### (Approx. 1,452)

### Describing the Quantity of Computer Storage

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Computers can store data or information in several ways internally and on various media and storage devices. How we describe the capacity of this storage has evolved considerably over the last 70 years, which explains some of the inconsistencies found in usage.

One of the first things one used to be taught in Physics, even in High School, was that a number representing a measurement was useless (and counted as an incorrect answer) if not accompanied by the appropriate unit of measure. The unit of measure (g, kg, lb, nt, W, ft, m, km, etc.) was essential to define not only the true magnitude of the value but to distinguish among types of measure: weight, mass, force, energy, distance, charge, temperature, etc.

#### How We Got Ambiguous Computer Storage Notation

While all computers in common use today tend to have storage organized around the concept of a "Byte" or "character" containing 8 "bits" (base-2 binary digits), this was not always the case. Earlier computers had organizations based on decimal digits, on characters represented by less than 8 bits, on "words" containing some number of decimal digits (10), or on "words" containing some number of bits (12, 16, 32, 36, 48, 60).

For computers organized around decimal digits with memory locations addressed in decimal, one talked about memory having so many "K" digits or words of memory, where "K" was "1000" (no computers had enough memory yet for "M" to be an issue). If varying amounts of memory could be purchased, the physical memory sizes had to be manufactured in quantities that were round numbers in base-10. Machines with 20,000, 40,000, or 60,000 digit memory were described as 20K, 40K, or 60K machines.

Computers that were not organized around decimal digits addressed internal memory locations using a binary address[[1]](#footnote-1), and this required that memory be manufactured in quantities that were round numbers in base-2. So you would have memory size increments of 1024 (210), 2048 (2 x 210 ), 4096 (4 x 210), 8192 (8 x 210), 16384 (16 x 210), etc.

Those that worked with such computers quickly tired of describing computer memory capacity in the cumbersome exact-decimal-value notation and adapted the shortcut of using K=1024= 210 so the above round numbers in binary could be expressed more simply as 1K, 2K, 4K, 8K, 16K. This was particularly convenient since even if your mind subconsciously saw these values "in decimal," you would only be off by 2.4%. Note that although this is a convenient notation, it is a "corrupted" usage of "K," which is a prefix derived from the Greek word for "thousand."

Computer storage other than central internal storage was a different matter. Disk storage and tape storage capacities were based on state-of-the-art recording techniques, choice of physical media dimensions, and recording densities. These factors produced capacities that tended to not be nice round numbers in either binary or decimal. Changing the definition of "K" in this context provided no notational simplification, so in the context of disk and tape capacity, "K" continued to have its customary meaning of "1000".

As maximum available and affordable computer storage capacities increased, the above conventions were extended to include the prefixes of

* M (mega), meaning 106 = 1,000,000 OR 220 = 1,048,576, depending on context
* G (giga), meaning 109 = 1,000,000,000 OR 230 = 1,073,741,824, depending on context
* T (tera), meaning 1012  OR 240, depending on context.
* and so on, for prefixes for powers of 103 higher than 1012.

Until the mid-1980s, the only people exposed to this prefix usage were the relatively small number of computer professionals who understood the conventions. The vast number of PCs and other computer devices that have become available over the last three decades have resulted in many computer users now being exposed to these conventions without the underlying knowledge of computer architecture to understand the context distinctions.

#### The Solution

To eliminate this decimal/binary ambiguity, in December 1998, the International Electrotechnical Commission (IEC) approved an International Standard for names and symbols for prefixes for binary multiples for use in the fields of data processing and data transmission. That standard is recognized by NIST (U.S. National Institute of Standards and Technology – formerly known as the US Bureau of Standards) and can be found at <https://physics.nist.gov/cuu/Units/binary.html>

By this standard, usages of prefixes K, M, G, and T where a power of 210 is intended should be replaced by Ki, Mi, Gi, and Ti, respectively. These abbreviations correspond to kilobinary, megabinary, gigabinary, and terabinary, and are pronounced as "kibi," "mebi," "gibi," and "tebi." So, 16 GB of RAM for a PC should more correctly be called 16 GiB of RAM. This would be spoken as "16 gibibytes" and mean 16 x 230 Bytes.

Getting people to adopt the newer non-ambiguous conventions has been a non-trivial exercise. After two decades, retail consumer hardware manufacturers are still frequently not observing it. You will find some computer software correctly using the new standards (system and file utilities in Linux), and some not (system and file utilities in Windows 10, which tends to report both RAM storage and Disk storage in "GiB," with both mislabeled as "GB"). That consumers are confused is evident when you see someone who erroneously believes that "GB" always means 230 for computers, or is just confused by Windows 10 misuse of "GB" complain that the capacity of his hard drive was exaggerated because he misinterpreted the manufacturers 500 GB to mean 500 GiB. I personally try to use the standard binary prefixes consistently where appropriate, both to avoid unnecessary ambiguity and to educate others about their existence.

If you are familiar with the conventions, it is clear when a retail PC advertises a RAM memory of "8 GB" that what they really mean is "8 GiB" because PCs use a computer architecture with binary memory addressing. It is similarly clear that a mechanical SATA Hard Drive advertising 1 TB of storage probably means it is close to, hopefully, a little over 1TB, and not 1 TiB, which would be 10% larger. Close but not exact because there is no reason why a physical device with varying physical track lengths should hit a capacity with a nice round decimal number.

Now in the case of a "240 GB" SSD solid-state drive, I am not certain what value is intended. Since there is discrete solid-state memory under the covers, no doubt the base storage inside the unit is really 256 GiB. But there also has to be a programmed computer processor inside that is emulating a SATA hard drive, so out of that 256 GiB, some memory must be used for the hard drive controller program, and some space taken for buffers and other data storage required for the hard drive emulation, and perhaps some space kept in reserve just in case marginal performance or failures are detected in some blocks of the memory, like having hidden alternate tracks on a mechanical hard drive that can transparently replace a failed physical track. After deducting the overhead for the device emulation, that could leave either 240 GB or 240 GiB usable storage for the emulated hard drive. I suspect they would mean the lower 240 GB in keeping with mechanical hard drive capacity conventions, but I am not 100% sure.

It ought to be possible to get RAM and PC manufacturers to use the more correct GiB in place of GB for RAM capacity. Hard drive and SSD manufacturers should specify their approximate capacity in both GB and GiB as well as the actual exact Bytes. While the current GB values are conventional usage, you still have the problem with neophytes seeing only a GB value and thinking it should be interpreted as GiB.

Another sloppy usage that drives me to distraction is hearing or reading someone describing his computer storage or speed as so many "gigs." So, he has "billions." Billions of WHAT? "G" is only a quantity multiplier, not a unit of measure! Without the correct units, the number is meaningless. This misuse is particularly confusing in the area of data transmission speeds, where units of both "bits per second" and "Bytes per second" are in common use.

1. An exception were some ingenious machines created at Moscow State University starting in 1958 ("Setun" and "Setun 70") based on the ternary (base-3) number system rather than binary. The ternary design required fewer discrete electronic components, a distinct advantage because of electronic component scarcities in the Soviet Union at that time. Soviet internal politics and software compatibility issues with the more-widely-adopted binary architectures caused the eventual demise of this architecture. [↑](#footnote-ref-1)