Systems and Networking – Unit I

B.Sc. in Applied Computer Science and Artificial Intelligence

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Where Are We?

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  - Processes and Threads
  - CPU Scheduling
  - Synchronization and Deadlock

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  - Memory Management
- … Later on:
  - File Systems and I/O Storage
  - Advanced Topics (?)

Part IV: Memory Management

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  - maximizing memory utilization and system throughput
- Guarantee isolation between processes
  - addressability and protection
- Provide a convenient abstraction to the programmer
  - illusion of unlimited amount of memory

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NOTE: In case of purely-interpreted language implementations, translation from source code to executable is done "on-the-fly" by the loaded interpreter

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How?

Generating Memory Addresses: Example

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1. Fetch instruction at address `128`
2. Execute istruction: load from address `[%R2]` (e.g., `1234`)
3. Fetch instruction at address `136`
4. Execute instruction: addition (no memory reference)
5. Fetch instruction at address `144`
6. Execute instruction: store to address `[%R2]` (`1234`)

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The program must be recompiled!

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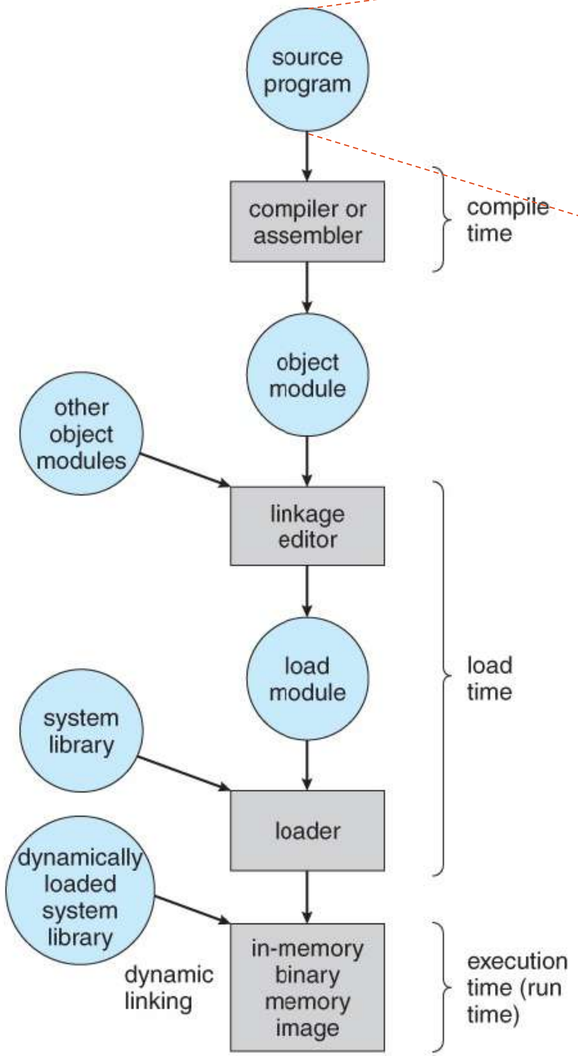


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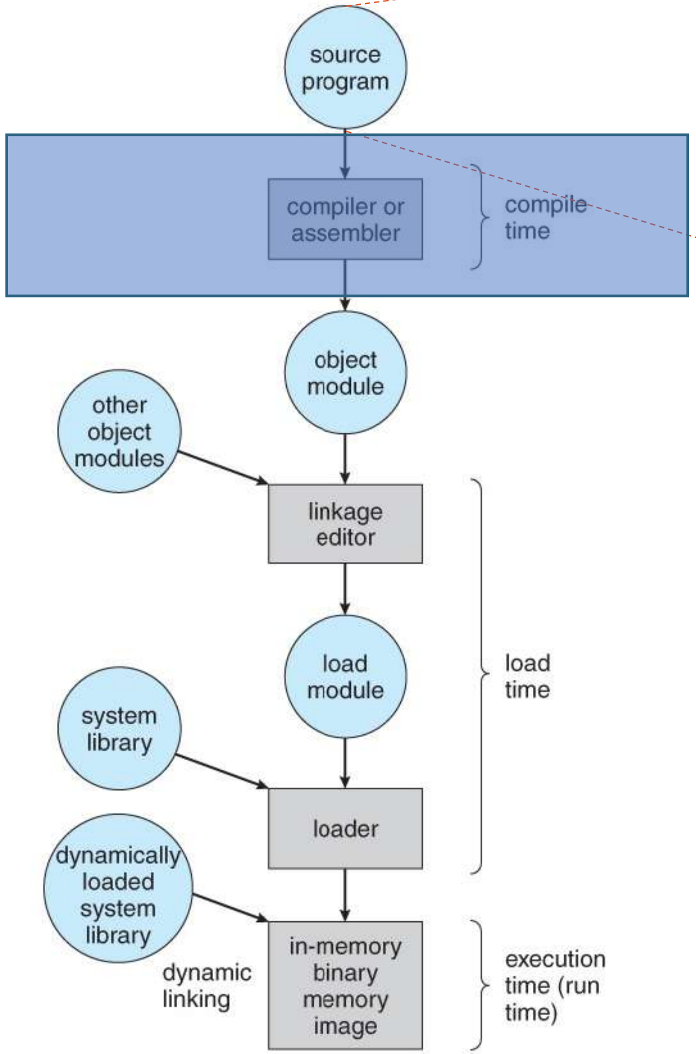


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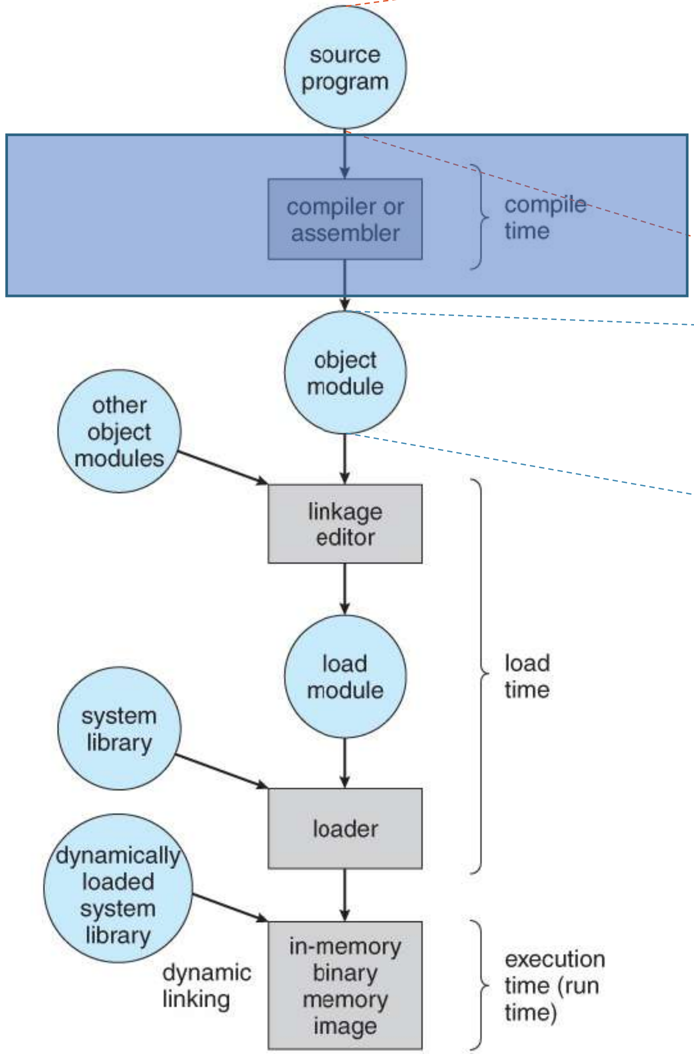


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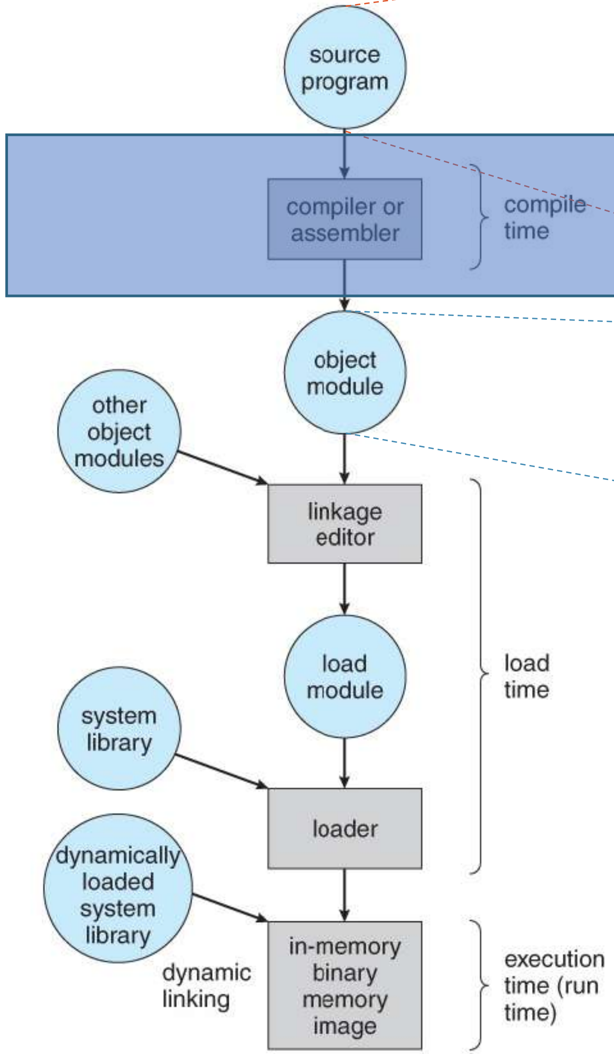


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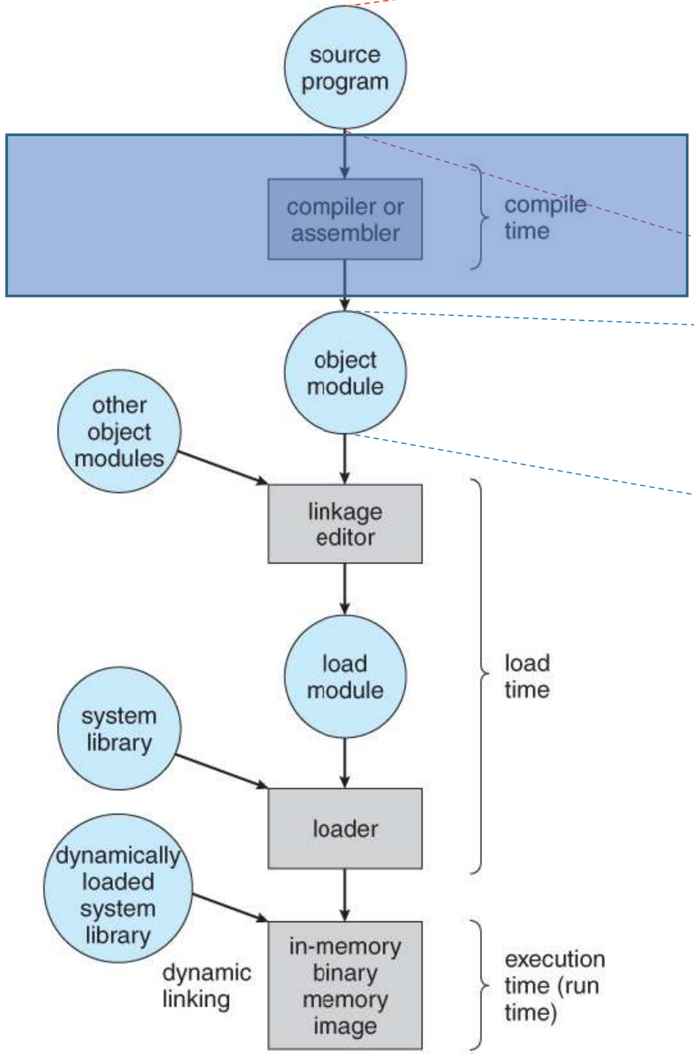


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The program must be reloaded but not recompiled!

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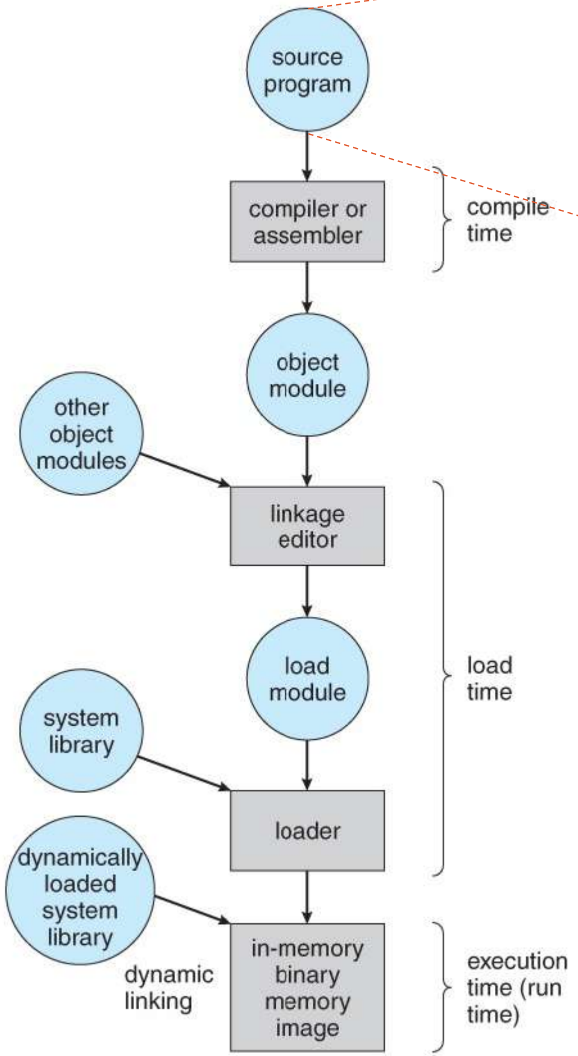


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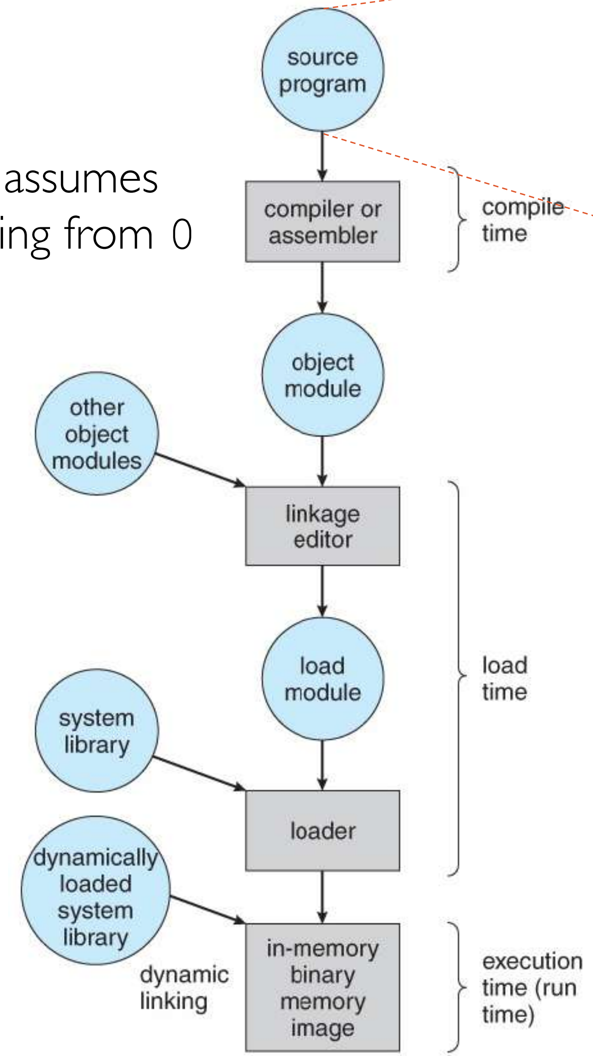


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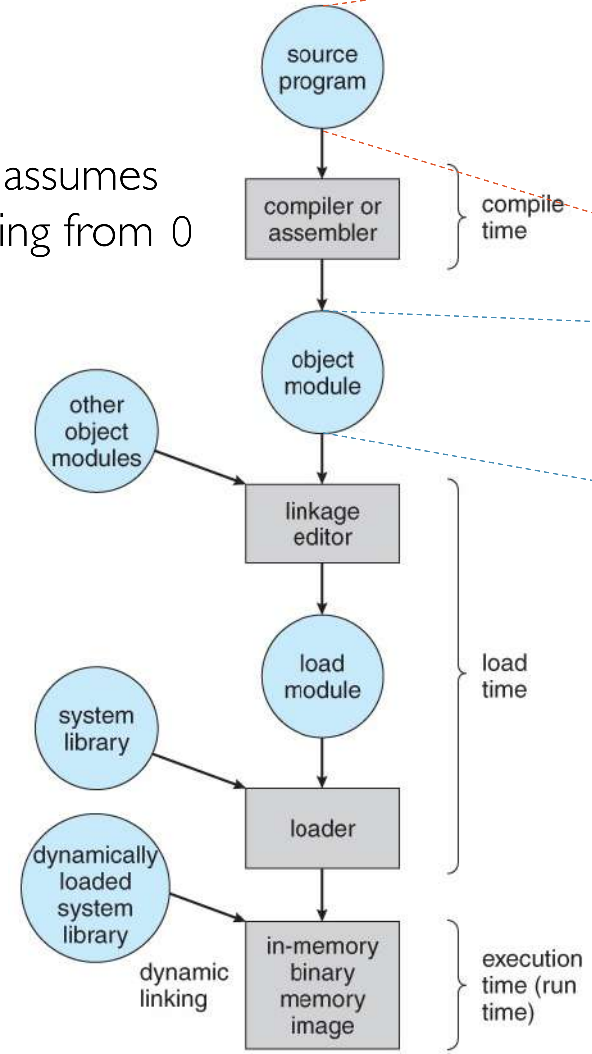


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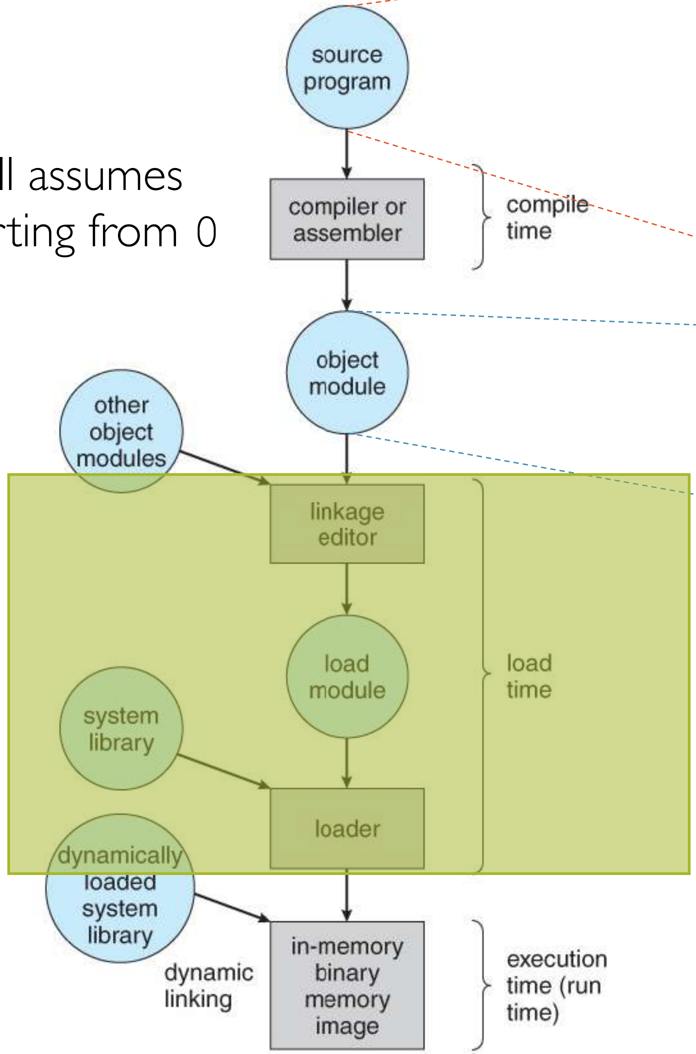


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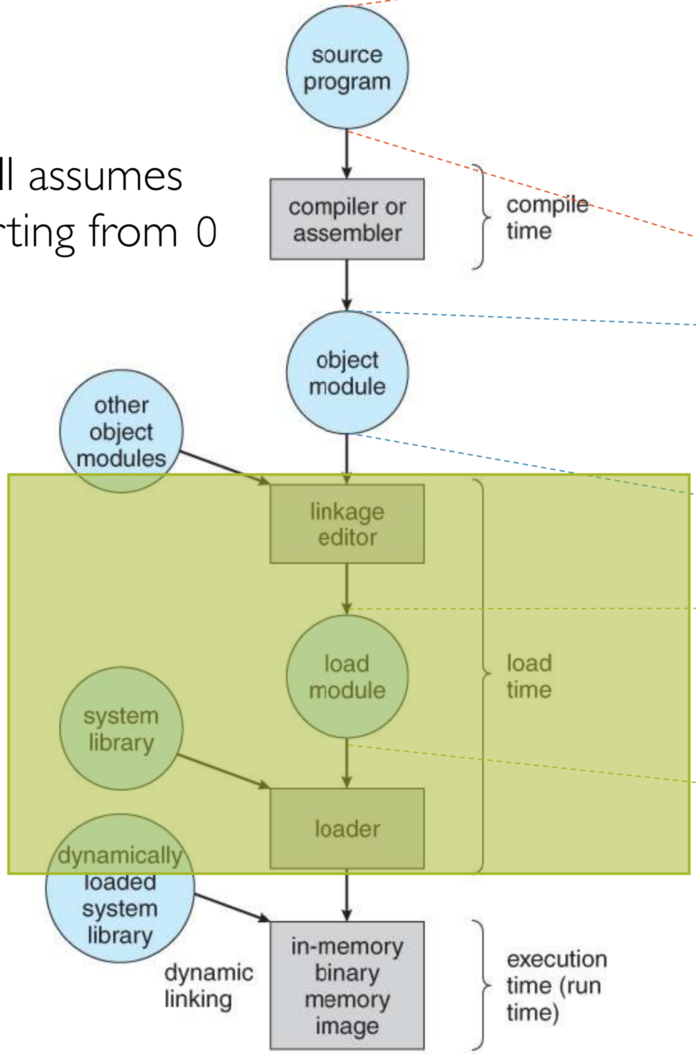


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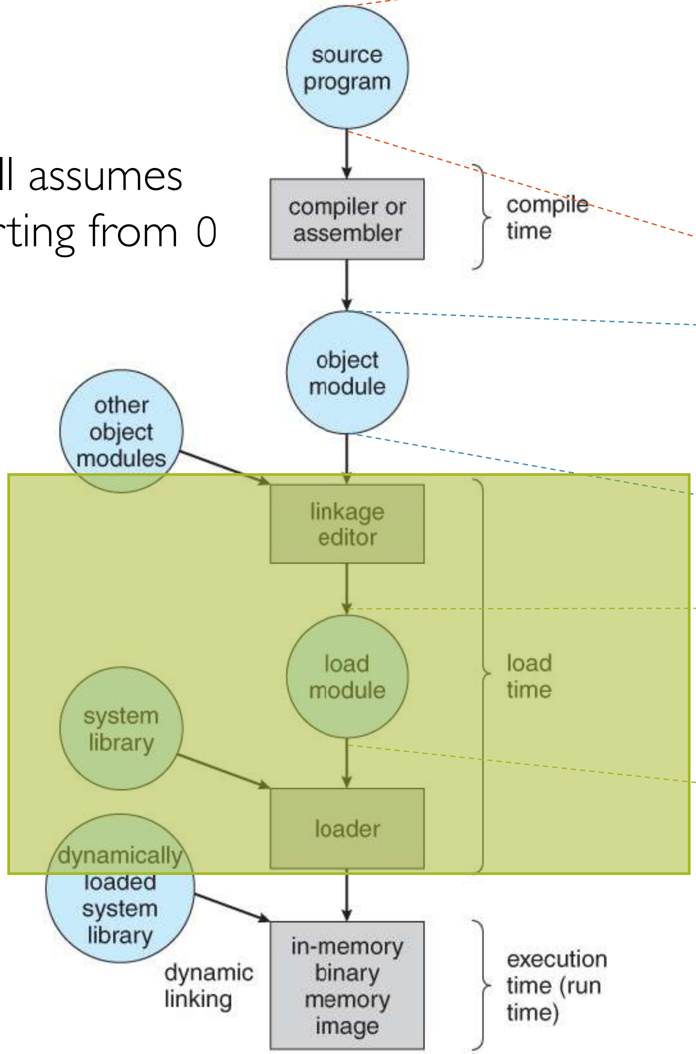


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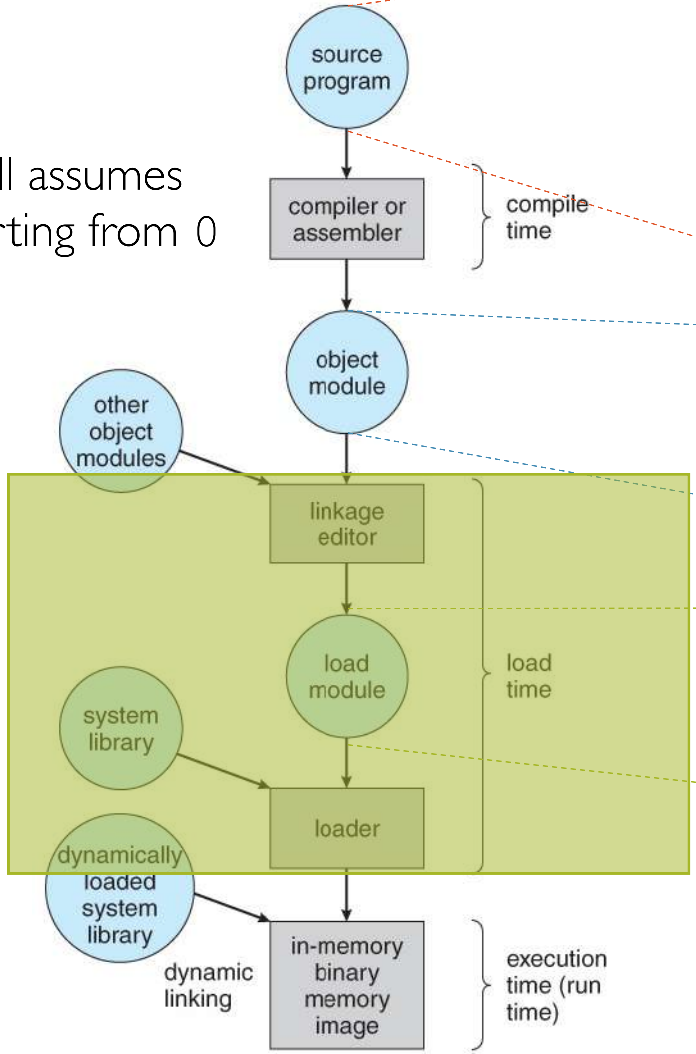


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Most flexible solution implemented by the majority of modern OSs

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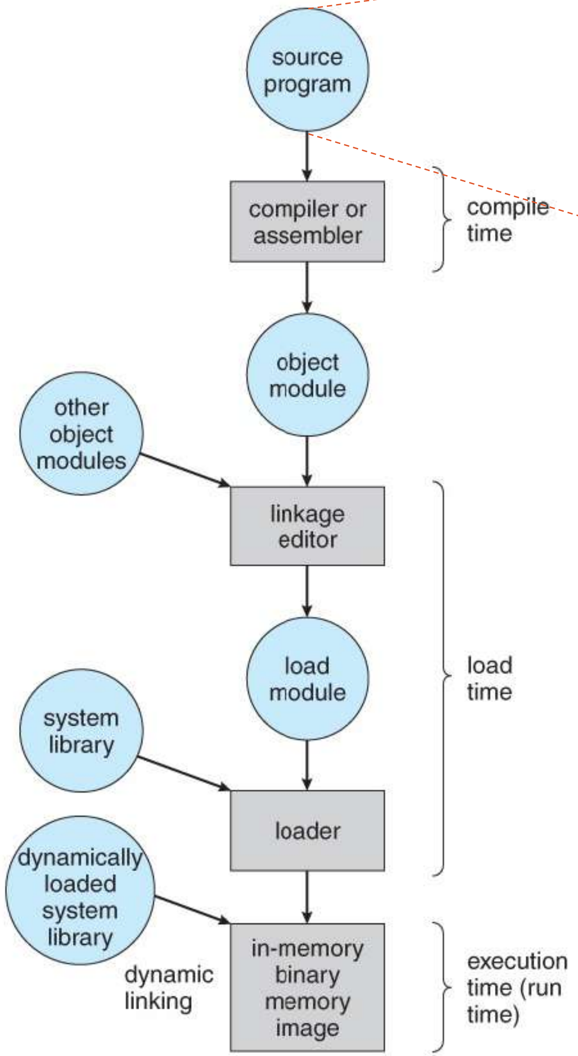


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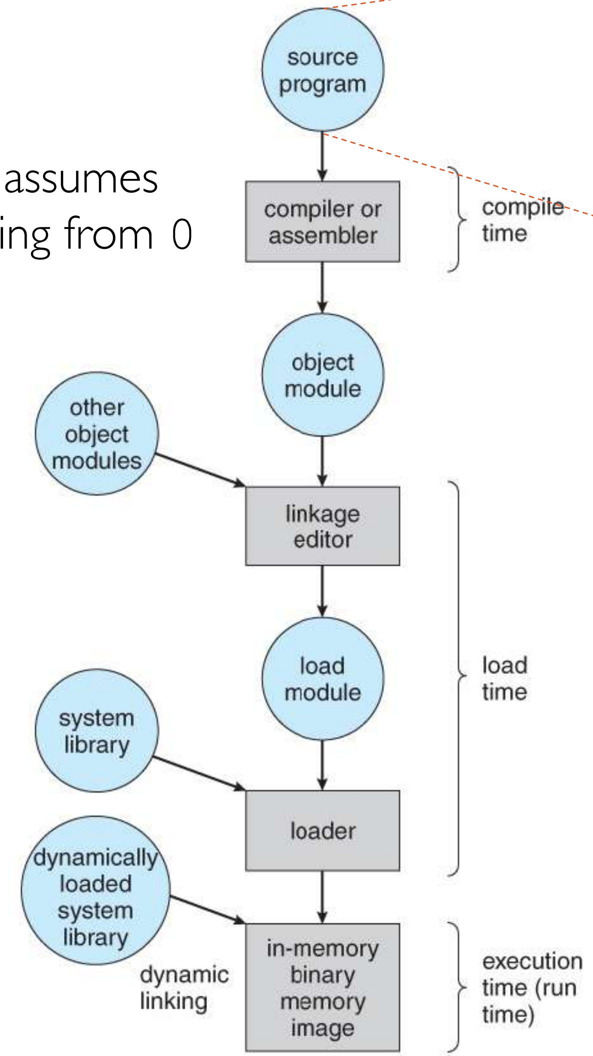


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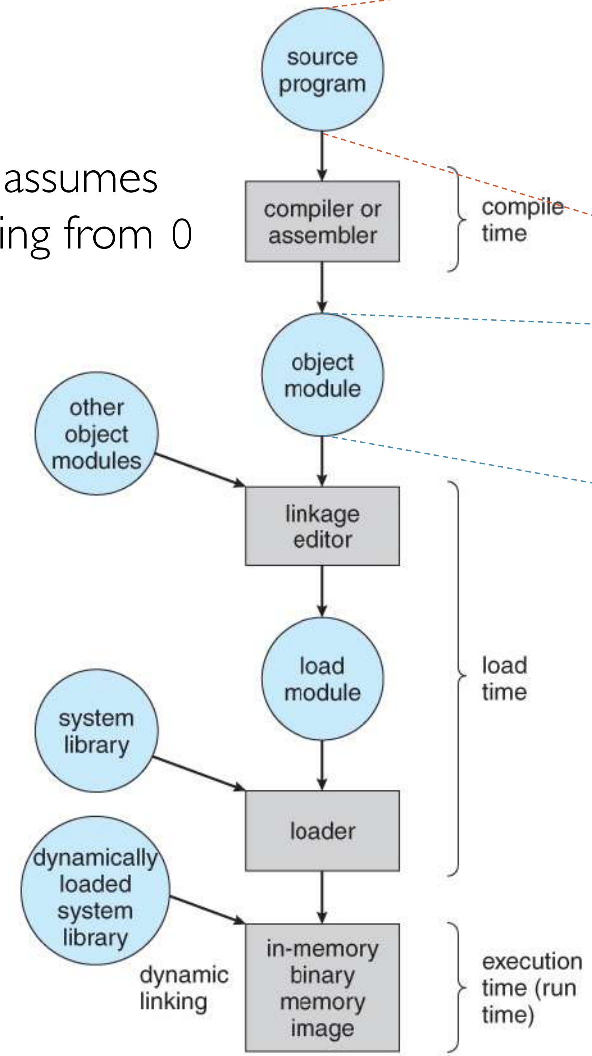


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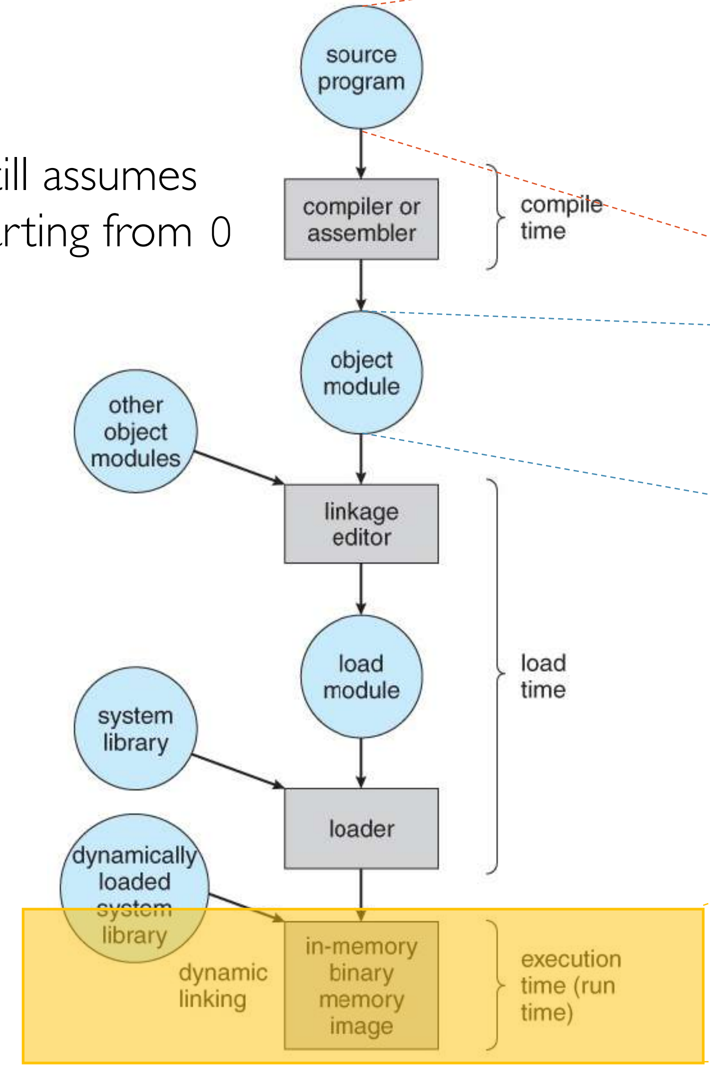


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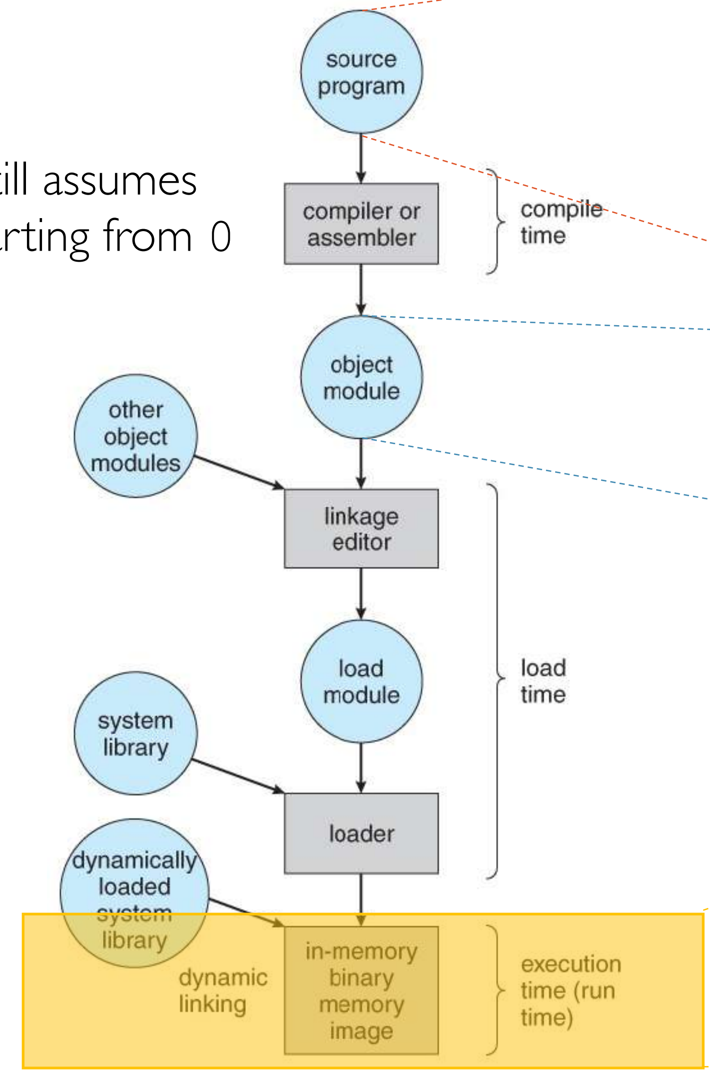


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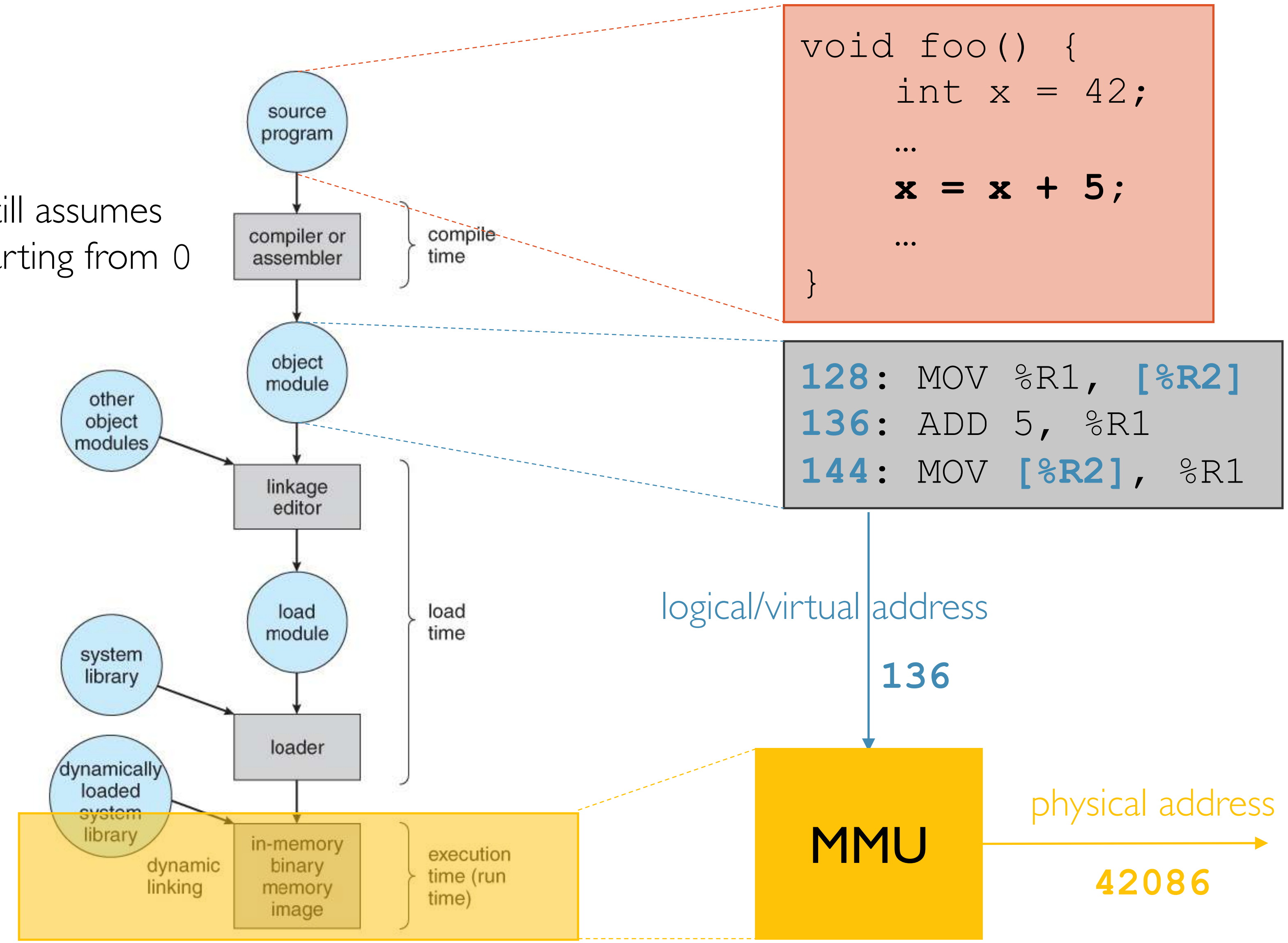

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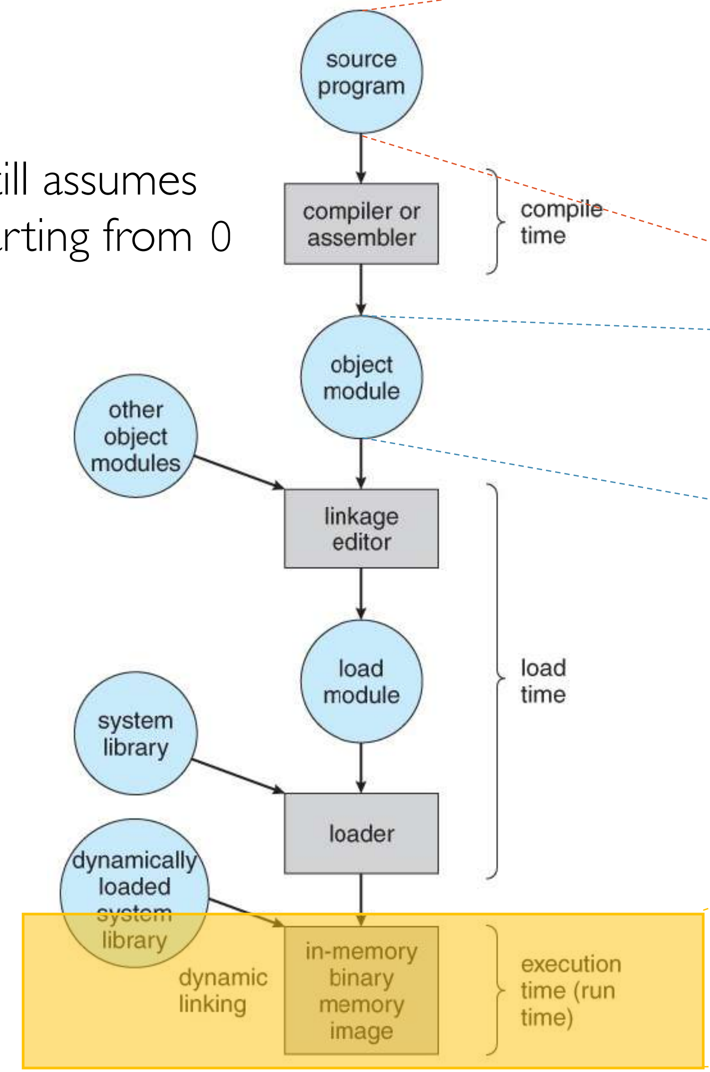


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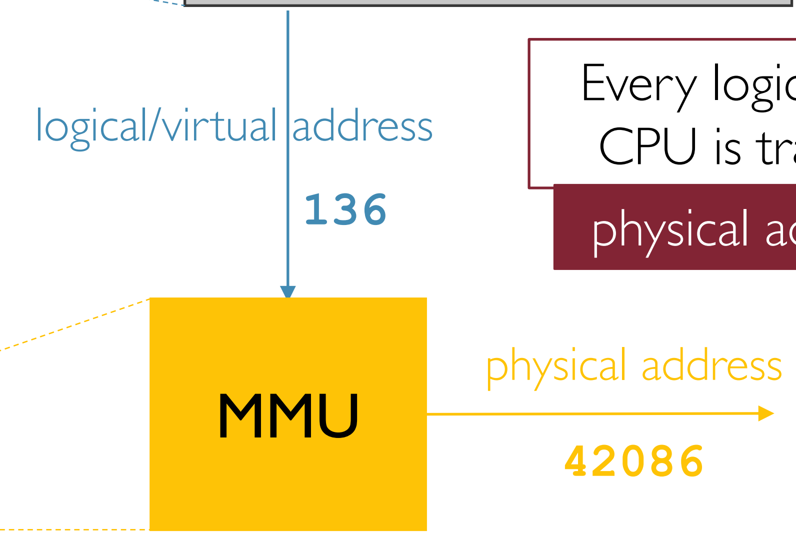

Every logical address referenced by the CPU is translated by HW at run time

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- Address binding can occur at compile time

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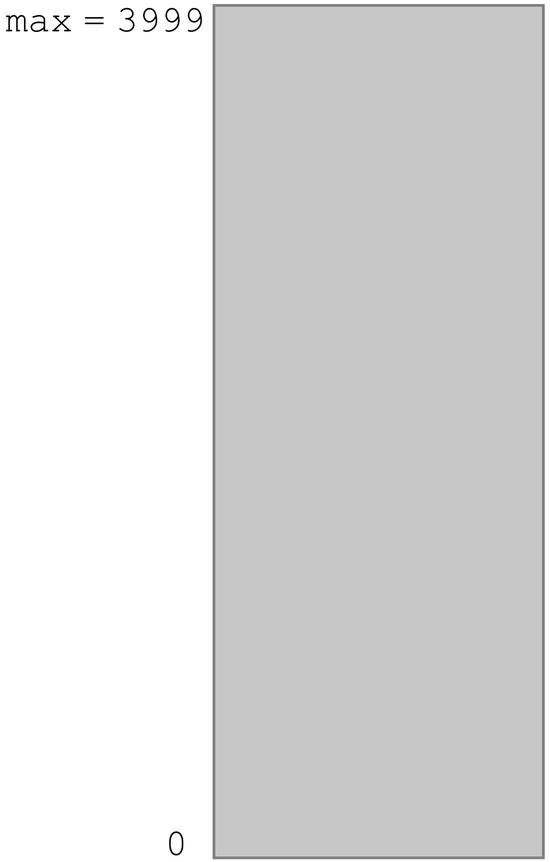
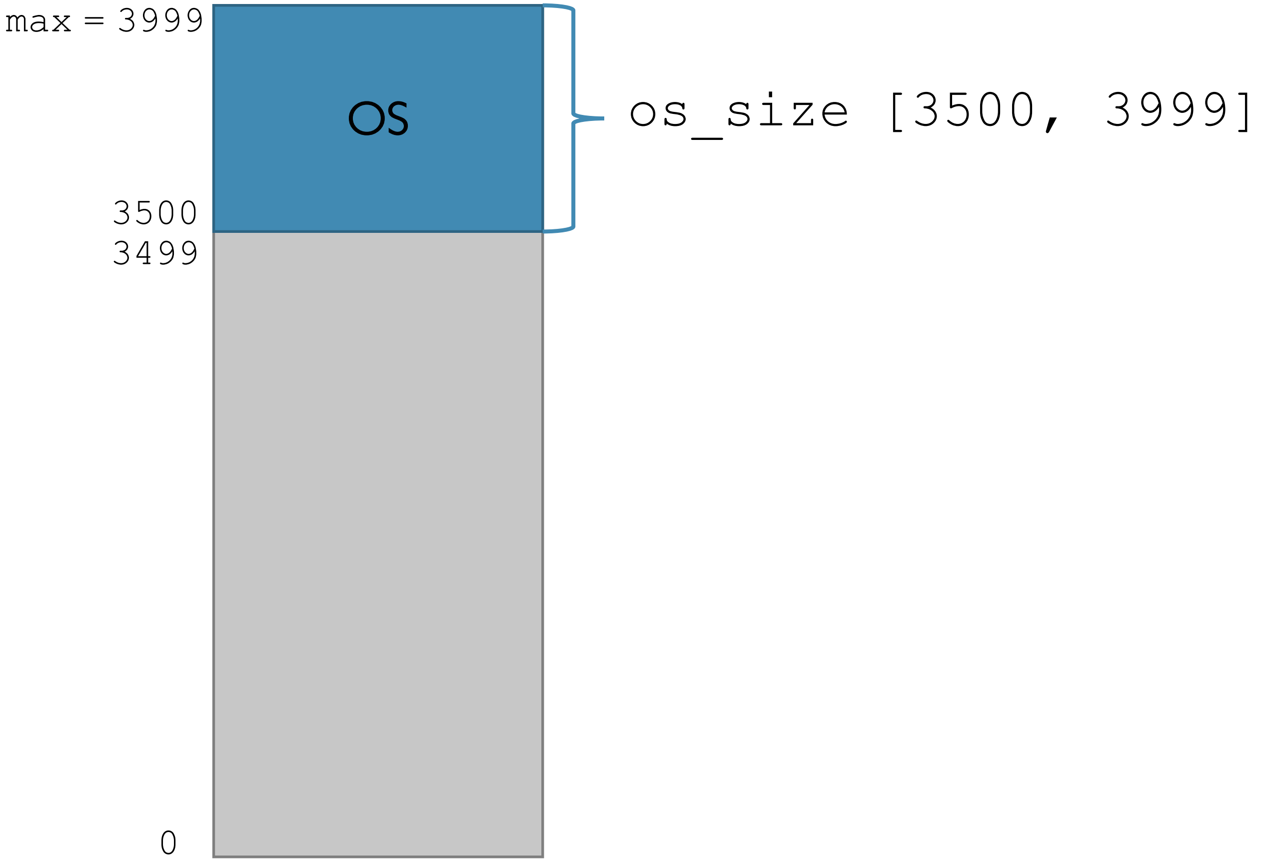
memory_size = 4000B = 4kB



Manage Uniprogramming Memory

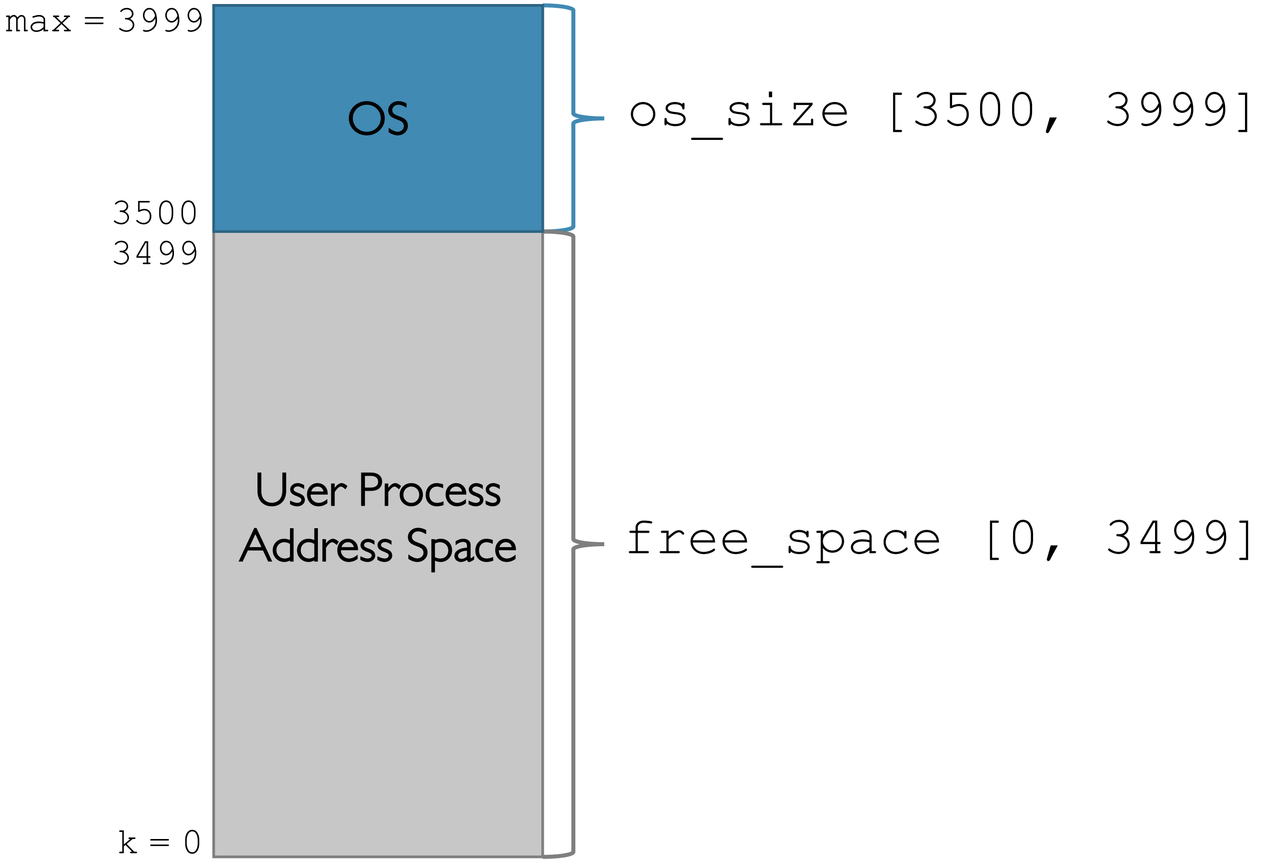
`memory_size = 4000B = 4kB`

`os_size = 500B`



Manage Uniprogramming Memory

memory_size = 4000B = 4kB | os_size = 500B | k = 0 | free_space = 3.5kB



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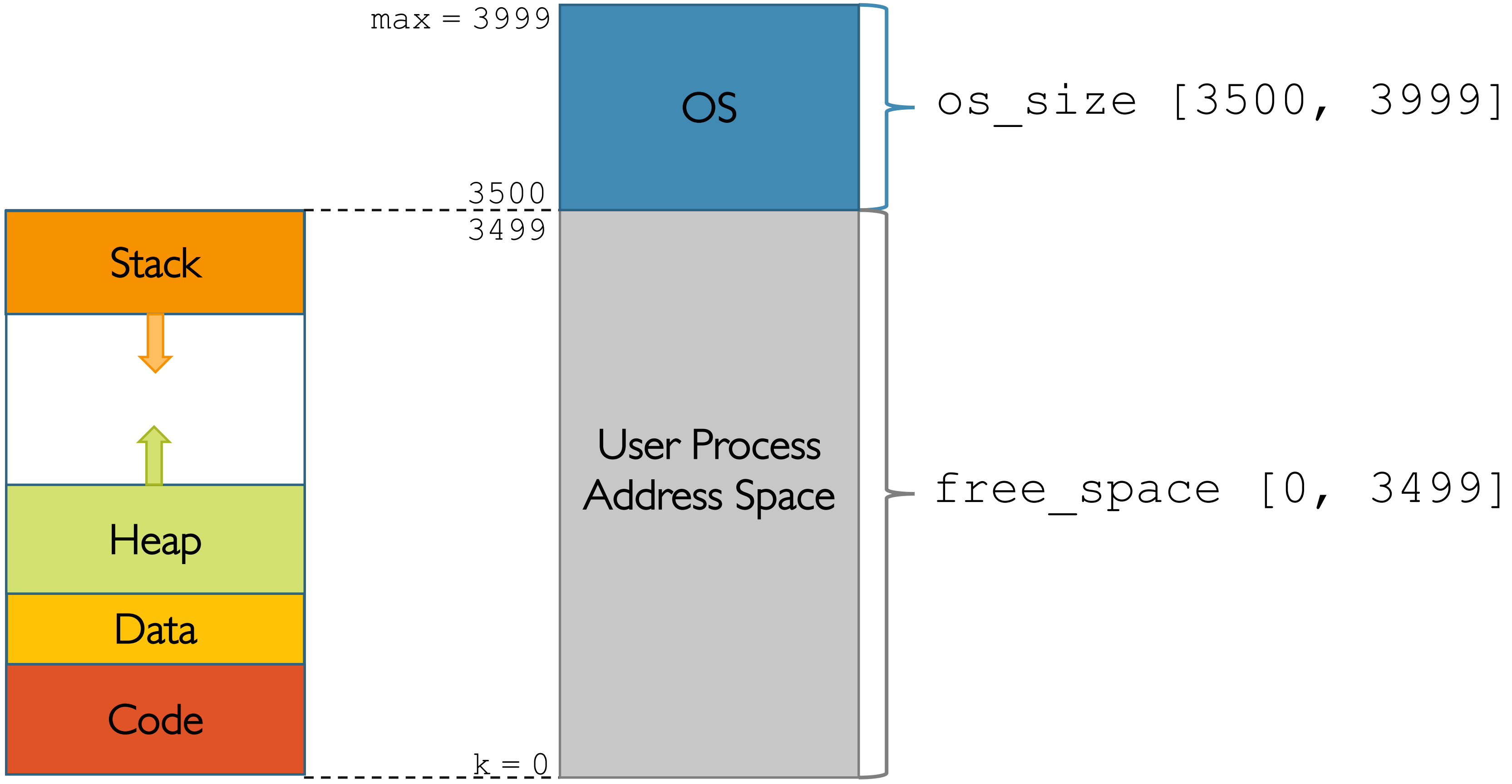

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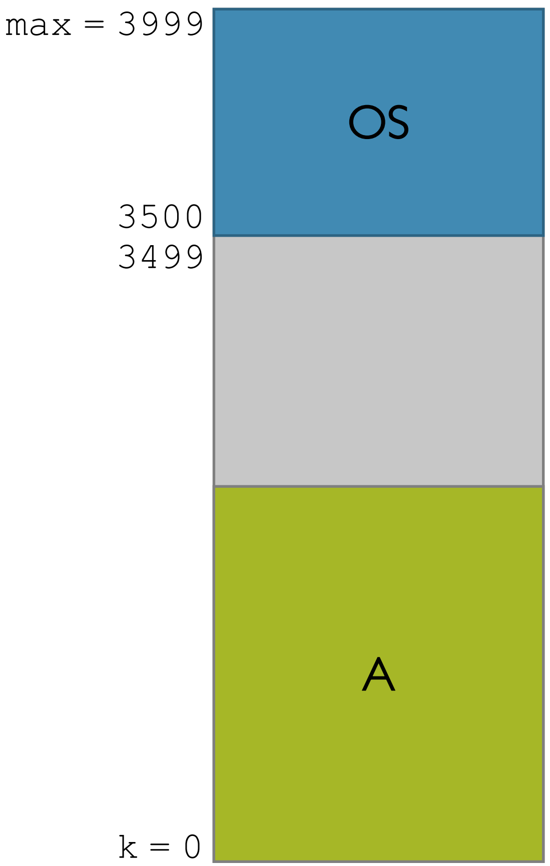

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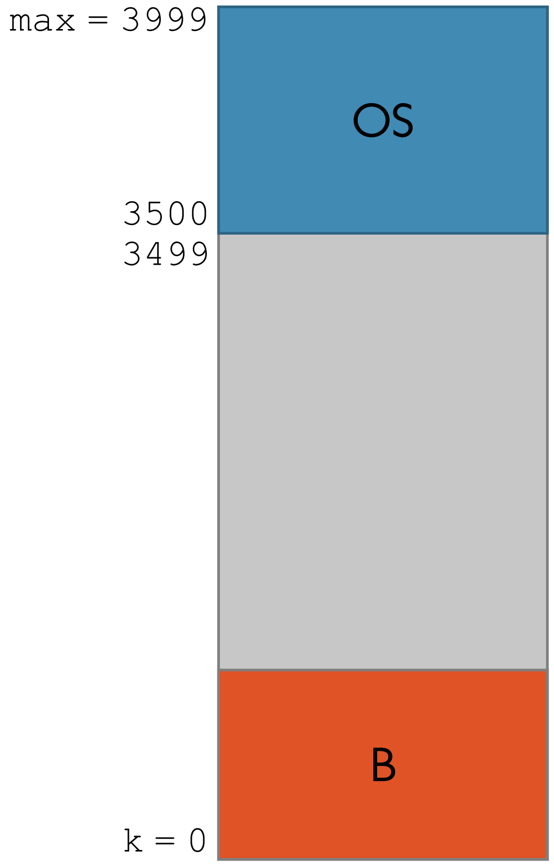

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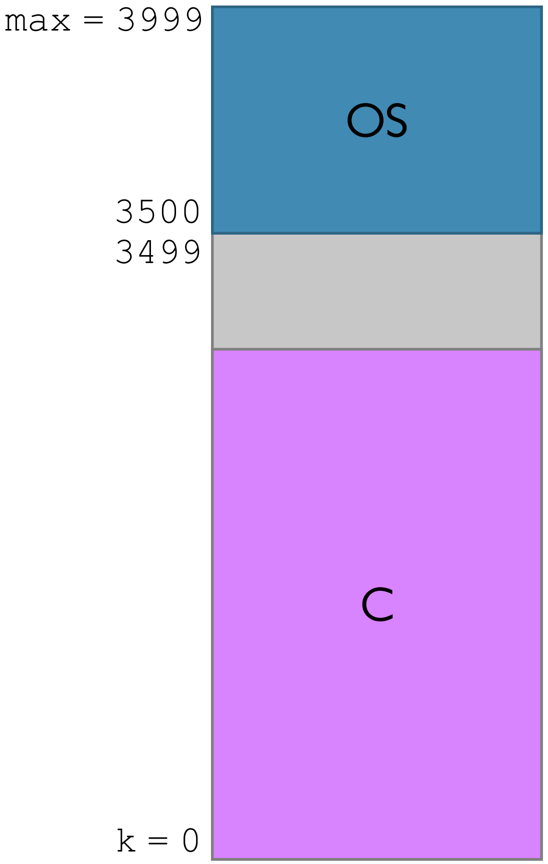

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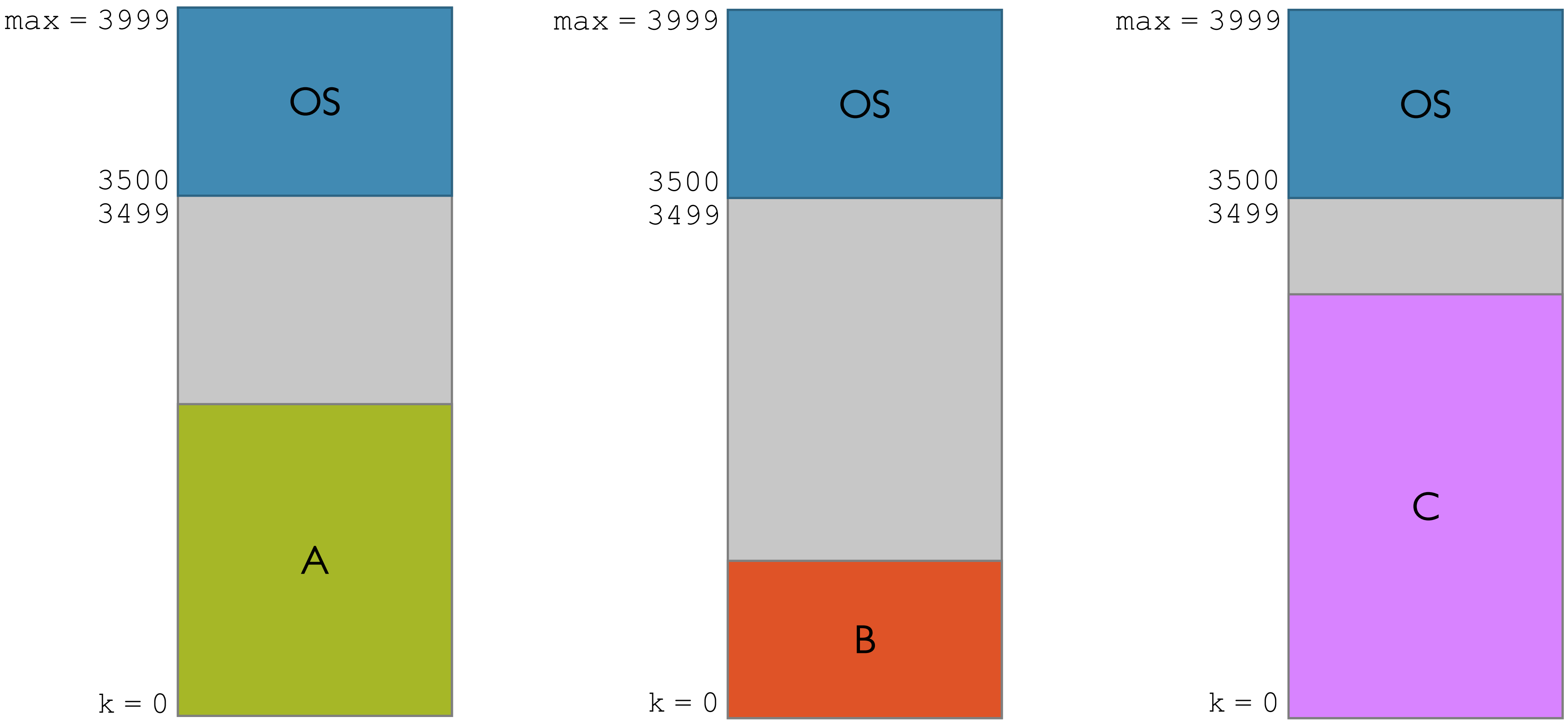

Very simple! But only one process executes at a time and no OS protection

Manage Multiprogramming Memory: Goals (1)

- Sharing
  - Several processes coexist in main memory at the same time
  - Cooperating processes can share portions of address space

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- Sharing
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- Transparency
  - Processes should not be aware that memory is shared
  - Processes should not be aware of which portions of physical memory they are assigned to

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  - Processes must not be able to corrupt each other or the OS
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- Protection/Security
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- Efficiency
  - CPU and memory performance should not degrade badly due to sharing
  - Keep memory fragmentation low

Relocation: Initial Idea

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- Load a process by allocating the first **contiguous segment** of memory in which the process fits
- Allow transparent sharing of memory: each process' address space may be placed anywhere in memory

Static Relocation

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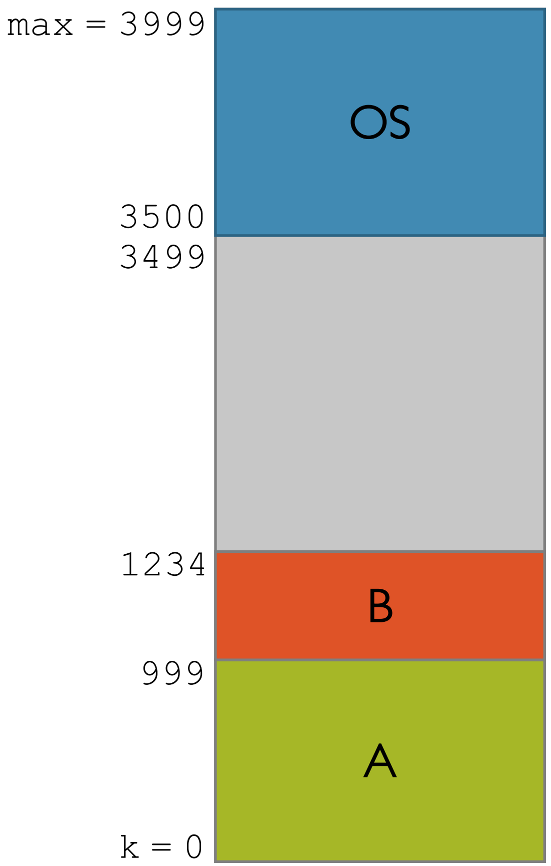
- PRO:
  - No HW support is needed
- CONs:
  - No protection/privacy → processes can corrupt the OS or other processes
  - Address space must be allocated contiguously → assuming worst-case stack and heap request
  - The OS cannot move a process (address space) once allocated in memory

Static Relocation



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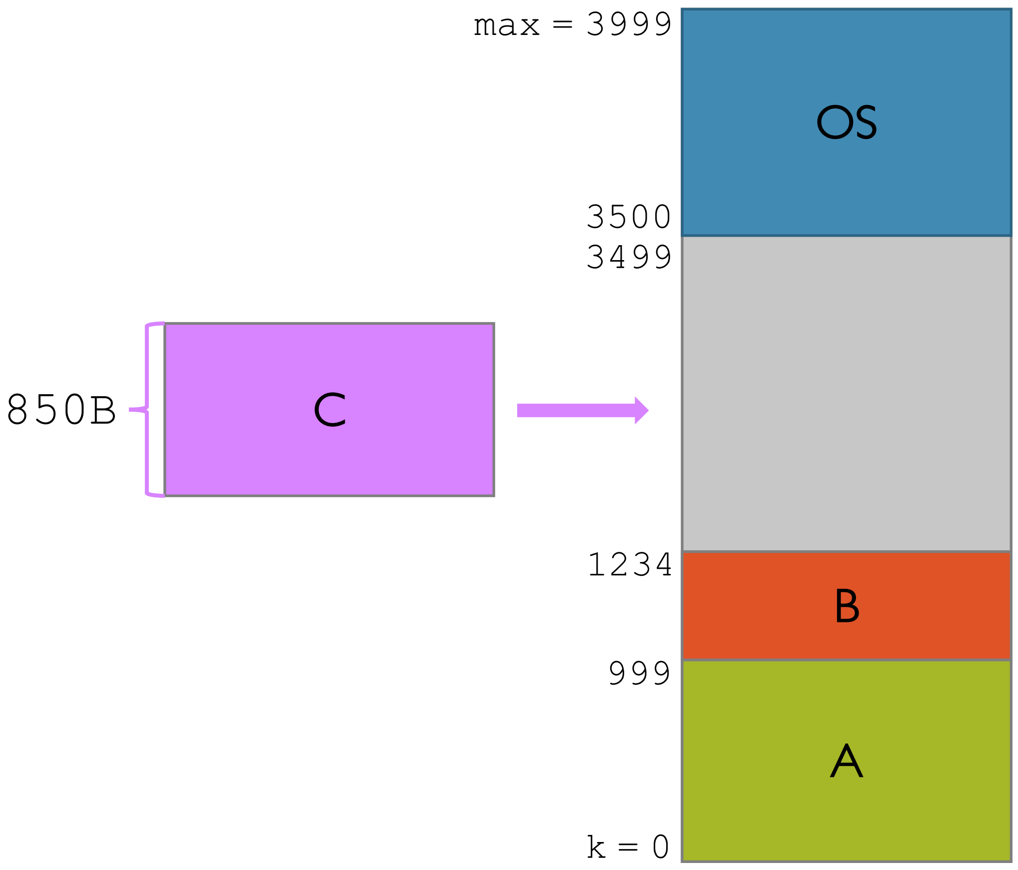

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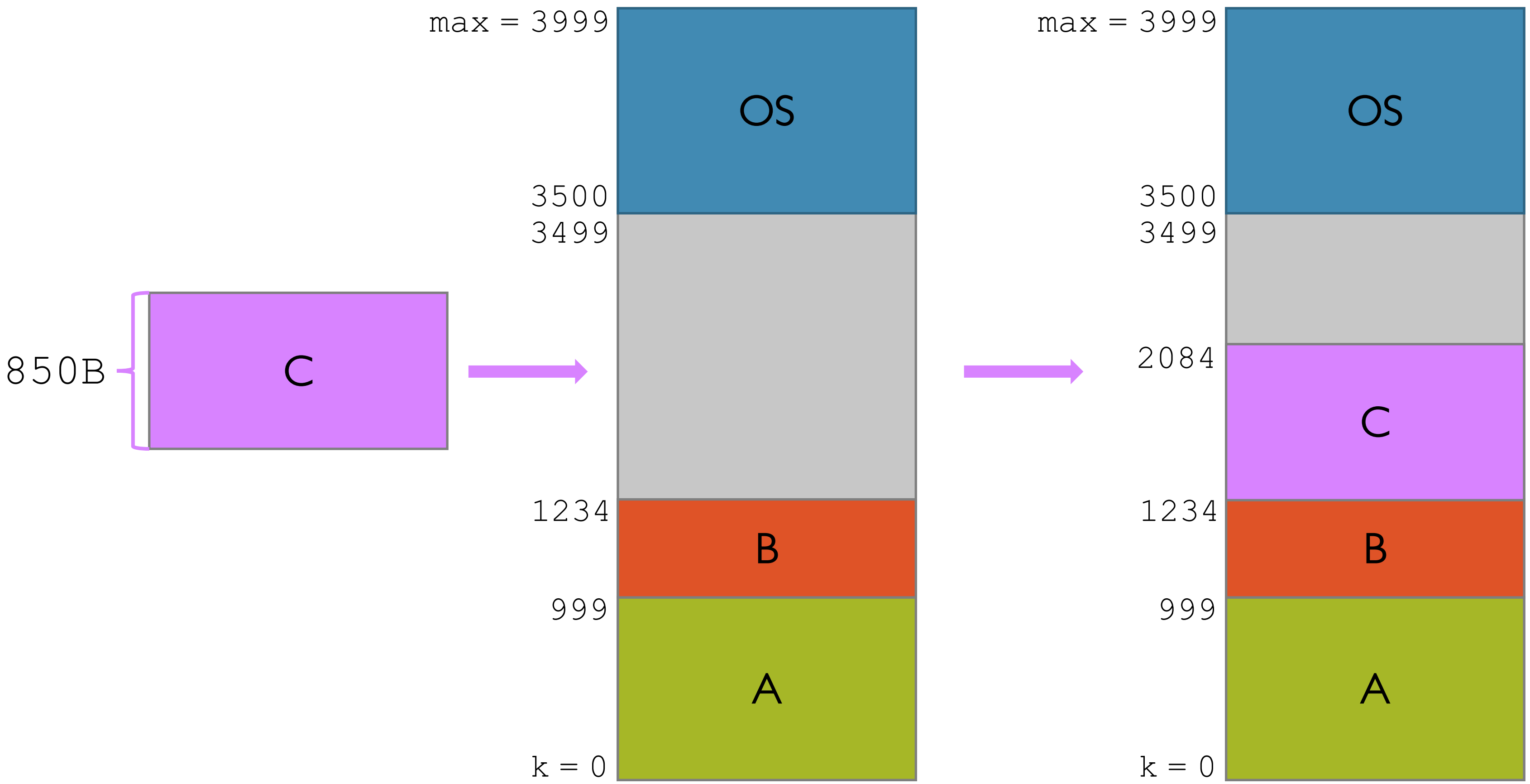

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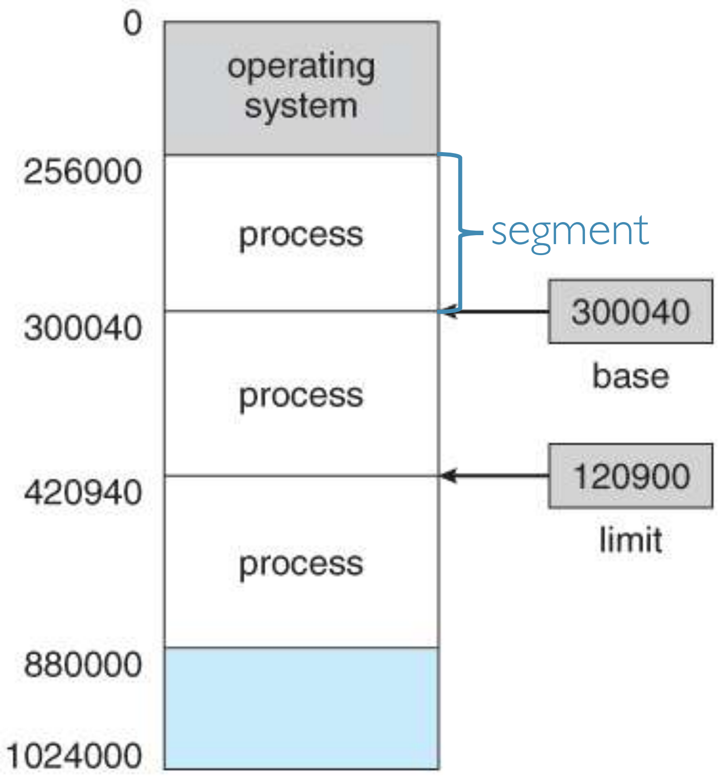
- CPU supports at least 2 operating modes:
  - privileged (kernel) mode when the OS is running
    - after issuing any trap (system call, interruption, or exception)
    - when manipulating sensitive resources (e.g., the content of MMU registers)
  - user mode when user process is running
    - while executing process instructions on the CPU

Base and Limit Registers: Idea



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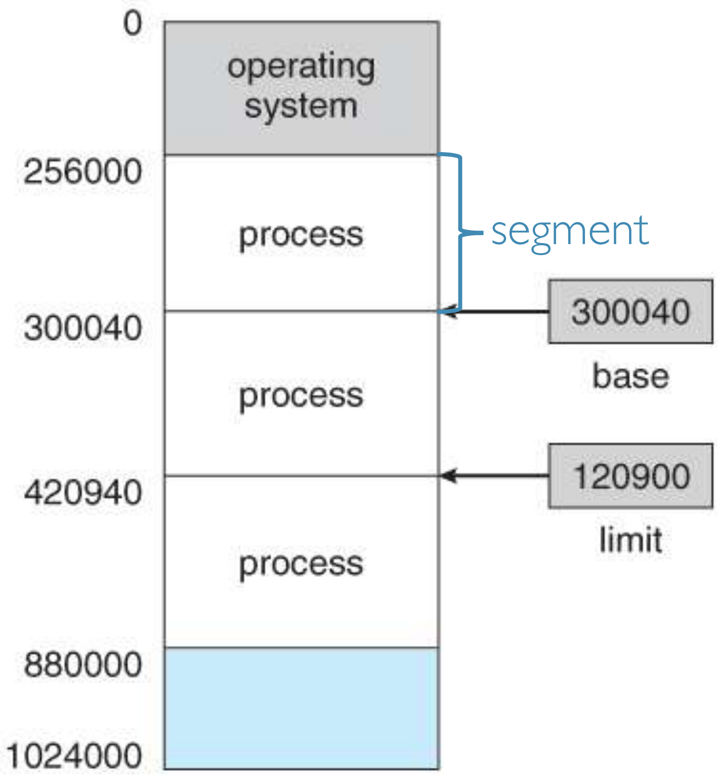

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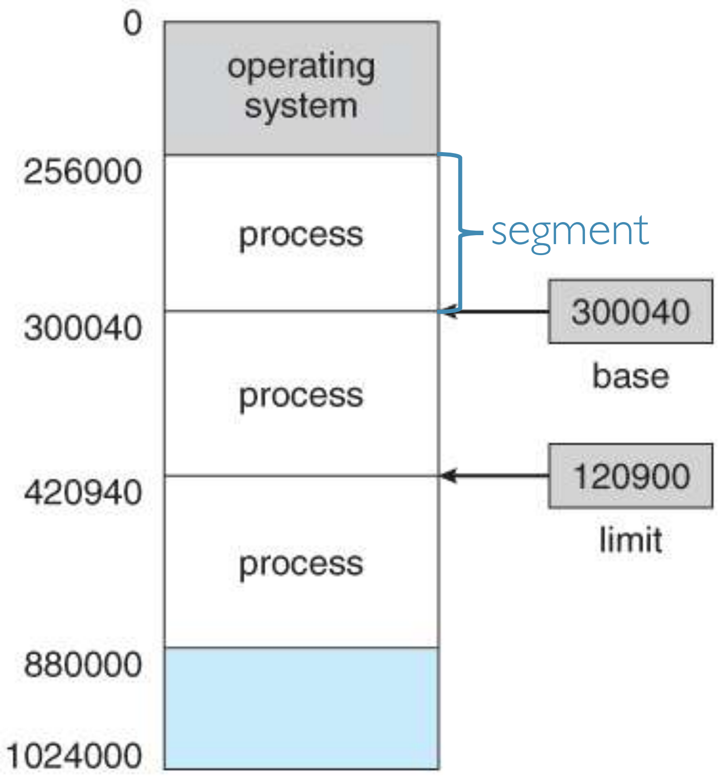

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Protection implemented using two MMU registers: base and limit

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CPU must check every memory access generated in user mode (i.e., by a user process) is within the correct [base, base + limit) range for *that* process

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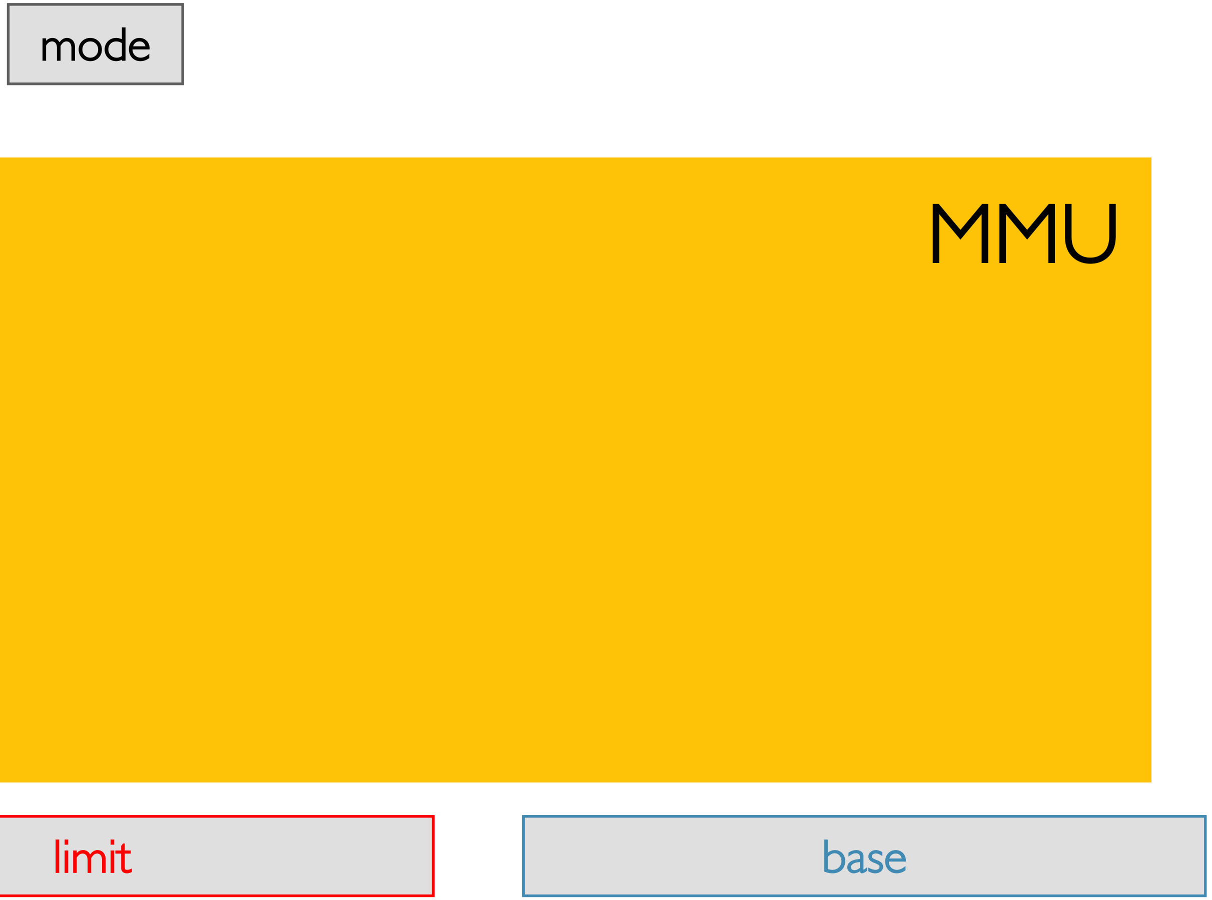

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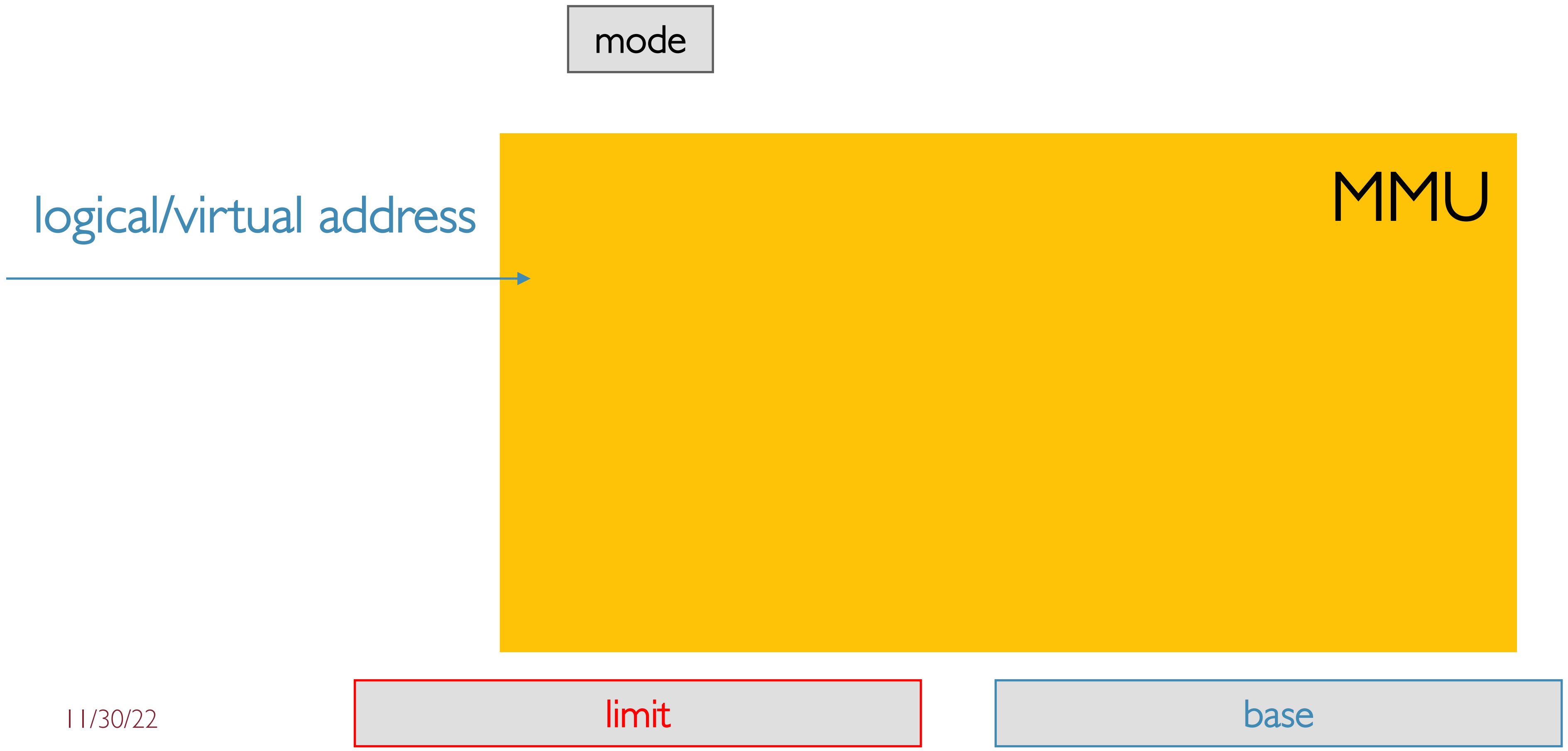

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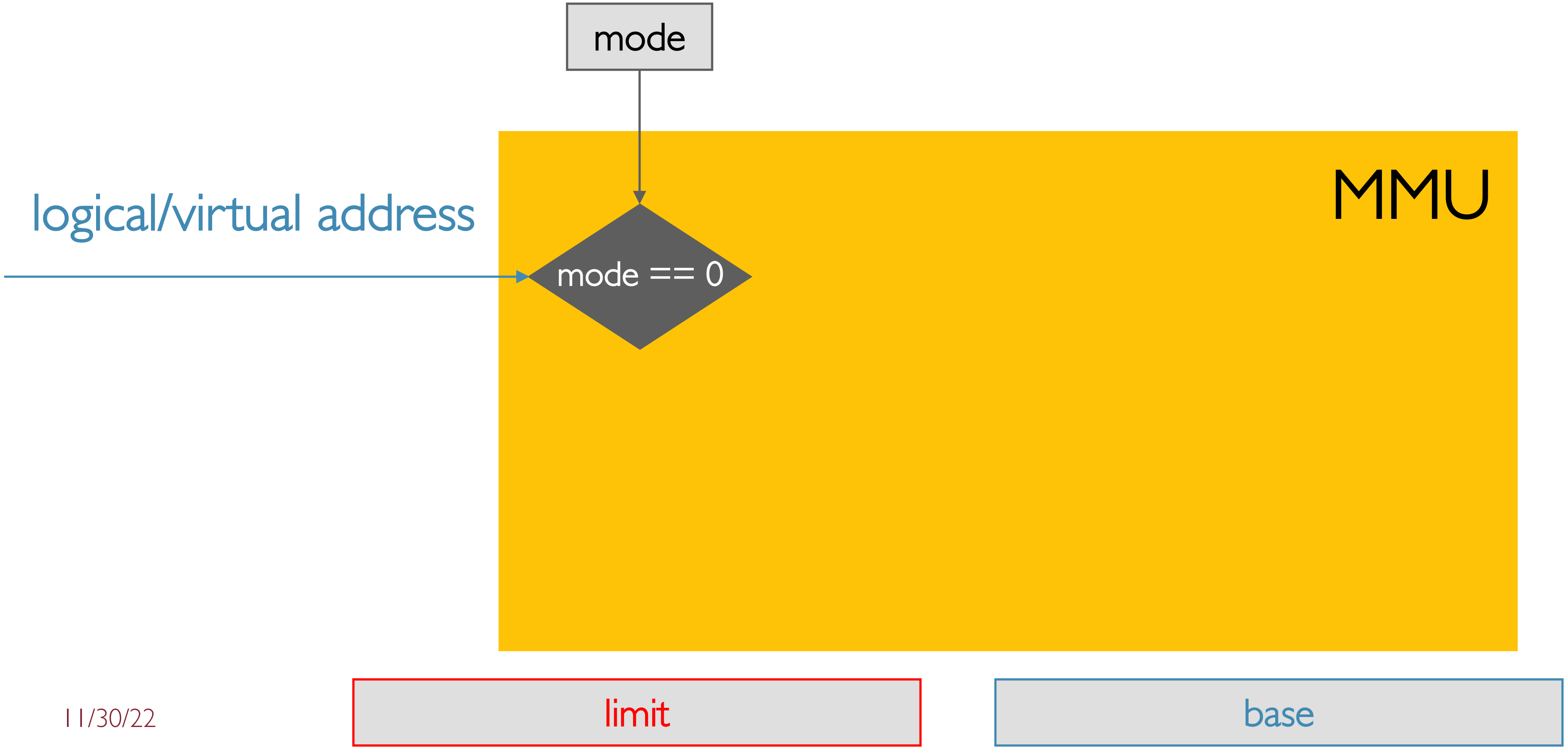

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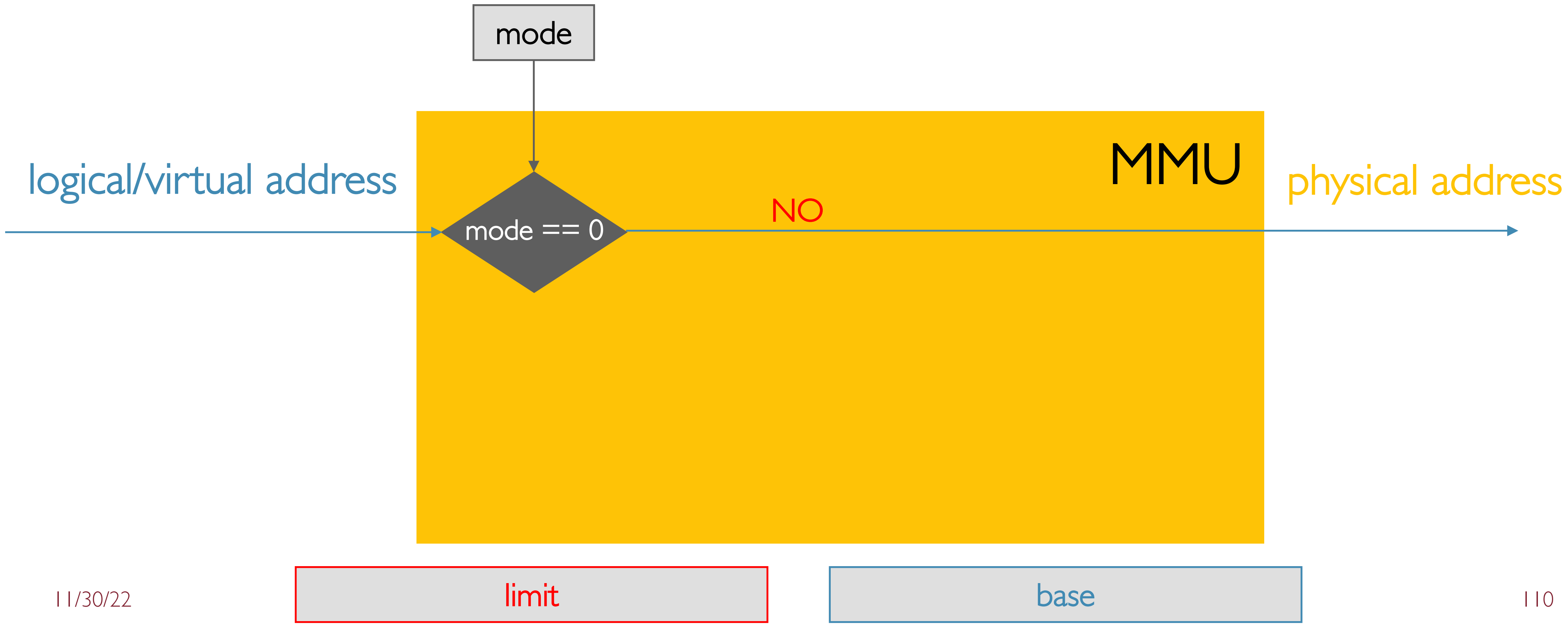

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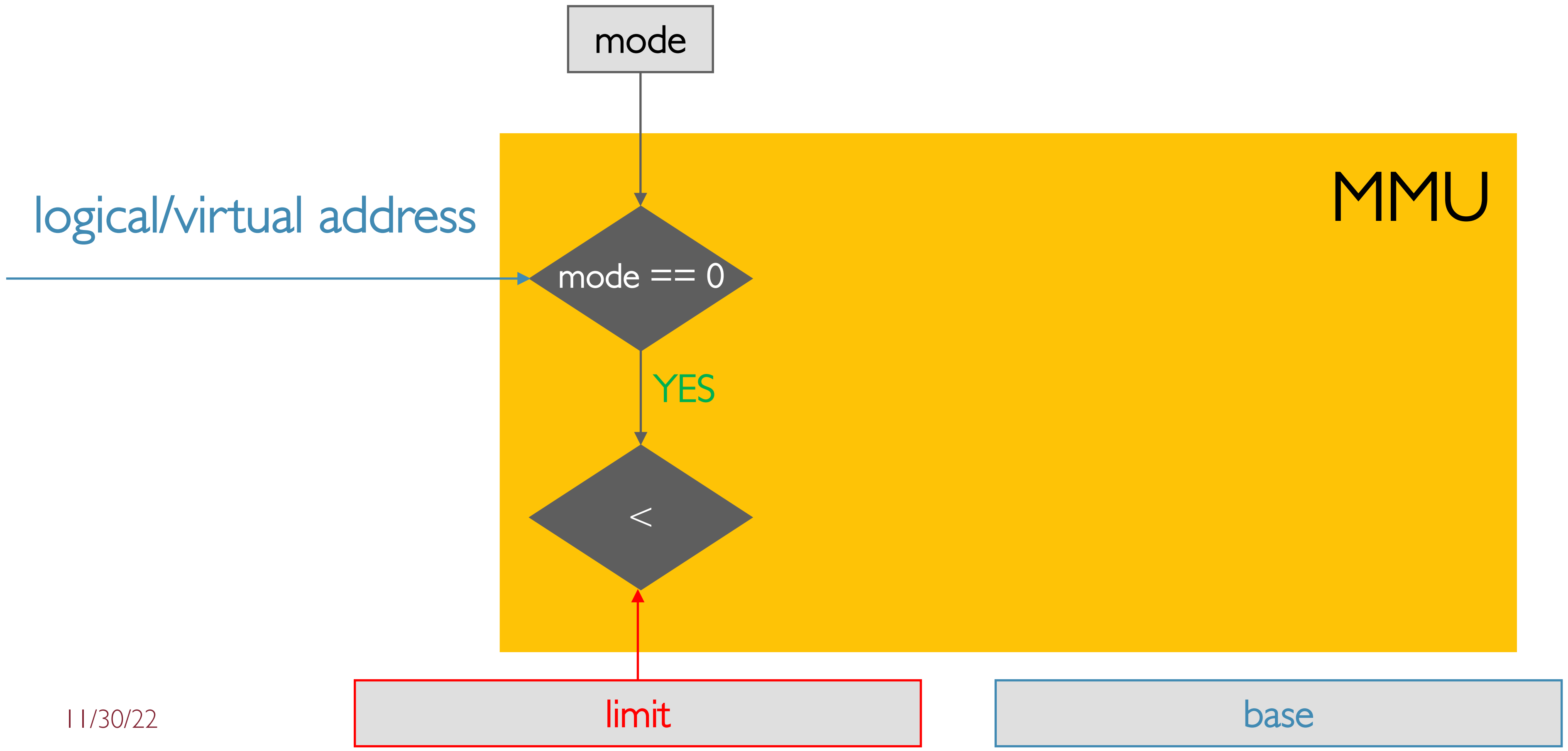

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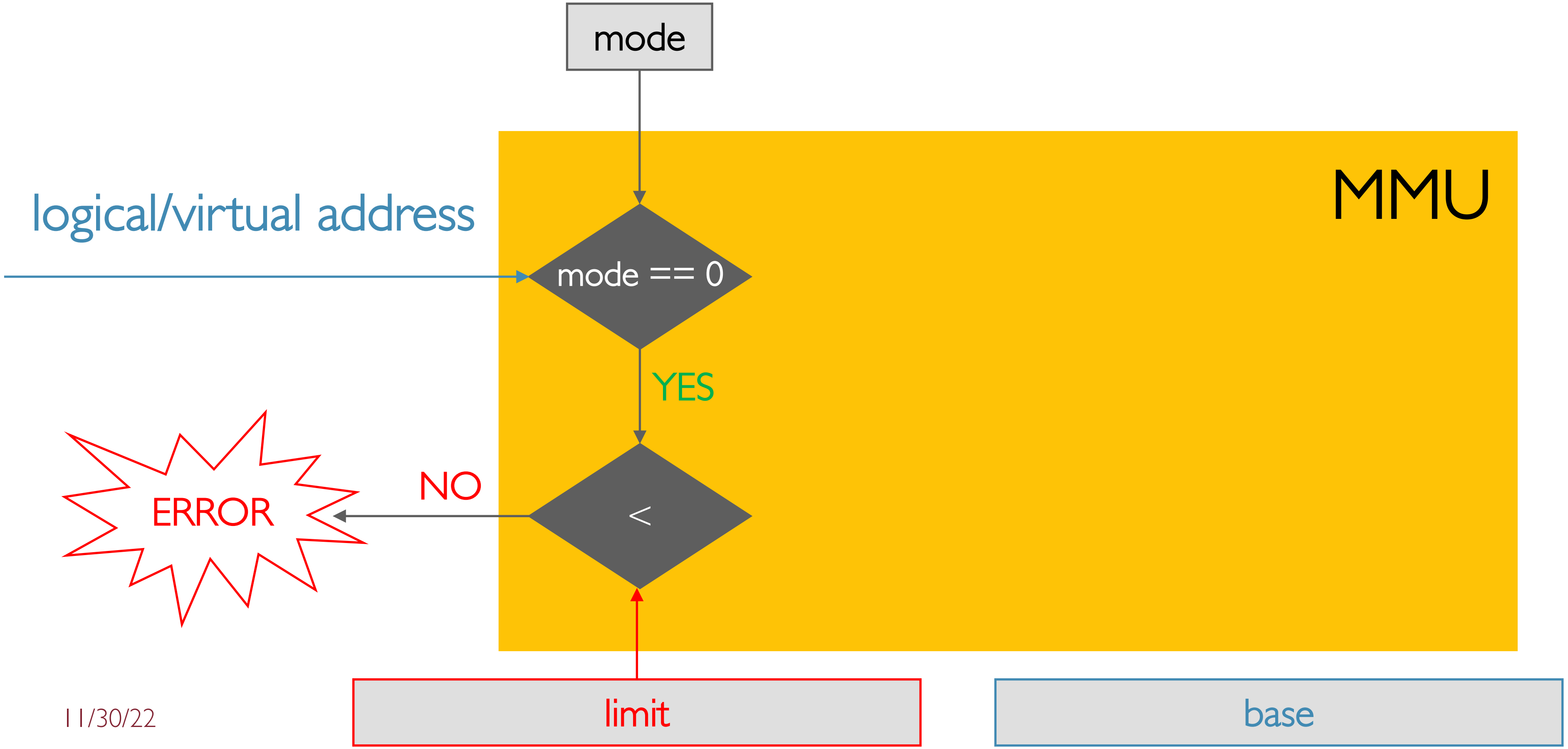

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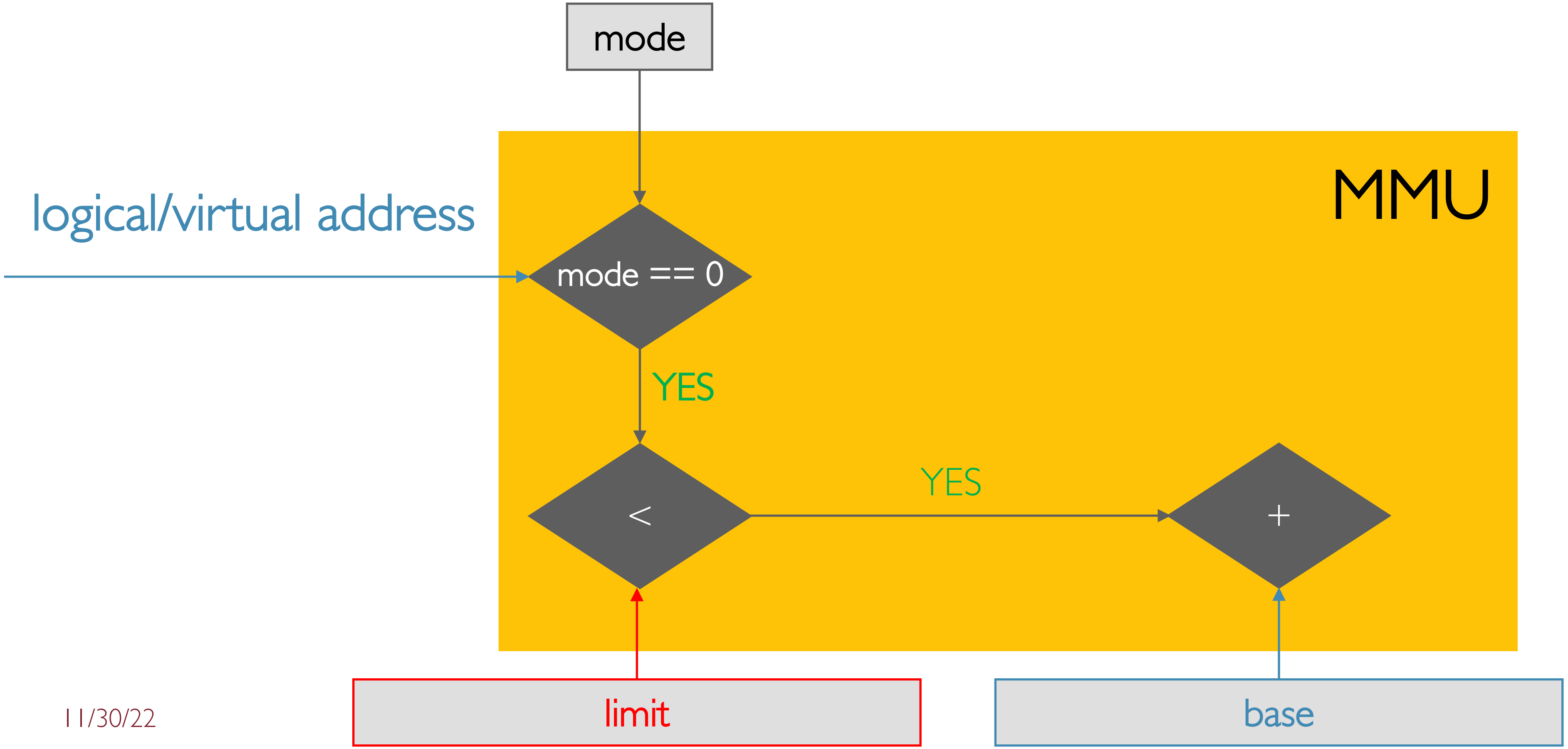

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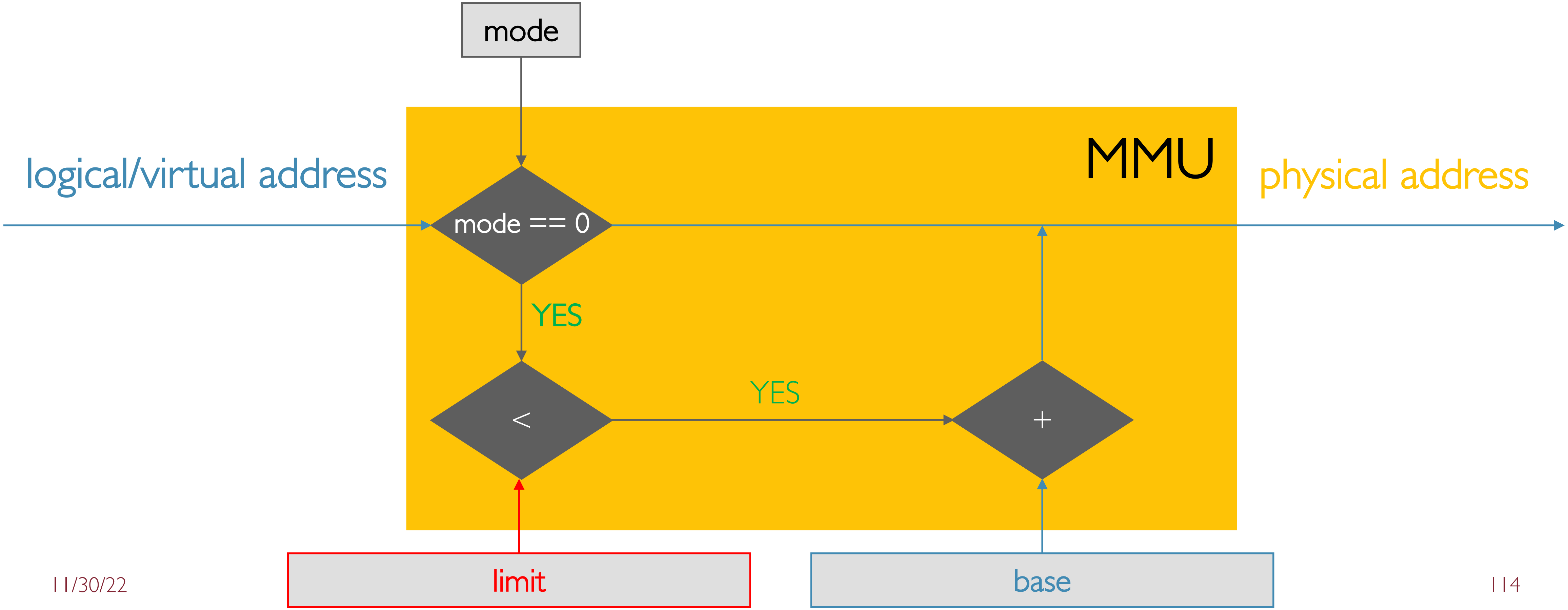

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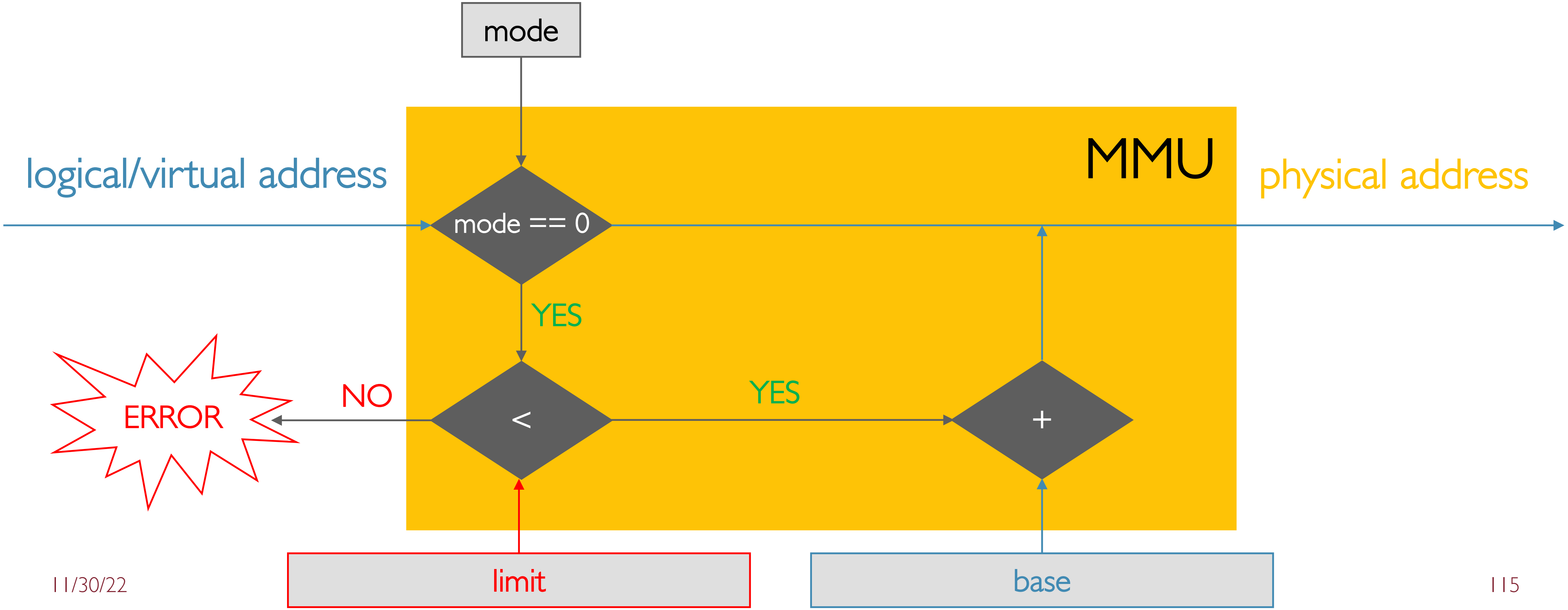

Dynamic Relocation

- PROs:
  - Provides protection (both read and write) across address spaces
  - OS can easily move a process during execution
  - OS can allow process to dynamically grow over time
  - Simple, fast hardware implementation (MMU):
    - 2 special registers, one add and one compare operation (can be done in parallel)

Dynamic Relocation

- CONs:
  - Little hardware overhead to pay at each memory reference
  - Each process must still be allocated contiguously in physical memory (possible memory waste)
  - Process is still limited to physical memory size
  - Degree of multiprogramming is bound since all memory of all active processes must fit in memory
  - No partial sharing of address space (e.g., processes can't share program's text)

Relocation: Properties

- Sharing/Transparency → processes are unaware of sharing memory
- Protection/Security → each memory reference is checked in HW
- Efficiency → somewhat achieved but if a process grows it may need to be moved to other location (very slow)

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Summary

- Effective memory management is crucial for system performance
- Very basic management doesn't even require OS intervention
- Modern OSs manage memory ensuring:
  - Transparency → logical/virtual vs. physical address space
  - Protection/Flexibility → dynamic relocation
  - Efficiency → hardware support
- We are still assuming the whole virtual address space of a process is fully and contiguously loaded in main memory → serious limitation!