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Multipliers-Driven Perturbations of Coefficients for Low-Power Operation in Reconfigurable FIR Filters

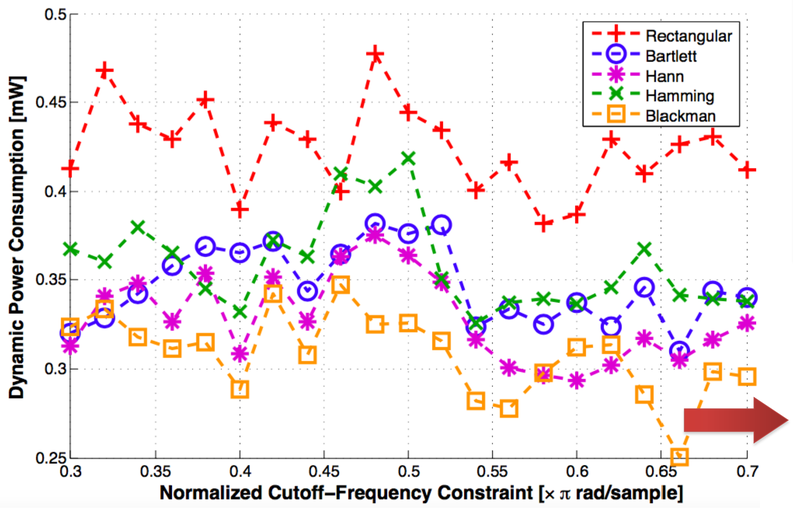
Andrea Bonetti, Adam Teman, Andreas Burg

Telecommunications Circuits Laboratory (TCL), École Polytechnique Fédérale de Lausanne (EPFL)

Low-Power Digital Signal Processing

Portable devices require digital signal processors able to:

- Support different communication standards
- Ensure a long battery life



Dynamic power of the 8x8-bit multipliers in a 16-taps FIR filter

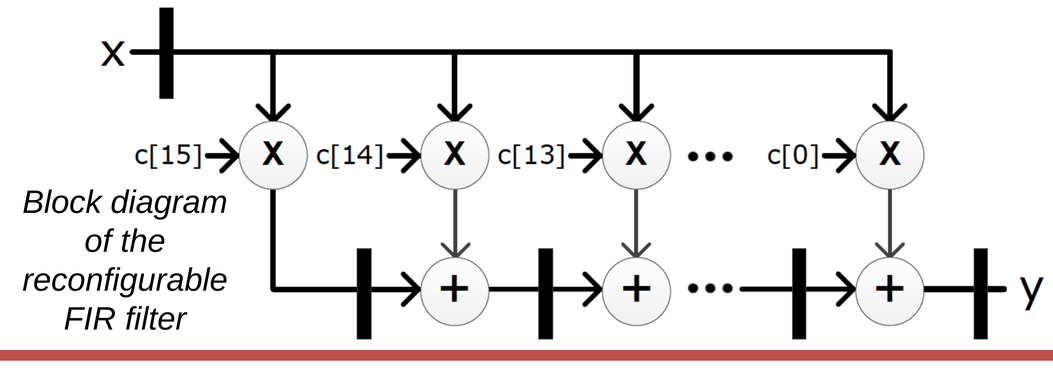
Reconfigurable FIR filters are widely implemented and it is essential to **limit their power consumption**.

Dynamic power significantly varies in multipliers with design constraints and windowing method.

Perturbation of FIR Coefficients

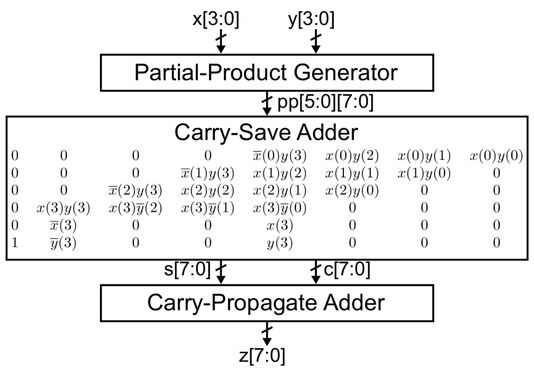
Coefficients in FIR filters are perturbed for low-power operation:

1. **Reconfigurable FIR filters** are considered where different coefficients can be assigned to the multipliers
2. **Analysis of switching activity** conducted in common **multipliers** to identify possible dynamic-power savings
3. **Gate-level power simulations** of multipliers for an accurate characterization of the possible power savings
4. **Perturbation** of exact **FIR coefficients** to trade accuracy of the filter for less power consumption

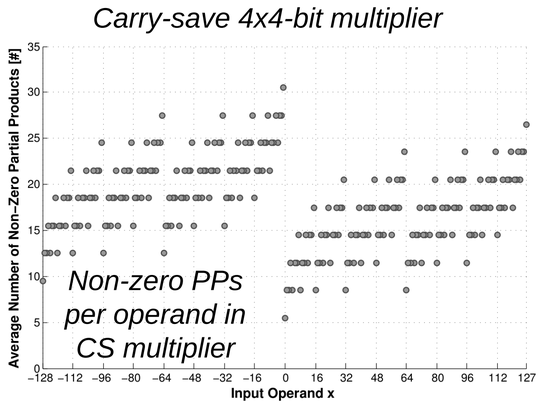


Block diagram of the reconfigurable FIR filter

Switching Activity in Multipliers



Carry-save 4x4-bit multiplier



Reduce dynamic power:

- **Limit switching activity** in the carry-save adder.
- Find operands that **minimizes** the **number of non-zero partial products** (PPs).

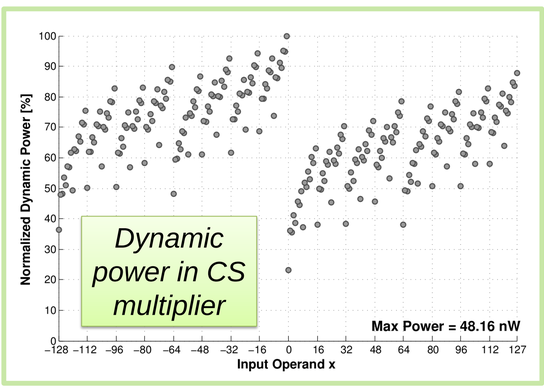
Carry-Save (CS) Multiplier

- Simple and medium speed
- *Symmetric*: power savings given for both input operands

Radix-4 Booth (BR4) Multiplier

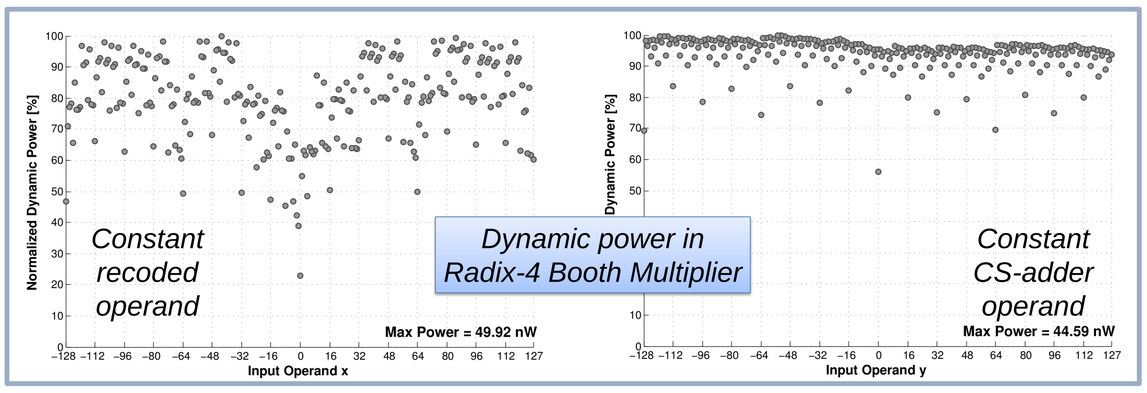
- Complex and high speed
- *Asymmetric*: savings given when assigning coefficients to the recoded operand

Gate-Level Characterization of Multipliers

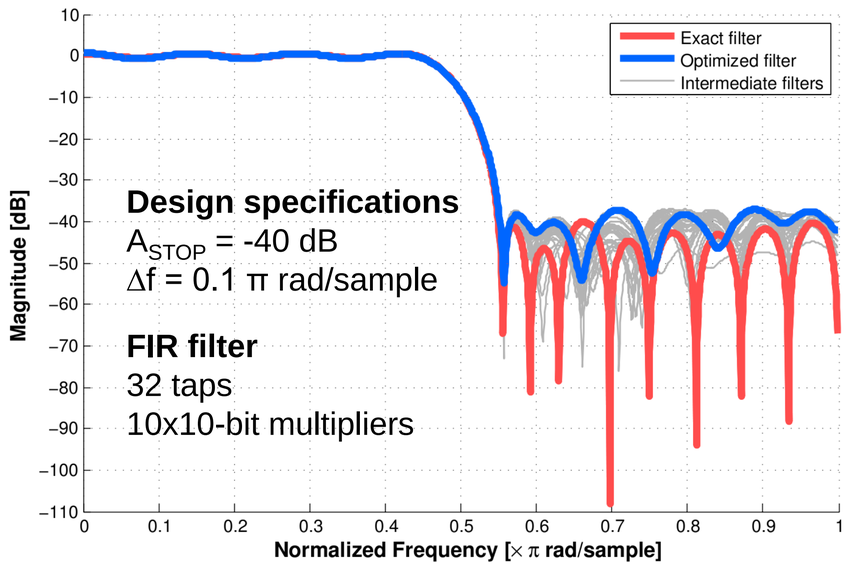


Gate-level simulations

- Accurate power characterization
- Confirmed expected savings
- Preferring the operand that allows for power savings does not affect the multiplier speed



Response of the Approximated FIR Filter



- The exact coefficients are perturbed based on multiplier characterization to **maximize the power savings**.
- Approximated filter obtained accepting only **3dB error** on stopband attenuation to **minimize accuracy degradation**

Power Savings and Conclusions

TABLE II
DESIGN SPECIFICATIONS AND POWER SAVINGS OF THE FIR FILTERS

A_s^a [dB]	F_t^a [$\pi \frac{\text{rad}}{\text{sample}}$]	Multipliers Width	Taps	S_{Mul}^b [%]	S_{FIR}^b [%]
-30	0.2	8×8	16	18.0	14.7
-40	0.2	10×10	16	24.2	19.5
-30	0.1	8×8	32	24.2	20.2
-40	0.1	10×10	32	14.6	11.7

[a] Design specifications of the exact filter.
[b] Obtained when tolerating a 3 dB error on the stopband attenuation.

Power savings in the FIR filter

- Coefficients perturbation verified on different FIR filters
- Dynamic power savings:
  - Up to **24.2%** in **multipliers** implemented in the filter
  - Up to **20.2%** in **FIR filters** due to design overhead

Conclusions

- **Exact operation** preferred when **accuracy** required
- **Approximated coefficients** used for **low-power** operation