



SYSmark[®] 2018

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About BAPCo

Business Applications Performance Corporation (BAPCo) is a non-profit consortium with a charter to develop and distribute a set of objective performance benchmarks for personal computers based on popular computer applications and industry standard operating systems.

For more information about BAPCo or a complete list of the current membership, see our website at <http://www.bapco.com/>.

Table of Contents

1	Introduction	4
2	BAPCo Development Process.....	5
2.1	Milestone Overview	6
2.2	Usage Model/Scenario Selection	7
2.3	Application Selection	8
2.4	Scoring Methodology	10
2.5	Workload Development Sessions	12
2.6	Scenario Workload Descriptions	13
2.7	Calibration System	14
2.8	Benchmark Implementation	15
3	Workload Characteristics	16
3.1	Sensitivity Analysis	16
3.2	Disk Cache Methodology	23
3.3	System Configuration Tool Items List	25
3.4	Application Contribution Analysis.....	26
	APPENDIX A: Application Program Versions.....	27
	APPENDIX B: Minimum System Requirements.....	28
	APPENDIX C: Screenshots	29
	APPENDIX D: Application Workload Datasets	30

1 Introduction

SYSmark[®] 2018 is the latest revision of the preeminent system performance benchmark series that measures and compares PC performance using real world applications, featuring new workloads, features, updated third-party applications, updated system configuration tool that restores user settings, localized GUI support for nine different languages, and support for Microsoft Windows 7 and 10 64-bit.

SYSmark 2018 gives commercial and government IT decision makers, media, channel buyers, consultants, and system and component designers and manufacturers an objective, easy-to-use tool to evaluate PC performance across the wide range of activities that a user may encounter.

SYSmark 2018 is designed for those who want to:

- Evaluate and compare current Windows-based desktop, notebook, 2-in-1 and tablet computers for purchase consideration based on system performance, system responsiveness and energy consumption.
- Provide useful information to their audience(s) to assist in the evaluation and purchase of desktop, notebook and tablet computers.
- Evaluate desktop, notebook and tablet computers to better optimize the performance, responsiveness, or the energy consumption of the system
- Establish standards for the measurement of system performance, system responsiveness, and energy consumption.

Unlike synthetic benchmarks, which artificially drive components to peak capacity or attempt to deduce performance using a static simulation of application behavior, SYSmark 2018 uses real applications, real user workloads, and real data sets to accurately measure how overall system performance impacts user experience.

SYSmark 2018 builds upon BAPCo's 27-year history of building benchmarks to evaluate platform technologies. Benchmarks designed by BAPCo are the result of cooperative development between companies representing the breadth of the computing industry. They harness a consortium of knowledge to better reflect the business trends of today and tomorrow.

This document describes the methodologies employed in the development of SYSmark 2018. For detailed instructions on how to install and run SYSmark 2018 products, please refer to the documentation provided on the installation media and/or the BAPCo web site (www.bapco.com).

Refer to the BAPCo product versions FAQ located in the SYSmark 2018 support section at www.bapco.com for more information.

2 BAPCo Development Process

BAPCo creates benchmarks in accordance with the BAPCo Development Process, a set of milestones and checkpoints collaboratively developed and agreed upon by the BAPCo membership.

Early in the process, prevailing business personal computer usage models are identified and grouped into scenarios according to their fit within a workflow. Applications are selected for each usage model on the basis of market research and technical feasibility.

BAPCo members then join together with expert application users in development sessions to collaboratively develop a workload specification for each scenario, defining each user/PC interaction which is to be simulated by the benchmark.

The goal of the development sessions is to produce representative business application workloads for the benchmark. Each application workload consists of three elements: the input data set, the tasks performed on the input data set, and the generated output. An example of generated output would be an image generated through an iterative process of steps to create a desired appearance. These three elements of the workload are chosen to represent the workflow of a user skilled in each given application.

After the workload specifications are created at the development sessions, BAPCo developers implement the workloads according to those specifications while satisfying benchmarking constraints to ensure the stability of the benchmark, the consistency of results, and the feasibility of implementation and distribution of the benchmark.

2.1 Milestone Overview

The BAPCo development process is divided into six major phases (Initialization, Design and Planning, Implementation, Validation, Characterization and Launch). Each phase consists of a series of milestones, some of which may be worked on concurrently.

The membership must vote to close each milestone. Once all the milestones within a phase are complete, the membership must vote to exit the phase and enter the next phase. BAPCo members work in a collaborative process where decisions regarding products are made by majority vote rather than unanimously.

The following is the list of the development phases and the corresponding milestones. Some of these milestones are explained in greater detail in the following sections, as noted in this list.

1. Initialization Phase

- a. Milestone 0 – Committee kickoff
- b. Milestone 1 – Benchmark market and customer analysis
- c. Milestone 2 – Product positioning and customer value proposition
- d. Milestone 3 – Preliminary marketing requirements document
- e. Milestone 4 – Final marketing requirements document

2. Design and Planning Phase

- a. Milestone 5 – Preliminary engineering requirements document
- b. Milestone 6 – Usage model selection ([see section 2.2](#))
- c. Milestone 7 – Application selection ([see section 2.3](#))
- d. Milestone 8 – Define member resource commitments
- e. Milestone 9 – Define development infrastructure
- f. Milestone 10 – Define scoring methodology ([see section 2.4](#))
- g. Milestone 11 – Define application licensing requirements
- h. Milestone 12 – Plan and execute workload development sessions ([see section 2.5, 2.6](#))
- i. Milestone 13 – Define product release criteria
- j. Milestone 14 – Select product name

3. Implementation Phase

- a. Milestone 15 – Create implementation schedule
- b. Milestone 16 – Determine calibration system ([see section 2.7](#))
- c. Milestone 17 – Software development ([see section 2.8](#))

4. Validation Phase

- a. Milestone 18 – Validation testing
- b. Milestone 19 – Define risk management plan

5. Characterization Phase

- a. Milestone 20 – Characterization testing
- b. Milestone 21 – Beta testing

6. Launch Phase

- a. Milestone 22 – Product pricing
- b. Milestone 23 – Pre-launch materials
- c. Milestone 24 – Release to manufacture vote and sign-off
- d. Milestone 25 – Duplicate and distribute media
- e. Milestone 26 – Post-launch materials

2.2 Usage Model/Scenario Selection

In milestone 6 of the BAPCo Development Process, PC usage models are chosen for inclusion in a benchmark. For SYSmark 2018, BAPCo chose a wide variety of usage models in which the user experience is influenced by system performance.

BAPCo then grouped related usage models into 3 scenarios – Productivity, Creativity, and Responsiveness. Each of these scenarios is described as follows:

Productivity

The Productivity scenario models productivity usage including word processing, spreadsheet data manipulation, financial analysis, software development, application installation, file compression and email creation/management.

Creativity

The Creativity scenario models using digital photos, machine learning and artificial intelligence for photo facial detection and digital video to create, preview, and render advertisements for a fictional businesses.

Responsiveness

The Responsiveness scenario models usages where the ability of the system to react quickly to the user's input impacts the experience of using the system (i.e. – user's want to feel like the system responds smoothly and quickly). Some workloads include: application launches, file launches, web browsing with multiple tabs, and multi-tasking.

2.3 Application Selection

In milestone 7, after the usage models have been collected into scenarios, applications are chosen for the scenarios on the basis of market research and technical feasibility.

Sufficient lead time is needed after the applications are selected for BAPCo to develop workloads, integrate the applications into the benchmark, and perform validation of the benchmark. Therefore, some of the application versions are not the newest available at the time of the launch of SYSmark 2018.

For SYSmark 2018, BAPCo has identified the following representative applications for the four usage scenarios.

A summary of the application versions installed and used by SYSmark 2018 version 1.0.0.37 is included in [Appendix A](#).

Table 1: Productivity Applications

Application	Version	Document Type
Adobe® Acrobat®	Pro DC	Portable document files, image files
Autolt	3.3	AU3 scripting files
BowPad	2.3	Application Installation
FileZilla	3	Application Installation
Microsoft® Excel®	2016	Spreadsheets
Microsoft® OneNote®	2016	Free-form information gathering and multi-user collaboration
Microsoft® Outlook®	2016	E-mails
Microsoft® PowerPoint®	2016	Presentation files, image files, video files
Microsoft® Word®	2016	Word processing documents
Microsoft® Windows® Built-in File Compression	N/A	Zip files, assorted document files

Table 2: Creativity Applications

Application	Version	Document Type
Adobe® Lightroom®	CC Classic	Image files
Adobe® Photoshop®	CC (2018)	Image files
CyberLink® PowerDirector™	15	Video files

Table 3: Responsiveness Applications

Application	Version	Document Type
Adobe [®] Acrobat [®]	Pro DC	Portable document files, image files
Adobe [®] Lightroom [®]	CC Classic	Image files
Adobe [®] Photoshop [®]	CC (2018)	Image files
CyberLink [®] PowerDirector [™]	15	Video files
Google [®] Chrome [®]	65	Web pages
Microsoft [®] Excel [®]	2016	Spreadsheets
Microsoft [®] OneNote [®]	2016	Free-form information gathering and multi-user collaboration
Microsoft [®] Outlook [®]	2016	E-mails
Microsoft [®] PowerPoint [®]	2016	Presentation files, image files, video files
Microsoft [®] Word [®]	2016	Word processing documents

2.4 Scoring Methodology

In milestone 10, BAPCo decides the types of results that will be produced by a benchmark and the scoring methodology that determines how those results are calculated.

Importantly, BAPCo determines the scoring methodology before determining the content of the workloads, which helps ensure that a methodology is chosen for its ability to generate results that correspond to user experience, not for the results it produces on a pre-determined set of workloads.

For SYSmark 2018, BAPCo evaluated the merits of a variety of scoring methodologies and chose a methodology on the basis of how it met the following criteria:

- The scoring methodology should give expected results:
 - The resulting score should differentiate between systems with different performance.
 - The resulting score should be repeatable and not have high variation.
 - The resulting score should not be affected by benchmark artifacts, such as the number of tasks within a scenario.
- The relative performance between any two systems should not be affected by the selection of the calibration system.
- The resulting score should reflect the performance of user initiated multitasking operations.
- The scoring methodology should be easy to understand.

SYSmark 2018 measures system performance by measuring the response time of tasks on a PC using real applications and simulated user input. In the SYSmark 2018 scoring methodology, task response times are used to generate a performance rating that reflects the user experience. The faster a PC responds to the application workloads in SYSmark 2018, the higher its SYSmark 2018 performance ratings will be.

For more information on how task response times are measured, [see section 2.8](#).

A complete SYSmark 2018 run will output three scenario performance ratings (one for each scenario) and an overall performance rating.

Scenario Rating

Each scenario has a rating calculated by taking the sum of the response times of tasks in that scenario as performed on the test system and then comparing it with the sum of those same task response times as performed on the calibration system ([see section 2.7](#)). The calibration sum is divided by the measured sum on the test system and multiplied by 1000. The result is then rounded to the nearest integer.

Overall Rating

The SYSmark Overall Rating is calculated by taking the geometric mean of all the scenario ratings (prior to rounding). The result is then rounded to the nearest integer. To obtain an overall rating, you must run all scenarios.

Scenario Energy Consumption

When the Energy Consumption Test is enabled each scenario has an energy consumption value in Wh. This is an aggregate of the total energy consumed (as measured by the power meter) during the active workload portion of the scenario. Each iteration's energy consumption is averaged to produce the scenario energy consumption value.

Overall Energy Consumption

When the Energy Consumption Test is enabled the SYSmark Overall Energy Consumption is determined by taking the summation of all the Scenario Energy Consumption values (prior to rounding).

2.5 Workload Development Sessions

Once the usage models, scenarios, applications, and scoring methodology for the benchmark are decided, BAPCo members and application experts meet to create the application workloads that will be used in the benchmark.

For SYSmark 2018, the workload development sessions consisted of a one week of face-to-face meetings hosted at Lenovo that included representatives from BAPCo member companies and expert application users who had professional experience with the applications chosen for the benchmark. The application experts included professionals in the fields of small business marketing, financial forecasting, graphic design, video editing, web development, and enterprise IT deployment.

In the workload development sessions, the experts take the lead, weaving the usage models supplied by BAPCo into a storyboard of user interactions with a series of applications. Each user/PC interaction is written down in a workload specification, the specification used to automate the workloads later.

At the end of the workload development sessions, BAPCo comes away with a detailed workload specification for each of the benchmark scenarios and all of the input data sets needed to reproduce the workloads created at the sessions.

Additional Workload Considerations

The following additional factors come into consideration at the workload development sessions:

Input Data Set

Frequently in the sessions, the experts need raw digital content to serve as an input data set for a workload. Examples of such content might include a video to transcode, a presentation to modify, or documents to compress. When experts need such content, care is taken to ensure that they use something that is functionally representative of content they might use or encounter professionally.

For instance, if pictures are needed in order to create a web photo gallery, an expert might walk outside and take pictures using the same equipment he/she uses professionally. If a 3D model of a building is needed for a landscape workload, an expert might purchase a stock model from his/her usual online resource. Like the user interactions, all of these source materials are captured at the development session and used later in the development of automated workloads.

Task Switching and Concurrent Execution

In some cases, experts are encouraged to switch between open applications (e.g., as a user might between an e-mail program, word processor, and spreadsheet) or to leave activities running in the background as they perform work in another application (e.g., as a user might leave a compression task to run in the background while browsing the web).

2.6 Scenario Workload Descriptions

The scenario workloads created at the workload development sessions for SYSmark 2018 are described below:

Productivity

Read and manipulate notes from a notebook. Archive a diverse set of files into a single compressed file. Convert a PDF document into an editable word processing document. Perform a mail merge. Install applications. View a complex presentation that include multimedia and export it to PDF/video. Combine multiple scanned pages from a complex document into an encrypted PDF document using optical character recognition (OCR). Execute a rule on email inbox. Unpack a single compressed archive with a diverse set of files. Use a spreadsheet program to do data analysis. Perform financial analysis using a spreadsheet program. Uninstall applications.

Creativity

Create a panoramic image using an image editing application, combine a set of photos into one high dynamic range (HDR) image, and adjust and prepare both images for print. Import photos into a catalog. Export a large set of photos from a catalog. Detect faces using machine learning and artificial intelligence on a catalog of photos for labeling and grouping. Transcode a video into a different format. Encode the video to a format suitable for web publishing using a video editing application.

Responsiveness

Launch a variety of creativity and productivity applications. Browse a large number of web sites. Save presentation documents. Install and uninstall applications in the background. Switch between various web browser tabs. Save a variety of documents to the file system. Switch between various applications.

2.7 Calibration System

The calibration system is a system chosen in milestone 16 as a reference point for all other SYSmark 2018 results. BAPCo chose the configuration below for its wide availability and its representation of a typical mainstream PC at the time of release of SYSmark 2018.

SYSmark 2018 has been calibrated in such a way that a PC with performance equivalent to this calibration system for a given workload will have a performance rating of 1000. A system twice as fast as the calibration system on a given workload (or, equivalently, that responds in half the time on average) will have a performance rating of 2000. This is true for both overall ratings and scenario ratings.

The calibration system for all SYSmark 2018 products has the following configuration:

- Dell[®] Optiplex 5050 tower
- Intel Core i3-7100 Processor (3.90GHz, 3MB Cache)
- 4 GB PC4-17000 (DDR4-2133) SDRAM (1 DIMM)
- Integrated Intel HD Graphics 630
- 128GB M.2 SATA III Storage
- Windows 10 Professional 64-bit, 10.0.16299 (Fall Creators Update)
- 1920x1080 Display Resolution

A fresh operating system installation is performed on the system (not an OEM factory optimized image).

The calibration sum for each scenario is obtained according to the following process:

- Run SYSmark 2018 on the calibration system (process idle tasks disabled, conditioning run enabled, Energy Consumption Test enabled, 3 iterations)
- Calculate an overall score for each of the 3 iterations by taking geometric mean of all scenario scores for that iteration
- Identify the median iteration by finding the iteration with the median overall score
- The calibration sum for each scenario is the response time total from that scenario in the median iteration
- The Energy Consumption value for each scenario and overall is derived from the median iteration

For more details about the configuration of the calibration system, please contact support@bapco.com.

Please note that the minimum requirements to run SYSmark 2018 products are listed in [Appendix B](#) and are not equivalent to the calibration system.

2.8 Benchmark Implementation

Once the workload specifications have been created, BAPCo begins the important work of translating the workload specifications into an automated benchmark in milestone 17.

SYSmark 2018 is built upon scripts that do things much the way a user would, using controls like buttons, text input boxes, and menus to navigate applications. See [Appendix C](#) for screenshots of the benchmark in action.

To ensure that SYSmark 2018 has deterministic behavior, BAPCo uses a framework to install applications, collect system information, run the scenario scripts, record performance measurements, calculate performance ratings, and display test results. The framework is kept lightweight, consuming a minimal amount of memory and compute resources, in order to ensure that performance measurements reflect the workload performance and do not include overhead from the framework.

The fundamental performance unit in SYSmark 2018 is *response time*. Response time is defined as the time it takes the computer to complete a task that has been initiated by the automated script. A task can be initiated by a mouse click or a keystroke. The duration of each task is measured by the framework. Examples of tasks include launching an application, finding text in a document, copying a file, encoding a video, and performing an image manipulation.

The framework has several methods of detecting task completion, depending upon the method the application uses to signal task completion to the user. For example, the framework may wait for the application to show a completion message in the form of a pop-up window, or may wait for a progress dialog to disappear and for control of the application to be returned to the user.

3 Workload Characteristics

This section provides data illustrating the performance characteristics of SYSmark 2018 version 1.0.0.37.

3.1 Sensitivity Analysis

The series of charts below shows the sensitivity of SYSmark 2018 to different system characteristics, including the amount of CPU frequency, number of CPU cores, storage, graphics adapter, system memory, and display resolution.

Within each study only one system component (e.g. memory) is varied. All the other system components are held constant. To best illustrate the sensitivity, one configuration is chosen as a baseline and the ratings for the other configurations are shown as the percentage difference relative to the baseline.

Due to system implementation differences, these figures are only accurate for the configuration description listed below in each sub-section. These sensitivities will vary from one configuration to the next.

3.1.1 Sensitivity Analysis Base System Configuration

CPU Model	Intel Core i9-7900X
Base CPU Frequency	3.3 GHz
CPU uArch	Intel [®] Core X-series Processors
Physical Cores	10
Logical Cores	20
Chipset	X299
RAM	2x8GB DDR4-2133 (16 GB Total)
Storage	Intel 545s SSD, 256 GB SATA III
OS	Windows 10 x64 April 2018 Update
Resolution	1920x1080
Graphics	AMD Radeon RX 580 8GB

Note: For these tests, Intel Turbo Boost Technology and Intel Hyper-Threading Technology have been disabled to better highlight the specific component being tested in each sensitivity study.

3.1.2 Sensitivity to CPU Frequency

The CPU frequency of a system is changed from 1.5 GHz to 3.0 GHz in steps of 500 MHz.

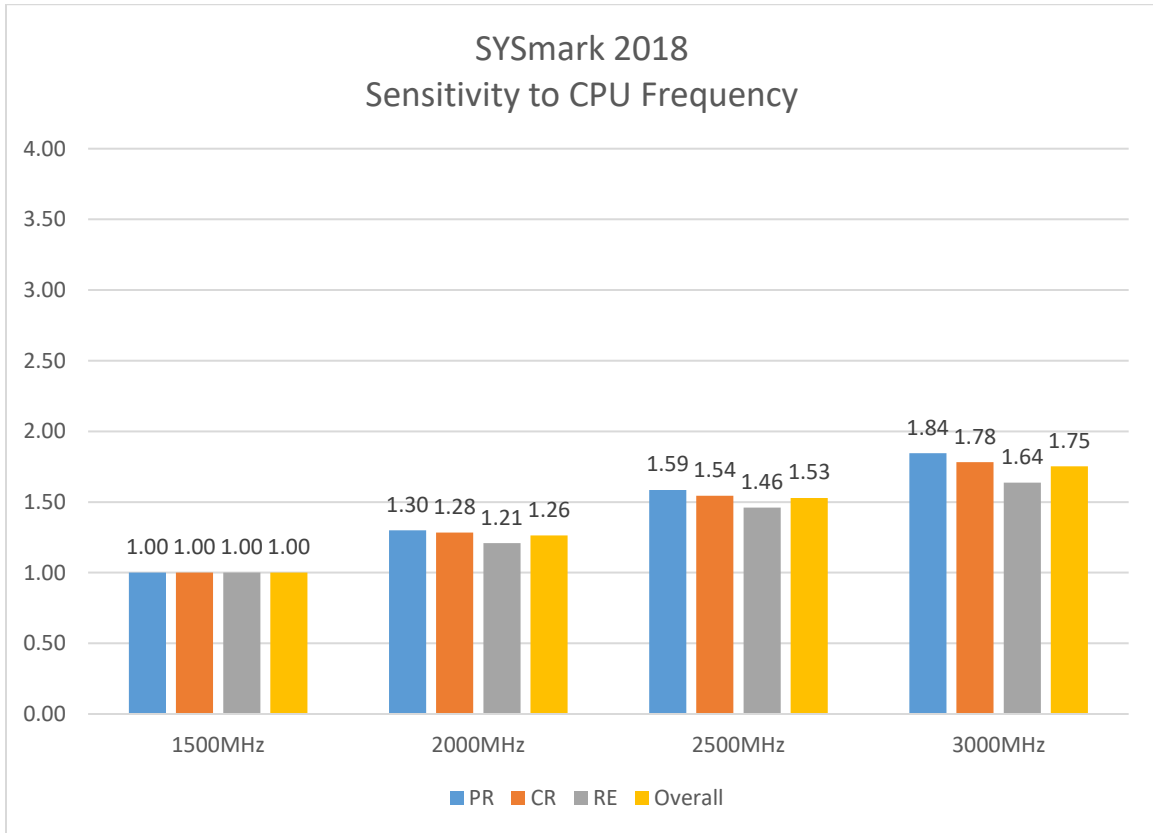


Figure 1: CPU Frequency Sensitivity

3.1.3 Sensitivity to CPU Core Count

The number of CPU cores is controlled by changing system BIOS settings to enable 2 cores, then 4 cores, 6 cores, 8 cores and finally all 10 cores of a 10-core processor.

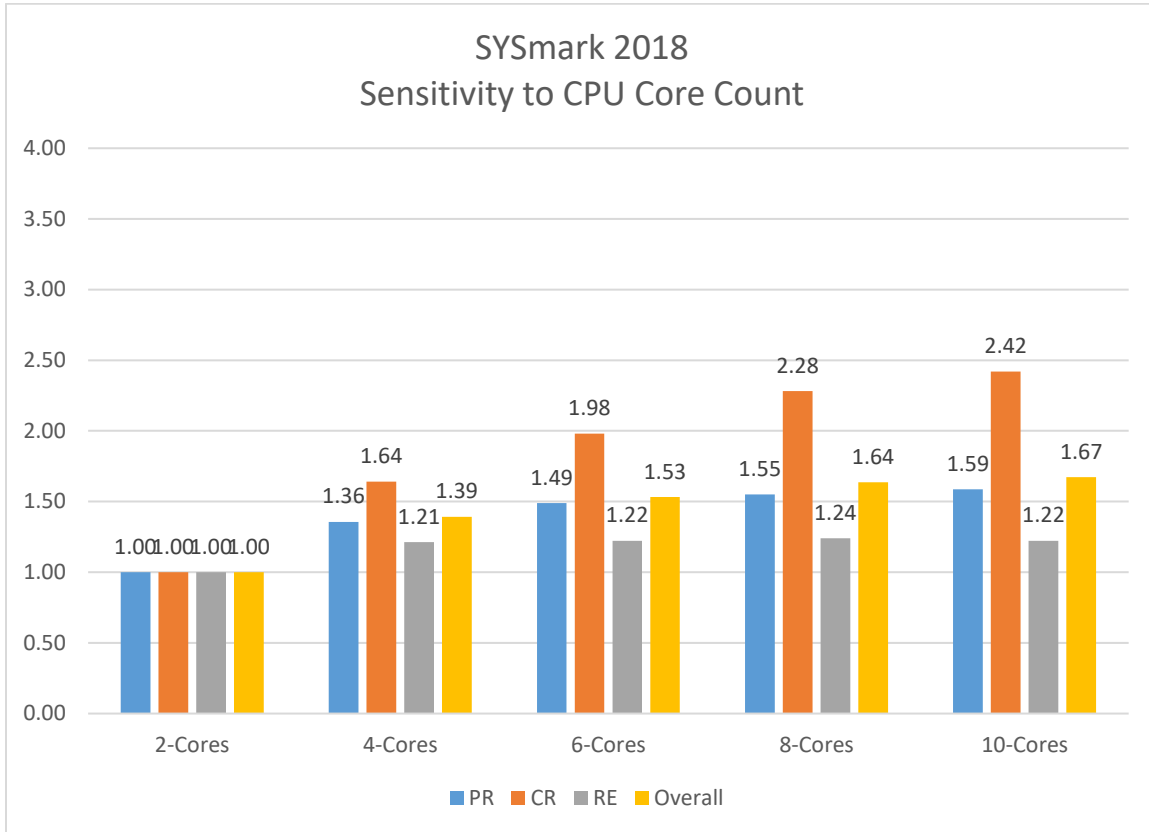


Figure 2: CPU Core Count Sensitivity

3.1.4 Sensitivity to Storage

The primary storage device is changed according to the figure below. A Seagate 5400RPM 1 TB SATA III hard drive, Western Digital Black 7200RPM 1TB SATA III hard drive, Intel 545s 256GB SATA III SSD, and Intel 900p Optane 280GB NVMe SSD.

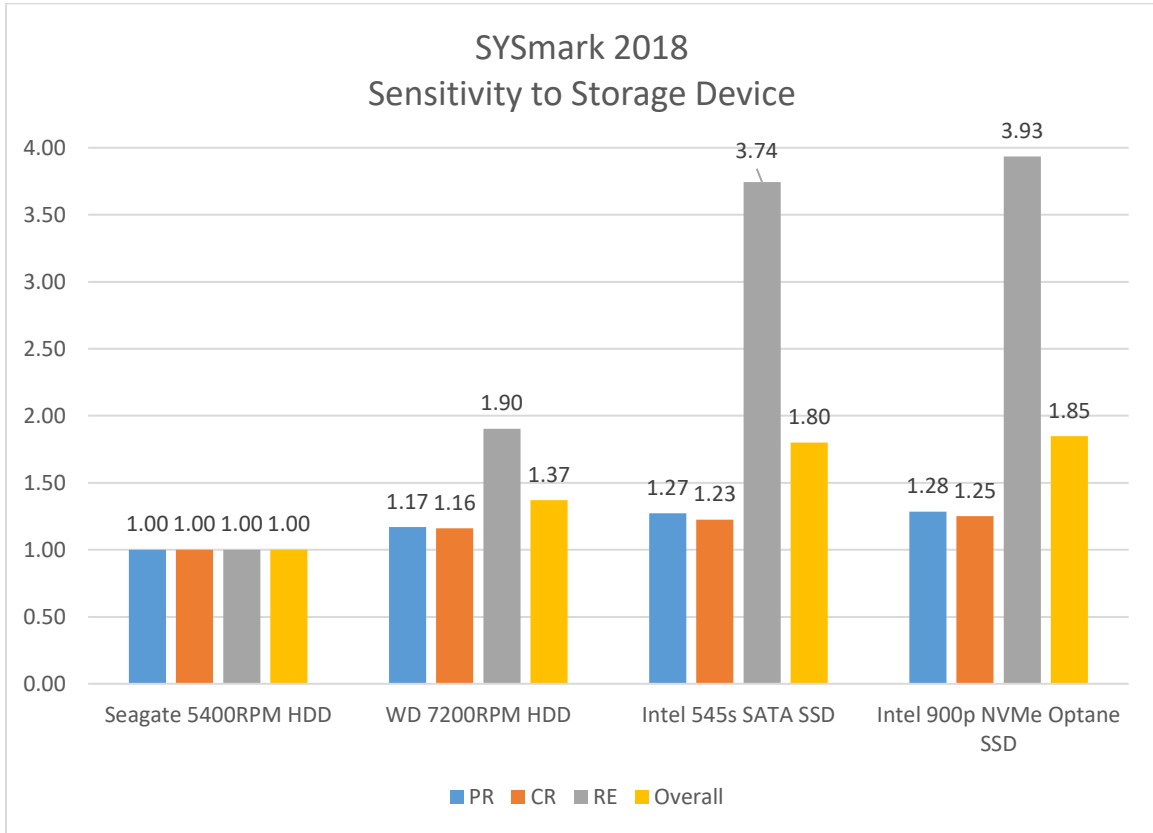


Figure 3: Storage Sensitivity

3.1.5 Sensitivity to Graphics Subsystem

The video card is changed according to the table below. For these tests, we used discrete video cards all from the same manufacturer to ensure the graphics driver family and available physical system memory from each configuration was constant. An AMD R5 230, AMD RX 580, and AMD RX Vega 64 was used.

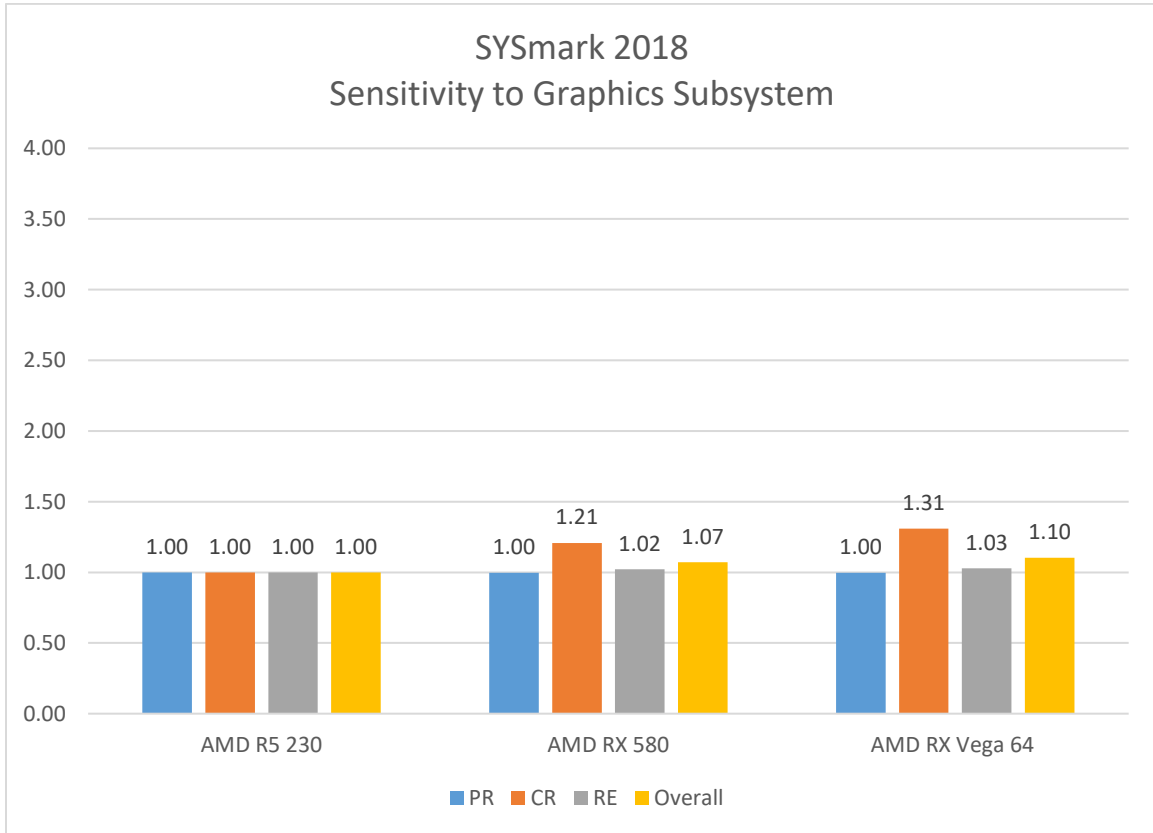


Figure 4: Graphics Subsystem Sensitivity

3.1.6 Sensitivity to System Memory Capacity

The total system memory is changed from 4 GB single channel, 8 GB dual channel, 16 GB dual channel, and 32 GB dual channel. The memory type for all tests is DDR4-2400. This section will be updated in a future revision of the SYSmark 2018 White Paper to include additional all single channel memory configuration and all dual channel memory configuration studies.

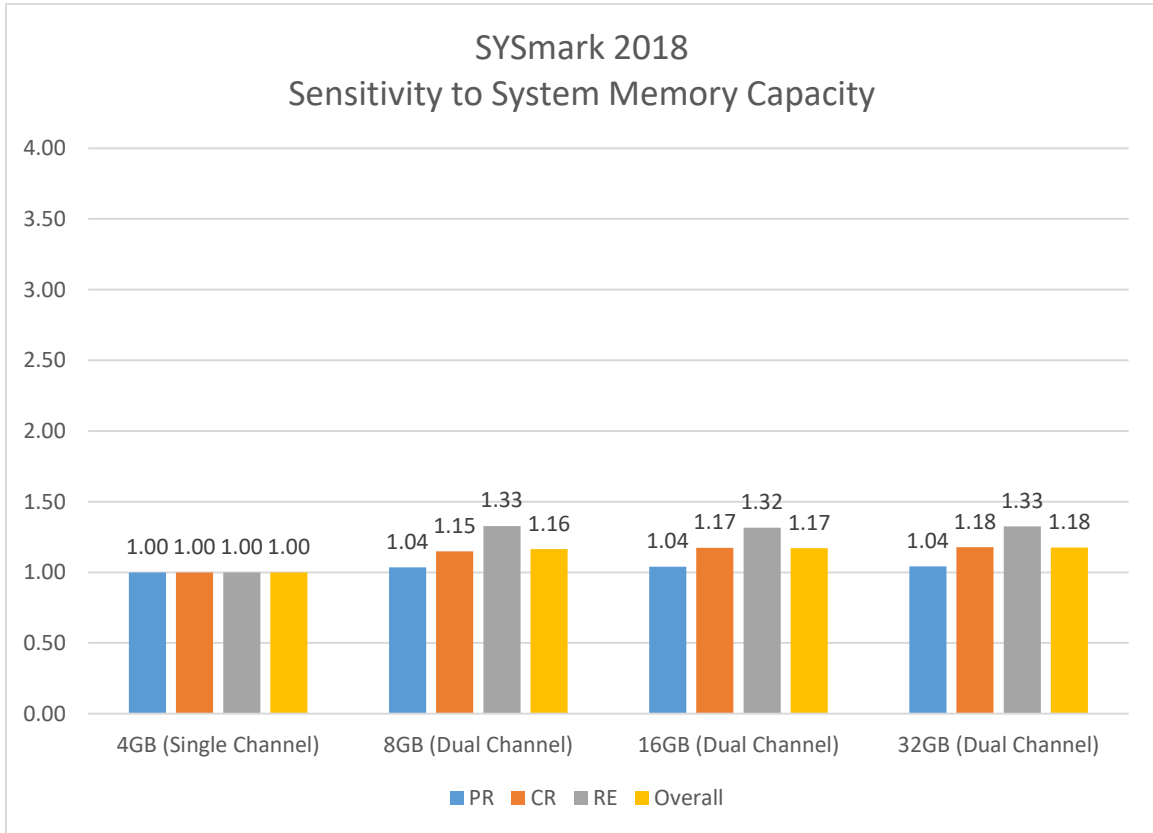


Figure 5: System Memory Sensitivity

3.1.7 Sensitivity to Screen Resolution

The screen resolution is changed according to the figure below.

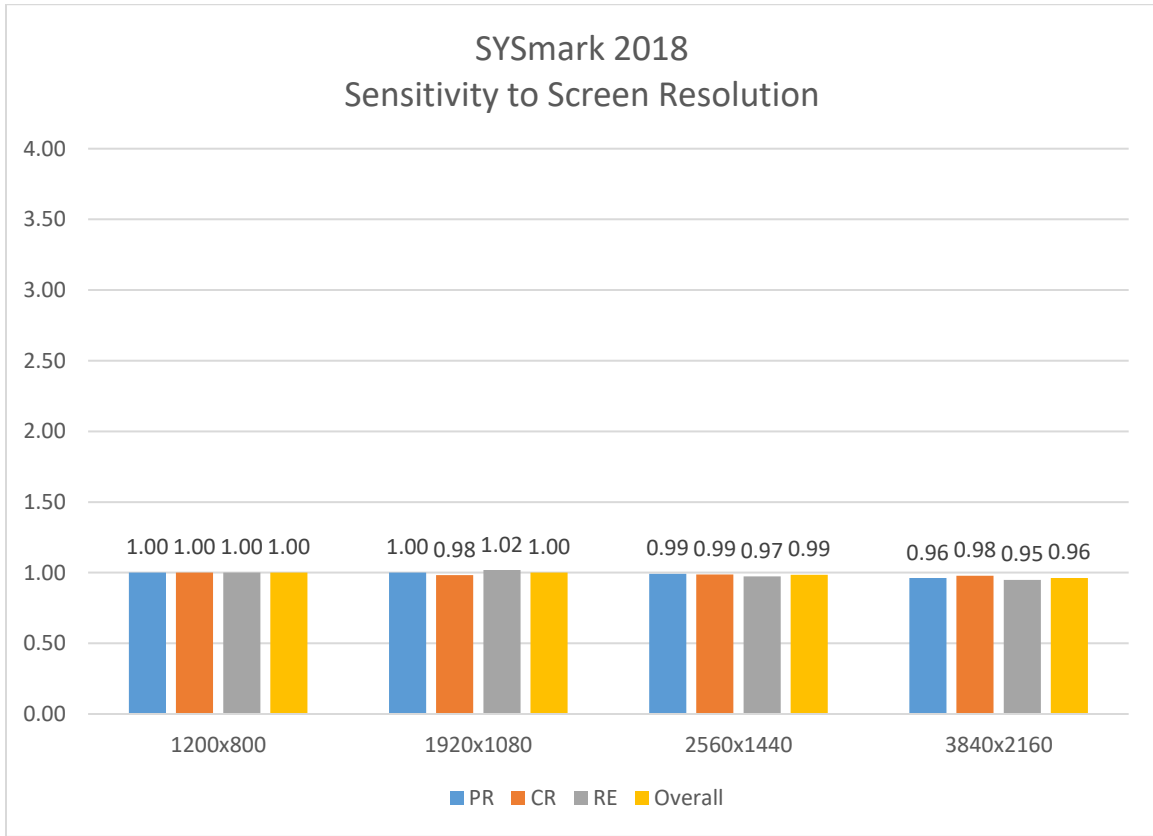


Figure 6: Screen Resolution Sensitivity

3.2 Disk Cache Methodology

This section explains the BAPCo Conditioning Run and disk caching methodology used in SYSmark 2018.

Conditioning Run

The Conditioning Run is an option which runs a single iteration of the benchmark prior to running scored benchmarked iterations. The results of the Conditioning Run are ignored when generating SYSmark 2018 scores. The Conditioning Run option is selected by default, but can be disabled by the user.

The goal of the Conditioning Run is to allow the operating system to optimize the performance of the system based on what it learns from a single iteration of the benchmark. This models a user experience where the applications have been used in the past.

BAPCo Disk Caching Methodology

Microsoft Windows uses a disk caching technology called SuperFetch. SuperFetch attempts to improve the efficiency of I/O operations by loading commonly used libraries and application components into memory before they are required. It does so by continually analyzing application behavior and usage patterns. Windows is able to allocate any memory not used by applications to be used by SuperFetch. SuperFetch is only enabled on systems that use hard disk drives. Systems with solid state devices (SSDs) do not use SuperFetch.

BAPCo has decided on a disk caching methodology that enables repeatable and consistent results with low run to run variation that models a real user experience. The disk caching methodology used varies depending on whether the Conditioning Run option was selected:

Option 1: Disk Caching Methodology when Conditioning Run is disabled

When a Conditioning Run is disabled, the SuperFetch cache is cleared prior to running each scenario within the benchmark. SuperFetch is able to cache applications that are used within the scenario, but is not able to cache information between scenarios or iterations. This models the case of a newly installed system where the user has not run the applications before.

This methodology is implemented using the following procedure prior to each scenario start:

- a. Stop SuperFetch service
- b. Delete prefetch folder
- c. Restart SuperFetch service

Note: The benchmark results for a hard disk drive system are expected to be slightly lower when the Conditioning Run option is not selected.

Option 2: Disk Caching Methodology when Conditioning Run is enabled

When a Conditioning Run is selected, a snapshot is taken of the SuperFetch cache after each scenario within the Conditioning Run. Those snapshots are used to restore the SuperFetch cache prior to running each scenario within the benchmark (see Figure 1). This enables SuperFetch to use what is learned from the Conditioning Run to optimize the performance of applications. Since the corresponding cache snapshot is restored before each scenario, SuperFetch is still not be able to cache additional information between scenarios or iterations. This allows us to take advantage of SuperFetch caching (on hard disk drive systems) while still maintaining consistent results regardless of the number of benchmark iterations.

This methodology is implemented using the following procedure prior to each scenario start:

- a. Stop SuperFetch service
- b. Delete prefetch folder
- c. Restore the scenario Conditioning Run snapshot to the prefetch folder
- d. Restart SuperFetch service

3.3 System Configuration Tool Items List

This section will be updated in a future revision of the SYSmark 2018 White Paper.

3.4 Application Contribution Analysis

The following charts shows the approximate contribution of each application to the SYSmark 2018 version 1.0.0.37 scenario ratings on the calibration system ([see section 2.7](#)).

Due to system implementation differences, this chart is accurate for the calibration system. These contributions will vary from one system to the next.

3.5.1 Application Contribution Analysis on the Calibration System

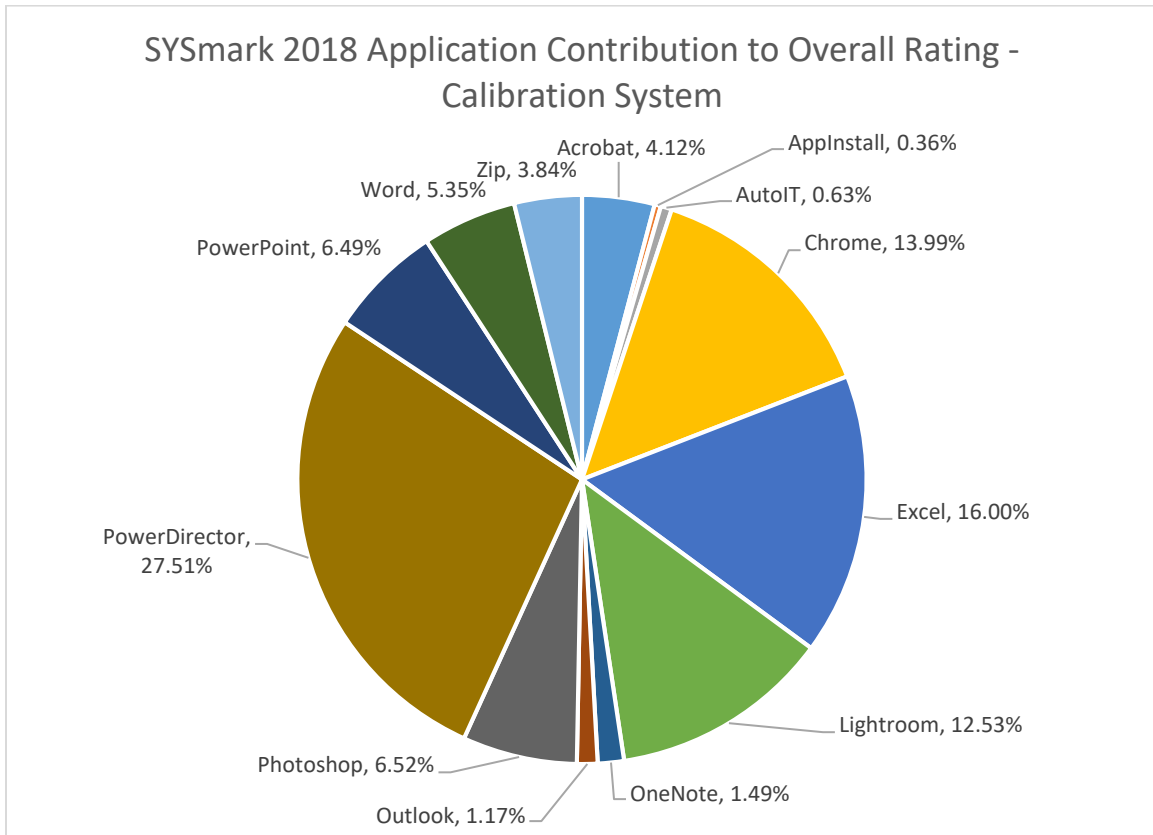


Figure 1: Application Contribution to Overall Rating

APPENDIX A: Application Program Versions

The following applications are installed and used by SYSmark 2018 version 1.0.0.37:

- Adobe[®] Acrobat[®] Pro DC
- Adobe[®] Photoshop[®] CC (2018)
- Adobe[®] Photoshop[®] Lightroom[®] Classic CC
- AutoIt 3.3
- BowPad 2.3
- CyberLink[®] PowerDirector[™] 15
- FileZilla 3
- Google[®] Chrome[®] 65
- Microsoft[®] Excel[®] 2016
- Microsoft[®] OneNote[®] 2016
- Microsoft[®] Outlook[®] 2016
- Microsoft[®] PowerPoint[®] 2016
- Microsoft[®] Word[®] 2016

APPENDIX B: Minimum System Requirements

SYSmark 2018 has the following requirements based upon the minimum system specifications of the applications installed and used in the benchmark:

- **CPU:** 1.5 GHz AMD[®] or Intel[®] dual-core processor
- **RAM:** 4 GB
- **HDD/SSD:** 25GB of free space on the primary drive
- **Operating System:** Microsoft[®] Windows[®] 10 64-bit or Microsoft[®] Windows[®] 7 64-bit
- **Resolution:** 1280x800 or 1366x768
- **Graphics:** DirectX 10 compatible
- **Supported Languages on Windows 10:** Brazilian Portuguese, Simplified Chinese, English (US), French, German, Italian, Japanese, Polish, Spanish (SP)
- **Supported Languages on Windows 7:** English (US)

APPENDIX C: Screenshots

This section will be updated in a future revision of the SYSmark 2018 White Paper.

APPENDIX D: Application Workload Datasets

This section will be updated in a future revision of the SYSmark 2018 White Paper.