Virtual Memory Translation

Consider a system with a 64-bit virtual address and 4KB page size.

A. What is the size of the virtual address space of a process?

B. How many bits in the virtual address represent the byte offset into a page?

C. How many bits in the virtual address are needed to determine the page number?

D. How many page-table entries does a process' page-table contain?

E. If one page table entry has a size of 4 bytes, what is the size of page table?

F. How many pages will be required to store the page table in physical memory?

VM Address Translation

Addressing

- 14-bit virtual addresses
- 12-bit physical address
- Page size = 64 bytes

How many bits is the offset?

Note:
Virtual address = Virtual Page Number + Virtual Page Offset
Physical address = Physical Page Number + Physical Page Offset

Virtual Page Offset and Physical Page Offset are same.

VM Address Translation

Addressing

- 14-bit virtual addresses
- 12-bit physical address
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How many bits is the offset?

$\log_2(64)$ = 6

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VM Address Translation

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Virtual adress : 0x0AC1

13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	1	0	1	0	1	1	0	0	0	0	0	1

Offset bits

Note:
Virtual address = Virtual Page Number + Virtual Page Offset
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VM Address Translation

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How many bits is the offset?

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So, how many bits are for VPN?

Virtual adress : 0x0AC1

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0	0	1	0	1	0	1	1	0	0	0	0	0	1

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So, how many bits are for VPN?
14 - 6 = 8

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Offset bits

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VPN bits | Offset bits

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VPN (in hex): 0x09

VPN	PPN	Valid
00	28	1
01	-	0
02	33	1
03	02	1
04	-	0
05	16	1
06	-	0
07	-	0
08	13	1
09	17	1
0A	09	1
0B	-	0
0C	-	0
0D	2D	1
0E	11	1
0F	0D	1

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0B	-	0
0C	-	0
0D	2D	1
0E	11	1
0F	0D	1

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07	-	0
08	13	1
09	17	1
0A	09	1
0B	-	0
0C	-	0
0D	2D	1
0E	11	1
0F	0D	1

PPN (in hex): 0x17

VM Address Translation

Addressing

- 14-bit virtual addresses
- 12-bit physical address
- Page size = 64 bytes

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Virtual address = Virtual Page Number + Virtual Page Offset
Physical address = Physical Page Number + Physical Page Offset

Virtual Page Offset and Physical Page Offset are same.

Virtual adress : 0x0AC1

13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	1	0	0	1	0	0	0	0	0	1

VPN (in hex): 0x09

VPN	PPN	Valid
00	28	1
01	-	0
02	33	1
03	02	1
04	-	0
05	16	1
06	-	0
07	-	0
08	13	1
09	17	1
0A	09	1
0B	-	0
0C	-	0
0D	2D	1
0E	11	1
0F	0D	1

PPN (in hex): 0x17

Physical address :

11	10	9	8	7	6	5	4	3	2	1	0

VM Address Translation

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0	0	0	0	1	0	0	1	0	0	0	0	0	1

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06	-	0
07	-	0
08	13	1
09	17	1
0A	09	1
0B	-	0
0C	-	0
0D	2D	1
0E	11	1
0F	0D	1

PPN (in hex): 0x17

Physical address :

11	10	9	8	7	6	5	4	3	2	1	0
0	1	0	1	1	1						

VM Address Translation

Addressing

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- Page size = 64 bytes

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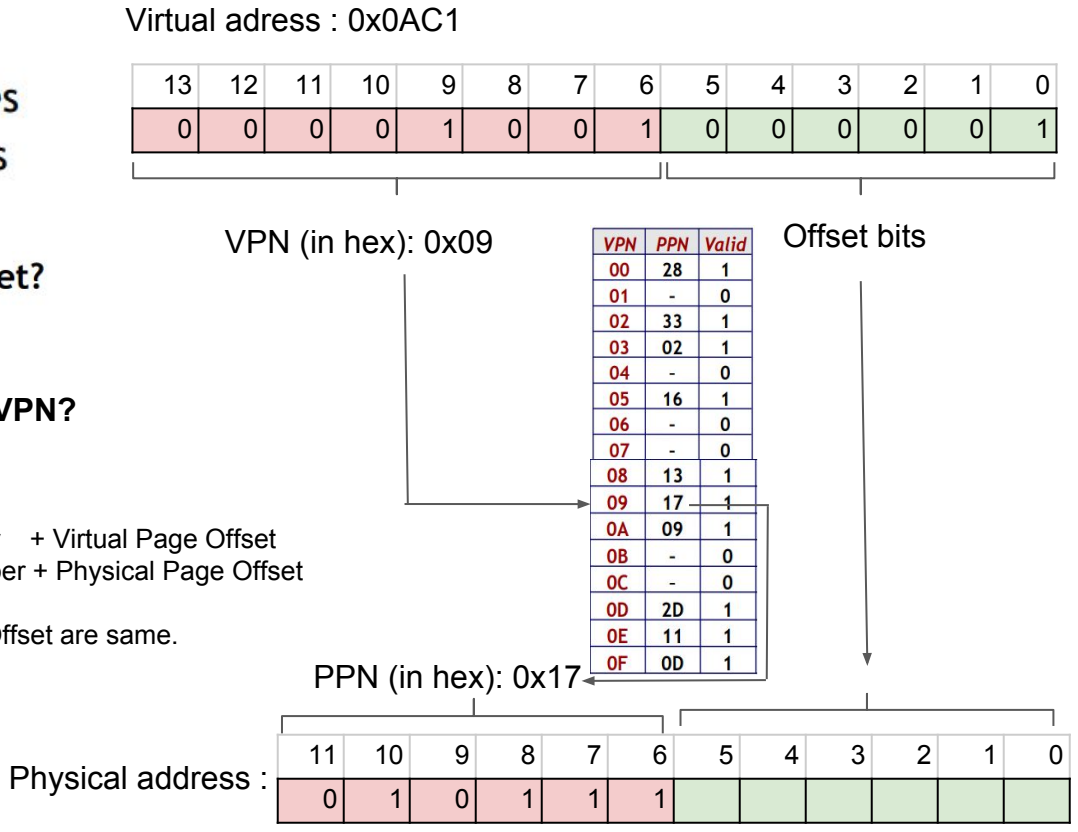

VM Address Translation

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How many bits is the offset?

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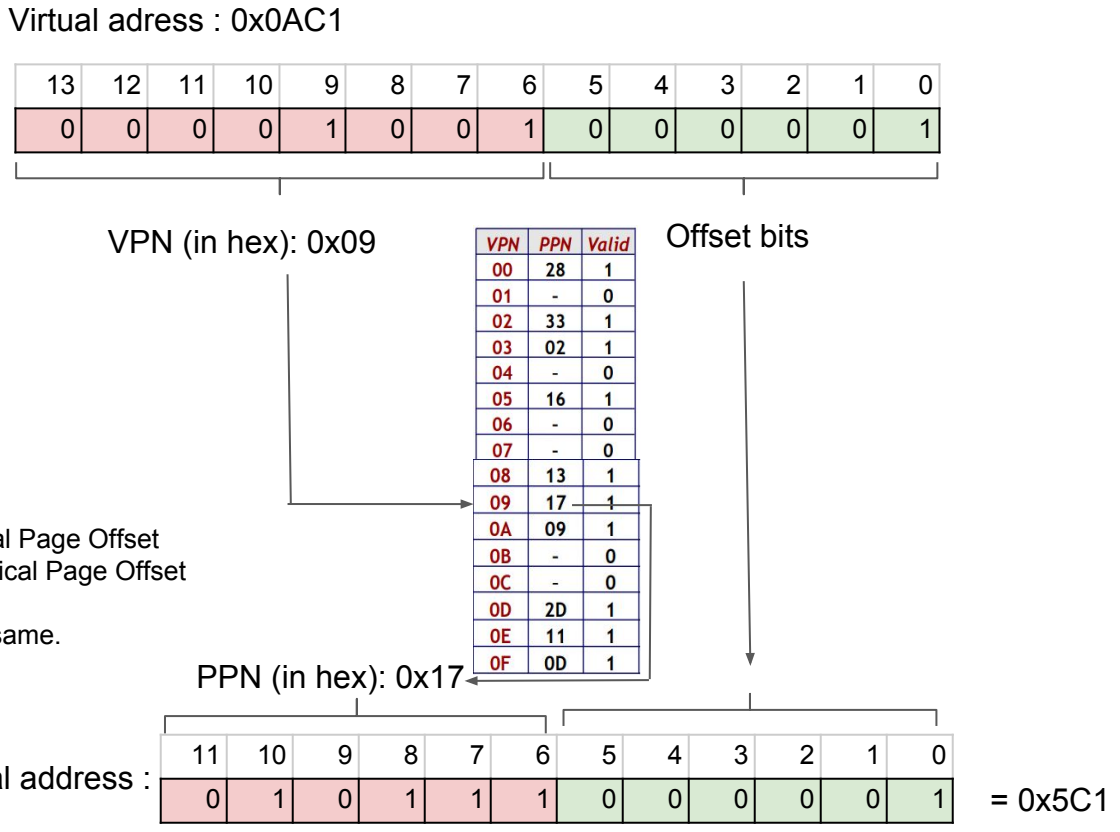


VM Address Translation with TLB

1 MB of virtual memory
256 KB of physical memory

4 KB page size
TLB: 8 entries, 2-way set associative

- How many bits are needed to represent the virtual address space? 20. (1 MB = 2^{20} bytes.)
- How many bits are needed to represent the physical address space? 18. (256 KB = 2^{18} bytes.)
- How many bits are needed to represent the offset? 12. (4 KB = 2^{12} bytes.)
- How many bits are needed to represent VPN? 8. (20-12.)
- How many bits are in the TLB index? 2. (4 sets = 2^2 set bits.)
- How many bits are in the TLB tag? 6. (8-2.)

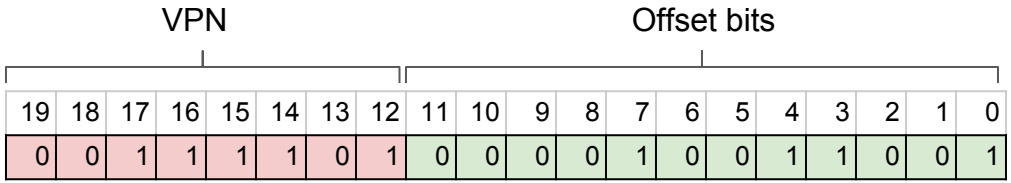
VM Address Translation with TLB

Virtual adress : 0x3D099

19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	1	1	1	1	0	1	0	0	0	0	1	0	0	1	1	0	0	1

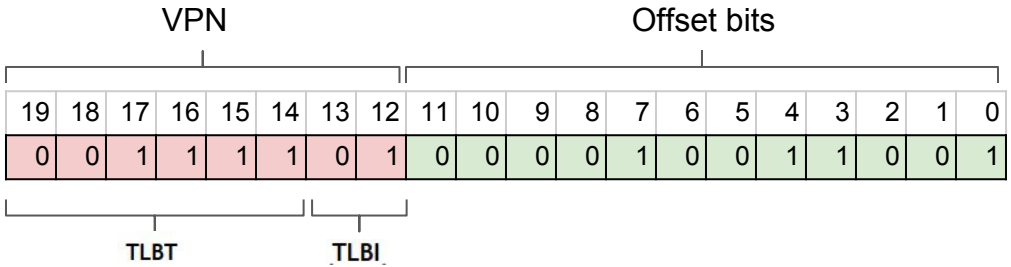
VM Address Translation with TLB

Virtual adress : 0x3D099



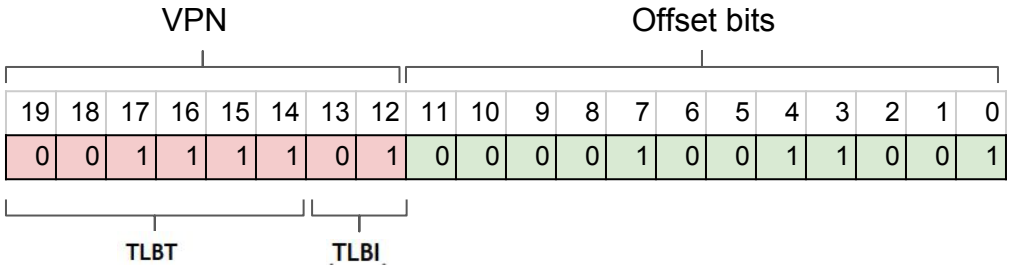
VM Address Translation with TLB

Virtual adress : 0x3D099



VM Address Translation with TLB

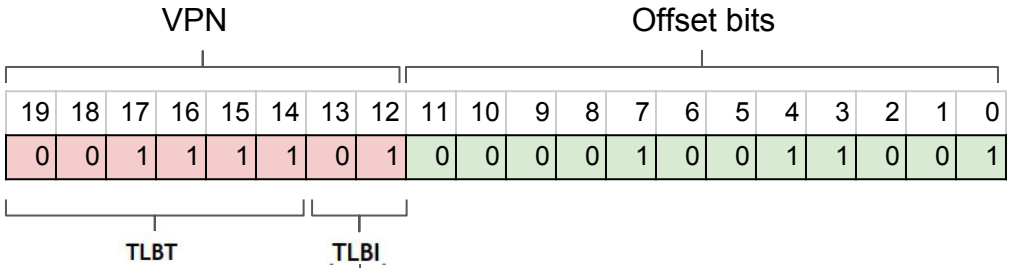
Virtual adress : 0x3D099



TLB			
Index	Tag	PPN	Valid
0	05	13	1
	3F	15	1
1	10	0F	1
	0F	1E	0
2	1F	01	1
	11	1F	0
3	03	2B	1
	1D	23	0

VM Address Translation with TLB

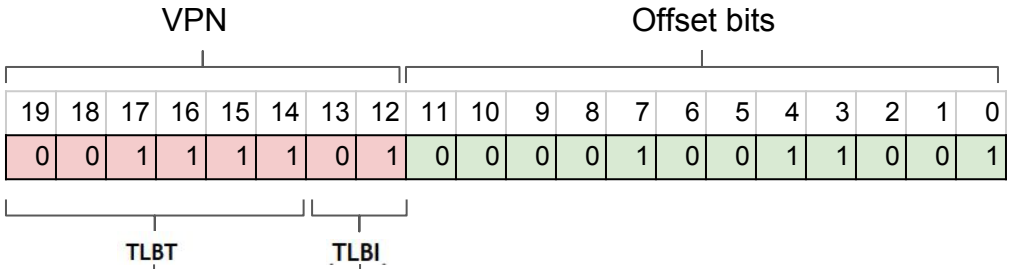
Virtual adress : 0x3D099



TLB			
Index	Tag	PPN	Valid
0	05	13	1
	3F	15	1
1	10	0F	1
	0F	1E	0
2	1F	01	1
	11	1F	0
3	03	2B	1
	1D	23	0

VM Address Translation with TLB

Virtual adress : 0x3D099



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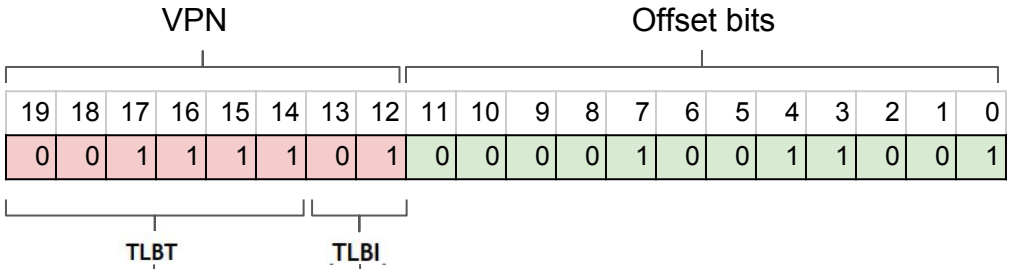
Index	Tag	PPN	Valid
0	05	13	1
	3F	15	1
1	10	0F	1
	0F	1E	0
2	1F	01	1
	11	1F	0
3	03	2B	1
	1D	23	0

VM Address Translation with TLB

Virtual adress : 0x3D099

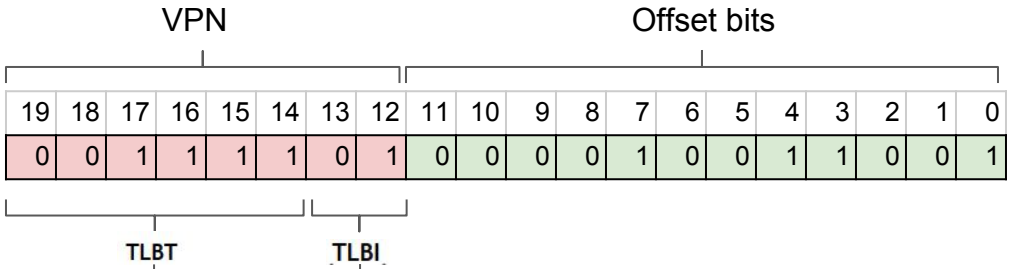


TLB			
Index	Tag	PPN	Valid
0	05	13	1
	3F	15	1
1	10	0F	1
	0F	1E	0
2	1F	01	1
	11	1F	0
3	03	2B	1
	1D	23	0

PPN (in hex): 0x1E

VM Address Translation with TLB

Virtual adress : 0x3D099



TLB			
Index	Tag	PPN	Valid
0	05	13	1
	3F	15	1
1	10	0F	1
	0F	1E	0
2	1F	01	1
	11	1F	0
3	03	2B	1
	1D	23	0

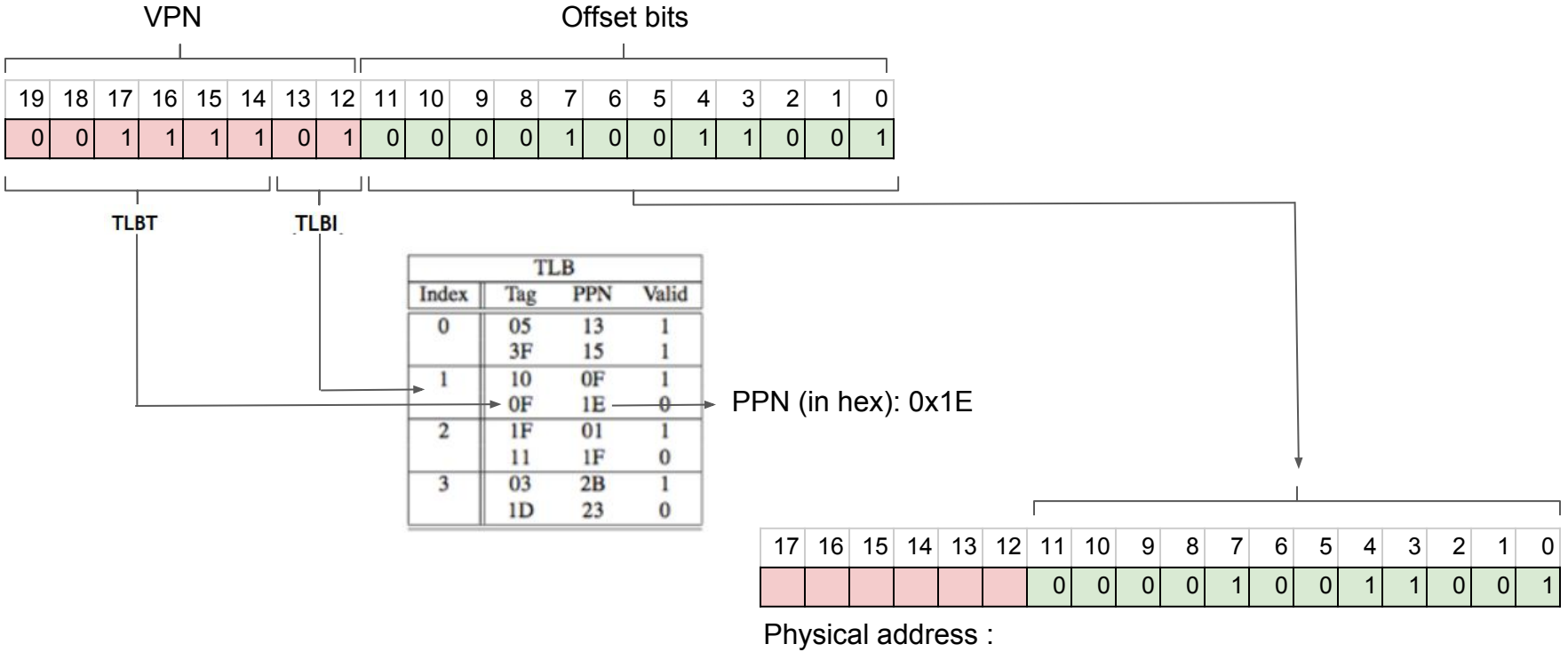
PPN (in hex): 0x1E

17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

Physical address :

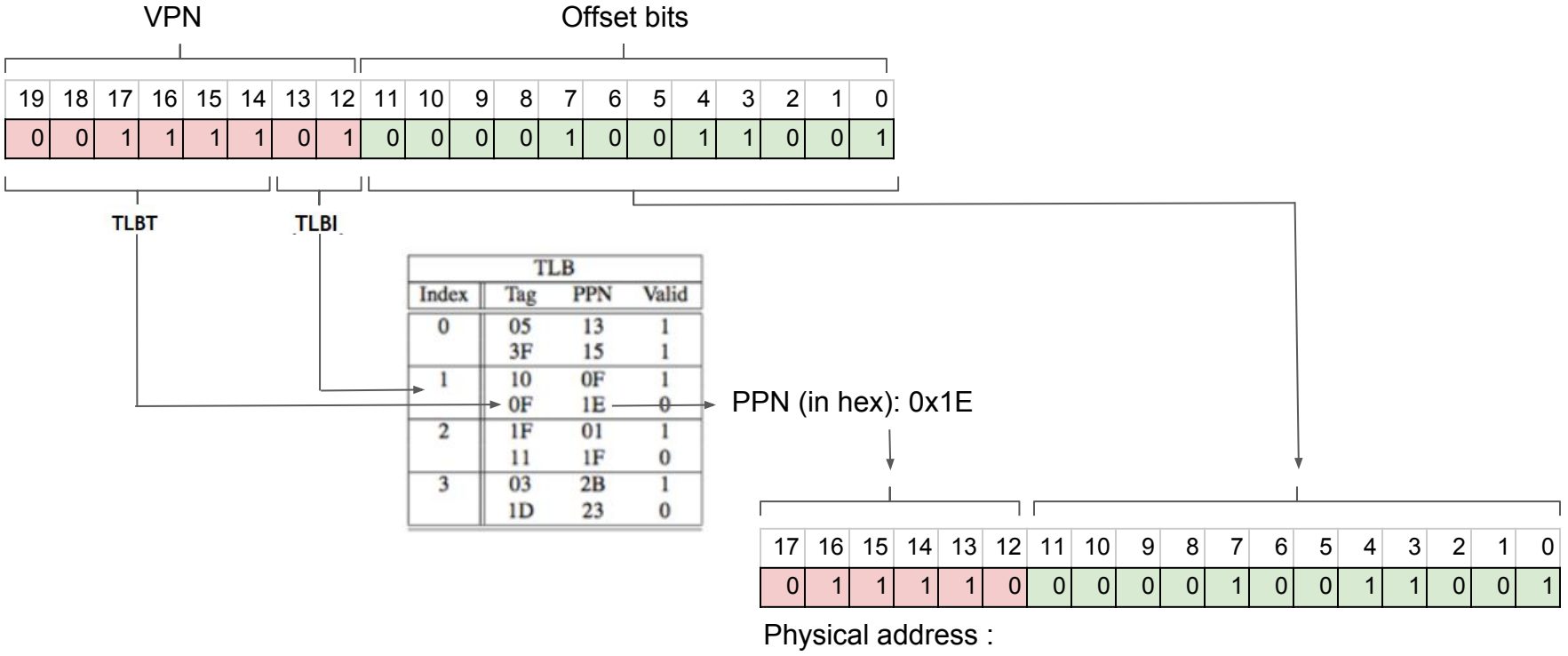
VM Address Translation with TLB

Virtual adress : 0x3D099



VM Address Translation with TLB

Virtual adress : 0x3D099



VM Address Translation with TLB

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