TECHNISCHE UNIVERSITÄT DRESDEN

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# SECURE, REAL-TIME AND MULTI-THREADED GENERAL-PURPOSE EMBEDDED JAVA MICROARCHITECTURE

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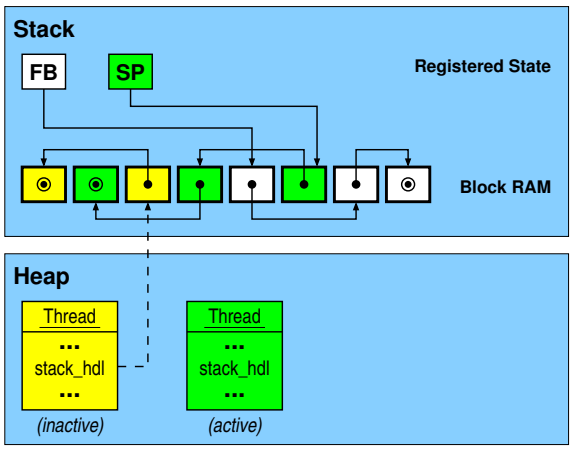
## Motivation

Object-oriented programming has led to fast and easy development of complex applications with a short time-to-market. Java is very popular as:

- The definition of a JVM addresses portability and security features.
- JVM implementations are available for various platforms.
- Compact Java bytecode leads to small memory requirements and reduced download time.

## Features of SHAP

- Embedded Java microarchitecture for security-related, real-time and multi-threaded applications without an underlying operating system.
- **New techniques for real-time support:**
  - integrated stack and thread management,
  - concurrent, CPU-independent garbage collector,
  - preemptive scheduling for autonomous control flows.
- **Manifold support of object-oriented concepts:**
  - automatic memory management, structured exception handling, multiple inheritance through interfaces,
  - object serialization, dynamic class loading.
- Provided API: “Connected Limited Device Configuration” (CLDC API).



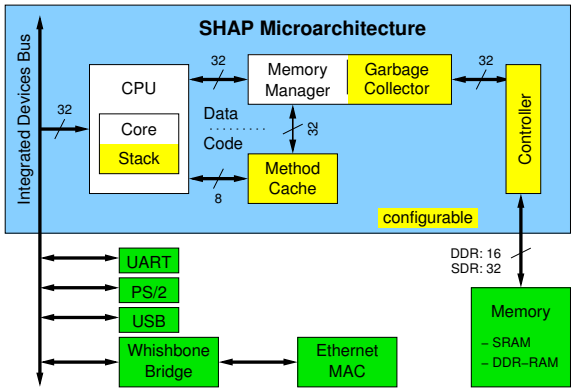

## Memory Manager with Garbage Collector

- Encapsulates the complete object management, the CPU only acts on references.
- Type: **incremental concurrent garbage collector.**
- The heap memory is divided into equally-sized segments:
  - An empty segment is selected as the allocation segment
    ⇒ constant-time bump-pointer allocation.
  - Memory cleaning based on segments
    ⇒ copying of used objects between segments.
  - Enhancement to generational garbage collection is available.
- All GC operations are interruptible to provide **constant and small execution time for CPU access**.
- Flexible configuration of GC policy at run time.

## Related Work

Several Java processors have been developed, **but:**

- The support for real-time threads is limited to the RTSJ specification, which excludes automatic garbage collection in the memory areas used by real-time threads.
- Dynamic class loading is not available because the whole application is pre-linked into a static memory image.




## Multi-Threaded Stack

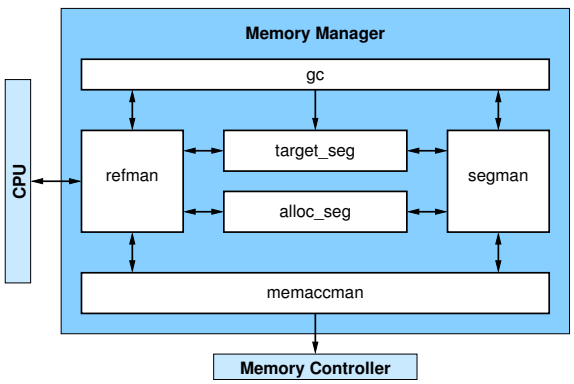
Enhanced, high-level operations for handling Java method invocation as well as multiple threads:

- method frame construction / destruction in 2 clock cycles,
- thread creation / switching in 5 cycles, thread killing in 3 cycles.

On-chip memory is used for storing application and internal management data. To provide a separate stack per thread:

- The storage space is divided into equally-sized blocks currently holding up to 64 words (configurable).
- The blocks are organized in multiple disjunct singly-linked lists.
- Each list, except for the free list, represents the stack of one thread.
- Fast dynamic growing and shrinking of the active stack by relinking of a block between the free block list and the list of the active stack.

Stack scanning by the garbage collector does not interfere with normal stack operation.




## Current Results

Example configuration on SPARTAN-3 Starter Kit Board:

- 8 KByte stack, up to 32 threads,
- 2 KByte method cache,
- memory controller for external 1 MByte SRAM,
- bus devices: UART, SEG7,
- clock frequency of 50 MHz.

Resource usage on the Spartan3 XC3S1000:

| | |
|---|---|
| Flip Flops | 1559 |
| 4 input LUTs | 4316 |
| - used as logic | 4047 |
| - used as a route-through | 183 |
| - used for Dual Port RAMs | 86 |
| 18kbit Block RAMs | 11 |
| 18x18 Multipliers | 3 |

Caffeine Mark Embed 3.0 Scores:

| | |
|---|---|
| SieveTest | 21 |
| LoopTest | 145 |
| LogicTest | 333 |
| StringTest | 300 |
| MethodTest | 123 |

Floating-point is not implemented.

Further available devices for integrated devices bus: Ethernet MAC 10/100 via Wishbone bridge, USB, LCD, PS/2.