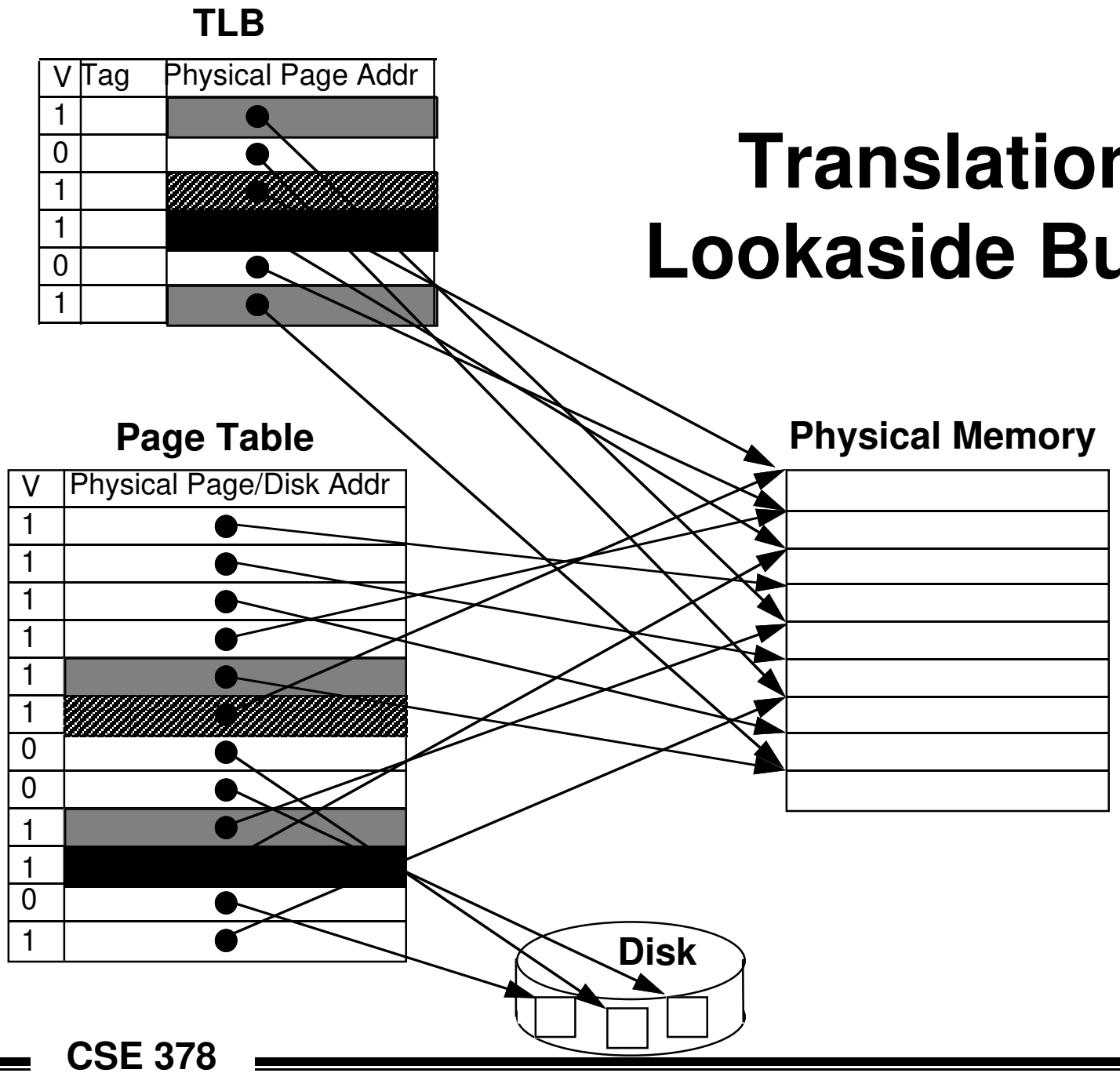
Translation-lookaside buffer

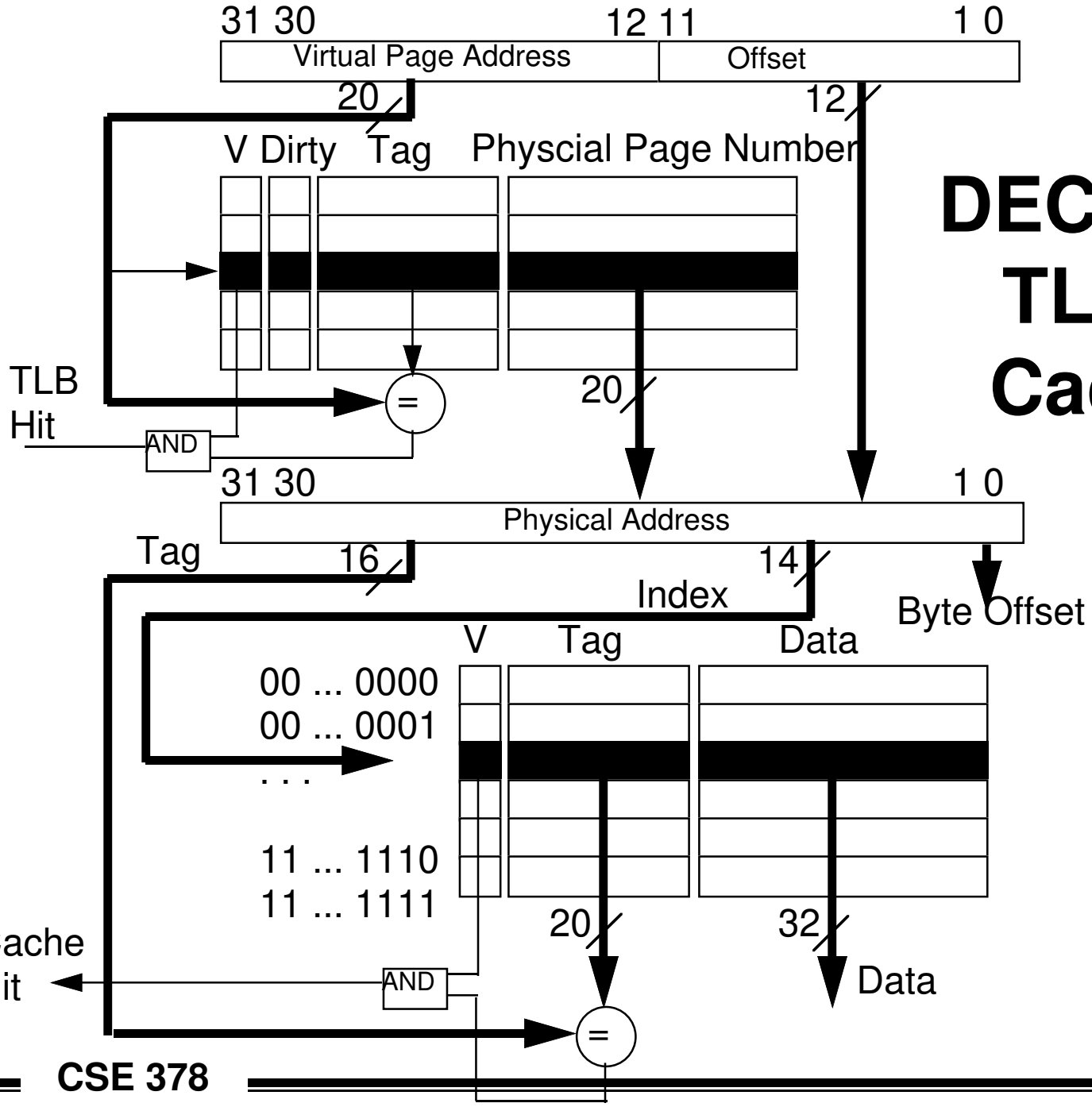
To save time in virtual to physical address translation, temporal locality is exploited by keeping a small cache of the most recent virtual-physical mappings.

Block size	1-2 page-table entries
Hit Time	1/2-1 clock cycle
Miss penalty	10-30 clock cycles
Miss rate	0.01%-1%
TLB size	32-1024 entries

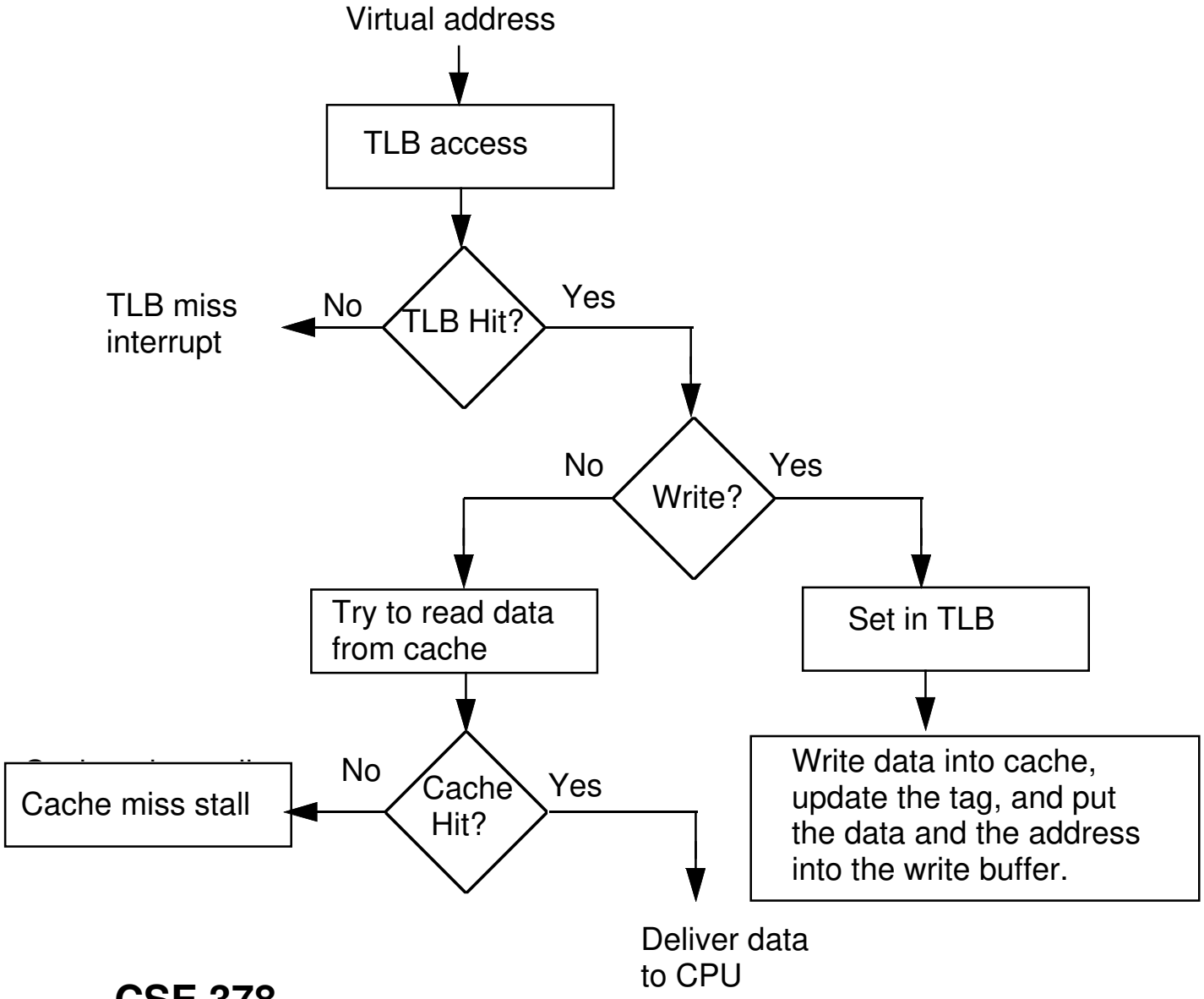
Translation Lookaside Buffer



DEC 3100 TLB & Cache



Logic of Memory Reference



A TLB Miss Means Either...

The page is present ==> only a TLB entry must be created.
The page is not present (i.e. page table entry for virtual address has 0 valid bit), a page fault exception is signalled.

The exception flushed the instruction, put the PC in the exception program counter (EPC) and interrupted the processor.
The operating systems, checking the cause, discovers a page fault was signalled, and knowing this is a time consuming operation, saves the state:

- GP and FP registers.
- Page Table Address.
- EPC & Cause.

What address is needed:

- Instruction Page Fault, find address in EPC.
- Data Page Fault, compute address from Inst.

OS then:

- Finds disk address in page table entry.
- Chooses victim to replace; writes back if dirty bit set.
- Initiates read of disk block.

Protection Through Virtual Memory

A multi-user environment requires protection.

Virtual address spaces are logically separate as long as they never reference the same physical page.

Operating System sets page tables.

- Two execution modes: user/supervisor.
- Page table address must be supervisor readable.

Sharing can be assisted with "write protection" or read/write bits.

Context switching can be assisted when there is a TLB by extending the tag field of TLB entry with a process ID.

- Matches require both the address and the ID to match.

Exercises

Memory:

Address	Contents
00...000ac	
00...000b0	
00...000b4	
. . .	
00...080ac	
00...080b0	
00...080b4	
. . .	
00...0e0ac	80...00000
00...0e0b0	80...0000e
00...0e0b4	80...0a0b4

Page Table Address: 00...0e0a8

Assuming 4K pages and "big-endian" addressing, i.e. the 0 byte of a word is the msb end, what are the contents of the memory location at the virtual address 00...020b7?

The TLB physical page number for tag 00...02 would be?

Assuming 4K pages and assuming the physical address from the TLB is 00...000b4, what is the tag field?

Solutions

Memory:

Address	Contents
00...000ac	
00...000b0	
00...000b4	
. . .	
00...080ac	
00...080b0	
00...080b4	
. . .	
00...0e0ac	80...00000
00...0e0b0	80...0000e
00...0e0b4	80...0a0b4

Page Table Address: 00...0e0a8

Q. Assuming 4K pages and "big-endian" addressing, i.e. the 0 byte of a word is the msb end, what are the contents of the memory location at the virtual address 00...020b7?

A. "0b7" is the page offset, and "00...02" is the virtual page number. Convert this to a displacement for the page table by multiplying by 4, and add to the page table address: 00...0e0a8 + 8 = 00...0e0b0". Find the physical page number at that location: 80...0e, where the msb is the "valid bit". Construct the physical address: 00...0e0b7. Find that byte in memory: b4.

Q. The TLB physical page number for tag 00...02 would be?

A. The TLB is a cache, so it has a tag field. The tag field holds the (portion of the) virtual page number (00...02) corresponding to the physcial page number. The previous question determined the physcial page number corresponding to this virtual page number: 00...0e.

Solutions (Continued)

Memory:

Address	Contents	
00...000ac		Page Table Address: 00...0e0a8
00...000b0		
00...000b4		
. . .		
00...080ac		
00...080b0		
00...080b4		
. . .		
00...0e0ac	80...00000	
00...0e0b0	80...0000e	
00...0e0b4	80...0a0b4	

Q. Assuming 4K pages and assuming the physical address from the TLB is 00...000b4, what is the tag field?

A. "Physcial address from the TLB" means the physical address produced using the TLB. Since the page offset is 0b4, the physical page number is 0...00. Which page table entry maps to that physical page number? The page table entry at 0...0e0ac. Subtracting from this the page table address yields: 0...0e0ac - 0...0e0a8 = 4. This is an address, which by dividing by 4, we can convert to a virtual page number: 4/4 = 1. So, 0...01 must be in the tag field.