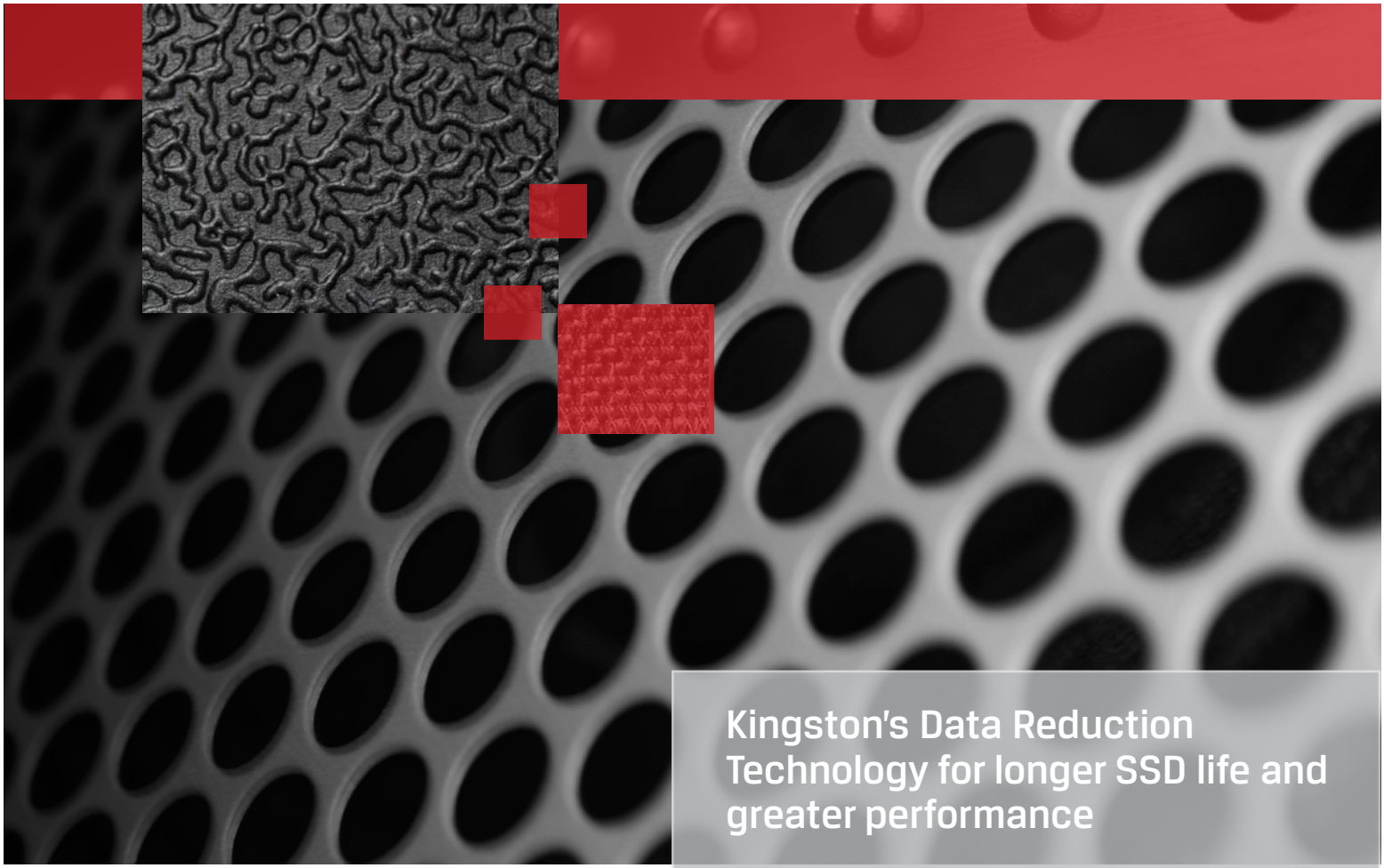

Kingston's Data Reduction Technology for longer SSD life and greater performance

Kingston Technology

Solid-State Drives (SSDs) have transitioned from being an expensive storage device to becoming common in tablets, and the preferred storage upgrade to notebooks, ultrabooks and desktops. SSDs deliver greater performance, longer battery life, and greater system reliability through the elimination of mechanical Hard Disk Drives (HDDs). The usable life of an SSD is generally dependent upon the wear of the Flash memory that is used to store the data. This brief will describe how Kingston's SSDs, incorporating SandForce® controllers from LSI, an Avago Technology company, with DuraWrite® technology, perform Data Reduction to enhance the usable life of the SSD and deliver better value to Kingston customers.

NAND Flash and Endurance

NAND Flash is the memory technology used in USB drives, SD cards, and SSDs. It is called a "persistent" or "non-volatile" storage technology compared to Dynamic Random Access Memory (DRAM); when power is turned off, NAND Flash memory retains all data stored in it whereas DRAM loses all data without power. In addition, NAND Flash storage cells wear out with usage, and typically are rated around 3,000 Write cycles each in the current generation of NAND used in SSDs (Kingston does offer Enterprise grade SSDs supporting higher Write cycles); this number could actually be misleading by itself and we will discuss better ways of judging an SSD's ability to deliver the specified amount of writes while functioning properly, also called its Endurance.

In practice, few users need to worry about their SSDs wearing out quickly when subjected to typical Client workloads such as doing Microsoft® Office file processing, surfing the Internet, etc. Today's SSDs are designed to support Client workloads and deliver many years of trouble-free service, often exceeding the system's useful life.

For additional customer guidance, Kingston SSDs provide an Endurance metric called TBW – for Total Bytes Written, as shown below in the Kingston SSD*Now* KC300 SSD's data sheet from the Kingston web site:

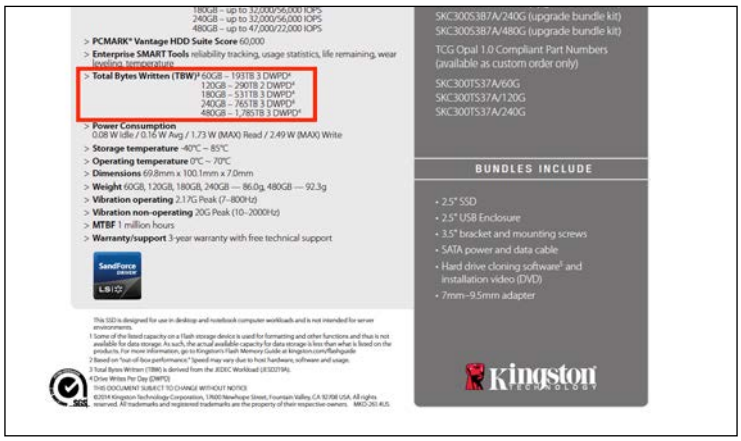

Figure 1: KC300 Data Sheet Showing Total Bytes Written (TBW)

This 120GB KC300 SSD is rated for up to 93TeraBytes or 93,000GigaBytes of data written by a user's (let's call it Host) system using a typical Client workload. We will explore what this number represents in a moment.

Kingston's TBW numbers are specified by testing SSDs utilizing an industry-standard workload defined by JEDEC, the international memory standards body; the applicable JEDEC standards are known as JESD218 and JESD219. There are two versions of workloads available, Client or Enterprise (Server), depending upon the type of SSD tested. The test results are then used to estimate the TBW specification for the SSD based upon the specific JEDEC workload.

To determine what TBW means to you, we can extrapolate it to determine how long the drive would last given a more specific workload.

Looking at the 120GB KC300, its TBW Endurance of 93TB means that, in a 3-year timeframe, the Host system, under workloads similar to those defined by JEDEC for Client systems, can be expected to perform Host Writes of

93,000GB / 3 / 365 or about 85GB of Host Writes to the SSD per day for 3 years!

The vast majority of Client system users write well under 10GB per day. So, under normal Client workloads as defined by JEDEC, this SSD can last a lot longer than 3 years if less than 85GB per day is written by the Host each and every day. As we will see next, Kingston SSDs incorporating SandForce controllers with DuraWrite technology deliver higher TBW ratings than many SSDs on the market.

DuraWrite Technology

We will first focus on DuraWrite's Data Reduction technology. Data Reduction, as its name implies, reduces the size of data written to the Flash memory, yet returns the full original data when read back from the Flash memory. For the purposes of this Brief, Data Reduction is similar to Data Compression.

Compressible versus Incompressible Data

Compressible data can be reduced in size through special algorithms, resulting in a smaller incompressible data footprint in the NAND storage. Once incompressible, data can no longer be reduced in size. For example, zip files are compressed files that can be decompressed to fully restore all files stored within the compressed file.

Typical Client workloads include the use of email, processing of documents, surfing the Internet among some of the key user activities, supported by the Operating System(OS) which also conducts a lot of file reads and writes to the storage device; often, more writes are conducted in the background by the OS and applications than the system user.

A large portion of the NAND Flash writes that result from many user activities is actually compressible. For example, many of the aforementioned activities could result in file compression on the order of 50%; in practical terms, that means that up to half of a specific file's size could be reduced in footprint in the SSD; through such Data Reduction or compression, less data is actually written to the NAND Flash by the SSD controller, resulting in less wear on the NAND Flash and increasing Endurance.

An LSI study of the compressibility of files reported the following results:

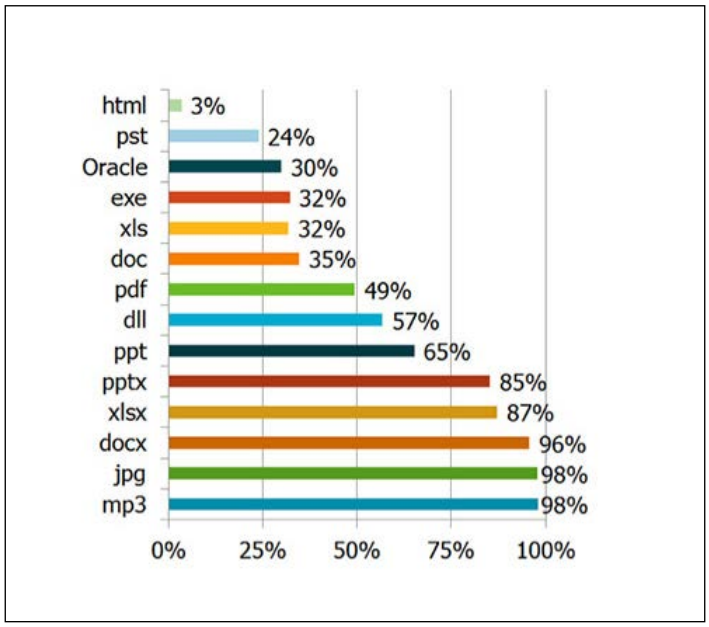

Figure 2: File Compressibility (Courtesy of LSI) based upon WinZip measurements
(Lower numbers mean the files are more compressible; 100% means they are incompressible)

This study shows that many types of files can be compressed successfully to smaller footprints that will reduce NAND Flash Writes - html for surfing the Internet (your browser caches them to your hard drive or SSD), exe and dll files for any applications and OS that you use, and Microsoft Office suites older than 2010. Picture files (jpg), movie (mpg) and MP3 music files are compressed and generally can't be compressed any more.

Through DuraWrite technology, the Kingston SSDs will reduce the footprint of the data on the SSD in the background, for user as well as system files.

Over Provisioned SSDs and Dynamic OP

All SSDs include some Over Provisioning (OP) in their NAND Flash storage (for example, a 120GB Kingston SSD*Now* drive actually contains 128GB of NAND; 8GB of NAND Flash is reserved for the SSD controller to use for any activities it needs to do, such as wear-leveling, garbage collection, handling incoming writes, etc. Without OP, the SSD could not operate properly. OP areas are not user-accessible, and that is why SSDs are labeled with a lower capacity than their actual NAND

capacity (for example, 120, 240, and 480GB SSD*Now* drives contain 128, 256, and 512GB of built-in NAND storage). Even SSDs with capacities of 128, 256GB, 512GB capacities include smaller OP areas.

Beyond the standard OP that is present on many SSDs, Kingston SSD*Now* drives can dynamically increase their built-in OP capacity through Dynamic OP, which is uniquely created as a result of the Data Reduction process.

The following example (courtesy of LSI) will illustrate this benefit:

Let's assume we have a standard 256GB SSD filled to 80% of its capacity with a typical Operating System, applications, and user data. The SSD has 20% free space, used by the SSD controller as its Dynamic OP. Next, let's take the same SSD with DuraWrite Data Reduction technology and compare them:

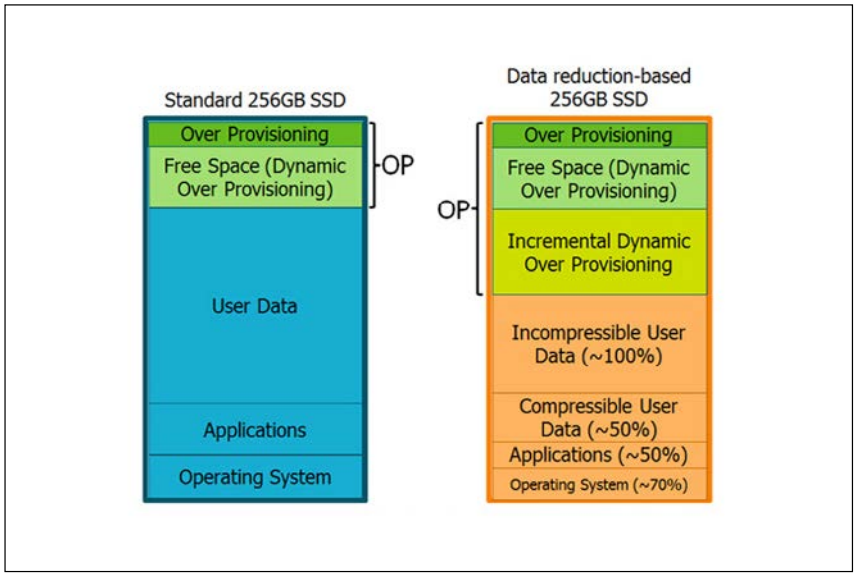

Figure 3: SSD without Data Reduction vs SSD with DuraWrite (Graphs courtesy of LSI)

Both SSDs have the standard OP area for a 256GB SSD (shown in the "Over Provisioning" box in dark green), followed by the Free Space area that functions as Dynamic OP for both types of SSDs.

However, in the SSD with DuraWrite Data Reduction technology on the right, we can see that the footprint of the Operating System, applications, and some of the User Data (the compressible portion) is smaller – resulting in less NAND Flash capacity being utilized on the SSD to store data. While both SSDs have 20% free space), the SSD on the right with DuraWrite technology has an Incremental Dynamic OP area that it can utilize to increase the SSD's performance and extend its

Endurance even more than the standard SSD on the left.

A common question has to do with incompressible data – what if the SSD is loaded with incompressible data? If an SSD contains an Operating System, applications and other data files, the user will still benefit from DuraWrite reducing the footprint of compressible data types. Any amount of additional Dynamic OP will benefit the SSD's Endurance by providing the SSD controller with more available NAND Flash resources.

Summary: The Benefits of DuraWrite Architecture

Kingston's SSDs incorporating SandForce controllers from Avago LSI, such as the KC300 and V300 SSDs, , deliver leading-edge Data Reduction that

- Raises the SSD's Endurance through smaller Writes to NAND Flash, thereby increasing Dynamic OP;
- Increases performance by processing Writes faster than many other SSDs, and with more efficient Garbage Collection

The SandForce controllers deliver lower Total Cost of Ownership to users by

- Processing Writes faster and then going to sleep, generally lowering power usage and increasing notebook/ultrabook performance while delivering longer battery life
- Generating less heat and requiring less cooling by completing Writes faster before entering lower power modes
- Enhancing the NAND's Endurance, thereby increasing the service life to the user and requiring fewer replacements due to NAND Flash wear

When considering SSDs, Kingston SSDs with DuraWrite technology with Data Reduction offer industry-leading overall performance and Endurance. They offer peace of mind storage with long service life for users looking for trouble-free, reliable storage backed by Kingston.

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