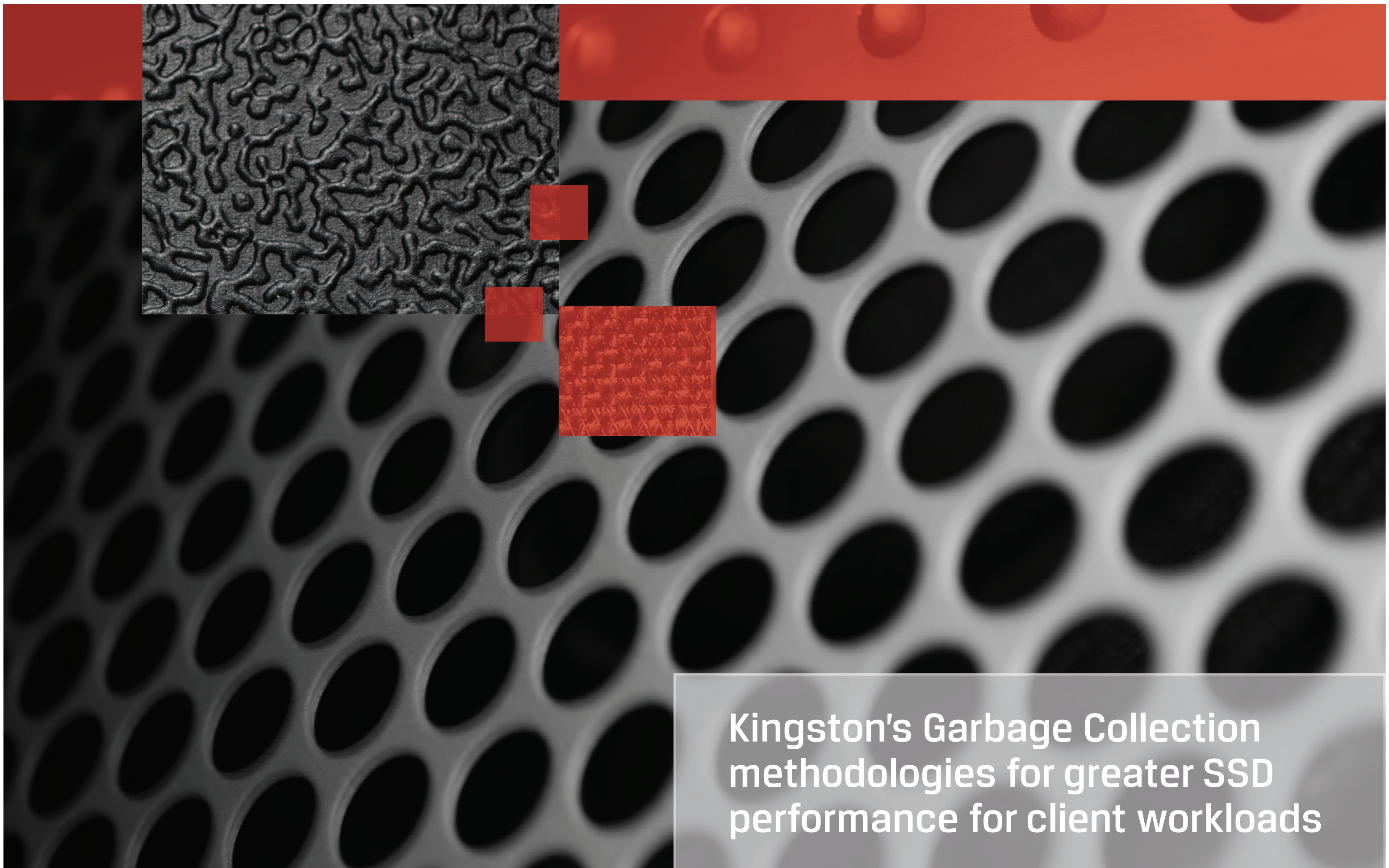


Kingston's Garbage Collection methodologies for greater SSD performance for client workloads

All NAND Flash–based storage devices, including Solid-State Drives (SSDs), are different in the way they deal with files that a user has previously deleted. Kingston SSDs incorporate controller-proprietary technologies that can significantly impact your system's performance. This paper will contrast Kingston's KC300 Client SSDs against a few other SSDs on the market and show how SSD management of deleted space is important for consistent SSD performance.

Garbage Collection (GC)

When a file is deleted in Windows or any Operating System, the file still exists on the storage device, be it a Hard Disk Drive (HDD) or SSD. For the purpose of this document, we will call data deleted by the OS but still residing on the storage device "garbage data". In the case of a file deletion, the OS marks the locations where that file resided as now empty and available to be written over again when needed. When the OS issues a command to write data to a location that previously contained data, the HDD will write over the garbage data with no impact on performance. With all NAND Flash–based storage (USB Flash drives, SD cards, SSDs etc.), direct over-writing of data at a specific location is not possible; the Flash storage device will need to first recover garbage data areas, group them into blocks of available free space, and then will erase the contents of all the memory cells in the available blocks before rewriting the new data into them. This total process of recycling previously deleted garbage data into reusable free space is called Garbage Collection.

Garbage Collection or GC methodology is a controller-proprietary technology that is programmed into the SSD controllers' firmware. SSDs that are designed with an efficient GC technology not only deliver good performance fresh out of the box, but also throughout their usable life. SSDs with less sophisticated GC technologies tend to slow down and perform sluggishly over time because their GC methodology interferes with consistent performance.

Garbage Collection is often confused with the support of the TRIM command by Operating Systems (OS). Microsoft's Windows® 7 was the first "SSD–aware OS": Upon recognizing an SSD installed in the system, it disabled features related to improving HDD performance that were not needed by SSDs. It also introduced a key SSD-specific optimization, called the TRIM command. Simply explained, the TRIM command enables the OS and the SSD to now communicate about the locations of garbage data and mark them for GC at a convenient time by the SSD. To enable this feature, SSDs must also support the TRIM command; note that all Kingston SSDs as well as newer SSDs on the market do support the TRIM command. TRIM is supported by Windows 7 and Windows 8 as well as specific versions of Linux and Apple's OSX (Apple will only enable TRIM for its own Apple branded SSDs though). While TRIM commands help SSDs with Garbage Collection, we will show in our testing below that GC is much more than having TRIM enabled on a Client system. We will also show the worst-case scenario on a system where there is no TRIM support, demonstrating the KC300's ability to efficiently conduct GC in the absence of TRIMs.

Kingston SSDs incorporating LSI® SandForce® controllers incorporate technology called DuraWrite® that performs data reduction; for the purposes of this paper, let's equate DuraWrite to Data Compression. Most Client workloads (operating system files, Microsoft Outlook, documents, web browsing, security software, etc.) can be compressed, resulting in data reduction that shrinks the data's footprint on the SSD. The smaller footprint translates to lower GC activity as fewer storage blocks need to be garbage collected when files are deleted and automatically increases the free space (over provisioning); both result in more stable and better GC performance. As a side-note, for most Client workloads, it is not the user's file deletions that cause the most NAND activity and GC – it is the background action by the applications (web browsers, antivirus, etc.) and the Operating System.

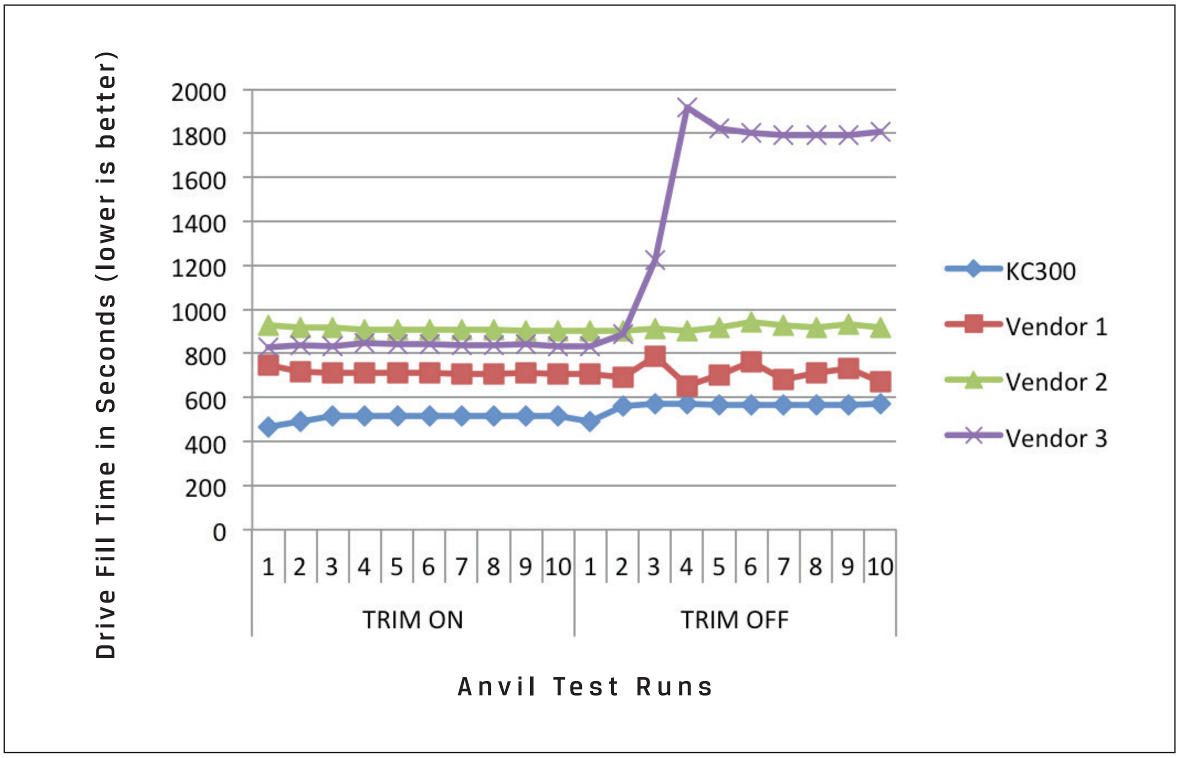
Even the timing of Garbage Collection can easily affect a user's experience or a notebook's battery life. GC can be either background (idle-time) or foreground (done when the SSD has incoming data, or on-demand). Many SSDs try to improve performance by conducting GC in the background, when the SSD is idle; the problem is that, should the user decide to use their system in the middle of that process, the system may seem slow and take significant time to respond as the GC activity is interfering with the processing of the commands from the system. In addition, background GC can often interfere with power saving modes on notebooks, PowerBooks or desktops –by overriding the power-saving commands from the system (thereby drawing more power), or by resuming GC when the system is powered back up to merge in new data coming in; these methodologies will result in sluggish boot up or wakeup performance and slow response times. Kingston SSDs with SandForce controllers are optimized to conduct foreground GC when data is received, and minimize performance or response time impacts. Foreground GC also extends the life of SSDs by not Garbage Collecting files until they are deleted by the user or the system; Background GC can increase SSD wear by processing files that are subsequently deleted by the user or the system. In addition, by avoiding unnecessary GC, Foreground Garbage Collection allows the SSD to enter idle mode faster and more often after the SSD is accessed for typical reads, which account of about 80% of typical Client workloads; this results in longer battery life for mobile platforms.

To demonstrate the effectiveness of the Kingston SSD GC methodology, we tested the Kingston KC300 SSD along with a number of competitor drives in March 2014.

For this testing, we installed each SSD to be tested in a notebook with Microsoft Windows 7 64-bit . The SSDs were in out-of-the-box new condition and all were partitioned to the same 120GB of user space. We then installed Anvil, a utility that completely fills up the SSD with data, then completely deletes all files on the drive (we left all Anvil settings at their defaults). Anvil then repeats a cycle of writing data to fill the drive and erasing it. On each run, Anvil measures the time the SSD took to complete the data fill in seconds. By completely filling up the empty space on the drive, deleting everything and then immediately filling it up again, we are forcing the controller on the SSD to "garbage collect" the entire drive while simultaneously writing new data to the drive. This is a good test for the efficiency of GC. We also ensured TRIM was set for all the SSDs tested and all SSDs supported TRIM.

Test Results

We subjected the Kingston KC300 along with three current competitor SSDs to 10 cycles of Anvil – completely writing, deleting, and rewriting onto the SSD. We set TRIM On, tested, and then retested fresh SSDs with TRIM Off. The test results are shown below (The left axis shows the Drive Fill Time (in seconds, lower is better), and the bottom axis shows the 10 consecutive runs with and then without TRIM):



The bottom axis shows the number of Anvil runs from Run #1 to Run #10, first with TRIM On, then with TRIM Off.

TRIM On: The Kingston KC300 performs GC very efficiently, leading this testing with a consistent ~500 seconds to refill the drive with data during all the ten runs of Anvil. Competitor drives (labeled Vendor 1, Vendor 2 and Vendor 3) take significantly longer to perform this same task. Kingston SSDs with LSI SandForce controllers incorporate DuraWrite Data Reduction technology, that reduces file footprint in the NAND Flash storage and increases the drive's Endurance and performance (More information is available in the Technical brief on DuraWrite on the Kingston web site).

TRIM Off: For older Operating Systems like Windows XP or to create a worst-case scenario, we then disabled TRIM on the test system. Now the SSDs are on their own to identify garbage data quickly and recycle it. The test results below show one SSD (Vendor 3) that struggles with Garbage Collection and the rest (Vendor 1 and Vendor 2) remaining mostly consistent with some fluctuations in fill time. The Kingston KC300 shows the smoothest Garbage Collection performance with TRIM On or Off, as seen in the near-flat line time-to-fill for the 10 cycles of writing and erasing all data on the SSD.

Many SSD uses, such as installing an SSD in

- Any RAID configuration (TRIM command depends upon the SATA interface and will not pass through a RAID controller) Apple Mac systems (where TRIM commands are only passed on to direct-attached Apple branded SSDs), or

- Systems with Operating Systems that do not support TRIM (Windows XP, Mac OS for non-Apple SSDs, etc.)

will force the SSD to function as if there is no TRIM support. In this type of scenario, the KC300 stands out with its ability to conduct GC efficiently even in the absence of TRIM. In fact, as shown in Figure 2, the KC300 delivers almost the same straight-line and stable performance in the Anvil benchmark - whether TRIM command is available or not.

Conclusion

All NAND Flash–based devices have to deal with previously deleted data by erasing the contents of memory cells before writing new data. Garbage Collection technology in an SSD will affect the SSD's ability to efficiently recycle "garbage data" and maintain consistent turn-around times for new writes to the SSD.

When considering a move to SSD technology for their users' Client systems, IT specialists and purchasers should look at a number of important attributes, which also should include an assessment of the SSD capabilities in recovering garbage data space and keeping up with user writes. Kingston's SandForce based SSDs, under testing with competitor drives, demonstrates very quick SSD fill times and best-in-class foreground GC consistency across 20 runs of testing; they also delivers the same stable performance in the absence of the TRIM command, supporting more customer use cases than many SSD drives on the market. In addition, the use of Forward GC allows these SSDs to enter idle mode faster after they are active, resulting in longer battery like.

Kingston internal testing. Results could vary depending on system and software selected.