

CSE 401: Computer Engineering (2)  
Fourth Year, Electronics & Communication Engineering

## Solution to Assignment #1

1. A 128M×8 DRAM is organized into a cell array that has 4096 rows. The DRAM follows a distributed refreshment approach. Instead of refreshing the whole cell array at once in a single refresh cycle, the array is refreshed incrementally in multiple small refresh cycles where only two rows get to be refreshed each cycle.
- (a) Suppose each memory cell can retain its data for up to 64 ms (without being refreshed). What should be the maximum time elapsed from the beginning of any refresh cycle to the next?

Number of refresh cycles each 64ms =  $(4096 \text{ rows}) / (2 \text{ rows per cycle}) = 2048 \text{ cycle}$

Maximum time between refresh cycles =  $(64 \text{ ms}) / 2048 = 31.25 \text{ } \mu\text{s}$

- (b) If it takes 0.25  $\mu\text{s}$  to refresh one row, what percentage of the DRAM time is spent in refreshment?

Time elapsed during each refresh cycle =  $(2 \text{ rows}) * (0.25 \text{ } \mu\text{s per row}) = 0.5 \text{ } \mu\text{s}$

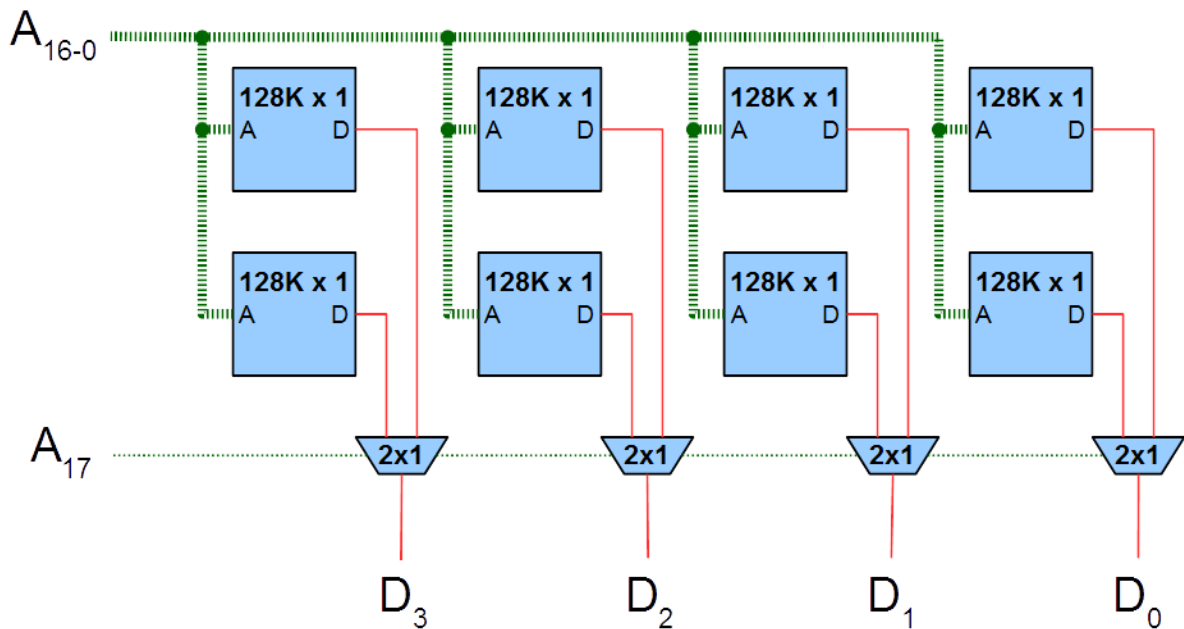
% of time spent in refreshment =  $(0.5 \text{ } \mu\text{s}) / (31.25 \text{ } \mu\text{s}) * 100\% = 1.6\%$

2. A 256K×4 read-only memory is to be implemented using 128K×1 ROM chips (with no chip-select (CS) lines) and 2×1 multiplexers.
- (a) How many ROM chips and multiplexers are required to implement this memory?

Number of ROM chips =  $(256\text{K} * 4) / (128\text{K} * 1) = 8$

Number of multiplexers = 4 (one multiplexer for each output data line)

- (b) Draw a block diagram of the memory to show how the ROM chips should be connected together with the multiplexers and how the input address lines and the output data lines are routed.



- (c) Calculate the overall access time of the memory given that the access time of each ROM chip is 10ns and the propagation delay of each multiplexer is 2ns.

Overall access time = ROM access time + multiplexer propagation delay = 10 ns + 2 ns = 12 ns

3. A memory chip is equipped with a SEC-DED mechanism that generates 13-bit codewords. Every codeword contains 8 bits of data, 4-bit Hamming code, and 1 global parity bit. For each of the following cases: specify whether the codeword is legal or not, and unless the codeword is legal, identify the error and correct it if possible.

Codeword format:



Data bits = "D<sub>12</sub>D<sub>11</sub>D<sub>10</sub>D<sub>9</sub>D<sub>7</sub>D<sub>6</sub>D<sub>5</sub>D<sub>3</sub>", Hamming code = "C<sub>8</sub>C<sub>4</sub>C<sub>2</sub>C<sub>1</sub>", Parity bit = "P"

$$C_1 = D_3 \oplus D_5 \oplus D_7 \oplus D_9 \oplus D_{11}$$

$$C_2 = D_3 \oplus D_6 \oplus D_7 \oplus D_{10} \oplus D_{11}$$

$$C_4 = D_5 \oplus D_6 \oplus D_7 \oplus D_{12}$$

$$C_8 = D_9 \oplus D_{10} \oplus D_{11} \oplus D_{12}$$

$$P = C_1 \oplus C_2 \oplus D_3 \oplus C_4 \oplus D_5 \oplus D_6 \oplus D_7 \oplus C_8 \oplus D_9 \oplus D_{10} \oplus D_{11} \oplus D_{12}$$

- (a) Data bits = "11011011", Hamming code = "1111", parity bit = "1".

$$D_{12}D_{11}D_{10}D_9D_7D_6D_5D_3 = "11011011"$$

Calculating Hamming code  $\rightarrow C_8C_4C_2C_1 = "1111" \rightarrow$  same as the given value!

Calculating Parity  $\rightarrow P = "0" \rightarrow$  different from the given value!

- Only parity bit is different
- Codeword is not legal
- **Single-bit error happened** in the parity bit (P)  $\rightarrow$  Data bits are correct!

(b) Data bits = “11001011”, Hamming code = “1011”, parity bit = “0”.

$D_{12}D_{11}D_{10}D_9D_7D_6D_5D_3 = “11001011”$

Calculating Hamming code  $\rightarrow C_8C_4C_2C_1 = “0110” \rightarrow$  different from the given value!

Calculating Parity  $\rightarrow P = “0” \rightarrow$  same as the given value!

- Only Hamming code is different
- Codeword is not legal
- **Double-bit error detected**  $\rightarrow$  No correction is possible!

(c) Data bits = “11001011”, Hamming code = “0110”, parity bit = “1”.

$D_{12}D_{11}D_{10}D_9D_7D_6D_5D_3 = “11001011”$

Calculating Hamming code  $\rightarrow C_8C_4C_2C_1 = “0110” \rightarrow$  same as the given value!

Calculating Parity  $\rightarrow P = “1” \rightarrow$  same as the given value!

- Both Hamming code and parity bit equal given values
- Codeword is legal
- **No Single-bit or Double-bit errors happened**  $\rightarrow$  No correction is needed!

(d) Data bits = “11001011”, Hamming code = “1111”, parity bit = “0”.

$D_{12}D_{11}D_{10}D_9D_7D_6D_5D_3 = “11001011”$

Calculating Hamming code  $\rightarrow C_8C_4C_2C_1 = “0110” \rightarrow$  different from the given value!

Calculating Parity  $\rightarrow P = “1” \rightarrow$  different from the given value!

- Both Hamming code and parity are not equal to the given values.
- Codeword is not legal
- **Single-bit error happened**, and it can be corrected
  - Position of the error = “1111”  $\oplus$  “0110” = “1001”  $\rightarrow D_9$
  - Correction: change  $D_9$  from “0” to “1”  $\rightarrow D_{12}D_{11}D_{10}D_9D_7D_6D_5D_3 = “11011011”$