Electronics at U of T

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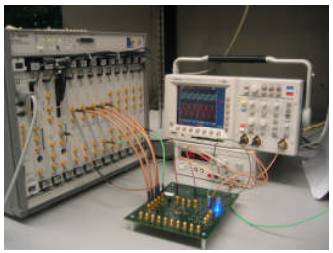
November 13, 2006

Some applications



- Digital communication
- Biomedical
- Radar
- High-speed computing
- Memories
- Sensor networks
- Reconfigurable hardware
- Energy conversion

and more…

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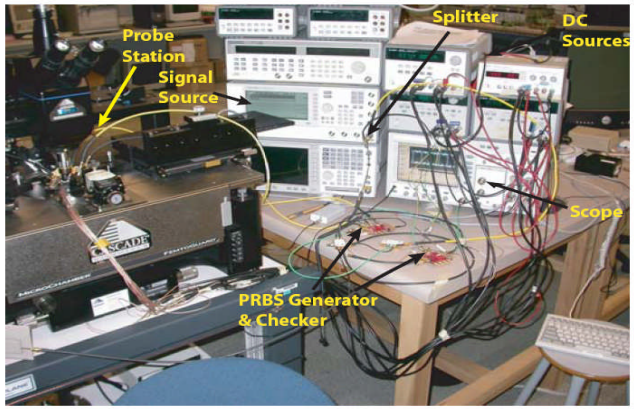
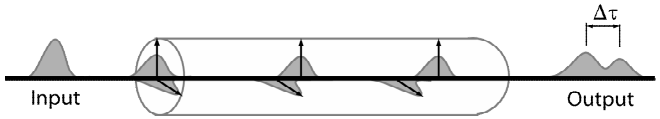
Integrated Circuits Research



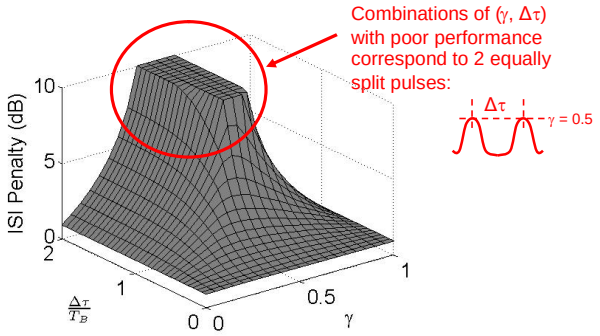
Example M.A.Sc. Project

- 40-Gb/s optical fiber communications
- Polarization-mode dispersion



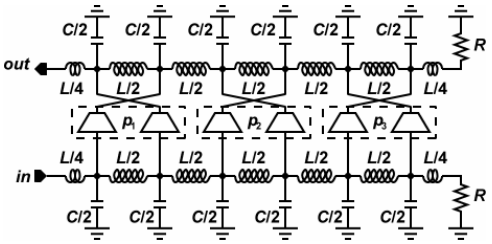
System-Level Analysis

- Matlab simulations used to identify difficult channels & derive specs for a compensator

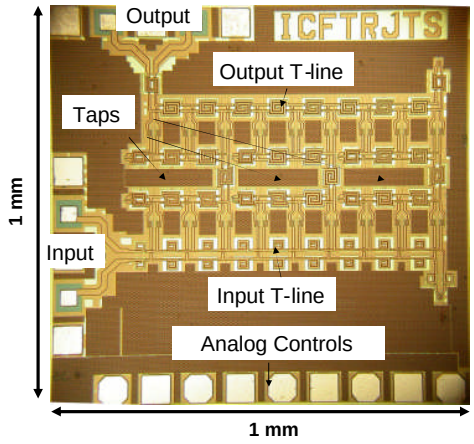


Circuit Design

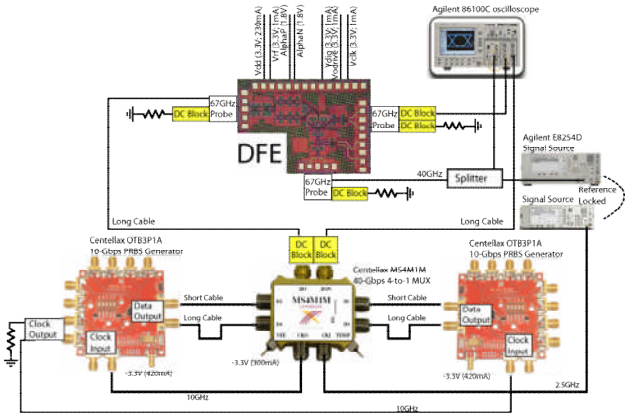
- Adaptive equalizer



Layout & Fabrication



Testing



http://www.vrg.utoronto.ca/EG/

Speakers:

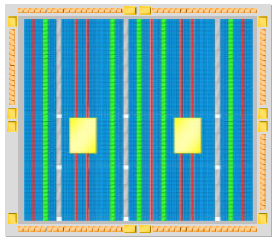
- Prof. J. Rose
- Prof. W.T. Ng
- Prof. R. Genov
- Prof. Y. Sun

FPGA Research: Architecture, CAD, Soft Processors and Systems

Jonathan Rose
Computer Engineering Group
and Electronics Group

Field-Programmable Gate Arrays

- Are pre-fabricated digital chips
  - Programmed to become anything
  - Including large systems!



FPGAs vs. Custom Silicon (ASICs)

- Advantages of FPGAs
  - Instant fabrication: **Seconds vs. Months**
  - Low cost prototyping; **$100 vs. $1M**
  - Cheaper at low volume
  - Don't need to sweat deep-submicron issues!
- Disadvantages of FPGAs
  - 20-30x more area
  - 3-4x slower
  - 10x more power consumption

If VLSI is the Technology of Our Time …

FPGAs <u>Democratize</u> Technology of Our Time

- Make it accessible to everyone
  - Not just the rich who can afford ASICs
  - The small outfit in Singapore, Texas, Winnipeg
  - Small parts of large companies

My Goal

- To replace all digital silicon with FPGAs!
  - By making them better (architecture, CAD, ease of creation)
  - And using them in new ways for new applications
- The score so far:
  - $4B FPGA, $31B Custom Silicon (ASICs)
  - But 99% of all design is done with FPGAs!
  - Very few ASICs gather most of the market

How: FPGA Research: Architecture

- Make better FPGAs by improving their architecture
  - What is the logic
  - How to make the routing better
- Central Question of FPGA Architecture:

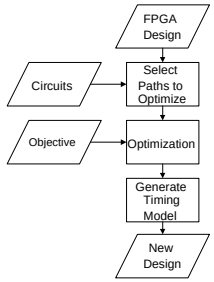
  What logic should be made "hard"?
- Where can we reduce the costly flexibility?
  - Deep question with interesting theoretical & practical branches

How: Computer-Aided Design

- Better tools make FPGAs faster, smaller, lower power
- High Level Synthesis
- Logic Synthesis
- Packing (memory, special structures, logic)
- Placement
- Routing
- To optimize: area, speed, power (dynamic and static)

How: The Creation of FPGAs Themselves

- Automated Layout *of FPGAs themselves*
- Automated Circuit Design of FPGAs
- Current Project:
  - Automating the transistor-level design of FPGAs



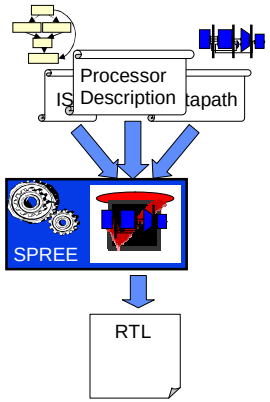
Systems & Applications

- The Transmogrifier Project
  - Creation of programmable systems
- New System: The Transmogrifier-4:
- Interested in applications on
  - Vision
  - Graphics
  - Bioinformatics – simulation
- Next Generation: Transmogrifier-5
  - Super cheap
  - Portable – wireless/full system

Soft Processors

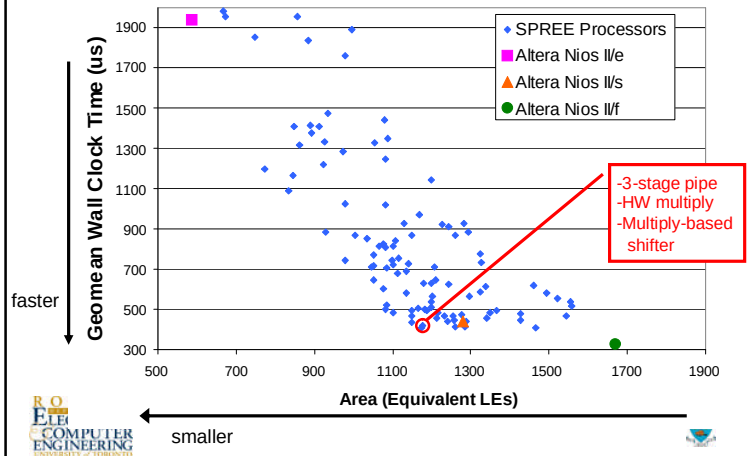
- For FPGAs to conquer, they must have good processors
- *Soft* processors are processors built on FPGA fabric
  - Fabric makes them slower, bigger than hard processors
  - Must use FPGA's flexibility to get this back!
- Example Projects:
  - Exploration of Soft Processor Micro-architecture
  - Super Small Soft Processor
  - Super Fast Soft Processor

Soft Processor Rapid Exploration (SPREE)



- Input: Processor Description
  - Hand-coded components, Datapath
- CAD/Compiler:
  1. Verifies ISA against datapath
  2. Instantiates Datapath
  3. Generates Control
- Output: Synthesizable Verilog

Spanning the Area/Speed Space



FPGAs: Poised To Conquer!

Smart Power ICs & Device Fabrication

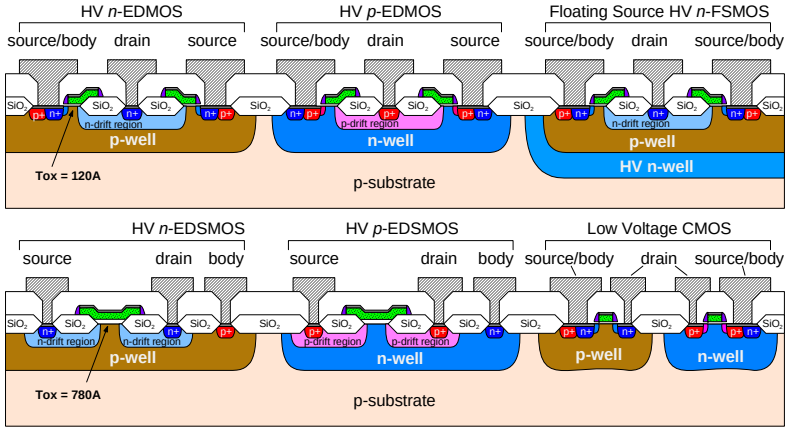
Prof. W.T. Ng
Associate Chair, Undergraduate Studies

Semiconductor Devices	RFICs	Smart Power ICs
RF SiGe HBTs	Active/Diversity Antenna	Motor Drive Circuits
RF BiCMOS	RF Transceiver Circuits	
MEMS Design & Fabrication		Automotive Electronics
High Voltage CMOS		Class D Power Amplifiers
Power MOSFETs		DC-DC Power Converters*
High-k Dielectrics, Deep sub-μ CMOS		VLSI Power Management

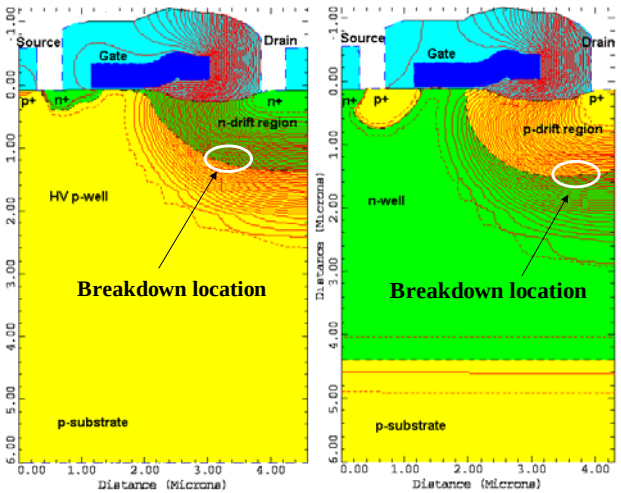
* Also in collaboration with Prof. Prodic's Laboratory for Low-Power Management and Integrated Switch-Mode Power Supplies

HVCMOS – Customized VLSI Fabrication Process for Smart PIC applications

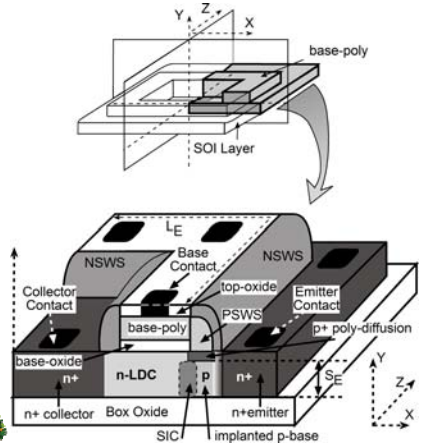
- A variety of HV, Power MOSFETs can be integrated onto the IC chip, accommodating both data processing and power electronic circuits.



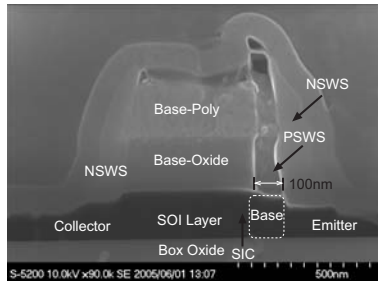
HVCMOS – Customized VLSI Fabrication Process for Smart PIC applications



RF Devices: Lateral BJT on SOI

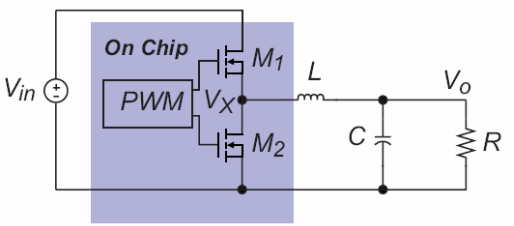


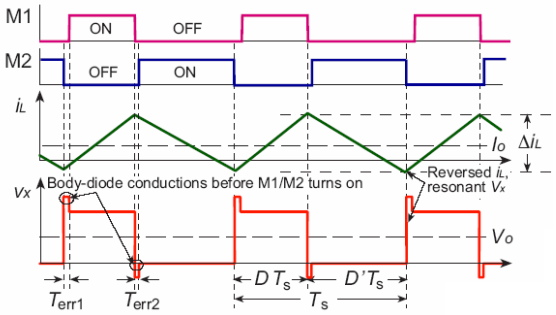
* Best Young Researcher Award at ISPSD 2005
M.I-Shan Sun



High Efficiency Integrated DC-DC Converters

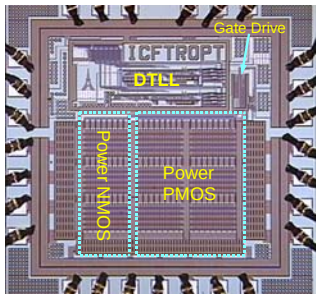
- Integrated PWM controller allows high switching speed e.g. > 5MHz
- Accurate gate drive timing to reduce unwanted switching losses.
- Requires predictive gate timing to make sure that the gate signal arrives at exactly the right moment.

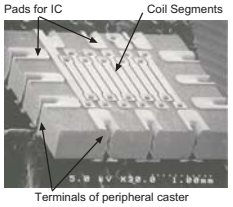




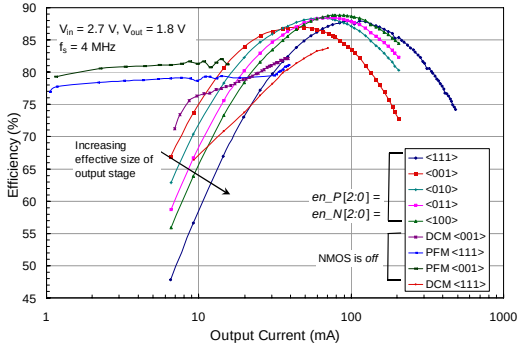
May 12, 2006

High Efficiency Integrated DC-DC Converters





- Design versatile digital controllers for various mode of DC-DC switching operations
- Use of miniaturized inductors to build true chip-size DC-DC converter modules.



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