



## Energy consumption aware software optimization of embedded systems

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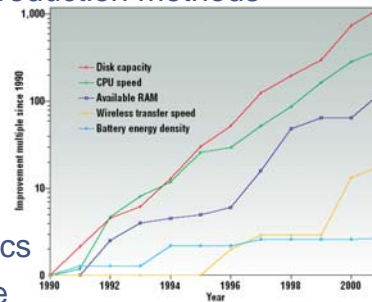
## Outline

- Energy optimization
- Energy aware software optimization
- Measuring instruction level energy consumption: case Atmega8515
- Results and verification
- Future work



## Energy optimization

- Energy consumption of embedded systems is reaching the limits of batteries
- Energy consumption reduction methods
  - Lower operating voltage
  - Lower operating frequency
  - Sleep modes
  - Low power electronics
- ⇒ Not always possible



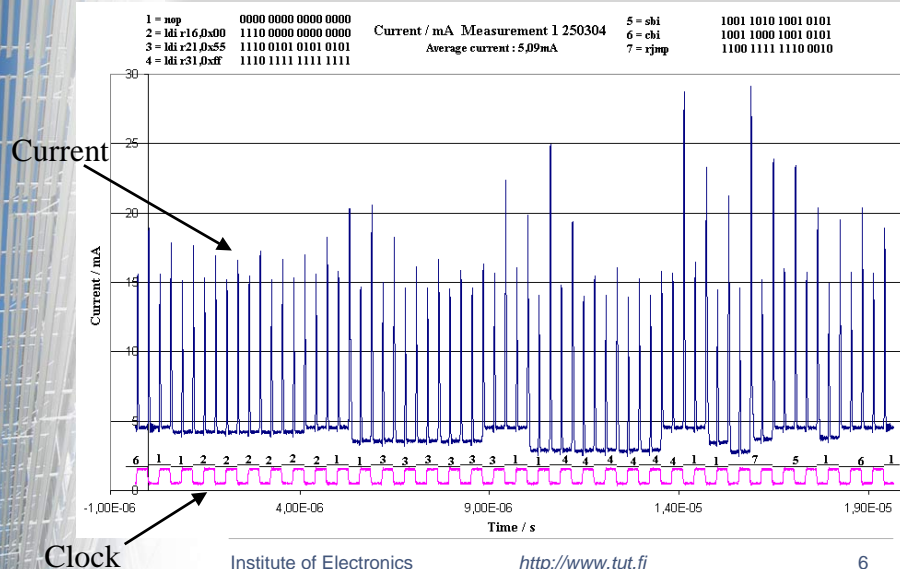
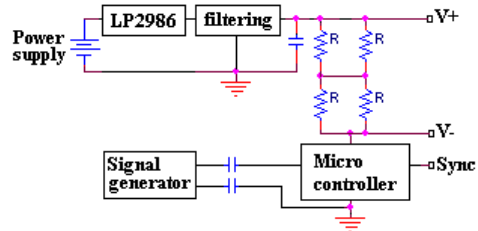
## Energy aware software optimization

- Try to choose instructions which consume as little energy as possible => minimized energy consumption
- Try to balance difference between consecutive instructions => maximize energy available from batteries
- Speed optimization is not always energy optimization.
  - What to do with saved time?
- + No changes to existing hardware



## Measuring instruction level energy

- Testing AT90S8515 and Atmega8515
- Energy of every instruction must be measured
- Pipelining makes measuring difficult
- Simple measurement system utilizes oscilloscope





## Results

- *Zeros* in the opcode are more expensive than *ones*
- In data *ones* are more expensive than *zeros*
- Configuration of unused IOs is important
- Instruction memory (flash) is divided to pages. Activation of new page is expensive
- Usage of some registers is more expensive than usage of other registers



## Results verification

- Simple program, counts an average of eight eight bit integer
- Average current of whole measurement system is measured

<b>Cheaper registers</b>	Data near \$00	Data near \$FF	<b>Expensive registers</b>	Data near \$00	Data near \$FF
Looping inside one page	5,209	5,350	Looping inside one page	5,282	5,449
Looping over page border	5,251	5,393	Looping over page border	5,323	5,492

- Result confirm that energy consumption can be decreased with energy aware software optimization



## Future work

- Implementation of an automatic measurement system
- Writing of a compiler, which can automatically optimize the written software according to the energy consumption



## Thank you

Questions?