# Study the Task completion Time of the Benchmarks @1GHz, 2GHz and 3GHz Processors

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**Abstract-** The AMD Opteron series processor are having 64-bit operating environment. The high-performance computing (HPC) community has helped processor manufacturers to implement a high performance and low cost processor with reduced instruction set (RISC) like. This paper explains the variation of task completion time with respect to different benchmarks in SPEC CPU INT 2006 benchmark suite using AMD Opteron 2000+ and AMD Opteron 8000+ Series performance scores. We have also calculated Memory wait time @1GHz, @2GHz and@3GHz processor frequency. The benchmarks 429.mcf, 445.gobmk, 456.hmmer, 458.sjeng, 464.h264ref and 483.xalancbmk shows less memory wait time @1GHz, @2GHz and@3GHz processor frequency. The other six benchmarks in INT suite shows high memory wait time. Among all benchmarks 483.xalancbmk (XSLT Processor) and 456.hmmer (Search a Gene Sequence Database) shows high performance on AMD Opteron 2000+ and AMD Opteron 8000+ Series.

**Keywords -** SPEC CPU INT 2006, Memory Wait Time, Performance.

## 1. Introduction

The Opteron processor implements the x86 instruction set with a 64-bit memory space. The processor runs 32-bit x86 programs in native mode without changes and provides a 64-bit mode for running 64-bit applications. The processor provides program-controlled execution in either 32-bit or 64-bit mode. 32-bit applications can run on top of a 64-bit operating system. The improvements in silicon include out-of-order execution, enhanced branch prediction, improved translation look-aside buffer (TLB), and speculative execution. AMD increased the parallelism by first converting to RISC-like micro-operations (OPs), with deeper scheduling queues, out-of-order issue, and improved branch prediction. AMD integrated the memory controller into the AMD Opteron processor. This lowers latency and increases the effective bandwidth to memory. AMD integrated the memory controller into the AMD Opteron processor. This lowers latency and increases the effective bandwidth to memory [1]. AMD Athlon processors are manufactured on AMD's robust 0.18-micron aluminum process technology and on AMD's leading-edge HiP6L 0.18-micron process technology featuring copper interconnects. The approximately 37-million-transistor new AMD Athlon processor has a die size of 120 mm2 on 0.18-micron technology [2]. Computer architectural complexity is growing so dramatically, the performance becomes an important approach to take full advantage of hardware's computational potential [3]. The CMOS scaling leading to ever increasing level of transistor integration on a chip, designers of high performance embedded processors have ample area available to increase processor resources in order to improve performance [4]. The SPEC CPU2006 benchmark suite contains several programs from different application areas such as Physics, Artificial intelligence and Combinatorial Optimization etc. The recently released SPEC CPU2006 benchmark suite is expected to be used by computer designers and computer architecture researchers for pre-silicon early design analysis [5]. Accuracy of the processor performance depends on the selected benchmarks in simulation study. The selected benchmarks should cover the vide spectrum of the application area. Increase in benchmarks program accelerates the simulation time, at the same time improper selection of the benchmarks may not accurately determines the performance of the processor Increasing size of the benchmarks makes detailed simulation an extremely time consuming process[6].

In this present study, we find out the task completion time by using different AMD Opteron series. The rest of the paper is organized as follows. In section 2, we discussed the scope of study in designing high performance processors. We explain the basic of SPEC CPU 2006 benchmarks in section 3; section 4 contains the methodology used in this paper and sections 5 discuss the results obtained from our analysis.

## 2. Scope of This Study

Building a high-performance microprocessor presents many reliability challenges. To day we are moving towards the nanotechnology era and also from 32-bit processor environment to 64-bit processor environment. The analysis of our study examines the weak spots in different series of AMD processors (AMD Opteron 2000+ and AMD Opteron 8000+ Series) which are fabricated for the requirement of the modern generation utility. This study is helpful to build complete benchmark suite which covers the entire spectrum of the application area and to predict the performance of the processor more accurately. We previously reported the performance prediction of the processors and evaluated scalability of the Memory Wait Time which degraded the performance of the processor by using a simple statistical correlation technique [7]. This analysis is more useful to performance engineers, scientists and developers to better understand benchmark behavior in workload space, and the scalability of the performance in modern generation commercial processors.

## 3. Growth of Device Density in Processors

We now routinely buy personal computer in which microprocessors with millions of transistors perform at gigahertz speeds, so it is easy to forget that the first microprocessor was not a simple or obvious choice to the produce [5]. In 1991, a 0.7μm lithography was used with 2 metal interconnects and a supply voltage of 5V. In 2001, a 0.18 μm lithography is used with 6 layers of interconnects and 2V internal supply. The CPU frequency for high performance microprocessors is above 1GHz, and the number of devices on a single chip is around 250 millions. The growth of device density provides two significant improvements, the reduction of the silicon area goes together with a decrease of parasitic capacitance, thus increase the switching speed of cells. Secondly, the shorter dimension of the device it self speeds up the switching, which leads to further operating clock improvements. The performance of modern processors is rapidly increasing as both clock frequency and the number of transistors required for a given implementation grow. The number of transistors per chip has continued to increase at an exponential rate over the last three decades, effectively confirming Gordon Moore's prediction on the growth rate of chip complexity. [6] [7] [8]. Figure 1 shows the transistor count per die of processors introduced by Intel over the past 35 years. Today's processor contains approximately one billion transistors [9] [10]. The Pentium 4 processor includes about 100,000,000 transistors integrated on a single piece of silicon no larger then 2cm X 2cm. Performance derived from physical scaling is near the limit, but dimension scaling is expected to continue to grow as predicted by Moore's law. Performance is now improved through innovations such as new transistor designs and the introduction of new materials and processes, including high-κ gate dielectric, FinFET, SOI, strained-silicon, and isotopically pure silicon substrates, to mention just a few of the recent developments [11]. Figure 2 is showing that how the Scaling of successive MPU Physical Gate length changing from 2004 to 2014. The physical gate length is rapidly decreasing in year after year. As well as decreasing the gate length parasitic capacitance also decreases due to this the switching speed will increase, power dissipation decreases. Low power required and increases the performance of the chip.

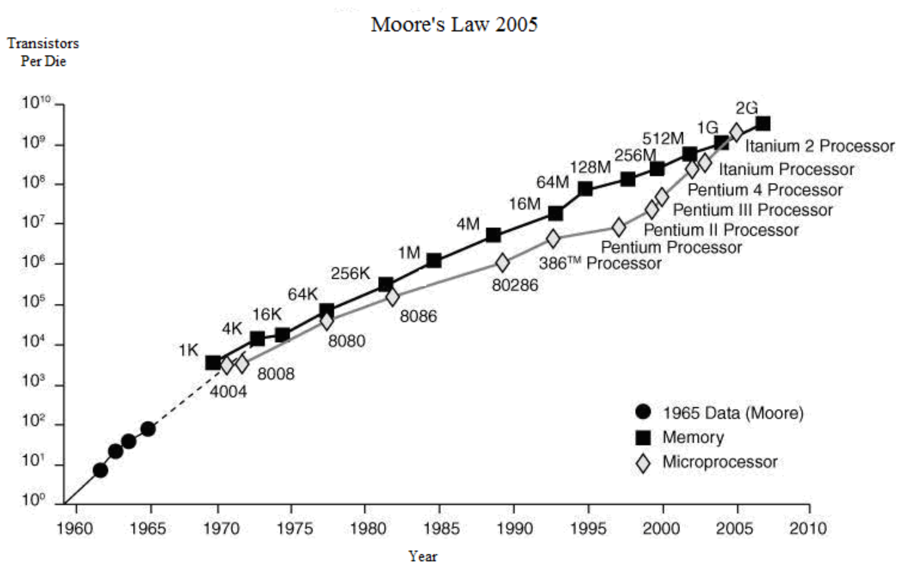


Figure 1: Scaling of transistors, the number of transistors is expected to continue to double about every two years, in accordance with Moore's Law. Over time, the number of additional transistors will allow designers to increase the number of cores per chip.

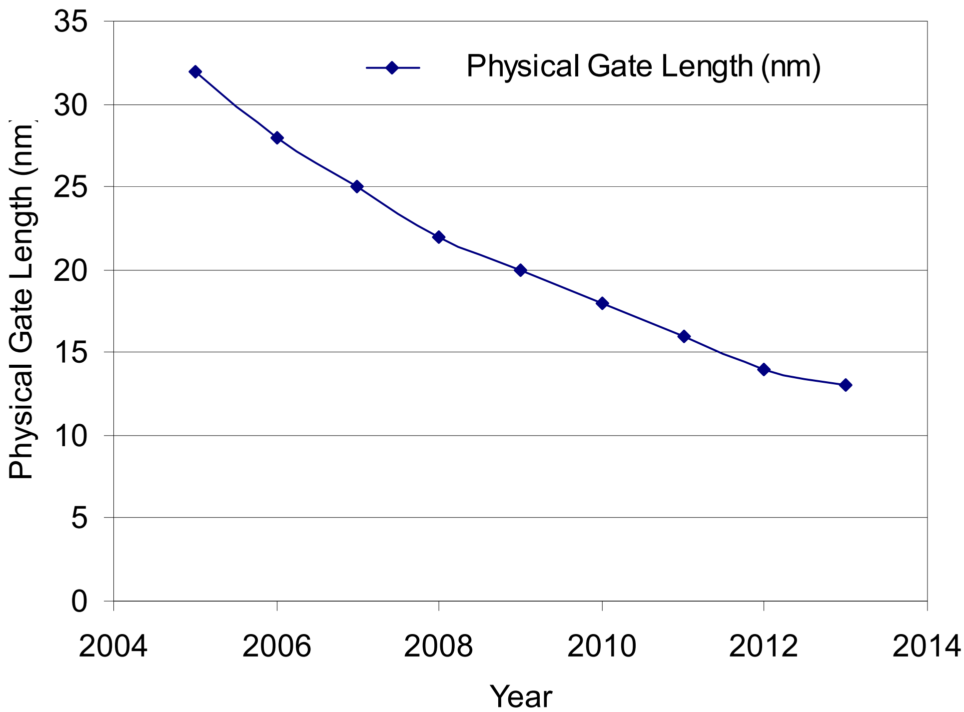


Figure 2: Scaling of successive MPU Physical Gate length from ITRS in near future

## 3. Benchmarks

Benchmarks are used for the performance evolution of the processors. The SPEC, HINT, and TPC are most important and popular benchmarks are available for performance evolution. SPEC is a nonprofit corporation formed to establish, maintain, and endorse a standardized set of benchmarks. SPEC's membership includes computer hardware and software vendors, leading universities, and research facilities worldwide. SPEC CPU2006 is designed to provide a comparative measure of compute-intensive performance across a range of hardware. Comprised of two suites of benchmarks, SPEC CPU2006 gauges compute-intensive integer performance with CINT2006 and measures floating-point performance with CFP2006. CINT2006 and CFP2006 results are presented as ratios, which are calculated using a reference time determined by SPEC and the runtime of the benchmark higher scores indicate better performance [8].

The SPEC CPU2006 suite contains 18 floating-point programs (Some programs are written in C and some in FORTRAN) and 13 integer programs (8 written in C, 4 in C++ and 1 in ANSI C). Table.1 and Table 2 provides a list of the benchmarks in SPEC CPU2006 suite. The SPEC CPU2006 benchmarks replace the SPEC89, SPEC92, SPEC95 and SPEC CPU 2000 benchmarks [8, 9, 10].

| S. No | Integer Benchmark | Language | Description |
|---|---|---|---|
| 1 | 400.perlbench | C++ | PERL Programming Language |
| 2 | 401.bzip2 | C | Data Compression |
| 3 | 403.gcc | C | C Language Optimizing Compiler |
| 4 | 429.mcf | C | Combinatorial Optimization |
| 5 | 445.gobmk | C | Artificial Intelligence : Game Playing |
| 6 | 456.hmmer | C | Search a Gene Sequence Database |
| 7 | 458.sjeng | C | Artificial Intelligence : Chess |
| 8 | 462.libquantum | C | Physics / Quantum Computing |
| 9 | 464.h264ref | C | Video Compression |
| 10 | 471.omnetpp | C++ | Discrete Event Simulation |
| 11 | 473.astar | C++ | Path – Finding Algorithm |
| 12 | 483.xalancbmk | C++ | XSLT Processor |

Table 1: The CINT 2006 Suite Benchmarks

| S. No | Floating Point Benchmark | Language | Description |
|---|---|---|---|
| 1 | 410.bwaves | Fortran – 77 | Computational Fluid Dynamics |
| 2 | 416.gamess | Fortran | Quantum Chemical Computations |
| 3 | 433.milc | C | Physics / Quantum Chromo Dynamics |
| 4 | 434.zeusmp | Fortran – 77 | Physics / Magneto Hydro Dynamics |
| 5 | 435.gromacs | C/Fortran | Chemistry / Molecular Dynamics |
| 6 | 436.cactusADM | C / Fortran-90 | Physics / General Relativity |
| 7 | 437.leslie3d | Fortran – 90 | Computational Fluid Dynamics |
| 8 | 444.namd | C++ | Scientific, Structural Biology, Classical Molecular Dynamics Simulation. |
| 9 | 447.dealII | C++ | Solution of Partial Differential Equations using the Adaptive Finite Element Method. |
| 10 | 450.soplex | C++ | Simplex Linear Programming Solver |
| 11 | 453.povray | C++ | Computer Visualization / Ray Tracing |
| 12 | 454.calculix | C/Fortran-90 | Structural Mechanics |
| 13 | 459.GemsFDTD | Fortran-90 | Computational Electromagnetic |

| | | | |
|---|---|---|---|
| 14 | 465.tonto | Fortran-95 | Quantum Crystallography |
| 15 | 470.lbm | C | Computational Fluid Dynamics |
| 16 | 481.wrf | C/Fortran – 90 | Weather Processing |
| 17 | 482.sphinx3 | C | Speech Recognition |

Table 2: The CFP2006 Suite Benchmarks

## 4. Methodology

In this study we utilize the integer benchmarks from the newly released SPEC CPU2006 suite for analyzing memory wait time. The Benchmark scores for AMD Opteron 2000+ series processors and AMD Opteron 8000+ series are obtained under the same operating conditions. We reported the performance scaling in AMD Opteron 2000+ series processors and AMD Opteron 8000+ series Processors [7]. We used a linear regression analysis for [12] for calculating memory wait time; we used commercial statistical software called STATISTICA v.7.0 [11] for this analysis.

## 5. Results and Discussion

Figure 3 shows the execution time variation with Benchmarks in different AMD Opteron Series Processors. The benchmark 462.libquqntun shows least execution time in AMD Opteron 2356 processor as compared to other processor. All the processors used in this analysis are having their core clock lies between 0.3 and 0.45 ns. We have calculated Memory wait time @1GHz, @2GHz and@3GHz processor frequency. Table 3 shows the variation of Memory Wait Time with benchmark. All individual trends were broken into two categories. First category contains individual tasks where the "memory wait time" (MWT) is very small of the total individual run time. Six individual tasks fall into the first category, i.e. 429.mcf, 445.gobmk, 456.hmmer, 458.sjeng, 464.h264ref and 483.xalancbmk. The second group contains four individual tasks where the MWT is grater than zero and above. The second group contains six bench mark programs 462.libquqntum, 400.perlbench, 401.bzip2.403.gcc, 471.omnetpp and 473.astar. The benchmarks 483.xalancbmk (XSLT Processor) and 456.hmmer (Search a Gene Sequence Database), shows good performance on AMD Opteron 2000+ and 8000+ series processors. The relationship between different benchmarks is shown in Figure 4.

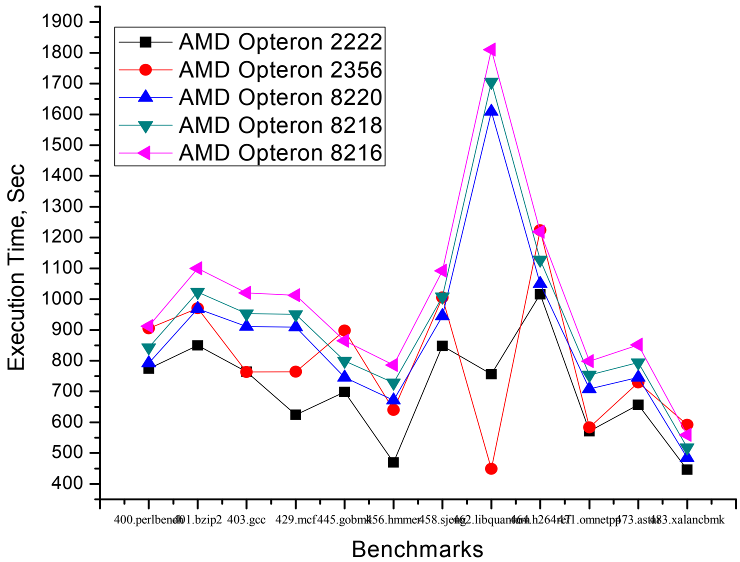


Figure 3: Execution Time variation with Benchmarks in different AMD Opteron Series Processors

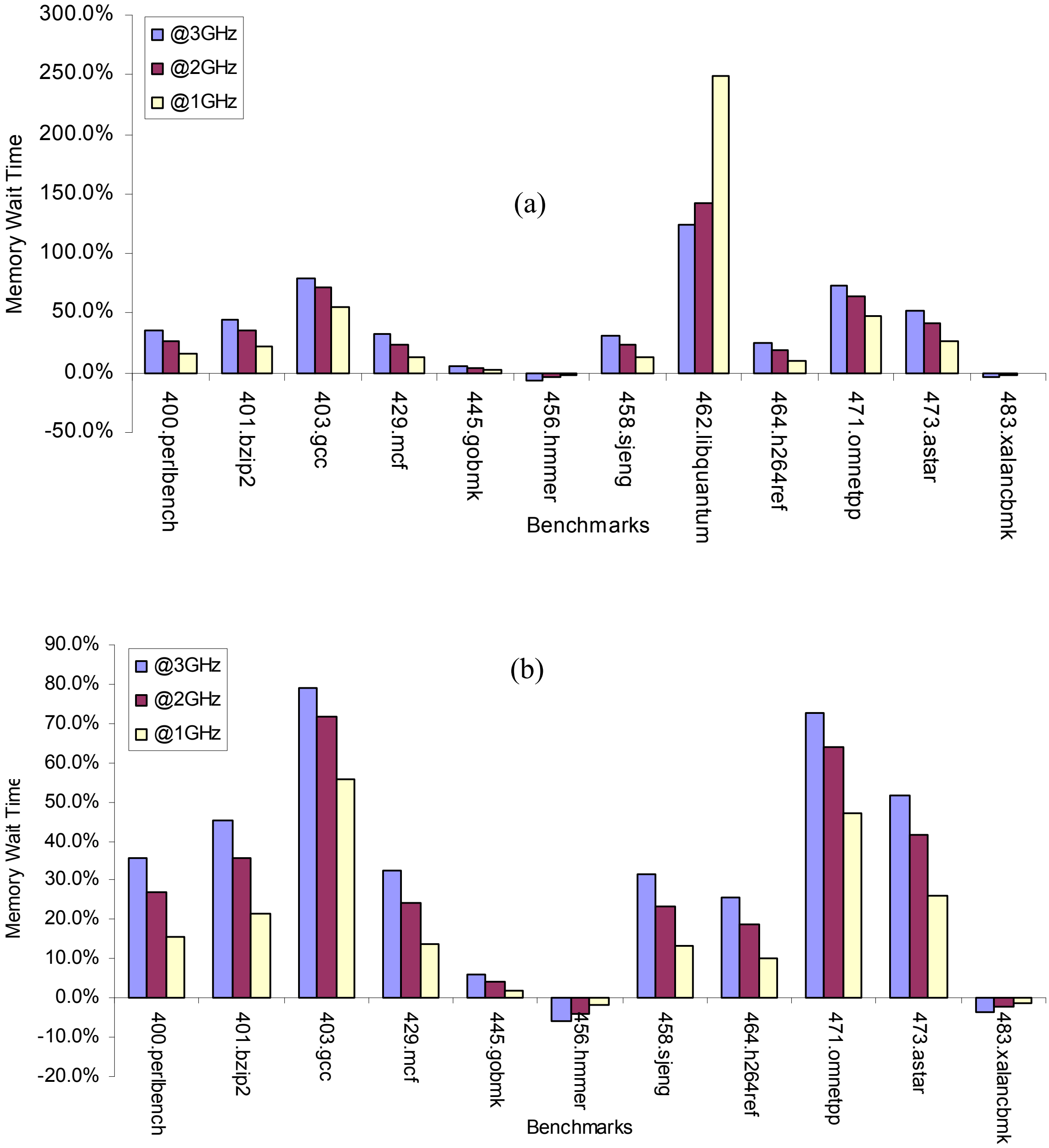


Figure 4: (a) The comparison of normalized task completion time @1GHz, @2GHz and @3GHz processor frequency on AMD processors, (b) Magnified view of (a) without 462.libquqntum benchmark.

| Core Frequency | 3000 | 2800 | 2600 | 2300 | 2400 | Memory wait time, % of TCT | | |
|---|---|---|---|---|---|---|---|---|
| base score | 14.7 | 12 | 11.3 | 13.2 | 10.5 | | | |
| Clock Cycle, ns | 0.333 | 0.357 | 0.384 | 0.434 | 0.416 | @3GHz | @2GHz | @1GHz |
| 400.perlbench | 774 | 792 | 843 | 905 | 912 | 35.8% | 27.1% | 15.7% |
| 401.bzip2 | 850 | 969 | 1023 | 970 | 1100 | 45.2% | 35.5% | 21.6% |
| 403.gcc | 764 | 911 | 953 | 763 | 1020 | 79.1% | 71.6% | 55.8% |
| 429.mcf | 624 | 909 | 950 | 764 | 1012 | 32.3% | 24.1% | 13.7% |
| 445.gobmk | 699 | 746 | 799 | 898 | 865 | 6.0% | 4.0% | 2.1% |
| 456.hmmer | 470 | 672 | 728 | 640 | 786 | -5.9% | -3.9% | -1.9% |
| 458.sjeng | 848 | 945 | 1008 | 1005 | 1092 | 31.6% | 23.6% | 13.4% |
| 462.libquantum | 756 | 1609 | 1705 | 449 | 1810 | 124.9% | 142.7% | 249.0% |
| 464.h264ref | 1016 | 1050 | 1128 | 1224 | 1219 | 25.6% | 18.6% | 10.3% |
| 471.omnetpp | 571 | 708 | 754 | 583 | 798 | 72.6% | 63.9% | 46.9% |
| 473.astar | 657 | 746 | 794 | 729 | 852 | 51.5% | 41.5% | 26.2% |
| 483.xalancbmk | 446 | 485 | 518 | 592 | 559 | -3.4% | -2.2% | -1.1% |

Table 3: Memory Wait Time @1GHz, 2GHz and 3GHz processor frequency.

## 6. Disclaimer

All the observations and analysis done in this paper on SPEC CPU2006int Benchmarks are the author's opinions and should not be used as official or unofficial guidelines from SPEC in selecting benchmarks for any purpose. This paper only provides guidelines for performance engineers, academic users, scientists and developers to better understand the benchmark suite and to build a complete benchmark suit which covers the entire spectrum of the memory space without weak spots.

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