1 (One) PetaByte in an Office Cubical & 600 GigaByte Tapes

Halftone Printing and Microprocessor Design Rules

1 PetaByte in 48 Square Feet (5 Square Meters) (The Area of an Office Cubical)

1 PetaByte = 1 thousand TeraBytes = 1 million GigaBytes

By mounting Serial ATA magnetic disk drives in a 4U (7 inch, 175 mm, high) drawer (shelf), 42 drives can be fit in a 750 mm (30 inch) deep shelf in a standard 19-inch (480 mm) wide rack. Ten of these shelves can be fit in a 42 U (74 inches, ~6 foot, ~1.8 meter) high 19 inch wide rack (internal dimensions). Thus, 420 disk drives can be fit in one rack that takes up 6 square feet (~ 1/2 square meters) of floor space. Eight of the racks holding 3,360 drives can be fit in 48 square feet (5 square meters).

Using 300 GigaByte drives; this provides a capacity of 1.008 PetaBytes (1.008 PetaBytes = 1,008 TeraBytes = 1,008,000 GigaBytes = 3,360 x 300 GigaBytes) An example of this configuration is the A16 system from Nexsan [http://www.nexsan.com/products/ATAbeastDataSheetlow.pdf] [http://www.Nexsan.com]

Each shelf weights 45 Kilograms (100 pounds) with disks. Each rack weighs 200 Kilograms (450 pounds) empty. The 80 shelves and 8 racks of the above configuration weigh a total of 5,200 Kilograms (11,600 pounds)

600 GigaByte Tapes

To establish the actual capacity of a tape, it is necessary to ask for two numbers: the storage capacity with uncompressed data (native), and the storage capacity with compressed data. Unless both numbers are obtained, it is impossible to determine whether the capacity measure provided was for uncompressed or compressed capacity.

Tapes come out in dynasties that last a few generations. Each generation lasts two or three years and usually involves a doubling of the capacity of the previous generation's capacity within the dynasty. Vendors usually try to maintain compatibility between generations in the same dynasties so that newer tape drives can read older tapes. Then it is time for new dynasties and the vendors hybridize their technology with cross-pollination, creating new dynasties that are substantially different from the previous dynasty, even if they are nominally in the same tape family. The time for new dynasties is at hand. The new dynasties should appear in the first half of 2003.

Sony is planning 500 GigaByte tapes (growing to 1 TeraByte, then to 2 TeraByte, and then to 4 TeraByte native capacity, over time). [http://www.nyq.eweek.com/article2/0,6071,768481,00.asp] Quantum is planning 600 GigaByte tapes (with a similar growth path planned) [http://www.nyq.eweek.com/article2/0,6071,757988,00.asp]

The bottom line is that 10 of the 600 GigaByte tapes are easier to handle than 100 of the older 60 GigaByte tapes.

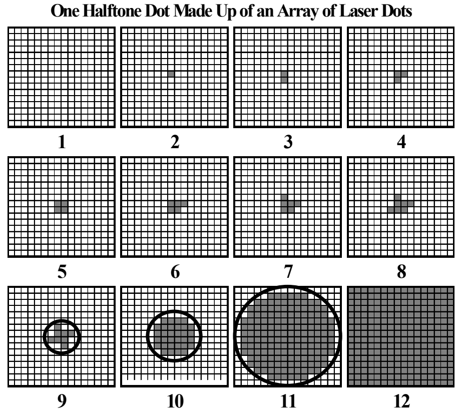
Halftone Printing (Dots)

Laser dots and inkjet dots are of a uniform diameter and are placed on uniformly spaced centers. Halftone dots have a variable diameter but are similarly placed on uniformly spaced centers. Laser dot, inkjet dot, and halftone dot centers are often placed on a square grid with each of the dots an equal distances from the four closest dots and with the vectors to the adjacent dots forming right angles. The vertical and horizontal spacing is not always equal and the adjacent pixel location vectors are not always at right angle, but the simplified model adds considerably to the clarity of explanation and does not vary much from what is actually done.

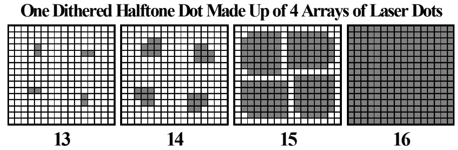
An array of 16 by 16 laser dots (or inkjet dots) contains 256 laser dots that can be used to create halftone dots of any diameter, up to a diameter of 16 laser dots. The minimum number of laser dots to be turned black is 0, shown in macropel 1 in the figure. Then one laser dot is turned black, shown in macropel 2. Then two laser dots are turned black, shown in macropel 3, and so on. At the largest diameter, the halftone dot pushes up against the edges (macropel 11) of the macropel (macro-pixel) made up of the array of the 256 laser dots. The pushing up is complete when the halftone dot becomes square and fills up (turn all of the laser dots black) the macropel, shown in macropel 12.

The physics behind halftoning is based on exceeding the areal bandwidth of the human eye. In music, when you exceed the bandwidth of an amplifier, you get mush. When you exceed the bandwidth of the eye, (or of a television broadcast channel – it is not legal to transmit more than 350 horizontal pixels of resolution in NTSC television because transmitting more pixels of resolution would exceed the authorized and allocated channel bandwidth.) you get blurring, or a gray image. To exceed the bandwidth of the eye, it is necessary to cause both a black and a white area to fall on the same rod in the eye. A rod image area is approximately 2 micrometers across, and a black halftone dot (and surrounding white area in the macropel in which the halftone dot is constructed from laser dots) of an 85 screen image (85 halftone dots per inch = 85 screen ruling) (3.5 halftone dots per mm, which is a halftone dot diameter of 300 micrometers) completely covers one rod when held at a newspaper reading distance of

One Halftone Dot Made Up of an Array of Laser Dots



One Dithered Halftone Dot Made Up of 4 Arrays of Laser Dots



16 inches (400 mm) in this scenario (with no dynamic focusing) in which the image on the retina is reduced about 150 times from the size of a printed image at a normal newspaper reading distance). Because both the white and black areas of the macropel fall on the same rod, the rod can only integrate (add up) the photons falling on the rod and give an average (gray) value for the entire macropel (the black dot in the middle of the macropel is not resolved (only gray is perceived).

With 300, and to some extent with 600 dpi laser printers, the size of halftone dots required to reproduce 256 shades (8 bits) of grayscale is so large that the halftone dots fall on 4 rods rather than 1 rod and the black dots can be resolved by the eye. This means that a person sees black dots rather than a continuous tone grayscale image. To eliminate this problem, while still reproducing 256 shades of gray, and while still using a low-resolution printer, the halftone dot is broken into multiple sub-dots and spread around the macropel. In the illustration, the halftone dot is broken into 4 sub-dots in macropels 13 through 16. When all 4 sub-dots press out to the edge for their respective sub-macropels, the entire macropel turns black as shown in macropel 16. Thus, for an all black macropel, the dithered macropel is the same as the halftoned macropel. Each sub-dot falls on a single rod, creating the blurring effect. Dithering creates a pseudo-increase in resolution (pseudo-resolution) for the purpose of exceeding the spatial bandwidth of the eye. There is no increase in resolution, because there are no new macropels to distinguish two lines (one black and one white line, known as an optical line or optical line pair), which is the definition of resolution.

However, because offset printing presses and low cost xerographic copiers (that do not have a built in optical screening mechanism) cannot reproduce a screen ruling much above 150 dots per inch (6 dots per mm), neither process can reproduce dithered images. A halftoned image must be provided for reproduction on these devices.

Conversely, attempting to scan a halftoned image will create a moiré effect, which is caused by the beat between the areal pattern in the halftone screen and the areal pattern in the pixel sampling mechanism of the scanner. The lower (coarser) areal frequency of the moiré pattern is the beat frequency (difference) of the two frequencies.

To produce 1440 dpi ink jet dots (57 dpmm, 18 micrometer diameter inkjet dots), a minimum ink drop volume of 6 picoliter (6 femtostere) is required, (1 stere = 1 m**3 = 1 cubic meter) as used in the Sherpa print engine by [http://www.Mutoh.com] for [http://www.Agfa.com]

Microprocessor and RAM (Random Access Memory) Design Rules (Pixel Size = Wire Width on the Chip)

Semiconductors are made using digital photographic techniques (pixels). Recently, microprocessor production processes were improved from .25 micron (.25 um, micrometer) (250 nm, nanometer) design rules to .18 um (180 nm) design rules. This means that the pixel size for semiconductor devices is now slightly less than 1/5 micron (200 nm). A micron is one 1 millionth of a meter. 180 nm design rules = 32.4 femto-m**2 (fs). = 10**-15 m**2 pixels (m**2 ::= square meter).

[There is no term for square meter, the closes is 'are' for 100 square meters (1 hectare = 10 thousand square meters.) Because 'are' is not an even 1 thousand multiple of meter, as a liter is 1/1 thousand cubic meters, and because 'are' is a verb in the English language, 'are' is a poor choice for representing area in the metric system. A word for a square meter would be a good idea.]

The largest silicon wafers in use today are 300 mm in diameter (12 inches). Assuming that a 200 x 200 mm area is available for producing transistors, and assuming (for exposition) that the transistors are densely packed, then the array of transistors would be approximately (200 mm / 200 nm) x (200mm / 200nm) transistors square, with a transistor count of (1 million *x* 1 million), or 1 trillion transistors per wafer array.

Using 200 nanometer (nm) pixels and assuming 1/25th of the area was used for active transistors, a 1 millimeter (mm) square area (about the size of the head of a pin) could hold 25 MegaPels (25 million pixels) and thus, for exposition, 1 million transistors. This is the basis for smart dust technology, developed at the University of California at Berkley, in which remote robots, called motes, could be built on ultra thin 1 millimeter square chips of silicon that float through the air and communicate with micro-lasers and micro-mirrors. Motes can remain suspended in the air for many hours, just like a cloud of dust or windblown seeds, collecting very detailed data. See also [http://robotics.eecs.Berkeley.edu/~pister/SmartDust] and International SEMATECH (SEmiconductor MAnufacturing TECHnology association) [http://www.SEMATECH.org]

The smallest practical pixel would be a pixel used as part of a halftone dot that represented the edge of the path of a sub-atomic particle, such as a neutrino. To create a smooth path in a specific color, a printed resolution of 2540 dpi (100 dpmm) would be used. Assuming a 1 ym (yoktometer) wide path, rendered as a 10 mm wide path so that it was visible to an observer (when viewing a printed page), the width represented by each pixel would be 1/1 thousand ym. For a superstring (2 x 10**-35 m wide), the pixel width would be 20/1 trillion ym.

Scanner Inflation: Halftone dots vary in size, but their centers are on a regular grid. Halftone dots are laser printed as an array of pixels. A 16 by 16 pixel array (or macropel) can represent any one of 256 shades of gray. As the number of black pixels printed in the center of the macropel array increases, the diameter of the halftone dot increases, creating the impression of a darker gray image. For this reason, a scanner that scans 8 bits (256 shades of gray) can be said to require 256 pixels (arranged in a 16 x 16 pixel array) to reproduce each scanned pixel as a halftone dot. This is the reason a 300 dpi scanner can be represented as 4800 dpi in advertisements (4800 dpi = 300 dpi x 16). See also GATF (Graphic Arts Technical Foundation) [http://www.GATF.lm.com]