Research Overview

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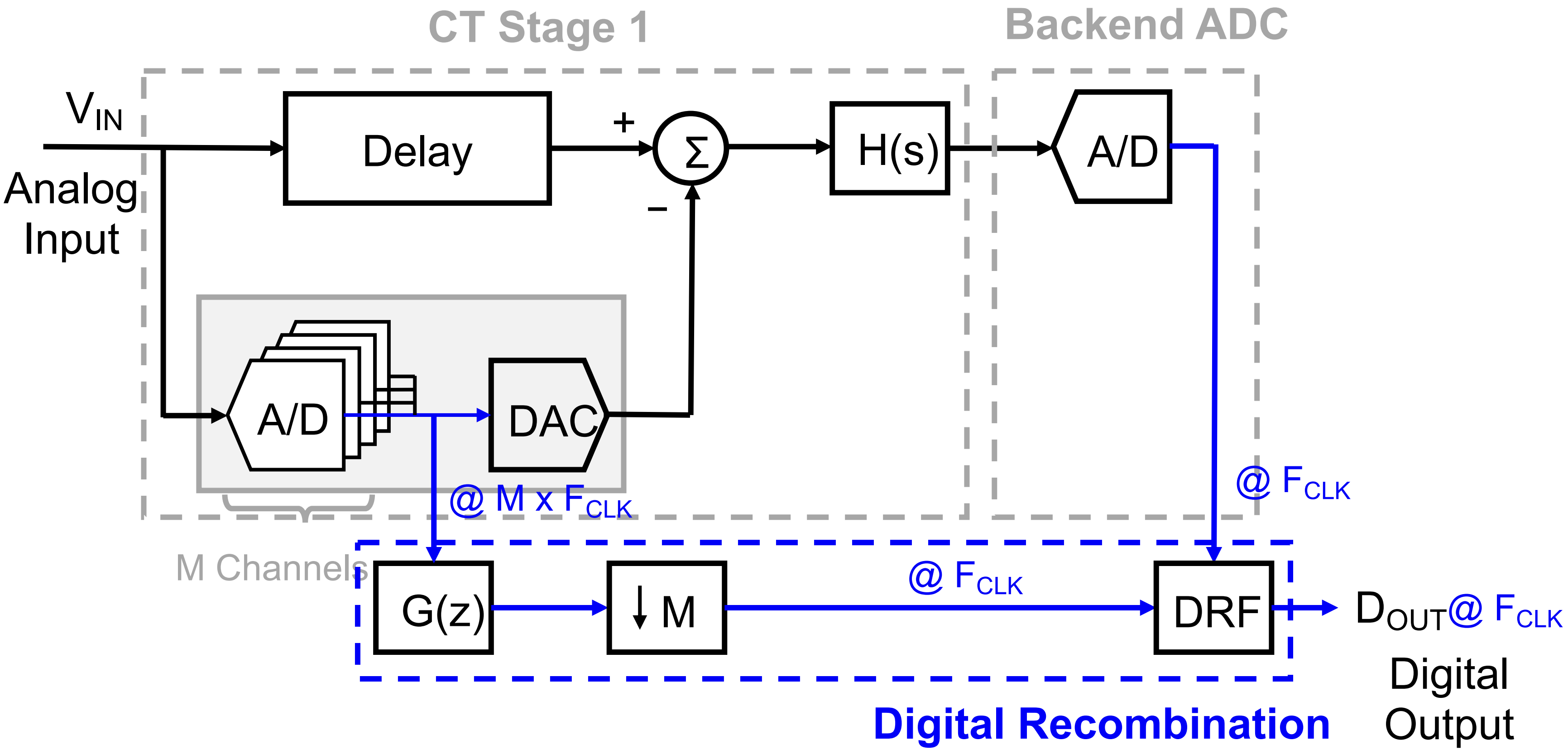
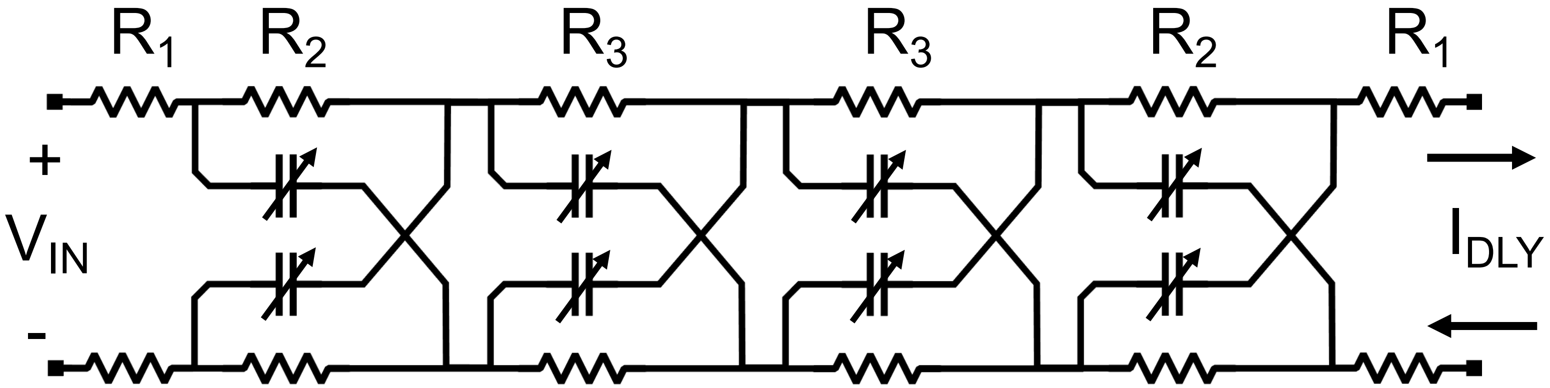
2nd Gen. Continuous-Time Pipeline (CTP) ADC

In collaboration with ADI

Time-Interleaved sub-ADC-DAC Path

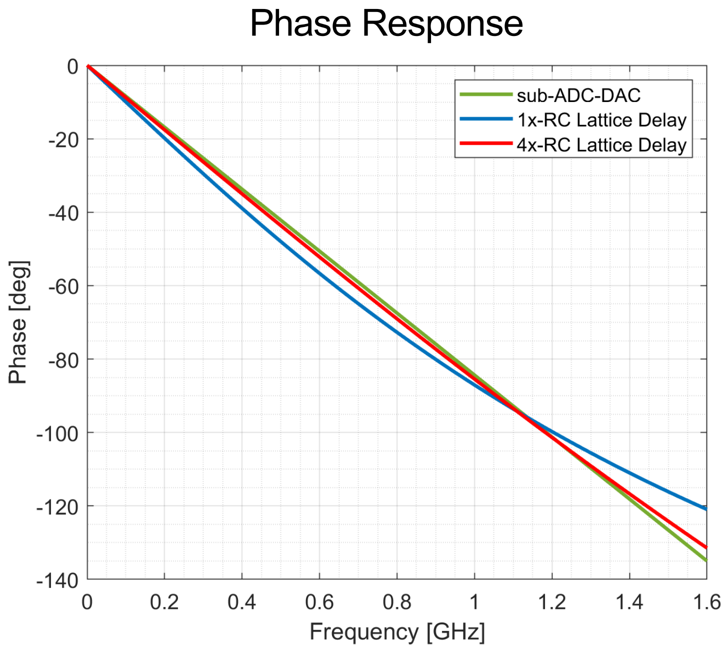


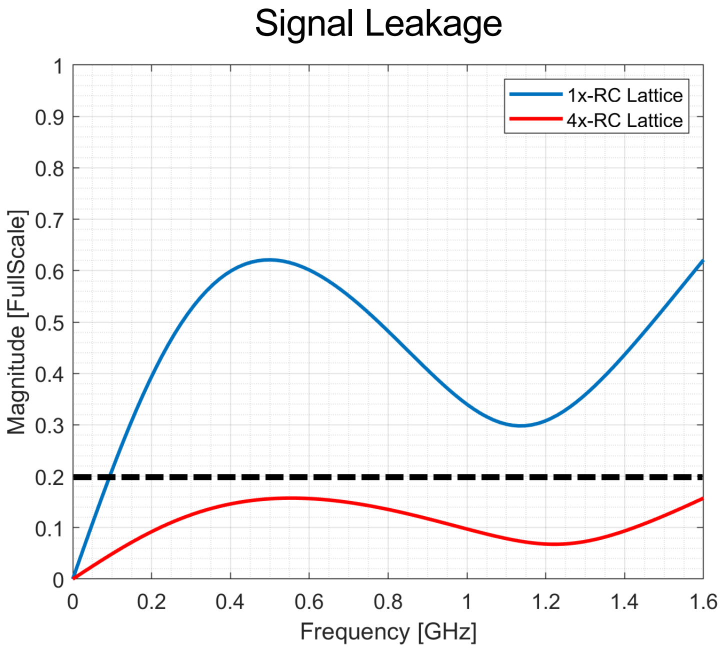
1st Gen. Delay Line



- 4x-cascaded RC-lattice-based delay line: no inductors
- Good phase matching, suitable up to 1.6 GHz BW

Phase Response and Signal Leakage





In the above plots we assume that both 1x- and 4x-RC lattice delay lines have been optimized for 1.6 GHz BW operation (i.e., all R and C values are chosen such that signal leakage is minimized in-band)

2nd Gen Directions

- Extend CTP to higher bandwidth (up to 5GHz)
- High-frequency analog delay line is critical
  - On-chip transmission line becomes practical at high frequencies
  - Currently running EM simulations for on-chip transmission lines
- Further mitigation of DAC clock jitter by “shaping” DAC pulses
- Increase time-interleaving factor

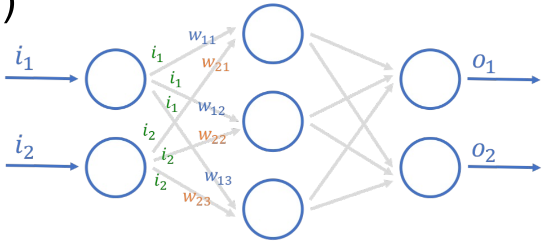
Analog Compute-In-Memory

In collaboration with Samsung

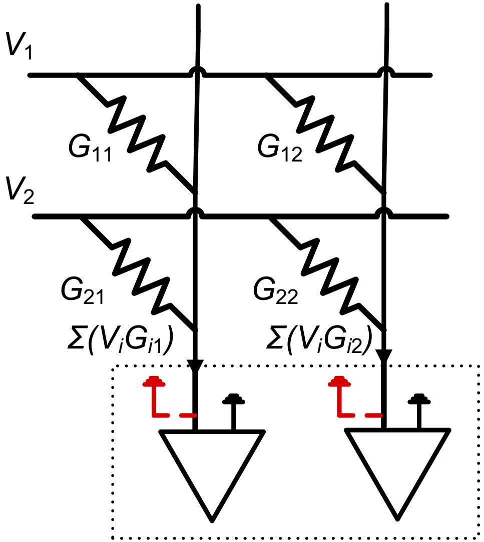
Analog Neural Networks

- Novel Non-volatile memory (NVM) technologies enable compute in memory (CIM)

- By enforcing (virtual) ground, the currents represent a matrix-vector product (MVM)



$$\begin{bmatrix} w_{11} & w_{21} \\ w_{12} & w_{22} \\ w_{13} & w_{23} \end{bmatrix} \cdot \begin{bmatrix} i_1 \\ i_2 \end{bmatrix} = \begin{bmatrix} (w_{11} \times i_1) + (w_{21} \times i_2) \\ (w_{12} \times i_1) + (w_{22} \times i_2) \\ (w_{13} \times i_1) + (w_{23} \times i_2) \end{bmatrix}$$

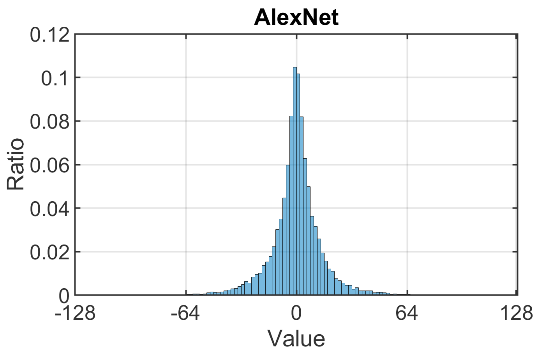


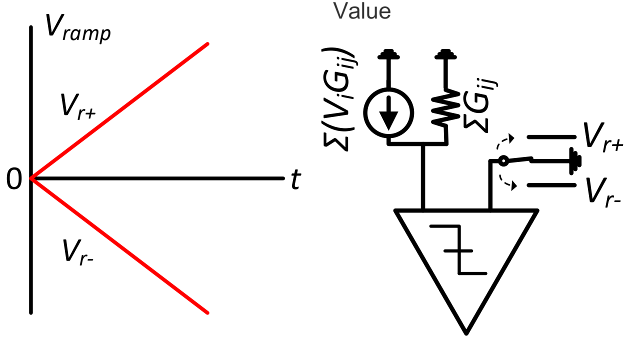
Current to voltage conversion

Dual Ramp Single Slope ADC

- Conventional SS ADC covers 2^N steps (slow)
  - Speed mitigated by column-parallel architecture
- Splitting the ramp into positive and negative halves ramps around 0:
  - Comparator determines the sign first
  - Reduces conversion time and resolution requirements by half
  - Enables early termination and time/energy savings for typical input voltage statistics for neural nets (concentrated near zero)

First convolution outputs in a pre-trained AlexN





Estimation of Cardiac output from Blood Pressure waveform

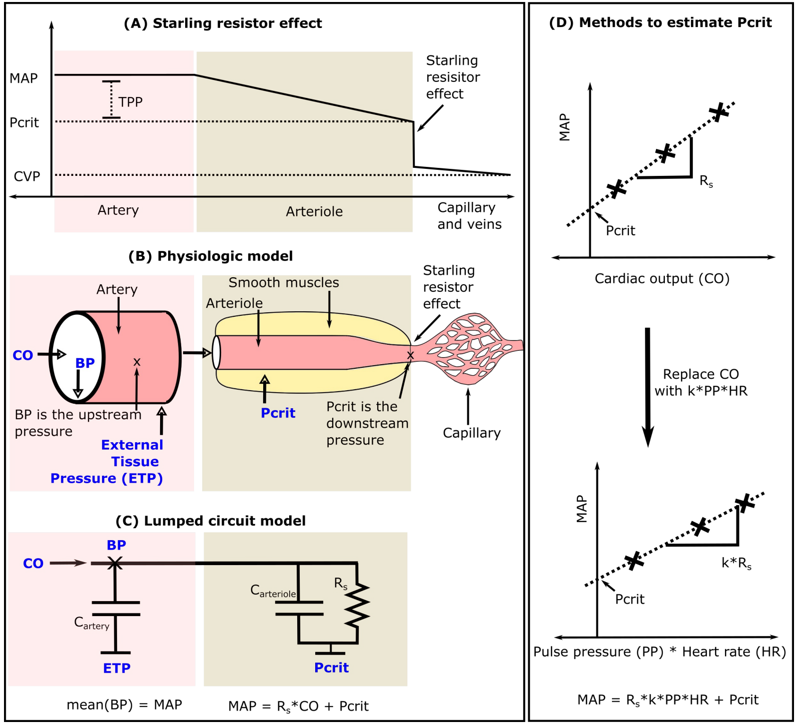
In collaboration with T. Heldt and C. G. Sodini

Estimation of Tissue Perfusion Pressure (TPP)

Pcrit: Critical closing pressure

Rs: Starling Resistor

Define TPP (Tissue Perfusion Pressure) = MAP - Pcrit



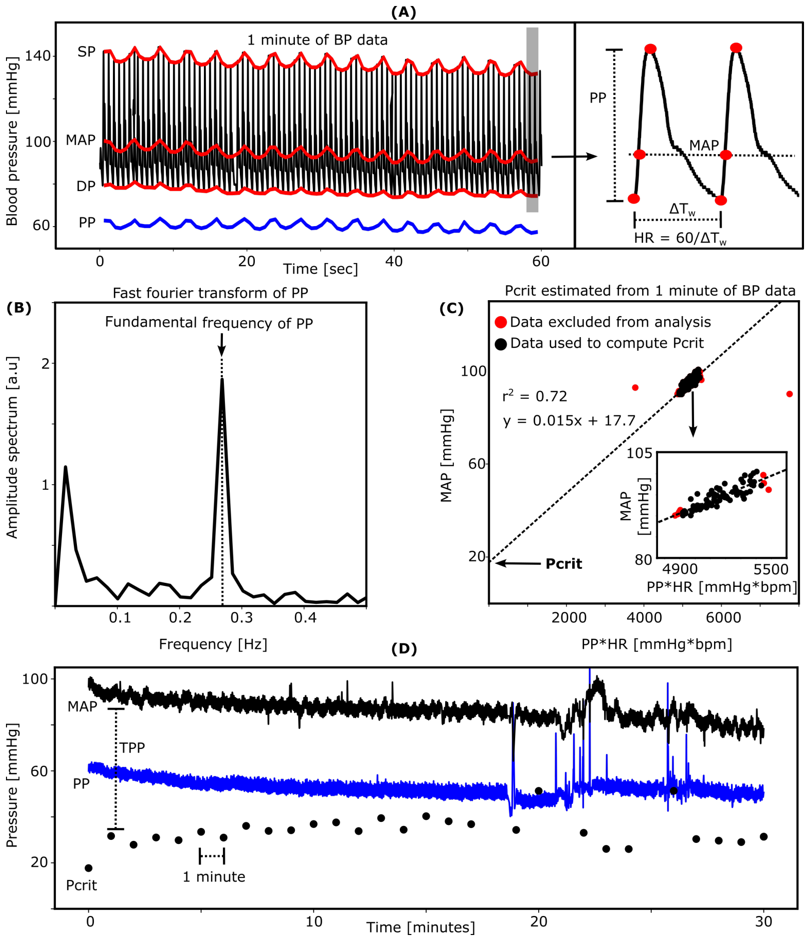
Estimation of TPP from BP Waveform

While MAP can be directly measured, Pcrit is not a measurable parameter in living patients

Alternative: Use natural variability in BP vs. blood flow to estimate Pcrit.

Pcrit is extrapolated from pulse pressure times the hear rate vs. MAP relation

We’re expanding this research to estimate cardiac output from BP waveform

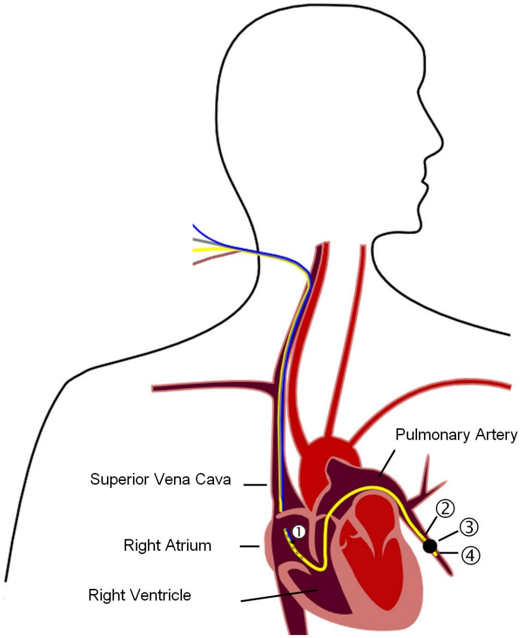


Importance of Cardiac Output Measurement in Clinical Decision Making

- Cardiac output (CO): Measure of the blood pumped out of the heart in units of L/min.
- Patients with poor heart functions have low CO.
- Clinicians give drugs to maintain a sufficiently high CO for better organ perfusion.
- Regular measurement of CO in an ICU adds value in the clinical decision making.

Current Method to Measure Cardiac Output

- Gold standard method: Thermodilution procedure:
  - Invasive procedure
  - Insert a catheter into the heart to measure CO.



Our Approach

- A physiology based model to estimate CO using Tissue Perfusion measurement

$$\mathrm{CO} \propto \frac{\mathrm{TPP}}{\tau}$$

$\mathbf{TPP}$: estimated from the plot of MAP vs. $\mathrm{PP} * \mathrm{HR}$

$\boldsymbol{\tau}$ is the time constant of the systemic circulation

$\boldsymbol{\tau}$ is estimated from TPP, PP, HR and shape of the BP waveform