Compu ure
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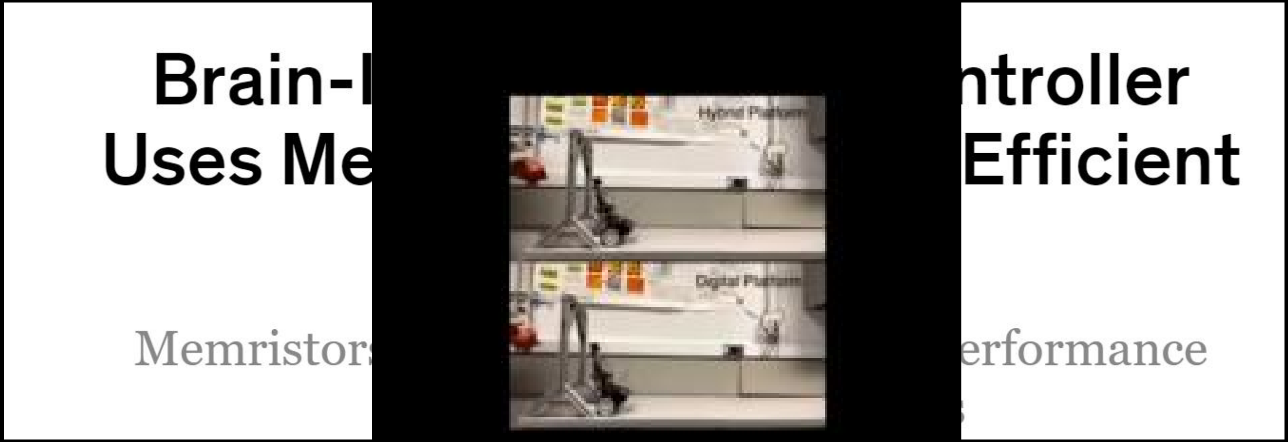
屏幕录制 现在
屏幕录制视频已存储到"照片"

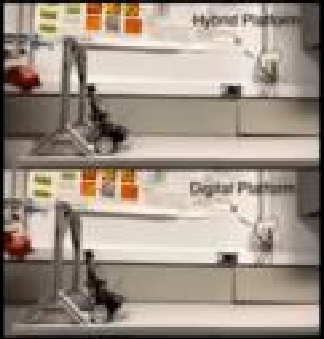
Lectu es II

Lecturer Yuanqing Cheng



Brain-I ntroller
Uses Me Efficient

Memristors erformance



Direct-Mapped Cache Terminology

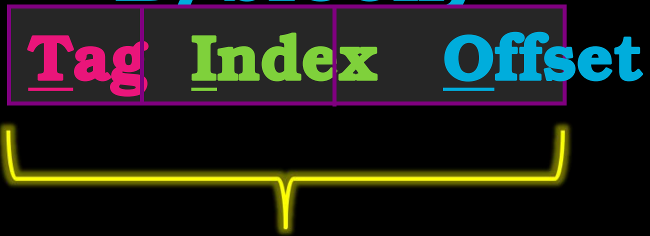
- All fields are read as unsigned integers.
- Index
  - specifies the cache index (or “row”/block)
- Tag
  - distinguishes betw the addresses that map to the same location
- Offset
  - specifies which byte within the block we want

ttttttttttttttttt	iiiiiiiiii	oooo
tag to check if have correct block	index to select block	byte offset within block

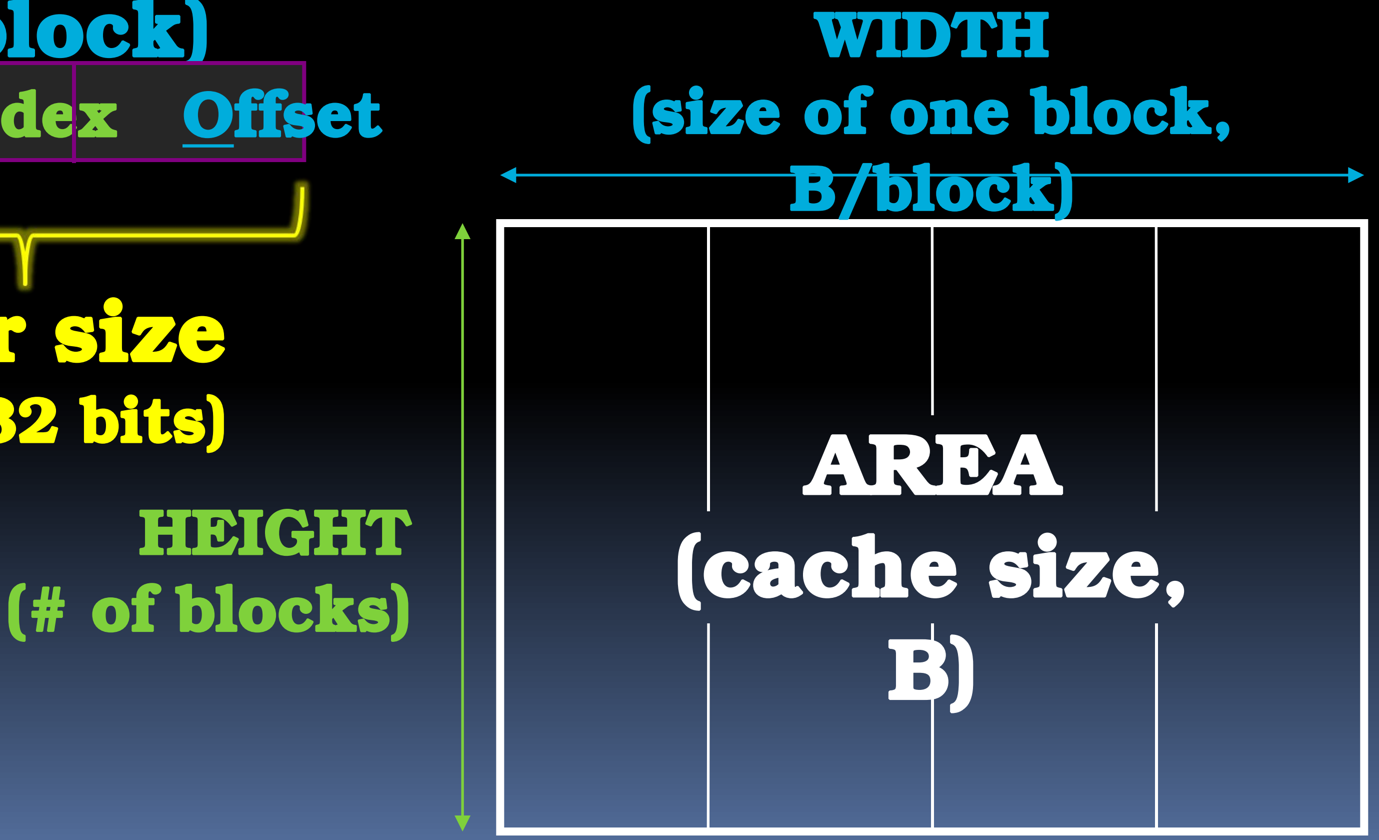
TIO Dan's great cache mnemonic

AREA (cache size, B)
= HEIGHT (# of blocks)
*** WIDTH (size of one block, B/block)**

$2^{(H+W)} = 2^H * 2^W$



Addr size (usu 32 bits)



Caching Terminology

- **When reading memory, 3 things can happen:**
  - **cache hit:**
    cache block is valid and contains proper address, so read desired word
  - **cache miss:**
    nothing in cache in appropriate block, so fetch from memory
  - **cache miss, block replacement:**
    wrong data is in cache at appropriate block, so discard it and fetch desired data from memory (cache always copy)

Accessing data in a direct mapped cache

- Ex.: 16KB of data, direct-mapped, 4 word blocks
  - Can you work out height, width, area?
- Read 4 addresses
  1. 0x00000014
  2. 0x0000001C
  3. 0x00000034
  4. 0x00008014

Memory

Address (hex)	Value of Word
...	...
00000010	a
00000014	b
00000018	c
0000001C	d
...	...
00000030	e
00000034	f
00000038	g
0000003C	h
...	...
00008010	i
00008014	j
00008018	k
0000801C	l
...	...

Accessing data in a direct mapped cache

- **4 Addresses:**
  - `0x00000014, 0x0000001C, 0x00000034, 0x00008014`
- **4 Addresses divided (for convenience) into Tag, Index, Byte Offset fields**

```
000000000000000000 0000000001 0100
000000000000000000 0000000001 1100
000000000000000000 0000000011 0100
000000000000000010 0000000001 0100
```

Tag **Index** **Offset**

16 KB Direct Mapped Cache, 16B blocks

- **Valid bit:** determines whether anything is stored in that row (when computer initially turned on, all entries invalid)

Index	Valid	Tag	0xc-f	0x8-b	0x4-7	0x0-3
0	0					
1	0					
2	0					
3	0					
4	0					
5	0					
6	0					
7	0					
...				...		
1022	0					
1023	0					

1. Read 0x00000014

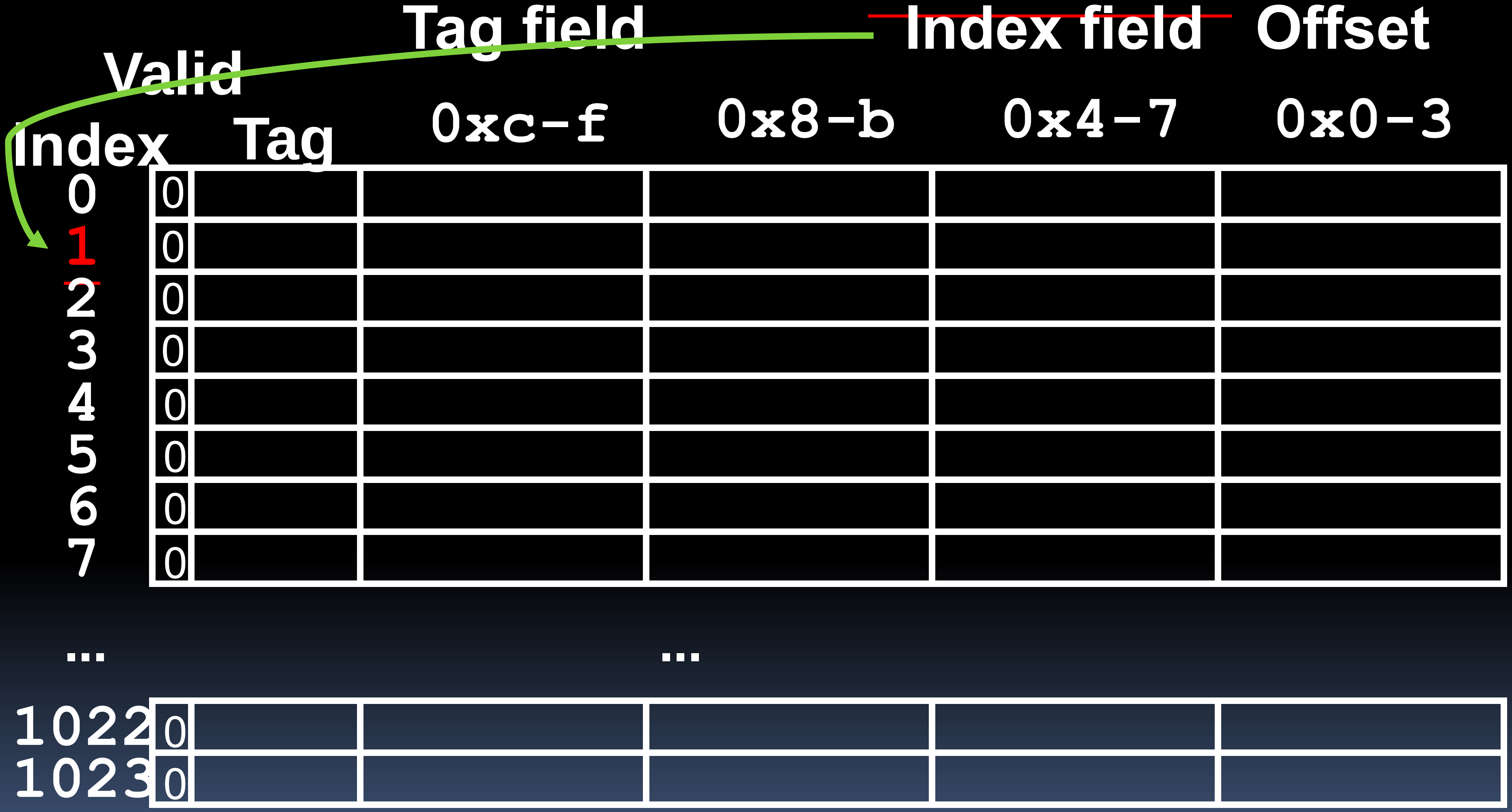
- 000000000000000000 0000000001 0100

Tag field Index field Offset

Index	Valid	Tag	0xc-f	0x8-b	0x4-7	0x0-3
0	0					
1	0					
2	0					
3	0					
4	0					
5	0					
6	0					
7	0					
...				...		
1022	0					
1023	0					

So we read block 1 (0000000001)

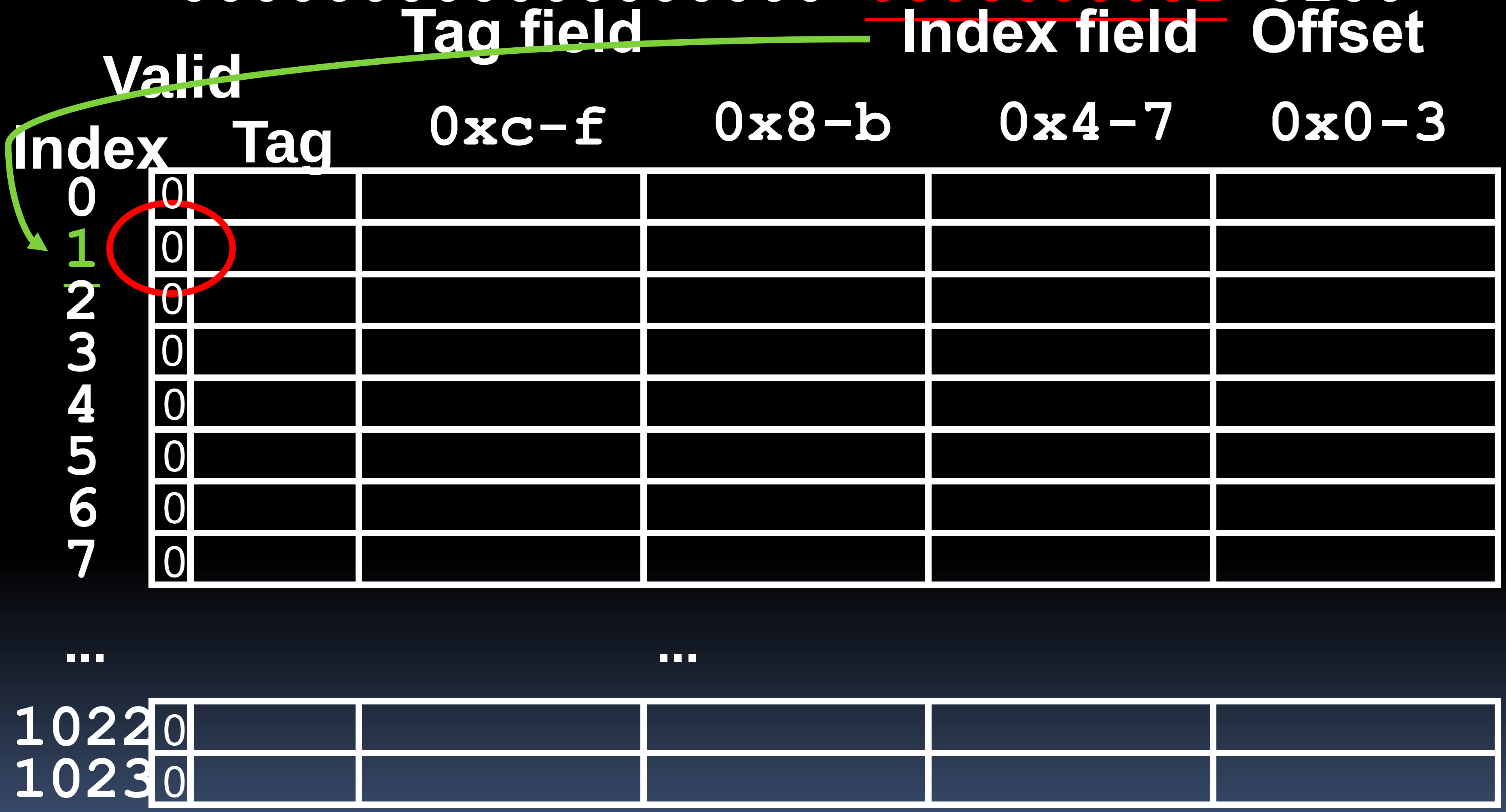
- 000000000000000000 0000000001 0100



Index	Valid	Tag	0xc-f	0x8-b	0x4-7	0x0-3
0	0					
1	0					
2	0					
3	0					
4	0					
5	0					
6	0					
7	0					
...			...			
1022	0					
1023	0					

No valid data

- 00000000000000000000 0000000001 0100



Index	Valid	Tag	0xc-f	0x8-b	0x4-7	0x0-3
0	0					
1	0					
2	0					
3	0					
4	0					
5	0					
6	0					
7	0					
...			...			
1022	0					
1023	0					

So load that data into cache, setting tag, valid

000000000000000000	0000000001	0100
Tag field	Index field	Offset

Index	Valid	Tag	0xc-f	0x8-b	0x4-7	0x0-3
0	0					
1	1	0	d	c	b	a
2	0					
3	0					
4	0					
5	0					
6	0					
7	0					
...			...			
1022	0					
1023	0					

Read from cache at offset, return word

- 000000000000000000 0000000001 0100

Tag field Index field Offset

Index	Valid	Tag	0xc-f	0x8-b	0x4-7	0x0-3
0	0					
1	1	0	d	c	b	a
2	0					
3	0					
4	0					
5	0					
6	0					
7	0					
...			...			
1022	0					
1023	0					

2. Read 0x0000001C = 0...00 0..001 1100

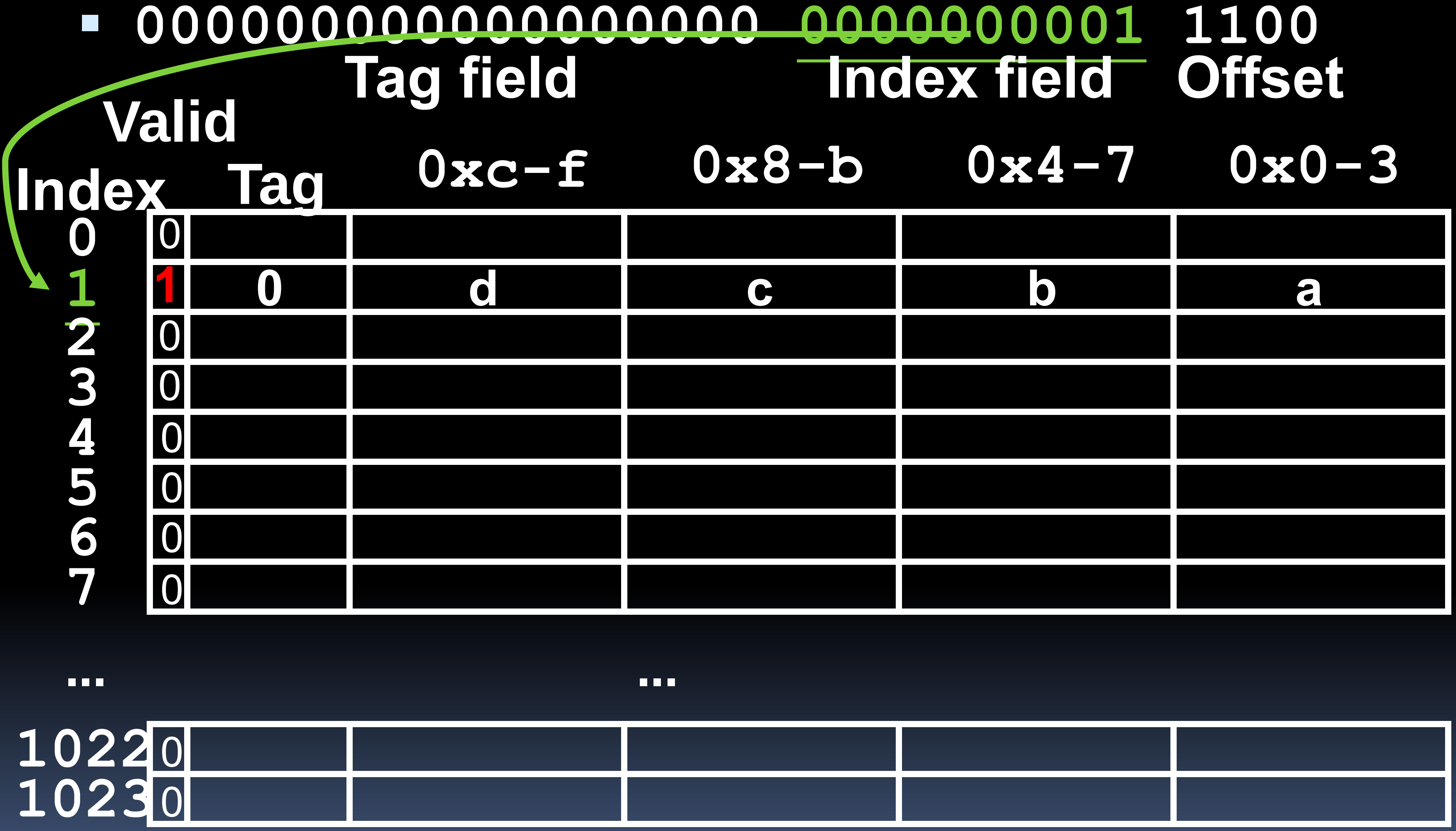
- 000000000000000000 0000000001 1100

Tag field Index field Offset

Index	Valid	Tag	0xc-f	0x8-b	0x4-7	0x0-3
0	0					
1	1	0	d	c	b	a
2	0					
3	0					
4	0					
5	0					
6	0					
7	0					
...				...		
1022	0					
1023	0					

Index is Valid

- 00000000000000000 0000000001 1100



Index	Valid	Tag	0xc-f	0x8-b	0x4-7	0x0-3
0	0					
1	1	0	d	c	b	a
2	0					
3	0					
4	0					
5	0					
6	0					
7	0					
...			...			
1022	0					
1023	0					

Index valid, Tag Matches

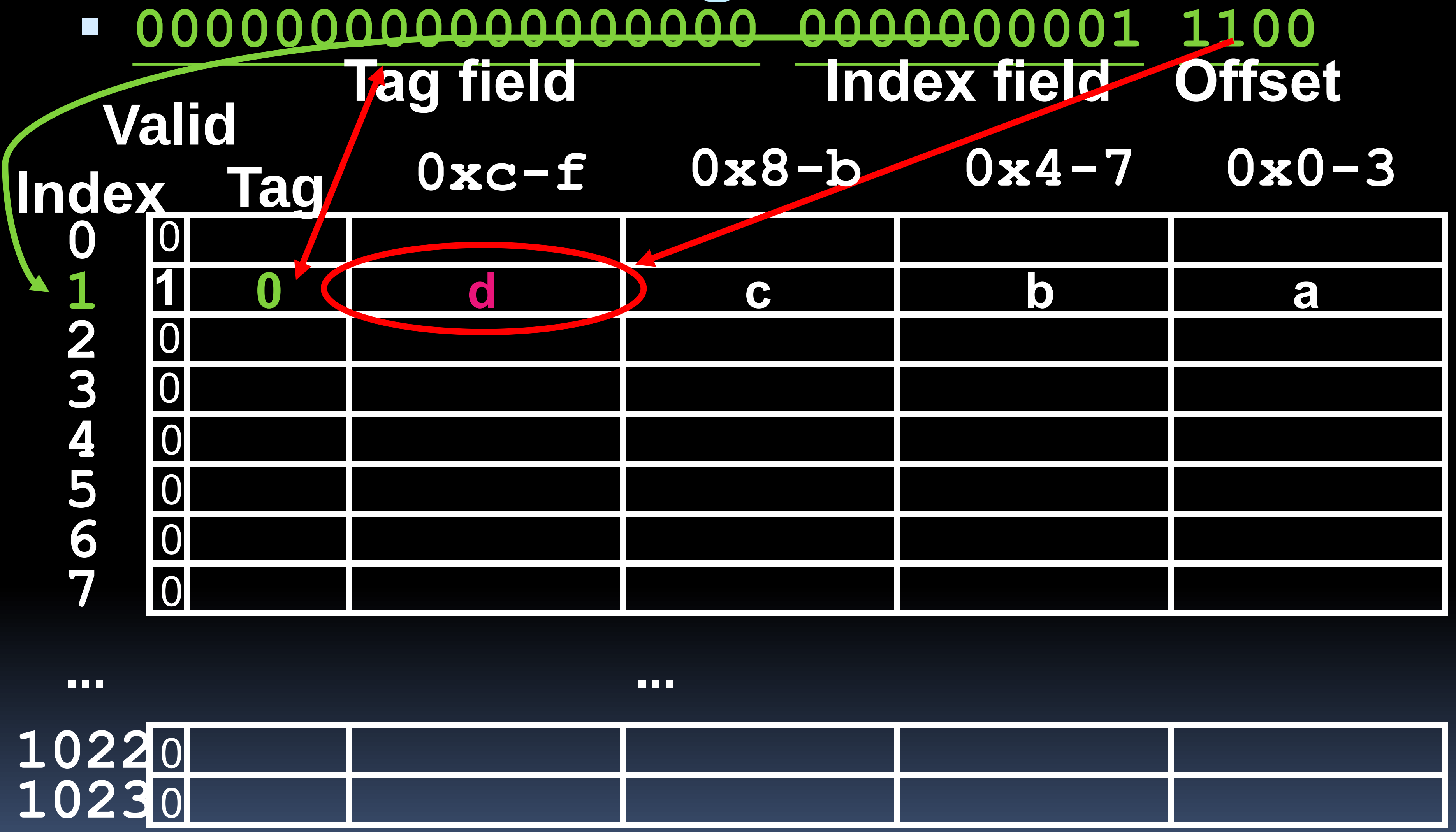
- 000000000000000000 0000000001 1100

Tag field	Index field	Offset
000000000000000000	0000000001	1100

Index	Valid	Tag	0xc-f	0x8-b	0x4-7	0x0-3
0	0					
1	1	0	d	c	b	a
2	0					
3	0					
4	0					
5	0					
6	0					
7	0					
...			...			
1022	0					
1023	0					

Index Valid, Tag Matches, return d

- 000000000000000000 0000000001 1100



Index	Valid	Tag	0xc-f	0x8-b	0x4-7	0x0-3
0	0					
1	1	0	d	c	b	a
2	0					
3	0					
4	0					
5	0					
6	0					
7	0					
...			...			
1022	0					
1023	0					

3. Read 0x00000034 = 0...00 0..011 0100

```
000000000000000000 0000000011 0100
    Tag field      Index field Offset
```

Index	Valid	Tag	0xc-f	0x8-b	0x4-7	0x0-3
0	0					
1	1	0	d	c	b	a
2	0					
3	0					
4	0					
5	0					
6	0					
7	0					
...			...			
1022	0					
1023	0					

So read block 3

- 0000000000000000000 000000011 0100

Tag field	Index field	Offset
0000000000000000000	000000011	0100

Index	Valid	Tag	0xc-f	0x8-b	0x4-7	0x0-3
0	0					
1	1	0	d	c	b	a
2	0					
3	0					
4	0					
5	0					
6	0					
7	0					
...				...		
1022	0					
1023	0					

No valid data

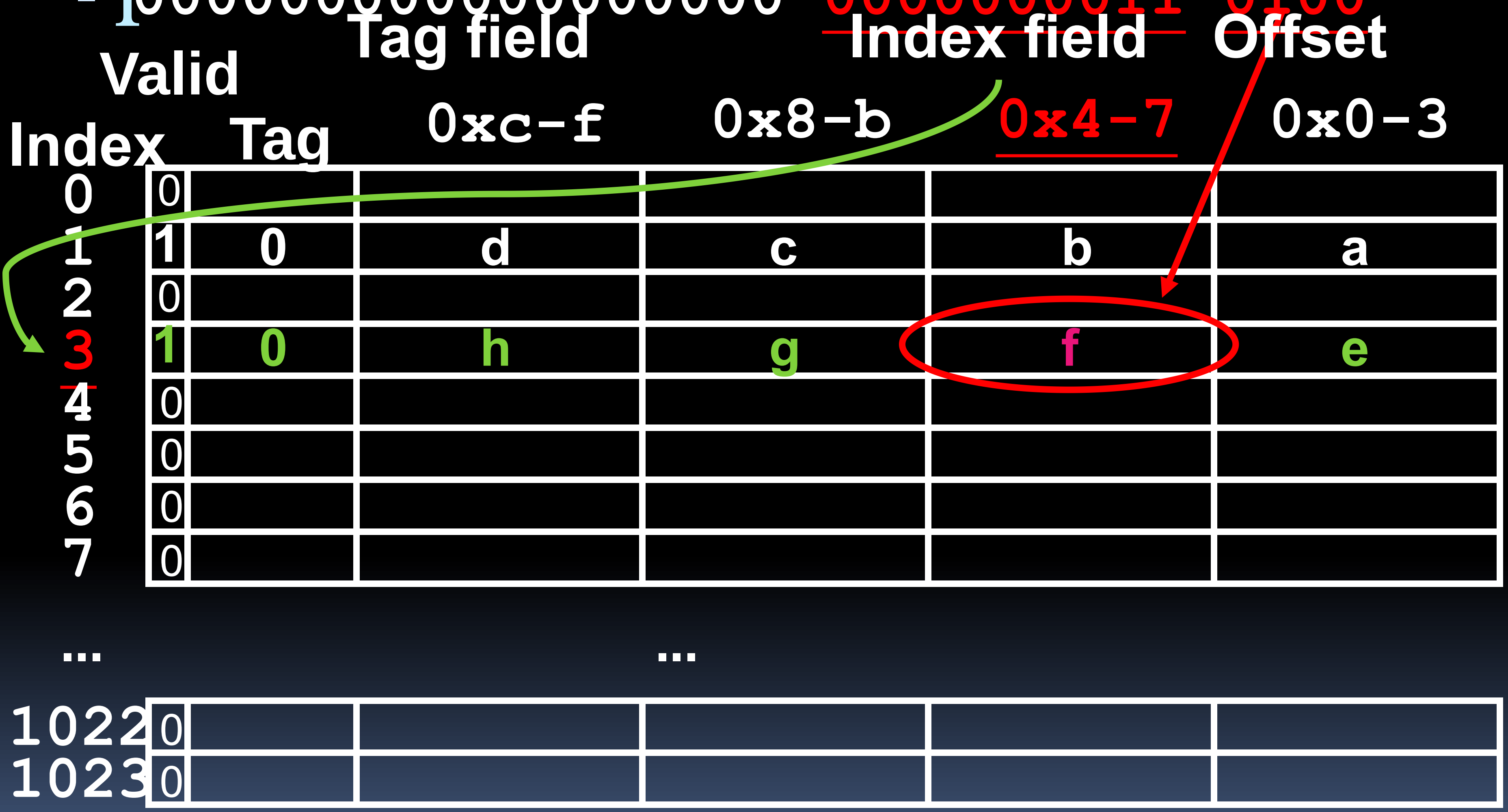
- 00000000000000000 0000000011 0100

Tag field | Index field | Offset

Index	Valid	Tag	0xc-f	0x8-b	0x4-7	0x0-3
0	0					
1	1	0	d	c	b	a
2	0					
3	0					
4	0					
5	0					
6	0					
7	0					
...				...		
1022	0					
1023	0					

Load that cache block, return word f

- 000000000000000000 0000000011 0100



Index	Valid	Tag	0xc-f	0x8-b	0x4-7	0x0-3
0	0					
1	1	0	d	c	b	a
2	0					
3	1	0	h	g	f	e
4	0					
5	0					
6	0					
7	0					
...			...			
1022	0					
1023	0					

4. Read 0x00008014 = 0…10 0..001 0100

- 000000000000000010 ~~0000000001~~ 0100

Tag field | Index field | Offset

Index	Valid	Tag	0xc-f	0x8-b	0x4-7	0x0-3
0	0					
1	1	0	d	c	b	a
2	0					
3	1	0	h	g	f	e
4	0					
5	0					
6	0					
7	0					
...			...			
1022	0					
1023	0					

So read Cache Block 1, Data is Valid

- 000000000000000010 0000000001 0100

Tag field	Index field	Offset
000000000000000010	0000000001	0100

Index	Valid	Tag	0xc-f	0x8-b	0x4-7	0x0-3
0	0					
1	1	0	d	c	b	a
2	0					
3	1	0	h	g	f	e
4	0					
5	0					
6	0					
7	0					
...			...			
1022	0					
1023	0					

Cache Block 1 Tag does not match (0 != 2)

- 000000000000000010 0000000001 0100

Tag field	Index field	Offset
000000000000000010	0000000001	0100

Index	Valid	Tag	0xc-f	0x8-b	0x4-7	0x0-3
0	0					
1	1	0	d	c	b	a
2	0					
3	1	0	h	g	f	e
4	0					
5	0					
6	0					
7	0					
...				...		
1022	0					
1023	0					

Miss, so replace block 1 with new data & tag

00000000000000000010	0000000001	0100
Tag field	Index field	Offset

Index	Valid	Tag	0xc-f	0x8-b	0x4-7	0x0-3
0	0					
1	1	2	l	k	j	i
2	0					
3	1	0	h	g	f	e
4	0					
5	0					
6	0					
7	0					
...			...			
1022	0					
1023	0					

And return word J

- 00000000000000000010 0000000001 0100

Tag field / Index field / Offset

Index	Valid	Tag	0xc-f	0x8-b	0x4-7	0x0-3
0	0					
1	1	2	l	k	j	i
2	0					
3	1	0	h	g	f	e
4	0					
5	0					
6	0					
7	0					
...			...			
1022	0					
1023	0					

Do an example yourself. What happens?

- **Chose from: Cache: Hit, Miss, Miss w. replace**
  Values returned: a ,b, c, d, e, ..., k, l
- **Read address 0x00000030 ?**
  `000000000000000000 0000000011 0000`
- **Read address 0x0000001c ?**
  `000000000000000000 0000000001 1100`

Cache

Index	Valid	Tag	0xc-f	0x8-b	0x4-7	0x0-3
0	0					
1	1	2	l	k	j	i
2	0					
3	1	0	h	g	f	e
4	0					
5	0					
6	0					
7	0					
...				...		

Answers

- 0x00000030 a **hit**

  Index = 3, Tag matches, Offset = 0, value = e

- 0x0000001c a **miss**

  Index = 1, Tag mismatch, so replace from memory, Offset = 0xc, value = d

- **Since reads, values must = memory values whether or not cached:**

Memory

Address (hex)	Value of Word
...	...
00000010	a
00000014	b
00000018	c
0000001C	d
...	...
00000030	e
00000034	f
00000038	g
0000003C	h
...	...
00008010	i
00008014	j
00008018	k
0000801C	l
...	...

Peer Instruction

1) Mem hierarchies were invented before 1950. (UNIVAC I wasn't delivered 'til 1951)
2) If you know your computer's cache size, you can often make your code run faster.

	12
a)	FF
b)	FT
c)	TF
d)	TT

Peer Instruction Answer

1) "We are…forced to recognize the possibility of constructing a hierarchy of memories, each of which has greater capacity than the preceding but which is less accessible." – von Neumann, 1946

2) Certainly! That's call "tuning"

1) Mem hierarchies were invented before 1950. (UNIVAC I wasn't delivered 'til 1951)

2) If you know your computer's cache size, you can often make your code run faster.

	12
a)	FF
b)	FT
c)	TF
[✓ d)]	[✓ TT]

Peer Instruction

1. **All caches take advantage of spatial locality.**
2. **All caches take advantage of**

	12
a)	FF
b)	FT
c)	TF
d)	TT

Peer Instruction Answer

1. All caches take advantage of spatial locality.

F A L S E

1. Block size = 1, no spatial!

2. All caches take advantage of temporal locality.

T R U E

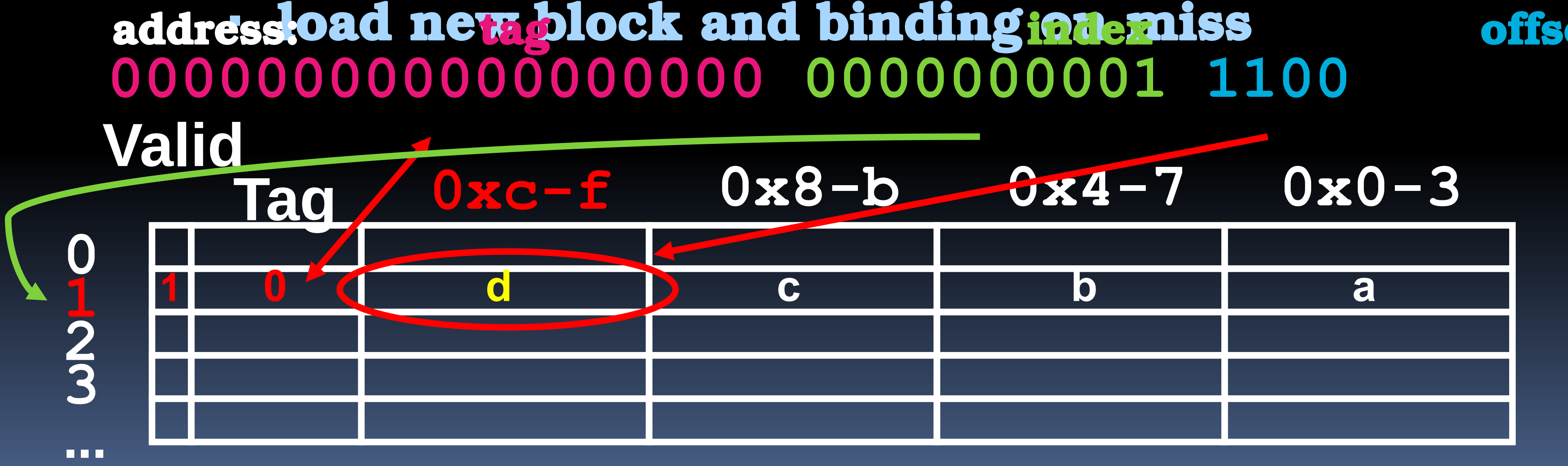
2. That's the idea of caches;
   We'll need it again soon.

1. **All caches take advantage of spatial locality.**
2. **All caches take advantage of**

	12
a)	FF
[✓ b)]	[✓ FT]
c)	TF
d)	TT

And in Conclusion…

- **Mechanism for transparent movement of data among levels of a storage hierarchy**
  - **set of address/value bindings**
  - **address ⇒ index to set of candidates**
  - **compare desired address with tag**
  - **service hit or miss**
  - **load new block and binding on miss**


address:
tag
index
offs
000000000000000000
0000000001
1100
Valid
Tag
0xc-f
0x8-b
0x4-7
0x0-3
0
1
2
3
...
1
0
d
c
b
a