



# Overview of Configurable Computing

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## Outline



- **Introduction**
- Configurable Computing
- Taxonomy of Reconfigurable Fabric
- Summary

## Introduction



- Configurable hardware  
some functions can adapt to precisely fit a problem, either
  - *statically* (off-line or just at the design time with the support of a compiler a/o a hardware generator)
  - *dynamically* (at run-time involving a local controller or a host processor with a memory subsystem, even with the OS support)
- Reconfigurable hardware  
the functions can be changed after fabrication or shipment (i.e. field configurable)

## How much 'Reconfigurability' do we need?



- Design-time customization (none)  
customization of a generic platform to optimize or differentiate a product
- Field customization  
for changing standards or communication protocols
- Slow adaptation  
for various operating parameters for mobile devices or multiple, time-varying standards in stationary receivers
- Fast adaptation  
for time-varying noise or speculative computation based on changing data sets

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# Configurable Computing

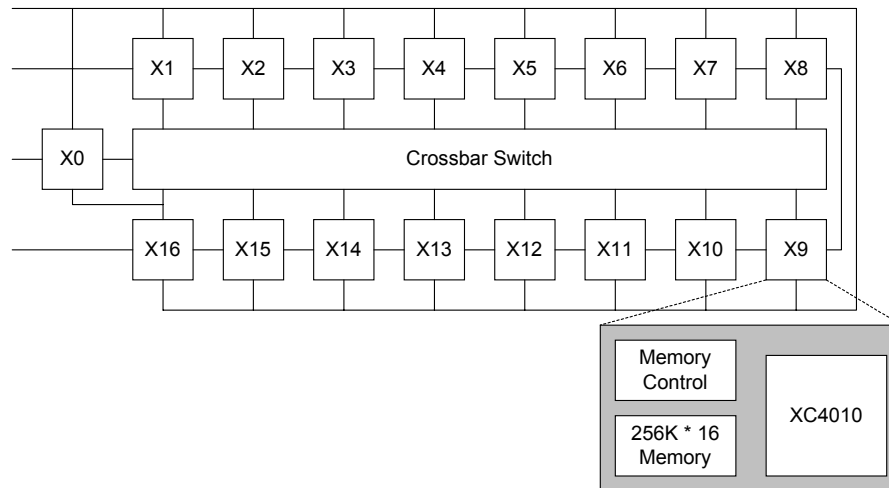


- Computation that involves dynamic (run-time) hardware reconfiguration (i.e. reconfiguration is required to complete the computation)
  - fault tolerant computing
  - **resource cycling** via dynamic reconfiguration
- Static configurable computing
  - with deterministic, pre-scheduled tasks
  - improve the resource utilization and the performance
- Dynamic configurable computing
  - evolvable hardware

## SPLASH-II (SRC, 1993)



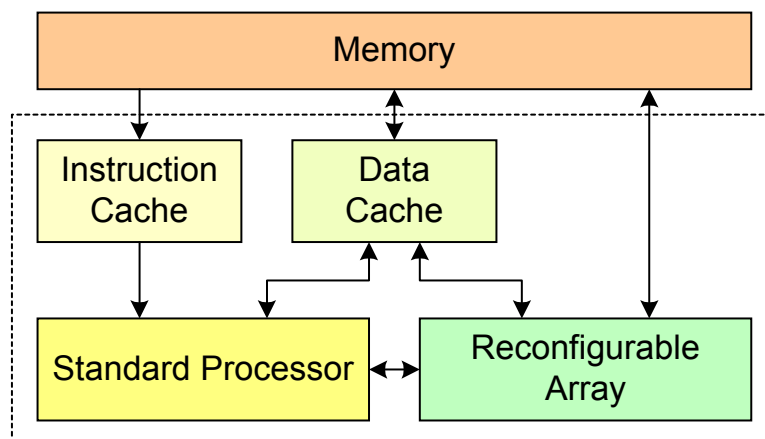
- Multi-FPGA parallel computer with orchestrated systolic communications to perform inter-FPGA data transfer



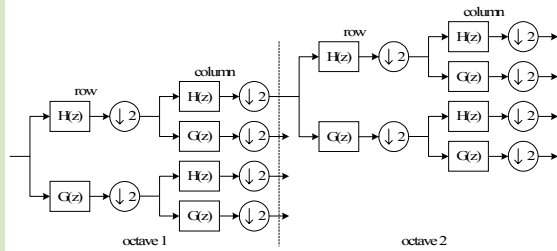
## Garp (UCB, 1997)



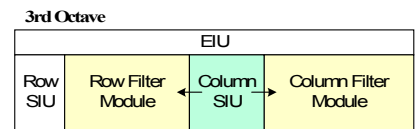
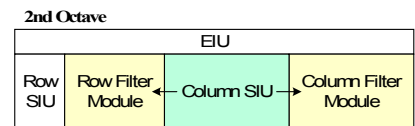
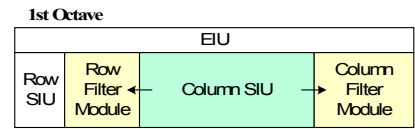
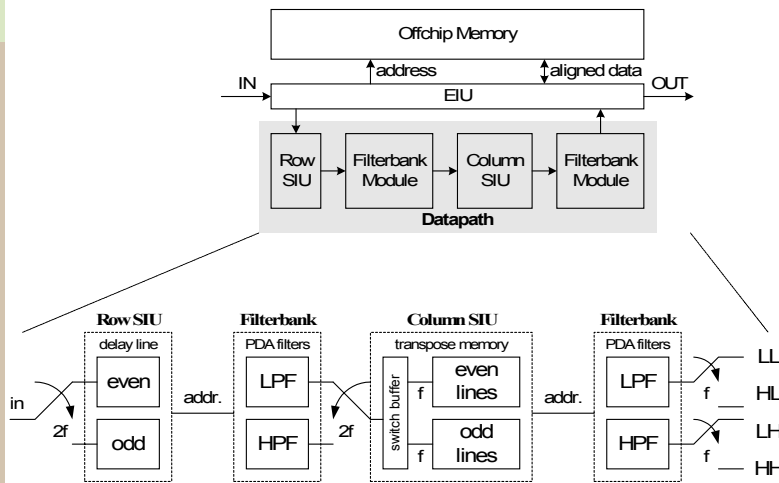
- For general-purpose loop acceleration
- A decreasing counter is set initially for computation synchronization



# Resource-Cycling DWT Encoder



Against worst-case designs, resource cycling among more divergent functional units is possible via *architecture transformation* at design time and *dynamic reconfiguration* with finer granularity at run time



# Configurability Metrics



- Structural
  - PE only
  - interconnection only
  - both
- Temporal
  - once (design time)
  - statically scheduled (run time)
  - dynamically scheduled (run time)
  - evolutionary (run time)
- Spatial (minimum addressable configuration point)
  - full
  - partial

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# Metamer – the Reconfigurable Fabric

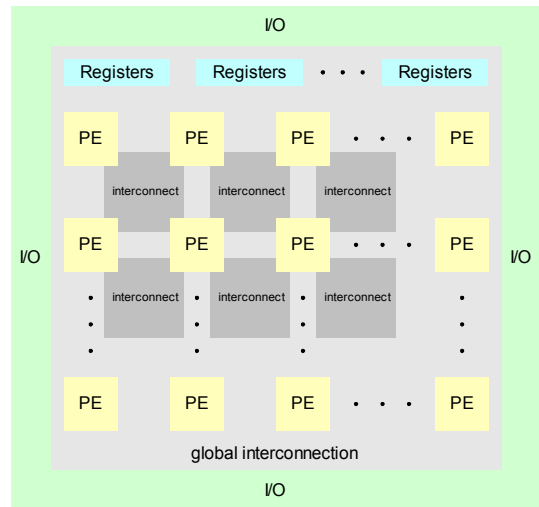


- General-purpose
  - RAM
    - implements the truth table as the 2-Level combinational logic (i.e. ROM) or pre-computed lookup table
  - FPGA & its descendants
  - reconfigurable array processors
- Application-specific
  - programmable filter length
  - fused DCT/IDCT, DWT/IDWT

# Parameters of the Metamer



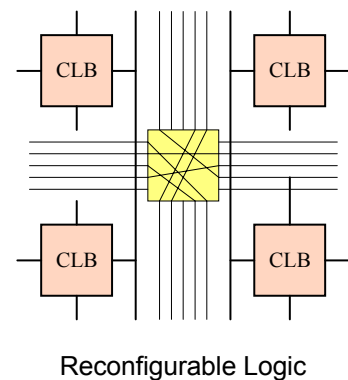
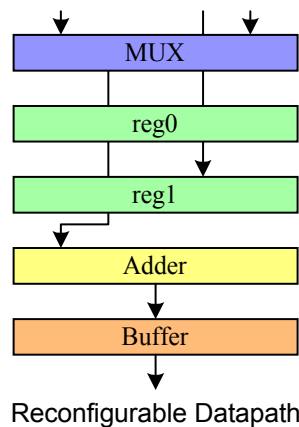
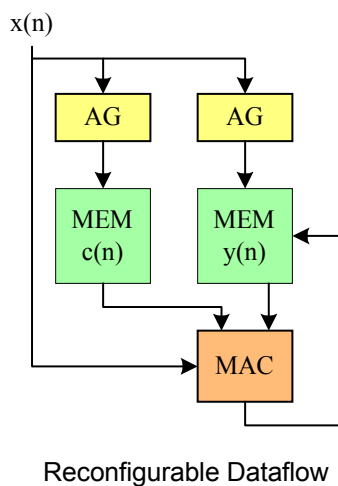
- PE granularity  
 (usually imply # of functionalities)
- Interconnection routability
  - neighbor (1-D) / mesh (2-D)
  - crossbar
  - bus
- Initialization mechanism
  - serial
  - parallel
  - hierarchical (e.g. cloning, global/local control)
- Context depth
  - single
  - multiple



# PE Granularity



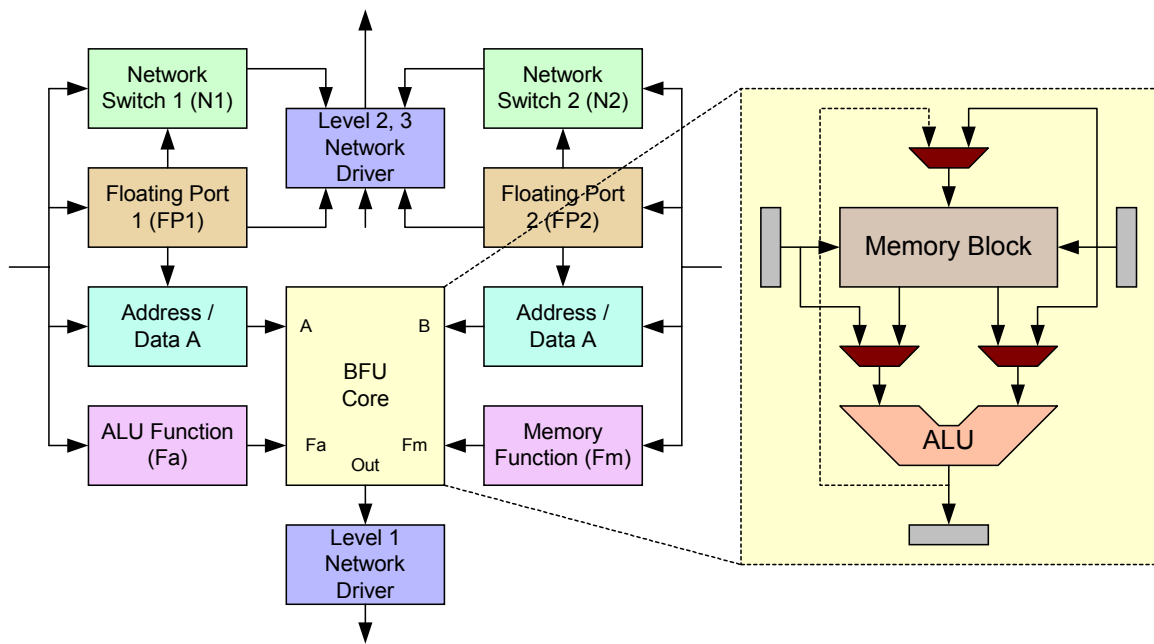
- Smallest unit of the reconfigurable fabric that can be reprogrammed
- tradeoffs between flexibility and reconfiguration overhead



# Coarse-grain Reconfigurable Fabric



- MATRIX (MIT, 1996)



# Reconfiguration Methods



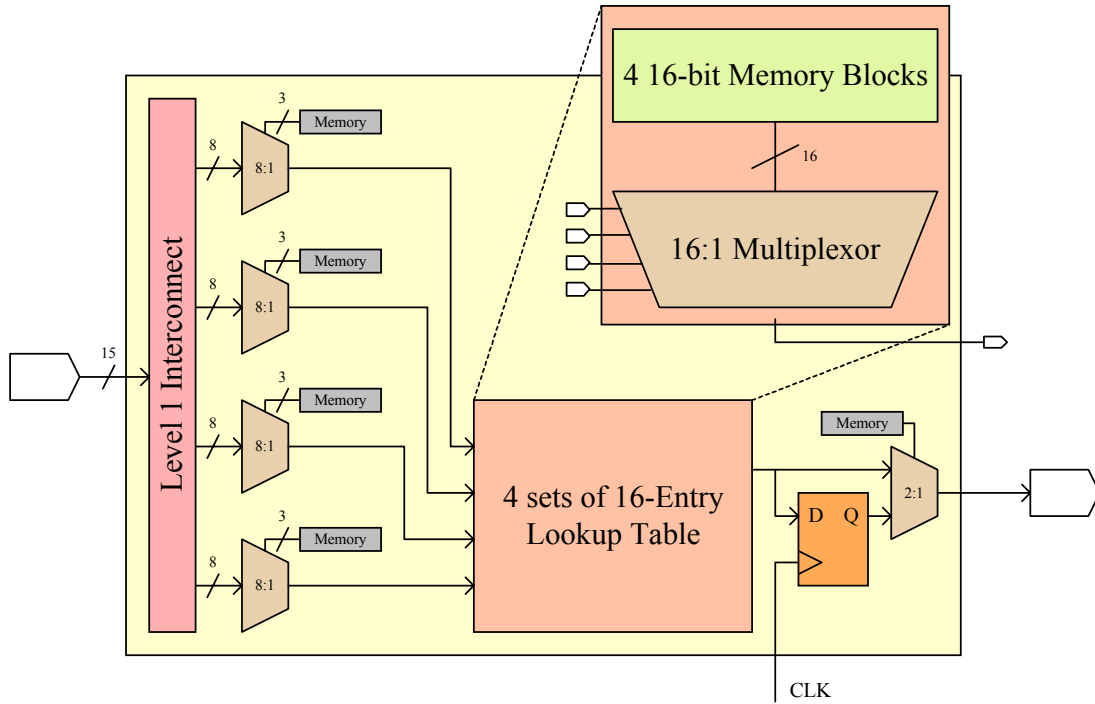
- Configuration storage
  - downloaded from external
  - in-situ
  - multi-context configurations
- Initialization Mechanism
  - full reconfiguration
  - partial reconfiguration
  - configuration cloning
  - stripe reconfiguration



# Multiple Contexts



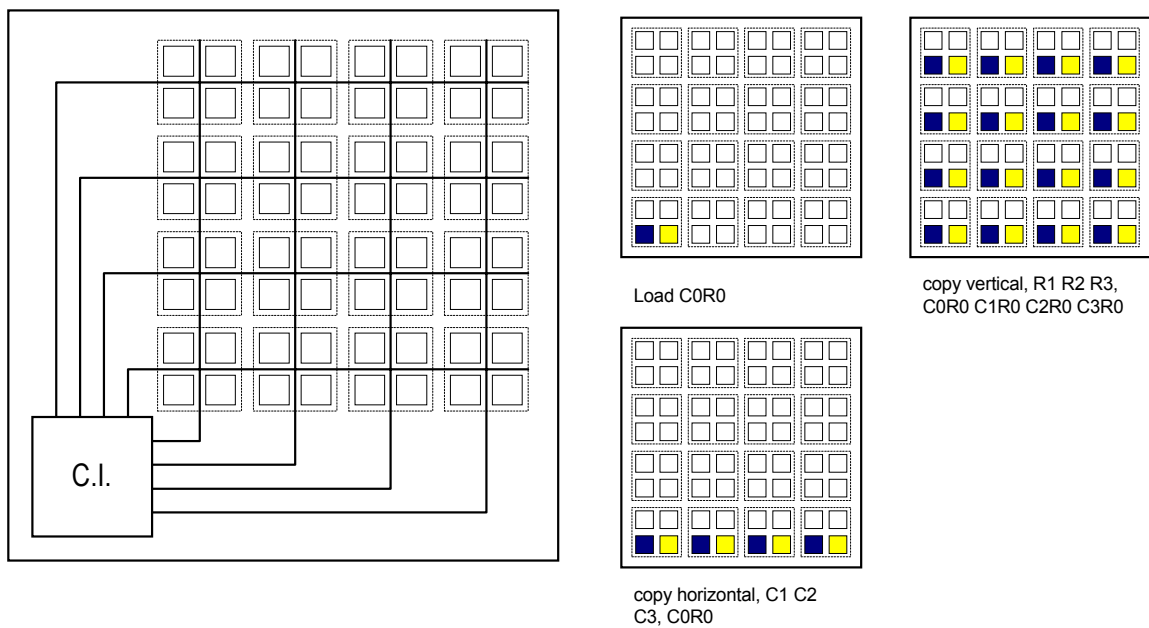
- DPGA (MIT, 1994)



# Configuration Cloning (UMASS, 1998)



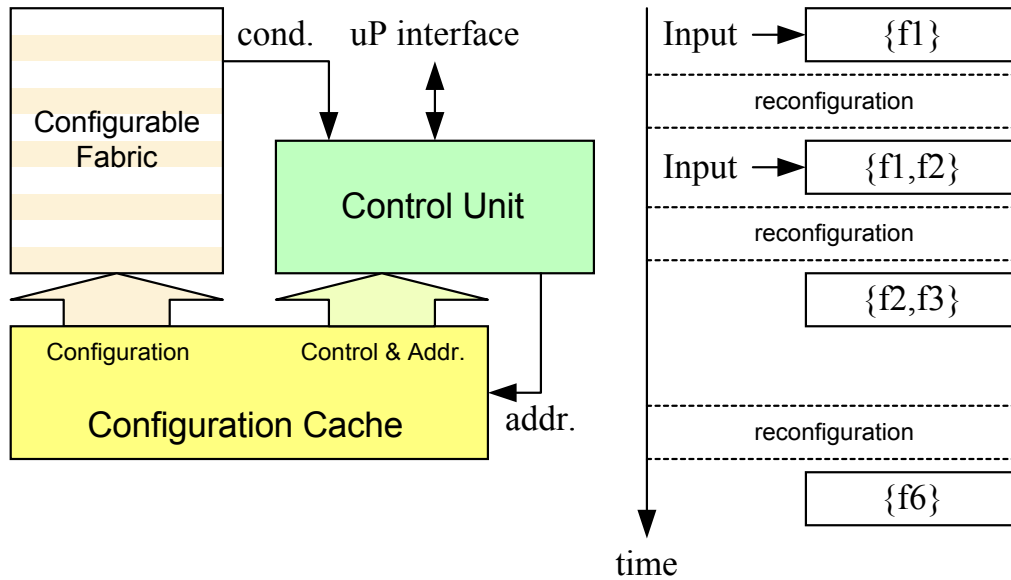
- Hierarchical initialization



# Stripe Reconfiguration (CMU, 1997)



- PipeRench project
- Forward compatibility



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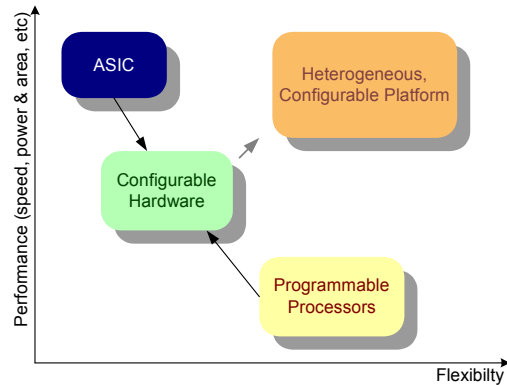


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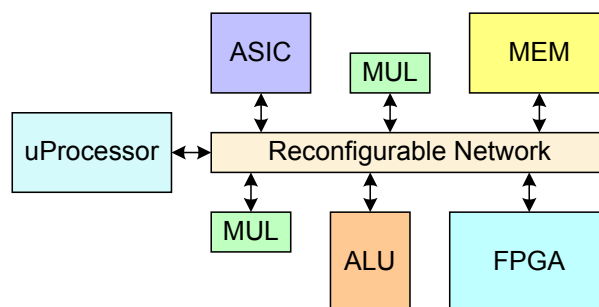


- Silicon pendulum
  - **standardization**  
flexibility, time to market & cost effectiveness
  - **customization**  
performance, differentiation & value addition



- Heterogeneous configurable platform
  - for an application domain, distinguish
    - what remains identical, and
    - what varies over time, or among different tasks, applications

# Heterogeneous Configurable Platform



- Pleiades (BWRC, 1999)
- Algorithms are categorized into classes of operations, which are defined as kernels, by identifying common sequences of operations via static and dynamic simulation & parsing
- Parameterize and control a set of application-specific programmable functional units (kernels) according to the specific needs