DECstation RISC Family

Graphics Performance Analysis

Digital Equipment Corporation

Workstation Marketing

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Contents

1 Graphics Performance

The performance measurements presented here are of 2D graphical operations performed most commonly by typical applications. Digital strongly believes that graphics performance comparisons should be based on benchmarks that measure what applications can actually expect to achieve. Accordingly, this 2D performance analysis only tests performance through X ™ (the industry-standard 2D graphics API) of operations a typical application might perform, coded the way the application would use X11. It also includes peak performance measurements through X11.

In addition to an overall performance rating over the entire test suite, results from individual tests are reported and analyzed. Use of a composite number by itself can be misleading in comparing graphics performance, as relative speeds of different operations will vary greatly between workstations (ie. one workstation may draw lines twice as fast but only display image data at half the speed of another). As different applications stress different graphics features, it is more important to understand performance of specific operations than to compare arbitrarily weighted averages.

The tests executed on Digital workstations were based on pre-release versions of ULTRIX™ Workstation software. As with all internal software, not all optimizations are in place. Digital expects that graphics performance will increase when production ULTRIX V4.0 software is released. At that time, the performance tests will be re-run and the report will be re-issued. All tests on Sun® workstations were executed using Sun production software. All tests on the IBM ® workstation were executed using IBM pre-release software.

1.1 Test Suite Derivation

Many of the tests use, or are based on, *x11perf (V1.2),* a widely available industry-standard X11 primitive test suite. *x11perf* measures performance of a very wide array of X11 functions; it is distributed with the X11 source code from MIT and thus is readily available to anyone for testing purposes. *x11perf* was also chosen as it employs a very accurate client-server synchronization technique to measure graphics operation completion time; namely reading a pixel back from the frame buffer. Other benchmarks, as distributed in the user-contributed X11 software directory from MIT, often report inaccurately high numbers for graphics-accelerator-based systems as they do not time exact completion of all operations in the accelerator pipeline.

Although it measures performance of the vast majority of individual X11 primitives, standard *x11perf* (as distributed by MIT) does not measure certain ways of using these primitives that are important in understanding application performance. For example, *x11perf* does not include a test to measure drawing many individual lines in sequence with different colors. It also does not measure a full range of small objects, such as 50-pixel polygons, typical in many CAD applications. Accordingly, several additional tests were added to this test suite. These include line tests to measure per-primitive overhead and the effect of attribute changes on 2D graphics performance In addition, 50-pixel polygon performance is measured. Our intention is to provide tests that mirror the type and size of primitives most often used by 2D graphics application developers. To the best of our knowledge, this is the first time performance of these typical

programming techniques has ever been published in workstation comparisons. All the additional tests utilize the same timing mechanism found in *x11perf*. A full description of each test can be found in Section 4.

Although *X11perf* includes an extensive suite of windowing tests, it was impossible to report these results in our analysis because the X servers on the IBM and Sun workstations could not complete the tests fully. We hope to be able to expand the scope of our analysis to include windowing performance at a later date.

1.2 Comparing Competitive Systems

In order to be sure that graphics performance is being compared fairly between systems, it is necessary to test systems using the exact same test suite. Today, unlike in the area of CPU performance where the SPEC (Systems Performance Evaluation Cooperative) CPU test suite is accepted by the industry as a defacto standard, there is no standard test suite for measuring 2D graphics performance. Thus, to be able to complete a comparison against a particular workstation model, it was necessary for Digital to run all of the tests reported in this paper on that system.

Because of the rapid rate of introductions of new competitive systems, it is impossible for Digital to test all variants of all vendors' workstations. In particular, access to IBM's new RISC workstation family was limited and allowed us to report results using only one display type. We do feel, however, that the results published in this paper represent the majority of systems which compete in a class comparable to our DECstation RISC workstation family.

The workstation industry is still struggling with developing a concise set of 3D graphics performance tests that evaluate all workstations on an equal basis. Currently, NCGA's Graphics Performance Committee (GPC) is working on its graphics test suite, planned on being released during NCGA's Spring '90 show. Digital is one of the sponsors of this effort and will support the GPC benchmarks on its workstations. A 3D performance summary similar to this report will be published when standard tests become available. In the meantime, Digital is releasing predicted 3D performance metrics through its product literature.

Digital hopes that tests such as *x11perf* and NCGA's GPC effort gain acceptance as effective tools for measuring graphics performance. One drawback with current 2D and 3D graphics testing is the lack of *typical* application benchmarks. We have tried to include some tests that we believe typify what real applications do. We realize that this in not all-inclusive, which is why Digital is working with SPEC and GPC to develop a standard, industry-recognized graphics test suite.

It is our intention to continue to expand this graphics performance analysis in the future to include other competitor systems. As tests become more standardized, we will include, rather than test, results published by the vendors themselves.

2 Graphics Performance Analysis

Digital's X Window System implementation, coupled with state-of-the-art CPU and graphics, provides industry-leading, X11-based, 2D graphics workstation performance on the desktop.

2.1 DECstation 5000 Model 200PX

- Over the entire range of tests, the DECstation 5000 Model 200PX averages 3 times faster than the SPARCstation 1/GX.
- Over the entire range of tests, the DECstation 5000 Model 200PX averages 6 times faster than the IBM POWERstation 320.
- Highlighted by 281,000 2D vectors/second, the DECstation 5000 Model 200PX delivers over 3 times the vector performance of the SPARCstation 1/GX over a range of 2D line tests. Through X11, the SPARCstation 1/GX attains only 25% (101,000) of its claim of 400,000 2D vectors/second.
- The DECstation 5000 Model 200PX delivers a maximum performance boost of 250% (filled polygons) over the DECstation 5000 Model 200CX while sustaining an average performance increase of nearly 80% over the entire test suite.
- The DECstation 5000 Model 200PX is 4 times faster than the SPARCstation 1/GX when drawing 50-pixel triangles.

2.2 DECstation 5000 Model 200CX

- Over the entire range of tests, the DECstation 5000 Model 200CX averages more than 4 times faster than the SPARCstation 1/CFB and 71% faster than the SPARCstation 1/GX.
- Drawing 10-pixel circles, the DECstation 5000 Model 200CX is 20 times faster than both the CFB and GX versions of the SPARCstation 1.
- Over the range of tests presented in this report, Digital's DECstation 5000 Model 200CX averages more than 3 times the graphics performance of IBM's comparably priced POWERstation 320.

2.3 DECstation 3100

- The overall performance of the DECstation 3100 is within 3% of the SPARCstation 1/GX.
- Over the entire range of tests, the DECstation 3100 averages 2 times the overall graphics performance of IBM's POWERstation 320. In the image operation subset, the DECstation 3100 averages 5 times faster than IBM's system.
- The DECstation 3100 outperforms the SPARCstation 1/GX on 10-pixel triangles and is an order of magnitude faster on 10-pixel circles.
- The DECstation 3100, based on a color frame buffer, averages over 2.5 times the overall performance of the SPARCstation 1 with color frame buffer.

2.4 DECstation 2100

- Over the entire range of tests, the DECstation 2100, Digital's lowest priced RISC workstation, averages 40% higher performance than the IBM POWERstation 320. On the image operation subset, the DECstation 2100 performance averages 4 times faster than the IBM POWERstation 320.
- The DECstation 2100 consistently outperforms the SPARCstation 1/CFB by a 2 to 1 margin.
- In the line test with color changes, a typical application usage, the DECstation 2100 outperforms the SPARCstation 1/GX by 240%.

3 Tests results

3.1 How to Interpret the Graphs

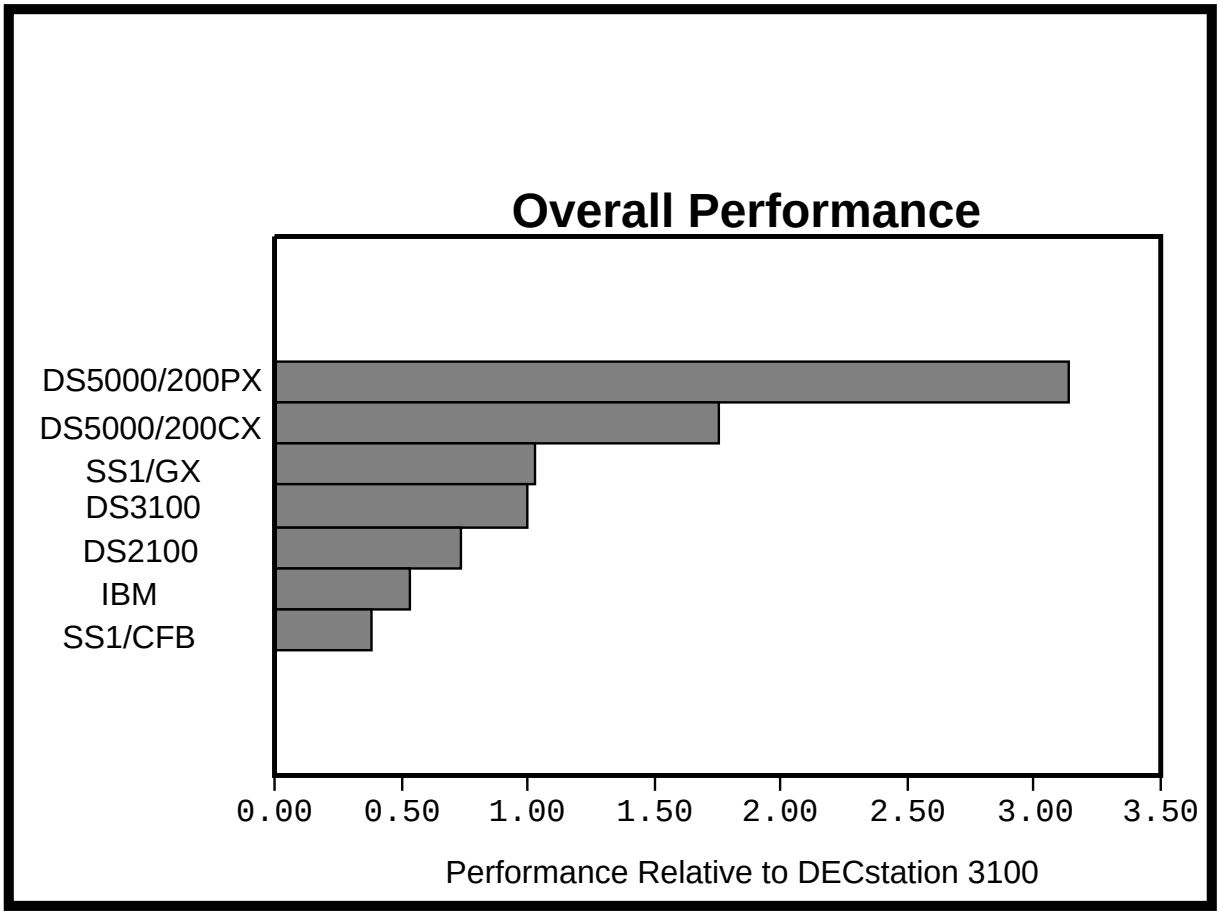
The test suite consists of 14 tests organized into five groups: lines, filled polygons, filled rectangles, text generation and image operations. Up to four different tests may be included in each group. The first graph displays the result of taking the geometric mean of all tests normalized to the DECstation 3100. Because a single figure of merit may be misleading, the results from each test group are presented separately. If a group consists of more than one test, the geometric mean of that group's results is plotted. Each test is described in detail in Section 4.

Key to Graphs

Abbreviation	Full Product Description	Graphics
DS2100	Digital DECstation 2100	8 Plane Color Frame Buffer
DS3100	Digital DECstation 3100	8 Plane Color Frame Buffer
DS5000/200CX	Digital DECstation 5000 Model 200CX	8 Plane Color Frame Buffer
DS5000/200PX	Digital DECstation 5000 Model 200PX	8 Plane Accelerated 2D
SS1/CFB	Sun SPARCstation ™ 1	8 Plane Color Frame Buffer
SS1/GX	Sun SPARCstation 1 with GX option	8 Plane Accelerated 2D
IBM	IBM POWERstation ™ 320	8 Plane Color Graphics Display Adapter

3.2 Overall Performance

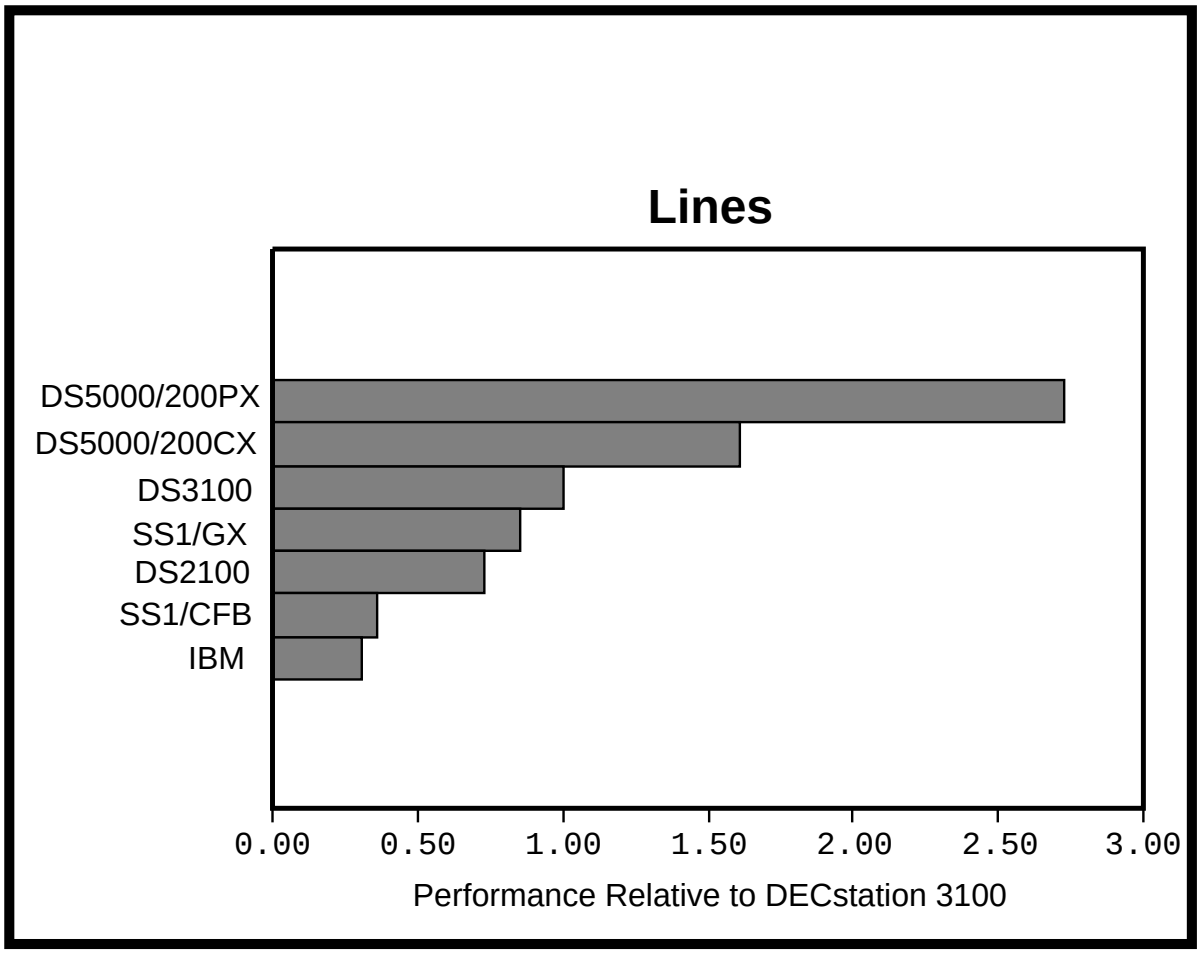
	DS2100	DS3100	DS5000 /200CX	DS5000 /200PX	SS1/CFB	SS1/GX	IBM
Geometric Mean	.74	1	1.76	3.14	.38	1.03	0.53
Relative to DS3100							



3.3 2D Lines

10 Pixel Lines (lines/second)

	DS2100	DS3100	DS5000 /200CX	DS5000 /200PX	SS1/CFB	SS1/GX	IBM
x11perf							
Lines	54,400	70,700	116,000	281,000	22,500	101,000	26,300
Additional Tests							
Disjoint Lines	35,800	49,900	76,100	148,000	18,200	53,300	14,100
Individual Lines	21,300	29,800	48,300	73,800	15,200	33,500	9,590
Individual Lines with color changes	8,360	11,600	19,400	22,100	3,380	3,440	3,100
Geometric Mean Relative to DS3100	.73	1	1.61	2.73	.36	.85	0.31

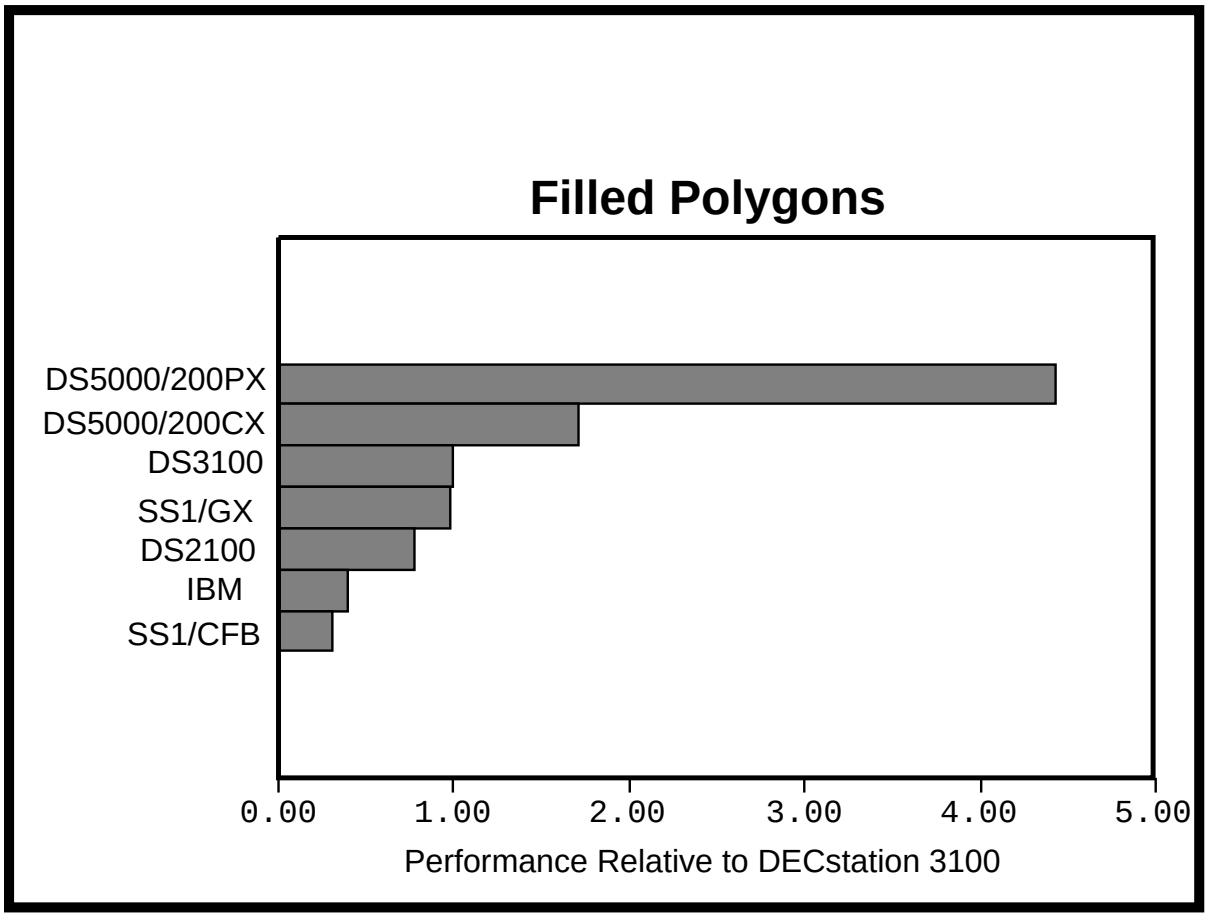


3.4 2D Filled Polygons

Filled Polygons (polygons/second)

	DS2100	DS3100	DS5000 /200CX	DS5000 /200PX	SS1/CFB	SS1/GX	IBM
x11perf							
10 pixel triangle[1]	5,060	5,970	9,630	20,700	2,340	4,960	2,260
100 pixel triangle[1]	715	950	1,690	9,750	480	4,940	660
10 pixel circle	5,500	7,410	13,200	8,220	699	650	913
Additional Tests							
50 pixel triangle	1,640	2,120	3,540	20,700	949	4,950	1,550
Geometric Mean	.78	1	1.71	4.43	.30	.98	0.39
Relative to DS3100							

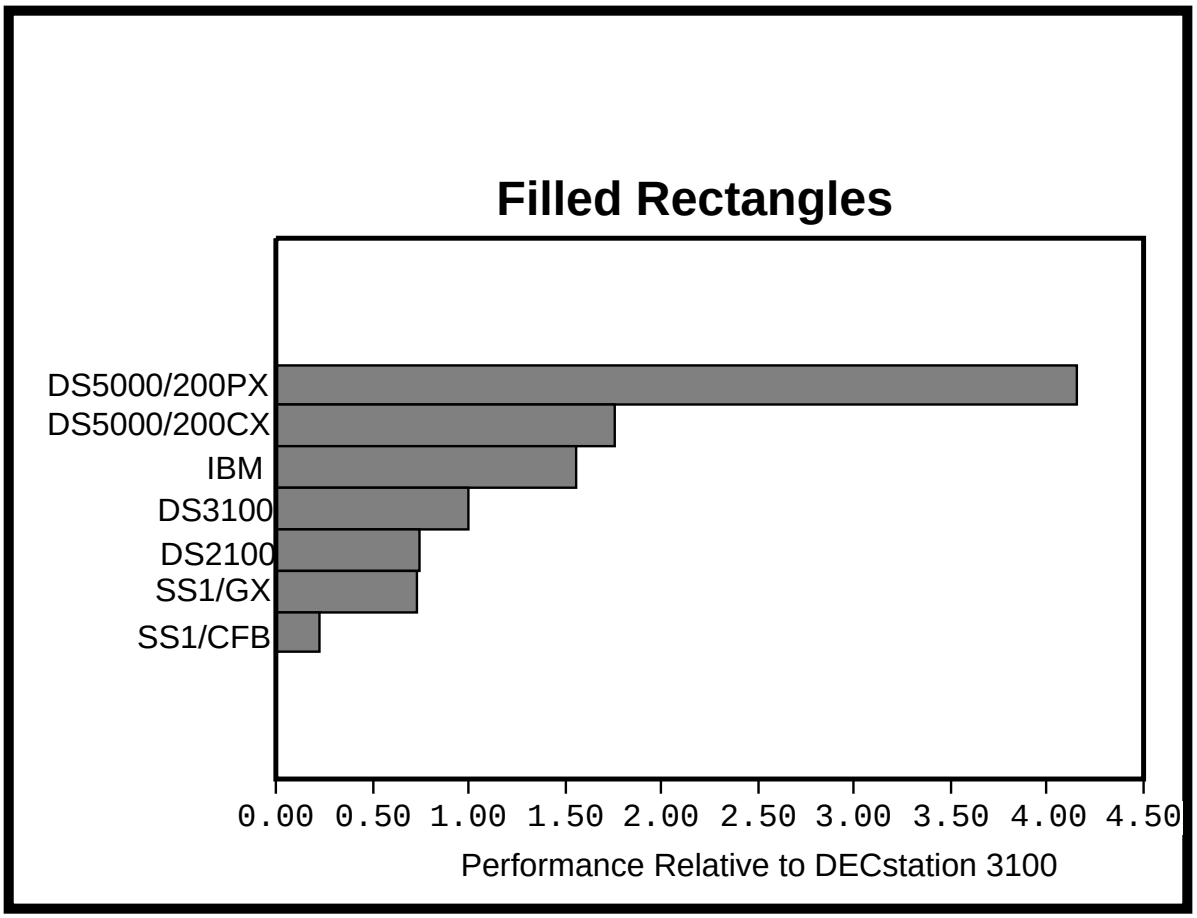
[1]Standard *x11perf* test incorrectly uses significantly larger triangles when claiming to measure 10 or 100-pixel-per-side triangles. The tests have been modified to draw triangles with the correct dimensions. This error will be fixed in a future distribution of *x11perf* from MIT.



3.5 2D Filled Rectangles

Filled Rectangles (rectangles/second)

	DS2100	DS3100	DS5000 /200CX	DS5000 /200PX	SS1/CFB	SS1/GX	IBM
Additional Tests							
10 x 10 pixel	29,000	39,000	62,400	138,000	4,570	8,690	46,100
50 x 50 pixel	2,630	3,620	6,980	17,700	1,650	8,810	7,410
Geometric Mean	.74	1	1.76	4.16	.23	.73	1.56
Relative to DS3100							

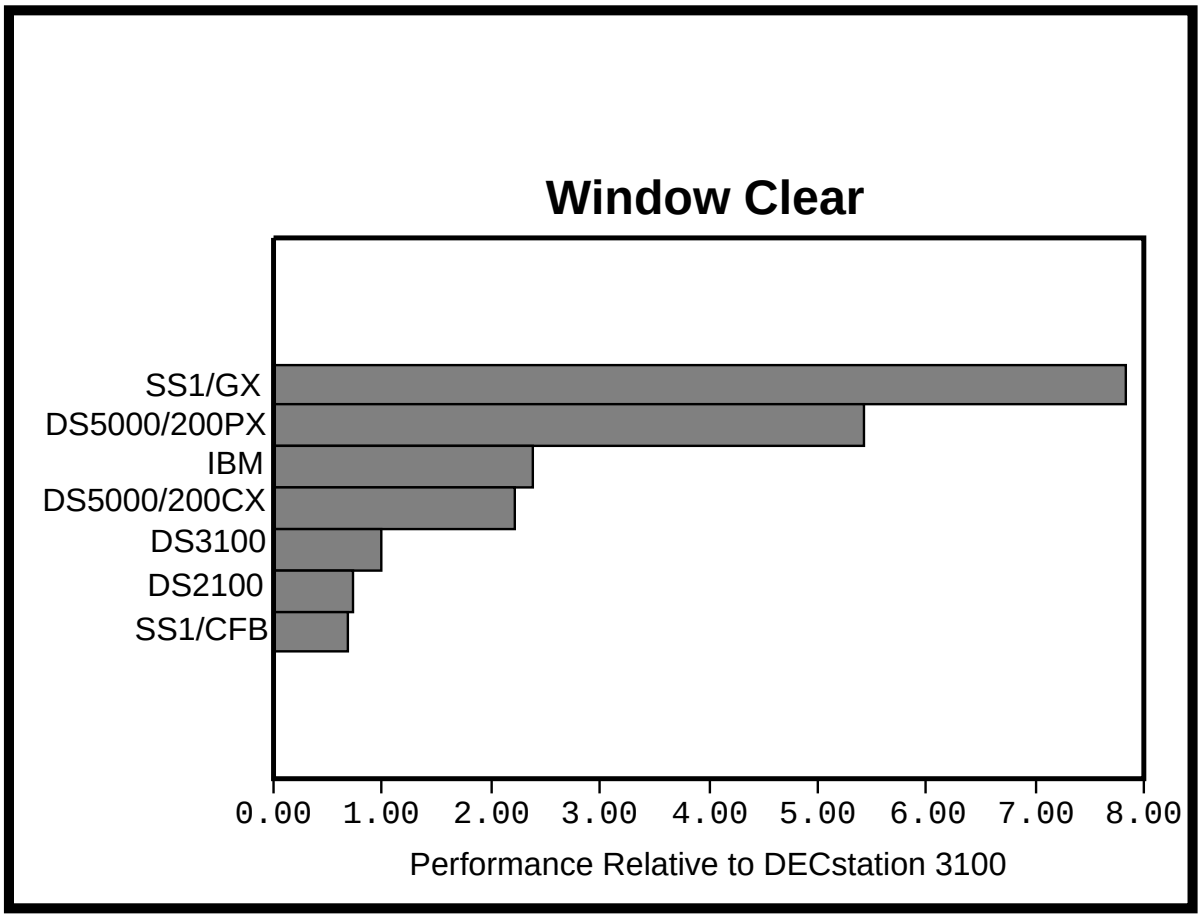


3.6 Window Clear

Window Clear (Mpixels/second)[1]

	DS2100	DS3100	DS5000 /200CX	DS5000 /200PX	SS1/CFB	SS1/GX	IBM
Additional Tests							
500 x 500 pixel window	7.3	10.0	22.1	54.3	6.9	78.3	23.9
Geometric Mean	.73	1	2.21	5.43	.69	7.83	2.39
Relative to DS3100							

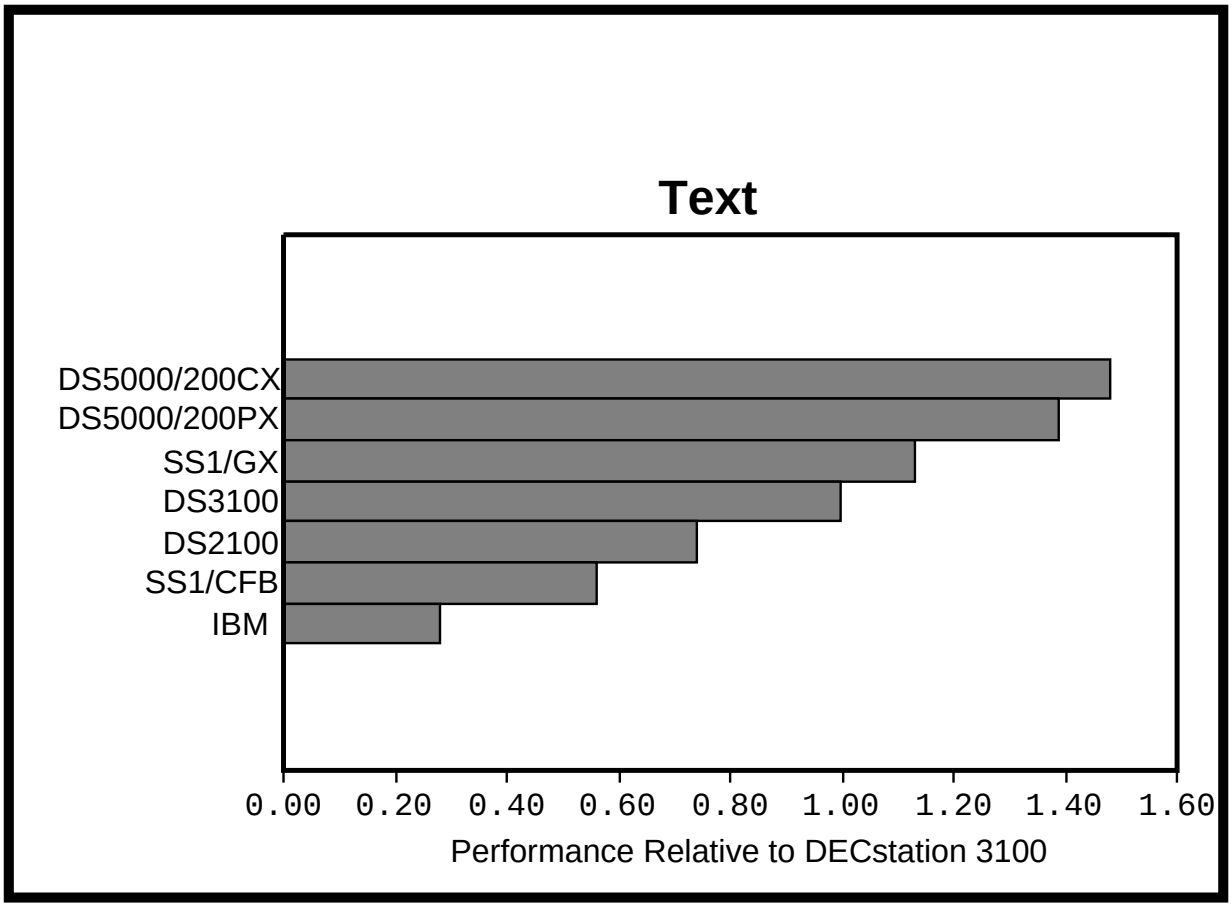
[1] *x11perf* reports "operations/second". These results have been converted to "Mpixels/second". To obtain the actual *x11perf* number, multiply the results above by 4 (1,000,000/ (500x500)).



3.7 Text

Text (Characters/second)

	DS2100	DS3100	DS5000 M200CX	DS5000 M200PX	SS1/CFB	SS1/GX	IBM
x11perf							
TR10 font	40,100	53,900	79,900	74,700	30,000	60,700	15,100
Geometric Mean	.74	1	1.48	1.39	.56	1.13	0.28
Relative to DS3100							

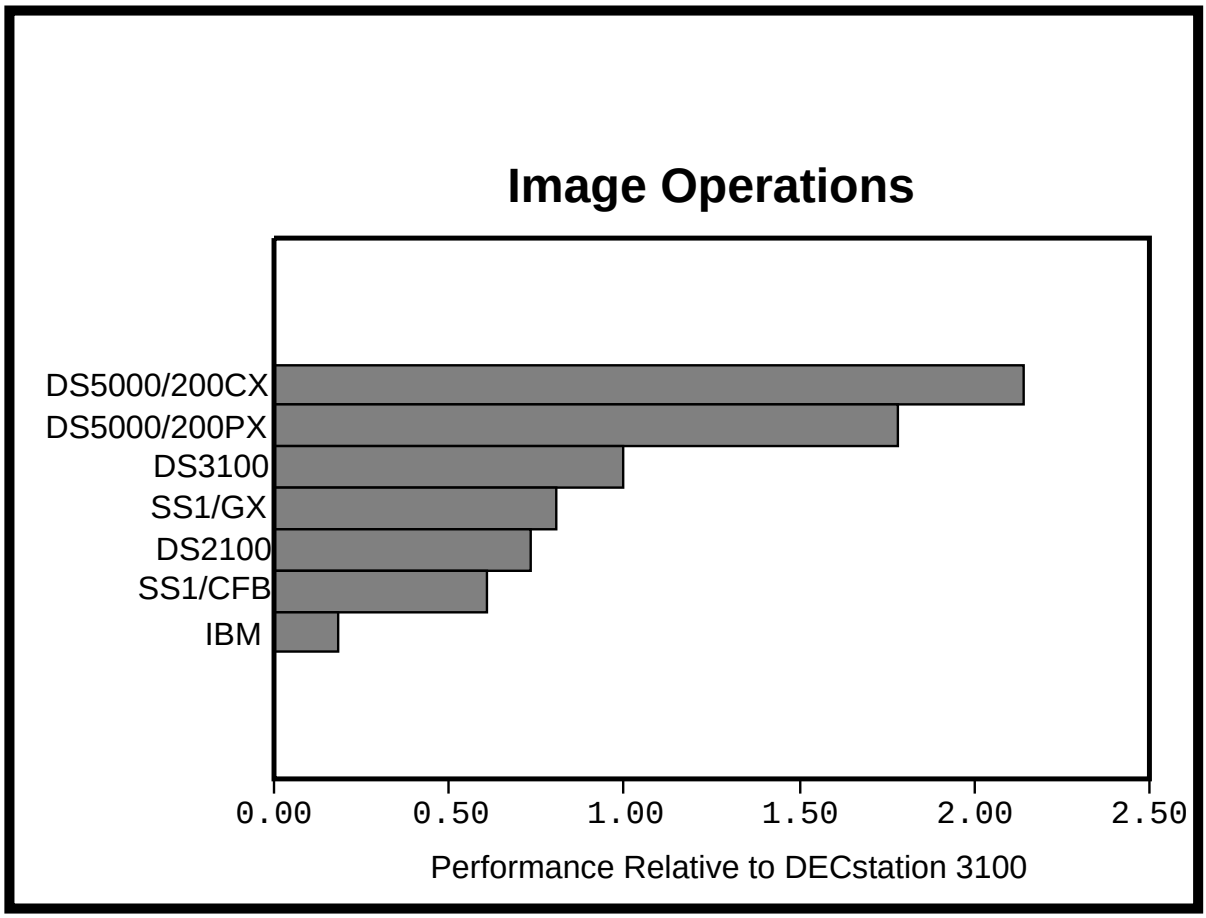


3.8 Image Operations

Pixel Image Operations (Mpixels/second)[1]

	DS2100	DS3100	DS5000 M200CX	DS5000 M200PX	SS1/CFB	SS1/GX	IBM
x11perf							
Copy 500x500 from pixmap to window	.63	.85	1.9	.85	.68	.7	0.4
PutImage 500x500 square	3.4	4.7	9.6	14.9	2.2	3.4	0.85
Geometric Mean	.73	1	2.14	1.78	.61	.81	0.18
Relative to DS3100							

[1] *x11perf* reports "operations/second". These results have been converted to "Mpixels/second". To obtain the actual *x11perf* number, multiply the results above by 4 (1,000,000/ (500x500)).



4 Description of 2D Tests

Each of the tests involved in the 2D benchmarking were run multiple times for varying amounts of times, using freshly started servers. These times ranged from 5 seconds to 30 seconds, in order to assess any variability in the test results, due to paging, swapping, and other system activity. Data collected for this report was gathered from a test time of 30 seconds for each machine, and was checked for consistency with other data gathered on previous test runs. All measurements reported here were determined to be representative for each test based on this analysis of test variability. During testing, no other user processes were running.

Test Descriptions

All tests used a 600x600 window (unless noted) and all graphics primitives were fully visible within the test window.

Some groups of tests include two types of tests: tests which are part of the *X11perf* suite as distributed on the MIT X source tape and additional tests based on X11 which were developed to tests area of X performance which Digital felt were typical of application useage, but were not already covered in *X11perf*. These additional tests are based on *X11perf* in that they use the same timing measurement and verification techniques. Digital plans to make the source code for these additional tests available through the user contributed X software distributed by MIT.

1. Line Tests

These tests are designed to measure the speed of drawing 10-pixel lines using various aggregate and attribute factors: as large and medium grouped polylines, as groups of disjoint line segments, and as individual lines, both with and without color changes.

x11perf

10-pixel polylines, drawn 1000 per polyline:

> 1,000 connected 10-pixel lines, of varying orientations are drawn as one polyline using "XDrawLines". This test is intended to measure the drawing speed of 10-pixel connected polylines with a high primitive grouping factor, and thus provides an approximate upper bound to the 10-pixel line drawing rate, via the server.

Additional Tests

10-pixel disjoint line segments, drawn 100 per group:

> 10,000 10-pixel diagonally oriented lines are drawn in groups of 100 disjoint line segments, using "XDrawSegments". This test is intended to measure the drawing speed of groups of disjoint line segments with a moderate primitive grouping factor, without color changes.

10-pixel lines, drawn individually without color changes:

> 10,000 10-pixel diagonally oriented lines are individually drawn using "XDrawLine", without color changes between lines. This test is intended to measure the speed of drawing lines individually versus

drawing them as polylines, and also to measure any additional overhead in drawing individual lines.

10-pixel lines, drawn individually, with color changes:

10,000 10-pixel diagonally oriented lines are drawn, each individually using "XDrawLine", changing color after each line by cycling graphics contexts with preassigned specific colors. This test is intended to measure the speed of drawing individually colored lines, which is common in many applications (e.g. CAD). Performance relative to the previous test provides information on additional overhead associated with processing per line color changes. This test provides an approximate lower bound for drawing 10-pixel lines with color changes.

2. Polygon Fills

These tests are intended to measure the speed of filling different polygons, and to obtain various polygon pixel fill rates.

x11perf

Filled triangles[1]:

1000 equilateral triangles, of varying orientations, are individually drawn as separate primitives, using "XFillPolygon". The two tests, use 10-pixel and 100-pixel per side triangles.

Filled circles:

1000 10-pixel diameter filled circles are drawn as one primitive using "XFillArcs". This test is intended to measure the speed of filled circle generation.

Additional Tests

Filled triangles:

1000 equilateral triangles, of varying orientations, are individually drawn as separate primitives, using "XFillPolygon". This test uses 50-pixel per side triangles.

3. Rectangular Fills

These tests are intended to measure pixel fill rates, using different sized fill areas.

Additional Tests

Filled rectangles:

5000 filled rectangles are drawn in a grid fashion, using "XFillRectangles" to draw all rectangles. For the 10x10 rectangle case, this test is intended to measure the speed of drawing small

rectangles, whereas for the 50x50 case, the intent is to measure the speed of generating moderately-sized rectangles.

4. Window Clear

Additional Tests

This test is intended to measure the speed of clearing a 500x500 window, and to obtain an approximate peak window clear rate.

5. Text Generation

This test is intended to measure the text drawing rates for a commonly used font.

x11perf

TR10 font[2]:

Generates 96 text strings, using the Times Roman 10-point, 75 dpi font. Each text string consists of 80 printable ASCII characters.

6. Image Operations

These tests are intended to measure the speed of copying different sized images from client and server pixmap memory to the screen.

x11perf

Transfer of pixel images from client to window:

Generates a pattern of lines in the test window, and creates an 8-bit deep image consisting of the pattern. The image is then repeatedly copied to varying areas fully within the window. It is intended to provide an approximate measure of peak memory bandwidth from client virtual memory to window memory.

Transfer of pixel images from pixmap to window:

Generates a pattern of lines in a pixmap, and then repeatedly copies the pixmap to varying areas fully within the test window. This test is intended to provide an approximate measure of the peak memory transfer bandwidth from server pixmap memory to window memory.

[1]Standard *x11perf* test incorrectly uses significantly larger triangles when claiming to measure 10 or 100-pixel-per-side triangles. The tests have been modified to draw triangles with the correct dimensions. This error will be fixed in a future distribution of *x11perf* from MIT.

[2]The TR10 font test for the DECstation 5000 Model 200CX did not run with the configuration server. Test results are from an earlier server, and are probably somewhat lower than expected.

5 System Configurations Tested

DECstation 2100 and DECstation 3100 :

ULTRIX T4.0-1, Rev 144
16 MB memory
RZ55 external disk (332 MB)

DECstation 5000 Model 200CX:

ULTRIX T4.0-1, Rev 129
16 MB memory
RZ55 external disk (332 MB)

DECstation 5000 Model 200PX:

ULTRIX X4.0-10, Rev 148
16 MB memory
RZ55 external disk (332 MB)

SPARCstation 1 Color Frame Buffer and GX Option

SunOS 4.0.3
16 MB Memory
OpenWindows 1.0
CG4 8-bit frame buffer or GX accelerator
(2) 104 MB internal disks
327 MB external disk

IBM POWERstation 320 with Color Graphics Display Adapter

IBM RISC CPU, 20 MHz.
AIX Version 3.1 (Tested 3/26/90)
24 MB memory
AIXwindows (Motif window manager)
320 MB internal disk