TAKING IT TO THE NEXT LEVEL: THE AMD GEODE™ LX 800@0.9W PROCESSOR

EMBEDDED x86 PROCESSOR PERFORMANCE RATING SYSTEM WHITE PAPER

A New Processor, a Refined Benchmark Suite

In our previous White Paper on the Embedded x86 Processor Performance-Power Rating System, we created a realistic method for measuring performance of high-end embedded x86 processors using well-recognized benchmarks. The benchmarks were targeted for defined applications such as internet appliances, thin clients, set-top boxes, very low cost PC's, and personal digital assistants (PDAs). EPRS solved the problem of ranking and rating a processor on just clock speed, a method that the industry by and large is moving away from. For example, both AMD and Intel no longer use just clock speed to price processors, and given multi-core processors becoming more prevalent, clock speed will surely become even more erratic as a true measure of the value of a system in the future.

A note on the difference between EPRS and PPR: Synchromesh Computing created the aggregative benchmark suite called EPRS (Embedded Processor Rating System). AMD has taken this suite and has added their specified power consumption figures, creating their own PPR (Power Performance Rating). We did not measure power consumption ourselves in EPRS.

EPRS / PPR was designed specifically for processors targeted at certain application spaces (internet appliances, PDA's, thin clients, very low cost PC's) in a Windows® XP Home or Windows CE environment. The benchmarks selected and built were a mixture of well-known/recognized PC benchmarks (i.e. SiSoft Sandra, HDBench), well-regarded technical synthetic benchmarks (HINT, Stream), and some we created to target those

application spaces mentioned above. EPRS, though, is not entirely suitable for desktop PC or server markets (for example, it includes 2D graphics but not a 3D graphics benchmark), but elements of it can and should be used in general PC benchmarking (HINT and Stream, again). However, desktop, workstation, and servers have different workloads than thin clients, internet appliances, and PDAs.

Indeed, Synchromesh Computing is working with AMD on a version of EPRS for Linux (not surprisingly called "L-EPRS"). That benchmark suite will be largely quite different, since Linux machines are often used in different ways than low-cost Windows CE or even Windows XP Home systems.

Since the initial version of EPRS, a number of additional experiments and tests have been performed. Synchromesh Computing took this opportunity to refine EPRS based on feedback, and on results of these experiments. We upgraded from *SiSoft Sandra 2002* to *SiSoft Sandra 2005*, and we removed the *IM Chat Room* test since it didn't really tell us a great deal more information than we could already glean from other benchmarks.

A Review: System Benchmarking Requirements

If we were just studying embedded processors alone, we would turn to the industry standard EEMBC benchmarks (http://www.eembc.org). However, those benchmarks are focused almost exclusively on the processor itself and not the processor interacting with the other components and operating system. In other words, we needed a system-level benchmark suite that included benchmarks accepted by designers in the application spaces under study, specifically internet appliances, PDAs, thin clients, and very low cost PCs in a Windows XP Home or Windows CE environment.

In developing our benchmark suite, our goal was to more closely replicate real-world usage in order to come up with a pragmatic measurement of processor performance. We knew we would need to incorporate performance parameters such as:

- raw CPU processing power
- L1 and L2 cache size and speed
- memory bandwidth
- multimedia performance
- file system performance
- available system headroom when running an application
- system storage (hard disk access) performance
- 2D graphics processing

Revised EPRS Benchmark Suite

The Revised EPRS benchmark suite is made up of the following tests:

- HINT for CPU and memory subsystem performance
- STREAM for memory subsystem testing
- SiSoft SANDRA 2005 for CPU, multimedia, memory and cache performance
- Synchromesh Computing SynchroBench™ for Internet-oriented benchmarking
- PCMark 2002 for complete subsystem testing
- HDBench for CPU, memory, graphics and hard drive performance
- Winbench® ’99 over RDP/ICA for thin client benchmarking (using Windows CE and Windows XP)

We recognize that the selection of benchmarks would certainly affect ratings, because different architectures perform differently when faced with different workloads. Nonetheless, the benchmarks chosen for this particular study were a well-balanced sample. We relied upon our own experiences in benchmarking stretching back over 20 years, accepted some input from AMD to determine what was currently popular with consumers (and rejected other input as unsuitable), discovered what was being used by design engineers, and in general picked benchmarks suitable to internet appliances, thin clients, very low-end PCs, and so on. These benchmarks may or may not be suitable for mid-range PCs or above (although HINT and Stream are well-used by performance engineers, and Winbench '99 over RDP is still used by very large software companies in benchmarking).

HINT (Hierarchical INTegration), written by Ames Research Lab, Department of Defense, has gained a reputation for being the most scalable and accurate measure of CPU and memory subsystem performance. We build HINT from C source code using Visual C/C++ 6.01, and build it the exact same every time with optimization turned on, according to the rules laid down by the HINT community.

Most benchmarks measure either the number of operations that can be performed in a given time period, or the time required to perform a given fixed calculation. HINT does neither; rather, it performs a particular calculation (estimating upper and lower bounds for the definite integral of a monotone decreasing function) with ever increasing accuracy. The accuracy of the result at any given time is called the "Quality"; we may measure the improvement in quality at any given time as "Quality Improvements per Second," or QUIPS. As the computation progresses and the quality of the results improve, more memory and more operations are required to improve the answer.... Higher is better. HINT curves are a

function of raw CPU processing power, L1 and L2 cache size and speed, and main memory bandwidth.[1]

More information on HINT can be found at:

http://hint.byu.edu/documentation/Gus/HINT/ComputerPerformance.html#Quips

STREAM, written by Dr. John McAlpin of Silicon Graphics, is another open source, industry-standard benchmark suite that does an excellent job of measuring sustainable memory bandwidth. Embedded processors are often connected to the Internet, and almost always must process large amounts of data typical of multimedia bit streams. We build STREAM from C source code using Visual C/C++ 6.01, and build it the exact same every time with optimization turned on, according to the rules laid down by Dr. McAlpin.

The STREAM benchmark is a simple synthetic benchmark program that measures sustainable memory bandwidth (in MB/s) and the corresponding computation rate for simple vector kernels. Computer CPUs are getting faster much more quickly than computer memory systems. As this progresses, more and more programs will be limited in performance by the memory bandwidth of the system, rather than by the computational performance of the CPU. As an extreme example, several current high-end machines run simple arithmetic kernels for out-of-cache operands at 4-5% of their rated peak speeds --- that means that they are spending 95-96% of their time idle and waiting for cache misses to be satisfied The STREAM benchmark is specifically designed to work with datasets much larger than the available cache on any given system, so that the results are (presumably) more indicative of the performance of very large, vector style applications.[2]

More information on STREAM can be found at:

http://www.austin.rr.com/mcalpin/papers/bandwidth/bandwidth.html

Sandra, a very useful PC tool written by SiSoft, stands for the System Analyzer, Diagnostic and Reporting Assistant. It also has a benchmarking component that has gained a certain amount of credibility by being quoted by other labs searching for a quick and direct way to measure CPU performance. The new version is called SiSoft Sandra 2005. We chose to discard, however, the Sandra benchmarks based on Dhrystone and Whetstone, because these were not relevant to our testing. We focused on the unique benchmarks that Sandra brings to the table:

SANDRA Multimedia CPU
SANDRA Filesystem
SANDRA Cache & Memory
SANDRA Memory Bandwidth

SiSoft Sandra 2005 comes in a pre-built binary format.

[1] Nicholas Coult, Ph.D., Assistant Professor of Mathematics, Augsburg College
[2] John D. McAlpin, creator, STREAM

SynchroBench, written by Synchromesh Computing, measures the amount of headroom available in a system running a set of user scenarios, including playback of an MP3 file, two MPEG files, a Macromedia Flash movie (audio and visual combined), web page browsing of complex web pages, and multiple real-time clocks. Unlike other benchmarks, SynchroBench seeks to measure the amount of processing power left available to the user while running these scenarios. It does this by using a unique proprietary technology that calibrates itself to the processor. We believe that this is an excellent way to measure real-world performance for embedded processors. Synchromesh Computing is working with key microprocessor and system vendors in the thin client, Internet appliance, PDA, and mobile phone markets to make this a new industry standard. It has been proven to work up to mid-range PC's in gauging headroom, and has been ported to Windows CE, XP, and Linux. We build this benchmark from C source code using gcc for x86 version 3.3.3, and build it the exact same every time with optimization turned on.

PCMark™ is now owned by Futuremark Corporation. It consists of system tests, CPU test, memory test, hard disk test, and 2D and 3D graphics tests. Although comprised of 70 subtests, we do not consider the 3D graphics tests applicable to very low cost PC/Internet appliance/thin client machines. We selected the well-sorted out PCMark 2002. It comes in a pre-built binary format.

HDBench is a useful tool for measuring general integer, floating point, hard disk, memory, and graphics performance. It is quite popular in Japan. It comes in a pre-built binary format. Despite its name, HDBench is not just a hard disk benchmark.

Around 1999, the standard for PC benchmarking included Ziff-Davis' **Winbench® '99**. Companies such as Microsoft® and Wyse use it to test and benchmark thin clients. It has a particularly strong graphics component (what was a weakness in the PC space – being susceptible to simply faster graphics cards – is actually useful when running this over RDP/ICA protocol). All of the processing occurs on the server, while the graphics is sent down the Ethernet wire to the client (the target under test). It comes in a pre-built binary format.

Because these processors support both Windows XP and Windows CE, we benchmarked both. Windows CE is particularly important in high-end embedded environments.

Why aren't other benchmarks included? It is always tempting to pan benchmarks in general, but benchmarking has been around for as long as processors and computer systems have been developed. It is even more tempting to say, "Well, we think this 3D graphics benchmark is important", but that ignores the special, though large, market segment these processors are targeted to.

A New Baseline: AMD to AMD Comparison

One criticism of the previous EPRS was that the baseline that was chosen was a competitor's product. While we defend the use of any processor in the same general performance class targeted at the same general price level at the same type of applications as a comparison point, we decided to re-baseline EPRS on an existing AMD processor with known performance characteristics. The new baseline for EPRS is thus the AMD Geode GX 533@1.1W processor, and all comparisons are based on that processor.

Introducing the AMD Geode™ LX 800@0.9W Processor

The Geode product line has quite a history, and AMD is obviously not standing still as it introduces this new Geode LX 800@0.9W processor. We decided to pit this processor head to head against the AMD Geode GX 533@1.1W processor, and see how it stacked up. Given the applications and the benchmarks, how could we rate this processor? Would our thesis that clock speed is an inadequate measure of overall performance stand up in this new round of benchmarking?

Since this was an AMD to AMD comparison, we used systems provided to us by AMD's Personal Connectivity Solutions Group. We verified the processor clock speed, and set up our environment to be repeatable and reliable (see Appendix 1 for details).

System Configurations

Manufacturer	Processor	Speed	RAM	Hard Disk	Motherboard	OS
AMD	Geode™ GX	400 MHz	DDR 256 MB (shared)	Western Digital 80 GB	Hawk	Windows® XP Home Windows CE
AMD	Geode™ GX	500 MHz	DDR 256 MB (shared)	Western Digital 80 GB	Hawk	Windows® XP Home Windows CE

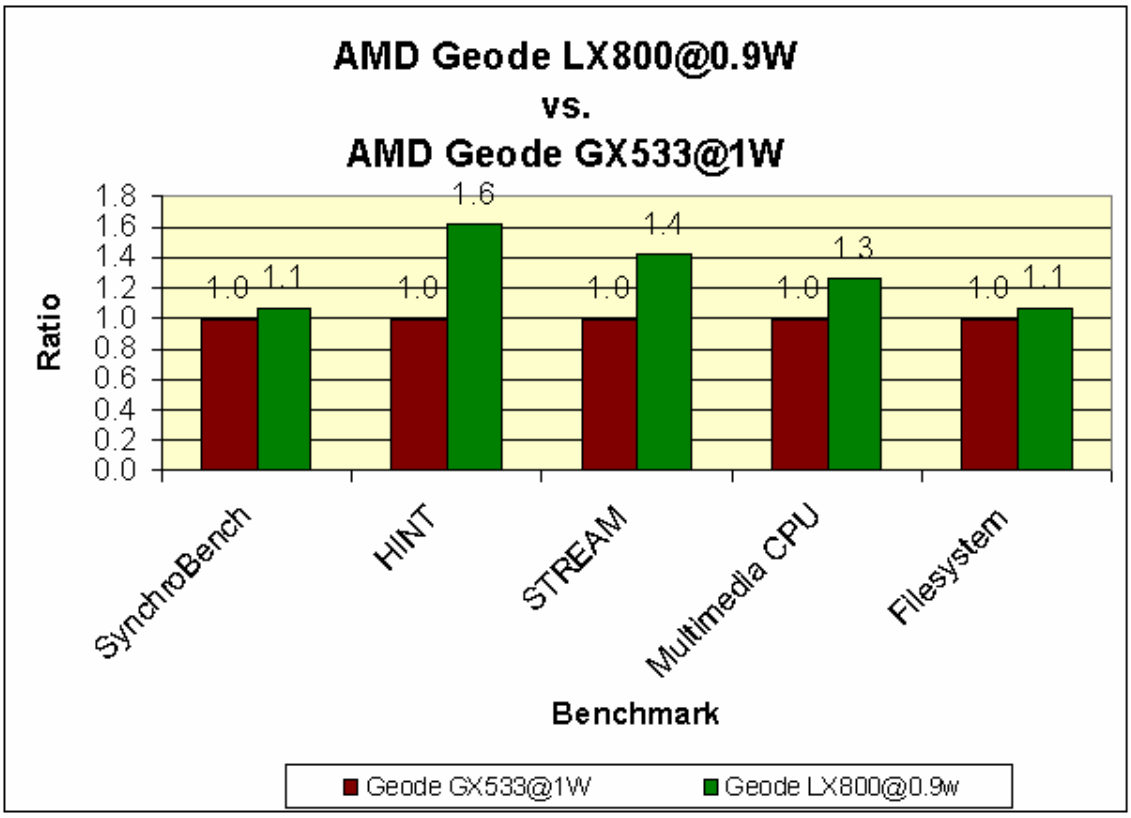
After selecting the processors and configurations, we ran each system through the benchmark tests that make up the EPRS benchmark suite. We generated the overall scores for each of the tests. Some benchmarks produced a single figure of merit (for example, HINT generates QUIPS). Some, such as Stream, produce a number of scores. For these tests, we used the Geometric mean within that suite so that the extremes were slightly discounted (benchmark suites such as EEMBC and SPEC, typically use the geometric mean, rather than the arithmetic mean).

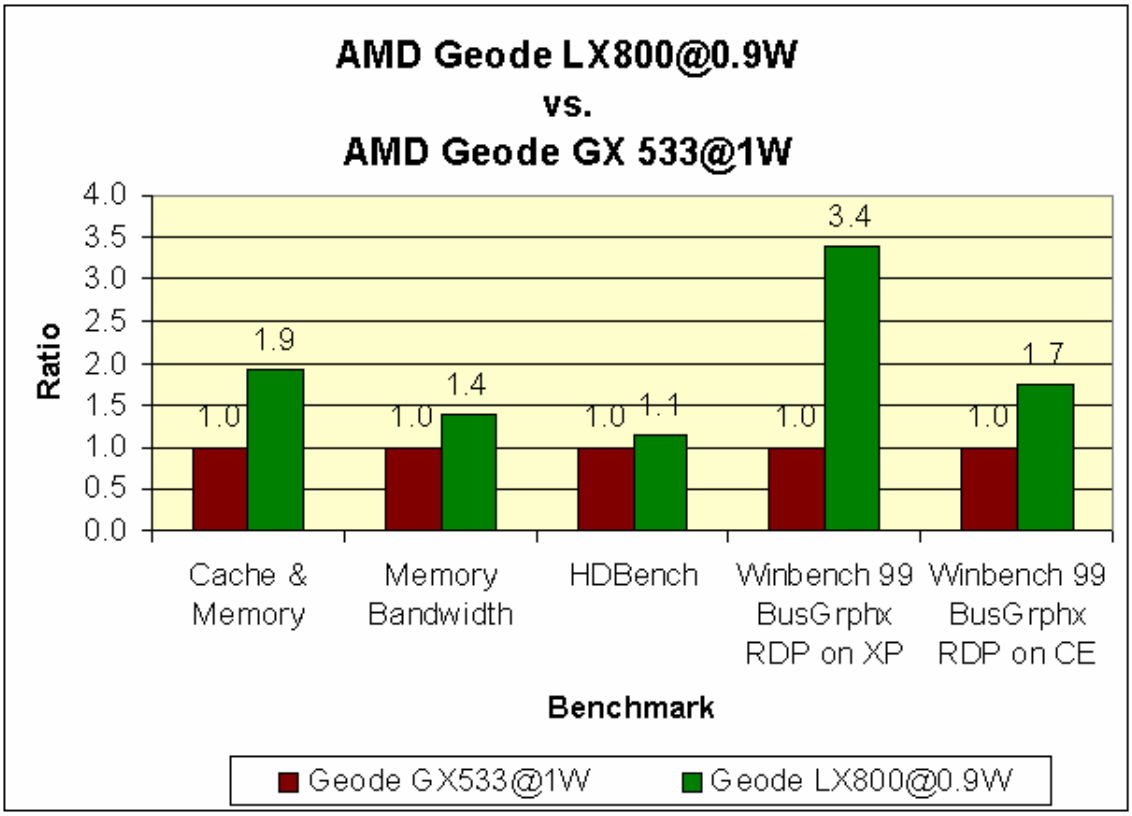
AMD Geode™ LX 800@0.9W Processor vs.
AMD Geode™ GX 533@1.1W Processor

SynchroBench	Score	569.05
HINT	QUIPS Score	863.33
STREAM	Geomean	760.08
SANDRA Multimedia CPU	Geomean	673.07
SANDRA Filesystem	Geomean	572.00
SANDRA Cache & Memory	Geomean	1016.78
SANDRA Memory Bandwidth	Geomean	735.91
HDBench	Overall Score	607.29
Winbench® 99 BusGrphx RDP on XP	Score	1802.94
Winbench® 99 BusGrphx RDP on CE	Overall Score	931.95
EPRS (Embedded Processor Rating)		**801.7636**

Table 1: Summary EPRS for AMD Geode LX Showing Equivalent Clock Speed Rating

What this says is simple: The Geode™ LX 800@0.9W processor can be rated at about the equivalent performance of an 800 MHz processor. The performance in graphical form looks like this:





Graph 1: Overall Summary Benchmark Scores

We can clearly see the effect the Geode processor's 2D graphics engine has on the thin client benchmarking results, because while the other benchmarks all show fairly good clustering, the Winbench 99 Business Graphics over RDP shows outstanding performance. We would like to note that these processors are used extensively in those types of applications. Even if we remove that particular benchmark from the calculations, the score drops to 780.87 - still very close to the equivalent of 800 MHz. Ignoring this benchmark, however, is not especially helpful since companies such as Wyse and Microsoft® use it to measure performance themselves, and since these processors are targeted at exactly this type of application.

Conclusion

Clock speed is not the only factor that goes into performance, and with this study we have once again shown that it is logical to rate a processor based on a suite of recognized benchmarks. Memory subsystem, graphics, bus speed, and instructions per clock cycle all play a role in overall performance.

Indeed, we believe that processor companies in this application space need to move beyond clock speed, and use EPRS benchmarking to position their products, to price their products, and provide meaningful product information to their customers.

The AMD Geode LX 800@0.9w processor earns its nomenclature based on our measured performance.

Synchromesh Computing welcomes all system, software, and processor vendors to submit their systems for benchmarking and certification.

About Synchromesh Computing

Synchromesh Computing provides benchmarking, performance analysis, software development, and software testing services. Located in Austin, Texas with customers world-wide, Synchromesh Computing has a first class client list, the full faith and confidence of the microprocessor and computer industry, and is known for fairness in benchmarking and performance.

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Appendix 1: SETTING UP A SYSTEM FOR EPRS

These steps are performed every time for every machine benchmarked using EPRS. As much as possible, hardware and software configurations are made identical. All source code benchmarks are compiled with the exact same compiler, the exact same way. Since no benchmark uses instruction set extensions such as SSE, 3DNow!™, AltiVec, etc. this is fair. Hard disk differences are minimized as much as possible and normalized as much as possible.

1. Go into the BIOS and select "Optimal Defaults". After these values are loaded, setup any embedded video memory share size to 16MB or as close as possible. Also, set first boot device to CD-ROM in preparation for the next step.
2. If no operating system or something other than Windows XP-Home SP1, insert the Win XP-Home SP1 disk and reboot the system. Then do a normal install
3. Install all necessary drivers, such as Video and Sound drivers.
    a. Set video to "1024x768x32", refresh rate of 75Hz
    b. Set Screensaver to "None"
4. Disable the following services:
    a. Alerter
    b. Auto Updates
    c. System Event Notification (Must be stopped before COM+ Event System.)
    d. COM+ Event System
    e. Error Reporting Service
    f. Fast User Switching Compatibility
    g. Messenger
    h. Routing and Remote Access (may already be disabled)
    i. Task Scheduler
    j. Terminal Services
    k. Themes
    l. Wireless Zero Configuration
5. Set the properties of the taskbar
    a. Enable "Autohide"
    b. Disable "Always on Top"
    c. Disable "Hide Inactive Icons"
6. Turn off Advanced Language Options
    a. Control Panel
    b. Regional and Language Options
    c. Languages
    d. Details
    e. Check "Turn off Advanced Language Options"
7. Remove any programs from the Startup directory and from the Run registry key.
8. After a re-boot, there should only be 14 services running. Once the balloon with the days remaining appears, there will be a 15th service. This should be stopped.
9. Copy directory \EPRS to the appropriate benchmark directory.
10. Install DirectX 9B. The setup file is C:\EPRS\directx9b\dxsetup.exe.
11. Install SisSoft Sandra. The install program is C:\EPRS\Sandra\sp2002_uni_NT_2K_XP.exe.
12. Defragment the hard disk.

RUNNING BENCHMARKS

Before running any benchmark, reboot the system.

1. Running Sandra
    a. In the Benchmarks directory is a file named “Bench.bat”. This file will run Sandra according to the setup in file “SandraScript.ini”. The results will be stored in a file named “System Report.txt” in the Benchmarks directory.
    b. The batch file should be run by using the Run start option. There will be a DOS window open until Sandra completes.
    c. After Sandra completes, rename the “System Report.txt” to “Sandra_Report_{system info}.txt”.

2. Running HINT
    a. The version of HINT used was compiled with VisualC++ Version 6. The executable is located in the Benchmarks directory and is named hint_prj.exe. It has a time/date stamp of December 26, 2003, 4:15:20 PM.
    b. Open a DOS window, change to the \Benchmarks directory and run the program. The program will take quite a while to run, over an hour in some cases, so do not check on it very often.
    c. At the end, the program will display a message “Finished with xxxx net QUIPs”. **NOTE**: the net QUIPS data is not saved.
    d. A file of data points will be saved in the INT file in the Benchmarks directory. This is the file used to generate the Quips plots. Only the first two columns of data are used. Insert the “Finished with xxxx net QUIPS” line at the end of the file and rename the file “HINT_{system info}.txt”
    e. When finished, close the DOS window.

3. Running STREAMS
    a. The executable for STREAMS is located in the Benchmarks directory and is named wstream.exe.
    b. To run this program, first open a DOS window. Next switch to the Benchmarks directory, then run the program. The program must be supplied with two parameters, speed of the system under test (in MHz) and number of iterations (100). The output can be redirected so that it is captured. The typical command line will look like this: wstream {Speed} 100 > STREAM_{system info}.txt
    c. If redirection is not used, the program will display a summary when finished. **NOTE**: Copy this information as it is not saved. If redirection is used, then the only indication that the program is finished is the display of another DOS prompt, but the results have been saved.
    d. When finished, close the DOS window.

4. Running HDBench
    a. Run the program using the Run start option. The executable to run is HDBENCH.EXE in the C:\EPRS\HDBENCH directory. Click on the “ALL” button to start the tests.
    b. The test results are not saved, copy the values. You can do an ALT-PrntScrn to copy the displayed data to the clipboard and then paste it into a Paint file. Name the file HDBENCH_{system info}.BMP.

5. Running SynchroBench
    a. Start Internet Explorer. Navigate to http://dickerman/cgi-bin/SynchroBench.
    b. Click “Run Benchmark” on the first page. Click on “Run Benchmark” on the second page.

c. When finished (approximately 15 minutes), a page of results will be displayed. This data is saved in a database, but it does not hurt to do a screen capture (ALT-PrntScrn) to copy the displayed data to the clipboard and then paste it into a Paint file. Name the file SynchroBench_{system info}.BMP.

6. Running Winbench 99 Business Graphics over ICA/RDP
    a. Connect to the applications server using the "START\All Programs\Accessories\Communications\Remote Desktop Connection" program.
    b. Log in to "Madison". This is a Windows 2003 Server machine. (It is a second drive in Madison).
    c. Close down any open windows.
    d. Run the Ziff Davis Winbench 99 (Start\All Programs\Ziff David Media Benchmarks\Ziff Davis Media Winbench 99). Select the "Business Graphics Winmark 99" option for the Run line. Then click on run. There will be an information set of displays that indicates that extra programs are running. This is ok, continue on with the test. When
    e. When finished, use the save results option and input a good description of the system being tested. NOTE: the results are saved in a special format that is not easy to access outside of the Ziff Davis programs, so write down the information.

GENERATING THE EPRS

1. Open the spreadsheet (Project_Systems_{newest date}_EPRS.xls).
2. On the "Raw Scores Data Entry" page, create a new column of information for this tested system. Put all the benchmark scores in the proper rows. The data formats can be copied from the previous column. (highlight the column to copy, select the Edit/Copy menu item, then move to the new column and select the Edit/Paste Special menu item. Make sure that only the Formats check box is checked in the Paste Special popup option box.) NOTE: Make sure to put the new system in the first free column after the existing data.
3. On the "Configurations" page, add the new system's data.
4. On the "TP1 Ratings" page, copy the rightmost column with data (i.e. the last one used) into the next column. Update the system information at the top of the column with that for the current system. Make sure the right system speed is entered. The new column will now have the proper values for the new system.
5. Copy all the text from the last system rated to a position below it, then move the new column of data to match the text. NOTE: It is important to move the data, not copy it. Update the system information summary to match the new system.

Appendix 2: Raw Scores for Geode LX 800@0.9w Processor

SynchroBench		
	Empty	538.44
	Jupiter	550.57
	Aerosmith	538.49
	Hockey	544.22
	Yatta	878.73
	Clocks	579.86
	Images	539.42
	Synchromesh (pages/sec)	649.14
	Score	569.05
Winbench 99 Business Graphics over ICA/RDP		1802.939
Winbench 99 Business Graphics over ICA/RDP Using WinCE systems		931.9521
HINT (Compiled VC6)		863.3264
STREAMS		
	Copy (MB/S)	699.3348
	Scale (MB/S)	860.4136
	Add (MB/S)	743.0776
	Triad (MB/S)	746.4719
Sandra		
CPU Arithmetic Benchmark		
	Drystone ALU (MIPS)	810.2879
	Whetstone FPU (MFLOPS)	675.4608
CPU MultiMedia Benchmark		
	Integer aEMMX/Asse (it/S)	674.4817
	Floating-Point aE3DNow! (it/S)	671.6667
File System Benchmark		

	Drive Index (KB/S)	572
	Buffered Read (MB/S)	533
	Sequential Read (MB/S)	533
	Random Read (MB/S)	547.8056
	Buffered Write (MB/S)	820
	Sequential Write (MB/S)	799.5
	Random Write (MB/S)	779
Note: Smaller score better.	Ave. Access Time (est) (ms)	609.1429
Memory Bandwidth Benchmark		
	RAM Bandwidth Int Buffered isse: (MB/S)	725.7625
	RAM Bandwidth Float Buffered isse: (MB/S)	746.2
Cache & Memory Benchmark		
	Combined Index (MB/S)	1016.782
	2KB Blocks (MB/S)	962.7054
	4KB Blocks (MB/S)	944.5401
	8KB Blocks (MB/S)	971.0508
	16KB Blocks (MB/S)	1038.457
	32KB Blocks (MB/S)	1698.778
	64KB Blocks (MB/S)	3248.07
	128KB Blocks (MB/S)	2516.944
	256KB Blocks (MB/S)	1845.759
	512KB Blocks (MB/S)	1234.316
	1MB Blocks (MB/S)	710.6667
	4MB Blocks (MB/S)	709.0216
	16MB Blocks (MB/S)	709.0216
	64MB Blocks (MB/S)	709.0216
HDBench		
	ALL	607.2853
	CPU Integer	676.3105
	CPU Float	663.9961
	Memory Read	631.4008
	Memory Write	830.7249
	Memory Read & Write	542.9139
	Video Rectangle	1643.731
	Video Text	1655.412
	Video Ellipse	1107.9
	Video BitBlt	304.5714
	Video DirectDraw	1232.563

Disk Read	538.1743
Disk Write	577.321
Disk File copy	551.8068