**1.**The system in question has 1MiB of physical memory, 32-bit virtual addresses, and 256 physical pages. The memory management system uses a fully associative TLB with 128 entries and an LRU replacement scheme.

a. What is the size of the physical pages in bytes?

***1MiB / 256 = 4KiB***

b. What is the size of the virtual pages in bytes?

***4KiB***

c. What is the maximum number of virtual pages a process can use?

***(2 ^ 32)B / 4KiB = 2 ^ 20***

d. What is the minimum number of bits required for the page table base address register?

***log2(2 ^ 20) = 20***

**2.Everybody Got Choices**

e. Answer “True!” or “False!” to the following questions

i. The page table is stored in main memory

***Ture!***

ii. Every virtual page is mapped to a physical page

***False!***

iii. The TLB is checked before the page table

***True!***

iv. The penalty for a page fault is about the same as the penalty for a cache miss

***False!***

v. A linear page table takes up more memory as the process uses more memory

***False!***

3. Example: Mapping VAs to PAs

Suppose •  virtual memory of 2^32 (4G) bytes •  physical memory of 2^30 (1G) bytes •  page size is 2^14 (16 K) bytes

1).  How many pages can be stored in physical memory at once?

***2 ^ 30 / 2 ^ 14 = 2 ^ 16***

2).  How many entries are there in the page table?

***2 ^ 32 / 2 ^ 14 = 2 ^ 18***

3).  How many bits are necessary per entry in the page table? (Assume each entry has PPN, resident bit, dirty bit)

***log2(2 ^ 16) + 1 + 1 = 18***

4). A portion of the page table is given to the below. What is the physical address for virtual address 0x00004110?



***map(0x00004110 >> 14) << 14 + 0b00 0001 0001 0000***

***= map(0x1) << 14 + 0b00 0001 0001 0000***

***= 0x7 << 14 + 0b00 0001 0001 0000***

***= 0x0001C000 + 0b00 0001 0001 0000***

***= 0x0001C110***

4. 某计算机系统有一个TLB和一个L1 Data Cache。该系统按字节编址，虚拟地址16位，物理地址14位，页大小为128B，TLB采用四路组相联方式，共16个页表项， L1 Data Cache采用直接映射方式，块大小为4B，共16行。系统运行到某一时刻时，TLB、页表和L1 Data Cache中部分内容如图示。请问:

(1)虚拟地址中哪几位表示虚拟页号？哪几位表示页内偏移？虚拟页号中哪几位表示TLB标记？哪几位表示TLB索引?

***Offset: log2(128) = 7 lower bits***

***VPN: 16 – 7 = 9 upper bits***

***Index: log2(16 / 4) = 2 middle bits***

***Tag: 9 – 2 = 7 upper bits***

(2)物理地址中哪几位表示物理页号？哪几位表示页内偏移?

***Offset: log2(128) = 7 lower bits***

***PPN: 14 - 7 = 7 upper bits***

(3)主存物理地址如何划分标记字段、行索引字段和块地址字段?

***Index: log2(16) = 4 middle bits***

***Offset: log2(4) = 2 lower bits***

***Tag: 14 – 4 – 2 = 8 upper bits***

(4)CPU从地址06FAH中取出的值是多少？说明CPU读取地址06FAH中内容的过程。

***TLB tag: 0b000 0011 = 0x03***

***TLB index: 0b01 = 0x1***

***∵ TLB valid == 1***

***∴ Physical address: 2D << 7 + 0b111 1010 = 0b01 0110 1111 1010***

***Cache tag: 0b0101 1011 = 0x5B***

***Cache index: 0b1110 = 0x0E***

***Cache offset: 0b10 = 0x2***

***∵ Cache valid == 1***

***∴ 5A***

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| TLB   |  |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | 行号 | 标记 | 页框号 | 有效位 | 标记 | 页框号 | 有效位 | 标记 | 页框号 | 有效位 | 标记 | 页框号 | 有效位 | | 0 | 03 |  | 0 | 09 | 0D | 1 | 00 |  | 0 | 07 | 02 | 1 | | 1 | 03 | 2D | 1 | 02 |  | 0 | 04 |  | 0 | 0A |  | 0 | | 2 | 02 |  | 0 | 08 |  | 0 | 06 |  | 0 | 03 |  | 0 | | 3 | 07 |  | 0 | 63 | 0D | 1 | 0A | 34 | 1 | 72 |  | 0 |   数据缓存CACHE   |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | | 行索引 | 标记 | 有效位 | 字节3 | 字节2 | 字节1 | 字节0 | | 00 | 19 | 0 | 12 | 56 | C9 | AC | | 01 | 15 | 1 |  |  |  |  | | 02 | 1B | 0 | 03 | 45 | 12 | CD | | 03 | 36 | 0 |  |  |  |  | | 04 | 32 | 1 | 23 | 34 | C2 | 2A | | 05 | 0D | 1 | 46 | 67 | 23 | 3D | | 06 |  | 0 |  |  |  |  | | 07 | 16 | 1 | 12 | 54 | 65 | DC | | 08 | 24 | 1 | 23 | 62 | 12 | 3A | | 09 | 2D | 0 |  |  |  |  | | 0A | 2D | 1 | 43 | 62 | 23 | C3 | | 0B |  | 0 |  |  |  |  | | 0C | 12 | 1 | 76 | 83 | 21 | 35 | | 0D | 16 | 1 | A3 | F4 | 23 | 11 | | 0E | 5B | 1 | 3D | 5A | 45 | 55 | | 0F | 14 | 0 |  |  |  |  | | 页表   |  |  |  | | --- | --- | --- | | 虚页号 | 页框号 | 有效位 | | 00 | 08 | 1 | | 01 | 03 | 1 | | 02 | 14 | 1 | | 03 | 02 | 1 | | 04 |  | 0 | | 05 | 16 | 1 | | 06 |  | 0 | | 07 | 07 | 1 | | 08 | 13 | 1 | | 09 | 17 | 1 | | 0A | 09 | 1 | | 0B |  | 0 | | 0C | 19 | 1 | | 0D | 2D | 1 | | 0E | 11 | 1 | | 0F | 0D | 1 | |