

## Exercise sheet 9 – Memory

### Goals:

- MMU
- Virtual memory

### Exercise 9.1: Intel x86/32 bit 1 level page table

Consider an Intel x86/32 bit architecture with a 1 level page table, similar to the 1 level page table in the lecture.

Given are:

- 32 bit architecture
- 4 KiB page/frame size
- 1 level page table
- Virtual address: 0x1202F494
- Real address: 0x00014494

The virtual address is mapped to the real address.

- State the *offset* part of the given addresses.
- State the *page number* and the page base address.
- State the *frame number* and the frame base address.
- State the entry and its position in the page table for the given situation. *Hint: You may want to draw a sketch, similar to the lecture. Specify as much details as possible with explicit numbers.*
- How many pages are possible for the given 32 bit architecture?
- Estimate the size in bytes for the page table. *Hint: You may simplify the address calculation by only considering to use a full word (address word) for each entry.*

### Exercise 9.2: Intel x86/32 bit 2 level page table

Now consider an Intel x86/32 bit architecture with a 2 level page table (without segmentation). Use the same addresses as given in exercise 9.1.

- Draw a sketch with the situation. Use as much details as possible with explicit numbers (*you may calculate them and make certain assumptions*).

### Exercise 9.3: Intel x86/64 bit architecture with 3 level page table

*Hint: Use the »AMD64 Architecture Programmer's Manual Volume 2: System Programming« to answer that question.*

Given is:

- Virtual address: 0x0000 FF00 1232 F494



- Real address: 0x0000 0078 0012 F494
  - Long-Mode Page Translation
  - Page size: 2 MiB
  - Bytes used for sign extension: 2
  - Maximum bits for real memory addresses: 52 bits
  - 3 level page table: *Page-Map*, *Page-Directory-Pointer*, *Page-Directory*
- (a) Have a look on [RA\\_exercises/sheet\\_09/AMD64 Architecture Programmer's Manual.pdf](#) file page 134 (PDF: 186).
- (b) How many bits are used for the offset? Show the offset in the given addresses.
- (c) How many bits are used for each page table level?
- (d) Draw a scheme for the page table situation. Use as much details as possible with explicit numbers (you may calculate them and make certain assumptions).
- (e) Calculate the maximum addressable real memory.