

Virtualization:

VM Review

(2 problems)

4K \Rightarrow 4K
 VA \Rightarrow 0101001000000000
 0x5000
 \Rightarrow PFN=20, off=0

load

fetch 4K:
 get PTE: 32K+4
 fetch inst: 4K
 execute: load 8192 \rightarrow r1
 get PTE: 32K+8
 fetch value: 20K

32768+4 \Rightarrow 32772

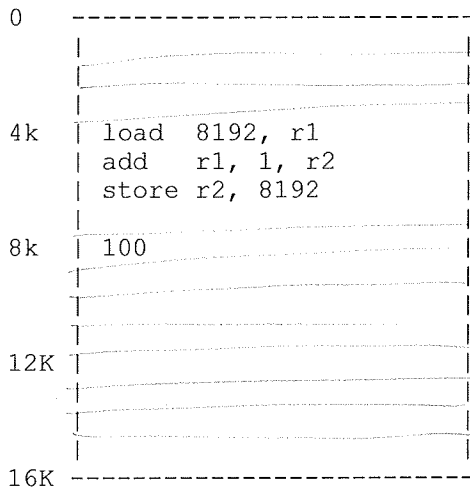
add: fetch 4K+4
 get PTE: 32K+4
 fetch inst: 4K+4

Here is some assembly code:

```
load 8192, r1 # loads value at memory (8192) -> r1
add r1, 1, r2 # adds 1 to r1; result into r2
store r2, 8192 # stores r2 into memory (8192)
```

Assume each instruction takes up 4 bytes in memory.

Assume the program counter (PC) is set to 4096 (4k) when running the first instruction of this sequence. The virtual address space of this process looks like this (not to scale):



VA: 4096

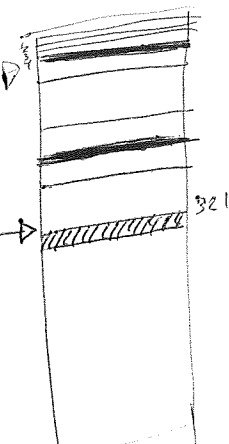
0100000000000000
 offset
 PFN \Rightarrow 4

0x1000

VA: 8192

1000000000000000
 PFN = 8

PTBR: 32K
 PC: 4K



Assume this is a system with a hardware-managed, linear page table.

The total size of this virtual address space is 16 KB. \Rightarrow 14 bits (VA)

The page size for the system is 1 KB.

Physical memory is of size 64 KB.

Each page table entry (PTE) looks like this:

valid	page frame number	protection bit
1 bit	6 bits	1 bit

(valid: 1 \rightarrow page is valid; protection: 1 \rightarrow read/write, 0 \rightarrow read only)

The PTBR for this process points to a physical address where the process's page table is located: 32KB.

The contents for this page table are:

0x00 0x00 0x00 0x00 0x88 0x00 0x00 0x00
 0xA9 0x00 0x00 0x00 0x00 0x00 0x00 0x00

0x88 \Rightarrow read only
 1000 1000
 w/r=2 PFN=4

Your task: List all the physical memory locations that are referenced during the execution of this three-instruction sequence, first assuming there is NO TLB, then assuming there is a TLB of infinite size.

10001010

10101001
 valid = 1 PFN=20 prot = read/write

Assumptions:

- The page size is an unrealistically-small 32 bytes
- The virtual address space for the process in question is 1024 pages, or 32 KB
- Physical memory consists of 128 32-byte pages

Thus, a virtual address needs 15 bits (5 for the offset, 10 for the VPN).

A physical address requires 12 bits (5 offset, 7 for the PFN).

The system assumes a multi-level page table. Thus, the upper five bits of a virtual address are used to index into a page directory; the page directory entry (PDE), if valid, points to a page of the page table. Each page table page holds 32 page-table entries (PTEs). Each PTE, if valid, holds the desired translation (physical frame number, or PFN) of the virtual page in question.

The format of a PTE is thus:

VALID | PFN6 ... PFN0

and is thus 8 bits or 1 byte.

The format of a PDE is essentially identical:

VALID | PT6 ... PT0

The **Page Directory Base Register (PDBR)** is set to decimal **99**. (this means the page directory is held in this page)

The problem: **Translate the virtual address 0x60B8**. What value do you get back from memory when you fetch this virtual address?

page 0: 1a 16 1a 10 17 09 06 11 16 1e 12 0c 07 10 1a 0c 15 06 1d 17 10 00 12 16 18 1c 00 17 0d 08 1e 02
page 1: 0c 08 14 15 18 1c 14 1b 01 16 00 10 08 04 1e 1d 09 03 1a 1d 0c 17 1d 08 0a 0b 05 0d 17 1d 03 13
page 2: 00
page 3: 00
page 4: 00
page 5: 7f b1 7f 7f 7f 7f 7f 7f
page 6: 7f 7f 7f bb 7f 7f 7f e1 7f
page 7: 17 00 17 07 1e 0f 1e 09 1d 09 02 0f 0d 0b 03 1b 06 0d 0c 01 14 06 0a 10 0d 0f 1e 0f 1d 1a 13 03
page 8: 00
page 9: 00
page 10: 15 02 0b 1d 13 00 08 15 0a 0f 18 11 18 12 18 08 15 12 0e 17 0f 0f 1b 19 17 11 05 04 09 11 1a 11
page 11: 0f 05 15 0d 05 1b 0c 08 16 1c 11 16 02 04 0f 15 09 07 08 02 0e 14 13 0a 0d 04 09 0e 17 16 1c 01
page 12: 0e 10 1e 04 14 0b 0f 06 14 07 0e 01 1e 0f 0e 16 0c 1b 00 19 0e 19 1d 1e 05 15 03 04 02 09 00 1a
page 13: 0c 1b 16 0f 14 11 17 1a 0f 1b 06 01 18 0a 0d 02 0d 02 03 0b 12 07 0c 07 07 07 0b 10 0c 19 11 14
page 14: 19 05 15 03 0c 09 1e 01 1b 10 02 1e 01 0d 02 16 03 06 16 0a 1c 0a 16 01 0e 00 0a 09 16 0d 15 01
page 15: 7f
page 16: 7f 7f 7f 7f aa 7f 7f 96 7f
page 17: 16 18 0d 0a 0c 00 15 0a 1a 0c 17 14 03 17 05 00 14 09 1e 00 09 04 15 12 1e 1a 00 1b 19 1b 0c 16
page 18: 16 12 08 1a 01 13 0f 19 03 1a 0a 0f 06 02 0d 05 02 0c 0c 0a 03 15 19 18 0c 00 00 02 0f 0a
page 19: 11 01 15 11 13 03 09 05 1e 18 01 12 19 16 05 1a 18 17 08 11 11 15 17 0f 0f 1e 14 04 01 0c 07 16
page 20: 00
page 21: 00
page 22: 0c 0c 1c 14 15 02 1c 15 08 1a 14 11 15 1c 12 09 1a 06 09 16 0b 12 06 0a 1b 06 0a 1a 18 13 10 05
page 23: 7f b7 7f
page 24: 7f
page 25: 00
page 26: 17 15 02 09 0c 0f 0f 0e 08 17 01 11 1c 06 0e 1d 0c 15 15 0a 12 10 0c 1a 0c 1a 12 0a 1a 0b 1e 03
page 27: 7f
page 28: 18 12 00 00 07 1b 19 1b 00 1d 04 0c 17 06 02 06 06 0b 1c 15 02 01 08 08 06 0f 18 17 01 1d 19 0b
page 29: 1b 1c 07 02 0a 13 0a 18 1b 12 00 04 03 1d 01 0d 02 1b 13 0b 17 08 0f 15 14 1e 1a 1a 17 01 02 06
page 30: 1e 1e 09 19 00 04 05 05 0e 07 1e 16 0c 17 03 14 01 1a 06 1a 18 18 05 09 19 06 0e 05 17 08 0e 00
page 31: 00
page 32: 00
page 33: 7f 7f 7f 7f 87 7f
page 34: 7f 7f 7f 7f 7f 7f 7f 7f f8 7f 7f eb 7f 7f 7f 7f 7f 7f 7f 7f 7f 7f 7f 7f 7f 7f 7f 7f 7f 7f
page 35: 08 07 1e 06 10 0f 16 01 1e 0d 1a 05 09 19 1d 10 05 18 10 06 07 01 05 0b 15 0f 10 1c 0c 18 0c 1e
page 36: 05 11 0c 0d 06 14 0e 1e 14 12 0c 0f 14 0e 1d 11 07 14 1a 1d 01 18 00 1b 15 0b 0a 01 06 1a 00 0d
page 37: 1d 1a 03 0e 0c 1b 1a 00 1e 1c 18 15 0e 0b 09 18 03 00 0f 04 0e 0f 1b 1a 0d 18 00 0a 07 0f 1b 1e
page 38: 7f 7f 7f bf 7f
page 39: 7f 7f 9e 7f
page 40: 7f
page 41: 14 07 1d 07 0e 02 05 11 01 0e 01 1e 0e 0c 02 14 1b 02 1d 08 11 0d 11 17 1e 13 14 03 00 09 18 0b
page 42: 0e 03 09 09 17 1c 05 1c 0f 0d 01 16 17 14 19 17 0f 06 15 18 17 04 02 1d 14 08 01 1a 04 1c 15 03
page 43: 00
page 44: 7f
page 45: 7f
page 46: 00
page 47: 1d 17 10 19 09 05 1b 1b 1a 0c 1a 0f 1e 1b 18 03 0a 06 0a 07 0f 0f 11 05 1e 11 0f 05 06 1a 17 19
page 48: 00
page 49: 02 19 1e 1a 19 05 0f 11 08 0c 04 0a 19 1d 1e 0b 12 04 18 06 01 13 07 1b 03 08 11 09 1a 13 04 12
page 50: 00
page 51: 04 0d 16 02 0e 0c 1c 04 1a 11 0f 1b 0e 18 00 16 1b 07 11 02 12 0a 08 1d 09 03 0c 0e 03 0c 08 16
page 52: 00
page 53: 0a 0e 19 15 05 1c 11 18 02 07 1a 12 16 1c 0a 14 12 12 0b 11 19 11 16 07 0b 01 04 11 1c 07 0e 1e
page 54: 00
page 55: 19 0d 07 02 04 06 1d 16 0d 1d 02 1e 0d 0c 1b 0a 0f 06 17 11 0c 1c 08 18 12 13 11 0c 00 07 0f 09
page 56: 00
page 57: 0a 0e 18 1d 1e 13 0f 0a 00 02 00 1b 07 0e 17 02 13 06 1c 1a 0c 11 1e 05 03 1c 0a 17 1c 0e 14 1e
page 58: 00
page 59: 19 00 14 08 1b 07 1d 06 1b 13 13 00 12 04 0e 04 12 1c 15 19 04 1b 1e 1b 14 19 18 00 0e 06 1c 0a
page 60: 7f
page 61: 00
page 62: 00 15 0d 0e 0d 13 11 05 09 16 15 18 1c 08 10 0b 0f 06 03 03 1e 05 11 17 1e 16 1a 08 0d 11 00 10
page 63: 0b 02 0e 1e 18 1a 1a 13 0d 0f 10 04 03 08 11 03 18 0e 0f 0c 02 19 11 0e 01 0d 0d 11 12 1b 07 07

