

Q2)

System Architecture:

Processor Name: Quad-Core Intel Core i5
Processor Speed: 1.4 GHz (Turbo Boost up to 3.9GHz)
Number of Processors: 1
Total Number of Cores: 4
L2 Cache (per Core): 256 KB
L3 Cache: 6 MB
Memory: 16 GB 2133 MHz LPDDR3

```
double flops = 2*m*n*k*NREPEATS/(1e9 * time);  
double bandwidth = (m*k+k*n+2*m*n)*NREPEATS/(1e9 * time);  
Since there are two calculations (one multiplication + one  
addition) in the inner most loop, flops = 2 * m * n * k  
*NREPEATS;
```

With various sizes of blocks:

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Block size = 16:

Dimension	Time	Gflop/s	GB/s	Error
16	0.618013	3.236183	0.404523	0.000000e+00
32	0.614190	3.256366	0.203523	0.000000e+00
64	0.672131	2.975847	0.092995	0.000000e+00
128	0.765384	2.613960	0.040843	0.000000e+00
256	1.155939	1.741671	0.013607	0.000000e+00
512	3.425196	0.626967	0.002449	0.000000e+00
1024	3.414555	0.628921	0.001228	0.000000e+00
2048	28.508439	0.602624	0.000588	0.000000e+00
4096	234.217722	0.586800	0.000287	0.000000e+00

Block size = 64:

Dimension	Time	Gflop/s	GB/s	Error
64	1.031919	1.938290	0.060572	0.000000e+00
128	2.934014	0.681893	0.010655	0.000000e+00
256	3.465481	0.580948	0.004539	0.000000e+00
512	4.450341	0.482544	0.001885	0.000000e+00
1024	4.851112	0.442679	0.000865	0.000000e+00
2048	38.837161	0.442356	0.000432	0.000000e+00
4096	335.808566	0.409278	0.000200	0.000000e+00

Block size=256:

Dimension	Time	Gflop/s	GB/s	Error
256	4.506534	0.446744	0.003490	0.000000e+00
512	4.882071	0.439871	0.001718	0.000000e+00
1024	4.954924	0.433404	0.000846	0.000000e+00

2048	41.505232	0.413921	0.000404	0.000000e+00
4096	344.796603	0.398609	0.000195	0.000000e+00

Block size = 1024:

Dimension	Time	Gflop/s	GB/s	Error
1024	13.650606	0.157318	0.000307	0.000000e+00
2048	111.605528	0.153934	0.000150	0.000000e+00

Optimal value for BLOCK SIZE: 16

WITH OMP:

With #pragma omp for schedule (dynamic, 4):

Dimension	Time	Gflop/s	GB/s	Error
64	0.136368	14.667361	0.458355	0.000000e+00
128	0.049487	40.428456	0.631695	0.000000e+00
256	0.044722	45.017350	0.351698	0.000000e+00
512	0.048109	44.637877	0.174367	0.000000e+00
1024	0.072503	29.619238	0.057850	0.000000e+00
2048	0.846901	20.285570	0.019810	0.000000e+00
4096	8.975206	15.313181	0.007477	0.000000e+00
8192	107.515193	10.226570	0.002497	0.000000e+00

With #pragma omp for schedule (dynamic, 8):

Dimension	Time	Gflop/s	GB/s	Error
64	0.139222	14.366686	0.448959	0.000000e+00
128	0.049297	40.584275	0.634129	0.000000e+00
256	0.045827	43.931872	0.343218	0.000000e+00
512	0.049335	43.528603	0.170034	0.000000e+00
1024	0.078284	27.431961	0.053578	0.000000e+00
2048	0.943384	18.210897	0.017784	0.000000e+00
4096	9.606116	14.307443	0.006986	0.000000e+00

With #pragma omp for schedule (dynamic, 32):

Dimension	Time	Gflop/s	GB/s	Error
64	0.152917	13.080029	0.408751	0.000000e+00
128	0.050380	39.711850	0.620498	0.000000e+00
256	0.046078	43.692563	0.341348	0.000000e+00
512	0.049320	43.541842	0.170085	0.000000e+00
1024	0.076871	27.936200	0.054563	0.000000e+00
2048	1.059672	16.212440	0.015832	0.000000e+00
4096	9.895262	13.889370	0.006782	0.000000e+00

With #pragma omp for schedule (dynamic, 64):

Dimension	Time	Gflop/s	GB/s	Error
64	0.207037	9.660876	0.301902	0.000000e+00
128	0.072636	27.543959	0.430374	0.000000e+00
256	0.057333	35.115307	0.274338	0.000000e+00
512	0.048948	43.872756	0.171378	0.000000e+00

1024	0.072103	29.783555	0.058171	0.000000e+00
2048	0.908972	18.900328	0.018457	0.000000e+00
4096	9.136296	15.043181	0.007345	0.000000e+00
8192	106.451296	10.328776	0.002522	0.000000e+00

With #pragma omp for schedule (dynamic, 128):

Dimension	Time	Gflop/s	GB/s	Error
64	0.208874	9.575910	0.299247	0.000000e+00
128	0.133204	15.019692	0.234683	0.000000e+00
256	0.088947	22.634444	0.176832	0.000000e+00
512	0.059289	36.220608	0.141487	0.000000e+00
1024	0.072666	29.552798	0.057720	0.000000e+00
2048	0.855878	20.072801	0.019602	0.000000e+00
4096	8.955562	15.346770	0.007494	0.000000e+00

With #pragma omp for schedule (dynamic, 512):

Dimension	Time	Gflop/s	GB/s	Error
64	0.207620	9.633748	0.301055	0.000000e+00
128	0.133580	14.977414	0.234022	0.000000e+00
256	0.169591	11.871302	0.092745	0.000000e+00
512	0.193050	11.123976	0.043453	0.000000e+00
1024	0.193871	11.076869	0.021635	0.000000e+00
2048	0.945620	18.167836	0.017742	0.000000e+00
4096	10.112125	13.591501	0.006636	0.000000e+00

With #pragma omp for schedule (guided, 4)

Dimension	Time	Gflop/s	GB/s	Error
64	0.135481	14.763389	0.461356	0.000000e+00
128	0.052902	37.818665	0.590917	0.000000e+00
256	0.044534	45.207390	0.353183	0.000000e+00
512	0.047989	44.749498	0.174803	0.000000e+00
1024	0.076135	28.206261	0.055090	0.000000e+00
2048	0.888259	19.341058	0.018888	0.000000e+00
4096	9.188283	14.958067	0.007304	0.000000e+00
8192	85.044010	12.928737	0.003156	0.000000e+00

With #pragma omp for schedule (runtime)

Dimension	Time	Gflop/s	GB/s	Error
64	0.190204	10.515860	0.328621	0.000000e+00
128	0.091477	21.870886	0.341733	0.000000e+00
256	0.053184	37.854729	0.295740	0.000000e+00
512	0.050032	42.922203	0.167665	0.000000e+00
1024	0.070858	30.306862	0.059193	0.000000e+00
2048	0.892628	19.246393	0.018795	0.000000e+00
4096	8.995530	15.278583	0.007460	0.000000e+00
8192	113.492221	9.687991	0.002365	0.000000e+00

#pragma omp for schedule (guided, 4) collapse(2) reduction(+:c)

Dimension	Time	Gflop/s	GB/s	Error
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64	0.079542	25.145945	0.785811	0.000000e+00
128	0.089526	22.347508	0.349180	0.000000e+00
256	0.153983	13.074599	0.102145	0.000000e+00
512	0.151034	14.218544	0.055541	0.000000e+00
1024	0.333764	6.434138	0.012567	0.000000e+00
2048	3.570437	4.811699	0.004699	0.000000e+00
4096	28.468071	4.827828	0.002357	0.000000e+00

OMP parallel for gave the best performance with (guided, 4).
Nested didn't work well.

For Dimension = 4096, (guided, 4) gave a flop rate of 14.95 giga flops/ second. The maximum possible is $3.9 \times 4 = 15.6$ giga flops/ second with turbo boost (of Intel). Without turbo boost the max limit is $1.4 \times 4 = 5.6$ giga flops/second.