RESEARCH ACTIVITIES

Self-Reconfigurable Embedded Systems

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Outline

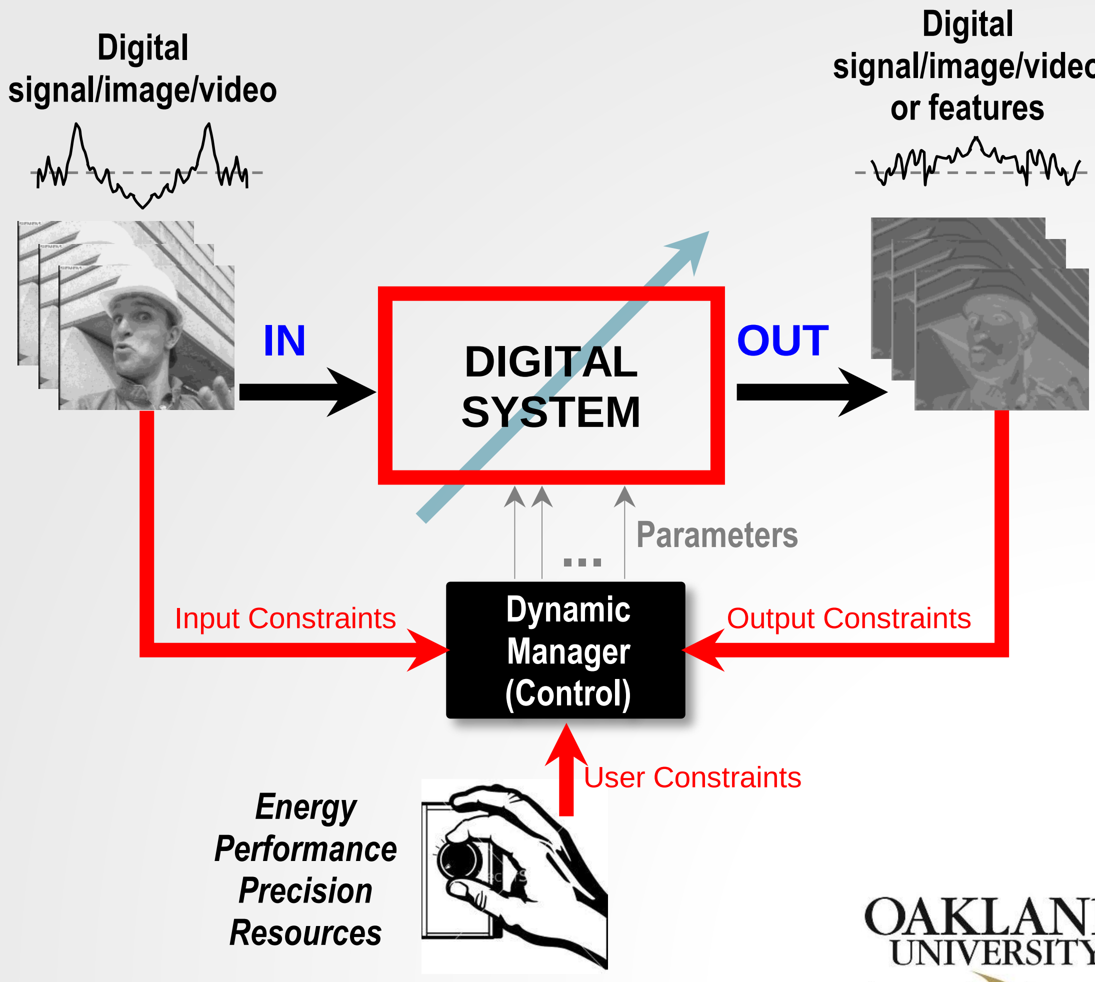
- Self-Reconfigurable Embedded Systems
- Current Research Activities
  - Video Compression: HEVC
  - Radon Transform and Radon-Based 2D Convolutions
  - Smart Antennas
  - Cylinder Pressure Estimation
- Goals

Self-Reconfigurable Embedded Systems

Digital systems can be characterized by a series of properties:

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

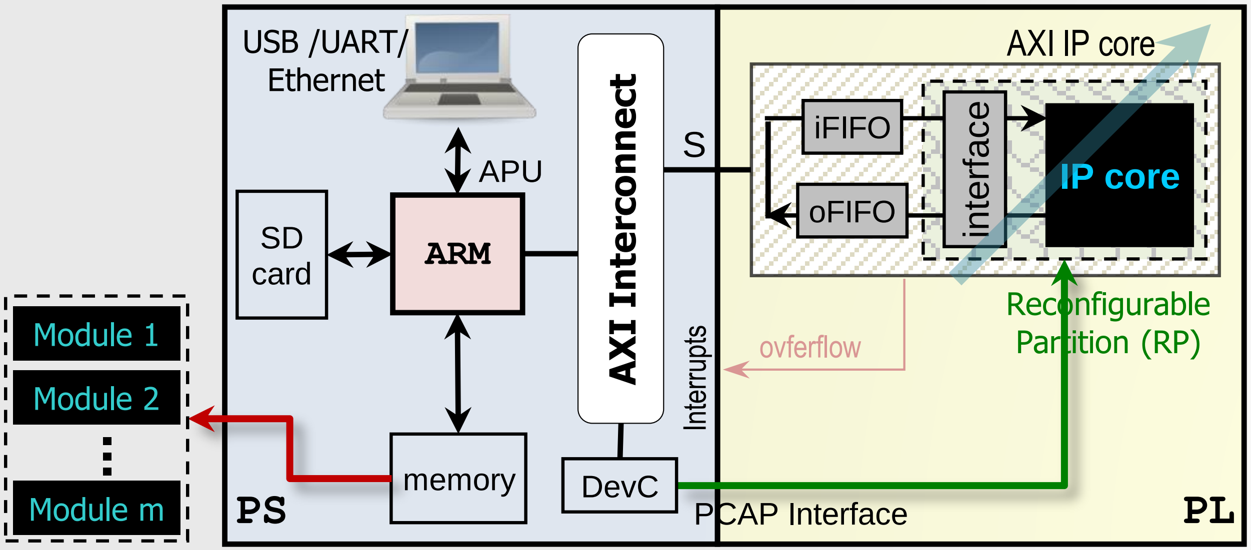
Self-Reconfigurable Embedded Systems *are self-adaptive systems that can satisfy time-varying requirements, optimizing* <u>*resources and energy*</u>*.*



Self Reconfigurable Embedded Systems

- ***Technology***: *Programmable System-on-Chip (SoC): They integrate:*
  - *Processing System (PS): A dual-core ARM® CortexTM-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:

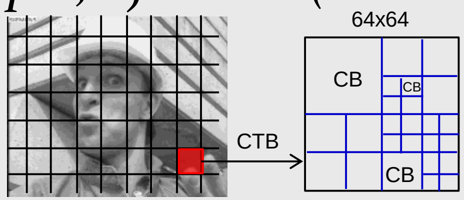


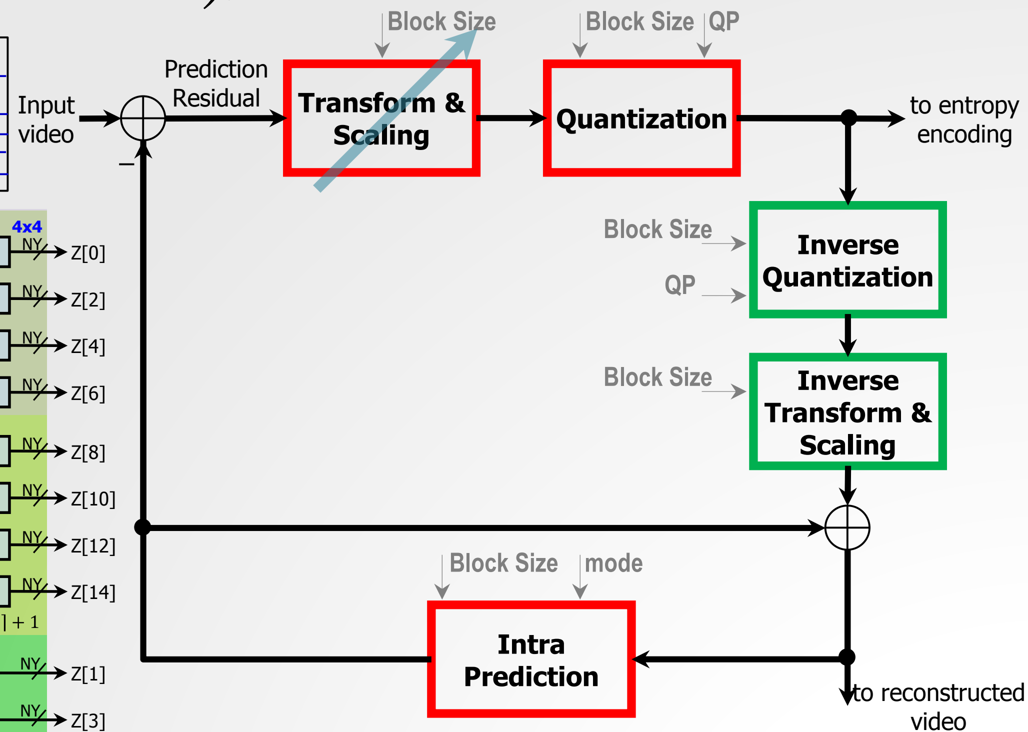
Embedded system with common peripherals, interrupts, and run-time alterable custom hardware.

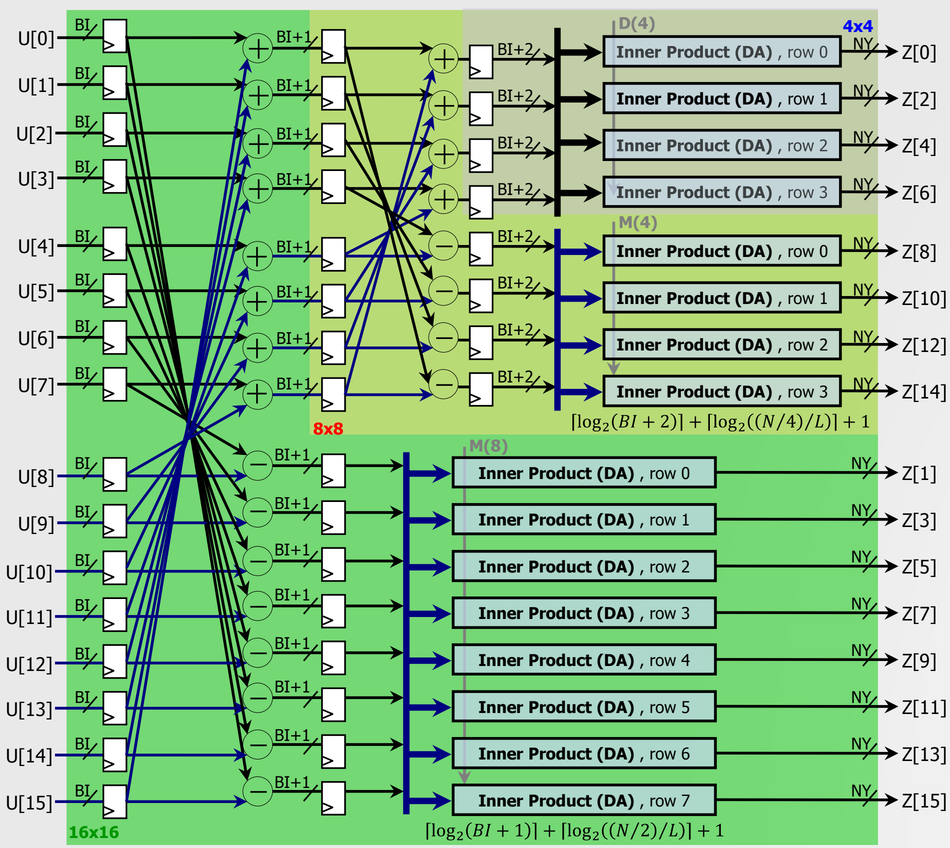
Current Research Activities

❖ *Video Compression Standard (HEVC) Implementation*

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







🡐 Fully-parallel architecture of the HEVC Transform (1D). Block size: 16x16 pixels.

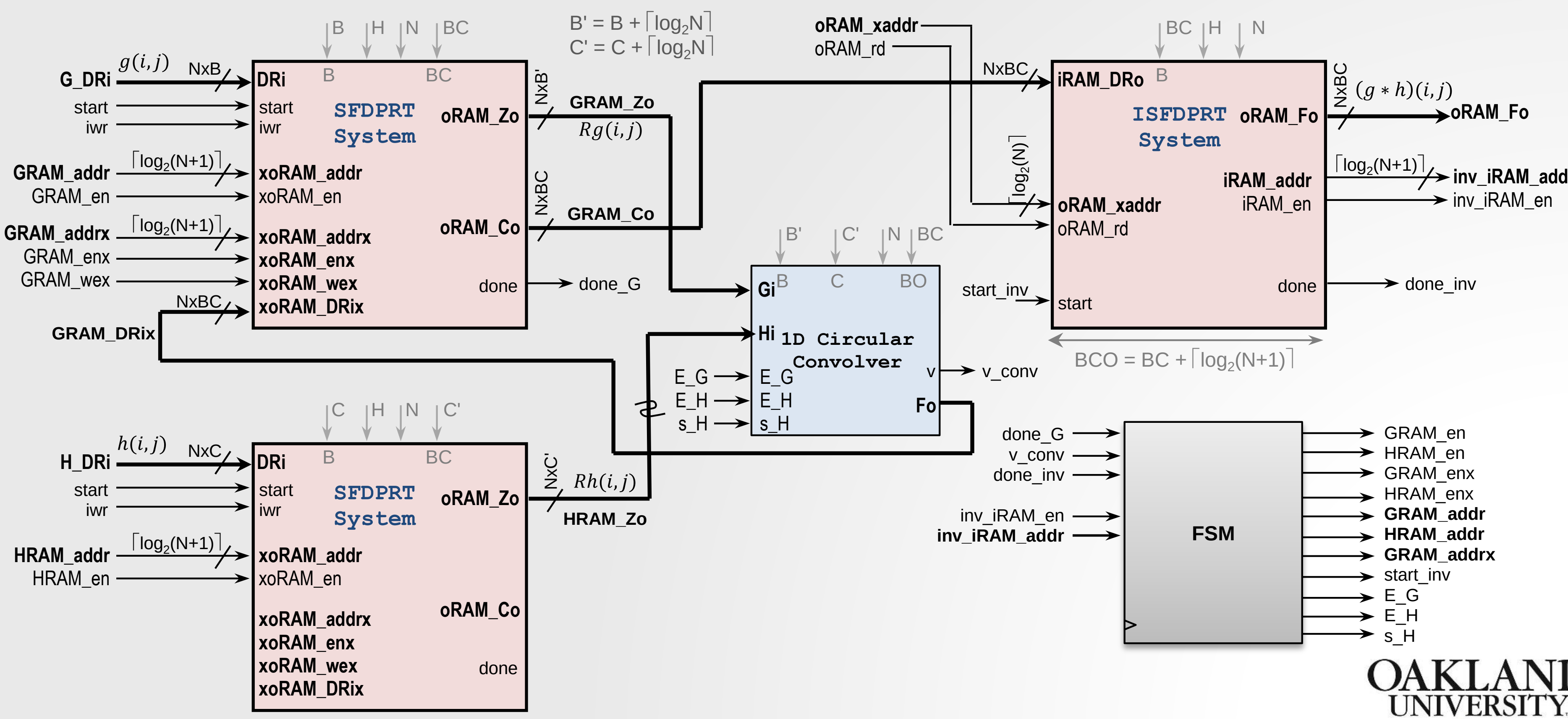
Current Research Activities

Reconfigurable Computing Research Laboratory

❖ *Radon Transform and Fast Convolutions*

- *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.*

2D Radon-based Convolution for prime-sized images:



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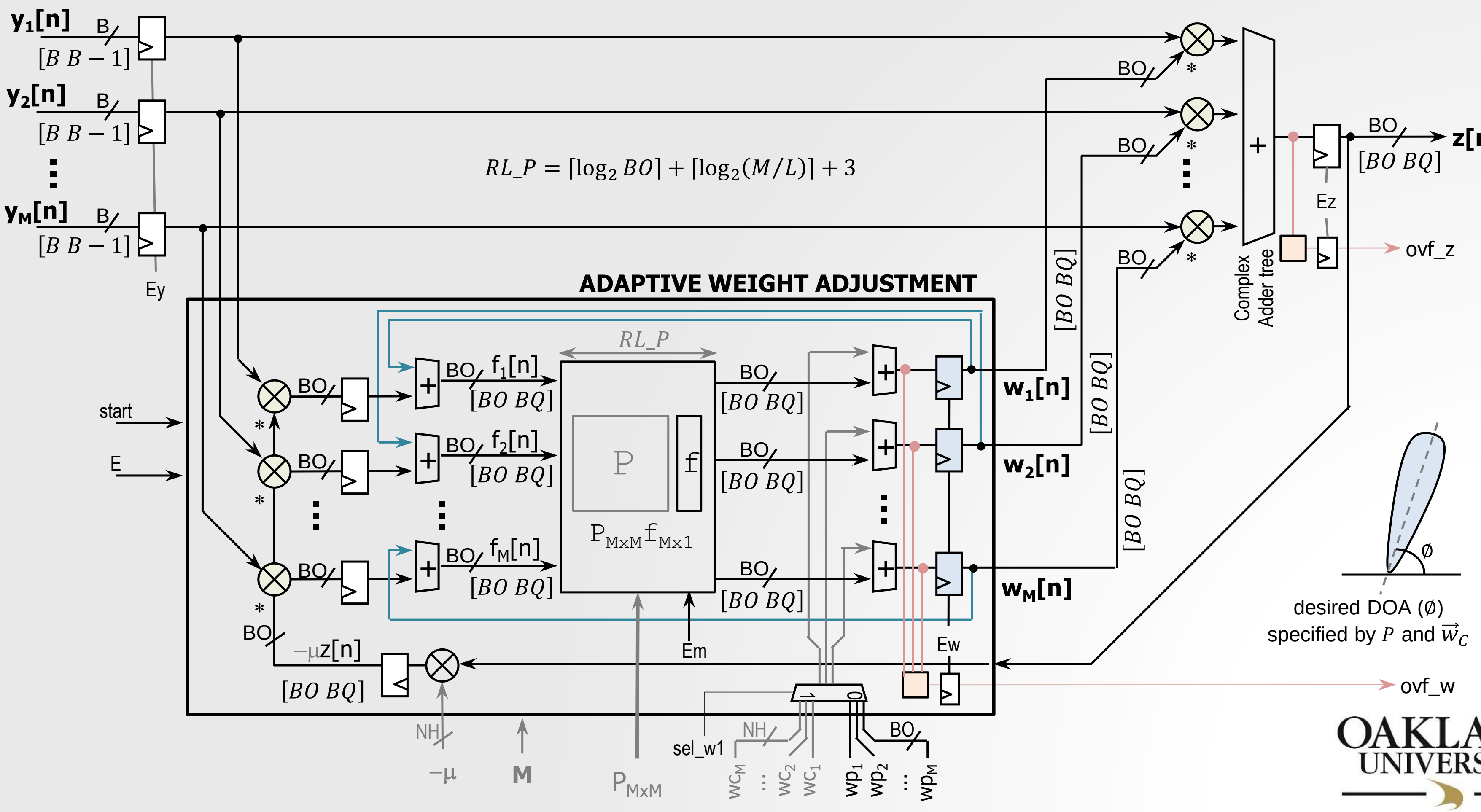
Current Research Activities

RECRLab
Reconfigurable Computing Research Laboratory

❖ 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



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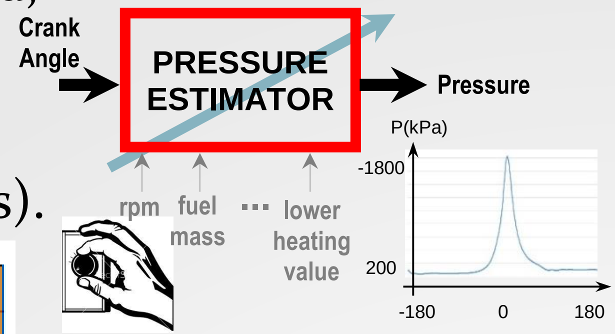
Current Research Activities

Reconfigurable Computing Research Laboratory

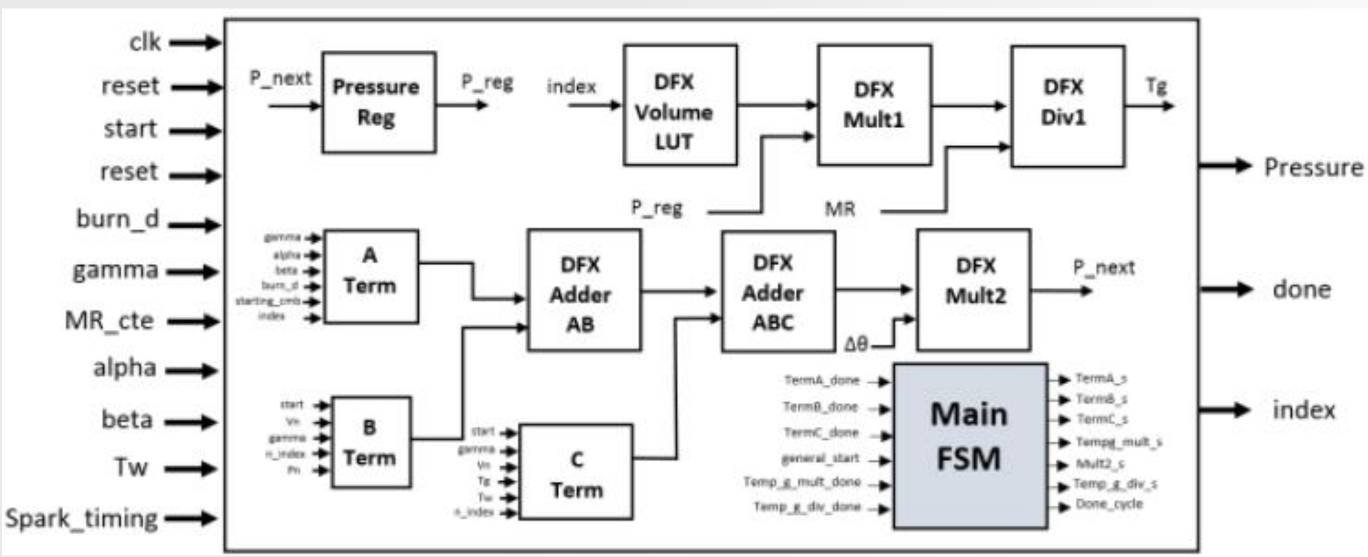
❖ **Cylinder Pressure Estimation**

- 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).



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

- 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).



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Goals

- **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.