

Drive Math

Mark E. Donaldson

A sector is 512 bytes - this is true on all hard drives in the PC world and also applies to floppy disks.

This refers to formatted data capacity - a sector actually uses more than 512 bytes. 512 bytes are available for data storage. Throughout this document and in most discussions of hard drive capacity, all figures assume formatted capacity (512 bytes/sector).

A megabyte (MB) can be properly defined in two different ways:

"decimal megabyte" = 1,000,000 bytes (10 to the 6th power)

"binary megabyte" = 1,048,576 bytes (2 to the 20th power)

(also easily calculated as 1024 x 1024)

Some of the values for MB and GB in this document are shown in parenthesis to indicate binary MB and GB rather than decimal.

To convert decimal MB to binary MB:

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decimal MB x 1,000,000
----- = binary MB
1,048,576
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To convert binary MB to decimal MB:

binary MB x 1.048576 = decimal MB

- DOS FDISK shows drive capacity in binary megabytes.
- Windows 3.x File Manager shows drive capacity in binary megabytes.
- CMOS setup in older ROM BIOSes will show drive capacity in binary megabytes.
- CMOS setup in newer ROM BIOSes (including all MFI BIOS upgrades) will show drive capacity in decimal megabytes.
- CHKDSK shows capacity in decimal megabytes (actually total bytes).
- Drive manufacturers report drive capacities in decimal megabytes.
- Gigabyte - GB - (can be pronounced giga or jiga)

"decimal gigabyte" = 1,000,000,000 bytes (10 to the 9th power)

"binary gigabyte" = 1,073,741,824 bytes (2 to the 30th power)

(1024 x 1024 x 1024)

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BIOS Int 13 Limitation

Cylinders limit is 1024 cylinders numbered 0-1023 (10 bits)
Heads limit is 256 heads numbered 0-255 (8 bits)
Sectors limit is 63 sectors numbered 1-63 (6 bits)

$1024 \times 256 \times 63 = 16,515,072$ sectors

$16,515,072 \times 512 = 8,455,716,864$ bytes 8.4GB (7.9GB)

ATA Specification

Cylinders limit is 65536 cylinders numbered 0-65535 (16 bits)
Heads limit is 16 heads numbered 0-15 (4 bits)
Sectors limit is 255 sectors numbered 1-255 (8 bits)

$65536 \times 16 \times 255 = 267,386,880$ sectors

$267,386,880 \times 512 = 136,902,082,560$ bytes 136.9GB (127GB)

Combined BIOS Int13 and ATA Limitation

Cylinders limit is 1024 cylinders numbered 0-1023 (10 bits)
Heads limit is 16 heads numbered 0-15 (4 bits)
Sectors limit is 63 sectors numbered 1-63 (6 bits)

$1024 \times 16 \times 63 = 1,032,192$ sectors

$1,032,192 \times 512 = 528,482,304$ bytes 528MB (504MB)

CHS Translation (also called ECHS Translation - Extended CHS)

Cylinders are halved and heads doubled until cylinders are 1024 or less

0-1024 cyls	16 heads
1025-2048 cyls	32 heads
2047-4096 cyls	64 heads
4097-8192 cyls	128 heads
8192-16384 cyls	256 heads
16385-32768 cyls	512 heads

Limit in BIOSes with 2.1GB Problem

Many older BIOSes erroneously allocate only 12 bits for the cylinder field in CMOS RAM.

Cylinders limit is 4096 cylinders numbered 0-4095 (12 bits)
Heads limit is 16 heads numbered 0-15 (4 bits)
Sectors limit is 63 sectors numbered 1-63 (6 bits)

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$$4096 \times 16 \times 63 = 4,128,768 \text{ sectors}$$

$$4,128,768 \times 512 = 2,113,929,216 \text{ bytes } 2.1\text{GB (1.97GB)}$$

Limit in BIOSes with 4.2GB Problem

All versions of DOS including WIN95 are unable to handle the value 256 (or any value over 255) for the number of heads. Although this is a problem with the operating system, a newer BIOS should compensate for it, normally by using Assisted LBA translation, which limits the total heads value to 255 or by using a revised form of ECHS translation, which adjusts 16 heads to 15 and increases the cylinder values by 16/15 before performing the normal ECHS translation.

8192 cylinders causes 16 heads to translate to 256

8191 cylinders causes 16 heads to translate to 128

Cylinders limit is 8191 cylinders numbered 0-8190 (13 bits)

Heads limit is 16 heads numbered 0-15 (4 bits)

Sectors limit is 63 sectors numbered 1-63 (6 bits)

$$8191 \times 16 \times 63 = 8,256,528 \text{ sectors}$$

$$8,256,528 \times 512 = 4,227,342,336 \text{ bytes } 4.2\text{GB } 4227\text{MB (3937MB)}$$

8.4 GB Limitation

16384 causes 16 heads to translate as 256 heads.

16385 would cause 16 heads to translate as 512 heads which is beyond the limits that a translating BIOS can handle.

Cylinders limit is 16384 cylinders numbered 0-16383 (14 bits)

Heads limit is 16 heads numbered 0-15 (4 bits)

Sectors limit is 63 sectors numbered 1-63 (6 bits)

$$16384 \times 16 \times 63 = 16,515,072 \text{ sectors}$$

$$16,515,072 \times 512 = 8,455,716,864 \text{ bytes} = 8456\text{MB} = 8.5\text{GB (8064MB, 7.875GB)}$$

The ATA-3 spec says that a drive with over 8 heads should use no more than 16383 cylinders. One of the first 8.4GB drives, the Quantum Fireball SE uses these values:

$$16383 \times 16 \times 63 = 16,514,064 \text{ sectors}$$

$$16,514,064 \times 512 = 8,455,200,768 \text{ bytes } 8.5\text{GB } 8455\text{MB (8064MB, 7.875GB)}$$

With Assisted LBA Translation the limit is lower:

The maximum translated values would be:

$$1024 \times 255 \times 63 = 16,450,560 \text{ sectors}$$

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$16,450,560 \times 512 = 8,422,686,720$ bytes 8.4GB 8423MB

Maximum untranslated CHS values:

$16320 \times 16 \times 63$

With revised ECHS translation the limit is even lower:

The maximum translated values would be:

$1024 \times 240 \times 63 = 15,482,880$ sectors

$15,482,880 \times 512 = 7,927,234,560$ bytes = 7927MB = 7.9GB

Maximum untranslated CHS values:

$15360 \times 16 \times 63$

Capacity Loss Due to Rounding During Translation

In translation algorithms, any non-whole numbers are rounded down to the nearest whole number. Depending on the factory CHS values used on a particular drive, there may or may not be a small loss in capacity due to rounding of non-whole numbers when the parameters are translated by the BIOS. This loss may vary with different types of translation.

Example using Maxtor 85120A 5.1GB

Factory CHS $9924 \times 16 \times 63 = 10,003,392$ total sectors

$5,121,736,704$ bytes .1GB

(4884MB, 4.77GB)

Assisted LBA $622 \times 255 \times 63 = 9,992,430$ sectors

$5,116,124,160$ bytes .1GB

(4879MB, 4.76GB)

loss = 10962 sectors 5,612,544 bytes 5.6MB (5.35MB)

Standard ECHS $620 \times 256 \times 63 = 9,999,360$

$5,119,672,320$ bytes .1GB

(4882.5MB 4.77GB)

loss = 4032 sectors 2,064,384 bytes

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Revised ECHS $661 \times 240 \times 63 = 9,994,320$

 $10585 \times 15 \times 63$

 loss = 9072 sectors 4,644,864 bytes

Example using Western Digital 22100 2.1GB

Factory CHS $4092 \times 16 \times 63 = 4,124,736$ sectors

ECHS $1023 \times 64 \times 63 = 4,124,736$ sectors - no loss

4092 is divided by 4 to get cylinders to 1024 or below.

4092 is divisible by 4 with no remainder, so there is no rounding.

Reference: <http://www.firmware.com/support/bios/hdmath.htm>