

Practica 5

Realizado por: Juan Sánchez Rodríguez

Apartado A

Lo primero que hemos hecho es consultar el modelo usando lscpu:

```
srjuan@eil40163:~/Escritorio/Home/EC/P5$ lscpu
Arquitectura:          x86_64
modo(s) de operación de las CPUs:32-bit, 64-bit
Orden de bytes:        Little Endian
CPU(s):                4
On-line CPU(s) list:   0-3
Hilo(s) de procesamiento por núcleo:1
Núcleo(s) por «socket»:4
Socket(s):             1
Modo(s) NUMA:          1
ID de fabricante:      GenuineIntel
Familia de CPU:         6
Modelo:                60
Model name:             Intel(R) Core(TM) i5-4460 CPU @ 3.20GHz
Revision:              3
CPU MHz:               926.367
CPU max MHz:           3400,0000
CPU min MHz:           800,0000
BogoMIPS:              6385.25
Virtualización:        VT-x
Caché L1d:             32K
Caché L1i:             32K
Caché L2:              256K
Caché L3:              6144K
NUMA node0 CPU(s):     0-3
Flags:                 fpu vme de pse tsc msr pae mce cx8 apic sep mtrr pge mca
cmov pat pse36 clflush dts acpi mmx fxsr sse sse2 ss ht tm pbe syscall nx pdpe1g
b rdtscp lm constant_tsc arch_perfmon pebs bts rep_good nopl xtopology nonstop_t
sc aperfmperf eagerfpu pni pclmulqdq dtes64 monitor ds_cpl vmx est tm2 sse3 sdb
g fma cx16 xtpr pdcm pcid sse4_1 sse4_2 x2apic movbe popcnt tsc_deadline_timer a
es xsave avx f16c rdrand lahf_lm abm epb tpr_shadow vnmi flexpriority ept vpid f
sgsbase tsc_adjust bmi1 avx2 smep bmi2 erms invpcid xsaveopt dtherm ida arat pln
pts
```

Después usamos make info para saber el tamaño de línea:

```
srjuan@eil40163:~/Escritorio/Home/EC/P5$ make info
line size = 64B
cache size = 32K/256K/6144K/
cache level = 1/1/2/3/
cache type = Data/Instruction/Unified/Unified/
srjuan@eil40163:~/Escritorio/Home/EC/P5$
```

Ahora que sabemos gracias a lscpu nuestro modelo lo buscamos en cpu world para ver los detalles de la caché:

Cache details				
Cache:	L1 data	L1 instruction	L2	L3
Size:	4 x 32 KB	4 x 32 KB	4 x 256 KB	6 MB
Associativity:	8-way set associative	8-way set associative	8-way set associative	12-way set associative
Line size:	64 bytes	64 bytes	64 bytes	64 bytes
Comments:	Direct-mapped	Direct-mapped	Non-inclusive Direct-mapped	Inclusive Shared between all cores

Después de ver esto hacemos la siguiente modificación en line.cc, añadiendo así el xor:

```
#include <algorithm>    // nth_element
#include <array>         // array
#include <chrono>        // high_resolution_clock
#include <iomanip>        // setw
#include <iostream>      // cout
#include <vector>        // vector

using namespace std::chrono;

const unsigned MAXLINE = 1024; // maximum line size to test
const unsigned GAP = 12;      // gap for cout columns
const unsigned REP = 100;     // number of repetitions of every test

int main()
{
    std::cout << "#"
               << std::setw(GAP - 1) << "line (B)"
               << std::setw(GAP + 1) << "time (µs)"
               << std::endl;

    for (unsigned line = 1; line <= MAXLINE; line <= 1) // line in bytes
    {
        std::vector<duration<double>, std::micro>> score(REP);

        for (auto &s: score)
        {
            std::vector<char> bytes(1 << 24); // 16MB

            auto start = high_resolution_clock::now();

            for (unsigned i = 0; i < bytes.size(); i += line)
                bytes[i] ^= 1;

            auto stop = high_resolution_clock::now();

            s = stop - start;
        }

        std::nth_element(score.begin(),
                        score.begin() + score.size() / 2,
                        score.end());

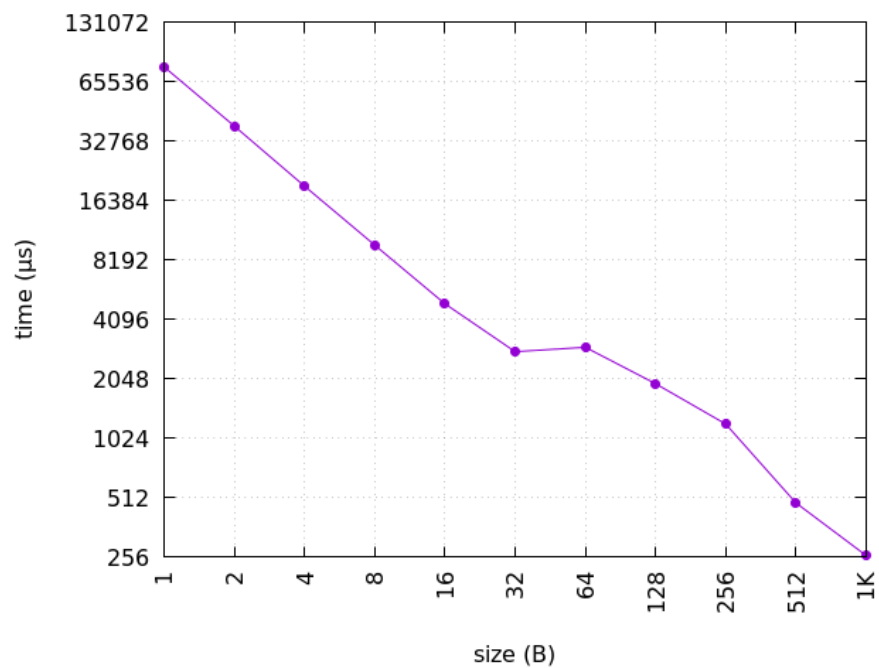
        std::cout << std::setw(GAP) << line
                  << std::setw(GAP) << std::fixed << std::setprecision(1)
                  << std::setw(GAP) << score[score.size() / 2].count()
                  << std::endl;
    }
}
```

Una vez añadido lo compilamos con -O0, -O1, -O2, -Ofast para ver cual es mejor:

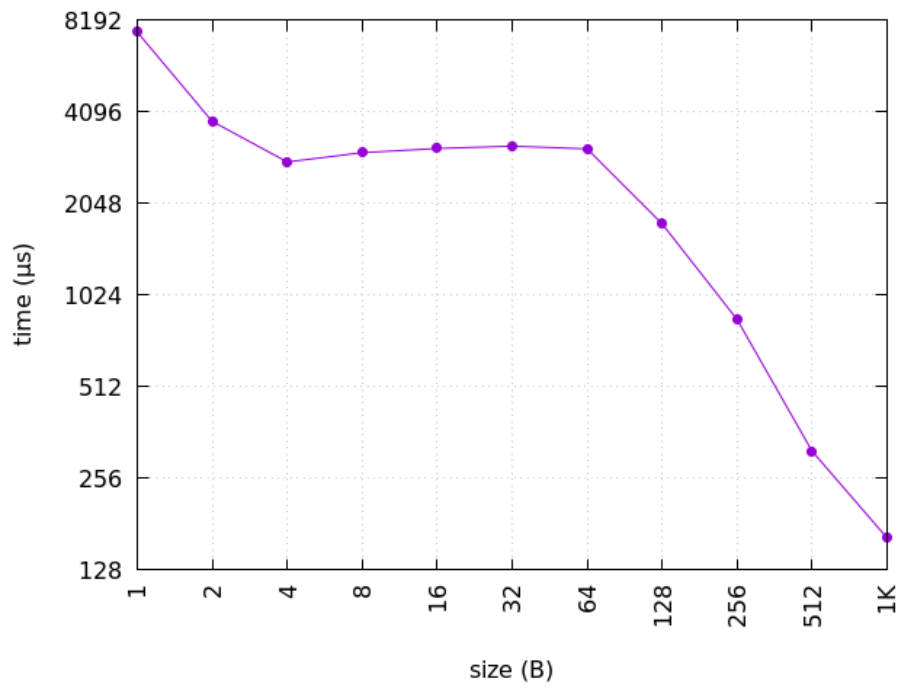
<div><div><div>-O0</div><table><tr><th>#</th><th>line (B)</th><th>time (µs)</th></tr><tr><td>1</td><td>77777.9</td><td></td></tr><tr><td>2</td><td>38998.8</td><td></td></tr><tr><td>4</td><td>19362.5</td><td></td></tr><tr><td>8</td><td>9741.9</td><td></td></tr><tr><td>16</td><td>4911.9</td><td></td></tr><tr><td>32</td><td>2810.7</td><td></td></tr><tr><td>64</td><td>2958.3</td><td></td></tr><tr><td>128</td><td>1934.6</td><td></td></tr><tr><td>256</td><td>1208.7</td><td></td></tr><tr><td>512</td><td>481.7</td><td></td></tr><tr><td>1024</td><td>260.9</td><td></td></tr></table></div></div>	#	line (B)	time (µs)	1	77777.9		2	38998.8		4	19362.5		8	9741.9		16	4911.9		32	2810.7		64	2958.3		128	1934.6		256	1208.7		512	481.7		1024	260.9		<div><div><div>-O1</div><table><tr><th>#</th><th>line (B)</th><th>time (µs)</th></tr><tr><td>1</td><td>7468.2</td><td></td></tr><tr><td>2</td><td>3801.8</td><td></td></tr><tr><td>4</td><td>2798.5</td><td></td></tr><tr><td>8</td><td>3002.5</td><td></td></tr><tr><td>16</td><td>3098.2</td><td></td></tr><tr><td>32</td><td>3152.7</td><td></td></tr><tr><td>64</td><td>3089.0</td><td></td></tr><tr><td>128</td><td>1753.3</td><td></td></tr><tr><td>256</td><td>850.6</td><td></td></tr><tr><td>512</td><td>314.2</td><td></td></tr><tr><td>1024</td><td>163.1</td><td></td></tr></table></div></div>	#	line (B)	time (µs)	1	7468.2		2	3801.8		4	2798.5		8	3002.5		16	3098.2		32	3152.7		64	3089.0		128	1753.3		256	850.6		512	314.2		1024	163.1	
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A continuación presentaré las gráficas:

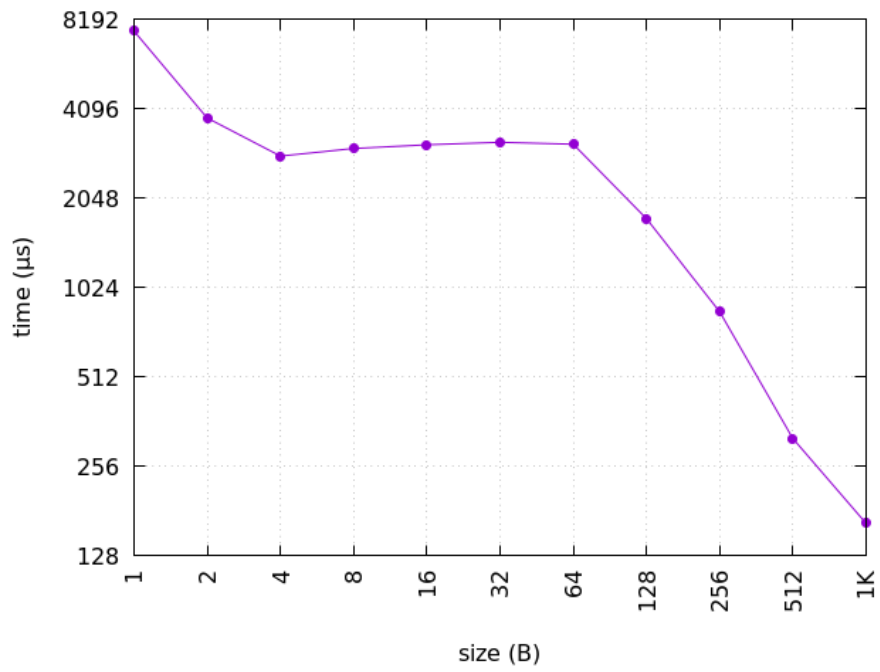
-O0



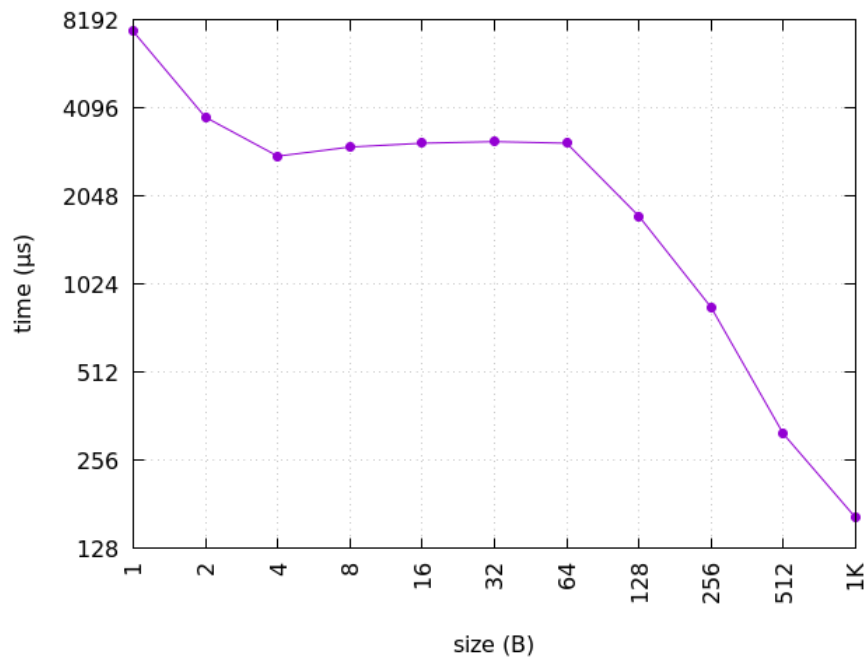
-O1



-O2



-Ofast



Cómo podemos apreciar menos -O0, las otras tres son mucho mejores y muy parecidas entre sí

Apartado B

El trabajo de esta semana consiste en adivinar los tamaños de caché de los ordenadores que estamos usando. Estos datos se pueden adivinar sabiendo el modelo del procesador:

```
srjuan@e1140163:~/Escritorio/Home/EC/PS$ lscpu
Arquitectura:          x86_64
modo(s) de operación de las CPUs: 32-bit, 64-bit
Orden de bytes:        Little Endian
CPU(s):                4
On-line CPU(s) list:   0-3
Hilo(s) de procesamiento por núcleo: 1
Núcleo(s) por «socket»: 4
Socket(s):             1
Modo(s) NUMA:          1
ID de fabricante:      GenuineIntel
Familia de CPU:         6
Modelo:                 60
Model name:             Intel(R) Core(TM) i5-4460 CPU @ 3.20GHz
Revisión:               3
CPU MHz:                926.367
CPU max MHz:            3400,0000
CPU min MHz:            800,0000
BogoMIPS:               6385.25
Virtualización:         VT-x
Caché L1d:              32K
Caché L1i:              32K
Caché L2:               256K
Caché L3:               6144K
NUMA node0 CPU(s):      0-3
Flags:                  fpu vme de pse tsc msr pae mce cx8 apic sep mtrr pge mca
cmov pat pse36 clflush dts acpi mmx fxsr sse sse2 ss ht tm pbe syscall nx pdpe1g
b rdtscp lm constant_tsc arch_perfmon pebs bts rep_good nopl xtopology nonstop_t
sc aperfmperf eagerfpu pni pclmulqdq dtes64 monitor ds_cpl vmx est tm2 ssse3 sdb
g fma cx16 xtpr pdcm pcid sse4_1 sse4_2 x2apic movbe popcnt tsc_deadline_timer a
es xsave avx f16c rdrand lahf_lm abm epb tpr_shadow vnmi flexpriority ept vpid f
sgsbase tsc_adjust bml avx2 smep bmi2 erms invpcid xsaveopt dtherm ida arat pln
pts
```

Entonces sabemos que es procesador es un Intel® Core™ i5-4460, y buscamos en cpuWorld:

Cache details				
Cache:	L1 data	L1 instruction	L2	L3
Size:	4 x 32 KB	4 x 32 KB	4 x 256 KB	6 MB
Associativity:	8-way set associative	8-way set associative	8-way set associative	12-way set associative
Line size:	64 bytes	64 bytes	64 bytes	64 bytes
Comments:	Direct-mapped	Direct-mapped	Non-inclusive Direct-mapped	Inclusive Shared between all cores

Por eso se que los resultados que nos deben salir es L1:32KB, L2:256KB, L3:6MB.

Esa misma información se puede obtener con el makefile del profesor Gustavo:

```
srjuan@eil40163:~/Escritorio/Home/EC/P5$ make info
line size = 64B
cache size = 32K/32K/256K/6144K/
cache level = 1/1/2/3/
cache type = Data/Instruction/Unified/Unified/
srjuan@eil40163:~/Escritorio/Home/EC/P5$
```

Pero el trabajo de esta semana consiste en averiguar esos datos con el código fuente de la práctica 5b:

```
#include <algorithm>    // nth_element
#include <array>        // array
#include <chrono>       // high_resolution_clock
#include <iomanip>       // setw
#include <iostream>     // cout
#include <vector>       // vector

using namespace std::chrono;

const unsigned MINSIZE = 1 << 10; // minimum line size to test: 1KB
const unsigned MAXSIZE = 1 << 26; // maximum line size to test: 64MB
const unsigned GAP = 12;         // gap for cout columns
const unsigned REP = 100;        // number of repetitions of every test
const unsigned STEPS = 1e6;      // steps

int main()
{
    std::cout << "#"
               << std::setw(GAP - 1) << "line (B)"
               << std::setw(GAP + 1) << "time (µs)"
               << std::endl;

    for (unsigned size = MINSIZE; size <= MAXSIZE; size *= 2)
    {
        std::vector<duration<double, std::micro>> score(REP);

        for (auto &s: score)
        {
            std::vector<char> bytes(size);

            auto start = high_resolution_clock::now();

            for (unsigned i = 0; i < size; i++)
                bytes[(i*64) & (bytes.size() - 1) & (size - 1)] ^= 1;

            auto stop = high_resolution_clock::now();

            s = stop - start;
        }

        std::nth_element(score.begin(),
                        score.begin() + score.size() / 2,
                        score.end());

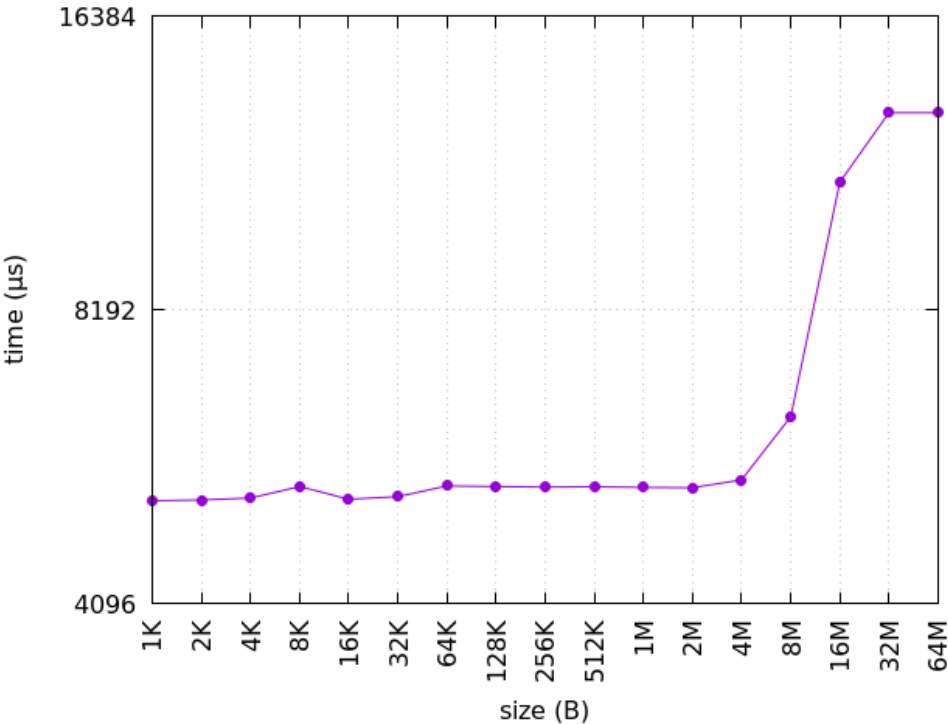
        std::cout << std::setw(GAP) << size
                  << std::setw(GAP) << std::fixed << std::setprecision(1)
                  << std::setw(GAP) << score[score.size() / 2].count()
                  << std::endl;
    }
}
```

He añadido la parte marcada. El resultado de ejecutar ese programa con las optimizaciones -O0, -O1, -O2, -Ofast es el siguiente:

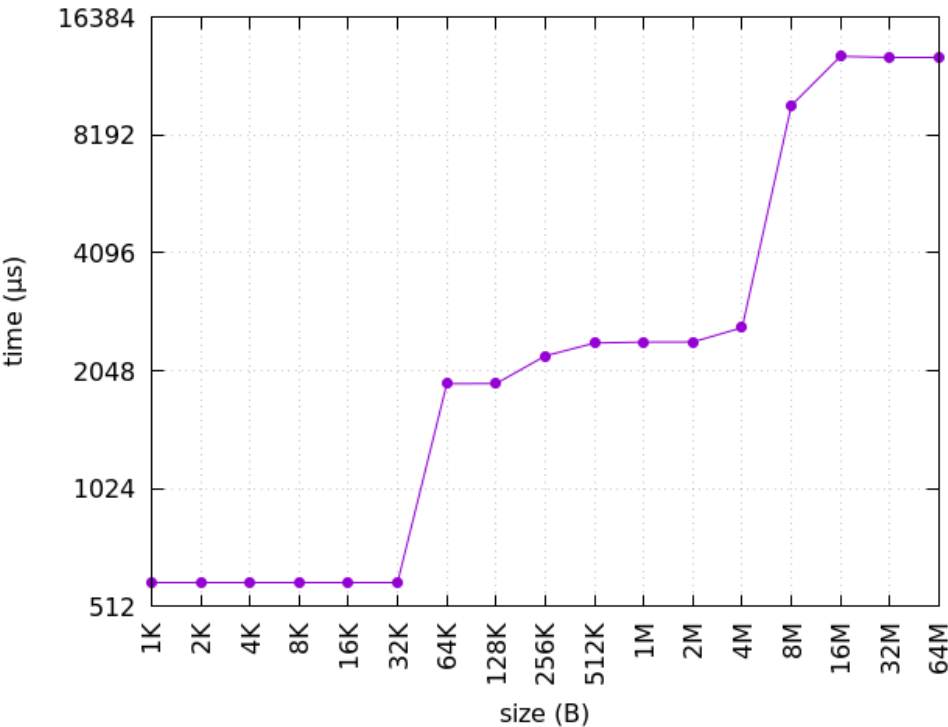
<div><div>-O0</div><table><tr><th>#</th><th>line (B)</th><th>time (µs)</th></tr><tr><td></td><td>1024</td><td>5223.9</td></tr><tr><td></td><td>2048</td><td>5232.7</td></tr><tr><td></td><td>4096</td><td>5257.3</td></tr><tr><td></td><td>8192</td><td>5401.8</td></tr><tr><td></td><td>16384</td><td>5242.0</td></tr><tr><td></td><td>32768</td><td>5274.1</td></tr><tr><td></td><td>65536</td><td>5409.6</td></tr><tr><td></td><td>131072</td><td>5401.2</td></tr><tr><td></td><td>262144</td><td>5394.5</td></tr><tr><td></td><td>524288</td><td>5398.2</td></tr><tr><td></td><td>1048576</td><td>5390.6</td></tr><tr><td></td><td>2097152</td><td>5386.9</td></tr><tr><td></td><td>4194304</td><td>5487.2</td></tr><tr><td></td><td>8388608</td><td>6370.3</td></tr><tr><td></td><td>16777216</td><td>11072.8</td></tr><tr><td></td><td>33554432</td><td>13041.3</td></tr><tr><td></td><td>67108864</td><td>13040.4</td></tr></table></div>	#	line (B)	time (µs)		1024	5223.9		2048	5232.7		4096	5257.3		8192	5401.8		16384	5242.0		32768	5274.1		65536	5409.6		131072	5401.2		262144	5394.5		524288	5398.2		1048576	5390.6		2097152	5386.9		4194304	5487.2		8388608	6370.3		16777216	11072.8		33554432	13041.3		67108864	13040.4	<div><div>-O1</div><table><tr><th>#</th><th>line (B)</th><th>time (µs)</th></tr><tr><td></td><td>1024</td><td>589.6</td></tr><tr><td></td><td>2048</td><td>589.6</td></tr><tr><td></td><td>4096</td><td>589.6</td></tr><tr><td></td><td>8192</td><td>589.6</td></tr><tr><td></td><td>16384</td><td>589.6</td></tr><tr><td></td><td>32768</td><td>589.6</td></tr><tr><td></td><td>65536</td><td>1898.1</td></tr><tr><td></td><td>131072</td><td>1899.6</td></tr><tr><td></td><td>262144</td><td>2234.9</td></tr><tr><td></td><td>524288</td><td>2410.2</td></tr><tr><td></td><td>1048576</td><td>2423.8</td></tr><tr><td></td><td>2097152</td><td>2425.5</td></tr><tr><td></td><td>4194304</td><td>2638.9</td></tr><tr><td></td><td>8388608</td><td>9748.2</td></tr><tr><td></td><td>16777216</td><td>13004.4</td></tr><tr><td></td><td>33554432</td><td>12938.3</td></tr><tr><td></td><td>67108864</td><td>12938.5</td></tr></table></div>	#	line (B)	time (µs)		1024	589.6		2048	589.6		4096	589.6		8192	589.6		16384	589.6		32768	589.6		65536	1898.1		131072	1899.6		262144	2234.9		524288	2410.2		1048576	2423.8		2097152	2425.5		4194304	2638.9		8388608	9748.2		16777216	13004.4		33554432	12938.3		67108864	12938.5
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Las graficas son las siguientes:

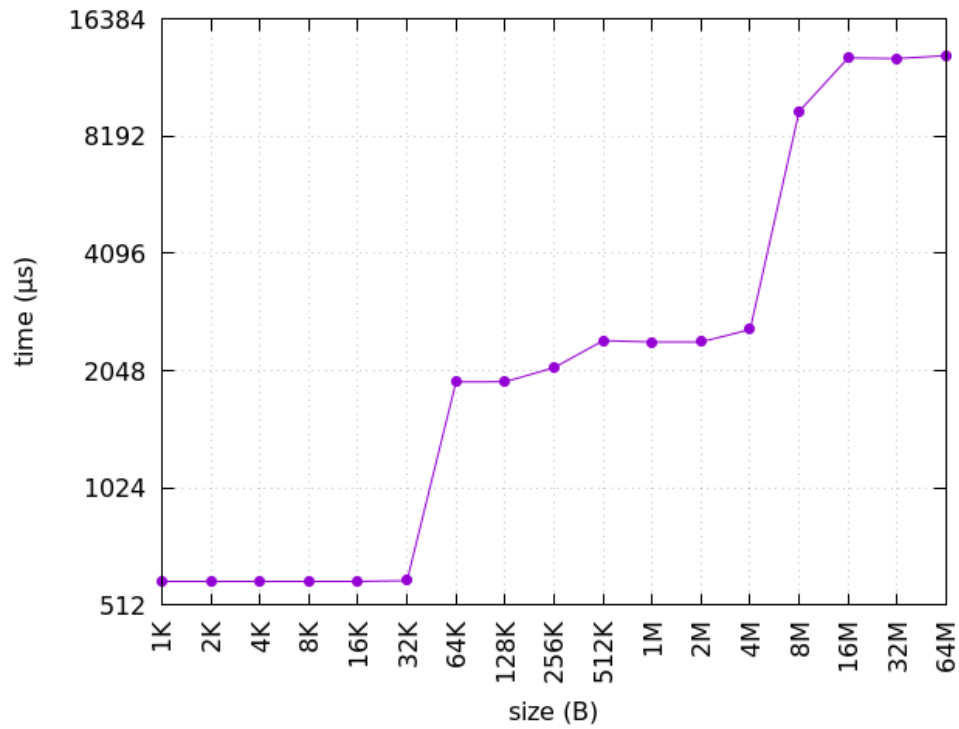
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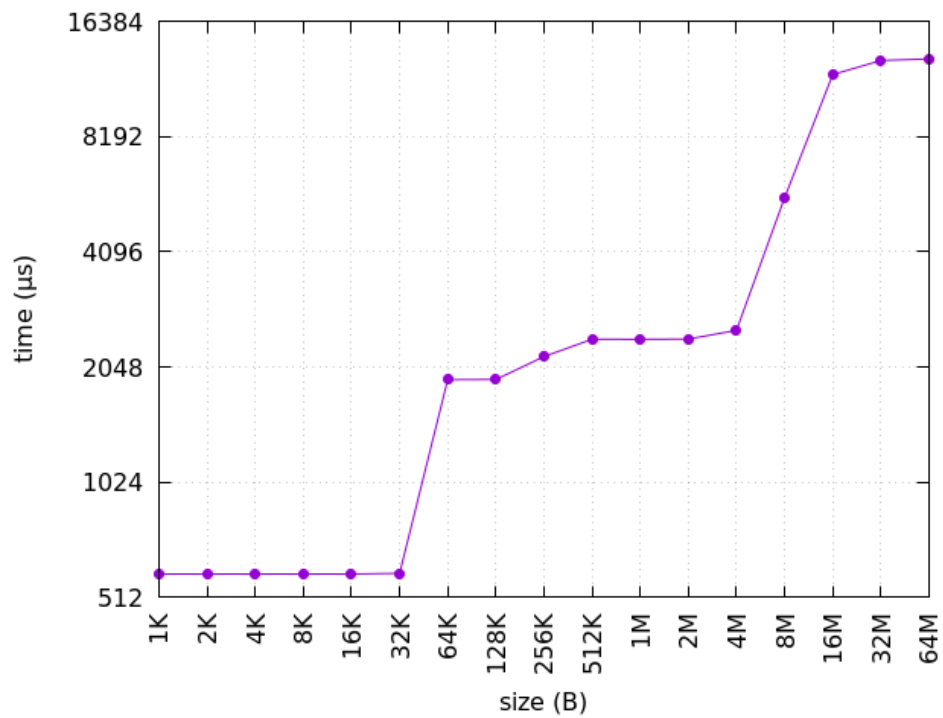
-01



-O2



-Ofast



Podemos observar que -O0 es la peor y las otras tres son igual de buenas y nos sirven para razonar que los tamaños de caché se corresponden con los vistos anteriormente, L1:32KB, L2:256KB, L3:6MB.

En resumen los tamaños de las caches son (he usado los datos de la optimización -Ofast):

	L1	L2	L3
TAMAÑO	32KB	256KB	6MB
TIEMPO	591.8	2180.1	2553.3