EXPLORING EFFICIENT APPROXIMATE MULTIPLIERS

VISHAL VIJAY DEVADIGA
(CS21BTECH11061)
GUIDE: DR. RAJESH KEDIA

Department of Computer Science and Engineering, IIT Hyderabad

INTRODUCTION

Approximate multiplication is a computational technique to calculate the product of two number with reduced precision to achieve specific trade-offs such as reduced computation time, power and area. It is useful in a lot of applications such as machine learning, signal processing and embedded systems where perfect precision is unnecessary.

ROBA Algorithm [1]

For a number X: Define X_R as the nearest power of 2. Then,

$$A \times B = (A - A_R) \times (B - B_R) + A_R \times B + B_R \times A - A_R \times B_R$$

On ignoring the term $(A - A_R) \times (B - B_R)$,

$$A \times B \cong A_R \times B + B_R \times A - A_R \times B_R$$

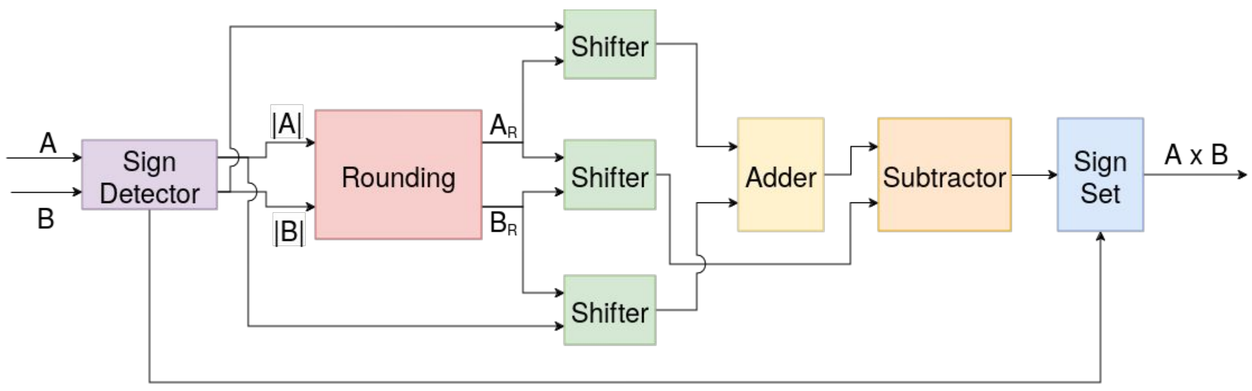

Fig 1: ROBA Multiplier

Research Question

Can we get a more precise value of $A \times B$ by approximating rather than ignoring the term $(A - A_R) \times (B - B_R)$?

Let $(X - X_R) = X'$. Then we can modify ROBA to recursively apply to the term $(A - A_R) \times (B - B_R) = A' \times B'$. That is,

$$A' \times B' \cong A'_R \times B' + B'_R \times A' - A'_R \times B'_R$$

TD-ROBA Algorithm

Suppose for a number X, X_R is the nearest floor power of 2.
This increases the max error rate of the original computation of ROBA to ***25%***, but now finding A' and B' is easier as:

$$X' = X - X_R = X \oplus X_R$$

The ROBA multiplication for A' and B' can be parallelly computed after finding A_R and B_R. The new max error rate is ***6.25%***.

R-ROBA Algorithm

Rather than having additional modules for computing the ROBA multiplication for A' and B', we can reuse the ROBA module sequentially to calculate $A' \times B'$.
This will:`

- Increase computation time compared to all variations of ROBA
- Increase the complexity of the circuit
- Slight increase the area compared to ROBA
- Improve the max error rate to ***1.21%***.

WORK DONE

- Reviewed multiple papers on Approximate Multipliers
- Identified ROBA as area to improve accuracy with tradeoffs in Power, Delay and Area.
- Designed and implemented TD-ROBA with verilog and analysed Power, Delay, Area metrics using Open-Source Libraries
- Designed R-ROBA and derived the possible error reduction

Comparison of Approximate Multipliers

Multiplier	Signed	Max Error	MRE	Power	Delay	Area
S-ROBA [1]	Yes	11.11%	2.91%	2.09	1.21	2.90
U-ROBA [1]	No	11.11%	2.92%	1.23	**1.00**	2.32
DRUM6 [2]	No	6.34%	1.47%	1.20	1.17	**1.00**
DSM8 [3]	No	9.99%	0.53%	**1.00**	1.29	1.53
HAAM [4]	No	13.76%	2.04%	4.01	2.63	4.07

Comparison of 32-bit inputs and 64-bit output multipliers. P, D, A Metrics are normalized.

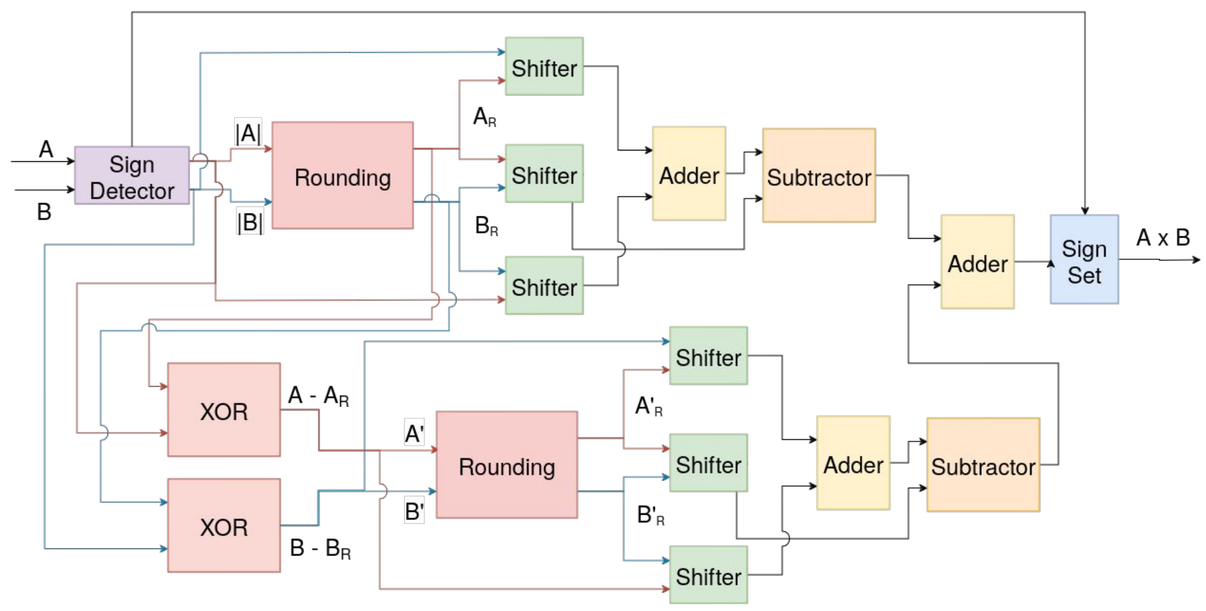

Fig 2: TD-ROBA Multiplier

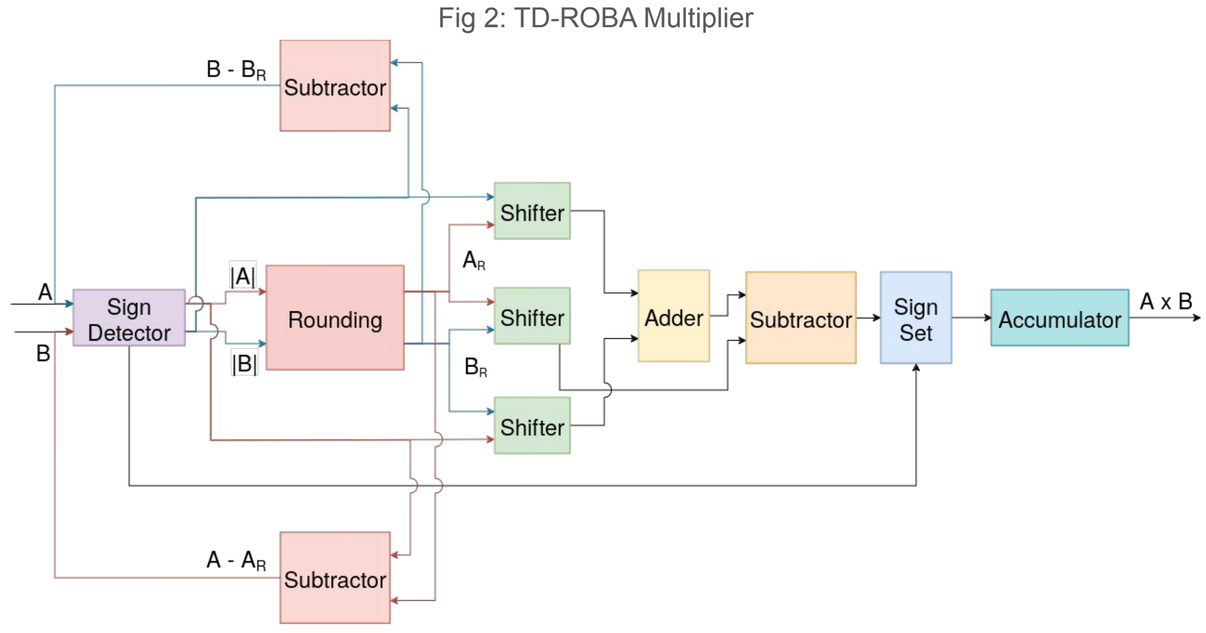

Fig 3: R-ROBA Multiplier

Comparison of ROBA Multipliers

Multiplier	Signed	Max Error	MRE	Power	Delay	Area
S-ROBA	Yes	11.11%	2.91%	1.70	1.21	1.25
U-ROBA	No	11.11%	2.92%	**1.00**	**1.00**	**1.00**
TD-ROBA	Yes	**6.25%**	**0.96%**	4.34	1.08	2.09

Comparison of 32-bit inputs and 64-bit output multipliers. P, D, A are normalized to U-ROBA

TOOLS

- YoSYS : Verilog RTL Synthesis
- OpenROAD : RTL to GDS Flow
- ABC : Mapping to target architectures

FUTURE WORK

- Comparison of TD-ROBA with other multipliers in real world scenarios
- Implementing R-ROBA and establishing the P, D, A metrics

REFERENCES

- [1] R. Zendegani, M. Kamal, M. Bahadori, A. Afzali-Kusha and M. Pe-dram, "Roba multiplier: A rounding-based approximate multiplier for high-speed yet energy-efficient digital signal processing", *IEEE Transactions on Very Large Scale Integration (VLSI) Systems*, vol. 25, no. 2, pp. 393-401, 2016.
- [2] S. Hashemi, R. I. Bahar, and S. Reda, “DRUM: A dynamic range unbiased multiplier for approximate applications,” in Proc. IEEE/ACM Int. Conf. Comput.-Aided Design (ICCAD), Austin, TX, USA, 2015, pp. 418–425.
- [3] S. Narayanamoorthy, H. A. Moghaddam, Z. Liu, T. Park, and N. S. Kim, “Energy-efficient approximate multiplication for digital signal processing and classification applications,” IEEE Trans. Very Large Scale Integr. (VLSI) Syst., vol. 23, no. 6, pp. 1180–1184, Jun. 2015.
- [4] C.-H. Lin and I.-C. Lin, “High accuracy approximate multiplier with error correction,” in Proc. 31st Int. Conf. Comput. Design (ICCD), 2013, pp. 33–38.