

[Public]

F-TFM: Accelerating Total Focusing Method on FPGA

Bizhao Shi, Jieran Zhang, and Guojie Luo

Peking University, Beijing City



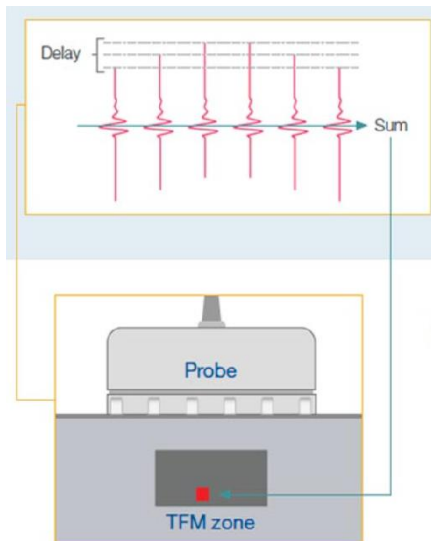
OpenHW2023



On board test by AMD KU19P

INTRODUCTION

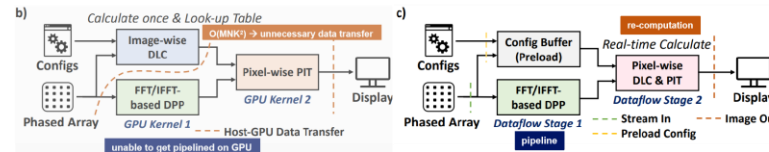
The **Total Focusing Method (TFM)** is a specialized ultrasound imaging algorithm employed for non-destructive testing in various industries. It finds applications in material science, aerospace, and beyond. The TFM Imaging System utilizes a 01D/2D ultrasonic phased array, incorporating Full/Half Matrix Capture for comprehensive data acquisition. The system also includes a dedicated post-processing processor to enhance the quality of imaging results. This integrated approach makes TFM an effective and versatile solution for precise imaging in non-destructive testing across different sectors, ensuring its relevance in fields such as material science and the aerospace industry.



Workflow organization

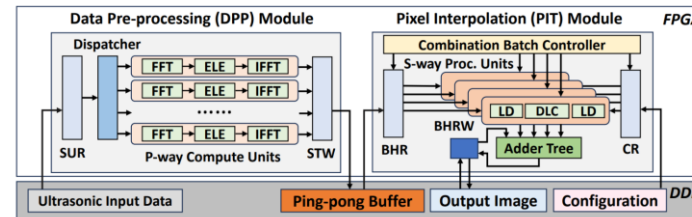
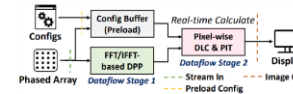
- ▶ Real-time pixel-wise DLC
 - Reduce more than 90% memory access
- ▶ DPP-PIT Dataflow
 - Reduce the context switching overhead

Task	Computation	Memory	Pattern
DLC	$O(MNK)$	Read: $O(K)$ Write: $O(MNK)$	Element-wise
DPP	$O(TK^2 \log K)$	Read: $O(TK^2)$ Write: $O(TK^2)$	Row-wise
PIT	$O(MNK^2)$	Read: $O(TK^2) = O(MNK^2)$ Write: $O(MN)$	Column-wise Element-wise

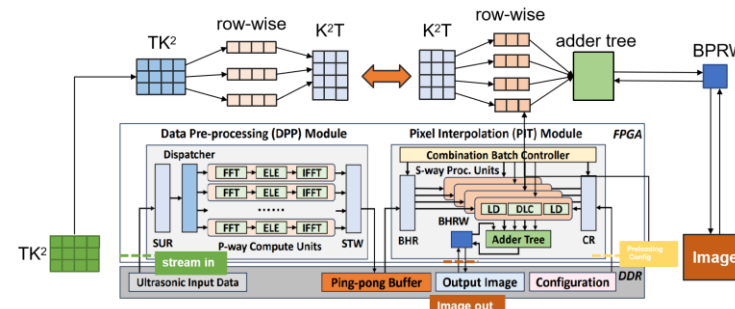


F-TFM Solution — Workflow Design

- ▶ Overall accelerator architecture design
- ▶ Parallel compute units in DPP and PIT modules.
- ▶ In-DDR ping-pong buffer.



Accelerator architecture design

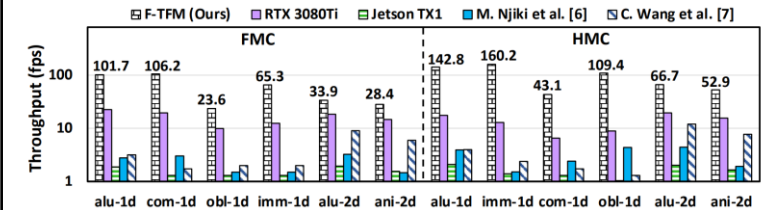


F-TFM Solution — Hardware Design

CREATIVE DESIGN

RESULT

The **F-TFM (Full Total Focusing Method)** is summarized through a comprehensive examination of its algorithm and workflow. This includes an in-depth analysis of its efficient accelerator design, encompassing workflow organization, dataflow design, and parameter optimizations. The result is a **high-performance and high-efficiency TFM imaging system with notable scalability.**



Throughputs of F-TFM

NORMALIZED ENERGY EFFICIENCY COMPARISONS

Format	Platform	alu-1d	com-1d	obl-1d	imm-1d	alu-2d	ani-2d
FMC	RTX 3080Ti	1.00 ×	1.00 ×	1.00 ×	1.00 ×	1.00 ×	1.00 ×
	Jetson TX1	1.49 ×	0.69 ×	1.55 ×	0.85 ×	1.98 ×	1.86 ×
	F-TFM (Ours)	34.13 ×	47.15 ×	19.54 ×	46.63 ×	14.26 ×	15.32 ×
HMC	RTX 3080Ti	1.00 ×	1.00 ×	1.00 ×	1.00 ×	1.00 ×	1.00 ×
	Jetson TX1	2.13 ×	0.96 ×	1.90 ×	0.98 ×	1.93 ×	1.85 ×
	F-TFM (Ours)	67.77 ×	108.20 ×	39.95 ×	147.21 ×	26.48 ×	26.86 ×

Energy efficiency of F-TFM