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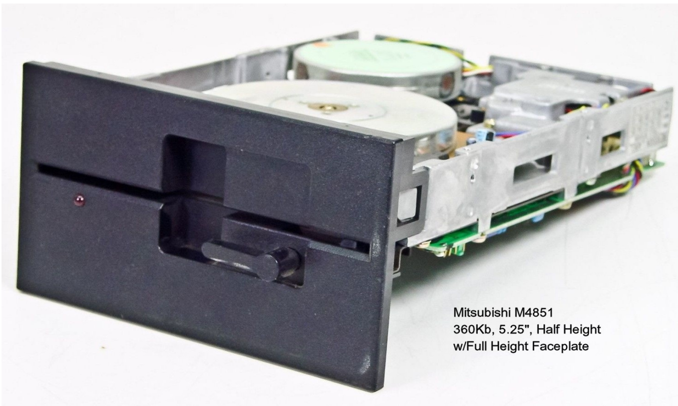

A Floppy Drive Primer

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Note: Portions of this article were taken from the documentation provided with "DiskPack", a Floppy Disk Device Driver from William Flanagin and distributed by Paul F. Herman, Inc. Other portions are from "Upgrading and Repairing PCs, 3rd Edition, by Scott Mueller and published by Que Corporation.

Floppy disk drives come in varying sizes, the most common of which are 3-1/2", 5-1/4", and 8", from the newest to the oldest in technology. For a better understanding of "Floppy" technology, some knowledge of the hardware is necessary. A Glossary is also provided later to help explain some of the stranger terms.

Read/Write Heads - While early drives only had one read/write head and only recorded information on one side of the floppy disk, adding a second head and using the other side of the media was quickly adopted to double the capacity of a disk.

In the 8" drive, there was another difference between double sided and single sided drives; the index hole in the media was in a different location, based on whether the media was single or double sided.

Recording Mode - Early drives were recorded with an encoding technique called FM, or Frequency Modulation. Another doubling of capacity was realized when a method called MFM, or Modified Frequency Modulation, was developed (It was also used on the early personal computer hard drives). These two recording techniques were termed single density and double density, respectively.

Track Density - The next area of improvement was track density, or Longitudinal Density. Each disk is recorded in a series of concentric circles, called tracks (or cylinders), with each adjacent circle getting closer to the center of the disk. The earlier drives could record at a track density of 48 tpi (tracks per inch). As stepper motor technology and the accuracy of read/write heads improved, drives were introduced with a 96 tpi density, which again doubled the drive's storage capacity.

However, the differences in recorded track width can result in data-exchange problems between 5-1/4" drives. The problem occurs if a high density drive is used to update a double density disk with previously recorded data on it.

Even in 360K mode, the high density drive cannot completely overwrite the track left by an actual 360K drive. A problem occurs when the disk is returned to the 360K drive. The 360K drive reads the new data as embedded within the remains of the previously written track, resulting in an "Abort, Retry, Ignore" error message. This problem does NOT occur if a new, unformatted disk is used, then formatted in the 1.2M drive as a 360K disk.

The 3-1/2" drives do not have this data interchange problem because both the high density and double density drives write the same number of tracks and these tracks are always the same width.
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One other little known factor involves the heads. Because the signal placed on the media by a head is effectively placed as an arc along the surface and into the thickness of the media, the two heads are offset by half a track width. The tracks on top of the disk (head 1) are offset towards the center of the disk from the tracks on the bottom of the disk (head 0).

Track Capacity - Still further improvements in read/write heads and disk media permitted higher densities (Linear Density) by packing data closer together on each track. This enhancement gave birth to the 5-1/4" IBM-AT type disk drive. These drives typically operate at a speed of 360 rpm, just like an 8" disk drive (versus the 300 rpm for a normal 5-1/4" drive.

These high density drives record at the same track density as the 8" drives, but in a smaller track circumference. For example, an 8" drive using MFM recording mode, will average about 10,400 bytes per track (depending upon which track), yielding an unformatted capacity of 1.6M for the entire disk. The AT type disk drive uses the same capacity as the 8" drive, and also has an average of 10,400 bytes per track.

Transfer Rate - These higher capacity drives require another consideration - called the transfer rate, or rate of data exchange between the controller and the drive. Drives recorded as double density (MFM) require a greater transfer rate than drives recorded as single density (FM), and 96 tpi drives require a greater transfer rate than 48 tpi drives.

The Z-207 controller uses a transfer rate of 500K for the 8" drives, via a 50-pin connector, and 250K for the 5-1/4" drives, via the 34-pin connector. In high capacity drives (like the high density 5-1/4" drive), the tranfer rates are the same as for 8" drives. The 50-pin connector is required or the Z-207 board must be modified to provide the faster transfer rate via the 34-pin connector.

The standard PC used yet a third transfer rate, 300K, for their low density 5-1/4" drives spinning at 360 RPM. This precluded having to use dual speed drives. This format is not compatible with the Z-100.

Media Size - Because of improvements in stepper motors, read/write heads, and media, it was possible to introduce smaller 3-1/2" drives.

These were introduced with capacities comparable to their 5-1/4" cousins. This caused greater confusion because a different track density had to be used to accommodate the smaller media.

The two formats established for the 3-1/2" disk were 67 tpi and 135 tpi. The 67 tpi was equivalent to the 48 tpi density of 5-1/4" disks, and the 135 tpi density was equivalent to 96 tpi. Of the two, only the 135 tpi is commonly used.

Although we have track densities of 48, 67, 96, and 135 tracks per inch, the actual recording formats are limited to 40, 77, or 80 tracks per disk. The 77 track format is only used for 8" disks. A 135 tpi spacing provides 80 tracks on the 3-1/2" disks.

Disk Media - A final factor is a disk's magnetic properties. The higher density disks require a much higher volume level for the recording than do the double-density disks, because they are approximately half as sensitive magnetically as the double density disks. These high density disks are called high-coercivity disks.

Because the high density disks need double the magnetic field strength for recording, you should not attempt to format a 1.2M high density disk as though it were a 360K disk, or a 360K disk as though it were a 1.2M high density disk.

While the 360K disk may appear to work formatted for 1.2M, with perhaps a large amount of bad sectors, the data is recorded at twice the recommended strength and density. This can imprint the disk with an image that is difficult to remove. Also, the adjacent magnetic domains on the disk eventually begin to affect each other and can cause each other to change polarity or weaken. Over time, the disk begins to erase itself and deteriorates, resulting in lost data!

Formatting a high density disk with a double density format is also a problem. When the 360K drive changes to reduced write-current mode (the last half of the disk), it may not create a magnetic field strong enough to record on the "insensitive" 1.2M disk! The result in this case is normally an immediate error message from the FORMAT command: "Invalid media or Track 0 bad - disk unusable".

A similar problem exists between 3-1/2" formats. You must always use a disk at its designated format capacity. Causing a 1.44M format to be written on a 720K disk renders it unreliable at best and requires a bulk eraser before reformatting it correctly.

Super High Capacity - There were some super high capacity floppy disk drives available. These drives may have unformatted capacities as high a 6 megabytes. Some of them rely on secondary 'fine-tuning' steppers to maintain track alignment, or other tricks which have not enjoyed widespread acceptance. One such drive was Kodak's short-lived 5.5M floppy drive. It was easily used on the Z-100 and was described in issue #5 of the LifeLine.

Other floppy drives that rely on special optical or laser sensors for tracking have claimed capacities of over 20 megabytes. These disk drives use special preformatted media and have more characteristics in common with removable hard disk drives than floppy drives. To my knowledge, none have been made to run successfully on the Z-100. I have no info on the "floptical" drive.

Floppy Disk Types:

There are five popular floppy drive types in current use. The following table shows the Floppy Disk Format Parameters:

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Disk Size (Inches):	5-1/4	5-1/4	3-1/2	3-1/2	3-1/2
Disk Cap (K bytes):	360	1200	720	1440	2880
Sides (Heads):	2	2	2	2	2
Spin Rate (Rpm):	300	360	300	300	300
Transfer Rate (KHz):	250	500	250	500	1 MHz
Tracks/Inch:	48	96	135	135	135
Bits/Inch:	5876	9646	8711	17434	34868
Tracks/Side:	40	80	80	80	80
Sectors/Track:	9	15	9	18	36
Bytes/Sector:	512	512	512	512	512
Sectors/Cluster:	2	1	2	1	2
FAT Length (sectors):	2	7	3	9	9
Number of FATs:	2	2	2	2	2
RootDir Lngth (secs):	7	14	7	14	15
Max Root Entries:	112	224	112	224	240
Total Sectors/Disk:	720	2400	1440	2880	5760
TotAvail Sectors:	708	2371	1426	2847	5726
TotAvail Clusters:	354	2371	713	2847	2863

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Table 1. Floppy Disk Format Parameters

Table Notes:

1. The quad density 5-1/4" disk is not included above. It stores the same linear data on each track and doubles the tracks. The quad density version of media is a more rigorously tested, higher quality disk able to store 720Kb.

2. To store the increased linear density for 5-1/4" high density, a cobalt high-coercivity magnetic coating, rather than ferrite, is used and the media thickness is 1/2 of other disks.

Do NOT substitute double density disks for high density disks, or high density disks for a double or quad density disks, or you will experience severe problems and data loss. The write-current must be different for these very different media formulations and thicknesses.

3. To store the increased linear density for 3-1/2" high density, a higher-coercivity cobalt magnetic coating is used, and the media thickness is nearly 1/2 of the other disk. As with the 5-1/4" disks, you must not substitute one disk format for another.

4. The extra-high density disks use a barium-ferrite compound, rather than cobalt, to cover the disk with a thicker coating, which enables a vertical recording technique to be used. In vertical recording, the magnetic domains are recorded vertically rather than flat, allowing greater density.

5. The 2.88 Mb floppy can NOT be used in the standard Z-100. The required 1 MHz data transfer rate is NOT supported.

MS-DOS Disk Format Information:

The DOS FORMAT utility must be used to prepare a floppy disk or hard drive to store information. FORMAT builds the required information tables on the disk so that files can be located.

For floppy disks, the FORMAT program also writes address information onto each data track of the disk so that sectors can be located and verified.

For hard disks, the FORMAT program may only initialize the table information, or verify data sectors for the purpose of flagging bad sectors so DOS won't try to use them. The actual data track address formatting for hard disks is usually done by a 'low level' format program, called PREP by Heath/Zenith.

Boot Loader - The first of the table areas written by the FORMAT program is a small program called the boot loader, which is used to load DOS into the system at the time the system is booted. The boot loader code is written into the boot sector, which is always the first sector on the disk.

There is also a table which explains certain media information to the monitor ROM boot code, and the boot loader code on disk. The table will have the sector size, number of sectors per allocation unit, number or reserved sectors, etc. The format of this table, from Zenith's viewpoint, comes in two varieties - the IBM version for IBM compatibles and the Z-100 type.

One of the main purposes of the boot loader table is to inform the boot code about the format of the media. The data contained in the boot loader table is pertinent to the disk format and does not relate to the disk drive's capabilities. Some additional information is defined by Zenith which relates to the boot process and not the format, therefore it was not included in the following table descriptions.

IBM Format for the Boot Loader Table

Offset	Length	Description
0	8 bytes	OEM name
8	2 bytes	bytes per sector
10	1 byte	sectors per allocation unit
11	2 bytes	number of reserved sectors
13	1 byte	number of FAT tables
14	2 bytes	maximum ROOT directory entries
16	2 bytes	number of sectors per media
18	1 byte	media descriptor
19	2 bytes	sectors per FAT
21	2 bytes	sectors per track
23	2 bytes	number of heads
25	2 bytes	number of hidden sectors

Zenith Format for the Boot Loader Table

Offset	Length	Description
0	1 byte	version number
1	2 bytes	bytes per sector
3	1 byte	sectors per allocation unit
4	2 bytes	number of reserved sectors
6	1 byte	number of FAT tables
7	2 bytes	maximum ROOT directory entries
9	2 bytes	number of sectors per media
11	1 byte	sect size shift count (log2 of size)
12	1 byte	sectors per track
13	2 bytes	first data sector number
15	1 byte	cluster factor shift count (log2 of factor)
16	2 bytes	first directory sector

Additional information on Zenith’s Boot Record can be found in Paul Herman’s issue #26 of the “*Z-100 LifeLine*”.

File Allocation Table (FAT) - The next table created by the FORMAT program, this one maps the status of each data cluster available on the disk. The FAT will map the location of all the clusters which are linked together to make up a data file. Bad sectors are also indicated by the FAT, so they will not be used by DOS. Though only one table is required, this table is written to the disk twice in the standard DOS format.

Root Directory Table - The last table built by FORMAT, this one is used to identify all the files and subdirectories in the ROOT directory of the disk. It holds information about the file length, attributes, and the starting cluster for each file or subdirectory. DOS can then consult the FAT table to determine the location of all parts of a file.

Note: All subdirectories under MS-DOS are merely data files with a special attribute set. No space is reserved on the disk for directories, except for the ROOT directory.

Data Space - consists of the remainder of the disk, which is divided into clusters, each of which is pointed to by a particular FAT entry. In other words, the first FAT entry corresponds with the first data cluster, the second FAT entry with the second data cluster, and so forth.

Before DOS writes a file to disk, it finds the first available data cluster by consulting the FAT. Data from the file is then written into the cluster, and the FAT is updated to show the cluster as being used for this file. Then another available data cluster is found, and the process repeats until the entire file is saved on disk.

As new FAT entries are reserved for the file, the previous entries are changed to point to the present entry so as to form a chain of pointers from one cluster to another. After the file is saved, the last cluster number is indicated in the FAT so that DOS will know where to stop when the file is read.

Because contiguous files can be read faster, MS-DOS v6 and above attempts to place a file in a contiguous string of available clusters large enough to hold the file. If this fails, then the file is broken up.

GLOSSARY:

Cluster - also called an allocation unit in DOS v4.0 or higher, it is the smallest unit of the disk that DOS can allocate when it writes a file. A cluster consists of one or more sectors. Having more than one sector per cluster reduces the file allocation table size and enables DOS to run faster because it works with fewer units of the disk.

The tradeoff is in some wasted disk space, because DOS can manage space only in the cluster sized unit. The 360K 5-1/4" disk and 720K 3-1/2" disk uses 2 sectors (each with 512 bytes) per cluster. The high density formats use 1 sector per cluster, probably because the drive's transfer rates are faster.

Coercivity - refers to the magnetic-field strength required to make a proper recording on a disk. With lower ratings, the disk can be recorded with a weaker magnetic field.

Cylinder - all the tracks that are under read /write heads on a drive at one time. For floppy drives, because a disk cannot have more than two sides and the drive has two heads, there are two tracks per cylinder (one under each head). Hard disks can have many disk platters, each with two or more heads, for many tracks per single cylinder.

Density - a measure of the amount of information that can be packed reliably into a specific area of a recording surface.

Double Density - When drive manufacturers changed from Frequency Modulation (FM) encoded drives to Modified Frequency Modulation (MFM) encoding, they began using the term "double density" for the new drives and "single density" for the older drives.

Longitudinal Density - reflects how many tracks can be recorded on the disk (tracks/inch).

Linear Density - reflects the capacity of individual tracks to store data (bits/inch).

Interleave - All standard floppy controllers support a 1:1 interleave, in which each sector on a specific track is numbered (and read) consecutively. On a hard drive rotating at 3600 RPM, however, by the time a sector is read or written, the next sector is already past and the drive must wait nearly another revolution to get to the next sector. Instead, on an MFM hard drive, sectors may have an interleave factor of 3:1 or 4:1, where the consecutive sectors are spaced to every third or fourth sector.

This spacing is based upon the time required to read a sector and send it to the controller, then be ready to read the next sector. This way, a disk doesn't need to make a full revolution to read/write the next sector.

Virtually all modern IDE and SCSI drives have returned to a 1:1 interleave because of the improvements in processing speed. An interleave factor of 4:1 works best on the Z-100's MFM hard drives.

Latency Time - The average time it takes for a specific sector to fall under the heads, once the heads are located on the specified track. At an interleave factor of 1:1, this would be time for one half a revolution.

Seek Time - The time it takes to move the heads from one track to another.

Thickness - The thickness of the disk media. The thinner the media, the less influence a region of the disk has on an adjacent region, allowing better linear density.

Transfer Rate - The rate of data exchange, in kilobits per second (or kilohertz or KHz), between the floppy disk controller and the drive.

The 360K 5-1/4" drive spins at 300 RPM, which equals exactly 5 revolutions per second, or 200 milliseconds per revolution. All standard floppy controllers support a 1:1 interleave, so to read and write consecutive bits to a disk at full speed, a controller must send data at a rate greater than 200,000 bits per second.

The 1.2M 5-1/4" drive spins at 360 RPM, or 6 revolutions per second, or 166.67 milliseconds per revolution. To send or receive 15 sectors (plus required overhead) six times per second, requires a 500K transfer rate.

The normal Z-207 controller card is capable of 250,000 bits per second (250 KHz) on the 34-pin connector to 5-1/4" drives and 500,000 bits per second (500 KHz) on the 50-pin connector to the 8" drives.

Note: When a standard 360K disk is running in a high density drive that doesn't reduce speed to 300 RPM (such as in a standard PC), it also is spinning at 360 RPM; a data rate of 300,000 bits per second (300 KHz) is required in order to work properly. While briefly used in the PC, the Z-100 does NOT support this data rate.

Vertical Recording - Used by 2.8M drives to achieve its greater linear density of 36 sectors per track. Instead of the standard medium where the magnetic particles are shaped like tiny needles laying flat on the surface of the disk, a special, barium ferrite medium is used. This technique uses tiny, flat, hexagonal platelets that can easily be arranged to have their axis of magnetization perpendicular to the recording surface. By placing the magnetic particles on end and stacking them side by side, density increases dramatically.

If you have any questions or comments, please email me at:

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Cheers,

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