

RESEARCH ACTIVITIES

Self-Reconfigurable Embedded Systems

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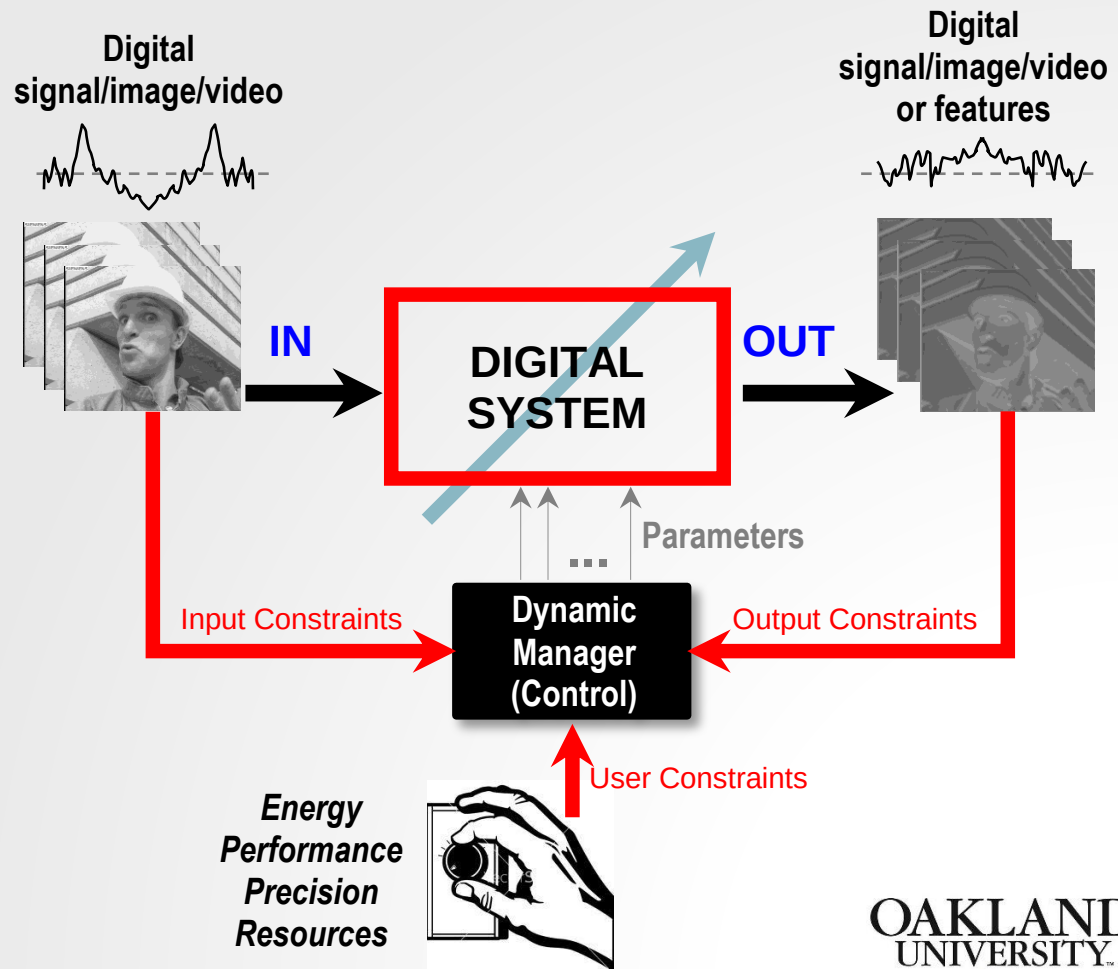
- Self-Reconfigurable Embedded Systems
- Current Research Activities
 - Video Compression: HEVC
 - Radon Transform and Radon-Based 2D Convolutions
 - Smart Antennas
 - Cylinder Pressure Estimation
- Goals

Self-Reconfigurable Embedded Systems

Digital systems can be characterized by a series of properties:

- *Energy*
- *Performance*
- *Precision,*
- *Bandwidth, Quality, etc.*

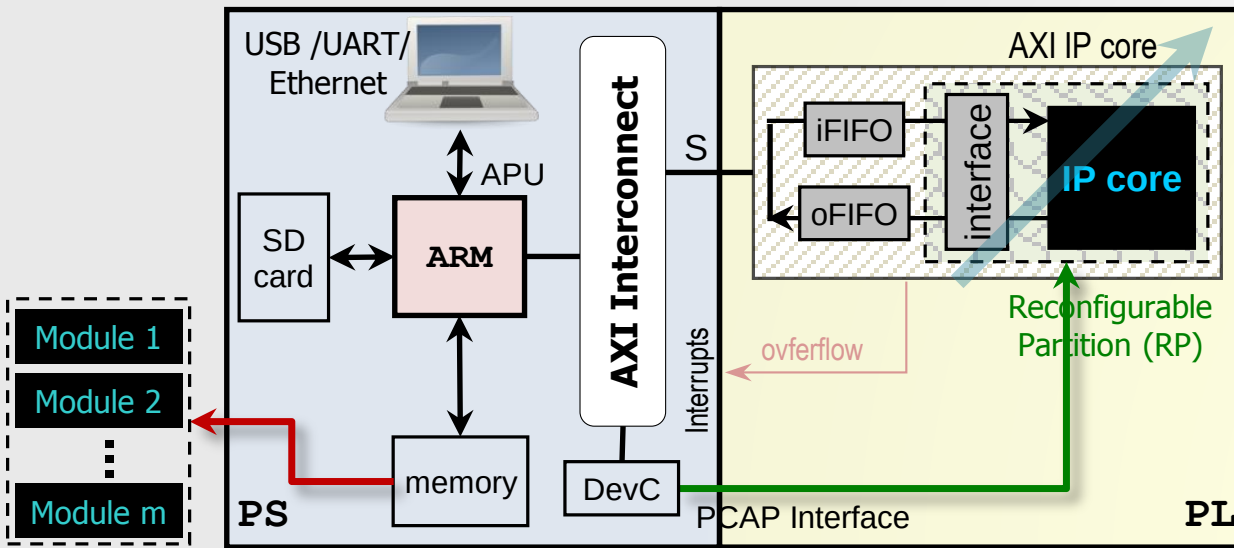
***Self-Reconfigurable Embedded Systems** are self-adaptive systems that can satisfy time-varying requirements, optimizing resources and energy.*



Self Reconfigurable Embedded Systems

- **Technology:** Programmable System-on-Chip (SoC): They integrate:
 - *Processing System (PS):* A dual-core ARM® Cortex™-A9 processor and common peripherals (USB, SD, etc.)
 - *Programmable Logic (PL):* Reconfigurable fabric (also known as FPGA) that can be reconfigured at run-time.

Xilinx Zynq-7000 All-Programmable SoC:

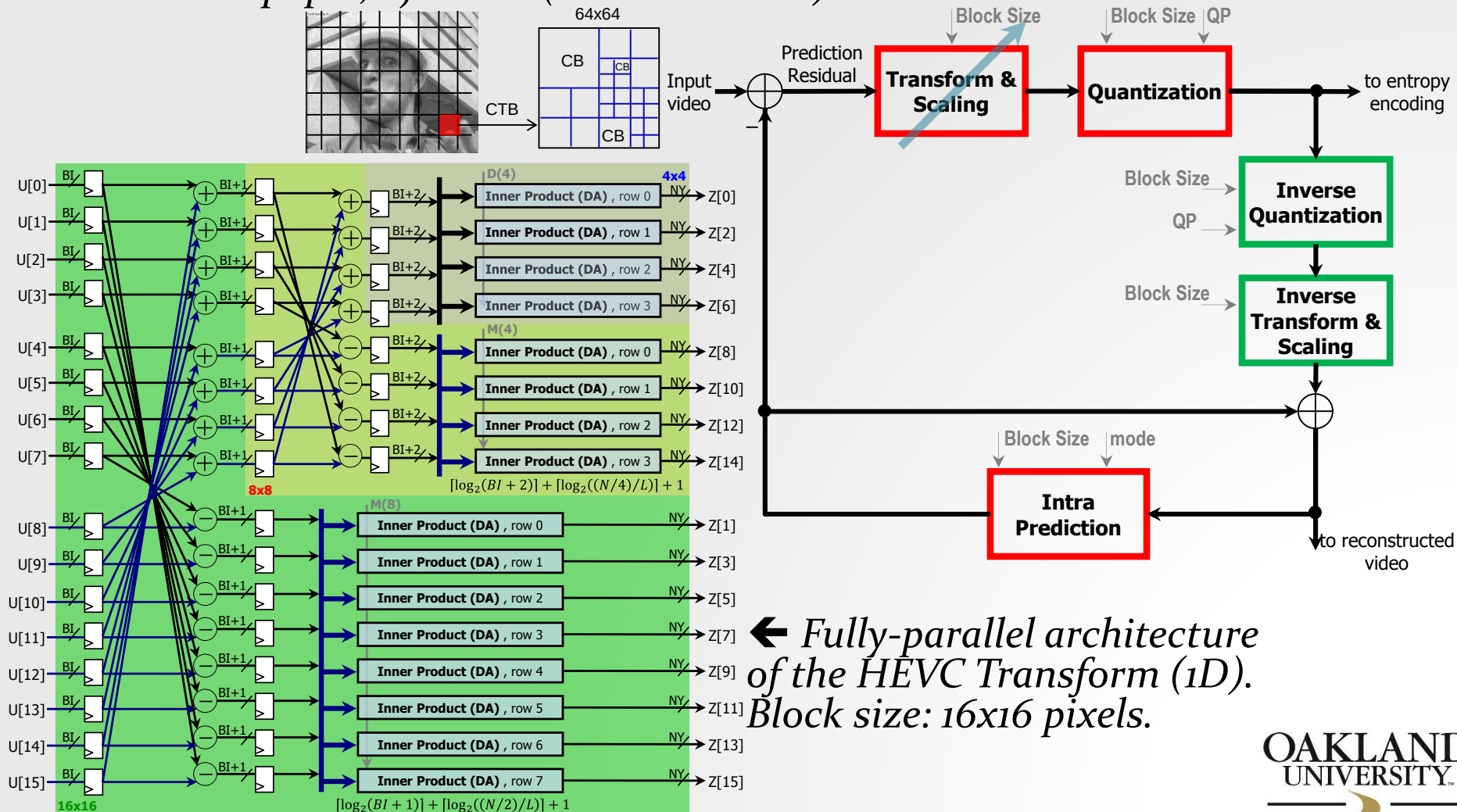


Embedded system with common peripherals, interrupts, and run-time alterable custom hardware.

Current Research Activities

❖ Video Compression Standard (HEVC) Implementation

- Self-reconfigurable hardware implementation: Transform (Forward and Inverse), Quantization, Intra-Prediction
- Products: 1 paper, 1 journal (minor revision).



RECRLab
Reconfigurable Computing Research Laboratory

- *Scalable dedicated architectures for Direct/Inverse Radon Transform and for Radon-based 2D Convolution (faster than FFT methods)*
- *Products: 2 conf. papers, 2 journals, 1 journal under review, one patent.*

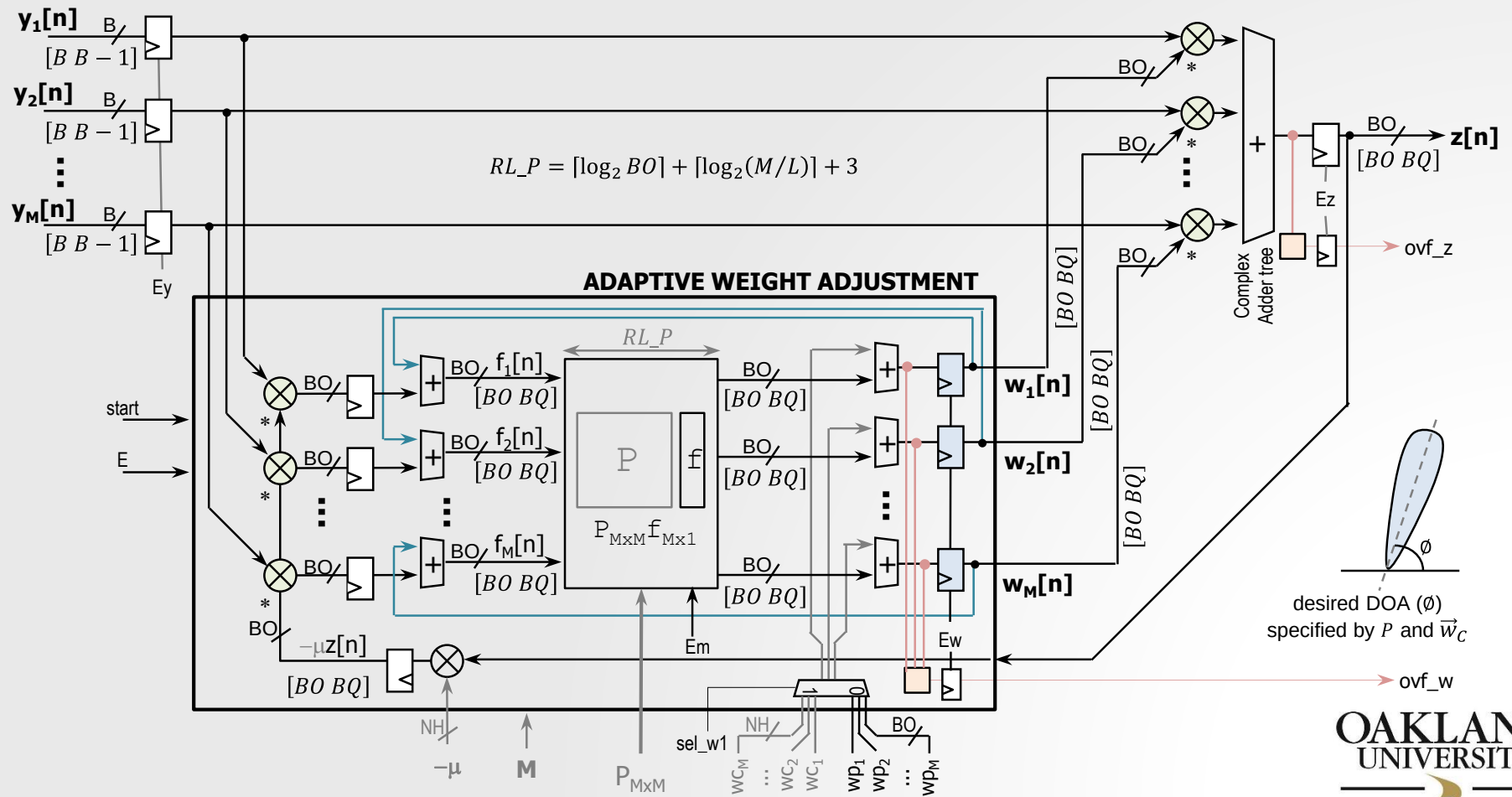
The diagram illustrates the high-level architecture of the proposed 1D-CNN accelerator. It consists of several main components and data paths:

- Input RAMs:** G_DRi and H_DRi provide inputs $g(i, j)$ and $h(i, j)$ to the **SFDPR** and **ISFDPR** systems, respectively. They also receive control signals like $start$, iwr , and BC .
- SFDPR and ISFDPR Systems:** These systems process the input data. G_DRi outputs $GRAM_Zo$ and $GRAM_Co$ to the **1D Circular Convolver**. H_DRi outputs $HRAM_Zo$ to the **1D Circular Convolver**. Both systems have **oRAM** (output RAM) and **oRAM_Co** (output RAM control) blocks.
- 1D Circular Convolver:** This block takes $GRAM_Zo$, $GRAM_Co$, and $HRAM_Zo$ as inputs. It outputs $GRAM_Co$ to the **ISFDPR** system and $HRAM_Co$ to the **FSM**. It also outputs $GRAM_Co$ to the **oRAM_Fo** block.
- ISFDPR System:** This system takes $GRAM_Co$ and $HRAM_Co$ as inputs. It outputs $GRAM_Co$ to the **oRAM_Fo** block and $HRAM_Co$ to the **FSM**. It also outputs $GRAM_Co$ to the **oRAM_Fo** block.
- oRAM_Fo and iRAM_DRo:** These blocks are part of the output RAM system. $oRAM_Fo$ outputs $GRAM_Co$ to the **FSM**. $iRAM_DRo$ outputs $GRAM_Co$ to the **FSM**.
- FSM (Finite State Machine):** This block receives control signals from the **oRAM_Fo** and $iRAM_DRo$ blocks. It outputs control signals like $GRAM_en$, $HRAM_en$, $GRAM_enx$, $HRAM_enx$, $GRAM_addr$, $HRAM_addr$, $GRAM_addrx$, $start_inv$, E_G , E_H , and s_H .

The diagram also shows various control signals and data paths, including $start$, iwr , $done$, $done_G$, $done_inv$, $start_inv$, $oRAM_xaddr$, $oRAM_rd$, $oRAM_en$, $oRAM_addr$, $oRAM_addrx$, $oRAM_enx$, $oRAM_wex$, $oRAM_DRix$, $GRAM_DRix$, $GRAM_Zo$, $GRAM_Co$, $HRAM_Zo$, $HRAM_Co$, $GRAM_en$, $HRAM_en$, $GRAM_enx$, $HRAM_enx$, $GRAM_addr$, $HRAM_addr$, $GRAM_addrx$, $start_inv$, E_G , E_H , and s_H .

❖ Smart Antennas

- Implementation of switched-beam smart antennas using self-reconfigurable architectures to steer the beamformer in a particular direction at run-time, and to respond to arithmetic overflow by updating the numerical format.
- Products: 1 conference paper, 1 journal under review

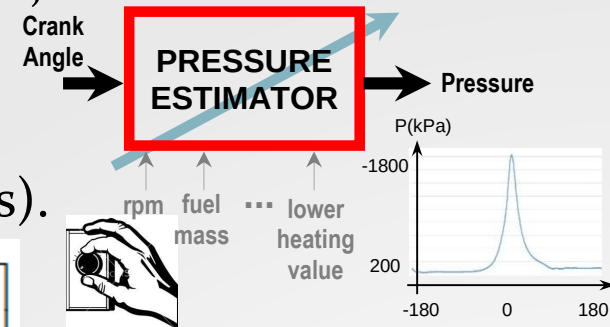


Current Research Activities

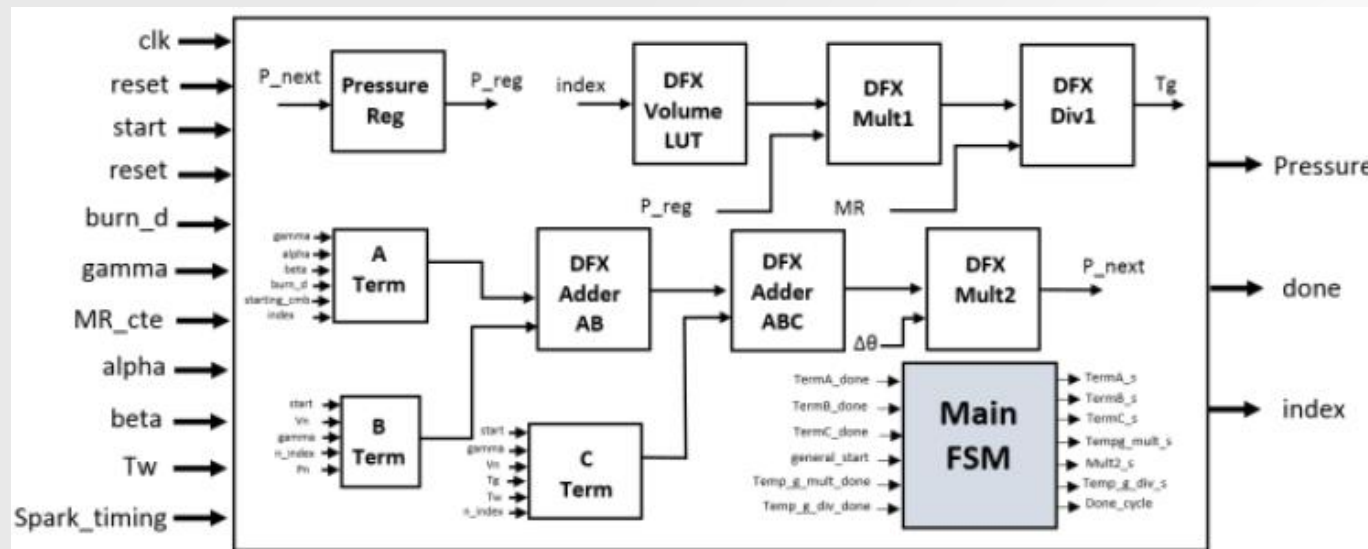
❖ Cylinder Pressure Estimation

- Closed Cylinder Engine: Based on Real pressure data, dQ_{HR} is computed for various load and rpm conditions. Then, a model for dQ_{HR} is derived.
- Then, Pressure can be estimated with the dQ_{HR} model (hopefully for many load and rpm conditions).

$$P(n+1) = P(n) + \Delta\theta \left[\frac{(\gamma-1)}{V(n)} \frac{dQ_{HR}}{d\theta} \Big|_n - \gamma \frac{P(n)}{V(n)} \frac{dV}{d\theta} \Big|_n - \frac{(\gamma-1)}{V(n)} \frac{dQ_{HT}}{d\theta} \Big|_n \right]$$



- Hardware implementation: It uses Dual Fixed-Point Arithmetic that provides a compromise between Floating Point Arithmetic (high hardware usage) and Fixed Point (reduced range of numerical values).



❖ Apply for funding to the following entities:

- Army Research Laboratory (ARL): Switched-beam Smart Antennas
- Office of Naval Research (ONR): Dynamic biomimetic sensors.
- NSF: Distributed Video Analysis using fast 2D Convolutions based on reconfigurable Radon Transforms and HEVC decoder/encoder
- Chrysler, Ford: Instantaneous Pressure estimation using self-reconfigurable embedded systems.