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RISC-V as an ASIP Platform for Portable Hearing Aid Devices

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Motivation

Background

- Hearing loss is one of the most prevalent sensory impairements
- 430 million individuals currently experience disabling hearing loss
- This number is expected to rise to 700 million by 2050 [1]
- Novel and efficient hearing aid algorithms are required

Challenges

- High-level programmable, low-power, and portable behind-the-ear (BTE) research platforms are required
- Hearing aids often rely on proprietary and closed source signal processors
- Market for hearing aid processors is highly restrictive and dominated by five major manufacturers [2]
- Access to their architectures is limited to selected research organizations

Custom Architecture

- Select `M` and `B` from default settings
- Enable writeback stage and branch predictor
- Add custom CORDIC unit in *custom0* opcode

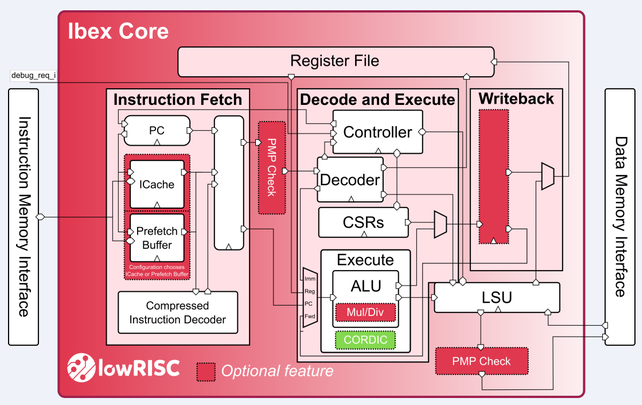

Figure 1: Custom CORDIC added to IBEX Architecture

Algorithms

- Balance audio quality with execution time
- Comparatively low sampling rate of 16kHz
- MATLAB based framework for fixed-point analysis

Monaural Loudness Compensation (MLC) [3]

- Adjust the audio spectrum to match hearing loss
- Amplify and compress audio to improve speech intelligibility
- Relies heavily on non-linear operations (log, exp)

MVDR-Beamformer [4]

- Filter out directional noise
- Focus on desired audio, i.E. speech
- Operates in the complex number domain

Results

- Initial evaluation in terms of computational performance
- Further evaluation using a 22nm FD-SOI ASIC technology

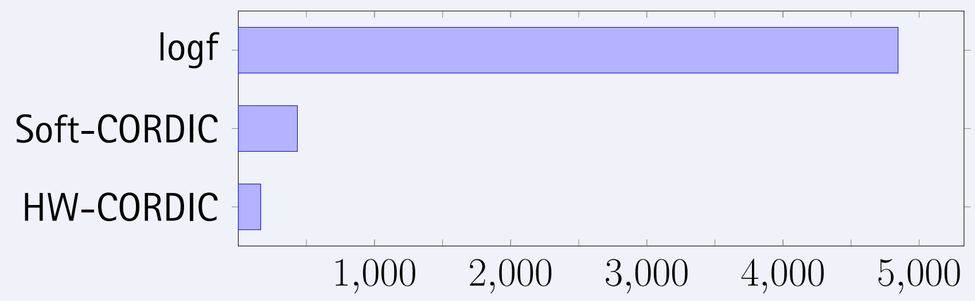

Figure 2: Cycles for execution log function

- Software CORDIC improves runtime by 85% compared to logf
- Hardware CORDIC achieves further 62% speedup
- Increased efficiency due to reduced data transfer

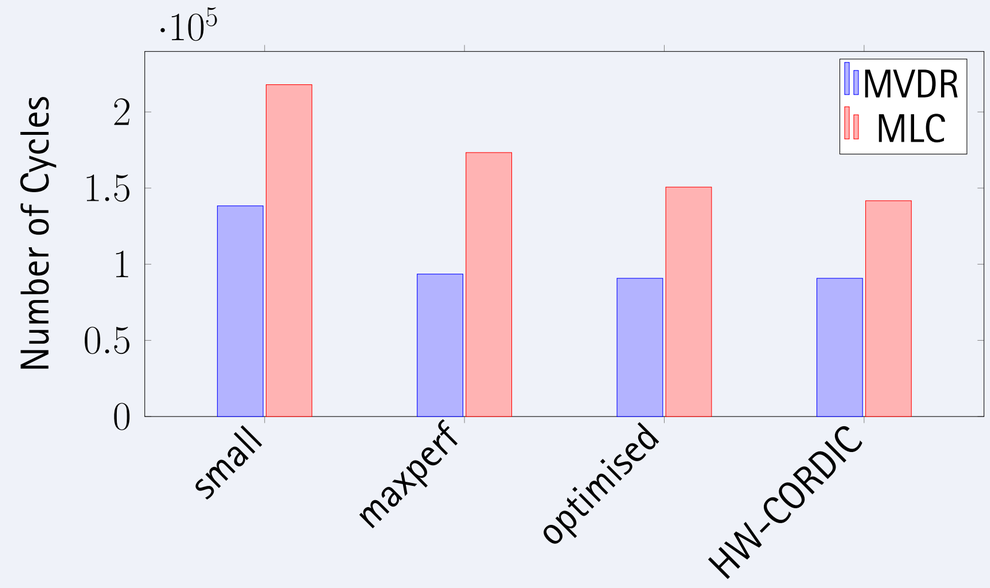

Figure 3: Cycles for execution of MVDR and MLC

- Speedup of 34% from *small* to *optimised* for the MVDR and a similar value of 31% for the MLC
- MLC algorithm is further accelerated by 6% by introducing the custom CORDIC unit (HW-CORDIC)
- *HW-CORDIC* is the fastest configuration, while *maxperf* is the most efficient
- Further optimisation for MVDR required

References

[1] WHO, Deafness and Hearing Loss, *Fact Sheet* 2024

[2] Statista, Global Hearing Aid Market Share by Company 2019

[3] Oetting et al. "Characterizing Individual Hearing Loss Using Narrow-Band Loudness Compensation", Proceedings of the International Symposium on Auditory and Audiological Research, 2015

[4] Adiloğlu et al. "A Binaural Steering Beamformer System for Enhancing a Moving Speech Source", Trends in hearing, 2015