

# Memory Hierarchy, Address Decoding, and RAM Expansion

## Memory Structure

- Memory Composition: Memory is built from the smallest unit (memory cell) up to larger structures.
  - A memory cell stores 1 bit
  - 8 cells = 1 byte
  - 4 bytes = 1 word (in MIPS)
  - Words can be grouped into blocks
- Access Pattern:
  - Building: from cell  $\rightarrow$  byte  $\rightarrow$  word  $\rightarrow$  block
  - Accessing: from block  $\rightarrow$  word  $\rightarrow$  byte  $\rightarrow$  cell (big to small)

Read: uses MUX

Write: In order to get to a specific location: uses decoders

## Memory Unit: Size and Structure

- Represented as  $2^k \times m$ :
  - $k$  = address size (number of bits needed for addressing)
  - $m$  = word size (number of bits per word)
- A memory unit includes:
  - Read/write control line
  - Input and output data lines
  - select line (for chip selection in multi-chip setups)
- Addressing Modes
  - Byte Addressing (eg. in MIPS): each address points to a byte
  - Word Addressing: each address points to a word

## RAM: Types and Characteristics

- Static RAM (SRAM)
  - Faster, more expensive
  - Used in cache memory
  - Doesn't need refreshing
  - Stores data using flip-flops
  - More reliable for frequent and fast access
- Dynamic RAM (DRAM)
  - Slower, cheaper
  - Used in most main memory systems
  - Stores data using capacitors that leak charge
  - Needs periodic refreshing (read then re-write the value to restore it)
  - Less expensive and denser than SRAM, allowing for higher capacity

## Expanding RAM with an Array of RAM Chips

Given a RAM configuration  $1K \times 16$ , we want to:

- Increase the RAM capacity 10 times
- Access word 3079 (draw the circuit and indicate the settings to accommodate this task)

To increase the capacity 10 times, we'll put 10 chips together  $\rightarrow C_0$  to  $C_9$

To access word 3079, we consider that each RAM chip holds 1024 words, so to access word 0-1023, we need to access  $C_0$ . To access word 1024, we need to access  $C_1$

$\hookrightarrow 3079 = 1024 \times 3 + 7 \Rightarrow$  our target word is on  $C_3$  with a word offset of 7

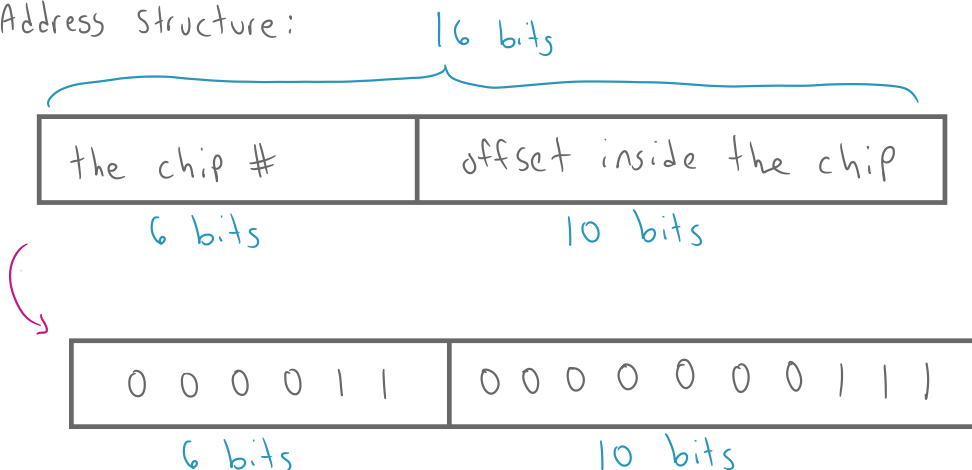
$$3079 = 3 \times 1024 + 7 = \underset{\substack{\downarrow \\ 2^11}}{2 \times 1024} + \underset{\substack{\downarrow \\ 2^{10}}}{1024} + \underset{\substack{\downarrow \\ 7}}{7}$$

Absolute Address: 

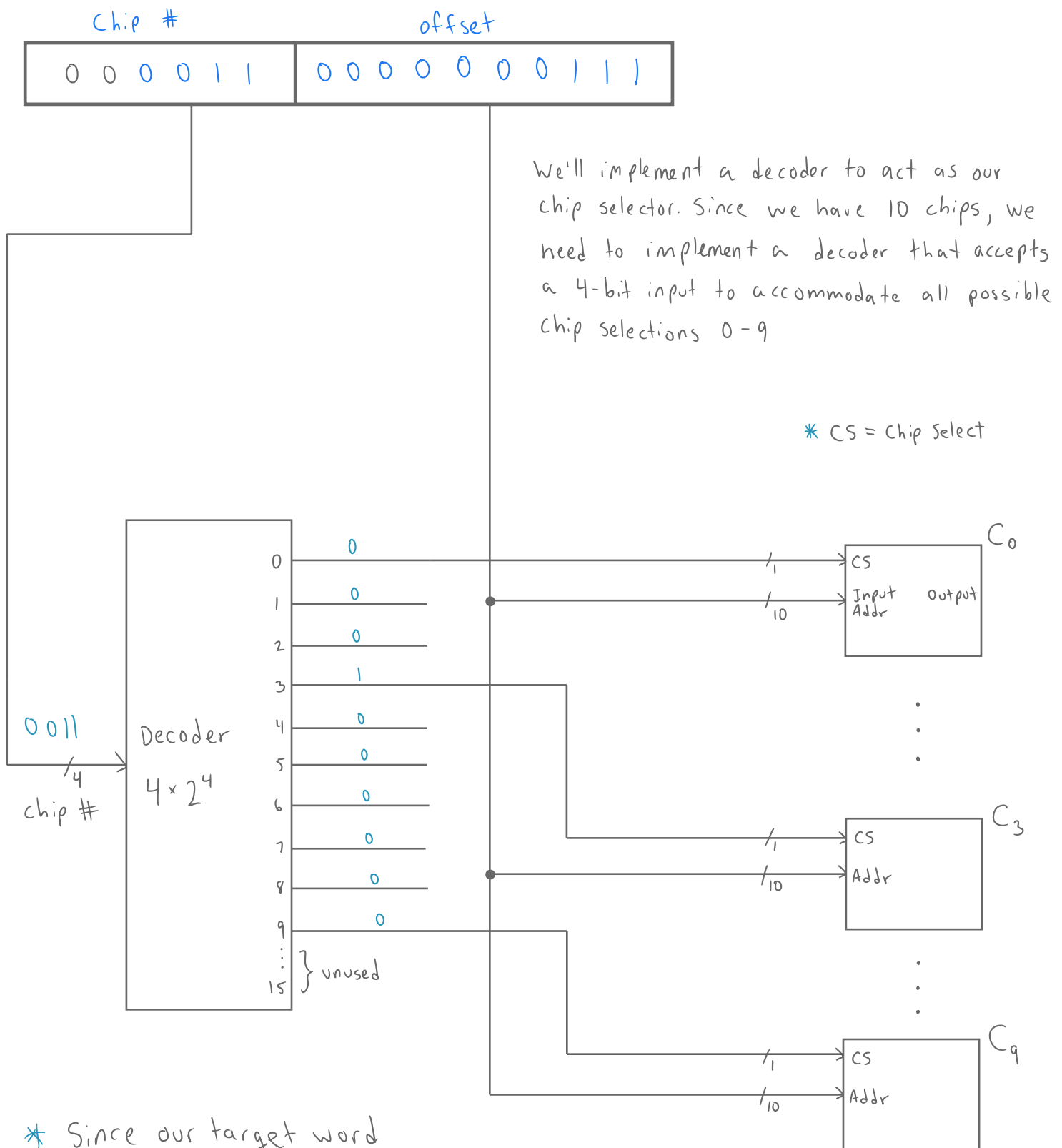
1	1	0	0	0	0	0	0	0	1	1	1
11	10	9	8	7	6	5	4	3	2	1	0

By examining our RAM config,  $1K \times 16 = 2^{10} \times 16$ , we can see that we need 10 bits to accommodate the offset. Since we have 16-bit words, we can assume a 16-bit address

Address Structure:



Our Address to access word 3079:



\* Since our target word resides in  $C_3$ , we'll use the decoder to select chip # 3, meaning the only decoder output that will be 1 will be line 3, which leads to  $C_3$