SNAKE GAME IMPLEMENTATION IN THE RIPES SIMULATOR

COMPUTER ORGANIZATION AND ARCHITECTURE

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Contents

INTRODUCTION

PURPOSE

The objective is to analyze the hit rate of different cache configurations while running the Snake game. The results help understand how cache mapping techniques affect performance.

REPOSITORY

Ripes-Snake

SYSTEM OVERVIEW

ARCHITECTURE

SIMPLIFIED FLOWCHART

Note: Refer to *flowchart.txt* file.

SNAKE C CODE BREAKDOWN

Note: Given the development environment of this project, the *stdlib.h* library could not be included to generate the apple's random coordinates, thus, extra custom functions to generate random numbers were creating for the project:

- Processor directives:

```
#define SNAKE_COLOR 0xff0000 // RED
#define APPLE_COLOR 0x00ff00 // GREEN
#define MAX_SNAKE_LENGTH 50
#define PIXEL_SIZE 2
#define GAME_SPEED 3000
#define SNAKE_START_X 10
#define SNAKE_START_Y 10
```

- Custom data types:

```
typedef enum {GAME_OVER, PLAYING} Status;

typedef enum {UP, DOWN, LEFT, RIGHT} Keys;

typedef enum {FALSE, TRUE} Boolean;

typedef struct {unsigned x, y;} Apple;

typedef struct {unsigned x, y; Keys direction;} SnakeSegment;

typedef struct {SnakeSegment segments[MAX_SNAKE_LENGTH]; int length; Apple apple;} Snake;
```

- Necessary variables for the code to interact with hardware and to generate random numbers:

```c
unsigned *led_base = (unsigned*) LED_MATRIX_0_BASE;
unsigned *switch_base = (unsigned*) SWITCHES_0_BASE;
unsigned *up = (unsigned*) D_PAD_0_UP;
unsigned *down = (unsigned*) D_PAD_0_DOWN;
unsigned *left = (unsigned*) D_PAD_0_LEFT;
unsigned *right = (unsigned*) D_PAD_0_RIGHT;
unsigned seed = 12345; // SEED USED TO GENERATE RANDOM NUMBERS
```

- Program functions:

```c
unsigned rand_ripes(); // CUSTOM RAND FUNCTION
unsigned rand_mod(unsigned max); // PART OF CUSTOM RAND FUNCTION
void create_snake(Snake *snake);
void clear_screen();
void delay();
void init_game(Snake *snake);
void init_apple_coordinates(Snake *snake, int seed);
void move_snake(Snake *snake);
Boolean wall_collision(Snake *snake);
Boolean snake_collision(Snake *snake);
Boolean snake_collision_with_apple(Snake *snake);
void change_head_direction(Snake *snake);
void move_snake_head(Snake *snake);
```

- rand_ripes() function:

This function implements a custom random number generator based on a linear congruential generator (LCG) algorithm. It updates the global seed using a specific formula and returns the new value. The modulo operation ensures the value stays within the bounds of a 32-bit signed integer. This random function is deterministic, meaning the same seed always produces the same sequence.

- rand_mod() function:

This function utilizes rand_ripes() to generate a pseudo-random number in the range [0, max - 1]. It simply takes the output of rand_ripes() and computes the remainder when divided by max, effectively constraining the result to the desired range.

- create_snake() function:

This function initializes a Snake object to its starting state. It sets the snake's initial length to 1, places its head at the coordinates (SNAKE_START_X, SNAKE_START_Y), and sets its initial direction to RIGHT. The apple's coordinates are reset to (0, 0), indicating that it needs to be placed later in the game.

```
void create_snake(Snake *snake) {
    snake->length = 1;
    snake->segments[0].x = SNAKE_START_X;
    snake->segments[0].y = SNAKE_START_Y;
    snake->segments[0].direction = RIGHT;
    snake->apple.x = 0;
    snake->apple.y = 0;
}
```

- clear_screen() function:

This function clears the LED matrix screen by iterating through all pixels and setting their color value to 0x000000 (black). It ensures the screen is reset at the start of each game frame. The nested loops handle the LED matrix's dimensions and pixel size to achieve this.

```
void clear_screen() {
    for (int y = PIXEL_SIZE; y < LED_MATRIX_0_HEIGHT; ++y) {
        for (int x = PIXEL_SIZE; x < LED_MATRIX_0_WIDTH; ++x)
            *(led_base + y * LED_MATRIX_0_WIDTH + x) = 0x000000;
    }

    for (int i = 0; i < LED_MATRIX_0_WIDTH; ++i) {
        for (int j = 0; j < PIXEL_SIZE; ++j)
            *(led_base + j * LED_MATRIX_0_WIDTH + i) = 0x000000;
    }
}
```

- delay() function:

This function introduces a delay by running an empty loop a number of times determined by the GAME_SPEED constant. The volatile keyword prevents the compiler from optimizing away the loop. This is used to control the game's speed by pausing execution between frames.

```
void delay() {
    volatile unsigned delay_var = 0;
    for (int i = 0; i < GAME_SPEED; ++i, ++delay_var);
}
```

- init_game() function:

This function draws the snake and apple on the LED matrix. It iterates through the snake's segments, setting the corresponding pixels to the snake's color (SNAKE_COLOR). If an apple is present, it sets the apple's position on the screen to the color APPLE_COLOR. This visually represents the game state.

```
void init_game(Snake *snake) {
    for (int i = 0; i < snake->length; ++i) {
        for (int x = 0; x < PIXEL_SIZE; ++x) {
            for (int y = 0; y < PIXEL_SIZE; ++y) {
                if (!i) *(led_base + (snake->apple.y + y) * LED_MATRIX_0_WIDTH +
                ↪   (snake->apple.x + x)) = APPLE_COLOR;

                *(led_base + (snake->segments[i].y + y) * LED_MATRIX_0_WIDTH +
                ↪   (snake->segments[i].x + x)) = SNAKE_COLOR;
            }
        }
    }
}
```

- init_apple_coordinates() function:

This function calculates random coordinates for the apple within the LED matrix bounds using the rand_mod() function. It ensures the coordinates are aligned with the pixel grid and fall within valid ranges. The apple is then assigned these coordinates.

```
void init_apple_coordinates(Snake *snake, int seed){
    int x = rand_mod(LED_MATRIX_0_WIDTH - PIXEL_SIZE);
    int y = rand_mod(LED_MATRIX_0_HEIGHT - PIXEL_SIZE);

    if (x % 2)
        --x;
    if (y % 2)
        --y;

    if (x < PIXEL_SIZE)
        x = PIXEL_SIZE;
    if (y < PIXEL_SIZE)
        y = PIXEL_SIZE;

    snake->apple.x = x;
    snake->apple.y = y;
}
```

- move_snake() function:

This function updates the position of the snake's body segments by shifting each segment to the position of the segment directly ahead of it. This effectively moves the snake forward while preserving its current direction.

```
void move_snake(Snake *snake){
    for (int i = snake->length - 1; i > 0; --i) {
        snake->segments[i].x = snake->segments[i - 1].x;
        snake->segments[i].y = snake->segments[i - 1].y;
    }
}
```

- wall_collision() function:

This function checks if the snake's head has collided with the walls of the LED matrix. If the head's coordinates are outside the valid boundaries, it returns TRUE, indicating a collision; otherwise, it returns FALSE.

```
Boolean wall_collision(Snake *snake){
    return (snake->segments[0].x < PIXEL_SIZE ||
           snake->segments[0].x >= LED_MATRIX_0_WIDTH - PIXEL_SIZE ||
           snake->segments[0].y < PIXEL_SIZE ||
           snake->segments[0].y >= LED_MATRIX_0_HEIGHT - PIXEL_SIZE) ? TRUE : FALSE;
}
```

- snake_collision() function:

This function detects whether the snake's head has collided with its own body. It compares the head's coordinates to those of each body segment. If a match is found, it returns TRUE, indicating a collision; otherwise, it returns FALSE.

```
Boolean snake_collision(Snake *snake){
    for (int i = 1; i < snake->length; ++i) {
        if (snake->segments[0].x == snake->segments[i].x && snake->segments[0].y ==
        ↪  snake->segments[i].y)
            return TRUE;
    }
    return FALSE;
}
```

- snake_collision_with_apple() function:

This function checks if the snake's head is on the same coordinates as the apple. If the coordinates match, it returns TRUE, indicating the apple has been "eaten." Otherwise, it returns FALSE.

```
Boolean snake_collision_with_apple(Snake *snake){
    return (snake->segments[0].x == snake->apple.x && snake->segments[0].y == snake->apple.y)
    ↪  ? TRUE : FALSE;
}
```

- change_head_direction() function:

This function updates the snake's head direction based on user input from the directional pad. It prevents the snake from reversing direction directly (e.g., moving UP when currently moving DOWN).

```c
void change_head_direction(Snake *snake){
    if (*up && snake->segments[0].direction != DOWN)
        snake->segments[0].direction = UP;

    else if (*down && snake->segments[0].direction != UP)
        snake->segments[0].direction = DOWN;

    else if (*left && snake->segments[0].direction != RIGHT)
        snake->segments[0].direction = LEFT;

    else if (*right && snake->segments[0].direction != LEFT)
        snake->segments[0].direction = RIGHT;
}
```

- move_snake_head() function:

This function moves the snake's head one step in its current direction. It adjusts the head's x or y coordinate based on whether the direction is UP, DOWN, LEFT, or RIGHT, maintaining the size of each step (PIXEL_SIZE).

```c
void move_snake_head(Snake *snake){
    if (snake->segments[0].direction == UP)
        snake->segments[0].y -= PIXEL_SIZE;

    else if (snake->segments[0].direction == DOWN)
        snake->segments[0].y += PIXEL_SIZE;

    else if (snake->segments[0].direction == LEFT)
        snake->segments[0].x -= PIXEL_SIZE;

    else
        snake->segments[0].x += PIXEL_SIZE;
}
```

- main function:

The `main()` function orchestrates the entire game, handling initialization, the game loop, and the restart logic.

1. **Initialization**:
    - A `Snake` object named `snake` is created to represent the game's snake.
    - The game's status is initialized to `PLAYING`, indicating the game is active.
    - `restart_flag` is used to track whether the game should be restarted.
    - `cnt` is initialized to zero to serve as a counter for random seed variation and other uses.
2. **Setup**:

   - `create_snake(&snake)` initializes the snake to its starting state (position, direction, and size).
   - `clear_screen()` ensures the LED matrix is cleared before the game starts.

3. **Game Loop**:

   - A nested `while (TRUE)` loop manages the game's execution, allowing for indefinite play.
   - Inside this loop, another loop (`while (gameStatus == PLAYING)`) handles the gameplay while the game is active.

4. **Gameplay**:

   - `clear_screen()` resets the screen at the beginning of each frame.
   - The game checks if the apple's coordinates are `(0, 0)` (unplaced). If so, it calls `init_apple_coordinates(&snake, cnt)` to generate a new position for the apple.
   - `init_game(&snake)` draws the current state of the snake and apple on the LED matrix.
   - `move_snake(&snake)` shifts the body of the snake forward.
   - `change_head_direction(&snake)` updates the snake's direction based on user input.
   - `move_snake_head(&snake)` moves the snake's head in the current direction.
   - `wall_collision(&snake)` and `snake_collision(&snake)` check if the snake hits a wall or itself, respectively. If either returns `TRUE`, `gameStatus` is set to `GAME_OVER`.
   - `snake_collision_with_apple(&snake)` checks if the snake has eaten the apple. If `TRUE`, the snake's length is incremented, and the apple's position is reset.

5. **Frame Delay**:

   - `delay()` introduces a pause between frames to control the speed of the game.
   - The counter `cnt` is incremented to track frame progress and vary the apple's position when needed.

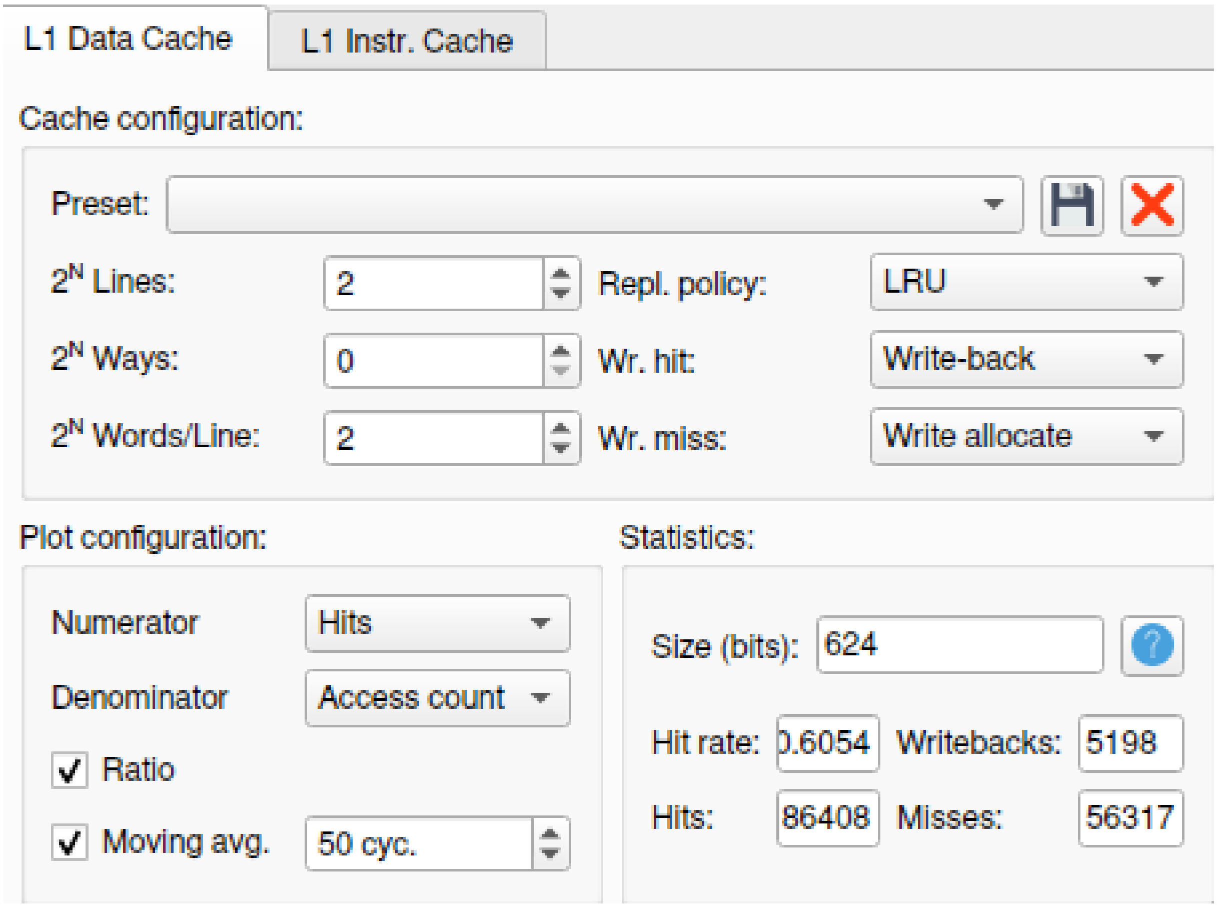
6. **Game Over and Restart**:

   - After `gameStatus` is set to `GAME_OVER`, the outer loop checks if `restart_flag` is set. This flag is activated when the player toggles a specific switch (using `*(switch_base) & 0x01`).
   - If `restart_flag` is `TRUE`, the snake is re-initialized using `create_snake(&snake)`, and the game restarts by resetting `gameStatus` to `PLAYING`.

```
void main(){
    Snake snake;
    Status gameStatus = PLAYING;
    Boolean restart_flag;
    unsigned cnt = 0;

    create_snake(&snake);
    clear_screen();
    while (TRUE) {
        while (gameStatus == PLAYING) {
            clear_screen();
            if (!(snake.apple.x && snake.apple.y)) init_apple_coordinates(&snake, cnt);

            init_game(&snake);
            move_snake(&snake);
            change_head_direction(&snake);
            move_snake_head(&snake);

            gameStatus = (wall_collision(&snake) || snake_collision(&snake)) ? GAME_OVER :
↪   PLAYING;

            if (snake_collision_with_apple(&snake)) {
                ++snake.length;
                snake.apple.x = 0;
                snake.apple.y = 0;
            }

            delay();
            ++cnt;
        }

        restart_flag = (*(switch_base) & 0x01 && gameStatus == GAME_OVER) ? TRUE : FALSE;

        if (restart_flag) {
            create_snake(&snake);
            gameStatus = PLAYING;
        }
    }
}
```

CACHE TESTING

MAPPING WITH 4 LINES



L1 Data Cache | L1 Instr. Cache

Cache configuration:

Preset:

2^N Lines: 2
Repl. policy: LRU

2^N Ways: 0
Wr. hit: Write-back

2^N Words/Line: 2
Wr. miss: Write allocate

Plot configuration:

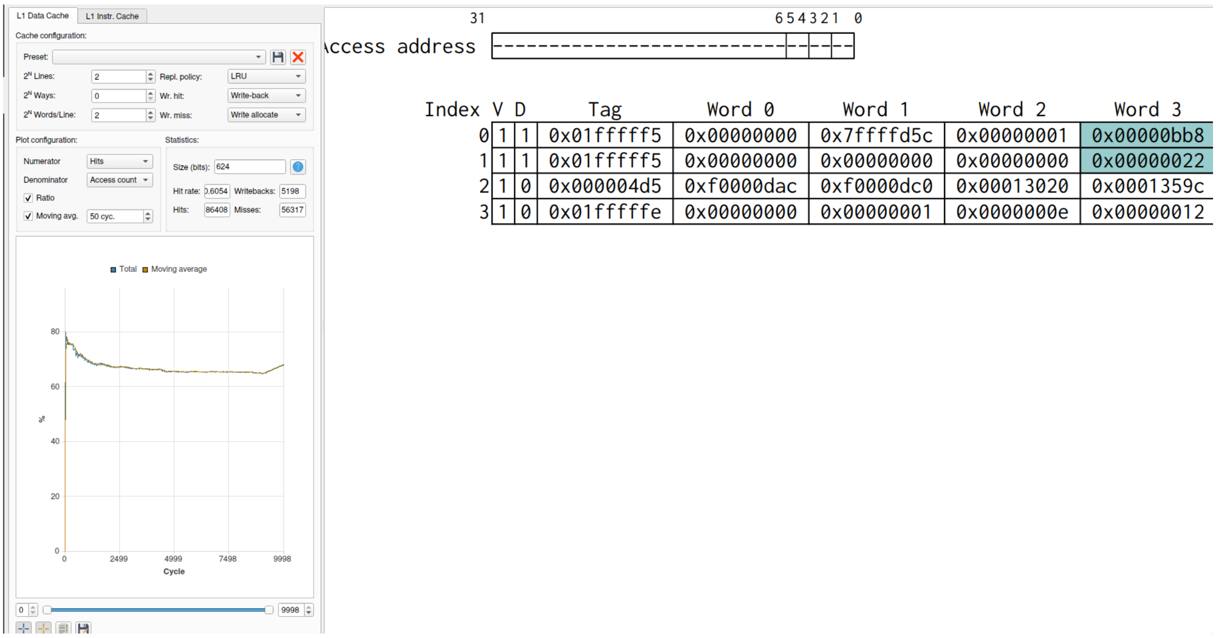
Numerator: Hits
Denominator: Access count
☑ Ratio
☑ Moving avg. 50 cyc.

Statistics:

Size (bits): 624

Hit rate: 0.6054
Writebacks: 5198

Hits: 86408
Misses: 56317



Cache configuration:

Preset:

2^N Lines: 2 Repl. policy: LRU

2^N Ways: 0 Wr. hit: Write-back

2^N Words/Line: 2 Wr. miss: Write allocate

Plot configuration:

Numerator: Hits

Denominator: Access count

☑ Ratio

☑ Moving avg. 50 cyc.

Statistics:

Size (bits): 624

Hit rate: 0.6054 Writebacks: 5198

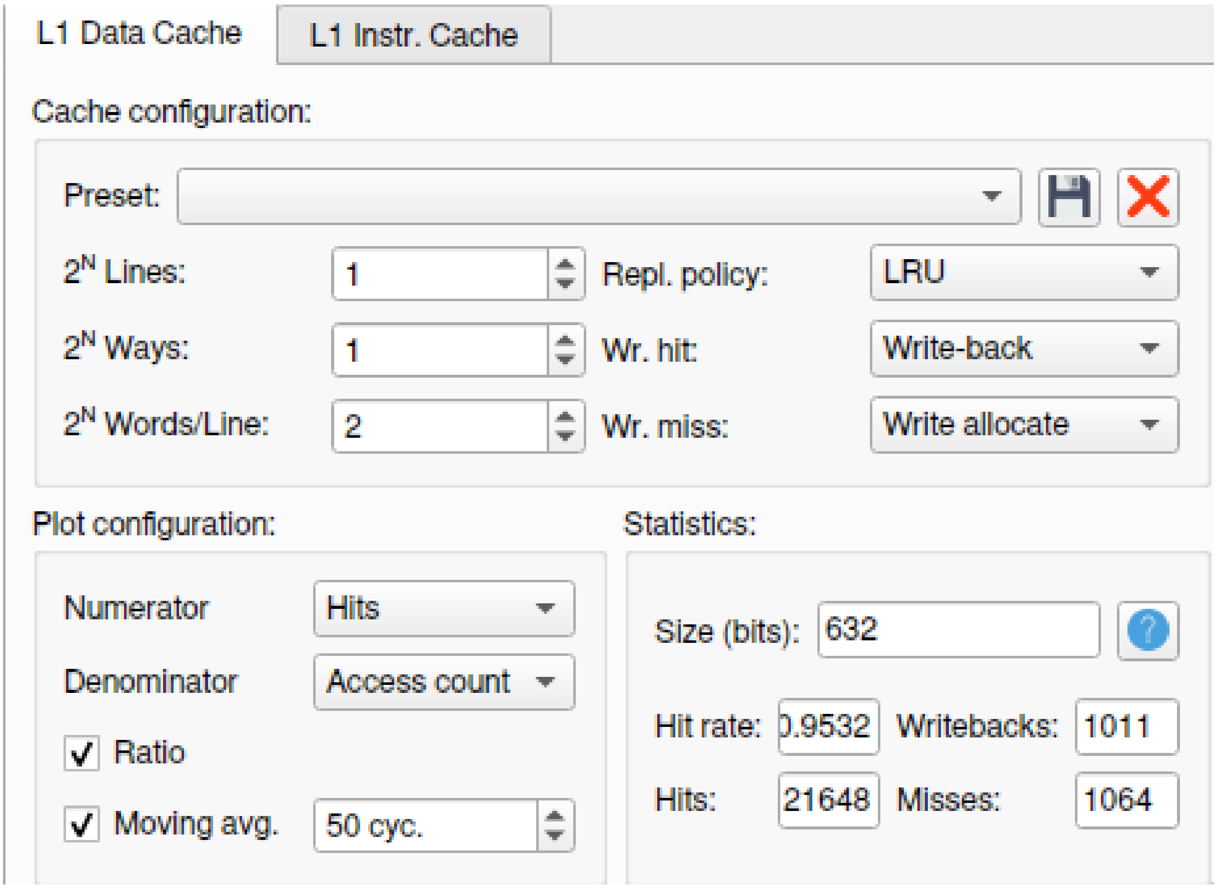
Hits: 86408 Misses: 56317

```
               31                          6 5 4 3 2 1  0
Access address
```

Index	V	D	Tag	Word 0	Word 1	Word 2	Word 3
0	1	1	0x01ffff5	0x00000000	0x7ffffd5c	0x00000001	0x00000bb8
1	1	1	0x01ffff5	0x00000000	0x00000000	0x00000000	0x00000022
2	1	0	0x000004d5	0xf0000dac	0xf0000dc0	0x00013020	0x0001359c
3	1	0	0x01fffffe	0x00000000	0x00000001	0x0000000e	0x00000012

HIT RATE: 0.6054

2 LINES AND 2 WAYS



Cache configuration:

Preset:

2^N Lines: 1

2^N Ways: 1

2^N Words/Line: 2

Repl. policy: LRU

Wr. hit: Write-back

Wr. miss: Write allocate

Plot configuration:

Numerator: Hits

Denominator: Access count

☑ Ratio

☑ Moving avg. 50 cyc.

Statistics:

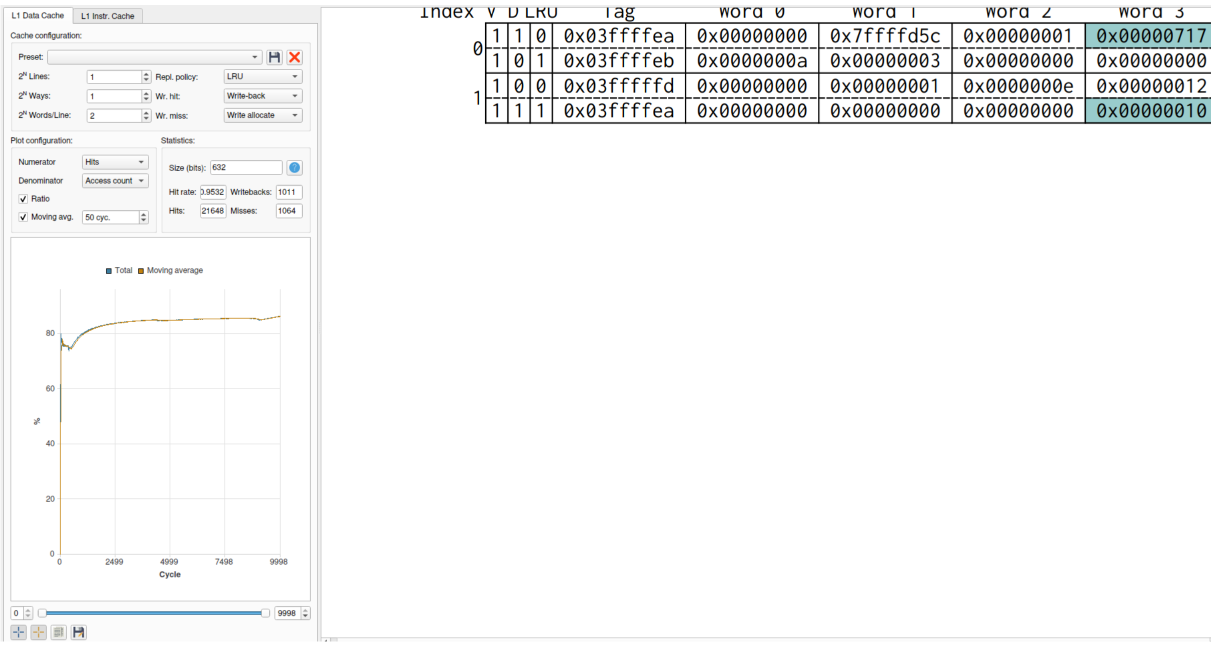
Size (bits): 632

Hit rate: 0.9532

Writebacks: 1011

Hits: 21648

Misses: 1064



Cache configuration:

Preset:

2^N Lines: 1

2^N Ways: 1

2^N Words/Line: 2

Repl. policy: LRU

Wr. hit: Write-back

Wr. miss: Write allocate

Plot configuration:

Numerator: Hits

Denominator: Access count

☑ Ratio

☑ Moving avg. 50 cyc.

Statistics:

Size (bits): 632

Hit rate: 0.9532

Writebacks: 1011

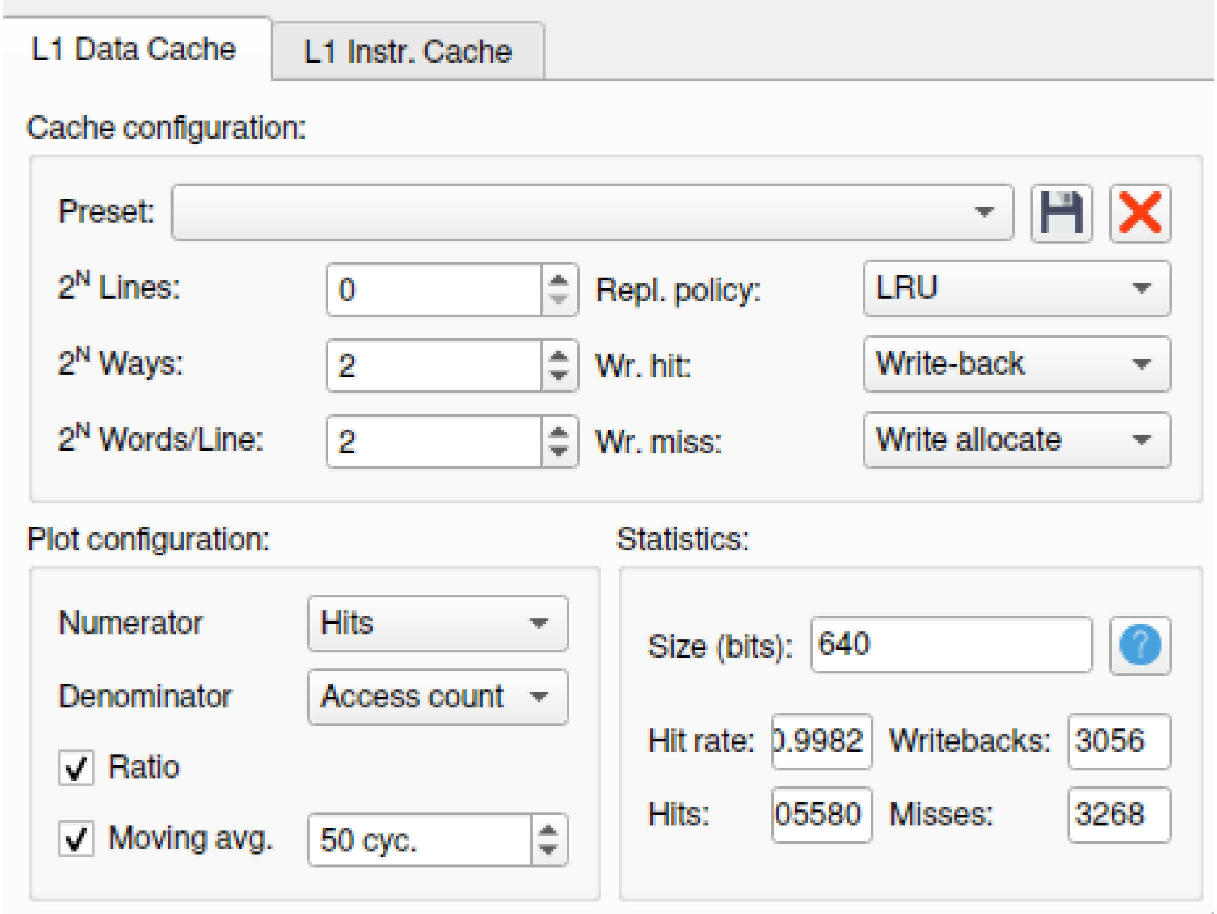
Hits: 21648

Misses: 1064

Index	V	D	LRU	Tag	Word 0	Word 1	Word 2	Word 3
0	1	1	0	0x03ffffea	0x00000000	0x7ffffd5c	0x00000001	0x00000717
	1	0	1	0x03ffffeb	0x0000000a	0x00000003	0x00000000	0x00000000
1	1	0	0	0x03fffffd	0x00000000	0x00000001	0x0000000e	0x00000012
	1	1	1	0x03ffffea	0x00000000	0x00000000	0x00000000	0x00000010

HIT RATE: 0.9532

4 WAYS



Cache configuration:

Preset:

2^N Lines: 0

2^N Ways: 2

2^N Words/Line: 2

Repl. policy: LRU

Wr. hit: Write-back

Wr. miss: Write allocate

Plot configuration:

Numerator: Hits

Denominator: Access count

☑ Ratio

☑ Moving avg.: 50 cyc.

Statistics:

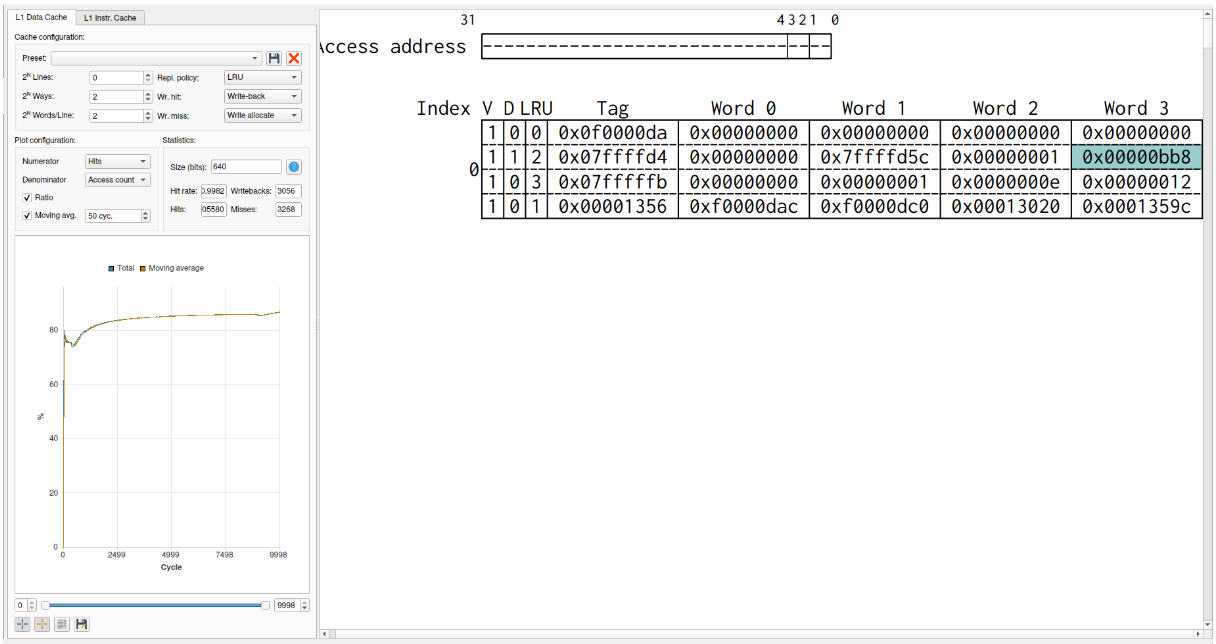
Size (bits): 640

Hit rate:).9982

Writebacks: 3056

Hits: 05580

Misses: 3268



Cache configuration:

Preset:

2^N Lines: 0 Repl. policy: LRU

2^N Ways: 2 Wr. hit: Write-back

2^N Words/Line: 2 Wr. miss: Write allocate

Plot configuration:

Numerator: Hits

Denominator: Access count

☑ Ratio

☑ Moving avg. 50 cyc.

Statistics:

Size (bits): 640

Hit rate: 0.9982 Writebacks: 3056

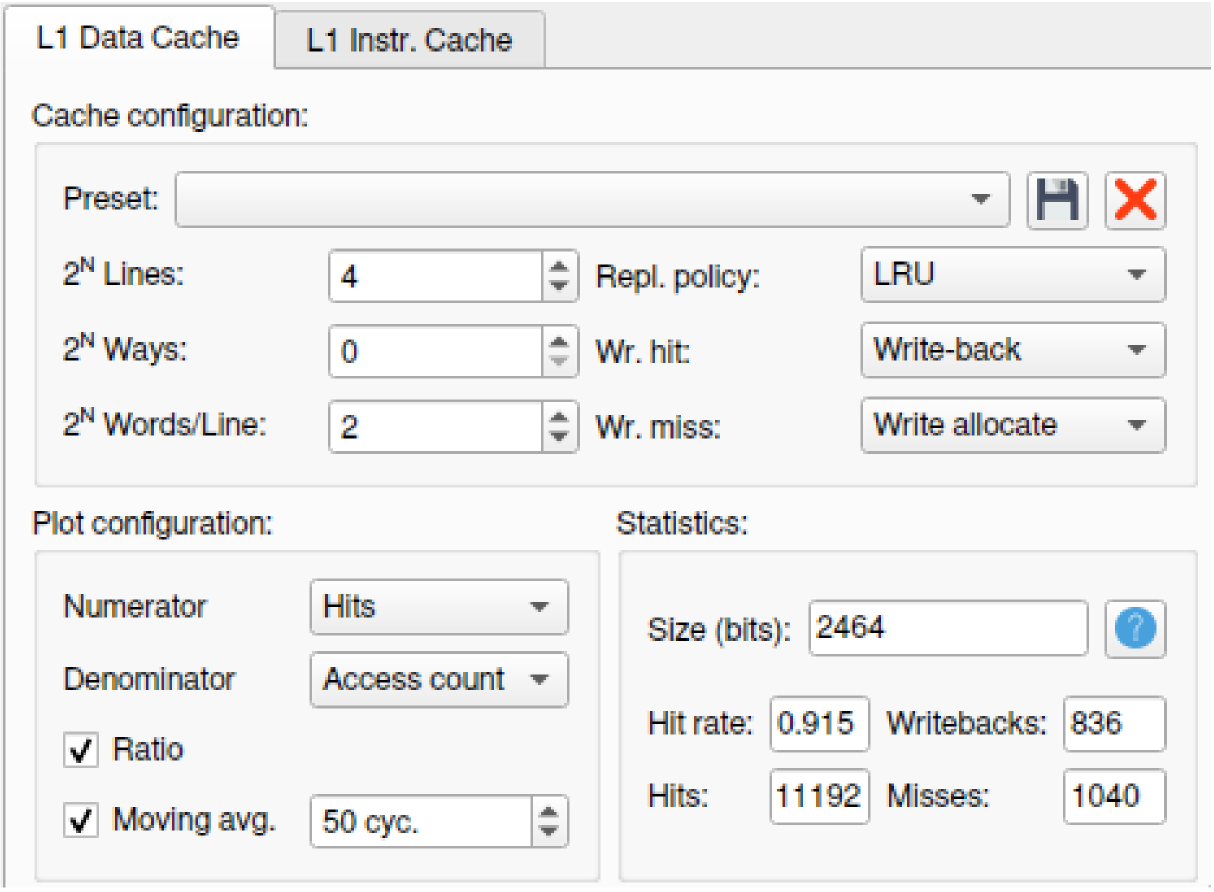
Hits: 05580 Misses: 3268

Access address

Index	V	D	LRU	Tag	Word 0	Word 1	Word 2	Word 3
0	1	0	0	0x0f0000da	0x00000000	0x00000000	0x00000000	0x00000000
	1	1	2	0x07ffffd4	0x00000000	0x7ffffd5c	0x00000001	0x00000bb8
	1	0	3	0x07fffffb	0x00000000	0x00000001	0x0000000e	0x00000012
	1	0	1	0x00001356	0xf0000dac	0xf0000dc0	0x00013020	0x0001359c

HIT RATE: 0.9982

16 LINES



Cache configuration:

Preset:

2^N Lines: 4

Repl. policy: LRU

2^N Ways: 0

Wr. hit: Write-back

2^N Words/Line: 2

Wr. miss: Write allocate

Plot configuration:

Numerator: Hits

Denominator: Access count

☑ Ratio

☑ Moving avg. 50 cyc.

Statistics:

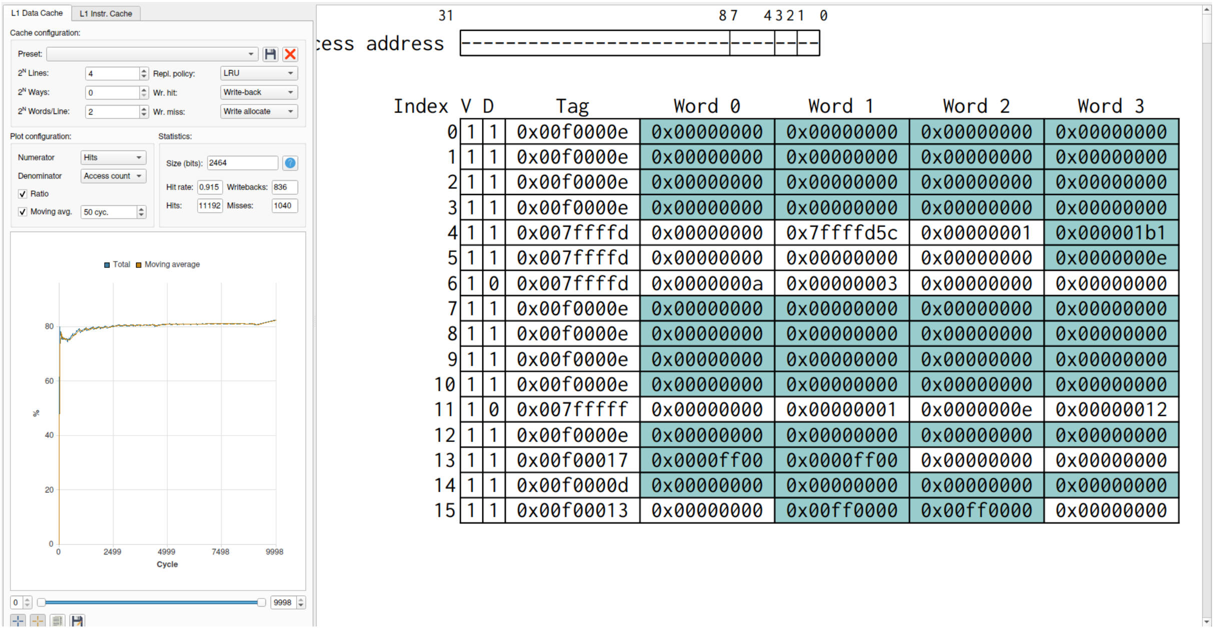
Size (bits): 2464

Hit rate: 0.915

Writebacks: 836

Hits: 11192

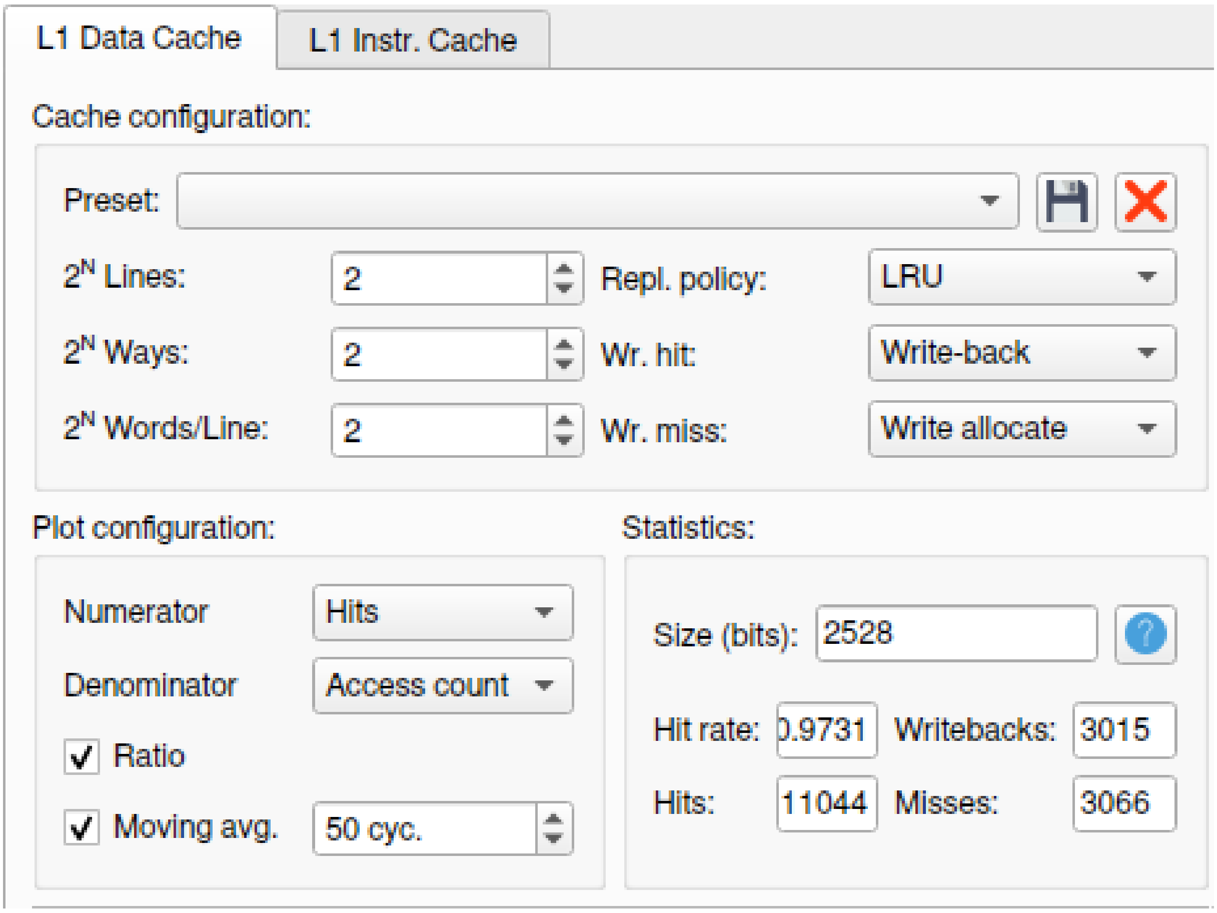
Misses: 1040



Index	V	D	Tag	Word 0	Word 1	Word 2	Word 3
0	1	1	0x00f0000e	0x00000000	0x00000000	0x00000000	0x00000000
1	1	1	0x00f0000e	0x00000000	0x00000000	0x00000000	0x00000000
2	1	1	0x00f0000e	0x00000000	0x00000000	0x00000000	0x00000000
3	1	1	0x00f0000e	0x00000000	0x00000000	0x00000000	0x00000000
4	1	1	0x007ffffd	0x00000000	0x7ffffd5c	0x00000001	0x000001b1
5	1	1	0x007ffffd	0x00000000	0x00000000	0x00000000	0x0000000e
6	1	0	0x007ffffd	0x0000000a	0x00000003	0x00000000	0x00000000
7	1	1	0x00f0000e	0x00000000	0x00000000	0x00000000	0x00000000
8	1	1	0x00f0000e	0x00000000	0x00000000	0x00000000	0x00000000
9	1	1	0x00f0000e	0x00000000	0x00000000	0x00000000	0x00000000
10	1	1	0x00f0000e	0x00000000	0x00000000	0x00000000	0x00000000
11	1	0	0x007fffff	0x00000000	0x00000001	0x0000000e	0x00000012
12	1	1	0x00f0000e	0x00000000	0x00000000	0x00000000	0x00000000
13	1	1	0x00f00017	0x0000ff00	0x0000ff00	0x00000000	0x00000000
14	1	1	0x00f0000d	0x00000000	0x00000000	0x00000000	0x00000000
15	1	1	0x00f00013	0x00000000	0x00ff0000	0x00ff0000	0x00000000

HIT RATE: 0.9663

4 LINES AND 4 WAYS



Cache configuration:

Preset:

2^N Lines: 2

2^N Ways: 2

2^N Words/Line: 2

Repl. policy: LRU

Wr. hit: Write-back

Wr. miss: Write allocate

Plot configuration:

Numerator: Hits

Denominator: Access count

☑ Ratio

☑ Moving avg. 50 cyc.

Statistics:

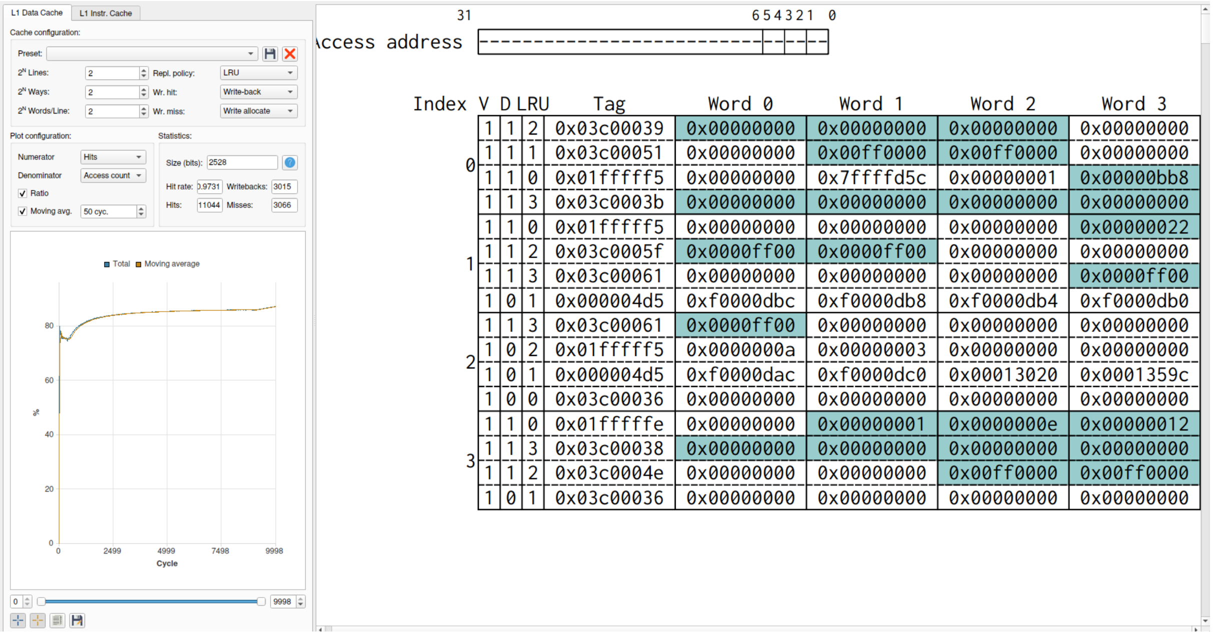
Size (bits): 2528

Hit rate: 0.9731

Writebacks: 3015

Hits: 11044

Misses: 3066



Cache configuration:

Preset:

2^N Lines: 2 Repl. policy: LRU

2^N Ways: 2 Wr. hit: Write-back

2^N Words/Line: 2 Wr. miss: Write allocate

Plot configuration:

Numerator: Hits

Denominator: Access count

☑ Ratio

☑ Moving avg. 50 cyc.

Statistics:

Size (bits): 2528

Hit rate: 0.9731 Writebacks: 3015

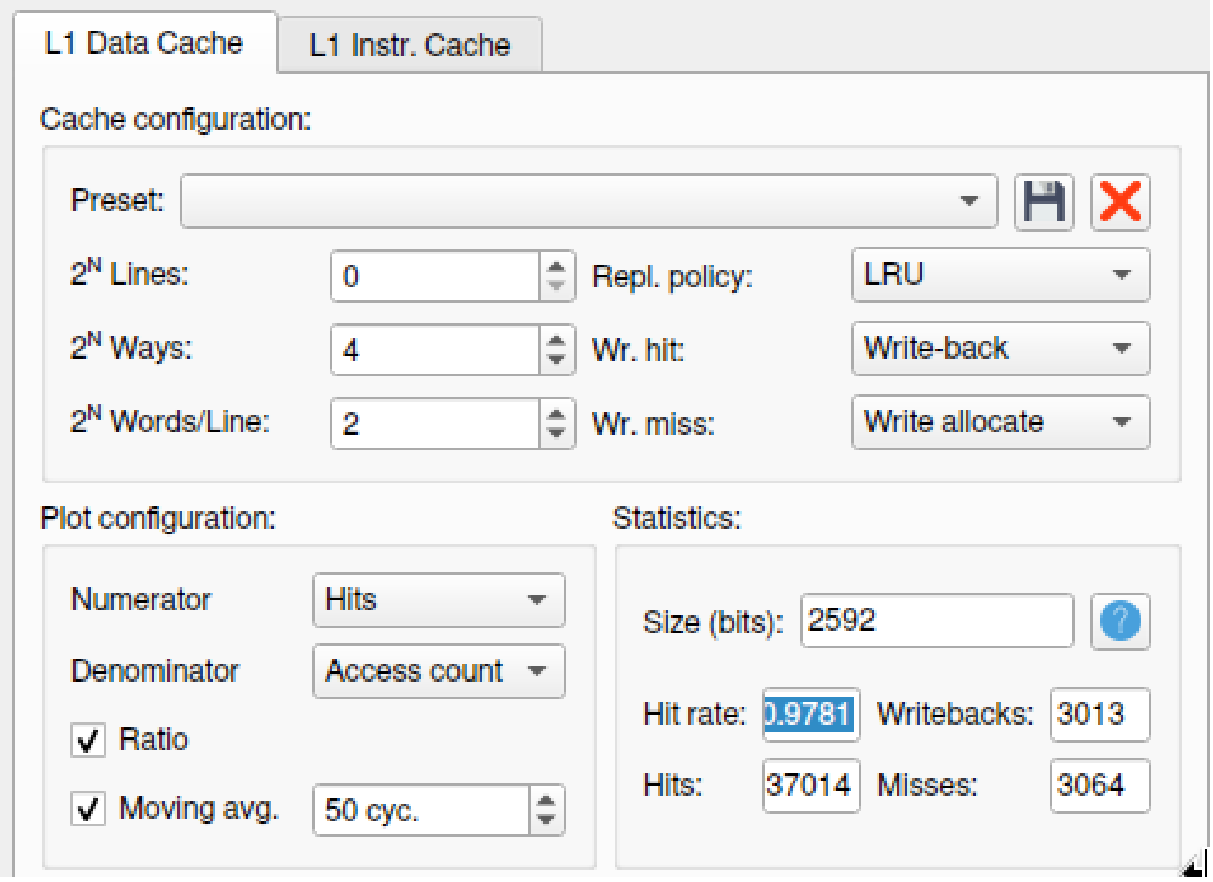
Hits: 11044 Misses: 3066

```
        31                      6 5 4 3 2 1  0
Access address  |------------------------|-|-|-|
```

Index	V	D	LRU	Tag	Word 0	Word 1	Word 2	Word 3
0	1	1	2	0x03c00039	0x00000000	0x00000000	0x00000000	0x00000000
	1	1	1	0x03c00051	0x00000000	0x00ff0000	0x00ff0000	0x00000000
	1	1	0	0x01fffff5	0x00000000	0x7ffffd5c	0x00000001	0x00000bb8
	1	1	3	0x03c0003b	0x00000000	0x00000000	0x00000000	0x00000000
1	1	1	0	0x01fffff5	0x00000000	0x00000000	0x00000000	0x00000022
	1	1	2	0x03c0005f	0x0000ff00	0x0000ff00	0x00000000	0x00000000
	1	1	3	0x03c00061	0x00000000	0x00000000	0x00000000	0x0000ff00
	1	0	1	0x000004d5	0xf0000dbc	0xf0000db8	0xf0000db4	0xf0000db0
2	1	1	3	0x03c00061	0x0000ff00	0x00000000	0x00000000	0x00000000
	1	0	2	0x01fffff5	0x0000000a	0x00000003	0x00000000	0x00000000
	1	0	1	0x000004d5	0xf0000dac	0xf0000dc0	0x00013020	0x0001359c
	1	0	0	0x03c00036	0x00000000	0x00000000	0x00000000	0x00000000
3	1	1	0	0x01fffffe	0x00000000	0x00000001	0x0000000e	0x00000012
	1	1	3	0x03c00038	0x00000000	0x00000000	0x00000000	0x00000000
	1	1	2	0x03c0004e	0x00000000	0x00000000	0x00ff0000	0x00ff0000
	1	0	1	0x03c00036	0x00000000	0x00000000	0x00000000	0x00000000

HIT RATE: 0.9731

16 WAYS



Cache configuration:

Preset:

2^N Lines: 0

2^N Ways: 4

2^N Words/Line: 2

Repl. policy: LRU

Wr. hit: Write-back

Wr. miss: Write allocate

Plot configuration:

Numerator: Hits

Denominator: Access count

☑ Ratio

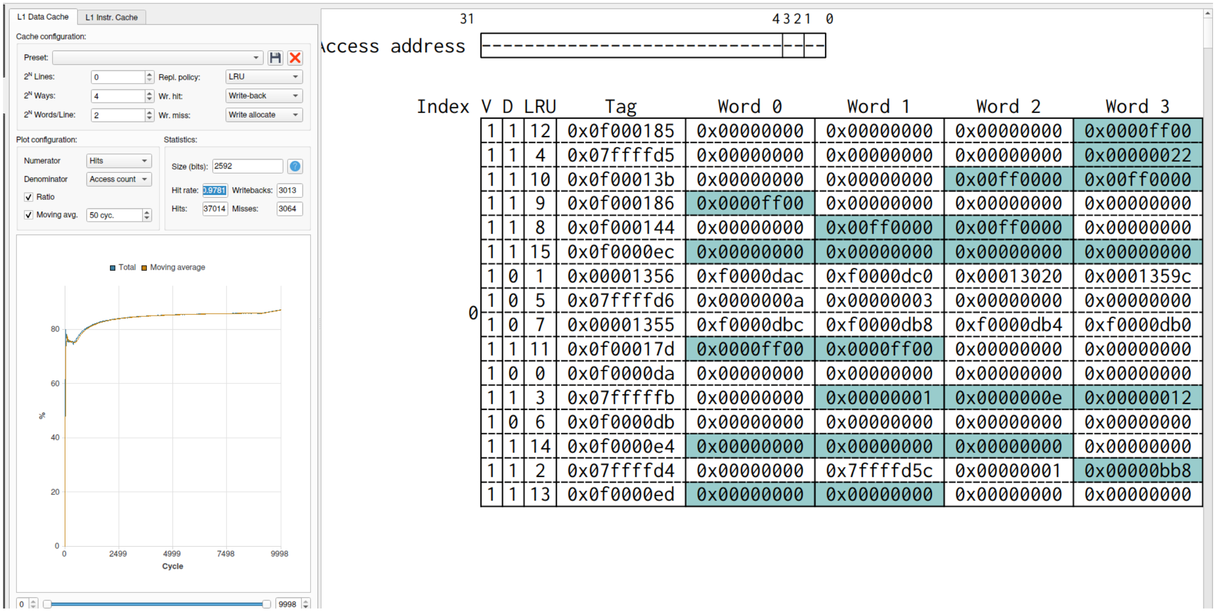
☑ Moving avg. 50 cyc.

Statistics:

Size (bits): 2592

Hit rate: 0.9781 Writebacks: 3013

Hits: 37014 Misses: 3064



```
            31                          4321  0
Access address  [---------------------------|--|--]
```

Index	V	D	LRU	Tag	Word 0	Word 1	Word 2	Word 3
0	1	1	12	0x0f000185	0x00000000	0x00000000	0x00000000	0x0000ff00
	1	1	4	0x07ffffd5	0x00000000	0x00000000	0x00000000	0x00000022
	1	1	10	0x0f00013b	0x00000000	0x00000000	0x00ff0000	0x00ff0000
	1	1	9	0x0f000186	0x0000ff00	0x00000000	0x00000000	0x00000000
	1	1	8	0x0f000144	0x00000000	0x00ff0000	0x00ff0000	0x00000000
	1	1	15	0x0f0000ec	0x00000000	0x00000000	0x00000000	0x00000000
	1	0	1	0x00001356	0xf0000dac	0xf0000dc0	0x00013020	0x0001359c
	1	0	5	0x07ffffd6	0x0000000a	0x00000003	0x00000000	0x00000000
	1	0	7	0x00001355	0xf0000dbc	0xf0000db8	0xf0000db4	0xf0000db0
	1	1	11	0x0f00017d	0x0000ff00	0x0000ff00	0x00000000	0x00000000
	1	0	0	0x0f0000da	0x00000000	0x00000000	0x00000000	0x00000000
	1	1	3	0x07fffffb	0x00000000	0x00000001	0x0000000e	0x00000012
	1	0	6	0x0f0000db	0x00000000	0x00000000	0x00000000	0x00000000
	1	1	14	0x0f0000e4	0x00000000	0x00000000	0x00000000	0x00000000
	1	1	2	0x07ffffd4	0x00000000	0x7ffffd5c	0x00000001	0x00000bb8
	1	1	13	0x0f0000ed	0x00000000	0x00000000	0x00000000	0x00000000

HIT RATE: 0.9781

BEST HIT RATE

0.9982

CONCLUSION

In this project, I implemented the Snake game on a hardware platform, focusing on optimizing memory usage through various cache configurations. By testing different cache mapping strategies, I analyzed their impact on performance, specifically their effect on hit rates. This experience also required creating custom solutions for random number generation, given the limitations of the development environment. Through this process, I gained a deeper understanding of memory management, hardware interfacing, and the importance of optimizing code for resource-constrained systems. Ultimately, this project not only improved my technical skills but also demonstrated the crucial role of efficient programming in achieving smooth and responsive gameplay.