshimasu

Noriyoshi Yamauchi

NTT ブロードバンドで、未知の自由へ。

MITSUBISHI

Analog Circuit Design and Simulation

Panasonic

Takaaki Baba

SHARP

Outline

- Introduction of the Grad. School of IPS Waseda University
- System LSI educational curriculum
  - Regular and invited lectures
- Subject: “System LSI design”
  - Actual LSI through lectures and exercises

Features of curriculums

- **Regular and invited lectures**
  - Regular lectures (fundamental and advanced subjects) are taught by 10 faculties of IPS and Prof. Ohtsuki (School of Science and Engineering)
  - Invited lectures are taught by guest professors (oversea/domestic) and leading-edge company's researchers. MEXT invests $5.0 M to Waseda University to run invited lectures (and to support graduate students financially).
- **Theoretical and practical education**
  - Algorithm, architecture and software
  - Voice, motion picture and ubiquitous applications
  - Actual LSI chip design and manufacturing

Fundamental subjects

Digital Signal Processing	●	E	Baba	**Introduction System LSI**	○	J	Goto
Analog Circuits	●	E	Yoshimasu	**Introduction Semiconductor**	○	J	Yoshihara
Computer Architecture	●	E	Watanabe	**Software Engineering**	○	J	Yoshimura
Digital Circuits	●	J	Kimura				
Numerical Analysis	●	E	Inoue				

●：Fall ○: Spring E: English J: Japanese

One subject: 12-15 lectures with one hour and a half

Advanced subjects

Digital LSI architecture	●	E	Watanabe	**System LSI architecture**	○	E	Kimura
Digital LSI design	●	E	Yamauchi	**System LSI design**	○	E	Ilkenaga
Multimedia LSI	●	J	Goto	**Algorithm Design**	○	E	Goto
Layout design	●	E	Yoshimura	**Wireless Communication**	○	E	Baba
Product design	●	J	Yoshihara	**Communication network**	○	J	Yamauchi
Interface design	●	J	Baba	**On chip memory**	○	E	Yoshihara
Micro Machine	●	E	Yamauchi	**Transmission circuits**	○	J	Yoshimasu
High frequency circuits	●	E	Yoshimasu	**System LSI Software**	○	J	Yoshimura
Design for testability	●	J	Kimura	**Low Power LSI Design**	○	J	Watanabe
LSI simulation	●	J	Inoue	**Analog LSI design**	○	E	Inoue
				Digital Integrated Circuits	○	J	Ohtsuki

●:Fall ○: Spring E: English J: Japanese

One subject: 12-15 lectures with one hour and a half

Invited lectures (oversea)

- Prof. Chong-Min Kyung* (KAIST)
  - Current Status and Challenges of SoC Verification for Embedded Systems Market
- Prof. Ernest S. Kuh (UCB)
  - Circuit Simulation Past, Present and Future
- Prof. C. L. Liu* (National Tsing Hua Univ.)
  - Optimization algorithm
  - Computer-aided design of VLSI circuits

* Guest professor of Waseda University

Invited lectures (domestic)

- Prof. Nozomu Togawa* (Univ. kitakyushu): Dedicated processor design
- Dr. Junji Namiki* (NEC): Technology trend of networking and network processor
- Dr. Masao Nakaya* (Renesas): SoC design methodology
- Dr. Takashi Mitsuhashi* (Toshiba): EDA technology
- Dr. Kazutoshi Wakabayashi (NEC): LSI design from C language
- Dr. Ichiro Kuroda (NEC): Video/Media Processing LSI
- Dr. Toshihiro Hattori (Super H Japan): Embedded Microprocessor
- Dr. Yukiyasu Tsunoo (NEC): Symmetric Key Cipher
- Dr. Kazuhiko Takamizawa (NEC electronics): DFT
- Dr. Masato Edahiro (NEC): On-chip Multiprocessor

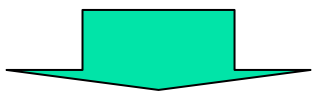
* Guest professor of Waseda University

Outline

- Introduction of the Grad. School of IPS Waseda University
- System LSI educational curriculum
  - Regular and invited lectures
- Subject: “System LSI design”
  - Actual LSI through lectures and exercises

Purpose of the subject

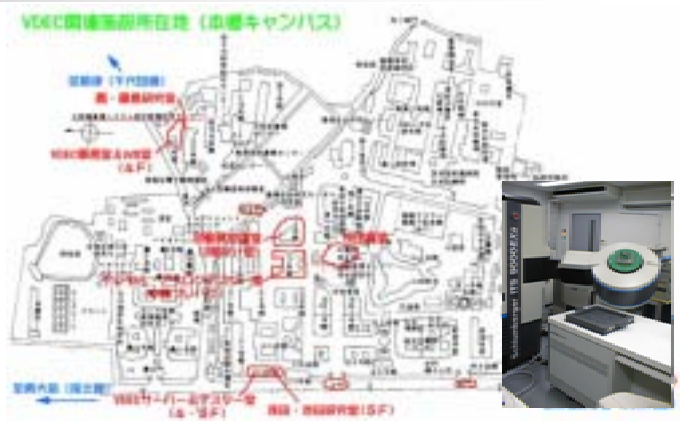
Master's course students of system LSI field are expected to design and fabricate two actual LSIs at least: one in education and the other through research.



"System LSI design": An actual LSI is designed through lectures and exercises. It's indispensable to master various system LSI technologies deeply.

Design environment

- 33 PCs and 5 Workstations
- EDA tools (Synopsis, Cadence)
- FPGA evaluation boards
- ASIC Fabrication: VDEC (VLSI design education center)



VDEC

EDA tools

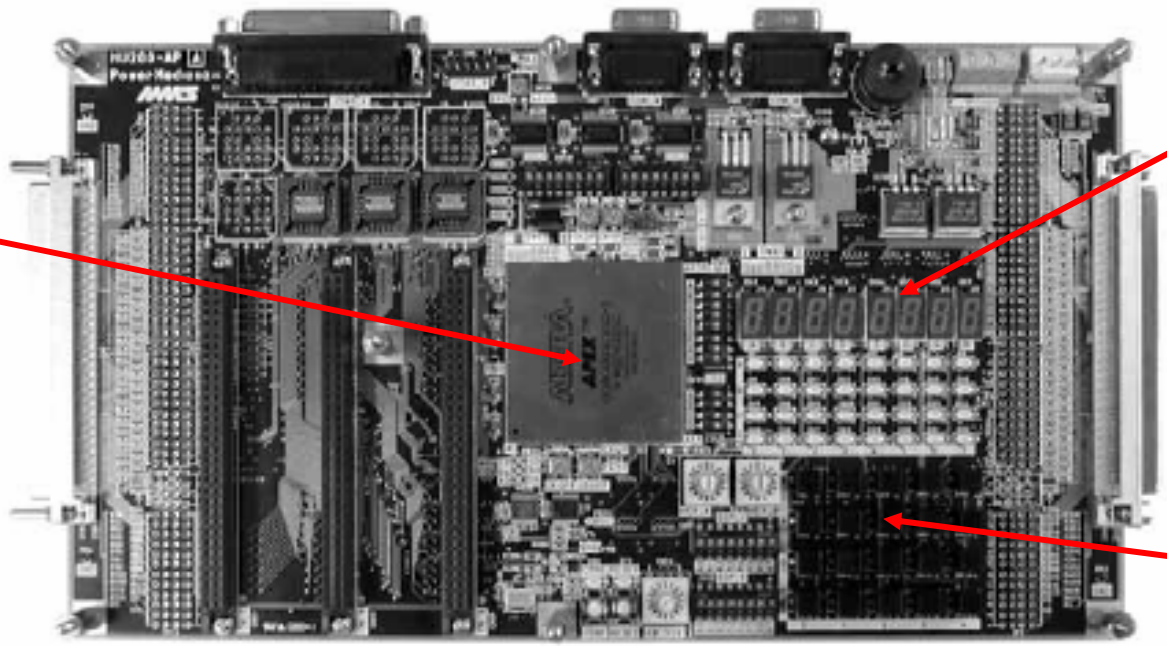
System LSI laboratory

Syllabus (first half)

- Top down LSI design methodology
  - Hardware description language (Verilog HDL), Functional simulation (VCS), Logic synthesis (Design Compiler), Layout (Milkyway/Applo) and design rule check (Dracula)
- Modeling and Simulation
  - Combinational Circuits: Multiplexer/Selector, Encoder, Decoder, Priority encode, Comparator, Adder and ALU (Arithmetic Logic Unit)
  - Sequential Circuits: Register file, Counter, Linear Feedback Shift Register and FSM (Finite state machine)

Project #1

- Design target: electric calculator
  - A simple but useful digital system
  - Can learn system design concept and I/O
- Implementation: FPGA board



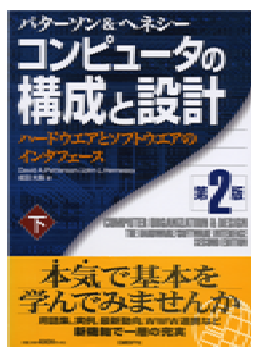
Result of project #1

Students define a specification of a calculator by themselves and implement it onto the FPGA board.

	given	attained
Digit	2 (-99 to 99)	3, .., 7 or 8 (-9999999 ～99999999)
Number	Integer	Floating point or fixed point decimal fraction
Operator	+, -	*, /, X^2, 2*X, +/-
Function	CE	Clear, MC, MR, MS, M+, “Error” display

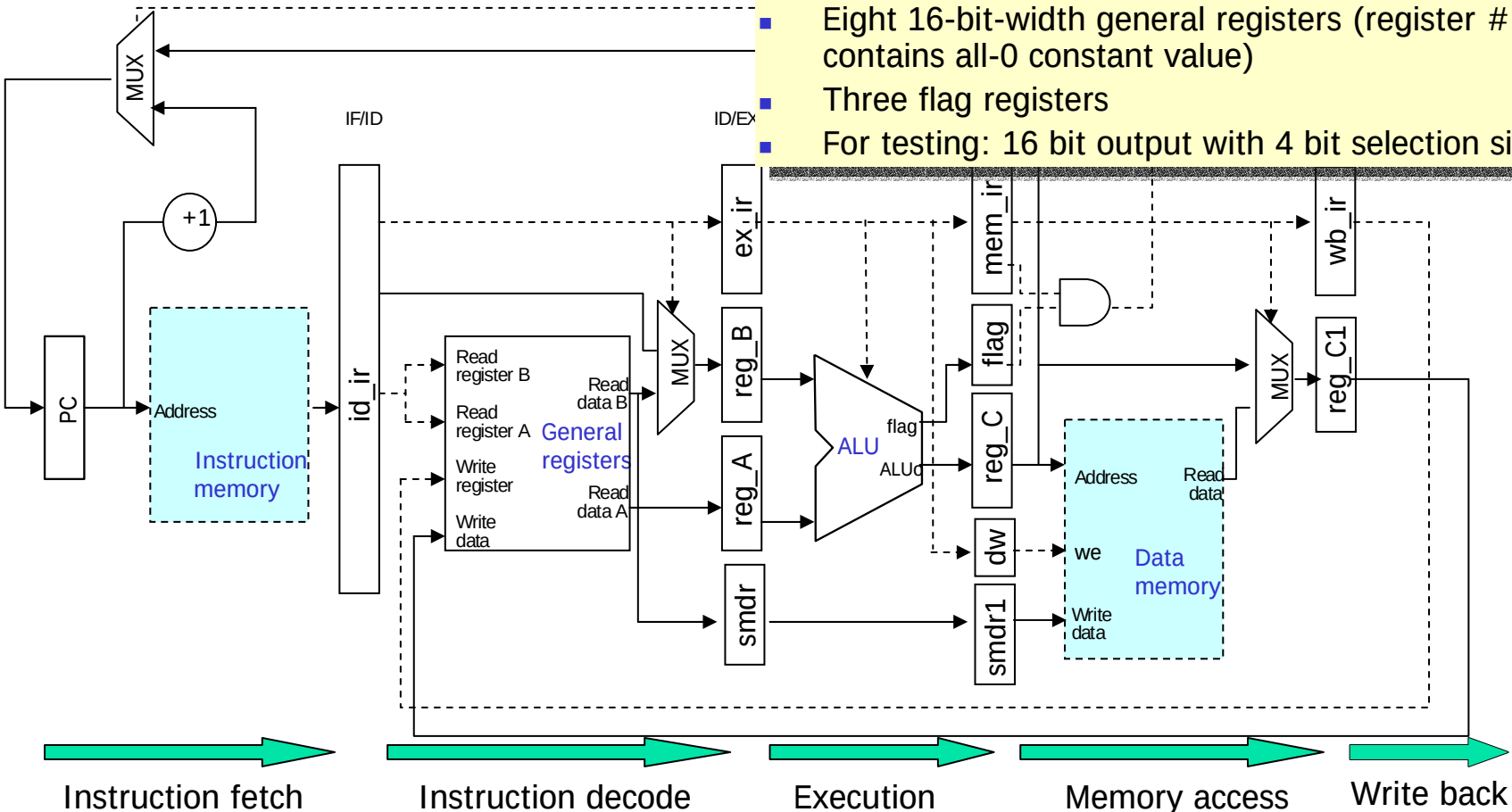
Project #2

- Design target: embedded pipeline processor (MIPS-based 16-bit processor)
  - The most important element in system LSI
  - Can learn hardware, software and their interface
- Implementation: ASIC chip through VDEC
- Linked with “System LSI architecture” and an open seminar on computer architecture.

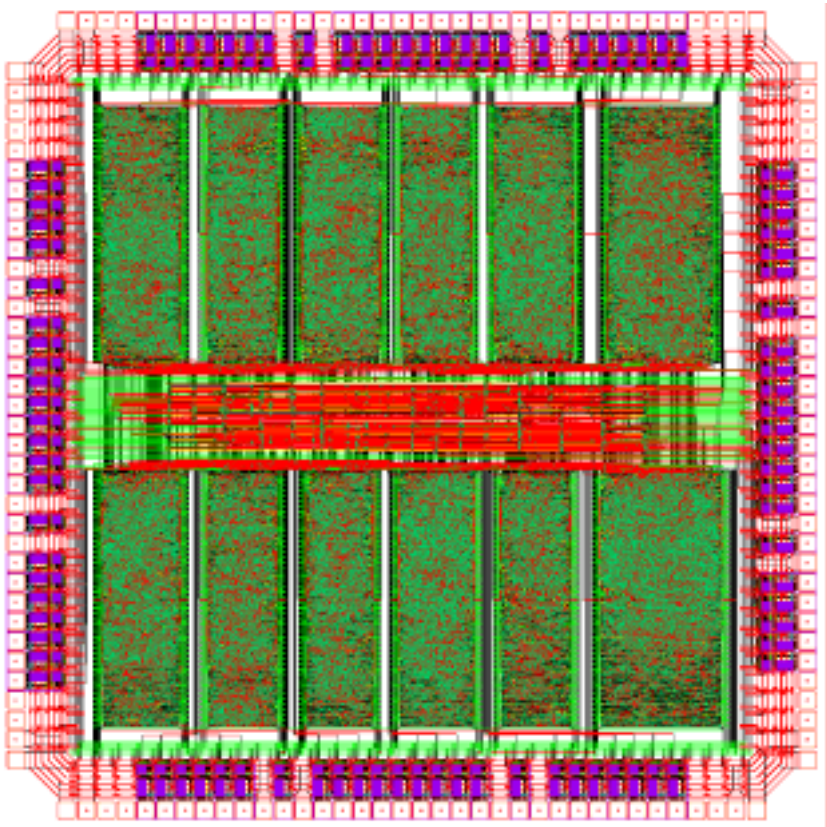


Specification of processor

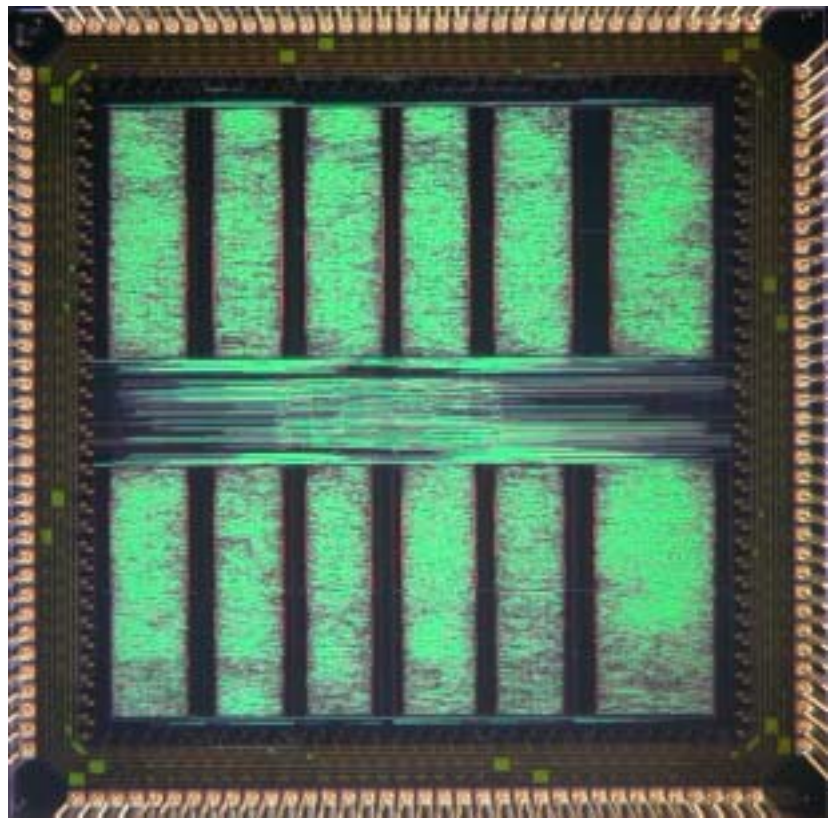
- 16 bit five-stage pipeline processor
- 28 RISC-type instructions + user-defined instructions
- Data and operation memories with 8-bit-width address and 16-bit-width data (256 words x 16 bit)
- Eight 16-bit-width general registers (register #1 contains all-0 constant value)
- Three flag registers
- For testing: 16 bit output with 4 bit selection signal



Result of project #2



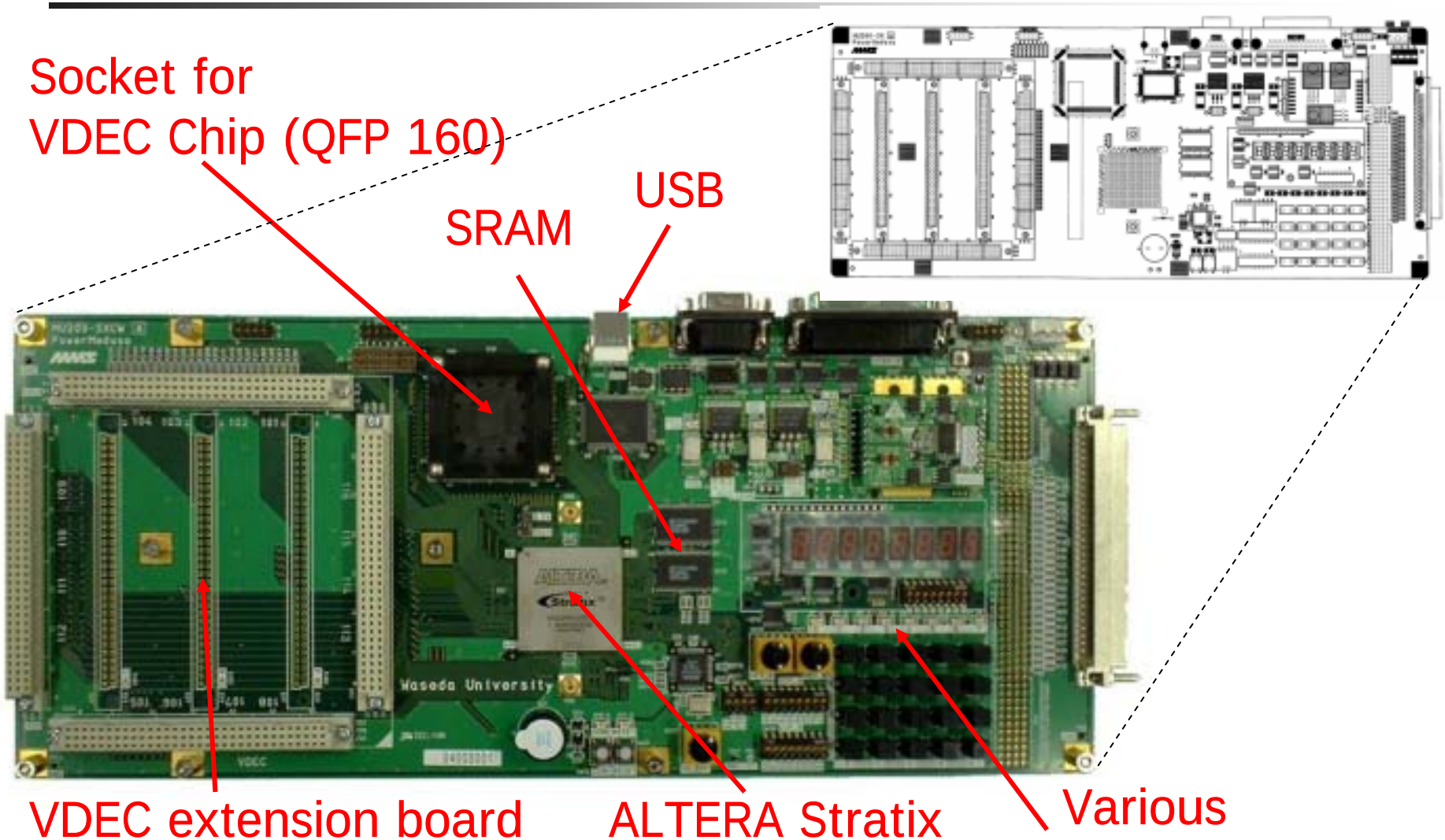
Chip layout



Micrograph of the chip

12 processors in VDEC 0.35 μm 4.9mm^2

Chip evaluation



From education to research

Programmable	Software	Embedded Processor (e.g. ARM, MIPS,TX, VR,SH,M32R)	
		Re-Configurable Processor	Xtensa, MeP, Quick Logic Elixent
	Hardware	Static	FPGA(e.g.Xilinx,Altera)
		Dynamic	DRP, Quick silver, IPFlex
Non-Programmable	Long TAT	CBIC	
	Short TAT	ISSP, RapidChip,GA	

Sensor interface

Image processing

Wireless communication

Cryptography

SoC classification by Prof. GOTO

Summary

- Grad. School of IPS Waseda University
  - IPS offers unique education and research environment in System LSI
- System LSI educational curriculum
  - Regular and invited lectures cover system LSI technologies widely and deeply.
- “System LSI design”
  - Experience of designing an actual LSI make a significant contribution to research.