

Howard University  
College of Engineering and Architecture  
Computer Organization II – Benchmark Project

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Computer Specifications:

Brand of CPU: Apple Silicon M2  
Model of CPU: Apple M2  
Number of Cores on CPU: 8  
The Clock Rate of CPU in GHz: 1952 MHz  
Memory: 16 GB  
Speed of Memory: LPDDR5  
Capacity of Hard Drive: 512 GB  
Type of Hard Drive: SSD  
Max Sequential Read Speed: 3.5 GB/s  
Max Sequential Write Speed: 2.8 GB/s  
Max Random Read Speed: 1 GB/s  
Max Random Write Speed: 800 MB/s

32-bit Integer Operation Benchmark – 166.989505 seconds

```
Users > daniellemcintosh > Desktop > Benchmark Project > test.c > main()
1  #include <stdio.h>
2  #include <time.h>
3
4  int main(){
5      clock_t start, end;
6      int32_t int1 = 1962, int2 = 2002, int_sum = 0, int_product = 0, int_quotient = 0;
7      start = clock();
8      for (long i = 0; i < 1000000000; i++){
9          /* 10^10 additions (of integer constants)*/
10         int_sum = int1 + int2;
11     }
12     for (long i = 0; i < 5000000000; i++){
13         /* 5 x 10^9 multiplications (of integer constants)*/
14         int_product = int1 * int2;
15     }
16     for (long i = 0; i < 2000000000; i++){
17         /* 2 x 10^9 divisions (of integer constants)*/
18         int_quotient = int2 / int1;
19     }
20     end = clock();
21     printf("32-bit Integer Operation Benchmark");
22 }
```

PROBLEMS OUTPUT JUPYTER: VARIABLES TERMINAL DEBUG CONSOLE C/C++ Compile Run - Benchmark Project

```
cd "/Users/daniellemcintosh/Desktop/Benchmark Project"
./"test"
(base) daniellemcintosh@Danielles-MacBook-Air ~ % cd "/Users/daniellemcintosh/Desktop/Benchmark Project"
(base) daniellemcintosh@Danielles-MacBook-Air Benchmark Project % ./"test"
32-bit Integer Operation Benchmark
Reference Time: 100 seconds
Time Taken: 166.989505 seconds
(base) daniellemcintosh@Danielles-MacBook-Air Benchmark Project %
```

## 64-bit Floating Point Operation Benchmark

```
Users > daniellemcintosh > Desktop > Benchmark Project > C test.c > main()
1  #include <stdio.h>
2  #include <time.h>
3
4  int main(){
5      double x = 285454.5482, y = 2356785.5348, result;
6      clock_t start, end;
7      start = clock();
8      for (long i = 0; i < 10000000000; i++) {
9          /* 10^10 additions (of floating constants)*/
10         result = x + y;
11     }
12     for (long i = 0; i < 5000000000; i++){
13         /* 5 x 10^9 multiplications (of floating constants)*/
14         result = x * y;
15     }
16     for (long i = 0; i < 2000000000; i++){
17         /* 2 X 10^9 divisions (of floating constants)*/
18         result = x / y;
19     }
20     end = clock();
21     printf("Reference Time: 100 seconds");
22 }
```

PROBLEMS OUTPUT JUPYTER: VARIABLES TERMINAL DEBUG CONSOLE C/C++ Compile Run - Benchmark Project

```
cd "/Users/daniellemcintosh/Desktop/Benchmark Project"
./"test"
(base) daniellemcintosh@Danielles-MacBook-Air ~ % cd "/Users/daniellemcintosh/Desktop/Benchmark Project"
(base) daniellemcintosh@Danielles-MacBook-Air Benchmark Project % ./"test"
Reference Time: 100 seconds
Time taken for 10000000000 floating point multiplications: 164.29 seconds
(base) daniellemcintosh@Danielles-MacBook-Air Benchmark Project %
```

## Memory Benchmark

```
Users > daniellemcintosh > Desktop > Benchmark Project > C test.c > main()
1  #include <stdio.h>
2  #include <stdlib.h>
3  #include <time.h>
4
5  #define SIZE 500000
6  #define BYTES_PER_ELEMENT 4
7  #define NUM_ELEMENTS 50000
8
9  int main(){
10     int i;
11     clock_t start, end;
12     int *data = malloc(NUM_ELEMENTS * BYTES_PER_ELEMENT);
13     if (data == NULL) {
14         printf("Error allocating memory!\n");
15         return 1;
16     }
17     start = clock();
18     for (int a = 0; a < 1000000; a++){
19         // Write to array elements
20         for (int i = 0; i < 50000; i++){
21             data[i] = i;
22         }
23     }
24 }
```

PROBLEMS OUTPUT JUPYTER: VARIABLES TERMINAL DEBUG CONSOLE C/C++ Compile Run - Benchmark Project

```
cd "/Users/daniellemcintosh/Desktop/Benchmark Project"
./"test"
(base) daniellemcintosh@Danielles-MacBook-Air ~ % cd "/Users/daniellemcintosh/Desktop/Benchmark Project"
(base) daniellemcintosh@Danielles-MacBook-Air Benchmark Project % ./"test"
Reference Time: 100 sseconds
Time taken to read and write from array elements: 15.374602 seconds
(base) daniellemcintosh@Danielles-MacBook-Air Benchmark Project %
```

## Hard Drive Benchmark 1

```

Users > daniellemcintosh > Desktop > Benchmark Project > C test.c > main()
1  #include <stdio.h>
2  #include <time.h>
3
4  #define FILE_SIZE 1000000000
5  #define BLOCK_SIZE 100
6
7  int main(){
8      FILE *fp;
9      char buf[BLOCK_SIZE];
10
11     // Open the input.bin file for writing
12     fp = fopen("input.bin", "wb");
13     if (!fp){
14         printf("\nError opening the 'input.bin' file for writing.");
15         return 1;
16     }
17
18     for (int i = 0; i < FILE_SIZE / BLOCK_SIZE; i++) {
19         // Write a block of data
20         fwrite(buf, BLOCK_SIZE, 1, fp);
21     }
22 }

```

PROBLEMS OUTPUT JUPYTER: VARIABLES TERMINAL DEBUG CONSOLE C/C++ Compile Run - Benchmark Project + v

```

(base) daniellemcintosh@Danielles-MacBook-Air Benchmark Project % cd "/Users/daniellemcintosh/Desktop/Benchmark Project"
(base) daniellemcintosh@Danielles-MacBook-Air Benchmark Project % ./"test"

Reference Time: 250 seconds
Time taken to read and write 1000000000 bytes: 1.811907 seconds
(base) daniellemcintosh@Danielles-MacBook-Air Benchmark Project %

```

## Hard Drive Benchmark 2

```

Users > daniellemcintosh > Desktop > Benchmark Project > C test.c > ...
1  #include <stdio.h>
2  #include <time.h>
3
4  #define FILE_SIZE 1000000000
5  #define BLOCK_SIZE 10000
6
7  int main(){
8      FILE *fp;
9      char buf[BLOCK_SIZE];
10
11     // Open the input.bin file for writing
12     fp = fopen("input.bin", "wb");
13     if (!fp){
14         printf("\nError opening the 'input.bin' file for writing.");
15         return 1;
16     }
17
18     for (int i = 0; i < FILE_SIZE / BLOCK_SIZE; i++) {
19         // Write a block of data
20         fwrite(buf, BLOCK_SIZE, 1, fp);
21     }
22     // Close the file
23     fclose(fp);
24 }

```

PROBLEMS OUTPUT JUPYTER: VARIABLES TERMINAL DEBUG CONSOLE C/C++ Compile Run - Benchmark Project + v

```

(base) daniellemcintosh@Danielles-MacBook-Air Benchmark Project % cd "/Users/daniellemcintosh/Desktop/Benchmark Project"
(base) daniellemcintosh@Danielles-MacBook-Air Benchmark Project % ./"test"

Reference Time: 250 seconds
Time taken to read and write 1000000000 bytes: 1.062705 seconds
(base) daniellemcintosh@Danielles-MacBook-Air Benchmark Project %

```

Compiled successfully!

Table Showing Benchmark Results

	Reference Time (s)	Execution Time (s)	Reference: Execution Time
Integer	100	163.990	0.610
Float	100	164.290	0.609
Memory	100	15.375	6.504
Hard Drive 1	250	1.812	237.969
Hard Drive 2	10	1.063	9.407

Geometric Mean:  $\sqrt[n]{\sum_{i=1}^n \text{Execution Time Ratio}_i}$

$$= \sqrt[5]{0.610 \times 0.609 \times 6.504 \times 237.969 \times 9.407}$$

$$= \sqrt[5]{5408.77842}$$

$$= 5.579815488$$