

SADEEM SAJID  
21L-1870  
6K

### PART (0)

I am using Kali Linux running bare metal. I've attached a screenshot of the system specifications below, using the "**lshw -short**" command:

H/W path	Device	Class	Description
/0	ASUS TUF Gaming F15 FX506LI_FX506LI	system	ASUS TUF Gaming F15 FX506LI_FX506LI
/0/0	FX506LI	bus	FX506LI
/0/0	64KiB BIOS	memory	64KiB BIOS
/0/3b	8GiB System Memory	memory	8GiB System Memory
/0/3b/0	8GiB SODIMM DDR4 Synchronous 3200 MHz (0.3 ns)	memory	8GiB SODIMM DDR4 Synchronous 3200 MHz (0.3 ns)
/0/3b/1	[empty]	memory	[empty]
/0/3b/2	[empty]	memory	[empty]
/0/3b/3	[empty]	memory	[empty]
/0/50	256KiB L1 cache	memory	256KiB L1 cache
/0/51	1MiB L2 cache	memory	1MiB L2 cache
/0/52	8MiB L3 cache	memory	8MiB L3 cache
/0/53	Intel(R) Core(TM) i5-10300H CPU @ 2.50GHz	processor	Intel(R) Core(TM) i5-10300H CPU @ 2.50GHz
/0/100	10th Gen Core Processor Host Bridge/DRAM Registers	bridge	10th Gen Core Processor Host Bridge/DRAM Registers
/0/100/1	6th-10th Gen Core Processor PCIe Controller (x16)	bridge	6th-10th Gen Core Processor PCIe Controller (x16)
/0/100/1/0	/dev/fb1	display	TU117M [GeForce GTX 1650 Ti Mobile]
/0/100/1/0.1	card2	multimedia	NVIDIA Corporation
/0/100/1/0.1/0	input22	input	HDA NVidia HDMI/DP,pcm=3
/0/100/1/0.1/1	input23	input	HDA NVidia HDMI/DP,pcm=7
/0/100/1/0.1/2	input24	input	HDA NVidia HDMI/DP,pcm=8
/0/100/1/0.1/3	input25	input	HDA NVidia HDMI/DP,pcm=9
/0/100/2	/dev/fb0	display	CometLake-H GT2 [UHD Graphics]
/0/100/4	Xeon E3-1200 v5/E3-1500 v5/6th Gen Core Processor Thermal Subs	generic	Xeon E3-1200 v5/E3-1500 v5/6th Gen Core Processor Thermal Subs
/0/100/8	Xeon E3-1200 v5/v6 / E3-1500 v5 / 6th/7th/8th Gen Core Process	generic	Xeon E3-1200 v5/v6 / E3-1500 v5 / 6th/7th/8th Gen Core Process
/0/100/12	Comet Lake PCH Thermal Controller	generic	Comet Lake PCH Thermal Controller
/0/100/14	Comet Lake USB 3.1 xHCI Host Controller	bus	Comet Lake USB 3.1 xHCI Host Controller
/0/100/14/0	usb1	bus	xHCI Host Controller
/0/100/14/0/1	input7	input	MosArt USB Keyboard
/0/100/14/0/2	card0	multimedia	USB Audio M5901
/0/100/14/0/3	input11	input	Logitech Gaming Mouse G402 Keyboard
/0/100/14/0/7		multimedia	USB2.0 HD UVC WebCam
/0/100/14/0/e		communication	AX201 Bluetooth
/0/100/14/1	usb2	bus	xHCI Host Controller
/0/100/14.2		memory	RAM memory
/0/100/14.3	wlan0	network	Comet Lake PCH CNVi WiFi
/0/100/15		bus	Comet Lake PCH Serial IO I2C Controller #0
/0/100/16		communication	Comet Lake HECI Controller
/0/100/17	scsi0	storage	Intel Corporation
/0/100/17/0.0.0	/dev/sda	disk	256GB TEAM T253256GB
/0/100/17/0.0.0/1	/dev/sda1	volume	511MiB Windows FAT volume
/0/100/17/0.0.0/2	/dev/sda2	volume	237GiB EXT4 volume
/0/100/17/0.0.0/3	/dev/sda3	volume	976MiB Linux swap volume
/0/100/1d		bridge	Comet Lake PCI Express Root Port #9
/0/100/1d/0	/dev/nvme0	storage	Micron_2210_MTFDHBA512QFD
/0/100/1d/0/0	hwmon2	disk	NVMe disk
/0/100/1d/0/2	/dev/ng0n1	disk	NVMe disk
/0/100/1d/0/1	/dev/nvme0n1	disk	512GB NVMe disk
/0/100/1d/0/1/1	/dev/nvme0n1p1	volume	259MiB Windows FAT volume
/0/100/1d/0/1/2	/dev/nvme0n1p2	volume	15MiB reserved partition
/0/100/1d/0/1/3	/dev/nvme0n1p3	volume	456GiB Windows NTFS volume
/0/100/1d/0/1/4	/dev/nvme0n1p4	volume	998MiB Windows NTFS volume
/0/100/1d/0/1/5	/dev/nvme0n1p5	volume	196iB Windows NTFS volume
/0/100/1d.6		bridge	Intel Corporation
/0/100/1d.6/0	eth0	network	RTL8111/8168/8411 PCI Express Gigabit Ethernet Controller
/0/100/1f		bridge	Comet Lake LPC Controller
/0/100/1f/0		system	PnP device PNP0c02
/0/100/1f/1		system	PnP device PNP0c02
/0/100/1f/2		system	PnP device PNP0b00
/0/100/1f/3		generic	PnP device INT3f0d
/0/100/1f/4		input	PnP device PNP0303

As you can see, I have Quad i5 10th generation processors, 8 GB 3200 MHz DDR4 of RAM, and 256 GB of SSD space.

This is after running “lscpu”

```
(sadeem@KALAMEET)-[~/../projects/courses/pdc/a1]
$ lscpu
Architecture: x86_64
CPU op-mode(s): 32-bit, 64-bit
Address sizes: 39 bits physical, 48 bits virtual
Byte Order: Little Endian
CPU(s): 8
On-line CPU(s) list: 0-7
Vendor ID: GenuineIntel
Model name: Intel(R) Core(TM) i5-10300H CPU @ 2.50GHz
CPU family: 6
Model: 165
Thread(s) per core: 2
Core(s) per socket: 4
Socket(s): 1
Stepping: 2
CPU(s) scaling MHz: 26%
CPU max MHz: 4500.0000
CPU min MHz: 800.0000
BogoMIPS: 4999.90
Flags: fpu vme de pse tsc msr pae mce cx8 apic sep mtrr pge mca cmov pat pse36 clflush dts acp
i mmx fxsr sse sse2 ss ht tm pbe syscall nx pdpe1gb rdtscp lm constant_tsc art arch_per
fmon pebs bts rep_good nopl xtopology nonstop_tsc cpuid aperfperf pni pclmulqdq dtes64
monitor ds_cpl vmx est tm2 ssse3 sdbg fma cx16 xtpr pdcm pcid sse4_1 sse4_2 x2apic mov
be popcnt tsc_deadline_timer aes xsave avx f16c rdrand lahf_lm abm 3dnowprefetch cpuid_
fault epb ssbd ibrs ibpb stibp ibrs_enhanced tpr_shadow flexpriority ept vpid ept_ad fs
gsbase tsc_adjust bmi1 avx2 smep bmi2 erms invpcid mpx rdseed adx smap clflushopt intel
_pt xsaveopt xsavec xgetbv1 xsaves dtherm ida arat pln pts hwp hwp_notify hwp_act_windo
w hwp_epp vnmi pku ospke md_clear flush_l1d arch_capabilities

Virtualization features:
Virtualization: VT-x
Caches (sum of all):
L1d: 128 KiB (4 instances)
L1i: 128 KiB (4 instances)
L2: 1 MiB (4 instances)
L3: 8 MiB (1 instance)
NUMA:
NUMA node(s): 1
NUMA node0 CPU(s): 0-7
Vulnerabilities:
Gather data sampling: Mitigation; Microcode
Itlb multihit: KVM: Mitigation: VMX disabled
L1tf: Not affected
Mds: Not affected
Meltdown: Not affected
Mmio stale data: Mitigation; Clear CPU buffers; SMT vulnerable
Retbleed: Mitigation; Enhanced IBRS
Spec rstack overflow: Not affected
Spec store bypass: Mitigation; Speculative Store Bypass disabled via prctl
Spectre v1: Mitigation; usercopy/swapgs barriers and __user pointer sanitization
Spectre v2: Mitigation; Enhanced / Automatic IBRS, IBPB conditional, RSB filling, PBRSE-eIBRS SW se
quence
Srbds: Mitigation; Microcode
Tsx async abort: Not affected
```

This is after running “lspci”:

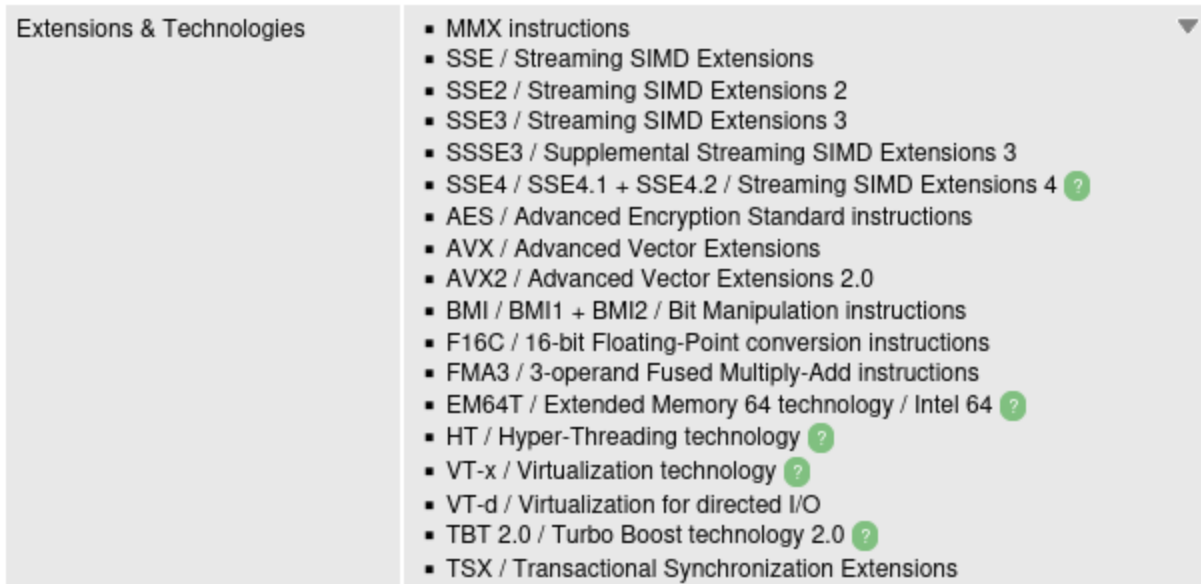
```
(sadeem@KALAMEET)-[~/../projects/courses/pdc/a1]
$ lspci
00:00.0 Host bridge: Intel Corporation 10th Gen Core Processor Host Bridge/DRAM Registers (rev 02)
00:01.0 PCI bridge: Intel Corporation 6th-10th Gen Core Processor PCIe Controller (x16) (rev 02)
00:02.0 VGA compatible controller: Intel Corporation CometLake-H GT2 [UHD Graphics] (rev 05)
00:04.0 Signal processing controller: Intel Corporation Xeon E3-1200 v5/E3-1500 v5/6th Gen Core Processor Thermal Subsystem (rev 02)
00:08.0 System peripheral: Intel Corporation Xeon E3-1200 v5/v6 / E3-1500 v5 / 6th/7th/8th Gen Core Processor Gaussian Mixture Model
00:12.0 Signal processing controller: Intel Corporation Comet Lake PCH Thermal Controller
00:14.0 USB controller: Intel Corporation Comet Lake USB 3.1 xHCI Host Controller
00:14.2 RAM memory: Intel Corporation Comet Lake PCH Shared SRAM
00:14.3 Network controller: Intel Corporation Comet Lake PCH CNVi WiFi
00:15.0 Serial bus controller: Intel Corporation Comet Lake PCH Serial IO I2C Controller #0
00:16.0 Communication controller: Intel Corporation Comet Lake HECI Controller
00:17.0 SATA controller: Intel Corporation Device 06d3
00:1d.0 PCI bridge: Intel Corporation Comet Lake PCI Express Root Port #9 (rev f0)
00:1d.6 PCI bridge: Intel Corporation Device 06b6 (rev f0)
00:1f.0 ISA bridge: Intel Corporation Comet Lake LPC Controller
00:1f.3 Audio device: Intel Corporation Comet Lake PCH cAVS
00:1f.4 SMBus: Intel Corporation Comet Lake PCH SMBus Controller
00:1f.5 Serial bus controller: Intel Corporation Comet Lake PCH SPI Controller
01:00.0 VGA compatible controller: NVIDIA Corporation TU117M [GeForce GTX 1650 Ti Mobile] (rev a1)
01:00.1 Audio device: NVIDIA Corporation Device 10fa (rev a1)
02:00.0 Non-Volatile memory controller: Micron Technology Inc 2210 NVMe SSD [Cobain] (rev 03)
03:00.0 Ethernet controller: Realtek Semiconductor Co., Ltd. RTL8111/8168/8411 PCI Express Gigabit Ethernet Controller (rev 15)
```

## PART (1)

Please refer to the README.md on how to execute the codes.

## PART (2)

These are the technologies my cpu supports:



I will be using AVX2, since (1) they're easily available, and (2) some research and reading the opinions of people online convinced me that it is much better.

Please see the graph and refer to **times.txt** for a view on the execution times.

## PART (3)

Please refer to the code, graph, and times.txt for performance results.

As mentioned above, I have 4 cores with hyper-threading, meaning 8 threads. I first made 4 threads, but I switched to 8 threads later on to get a slightly better performance.

Using more threads than what the processor can run at a time hurts the performance because some threads will need to be blocked before the processor can execute them. This significantly raises overheads.

#### PART (4)

Refer to the codes and times.txt for performance.

#### PART (5)

(a) I learned how valuable optimization techniques can be in drastically reducing execution times. I previously knew that there are some techniques that reduce execution times, but I did not know they could have such a great impact, and something as simple as changing a language can become a make or break decision in computing.

I also got introduced to vector instructions, although it will take a while for me to digest the concept.

(b) We can see that language switches had by far the greatest impact on execution times, which is clearly shown by the gradient of the graph. After that, the greatest impact was produced by using both vector instructions and pthreads in a single program.

(c) It does start to plateau. This indicates that there are some parallelization overheads that are there due to the code, possibly because of some inevitable serial portion.