PRO-DASP
Power Reduction for Digital Audio Signal Processing
Using Transformations to Implement Hardware-Macros for a Low Power Design Methodology

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Structure

1. Macro-Module Library for Audio-Processing
2. Power-Reduction Strategy
3. Design-Flow
4. Module-Hierarchy
5. Examples (Module and Algorithm)
6. Conclusion
Basic Idea

A library of Macro-Modules for low-power audio digital signal processing
Audio Signal Processing

- Filters are the Central Concept of Signal Processing
- Two main mathematical principles: FIR & IIR

Library

Audio algorithms can be partitioned to a set of filters

=> Library approach is sensible
Macro-Library

Design-goals:
1. Technology independence
   => Low-level (automatic) optimization possible
   => Extensive applicability (technology, size)
2. High level of optimization
3. Easy useability
   => Development of a software-framework

Audio Filter Example: GSM-Compression 1
GSM 06.10 audio compressor model for human speech
GSM Compression 2

- Two filters: 1. Short term prediction
  2. Long term prediction
- Exploits correlation in speech to reduce data-rate
- Implemented in every cellular phone
- 3G: advanced compression scheme

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Power-Reduction Strategy 1

- Two trends related to Moore’s Law:
  - Reduction of energy-delay product
  - Standby-power is becoming more important
Reason:
As Supply Voltages become smaller, the relative Gate-Overdrive has to be reduced as the delay depends on the gate-overdrive

=> For modern technologies, Vdd-Reduction is limited due to relatively high gate-delay for smaller Voltages
Power-Reduction Strategy 5

Consequence for PRO-DASP:
Reduction of switched capacitance by exploiting locality (modularisation, library approach)

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Design-Flow 1

- Partitioning of algorithm to modules
- Heuristical/probabilistical refinement
- Quality assurance via MEDI testbench
- Further optimization through ORINOCO
- Optimization through compiler/back-end tools
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Module-Hierarchy 1

• Two-level approach:
  – Low-level modules for number systems and number representation
  – High-level modules for actual filter architecture
• „Glue-layers“
Module-Hierarchy 2

Low-Power Macro-Module Library

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Example-Module: DECOR 1

- DECoRrelation transform: exploitation redundancy of coefficients to reduce strength of multiplication by only multiplying differences of coefficients (cf. DCM)
- Mathematically a multiplication of the Z-transfer-function with unity

Example-Module: DECOR 2

Direct-FIR

DCM-FIR

DECOR-FIR
Example Module: DECOR 3

\[ Y(z) = H(z) \frac{(1+\alpha z^{-\beta})^m}{(1+\alpha z^{-\beta})^m} X(z) \]

Example Algorithm: Resynthesis 1

- Gammatone-resynthesis is used as pre and post-Processing for audio algorithms
- Set of band-pass filters, frequency selection is approximation of basilar membrane filtering of inner ear
Example Algorithm: Resynthesis 2

Resynthesis Results Fix-Point
Resynthesis Results Floating Point 1

Resynthesis Results Floating Point 2
Resynthesis Results Floating Point 3

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Conclusion

• Modularization is a sensible approach
  – Energy savings for modern technologies
  – Audio algorithms are easily partitioned to modules
  – Modules can be optimized by external tools

• Modules are embedded into a SW-frame
  – Application of probabilistic/heuristic methods for selection and optimization of modules
  – Exploration of a multi-dimensional solution space possible
Conclusion

• Independent of target technology through focusing on algorithmic level (in contrast to existing high-level tools like HYPER-LP)

Outlook

• Integration of probabilistic/heuristic methods for module selection
• Automatic generation of VHDL hardware description in SW-FW
• VLSI chip-design for example algorithm