SAS® System Performance on 80386 Class PC's

Mark Pabst, Bureau of Reclamation

Abstract

With the advent of the SAS® System on microcomputers, some confusion has arisen about the best hardware and software for maximum performance. This paper discusses in depth two 80386 systems. The first is a 16 MHz machine with two 28-ms hard drives; the second, a 25 MHz machine with a 14-ms hard drive. Several other systems are included for comparison. Variations on the following setups are considered: math coprocessor, CPU speed, EMS, hard drive utilization, operating environment (DOS® 3.21, DOS 3.3 and VM/386™), and disk caching. Typically, users plagued with poor system performance try to solve the problem by purchasing a faster PC with more memory. In most instances, this will not have the greatest impact on system performance.

Background

Information presented at SUGI 14 (Towey, 1989) dealt with the issue of PC performance and the SAS System. His organization was thinking of migrating their work over to IBM PS/2™ from their base of AT's. His benchmark testing showed that the PS/2's actually performed worse than the AT's.

At the Yucca Mountain Project Group of the Bureau of Reclamation, we are also interested in PC performance issues, especially as they relate to non-IBM equipment and multiuser/multitasking (MUT) software. Historically, we have acquired newer, faster machines and loaded them with memory. Seldom did we consider: a) benefit of processor speed, b) kind of memory, c) what should be the speed of the math coprocessor for a given CPU, d) speed of the RAM, or e) throughput of the hard disk system.

I performed benchmark testing on several 80386 machines using Towey's outline. I modified Towey's benchmark program to add graphics generation and more rigorous processor loading. This study will focus on improvements which will increase performance twofold or more.

Hardware

PC Designs GV-386 - 80386 at 16 MHz, switchable to 8 MHz, 4 Mb of 100-ns DRAM on the motherboard, AT style architecture, 64-Kb RAM caching circuit for 0-wait state, two 45-Mb 25-ms hard drives, EGA 256-Kb host display, three Wyse 60™ terminals driven by a Digiboard COM 4/1™ card, 80277 10-MHz math coprocessor.

Mini Micro System Micro Cache 386/24™ - 80386 at 25 MHz, 5 Mb of 80-ns DRAM on the motherboard and card, AT style architecture, 384-Kb of shadow memory, 32-Kb caching circuit - 0-wait state, one 160-Mb 14-ms hard disk, VGA 256-Kb host display, four VGA 256-Kb displays driven by two Unterminal™ cards, 80387 25-MHz math coprocessor.

Dell 325™ - 80386 at 25 MHz, 4 Mb of 80-ns DRAM on the motherboard, AT style architecture, 394-Kb shadow memory, 32-Kb caching circuit - 0-wait state, one 160-Mb 14-ms hard disk, VGA 256-Kb host display, three VGA 256-Kb displays driven by two Unterminal cards, 80387 25-MHz math coprocessor.

Operating Environments

DOS - Versions of DOS were 3.21 and 3.30 supplied by Microsoft. Quarterdeck's QEMM™ driver was used to set up EMS. On the GV-386, Speedstorm's SSTCH™ driver was used to access the two large disk drives. PC-Kwik™ by Multisoft was used to cache the large disk drives. These disks are driven simultaneously by a Western Digital 1003 Controller. One test was made by having the SASSWIRK directory on the same drive as the SAS System. An additional test was made with SASSWIRK on the second hard disk.

Disk Cache - The PC-Kwik cache was set up in EMS as defined by the QEMM driver for the DOS runs. For tests with no cache, the caching software was not installed during system boot. The VM/386 disk cache utilizes extended memory along with the rest of the VM/386 components.

Active VM's - VM/386 was configured to run with a number of user stations, a spooler, and the VM Manager (VMM). The number of VM's on a machine is then the number of users plus two. For the GV-386, there are six VM's, while the Mini Micro has seven. In the test where two VM's are active, the benchmark was run with the EM/386 - Multiuser runs were made with VM/386 by IGC. VM/386 is add-on software that allows harnessing of multitasking/multiuser capabilities of the 80386 processor. IGC recommends that you estimate 1 Mb RAM per user. Because you will want to use the EMS option in SAS with VM/386, I recommend that you estimate at least 1.5 Mb RAM per user. VM/386 is a program that runs like any other piece of software. Therefore, setting up the PC to boot without automatically invoking VM/386 will result in a standard DOS machine. This is termed the front end. When VM/386 is invoked, the PC operates in a MUT environment. For the testing done in this paper, the DOS runs were made in the front end. VM/386 has the ability to turn off nodes which are inactive. This way, the remaining active nodes get a greater share of processor time. For our systems, we have the inactivity timeout set at 7 seconds. During testing on a single node, care was taken to make sure all other nodes were idle. All of the nodes had insufficient memory to use EMS while in this environment. Disk caching is supported by the cache option supplied with VM/386.

Setups

SAS - All runs were made with SAS for Personal Computers, Release 6.03, utilizing Display Manager. SAS/Assist was not invoked during testing. The SAS session was ended at the completion of an individual run. This was done because, as multiple submissions are made during a session, an increasing number of files may be opened and some files increase in size. This virtualizing process can degrade performance if the disk drive does not contain a large area of contiguous space. To eliminate the effect, the SAS session was ended so the workspace would be in the same arrangement for every run. For the "Cowboy Hat" graphics portion of the benchmark, the graphics output is written to the screen. A key must be pressed for SAS to clear the display and complete processing. SAS accumulates the time the user takes to press the key and includes it in the execution time. Therefore, in all tests, the continuation key was pressed immediately after the graphics completion. Finally, the Filebuffer statement in the CONFIG.SAS file was set to 10 512 on the DOS setups and 5 512 for VM/386 setups.

EMS - The size of the EMS is defined with the -EMS option in the CONFIG.SAS file. For this testing, EMS sizes that were used included 0, 384 and 1024 Kb.

CPU Speed - CPU speed was varied by adjustments of the hardware on the PC's. Speeds that were tested included 8, 16, and 25 MHz. Recall that the SAS System for PC's is not written to take advantage of the 80386 processors' special features, that is, 32-bit math. Processor manufacturers claim that this is where real speed improvements can be realized.

Number of Hard Disks - The GV-386 contains two physical hard disks. These disks are driven simultaneously by a Western Digital 1003 Controller. One test was made by having the SASSWIRK directory on the same drive as the SAS System. An additional test was made with SASSWIRK on the second hard disk.

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while another user would print a large document. The test where five VM's are active is an actual work day where five users are working with their individual applications. Not all users are active at all times and VM's do go idle during the duration of the benchmark. Note: We are unable to get two SAS sessions to execute simultaneously without spurious errors. Therefore, two SAS sessions could not be run simultaneously under VM/386.

Math Coprocessor - Math coprocessors can be disabled by the SAS command $NONDOP in the CONFIG.SAS file. If the PC contains a math coprocessor, SAS will use it by default.

Benchmark Code - Code from SUGI 14 (Towey, 1989) was used so comparisons could be made between those runs and those in this paper. Code was added to more rigorously load the PC. The popular "Cowboy Hat" example given in the SAS/GRAPH manual was selected.

```sas
DATA Short;
  RUN;
  PROC SORT DATA=Long;
  BY VAR1 VAR2;
  RUN;
  DATA Short;
  DO i=1 TO 1000;
    VAR1=UNIFORM(958); VAR2=UNIFORM(958);
    Char1='ABC';
  OUTPUT;
  END;
  RUN;
  PROC SORT DATA=Short;
  BY VAR1 VAR2;
  RUN;
  OPTIONS DEVICE=EQUAL
    CIAXIS=ORANGE;
    CTEXT=YELLOW;
    CAXIS=BROWN;
  CIAXIS=ORANGE;
  DATA Hat;
  DO x=-5 TO 5 BY .25;
    y=sin(sqrt(x*x + y*y));
  OUTPUT;
  END;
  RUN;
  TITLE F=SWISS H=4 G=PINK 'The Cowboy Hat'; TITLE2 H=2 ANGLE=90 ' '; PLOT y*x=z;
  RUN;
```

Compatibility

Math Coprocessors - A common problem today involves vendors setting up systems with an incorrect math coprocessor. This point was well made at SUGI 14 (Bruhlitt, 1989). Remember to obtain a system in which the math coprocessor speed and the socket speed are the same. Mismatched speeds can cause unpredictable results. The literature given with the PC will usually have this information. If it is not there, contact your vendor and have them find out from the factory. Also, do not assume that if a vendor supplies you with a system already set up, that the correct math coprocessor is in the machine. Check the manuals against what you have.

0-wait State - Many manufacturers are advertising their machines as having great increases in performance due to their use of o-wait state technology. In simple terms, o-wait state is a way to get slow RAM to perform better with a faster CPU. With CPUs that run at 4.77 or even 6 MHz, RAM chips are able to keep up with the processing. But with the advent of faster CPUs, RAM is left behind the processor. Thus, the CPU will have to wait a number of clock cycles (wait state) for RAM to finish its processing. The problem then is to find a way to get RAM to keep up with the CPU. You could put in very fast RAM, but the cost would be prohibitive. Unfortunately the solutions offered are as diverse as the manufacturers. Common today is what has become known as the RAM Cache. In this scheme, you take a very fast RAM chip (32 or 64-Kb) and use it to cache instructions and data between the CPU and the slower standard RAM. This is the same technique that is used in disk caching, but the hardware and software are different. With this technique, you are then able to get the CPU to process without waiting for the RAM; this is the 0-wait state. Unfortunately, some manufacturers may use a low-quality technique to get this increase in performance. For the past year, users have called the Institute reporting problems where SAS warns that some fonts are unavailable to SAS/Graph. We encountered this problem and reported it. The Institute responded that they had seen it on their own machines but could not duplicate it on identical hardware. After investigation, we found that the 0-wait state technique on some machines causes the problem. Disabling 0-wait state will solve it. On other machines, as in the benchmark test run on the three VM/386 machines, as well as an 80386 PS/2 machine, alterations had to be made to the motherboard. Some machines may provide a 0-wait state technique of sufficient quality to handle SAS, but do some checking first. The benchmark code given in this paper should be sufficiently rigorous. When in doubt, disable 0-wait state. The loss in performance from disabling of a poor quality 0-wait state technique will not be large. On one machine, 0-wait state gave no performance increase for this benchmark.

EMS - For 80386 class PC's, the processor can use extended memory as expanded (EMS) memory. You will need a driver such as QEMM or CEMM to make the conversion. For 80286 machines, products have come onto the market which purport to be EMS drivers. They are in fact only software which gives the appearance of EMS memory and does not provide 100% compatibility with hardware-driven EMS. Make sure to use EMS which add-in card you might use.

Observations

Tables 1 and 2 show the results for the benchmark tests executed. Subtotal times on these machines are referenced to Towey's PS/2 Model 80 run of 14.04 minutes. Table 1 shows the runs from the machines comparing DOS and VM/386. Table 2 compares a variety of machines while varying the options setup. Graphical representations of these results are included in Figures 1 and 2. Note the DTK-12 machine is an AT clone not otherwise discussed in this paper. Several other machines, which were not as extensively tested, are presented for comparative purposes. Figure 1 illustrates the performance increase (or decrease) at the subtotal time level when options are added. Option setups were kept as similar as possible. Figure 2 is an illustration of the complete benchmark test run on the three VM/386 machines, as well as an 80286 workstation on a LAN, the DTK 80286, and two other 80386's. This figure compares stand-alone benchmarks against VM/386. The vertical reference line in both figures is Towey's standard of 14.04 minutes.

To evaluate the cost/performance relationship of the different PC's a performance product was calculated. The performance product can be thought of as a kind of cost/benefit ratio. The
performance product is the cost of the PC multiplied by the total run time. This value is then divided by 1000 and the number of stations (users). Smaller values are better. Costs were taken from requisitions and the benchmark times were taken from Tables 1 and 2. Figure 3 presents the performance product for 80286 and 80386 machines with processor speeds between 12 and 25 MHz. Since some of these computers are several years old, current prices may be less. Note that for the three VM results, the tests were run with a single user active. These values are then the best that could be expected.

The following observations can be made based on the results of the testing. Remember that these results are only applicable to this particular benchmark code and selected hardware:

1. Without options, most machines run the benchmark in about the same amount of time, regardless of processor type or speed. Adding options increased performance on all machines except the Compaq, which stayed the same, and the PS/2, which got worse. Performance of I/O overrides CPU performance.

2. EMS is not a speedup product. It is used so larger applications can be run with SAS. SAS uses optimized EMS images to replace the standard base memory images. Because of this, you get an apparent performance increase. For this benchmark the best amount of EMS is 384 Kb. Going to 1024 Kb is of no benefit.

3. Doubling CPU speed does not cut execution time in half. The performance increase is about 65%.

4. Using two hard disks instead of one while running in DOS is of no benefit. While the disk controller is capable of driving two hard disks at the same time, the bus cannot handle them simultaneously. There is a twofold increase in performance in VM/386, depending on drive type. VM/386 appears to handle MFM controllers better than ESDI controllers.

5. Adding a 384-Kb EMS, a math coprocessor and 384-Kb disk cache to a 80386 will give a performance increase of about 410% for MM 386, 450% for Dell 325 and 130% for GV-386.

6. Math coprocessors Increased performance about 200% in the HAT DATA step. Other studies done by us have shown performance increases in other SAS functions and operators to range from 110% (addition) to 200% (ine).

7. With two VM's running, there is a small increase in benchmark time above one VM running. Performance degradation caused by additional user tasks is small. It appears that VM/386 inserts a lot of blank time while controlling the hard disk. This free time is taken by other users.

8. The larger the disk cache, the better the performance. Increasing it from 354 Kb to 2440 Kb or more will give an increase of 110 to 220%.

9. Benchmark runs in VM/386 take 1.5 to 21 times longer than on a stand-alone PC.

10. The performance product is equivalent for the 80286 running at 12 MHz and the 80386's running at 25 MHz. Older technology 80386 PCs do not have as good a performance product as the newer machines, indicating that PCs are becoming more cost effective with time. The degradation in performance of the VM/386 benchmarks is not offset by reduced cost per user.

11. A good deal of judgement is needed for addition of options to a PC or purchase of a new machine. Increasing performance on computers is a relatively complex process because many operations are interrelated. Figure 4 illustrates how improving/updating hardware may have no appreciable impact.

**Recommendations**

Efficient Coding - Firstly, the best way to improve performance is by good coding. One of the strengths of the SAS System is the variety of ways in which you can solve the same problem. Be sure to investigate all of your coding alternatives. Papers entered at SUGI are very helpful in this area. Performance is also dependent on the Institutes code. Plans for release 6.07 to utilize Windows will circumvent the DOS 640 Kb barrier. Release 6.07 will then be able to reduce coding overlays and subsequently reduce disk accesses.

MUT - Moving the SAS System onto a PC multiuser environment will bring about unacceptable performance. At this time SAS should only be run on stand-alone PCs. For rigorous SAS applications, the stand-alone microcomputer may not be an appropriate platform. If better performance is needed, move to another operating system or platform.

Options - Math coprocessors and disk caching are beneficial and cost effective for AT style machines. Math coprocessors can double the speed of some parts of the SAS System, but for an application as a whole, the increase will be about 10%. Disk caching can improve performance up to 330%. Size of the disk cache is dependent on the machine configuration. Do not get a hard drive system slower than 28 ms. Greater amounts of memory will allow you to increase performance. Two to four MB should be appropriate. Considering the advent of Windows and OS/2, more memory will give an additional benefit in the future.

286 vs. 386 - 80286 machines can outperform some 80386 machines when options are used. The performance product for 80386 machines is competitive with top-of-the-line 80386 systems. Users who need to keep down up-front costs may find an 80286 a better choice.

High Performance 80386 - 80386 machines do exist that have acceptable performance at a greater cost than other PC's. Be aware of differences in manufacturers' 80386 products. Some brands may be as much as two times faster than others.

**References**


The author can be contacted at the YMPG BSS - (303) 236-9813, B-N-1, 1200/2400/19200 Trailblazer or voice (303) 236-4178.

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### PCD GV-386 Running DOS 3.21

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### PCD GV-386 Running VM/386 1.22

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### Mini Micro 386/25 Running VM/386 1.22

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<th>Hat</th>
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### Dell 325 Running DOS 3.30

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### Dell 325 Running VM/386 1.22

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**TABLE 1**
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<th>Long Sort (min)</th>
<th>Short Sort (sec)</th>
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<th>Rel. to Hat (min)</th>
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IM - Insufficient Memory
NI - Not Installed
NEC-LAN: PC as a workstation on a Novell LAN. No other workstations active. SASWORK on server hard disk.
DTK: See description elsewhere.
PC Designs: See description elsewhere.
Dell 1/2: Standalone PC.
Dell 325: Memory on motherboard. Four empty bus slots.
MM: Memory on 32-bit card. One empty bus slot.
Sun: Sun workstation with Sun/OS (UNIX) running a DOS process.

TABLE 2