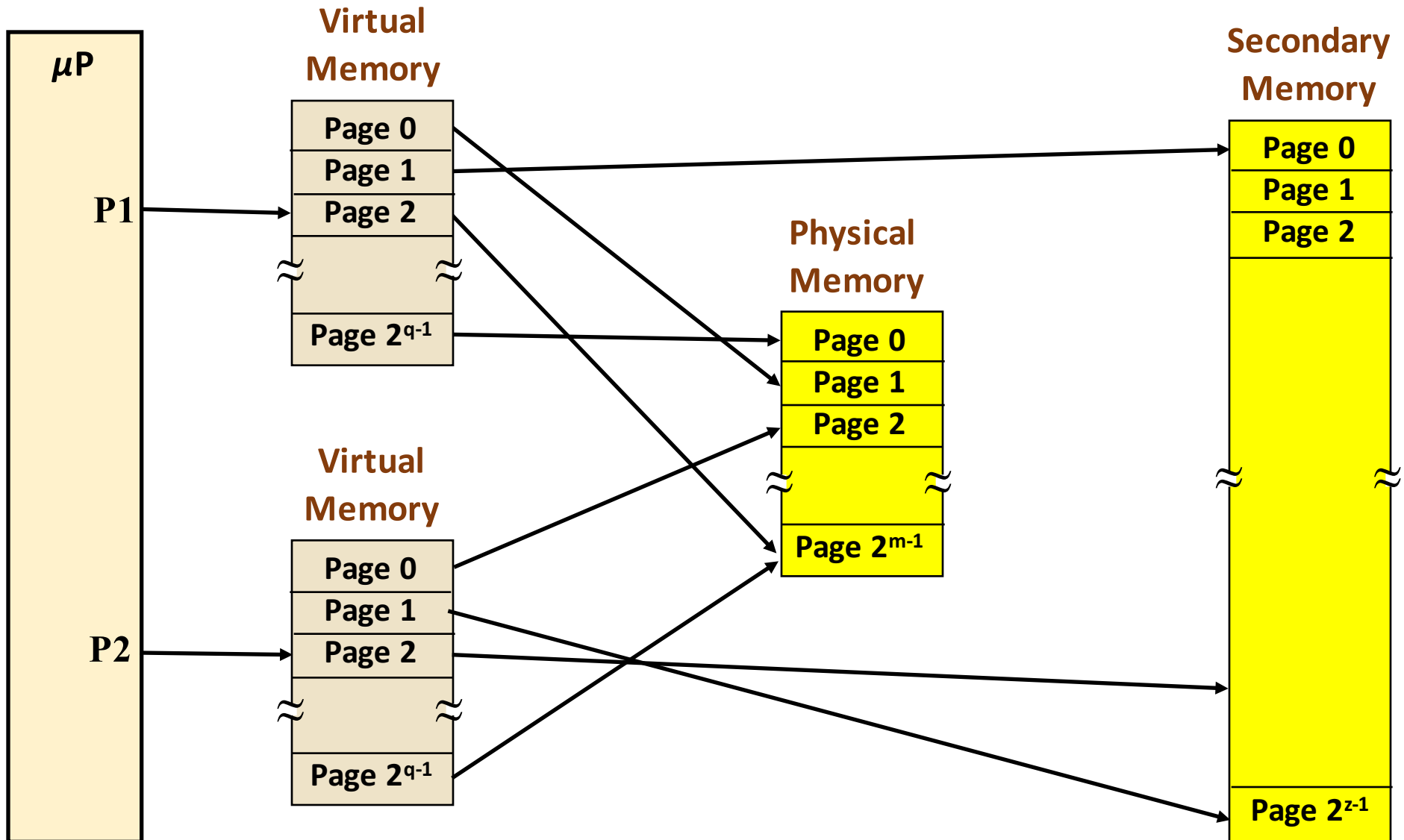


Virtual Memory

Multi-level Page Tables



Memory Space Demand by Page Tables

- Each process running on a CPU with virtual memory requires a page table.
- For a system with a virtual space of 2^{32} bytes and pages of 2^{10} bytes there are 2^{22} pages.
- If each page table entry is 4 bytes then, the space required for the page table is $2^{22} \times 2^2 = 2^{24}$ bytes (16 Mbytes)
- If 50 processes run concurrently on the CPU, a memory space of 50×16 Mbytes is required, this is 800 Mbytes, which is close to one forth the total virtual space.

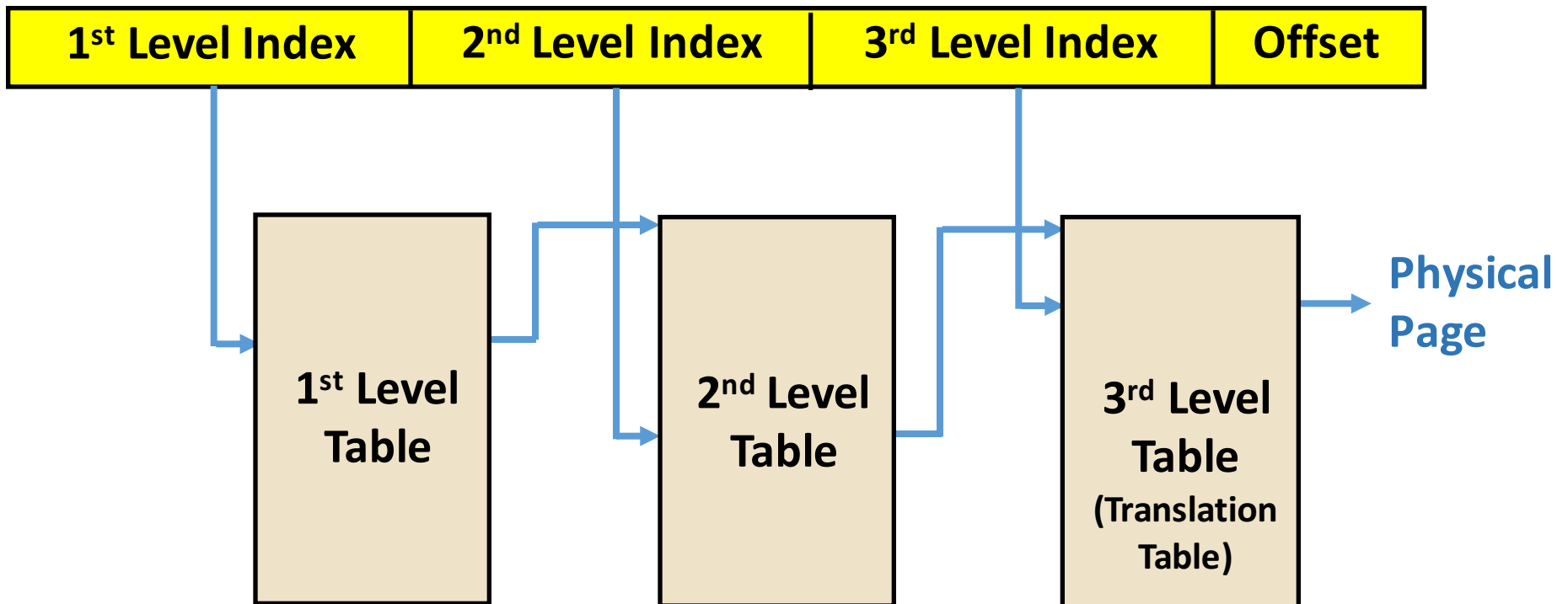
Alternatives for Reducing the Memory Space Required by Page Tables

- Multi-level page tables
- Segmentation

Multi-level Page Tables

- Various levels of address indirection are used to get to the page table that will provide the translation:
- The page field of the virtual address is broken into sub fields corresponding to the different page table levels and an offset.

Virtual Address



Two-level Page Tables

- Base Table – first level table of base addresses of second level tables (the beginning addresses of the a translation table).
- Translation Table - second level table that translates the virtual page to a physical page. Has control bits and physical page fields like a single-level page table.
- The Base Table of a process must reside in physical memory.
- At least one Translation Table must be in physical memory.
- Translation tables are brought to physical memory from secondary memory on demand (like on single-level page tables).

Page Faults on Two-level Page Tables

- Page faults may occur on accesses to either a Base Table or a Translation Table.
- A page fault on a Base Table requires a transfer of a Translation Table to physical memory.
- A page fault on a Translation Table requires the transfer of a page to main memory.

Physical Memory

Translation Page

⋮	⋮

Translation Page

⋮	⋮

Translation Page

⋮	⋮

Base Page

⋮	⋮

Secondary Memory

Translation Page

⋮	⋮

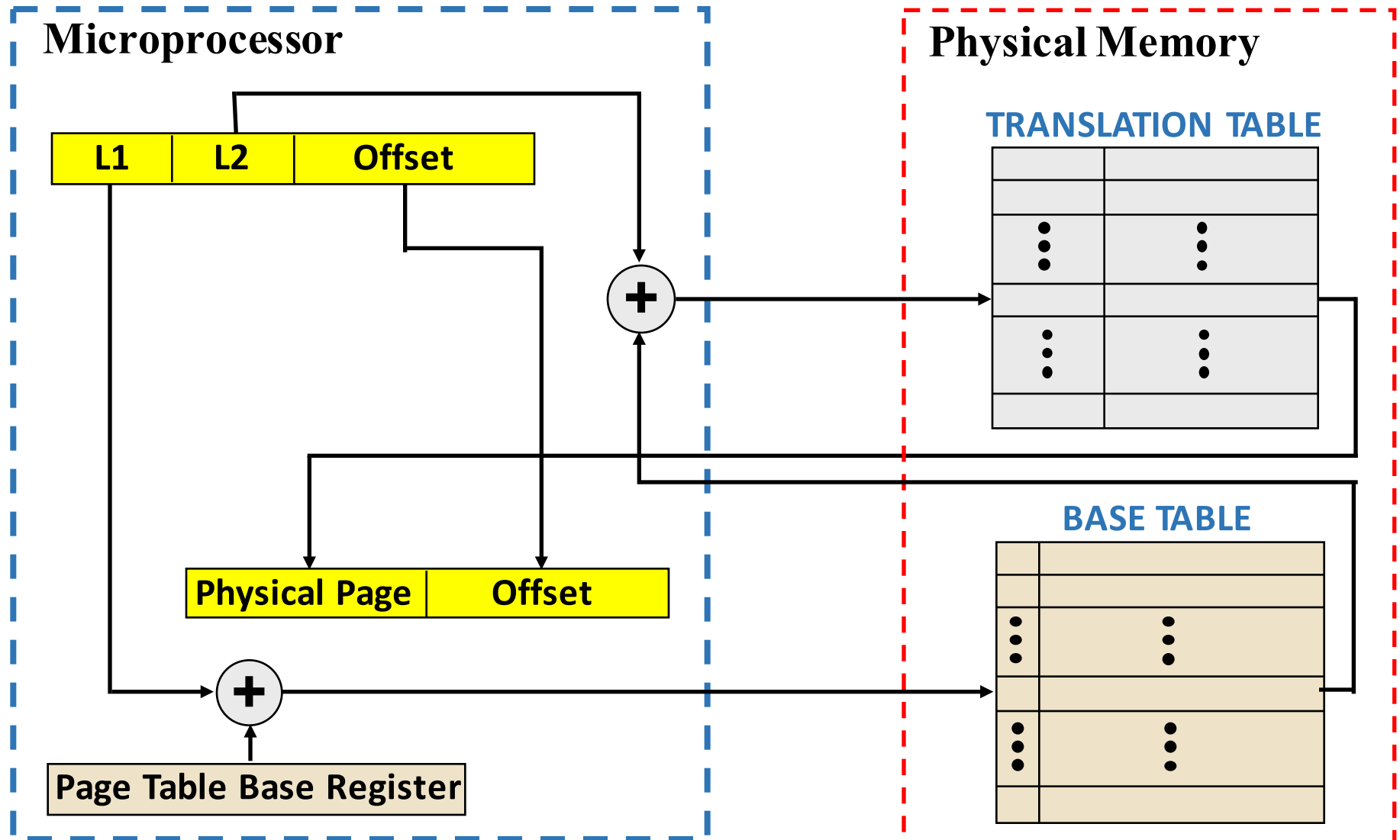
Translation Page

⋮	⋮

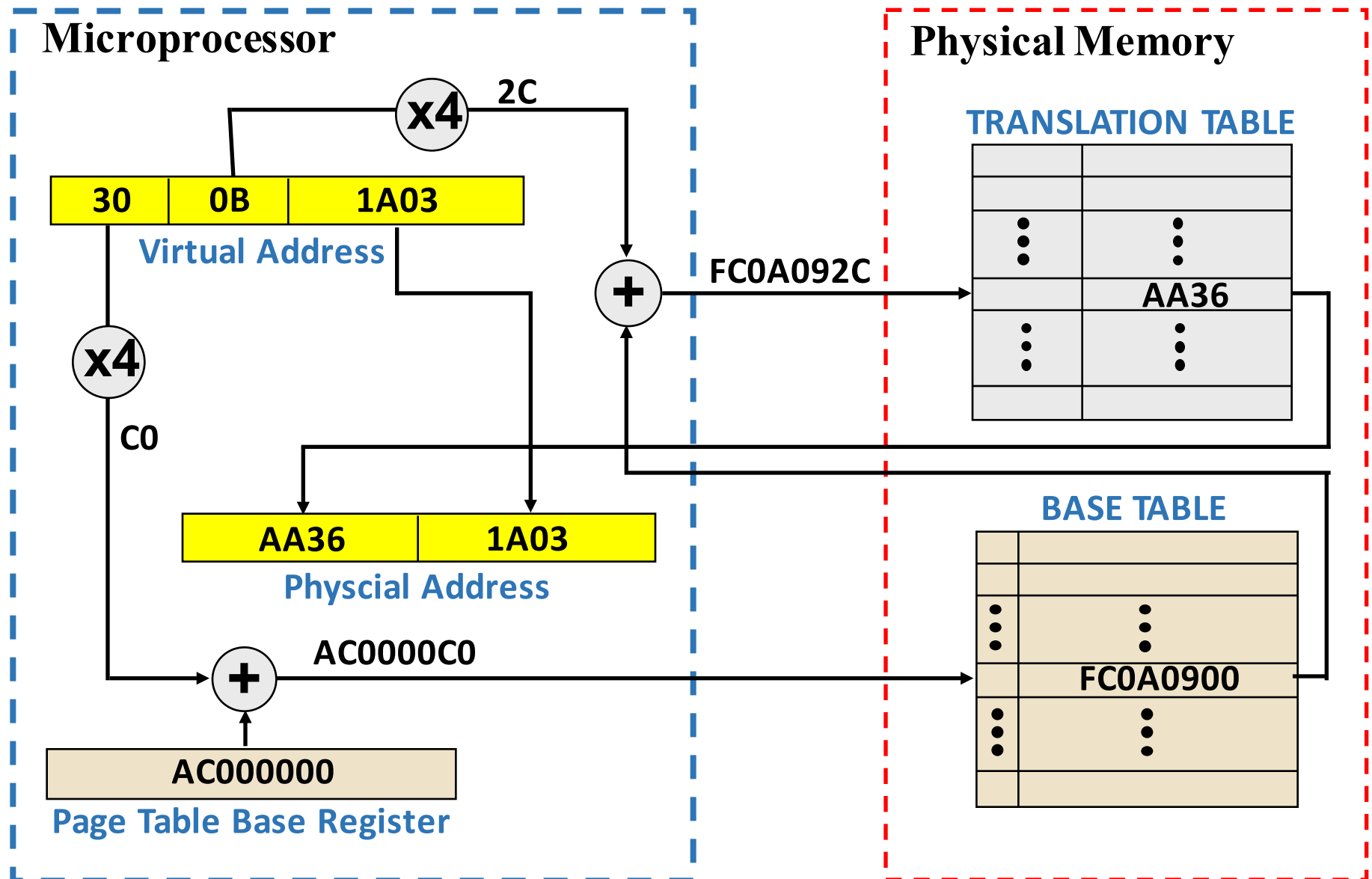
Translation Page

⋮	⋮

Two-Level Table Address Translation



Example: Two-level page tables, 2^{32} -byte virtual memory, 64K-byte page, 4-byte page entry



Memory Space Demand by Multi-level Page Tables

- Each process running on a CPU with virtual memory requires a Base Table and at least one Translation Table.
- For a system with a virtual space of 2^{32} bytes and pages of 2^{10} bytes there are 2^{22} pages.
- If the first and second level fields of the virtual address have 11 bits, and each page table entry is 4 bytes then, the space required for each page table is $2^{11} \times 2^2 = 2^{13}$ bytes (8 Kbytes)
- If 50 processes run concurrently on the CPU, a minimum memory space of 800 Kbytes ($50 \times 2 \times 8$ Kbytes) is required. (1/1000 the size required for a single level table).