

# Contributions to computer arithmetic and applications to Embedded systems

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# Floating-Point in embedded systems

- Floating-point is everywhere
  - Graphics processing
  - Scientific computing
  - Digital signal processing
- Challenge: versatility versus efficiency
  - Wide range of operations
  - High performance required

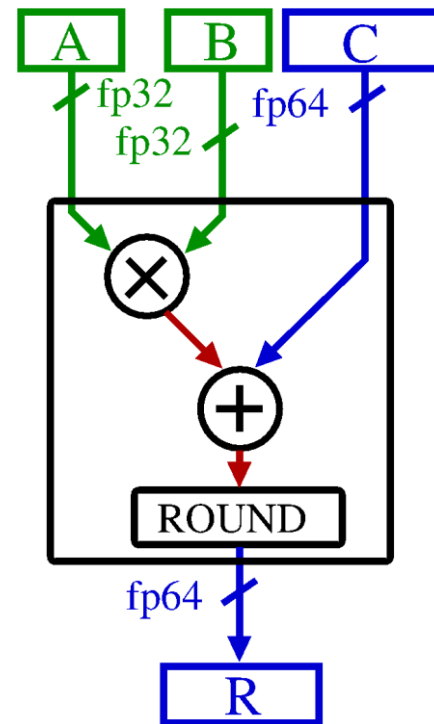


# Divide and conquer

- Categorize elementary operations:
  - Basic primitives
  - Complex primitives
  - Mathematical functions
- Adapt the implementation:
  - Balance between:
    - Cost (including development)
    - Efficiency

# Floating-Point Unit

- Dedicated hardware
  - Support 4 operations (+, -, \*, FMA)
  - Fastest and most efficient solution
- Contributions
  - MPFMA, 2D dot-product
  - Time predictability on subnormals



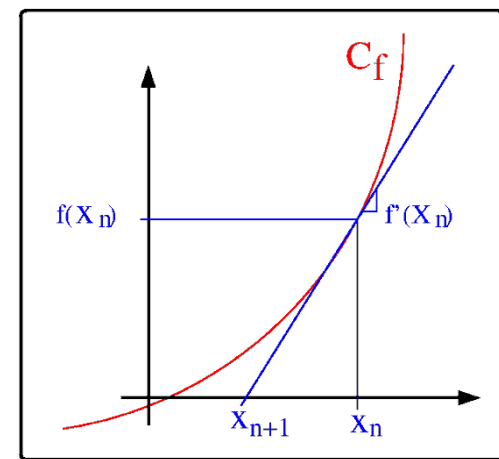
# Floating-Point Unit

Operator	Latency (ns)	Area ( $\mu\text{m}^2$ )
FMA 32	3.5	10600
FMA64	3.5	24500
MPFMA32	3.5	14000
K1 FPU	2.5	33900
K1 Core	2.5	153400

Efficient but expensive solution

# Software Primitives

- Less frequent operations
  - Division, square root
  - High performance
- Solution: FPU-based software
  - Newton-Raphson algorithm
  - Manually developed
  - ISA extension (seed and RN)



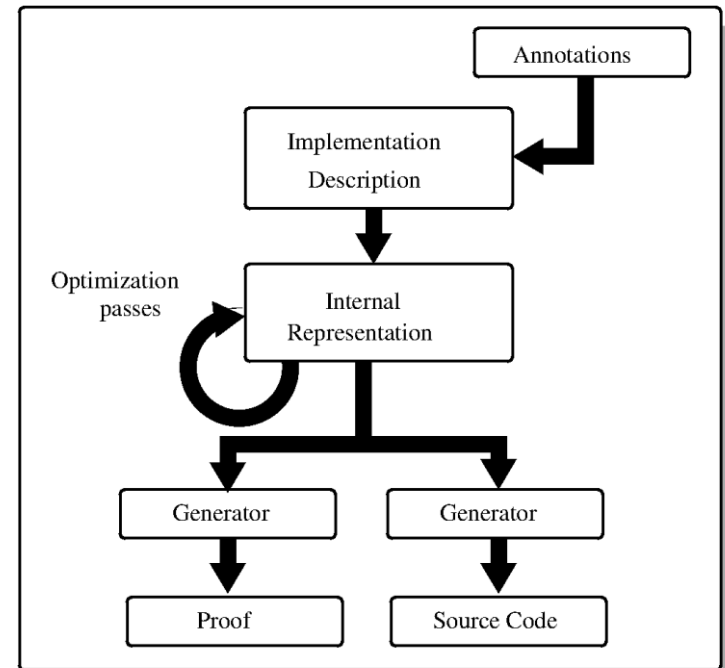
# Software primitives

Description	Latency (cycles)	Throughput (CPE)
K1 reciprocal	25	8
K1 division	45	13
K1 square root	34	14
FLIP division (ST 231)	35	35
FLIP square root (ST231)	21	21
ARM Cortex-A9 fdiv	15	10
ARM Cortex-A9 fsqrt	17	13

Better balance but still costly development time

# Mathematical functions: Metalibm

- Automatic code generation
  - MDL description
    - User knowledge
  - Code generator
    - Various parameters
    - Many targets
- Contributions:
  - Vectorization
  - Certification





# Metalibm applications

Description	Throughput (CPE)	Error (ulp)
Intel's libimf exp	45,89	0,503
Glibc libm exp	130,86	0,5
Metalibm exp	79,62	0,5009
Intel's VML vectorized exp (AVX)	7,59	0,63
Metalibm vectorized exp (AVX)	11,59	0,5009
Metalibm vectorized CR exp (AVX)	20,99	0,5

# Conclusion

- A solution adapted to each category
- Work integrated into Kalray's MPPA
- New FPU version under development
  - FMA64
  - SIMD fp32
- Merge with ANR Metalibm project

# Questions ?