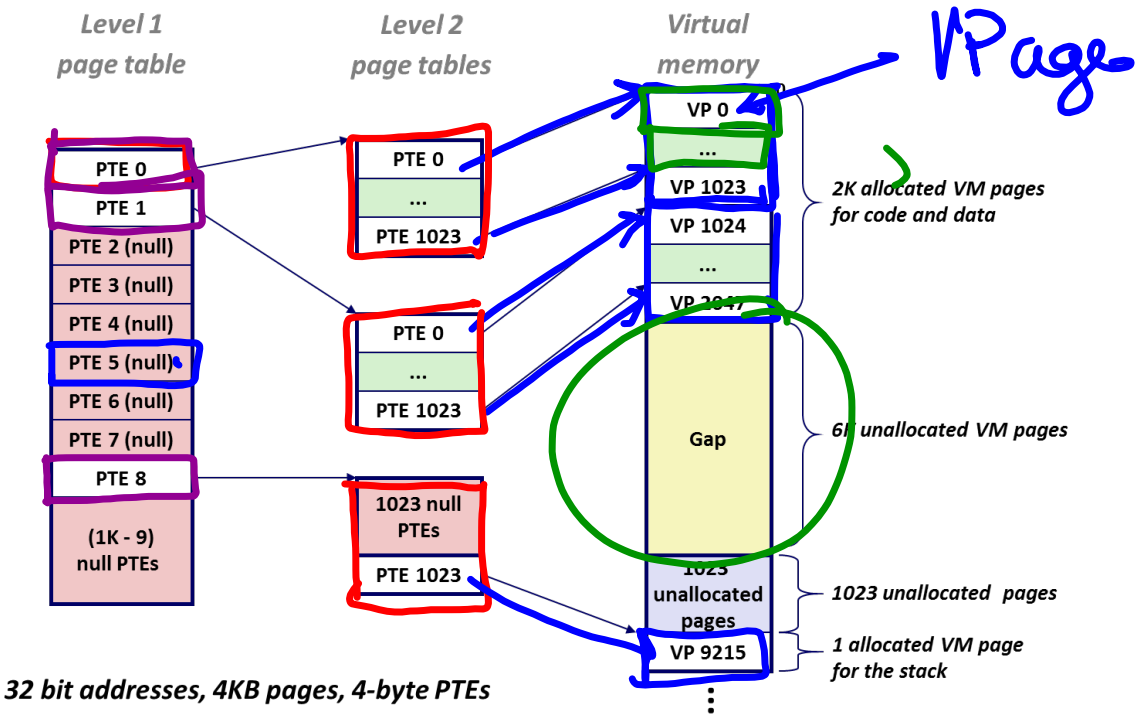
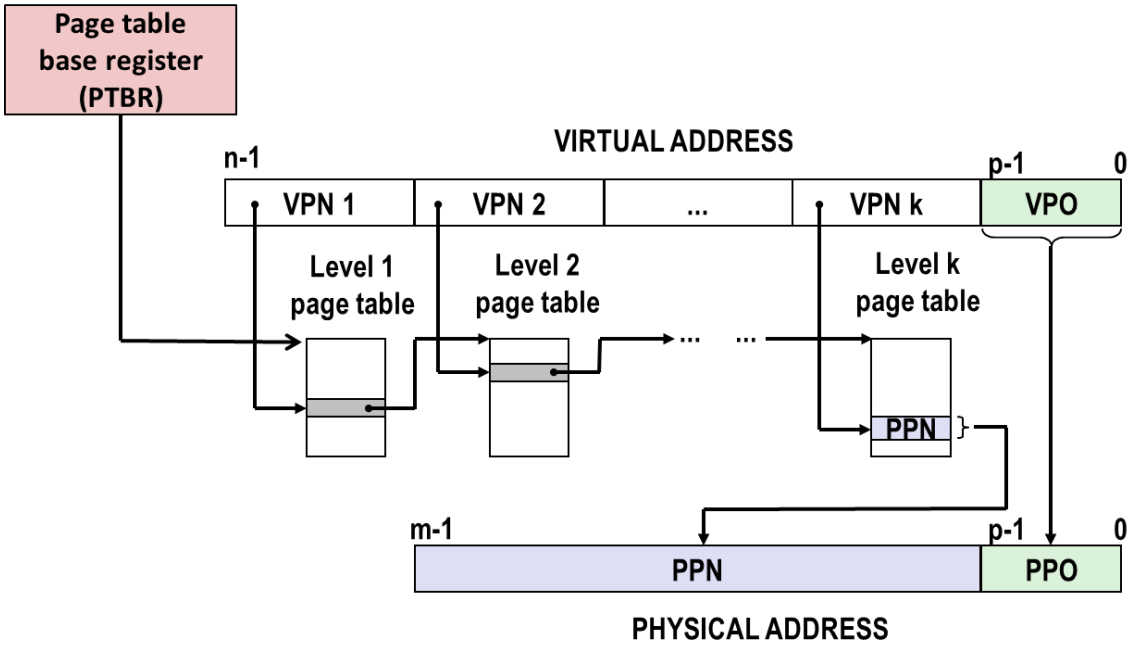
- Final Exam Tues 11:15Am
  Javits 102

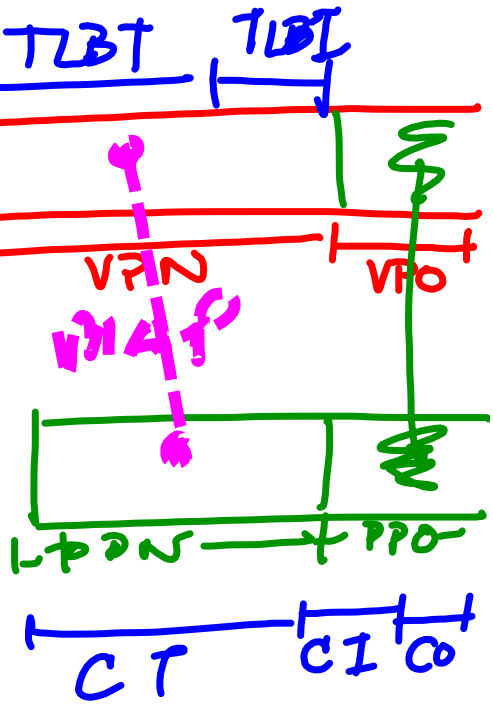
- HW grades coming. Watch PIAZZA



32 bit addresses, 4KB pages, 4-byte PTEs


Page table base register (PTBR)
VIRTUAL ADDRESS
n-1
p-1
0
VPN 1
VPN 2
...
VPN k
VPO
Level 1 page table
Level 2 page table
Level k page table
PPN
m-1
p-1
0
PPN
PPO
PHYSICAL ADDRESS

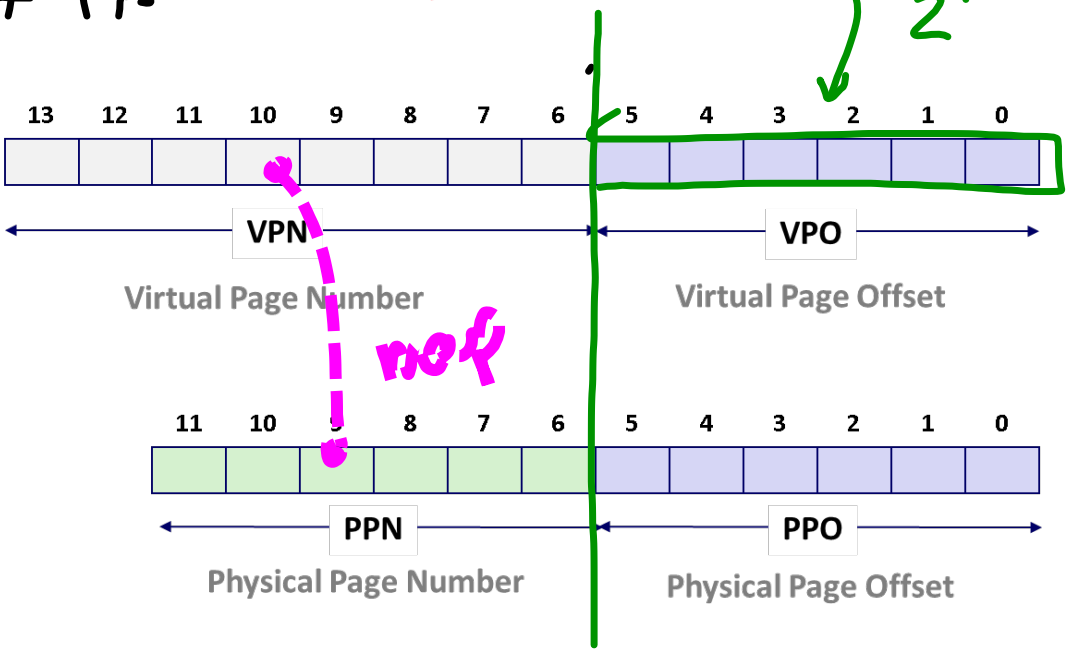
- **Basic Parameters**
  - **N = 2^n** : Number of addresses in virtual address space
  - **M = 2^m** : Number of addresses in physical address space
  - **P = 2^p** : Page size (bytes)
- **Components of the virtual address (VA)**
  - **TLBI**: TLB index
  - **TLBT**: TLB tag
  - **VPO**: Virtual page offset
  - **VPN**: Virtual page number
- **Components of the physical address (PA)**
  - **PPO**: Physical page offset (same as VPO)
  - **PPN:** Physical page number
  - **CO**: Byte offset within cache line
  - **CI:** Cache index
  - **CT**: Cache tag

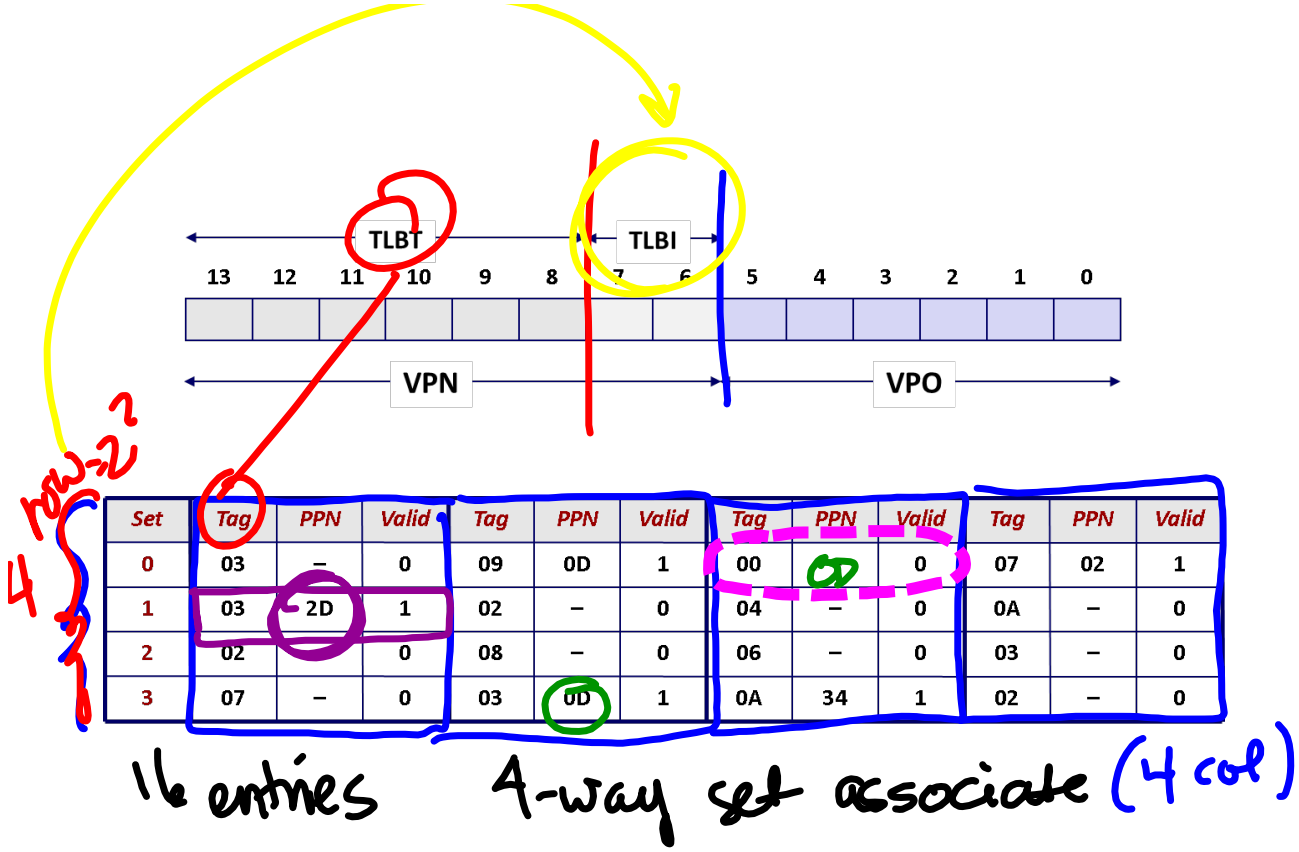


14-bit VA
12-bit PA

Page = 64 bytes

2^6





Set	Tag	PPN	Valid	Tag	PPN	Valid	Tag	PPN	Valid	Tag	PPN	Valid
0	03	–	0	09	0D	1	00	0D	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	03	0D	1	0A	34	1	02	–	0

16 entries 4-way set associate (4 col)

Page Table

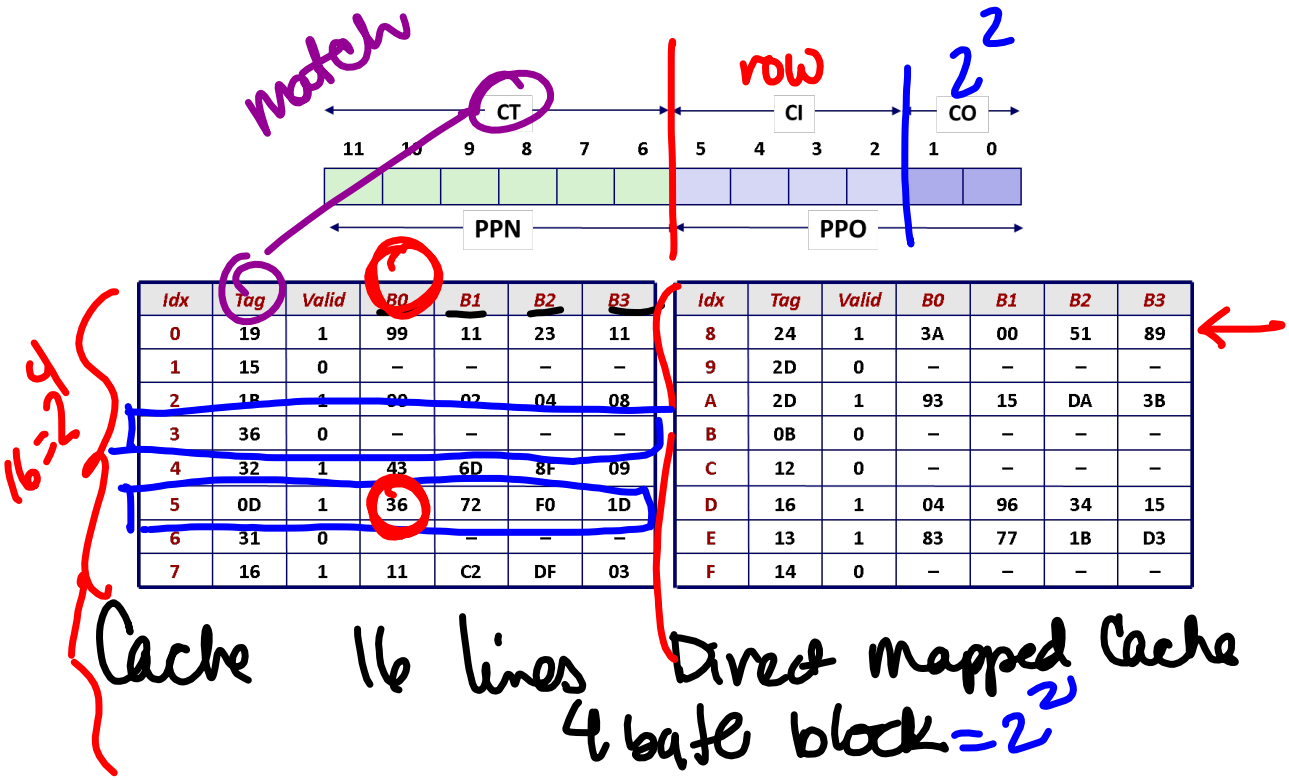
Only show first 16 entries (out of 256)

Page hit

VPN	PPN	Valid
00	28	1
01	–	0
02	33	1
03	02	1
04	–	0
05	16	1
06	–	0
07	–	0

VPN	PPN	Valid
08	13	1
09	17	1
0A	09	1
0B	–	0
2E	–	0
0D	2D	1
0E	11	1
0F	0D	1

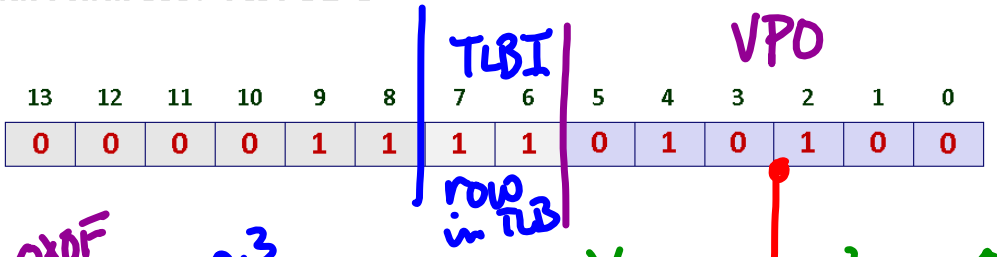
Page Fault



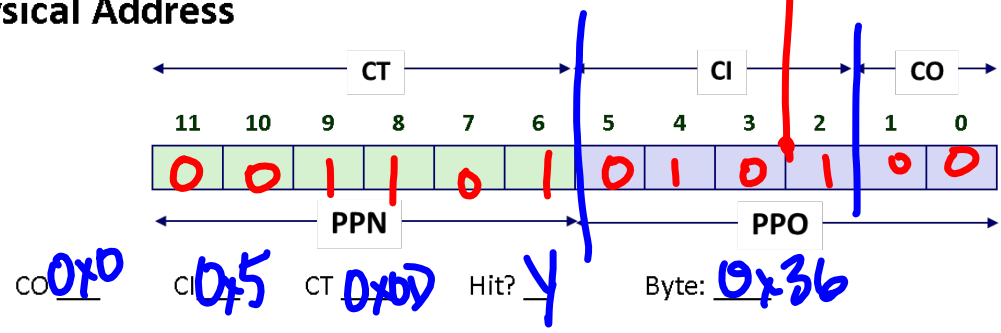
Idx	Tag	Valid	B0	B1	B2	B3
0	19	1	99	11	23	11
1	15	0	–	–	–	–
2	1B	1	00	02	04	08
3	36	0	–	–	–	–
4	32	1	43	6D	8F	09
5	0D	1	36	72	F0	1D
6	31	0	–	–	–	–
7	16	1	11	C2	DF	03

Idx	Tag	Valid	B0	B1	B2	B3
8	24	1	3A	00	51	89
9	2D	0	–	–	–	–
A	2D	1	93	15	DA	3B
B	0B	0	–	–	–	–
C	12	0	–	–	–	–
D	16	1	04	96	34	15
E	13	1	83	77	1B	D3
F	14	0	–	–	–	–

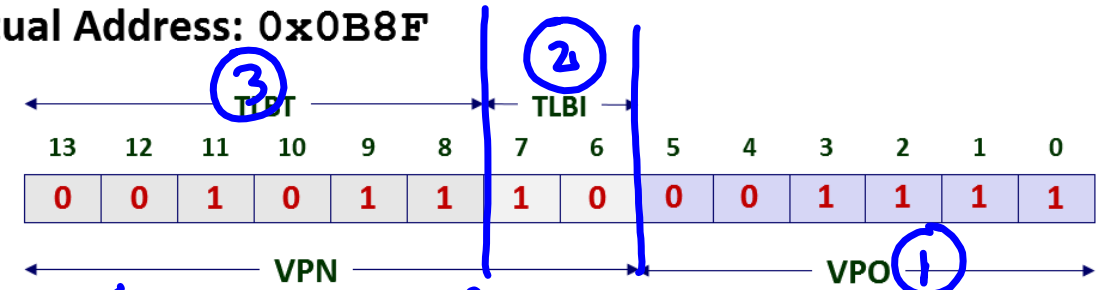
Virtual Address: 0x03D4



Physical Address

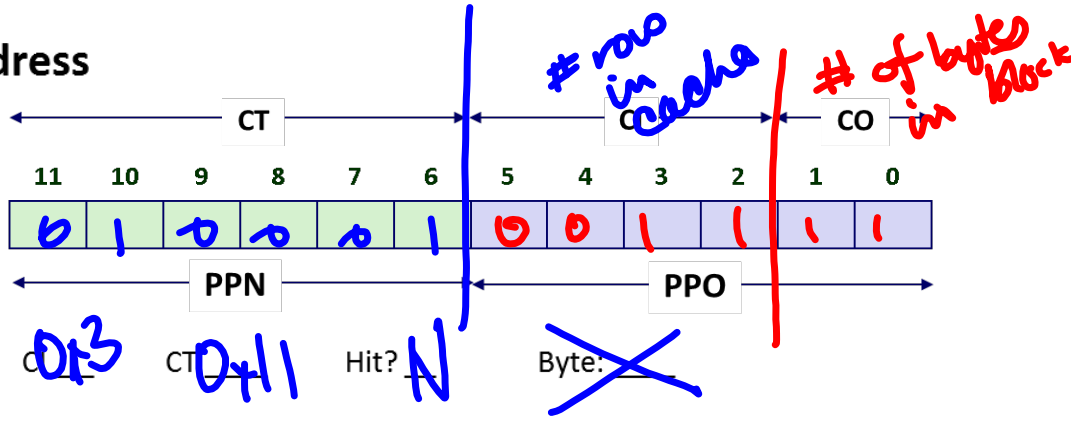


Virtual Address: 0x0B8F

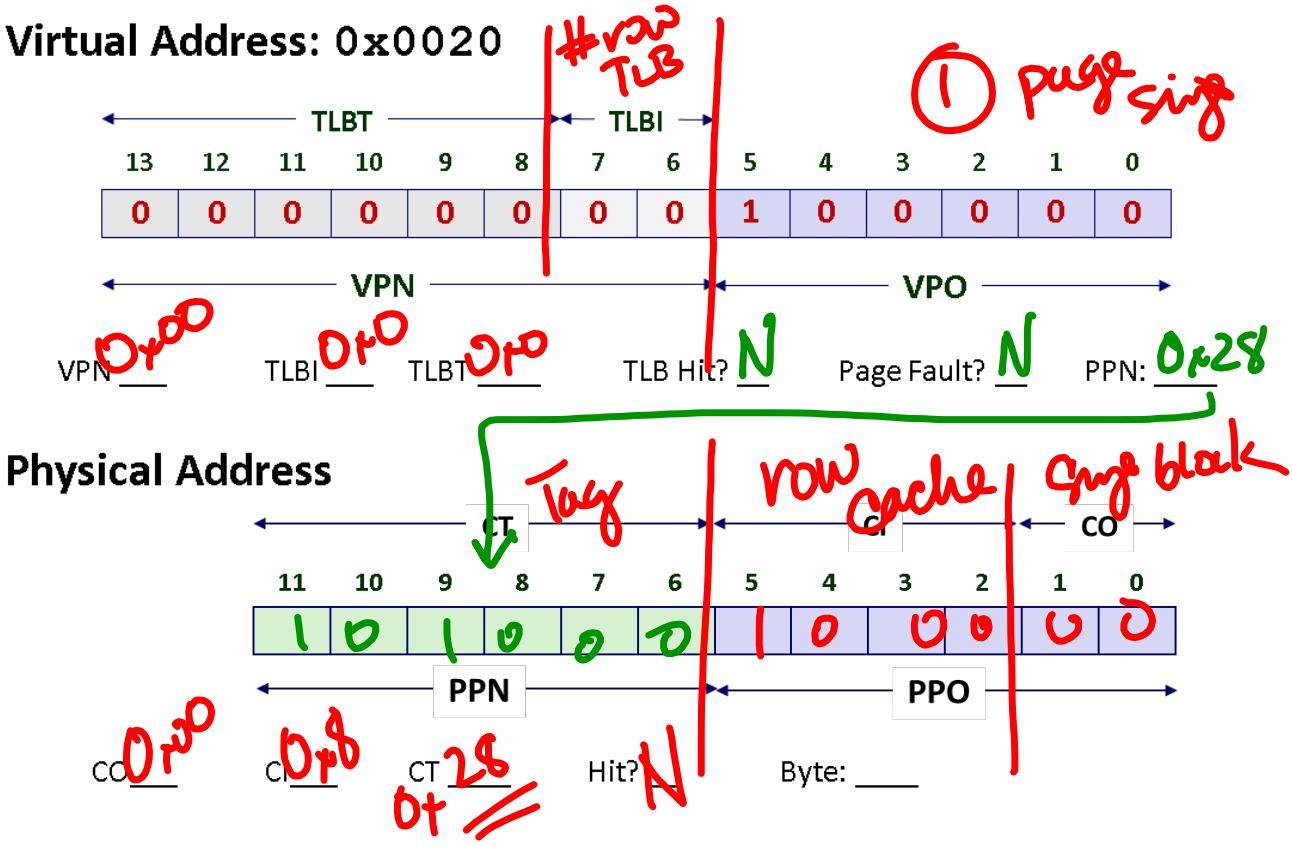


VPN 0x2E TLBI 0x2 TLBT 0x0B TLB Hit? N Page Fault? N PPN: 0x11

Physical Address



CO 0x3 CI 0x3 CT 0x11 Hit? N Byte: ____


Virtual Address: 0x0020
TLBT
TLBI
13 12 11 10 9 8 7 6 5 4 3 2 1 0
0 0 0 0 0 0 0 0 1 0 0 0 0 0
VPN
VPO
VPN 0x00 TLBI 0x0 TLBT 0x0 TLB Hit? N Page Fault? N PPN: 0x28
Physical Address
CT
CI
CO
11 10 9 8 7 6 5 4 3 2 1 0
1 0 1 0 0 0 1 0 0 0 0 0
PPN
PPO
CO 0x0 CI 0x8 CT 28 0x28 Hit? N Byte: ____