System-on-Chip Design
Data Flow hardware Implementation

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Single-Rate SDF to Hardware

- Single-rate SDF: all production/consumption rates are a fixed number = 1.
  - The entire circuit controlled by a single clock.
- Implementation
  - Actors -> combination circuits
  - Queues -> wires
  - Initial tokens -> registers.

Single-Rate SDF to Hardware

sort

```
out1 = (a > b) ? a : b;
out2 = (a > b) ? b : a;
```

diff

```
out1 = (a !=b) ? a – b : a;
out2 = b;
```

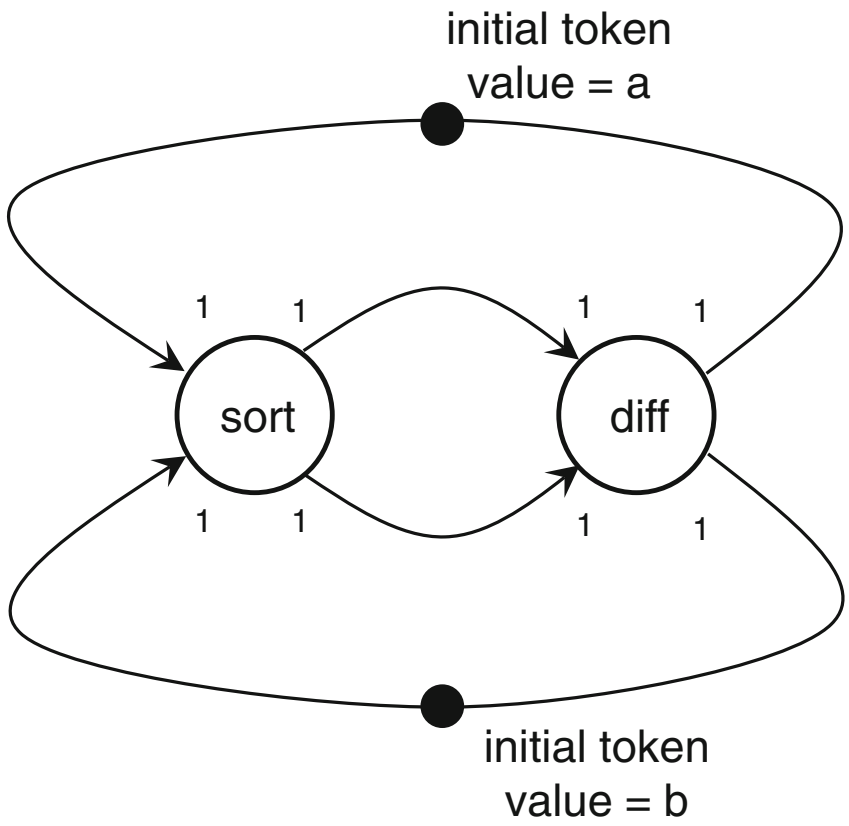


Fig. 3.10 Euclid's greatest common divisor as an SDF graph

Single-Rate SDF to Hardware

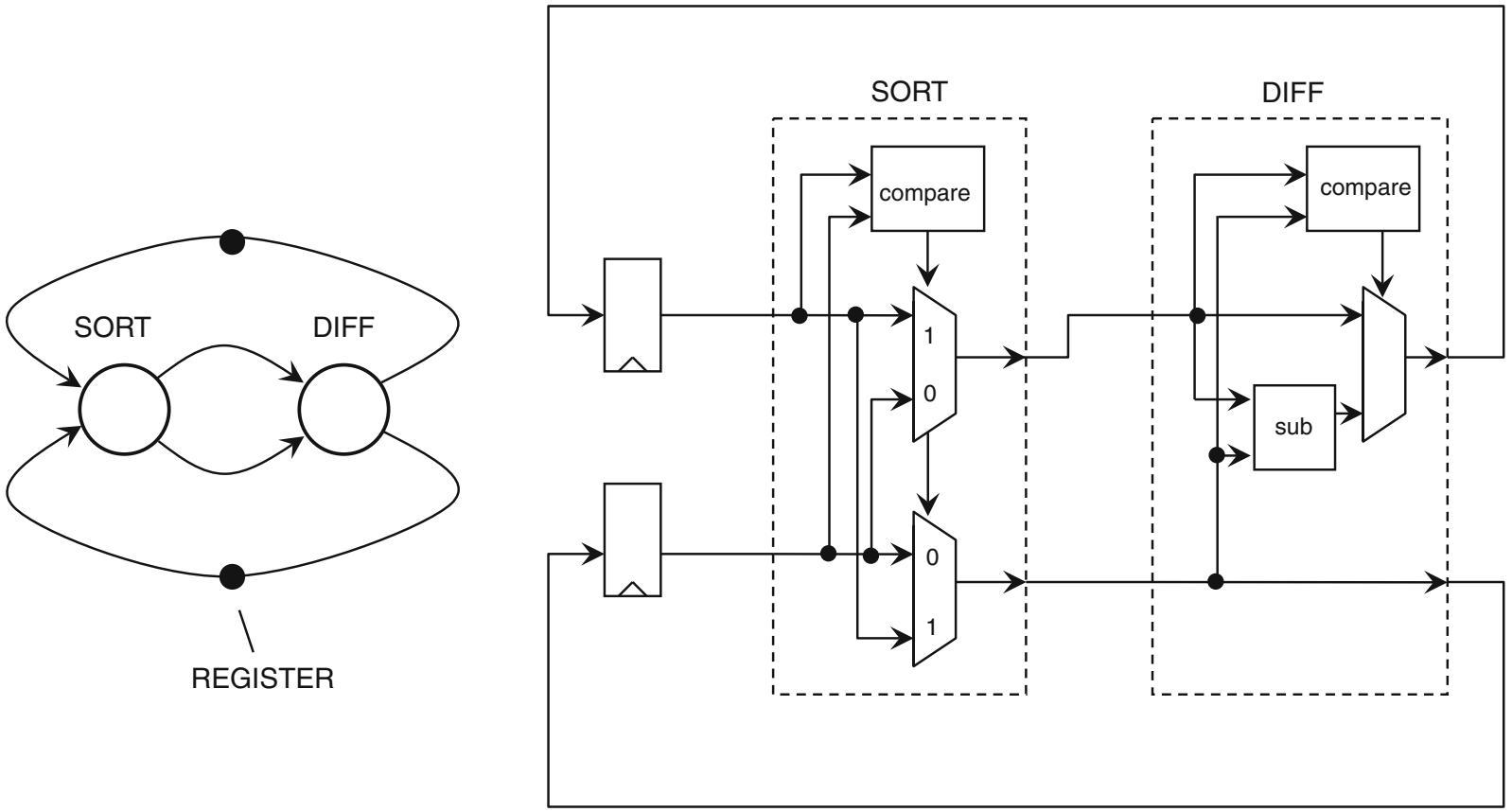


Fig. 3.11 Hardware implementation of euclid's algorithm

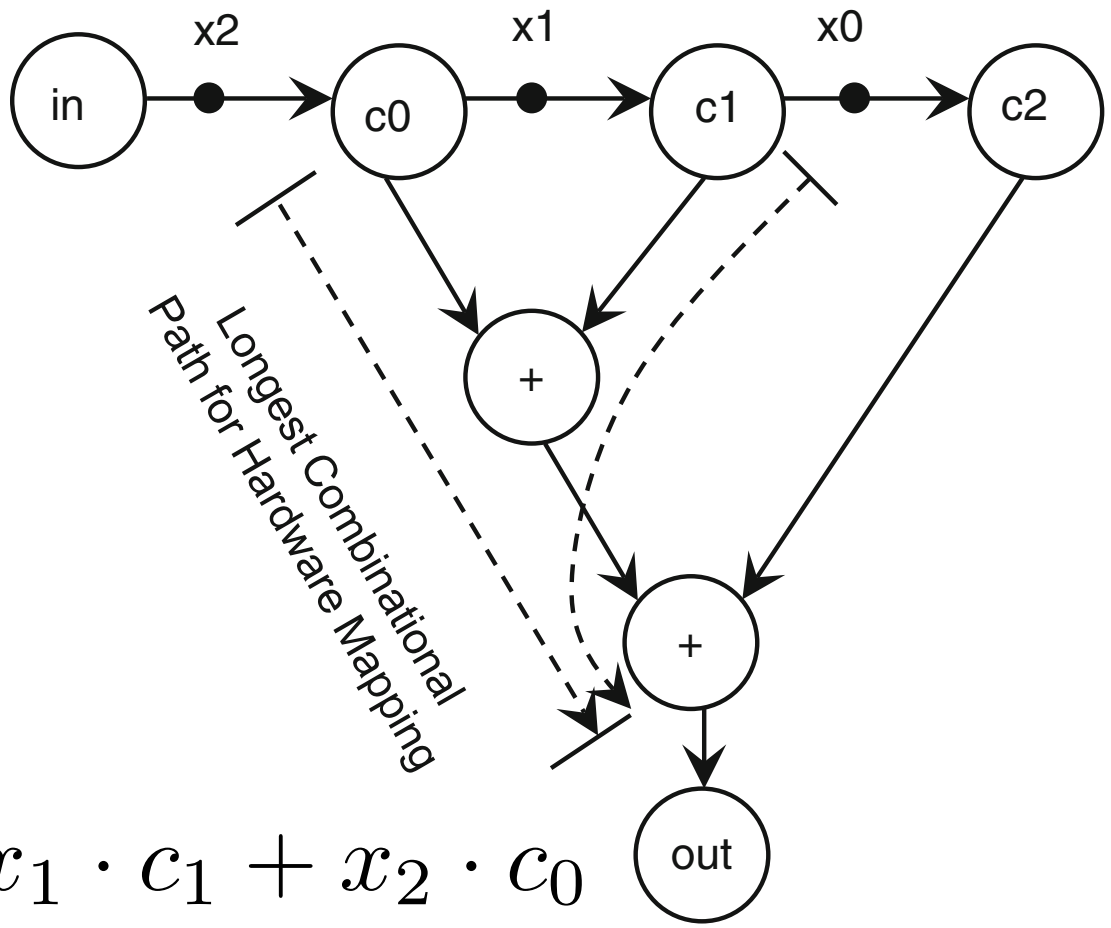
Can lead to long combination paths.

SDF HW Implementation

- Combinational path is a sequence of actors s.t. edges between these actors do not have initial token.
- Critical path is a combinational path s.t. the sum of latencies of all actors on that path is the longest.
- Critical path delay determines the clock frequency.
  - Should be minimized to increase clock speed.

Pipelining: Break Long Comb. Paths

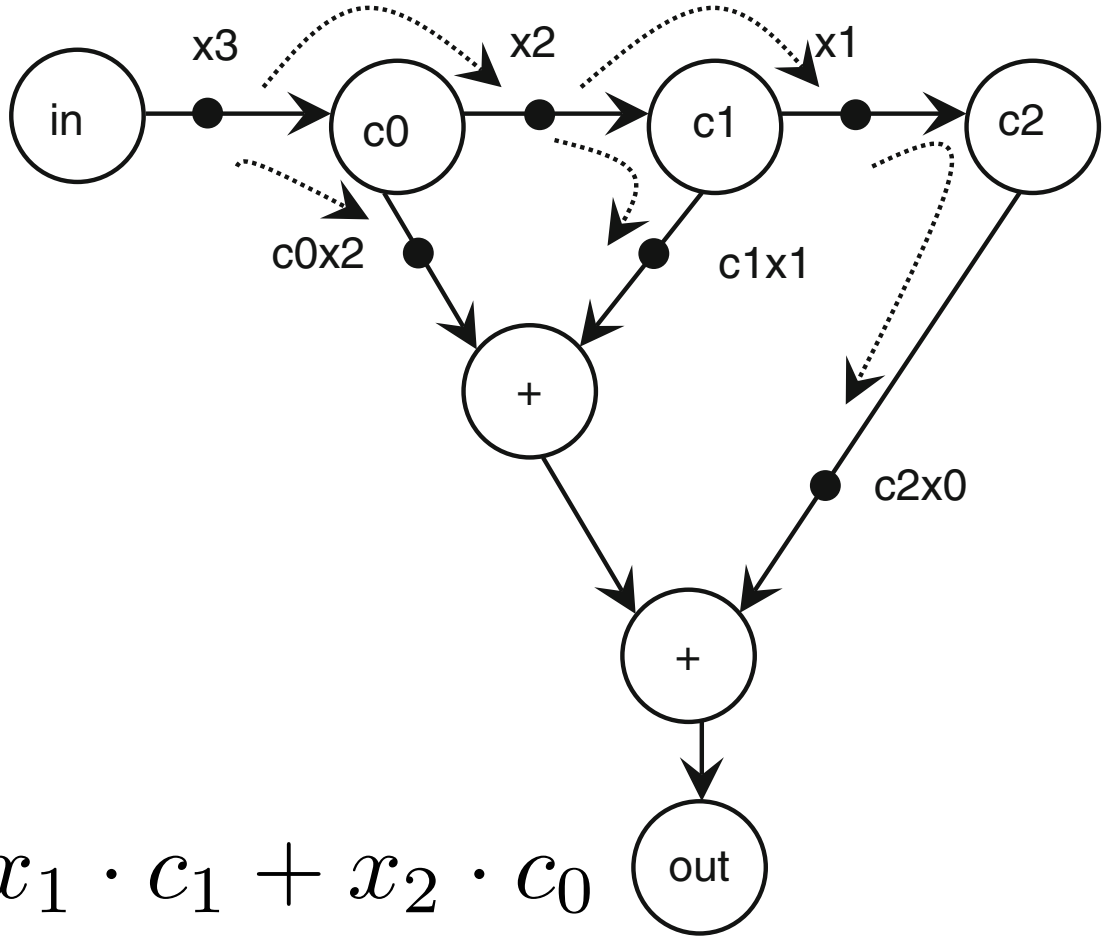
Fig. 3.12 SDF graph of a simple moving-average application



$$out = x_0 \cdot c_2 + x_1 \cdot c_1 + x_2 \cdot c_0$$

Pipelining: Break Long Comb. Paths

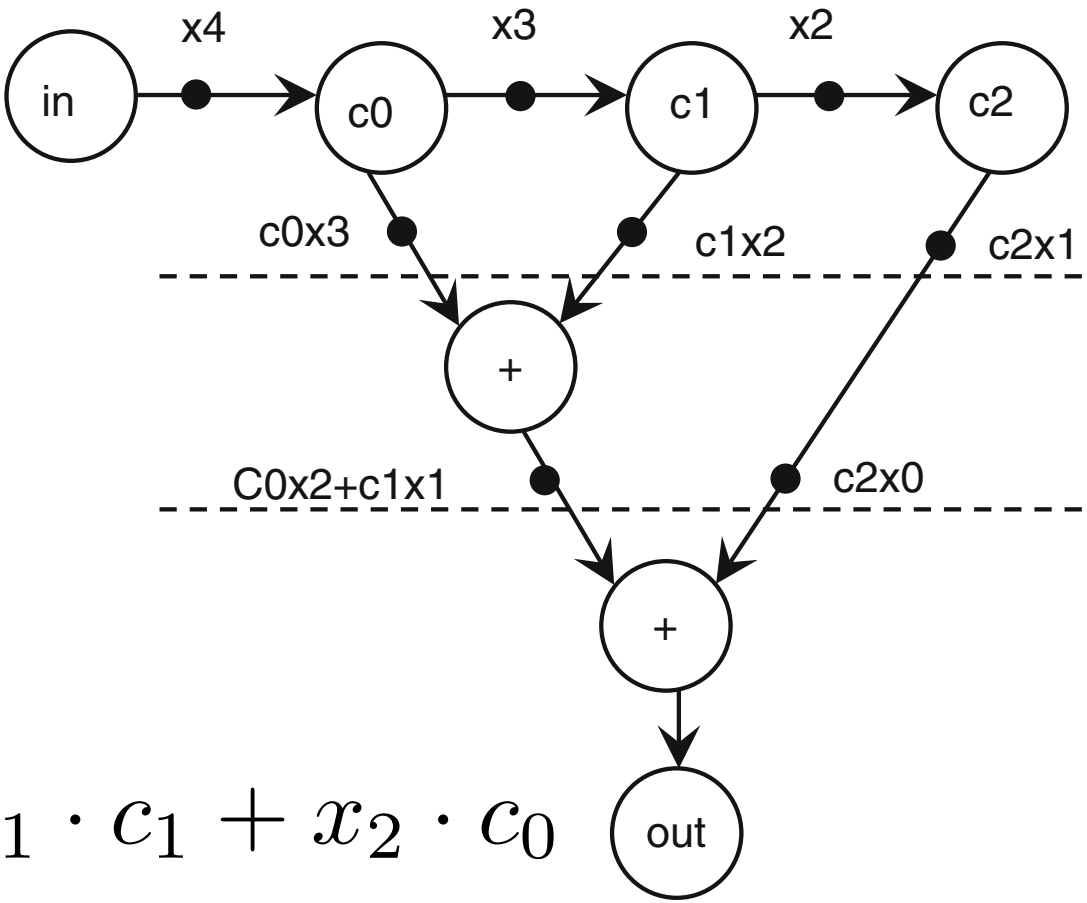
Fig. 3.13 Pipelining the moving-average filter by inserting additional tokens (1)



$$out = x_0 \cdot c_2 + x_1 \cdot c_1 + x_2 \cdot c_0$$

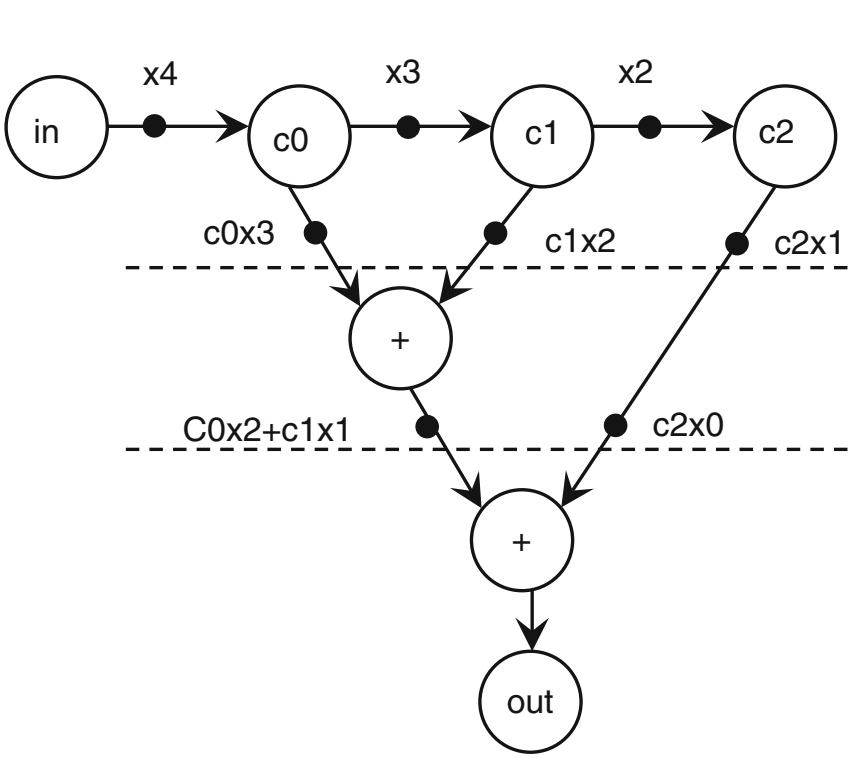
Pipelining: Break Long Comb. Paths

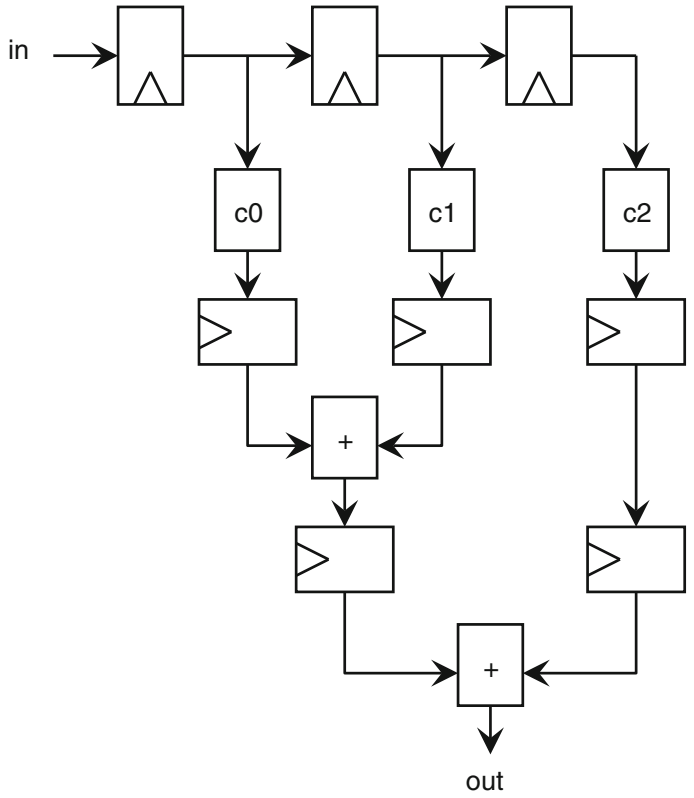
Fig. 3.14 Pipelining the moving-average filter by inserting additional tokens (2)



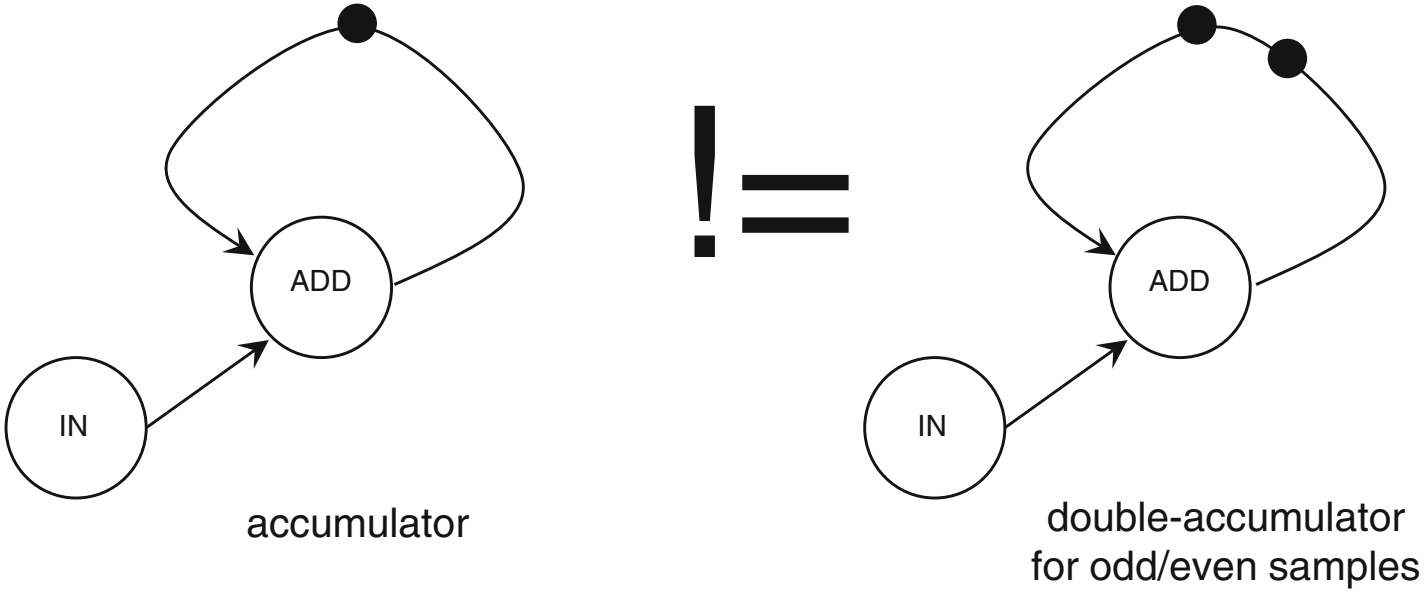
$$out = x_0 \cdot c_2 + x_1 \cdot c_1 + x_2 \cdot c_0$$

Pipelining: Break Long Comb. Paths



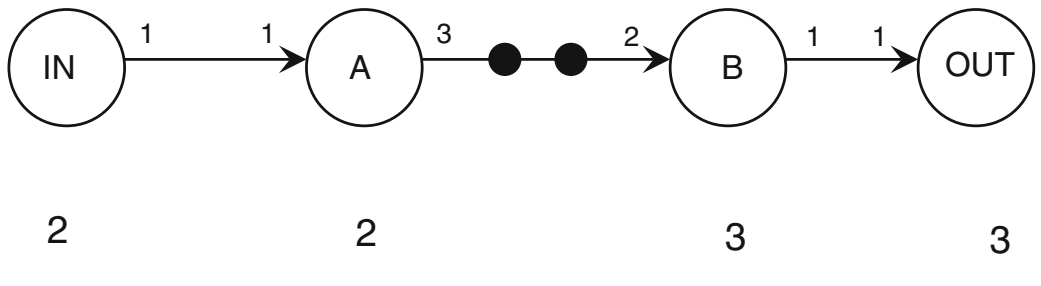


Pipelining: Pitfall

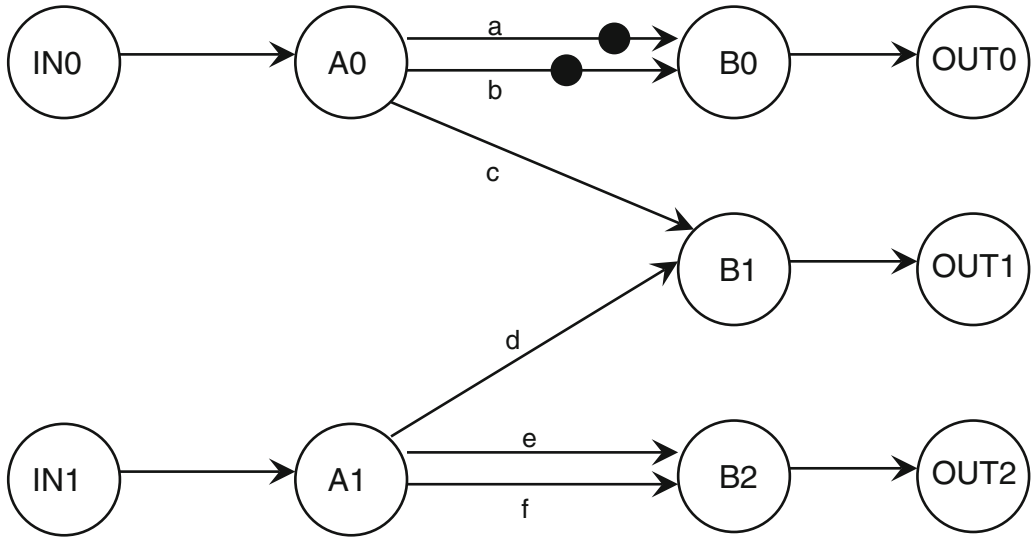


Do **Not** add initial tokens unless they can be injected by a sequence of actor firings.

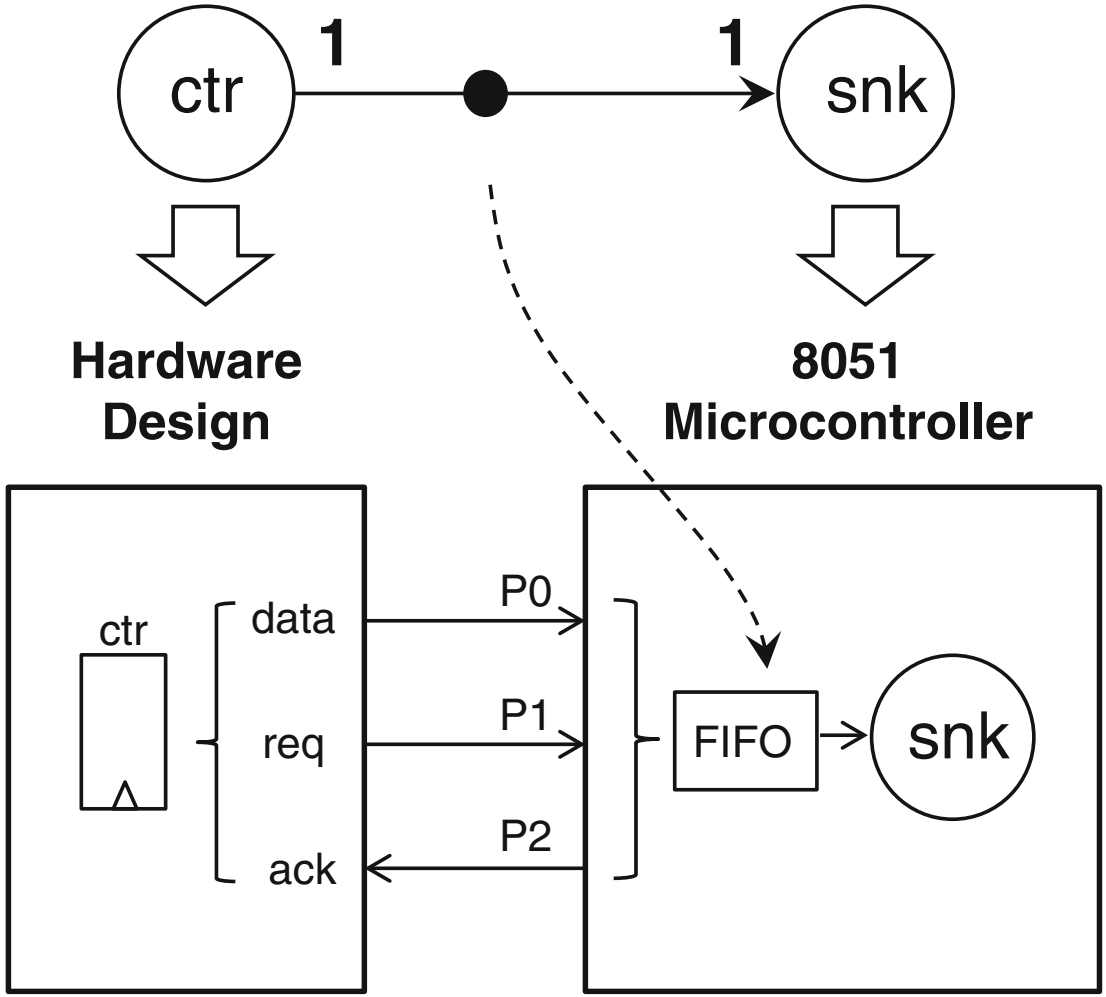
Multi-Rate Expansion (Sec. 2.5.1)



This single-rate DFG can be mapped to HW as shown previously.



HW/SW Hybrid Implementation



Interface btw. HW & CPU

Interface btw. SW & CPU

Reading Guide

- Section 3.2 - 3.3, the *CoDesign* book.