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Training Manual

Intro. to Magnetic Disk Drives

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An Introduction to Magnetic Disk Drives

Philips Telecommunication and Data Systems

PHILIPS

A Publication of
PHILIPS TELECOMMUNICATIE EN DATA SYSTEMEN NEDERLAND B.V.
Customer Service Documentation and Training
Apeldoorn, The Netherlands

Pub. No. 5122 991 35171

Date November 1987

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Introduction

1.1 BASIC TERMS

Magnetic disk drives are peripherals used for data storage, combining large storage capacity with fast access. The storage medium is the magnetic layer of oxide on the disk(s).
Two types of disks - **floppy** (flexible plastic) and **hard** (rigid metal) disks.
Each disk surface is divided into concentric **tracks**, sub-divided into fixed capacity (fixed length) **sectors**, as in Fig. 1.1.
For hard disk drives only, several disks may be stacked above each other on one **spindle**, driven by a **spindle motor**. The same track on each surface forms a **cylinder**, as in Fig. 1.1.
Data transfer between disk and drive is via **heads,** one per surface.
Data is transferred serially to (**write**) and from (**read**) the disks while the disks rotate under the stationary heads.
To access different tracks, the heads are moved radially (together) across the disks.This is a **seek**.
In floppy drives, the heads are always in contact with the disks during read and write. In hard disk drives, head to disk contact is usually not allowed, although later drives have head to disk contact before and during motor run up.
For drives with low track densities, measured in tracks/inch, (includes all floppy drives), a **stepper motor** is used for head positioning, which moves the heads in fixed steps (tracks) to the next track address.
For drives with high track densities, the **head positioner** consists of a moving part, the **voice coil**, to which the heads are attached, inside a fixed **permanent magnet**. The positioner uses information from a specially coded disk surface, the **servo** surface, which cannot therefore be used for data storage.
Floppy drives have one removable disk, which can be used on other drives. Hard disk drives have unlimited numbers of disks of which none, one, or all are removable (**cartridge** disks). Most modern hard disk drives do not have cartridge disks. The heads and disks are sealed in an air-tight container (**head / disk assembly, HDA**) .
Hard disk drives which have a sealed HDA, with lightweight heads allowing head to disk contact, are often referred to as Winchester drives, although this term really applies to a special magnetic media coating which allows the heads to rub against the disk without much friction.

1.2 COMPARISON OF PERIPHERALS FOR DATA STORAGE

RANDOM ACCESS MEMORY, RAM:
Fastest access, because no moving parts.
Capacity limited to capacity of I.C. 's - 1Mbit per chip.
Volatile memory - back-up battery necessary.

TAPE:
Slow access with high storage.
Non volatile memory.
Tape is organised in blocks, serially.
Average access is the half tape length (typical speed 90 in/s. , tape length 200 m.).
Data transferable to other systems on cassettes.

DISK:
Combines fast access with high storage capacity.
Slower than RAM because of seek time, but non-volatile.
Currently the most popular medium for data storage.
A disk is organised in tracks and sectors, see Fig. 1.1

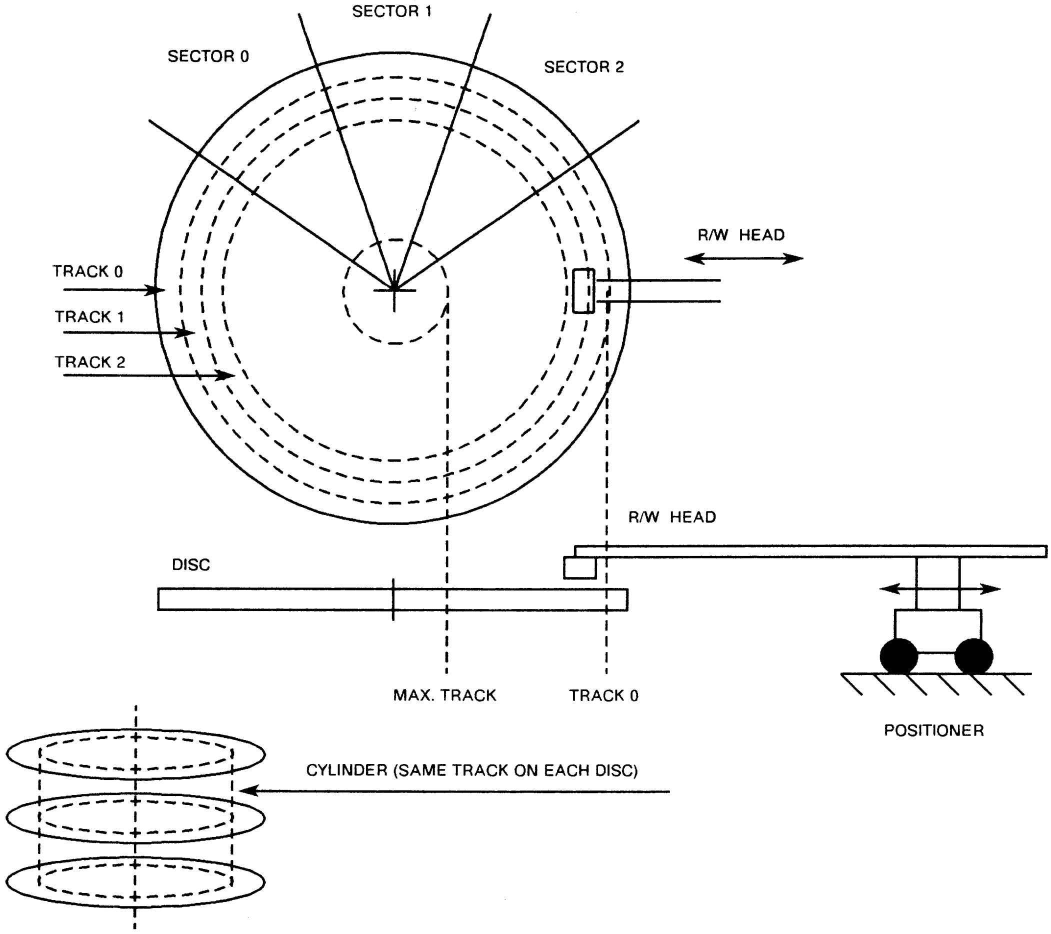


Figure 1.1. Drive Sectors, Tracks and Cylinders

1.3 DATA ORGANISATION

A block of data stored on a disk is a **file**, with an identifying **filename**. The file can fill several sectors. Sector length is selected at installation, to store a convenient, fixed number of data bytes, and is thereafter not altered. A sector consists of two parts, an **identifier** (or **header**), containing sector address and flag (good or bad track status), and the user data area, shown in Fig. 1.2. Normally, a **directory**, consisting of an index of files (filenames, file addresses and file lengths, in bytes), together with a list of empty sectors, is stored on reserved disk tracks.

When writing to disk, the directory is used to select, and then write to, empty sectors, until the file is complete. Usually, tracks are written sequentially, i.e., when the empty sectors of one track are full, the next track is selected. Finally, the file name, address and length are written in the directory, and the sectors used for that file deleted from the list of empty sectors. If more than one area of disk is used to store a file, then the start address and block size of each segment of the file must be in the directory.

When reading from disk, the directory is used to find the start address of the identifying filename, and to read the required number of bytes (indicated by the filelength).

Error checking and correction data, **ECC**, checks that the data is correct. **Gaps** separate sectors, headers and user area to prevent data overwrite, and also to identify the start of sync data, used to synchronise the drive to data on the disk at the start of a read process. Note that all sectors on each disk surface will have the same head address, and that all sectors on the same cylinder will have the same track number.

Before data can be stored on a disk, the identifiers must be written at the start of each sector, a process termed "**formatting**". The amount of user data which can be stored after formatting is known as the formatted capacity. It is calculated as follows:-

Drive capacity = no. data surfaces × no. tracks / surface (cylinders)
× no. sectors / track × no. bytes / sector

Manufacturers normally specify the unformatted capacity, which includes the areas used by the identifier, and gaps between sectors, because the number of sectors is selected by the operator.

Unformatted capacity = no. data surfaces × no. cylinders × no. bytes / track

A format program also checks for bad spots on the disks, where the recording media is defective, with a write - read operation. Bad areas should be written on the defect map (see section 4.4.), so that the user does not try to read or write in that area.

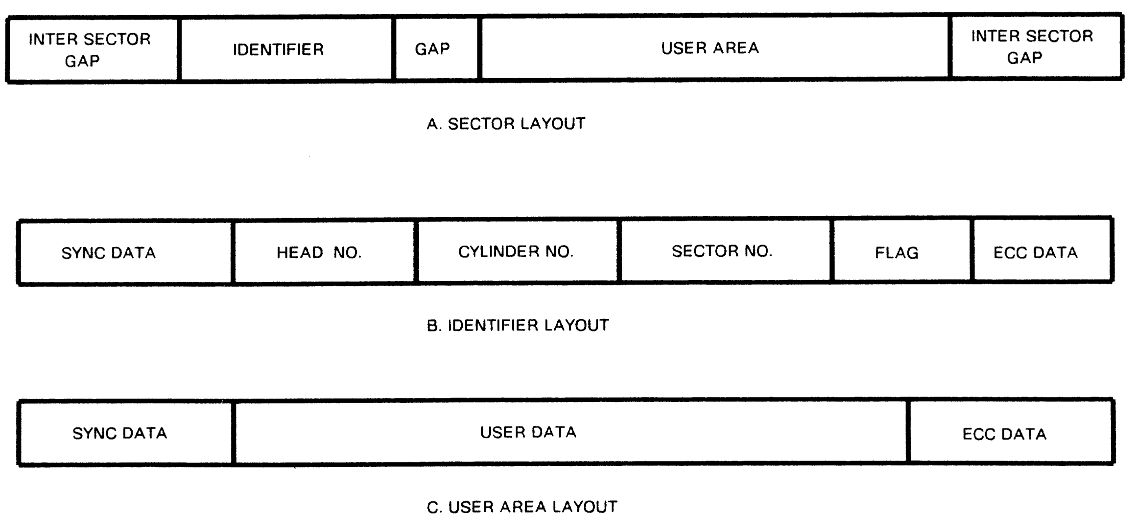


Figure 1.2. Sector Format

1.4 SYSTEM ORGANISATION

The drive interfaces with the system via its controller, as shown in Fig. 1.3. Data transfer within the system is along data buses. The controller therefore performs parallel to serial data conversion for write, and serial to parallel during read. For floppy drives and non-intelligent hard disk drives, the controller also performs some drive functions, e.g. data encoding / decoding. Data inside the system is referred to as non- return to zero (NRZ), with (for positive logic), logic "1" at the high level, and logic "0" at the low level.
Some controllers use sector interleaving. If data transfer between controller and main memory is slow (due to the host interrupt system), there will be a build up of data inside the controller. To avoid this, after one sector is read from disk, the next sector (s) are skipped while data is transferred to main memory. This is sector **interleaving** . A **skip** or **interleave** factor of two means read or write one sector, and skip the next. Two revolutions are needed to read the whole track. A skip factor of three, requires three revolutions to read the whole track. The sector addresses are also interleaved, with the next higher sector number address being the next interleaved sector read, although for an interleave factor of three, it will be physically separated by two sectors from the last sector read. The interleave factor must be selected before formatting the disk.

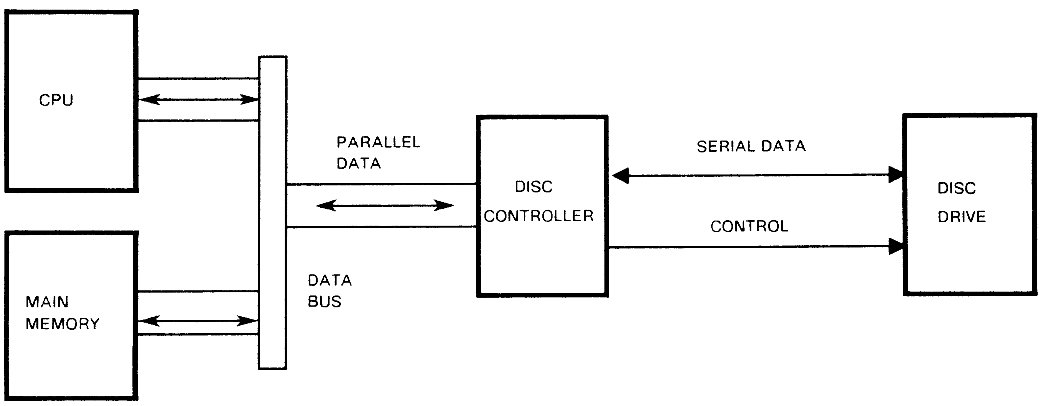


Figure 1.3. System Organisation

1.5 DRIVE SEQUENCE

1.5.1 Hard Disk Drives

Some drives start motor run up and head load at power on. Other drives require a command from the drive controller. A limited time is allowed for the motor to reach the rated speed of 3,600 rev. / min. Speed is checked with sensors, and usually controlled with feedback from these sensors. At rated speed, the heads are loaded, i.e., moved from the landing area to track 0. Any faults are indicated (flagged) to the drive controller across the interface, and if there are no faults, the drive is ready to read or write. The sequence for read or write is:-

(a) the drive controller commands the drive to seek to the track where the file is to be read or written, and waits for the drive to carry out the seek and then lock on the required track.
(b) the controller selects a data head.
(c) at each sector pulse, the sector address is read from the identifier. The controller waits for the required sector. This is the latency time.
(d) at the required sector, a read or write operation is commanded by the controller when over the user data area, and read or write data is transferred to or from the drive controller across the interface.

1.5.2 Floppy Disk Drives

The sequence is similar to that for hard disk drives in section 1.5.1. A floppy disk must first be loaded into the drive however. Also, because data heads are in contact with the disk, it is usual to reduce head and disk wear by either:-

(a) running the motor up only when a read or write is required, and running it down when idle again. This requires only a short time as drive speed is 300 rev / min.
(b) retracting the heads from the disk surface when idle.

Chapter 2

Drive Functions

2.1 OVERVIEW OF DRIVE HARDWARE

Fig. 2.1. shows the main drive components for a hard disk using a servo disk for head position control (closed loop control). The main drive functions are:-

(a) To control speed of rotation of the disks. This means starting and stopping the spindle motor, and (usually) maintaining the disk speed at its rated value (normally 3600 rev./min.) for read and write. Spindle speed is checked.

(b) To control head position . This means moving the heads to track 0 when the motor reaches rated speed (head load), seeking to a requested data track, locking on data track centre when idle or during read / write, and returning the heads to the landing zone before the motor is run down.

(c) Encoding write data received from the host, and decoding read data.

(d) Drive control, requiring the implementation of host commands, i.e., seeking, motor run up and run down, and status reporting, including fault conditions.

Control of read and write is normally from the host through the interface. Some hard disks, e.g. those with the ST 506 interface, and also floppy disk drives, have no servo disk, and no data encoding or decoding. For these drives, the head positioner is a stepper motor, without feedback control, i.e. open loop control, and data encoding is done by the drive controller.

2.2 MOTOR CONTROL

Motor run up is effected, either at power on, or when requested at the host interface. Speed is sensed by a transducer, e.g. Hall sensors, and on most drives, corrected by controlling power to the motor. Speed faults disable read and write. Motor drive is a two or three phase square wave. Power is varied by altering the mark-to-space ratio (duty cycle), thus varying the average power to the d.c. motor.

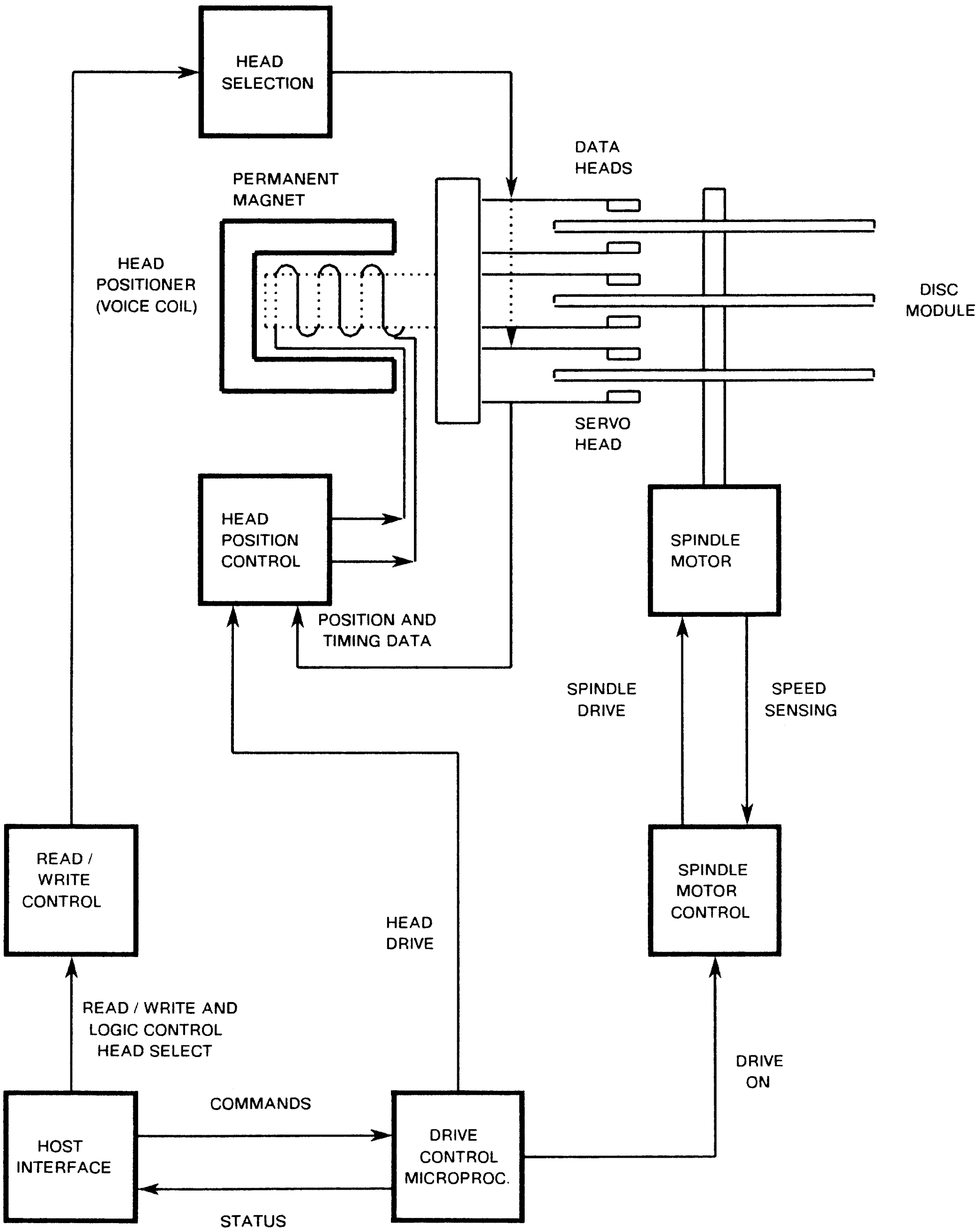


Figure 2.1. Intelligent Hard Disc Drive Block Diagram

2.3 HEAD POSITIONING

2.3.1 Head Positioner Assembly with a Voice Coil

For drives with closed loop head position control heads are mounted on a common head assembly, mounted on rails, so that all move radially together, as shown in Fig.2.2. The head position is controlled by the current in the voice coil, using position data from the pre-written servo surface, explained in section 2.3.2. Data track positions are defined by the servo track positions.
For drives with no removable disks (most modern drives), relative head position does not need to be altered. For drives with data cartridges, data heads are aligned. i.e. each head is separately adjusted to be vertically above the servo head (see section 4.6.). This enables interchange of cartridges between drives without data errors.

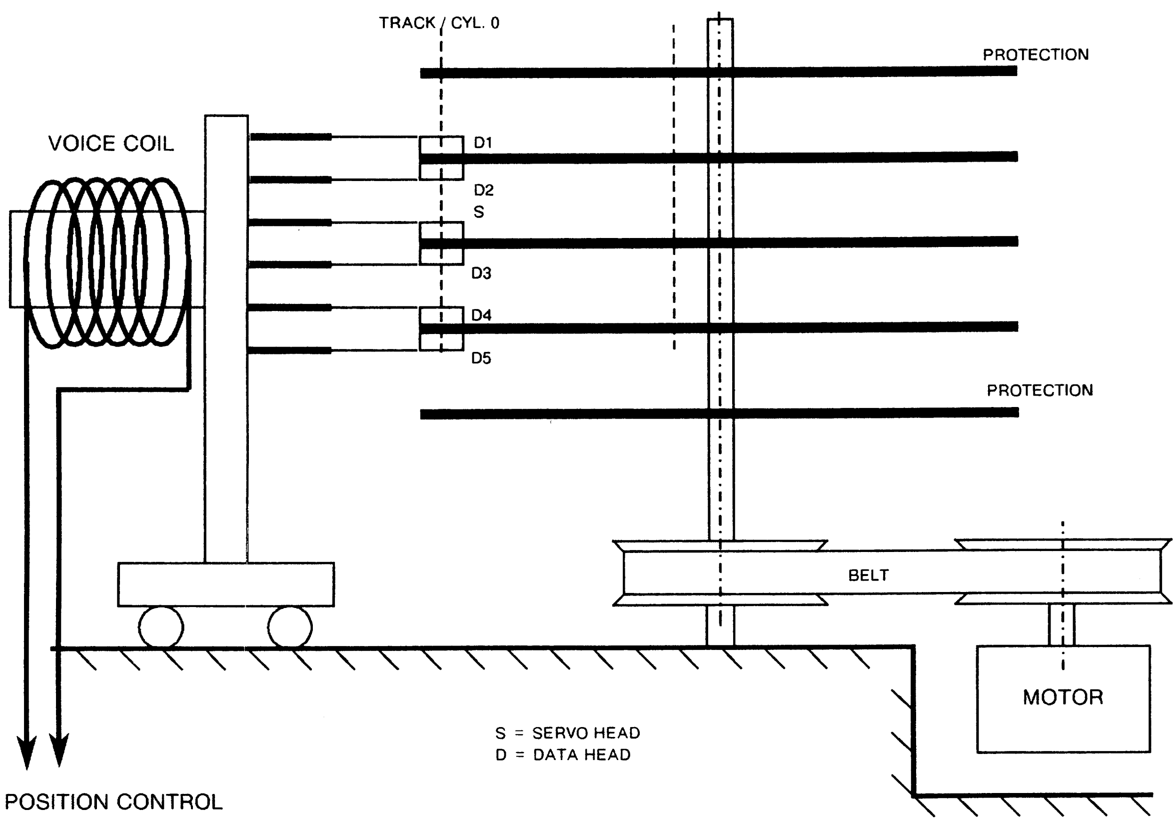


Figure 2.2. Head Disk Assembly (example shows CDC SMD 80 MB drive)

2.3.2 Servo Disk Data

Contains position data for head position control and timing data for clocks.
Written at factory - thereafter read only - not user accessible.

Synchronisation pulses vary with disk speed and are therefore used to generate timing generate clocks for the following functions.

(a) Writing. Varying the write clock with disk speed keeps the data density on the disk constant. A fixed frequency write clock could cause data to overwrite the next sector, if the disk speed increases.

(b) Sector pulse generator. Sector length must remain constant when the disk speed changes. Using a fixed number of sync pulses to decrement a counter and generate a sector mark at count 0 is usual.

(c) Locking the read phase locked loop, PLL, when not reading. The principle of the PLL is explained in section 2.3.8. During read, the PLL for generating read clock synchronises to read data transitions. To keep the PLL within its range of lock when not reading, a reference of approximately the same frequency must be supplied. Write clock, dependent on disk speed ,see paragraph (a) above, is often used.

(d) Demodulating position pulses (see below). To separate composite position data in the servo signal, coming from different servo tracks, a clock in phase with the position data from the servo disk is necessary.

Position pulses are used for head speed control during seeks, and track following when reading or writing.
Fig. 2.3. shows an example of dipoles written on disk, N-S indicating direction of magnetisation.
At each N or S there is a change in polarity, generating a pulse in the servo winding.
N poles occur on all tracks at the same time. They are timing pulses and define the frame, within which is a position pulse.
S poles occur at the 1/3 or 2/3 frame position and are track position pulses.
In the example shown in Fig 2.3., position pulses from ODD and even tracks are separated by 1/3 frame time intervals in the composite (ODD + EVEN) signal in the servo winding.
When track following (POSITION or LOCK-ON-TRACK mode) during read or write, servo head is mid-way between an odd and even track, and the position pulses are of equal amplitude. If the head wanders off track junction towards the odd track, an error voltage is generated from a sampling circuit, measuring position pulse amplitude, which is amplified and drives the voice coil, with polarity selected so that the servo head is moved back to the servo track junction. This is the POSITION control loop described in section 2.3.3.
During a seek, the error voltage is a sine wave, used to count tracks crossed.

Zones of servo surface
The servo disk surface is divided into a number of different zones, radially, each with an identifying data pattern. An example is shown in Fig. 2.4. The zones are:-

(a) servo data track zone.This zone defines user data tracks, and the servo data is used for seeking and lock-on-track.

(b) outer guard band, used to inform drive control that it has reached the outer servo track (track 0)

(c) inner guard band, used to inform drive control that it has reached the inner servo track (highest track number).

(d) an optional landing zone (sealed HDA drives only), where the heads are positioned when stationary (parked) and during motor run up. Modern drive data and servo heads are lightweight, the disk surface is coated with a frictionless lubricant, and the air is filtered, so the risk of damage from head to disk contact is small. Any defects in the surface of the landing zone are not important. When the motor is at speed, the disk rotation causes the heads to fly over the surface, and they may then be moved to the servo data track area. The landing area is usually the zone nearest to the spindle.

(e) some drives also have a special pattern to identify track 0.

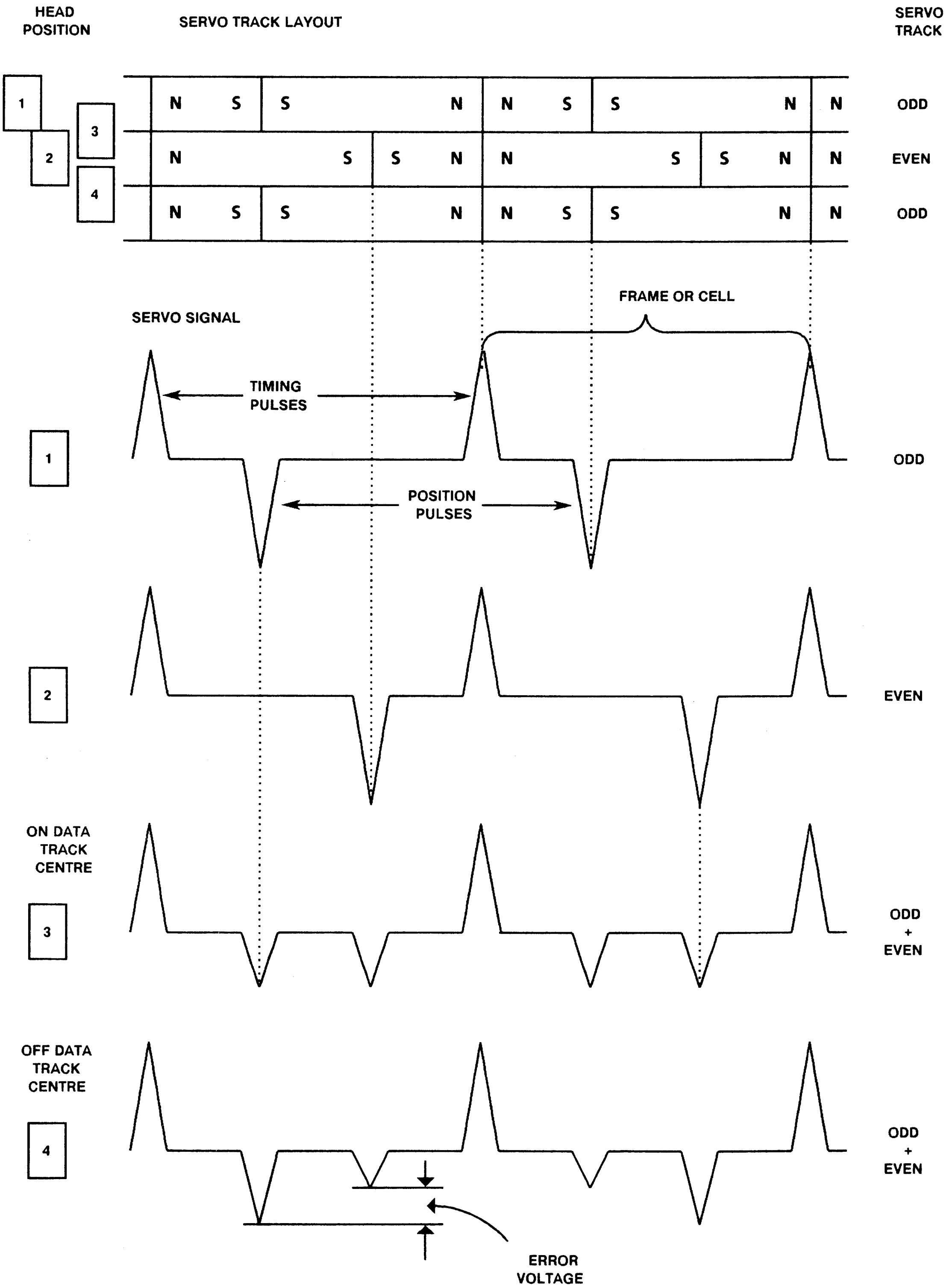


Figure 2.3. Example of Servo Data (Priam 3450)

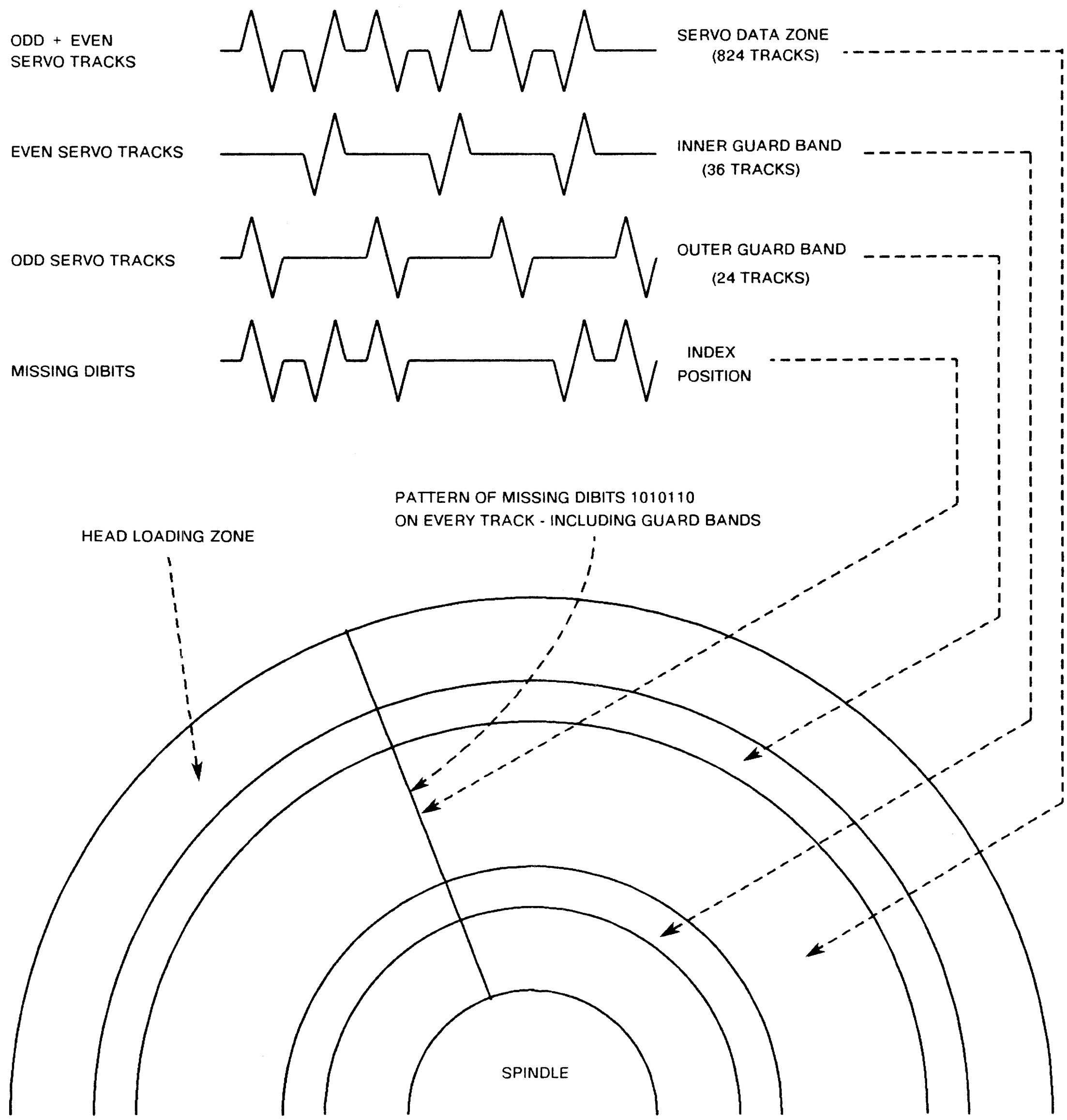


Figure 2.4. Servo Data Zone Waveforms (CDC CMD 10 / 50 Drive)

The example shown in Fig. 2.4. is for the older type of 14 inch drives with no sealed HDA. Heads are retracted clear of the disks at motor run down to prevent head crash. The head landing zone shown is where the heads dip towards the disk surface when released from a restraining spring at head load. If the heads dip too far and damage the magnetic coating, servo data is not lost.
The index pulse is also obtained from the servo surface, as a special pattern decoded by the drive control. This is at the same position on each track, as shown in the example.

2.3.3 Position Mode and Servo Demodulation

Servo dibits are first separated into position and sync pulses. Position pulses are then separated in a demodulator, using a timing circuit obtained from the sync pulses, which selects sequentially the pulses from the odd and the even track. The peak levels of each are then sampled and compared in a differential amplifier to find the error voltage. In the position mode, for reading and writing, this error voltage is used to keep the heads on track centre . An enable for the position loop disables the loop when seeking. When seeking, the servo head passes over odd and even tracks alternately, causing the peak samplers, and error signal generator, to output a sine wave, with each half wave indicating one track crossed. This is used for velocity measurement, and for counting down the tracks still to be crossed.

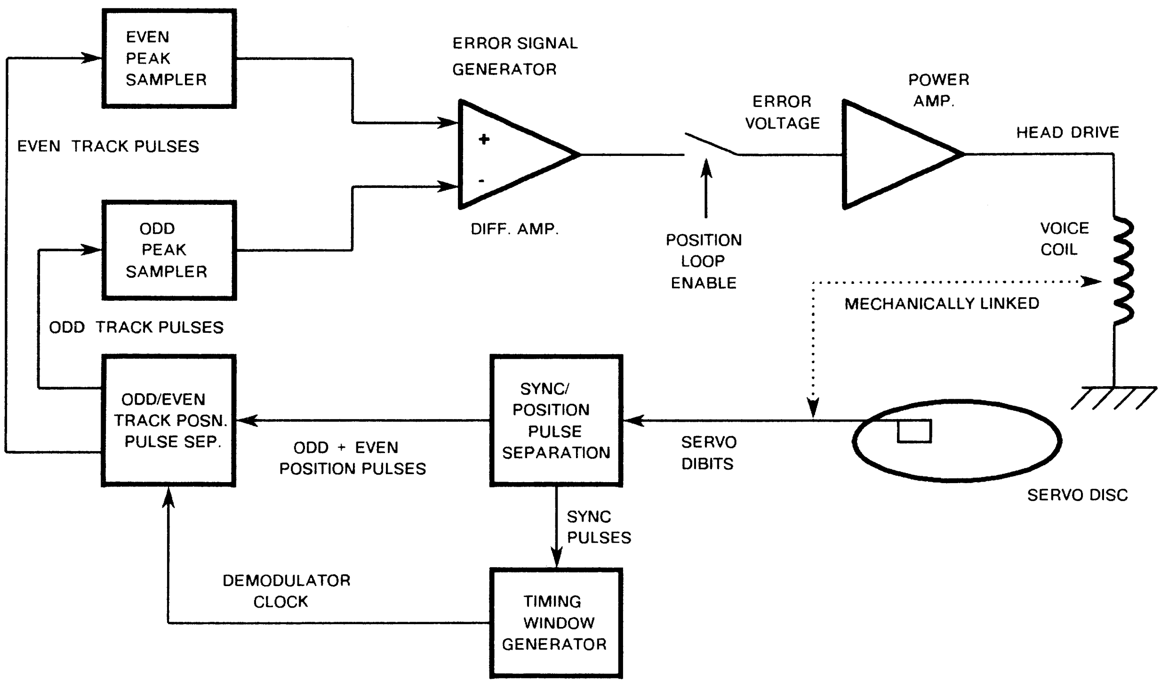


Figure 2.5 Position Mode Block Diagram

2.3.4 Seek Mode

In modern intelligent hard disk drives, seeks are controlled by a drive microprocessor, using the position data from the servo surface.

The sequence is as follows:-

(a) The host sends the seek address (new track address, N.T.A.) to the drive, read by the microprocessor, which also has a register of the present track address, P.T.A., of the servo head, updated when tracks are crossed.

(b) The microprocessor calculates the number of tracks to cross from

tracks-to-cross = N.T.A. - P.T.A.

and also the required direction.

(c) The microprocessor starts the seek by issuing a **required velocity** (see Fig. 2.6.) to generate head drive in the voice coil, obtained from the tracks-to-cross of the velocity table of its microprogram, represented in Fig. 2.7. Drive for the voice coil is the output of the summer

i.e. head drive = required velocity - actual velocity

where actual velocity is usually obtained from servo position data as rate of crossing tracks from a velocity generator, described in section 2.3.5.

Alternatively, it may be measured directly with a transducer inside the voice coil.

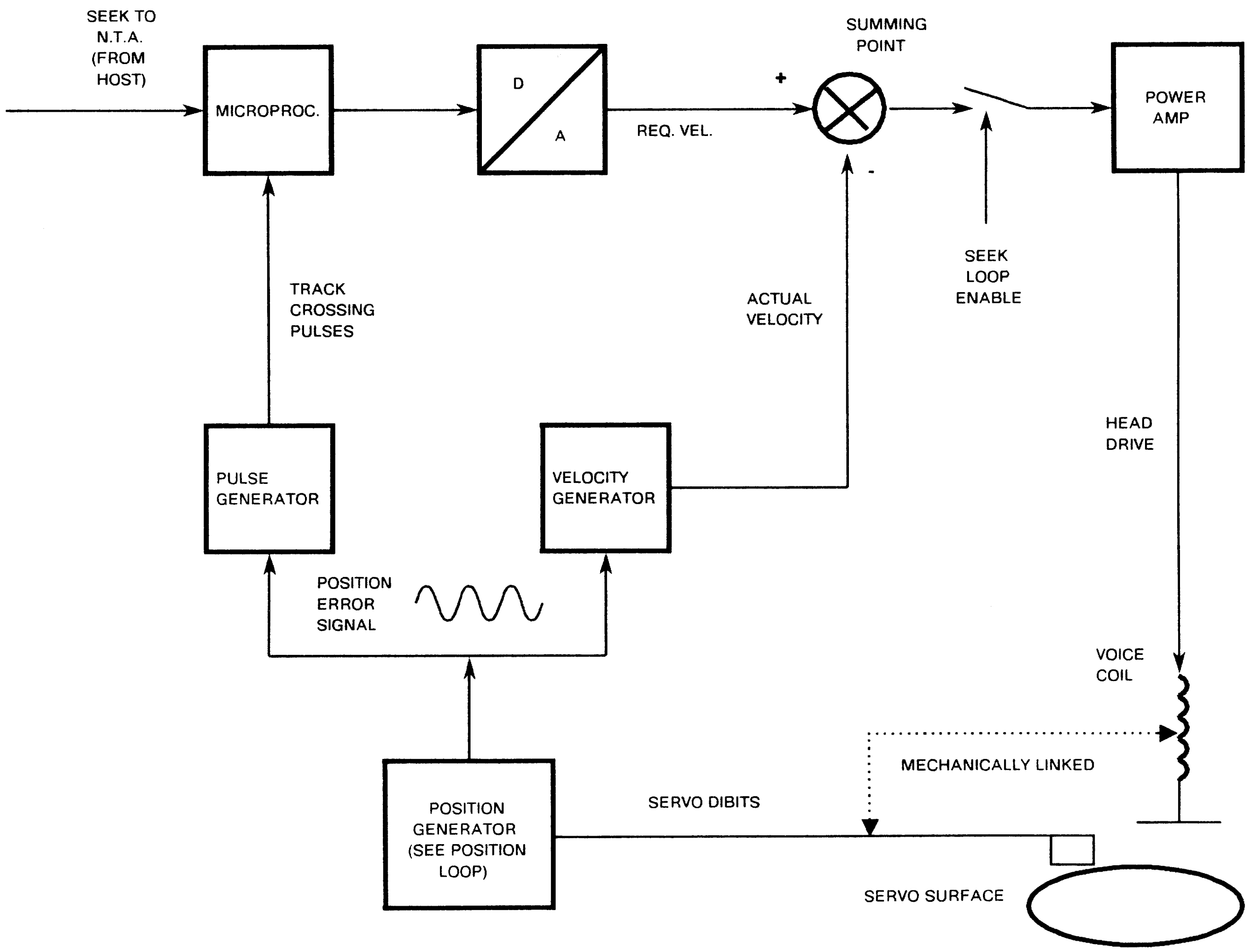


Figure 2.6. Seek Control block Diagram

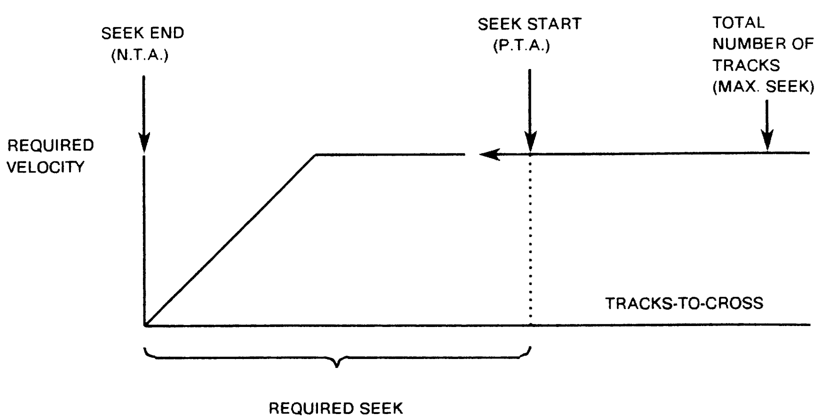


Figure 2.7. Velocity Table

(d) Current control of the voice coil* is shown in Fig. 2.8. Current magnitude determines the acceleration, and hence velocity of the voice coil and head assembly. Current direction determines direction i.e. forward or reverse seek. With no current, the head assembly is either at rest (for read and write), or moving at constant speed (seek).

(e) Initially, during a seek, actual velocity is low, so there is a large accelerating current to the voice coil, as shown in Fig. 2.9. When the actual velocity reaches the required, head drive is removed and the voice coil speed is constant. The servo position signal is digitized to generate a pulse for each track crossed. This counts down the tracks-to-cross, and the microprocessor reduces the required velocity in accordance with its velocity table (Fig. 2.7.), as the N.T.A. is approached, to prevent overrun. Head drive is then negative, and the head assembly slows down.

(f) When the N.T.A. is reached, the seek enable switch is opened, to allow the position loop to be switched in for lock-on-track.

For drives with a stepper motor (including floppy drives), a seek is commanded by the host sending a series of pulses on the STEP signal line of the interface, one pulse for each track to be crossed. Seek direction is set by the DIRECTION IN signal of the interface, true for a forward seek, false for a reverse seek. At seek end, the heads are locked on track with a d.c. current to the stepper motor windings (see section 2.3.6.).

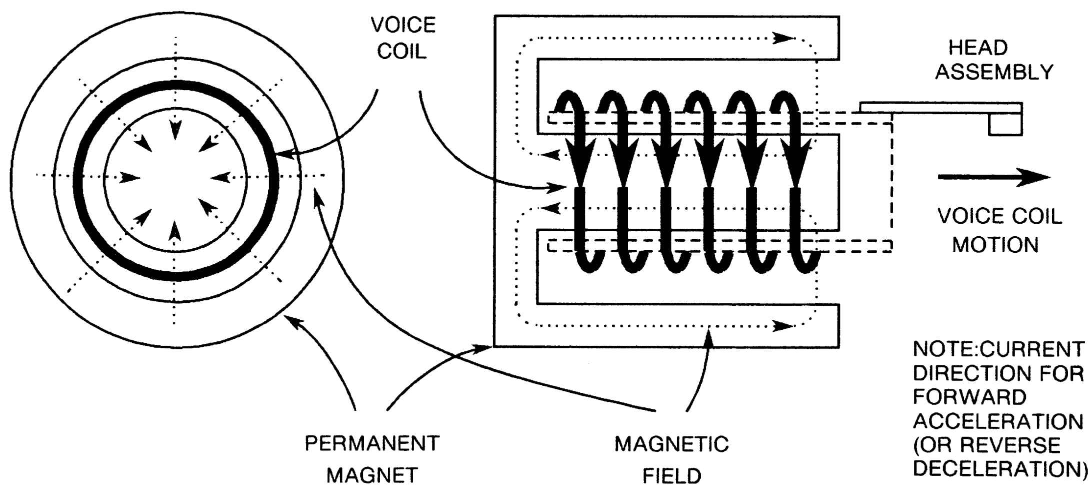
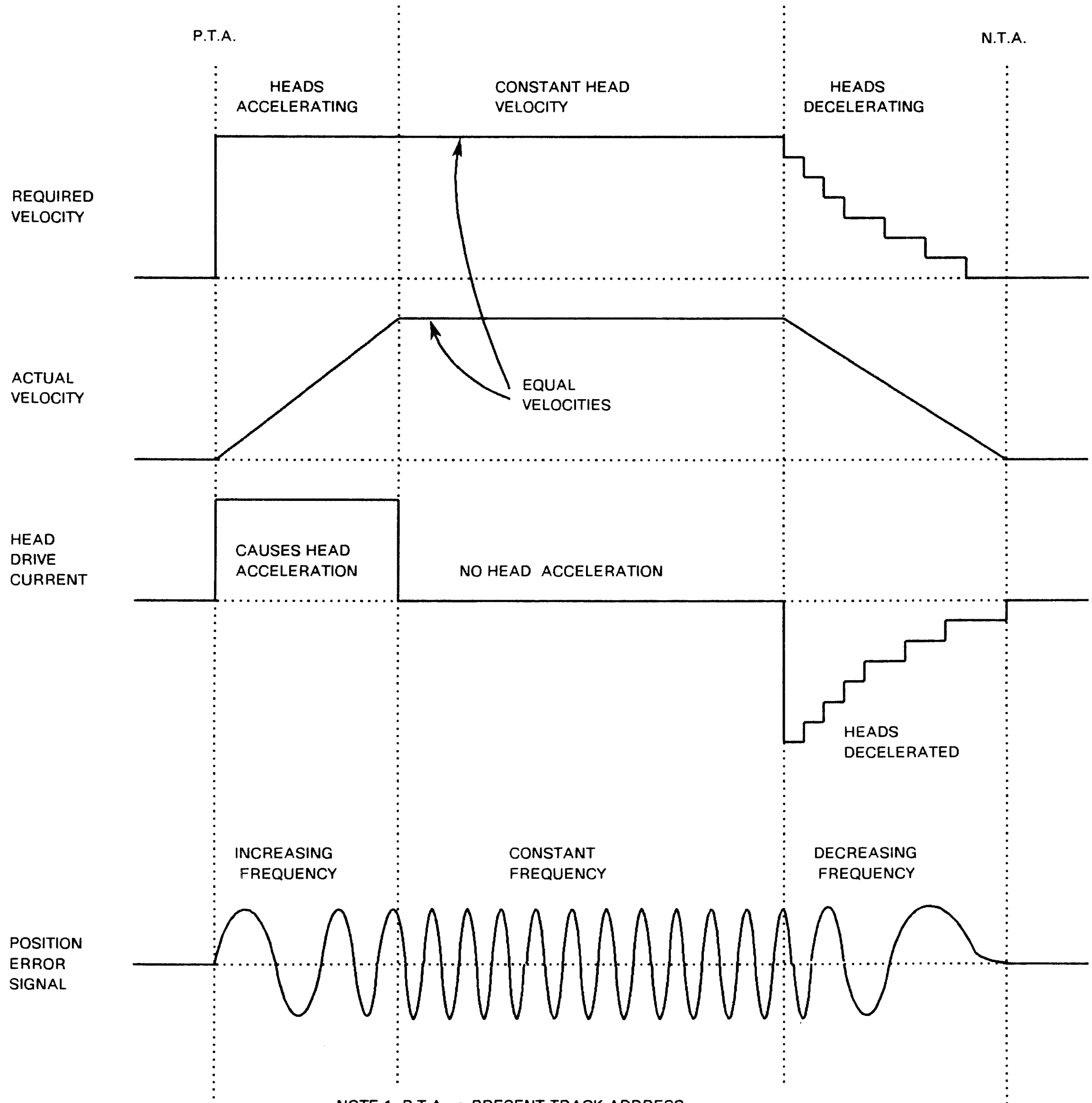


Figure 2.8. Current Control of Voice Coil



NOTE 1: P.T.A. = PRESENT TRACK ADDRESS
N.T.A. = NEW TRACK ADDRESS
NOTE 2: POLARITY REVERSES WITH FORWARD AND REVERSE SEEKS.

Figure 2.9. Seek Control Waveforms

2.3.5 Velocity Generation

The velocity generator uses the position error signal from the servo demodulator (section 2.3.3.) to measure speed of crossing tracks, which is fed back to the head drive to control the current in the voice coil.

The sequence is shown in Fig. 2.10.

(a) Shows the position data error during a seek, with constant amplitude, but varying frequency. Each half wave is one track crossed, with each zero voltage crossing atrack centre.

(b) Shows the signal after passing through a differentiator, which measures the slope or gradient of the input. The amplitude varies with the frequency.

(c) Shows the signal after full wave rectification., with the envelope a measure of rate (speed) of track crossing , i.e. head velocity.

(d) Shows the envelope demodulated (e.g. by charging the capacitor of an integrator).

At the start and end of a seek, when head velocity is low, the gradient of the servo position signal is small and inaccurate. Many drives measure the voice coil current during these periods, feed this to the demodulating integrator, and use this as a more accurate measure of actual head velocity.

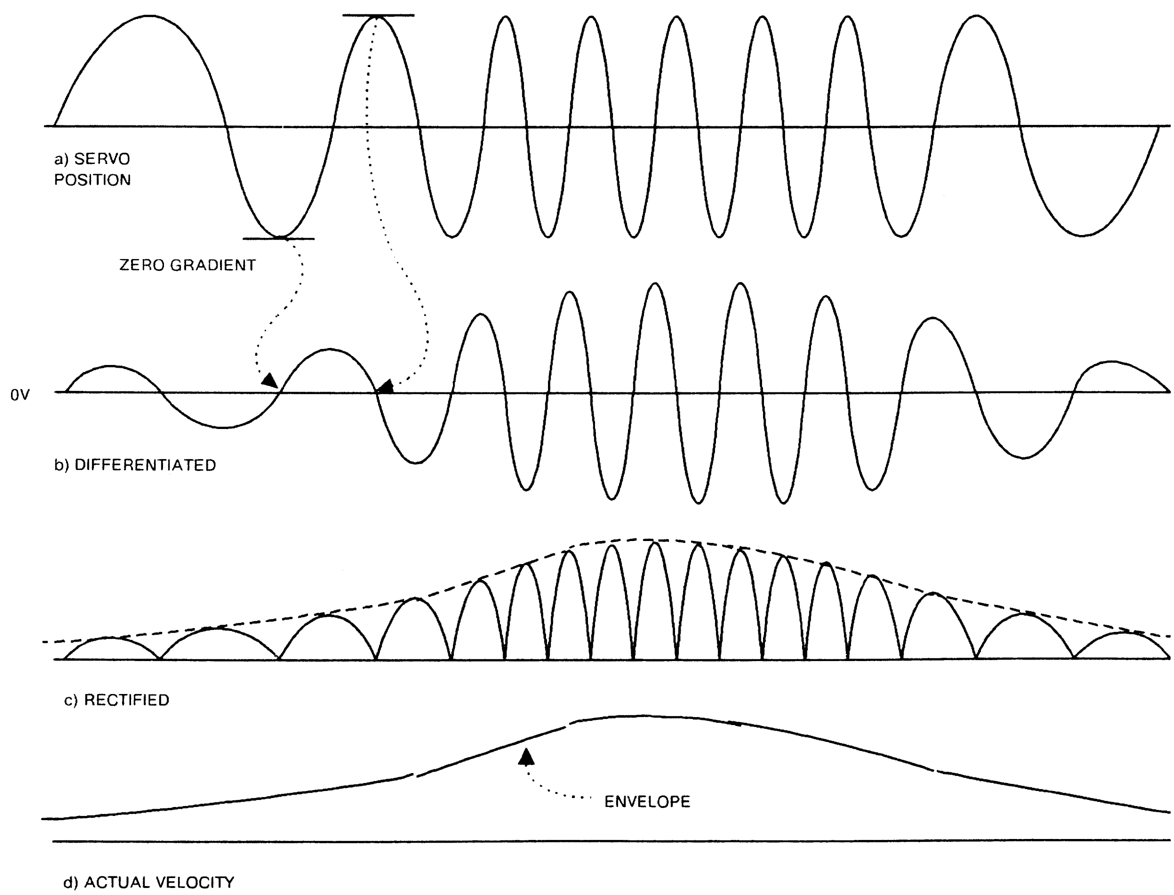


Figure 2.10. Velocity Generation

2.3.6 Head Control with Stepper Motor

Floppy drives and Winchester drives with ST 506 interface use a stepper motor for head positioning, with each step positioning the heads on the next track. The principle of the stepper motor using a simple 4-pole stator with a permanent magnet for the rotor is shown in Fig. 2.11. The polarity of the stator poles is fixed by the current direction in the pole winding. In the step sequence at step 1, the current directions cause coils A and D to set up north poles, B and C to set up south poles. The rotor moves to a position with its south pole opposite the north poles of the stator. The current directions to the coils are shown in step 1 of the current switching diagram. If these directions do not change, the rotor does not move , the floppy data heads are fixed over a data track for read or write.

To seek to a different track, the rotor must step to a new position. This is enabled by switching coil current directions to generate a rotating magnetic field in the stator poles. Fig. 2.11 shows the sequence for a field rotating clockwise, with the currents switching from steps 1 to 4, giving a 4 track seek (inwards, for example). An 8 track seek outwards would therefore be two revolutions of the rotor (steps 4 to 1, repeated two times), in an anti-clockwise direction.

The example shown in Fig. 2.12. is a stepper motor with a multiple pole rotor, used in the X3130-3 floppy drives.

The stator has two windings, X and Y, on four poles, 1-4. Note that:-

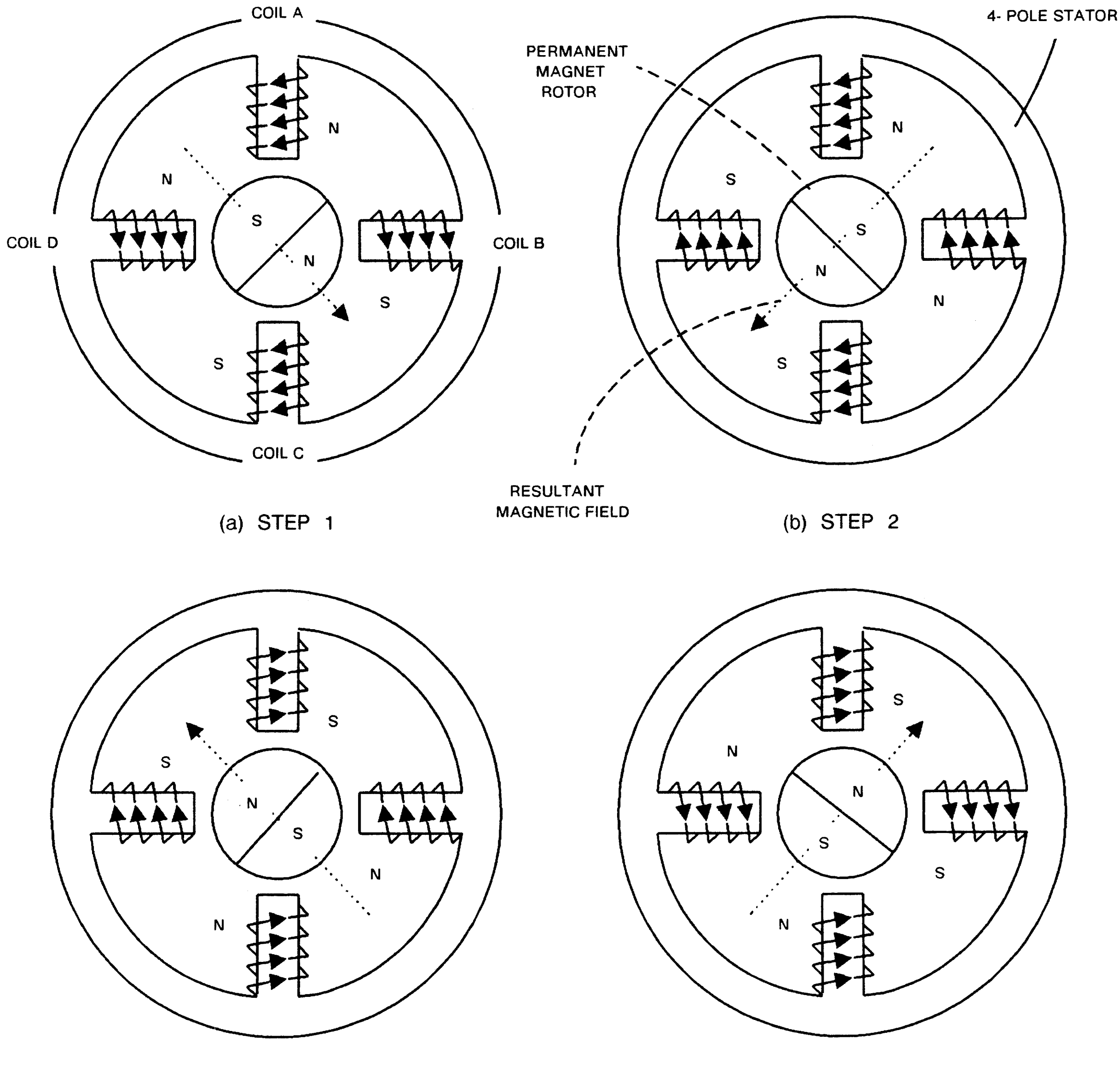
(a) the polarity of the stator poles is controlled by the current directions in the stator windings.
(b) the rotor is a cylindrical permanent magnet, with, at one end, the north pole opposite the stator poles.
(c) The north of the rotor is segmented to form the 100 (for 48 tpi floppy drives) or 200 (for 96 tpi floppy drives) mini-poles.
(d) Each pole of the stator is also segmented into mini-poles of the same pitch as those of the rotor.
(e) The air gap is smallest when the mini-poles of rotor and stator are directly opposite each other.
(f) Where there is a south pole on the stator, the strong attraction field tends to position the rotor so that its mini-poles are opposite the mini-poles of the stator. Where there is a south pole on the stator, the rotor tends to be positioned with its mini-poles opposite the inter-pole gaps of the stator.

For the current directions in X and Y as shown, the magnetic fields in 2 and 4 neutralise each other, pole 1 is a south pole, and 3 a north pole. The rotor aligns itself as shown, with the north poles of the rotor attracted to pole 1, and repelled by pole 3 of the stator (there is an offset of 1/4 of a pole pitch between each successive pole of the stator, so that when pole 1 of the stator is directly opposite a north pole of the rotor, pole 3 is opposite a gap between rotor poles).

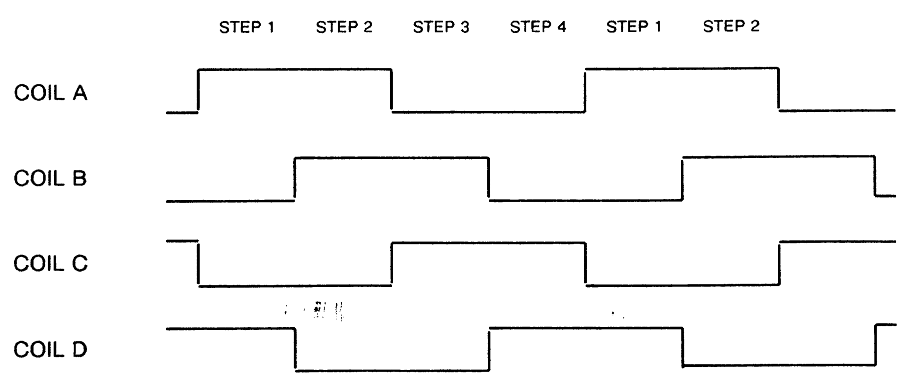
If the current in Y is reversed, then poles 1 and 3 become neutral, pole 2 becomes a south pole and pole 4, a north pole. The rotor then moves 1/4 pole pitch clockwise to position the nearest north pole opposite pole 2. By switching the direction of current in windings X and Y, the rotor can be made to step clockwise or anticlockwise in steps for forward, F, or reverse, R, seeks, as shown in Table 2.1.

Current direction		**Stator pole**		**Sequence**	
X	**Y**	**N**	**S**	**Clockwise**	**Anticlock-wise**
F	F	3	1	1	4
F	R	4	2	2	3
R	R	1	3	3	2
R	F	2	4	4	1

Table 2.1. Stepper Motor Rotation

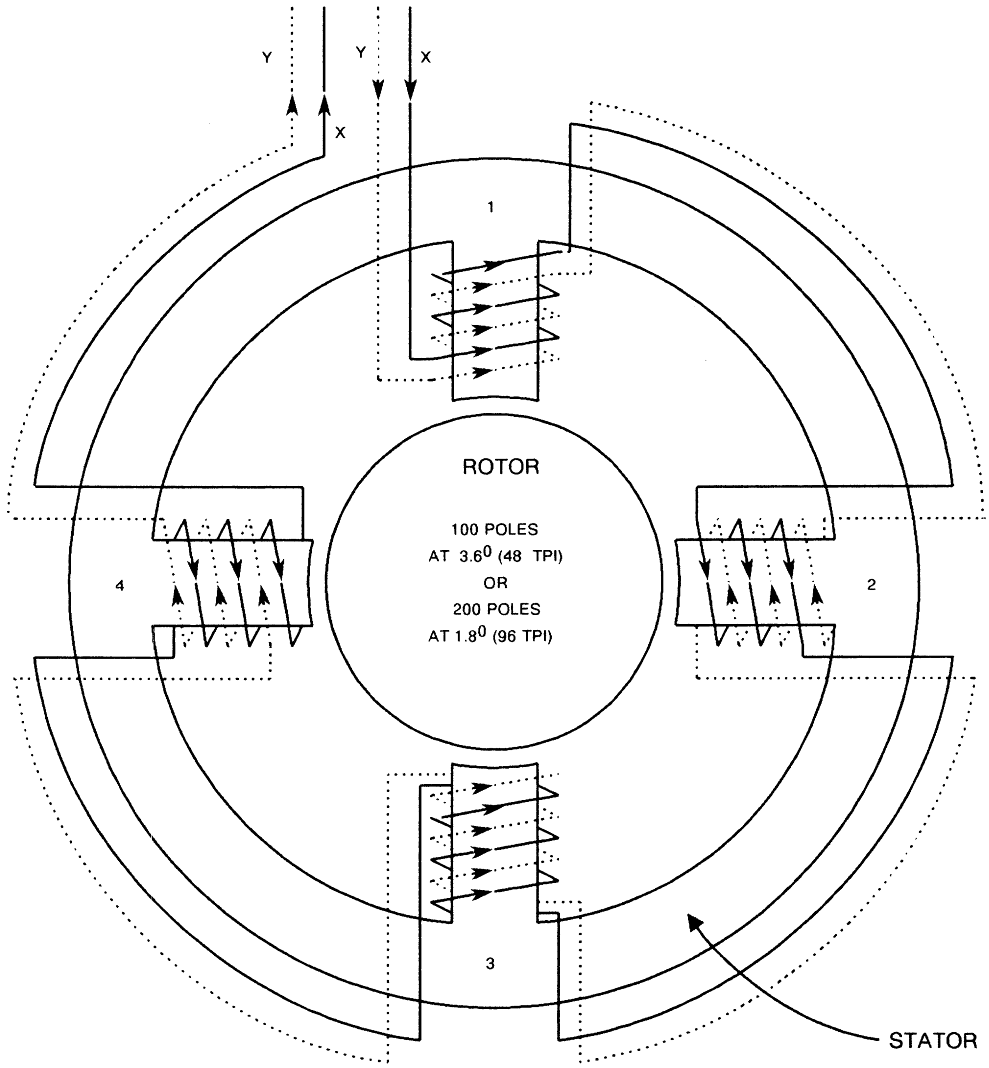


STEP SEQUENCE FOR ROTATING MAGNETIC FIELD

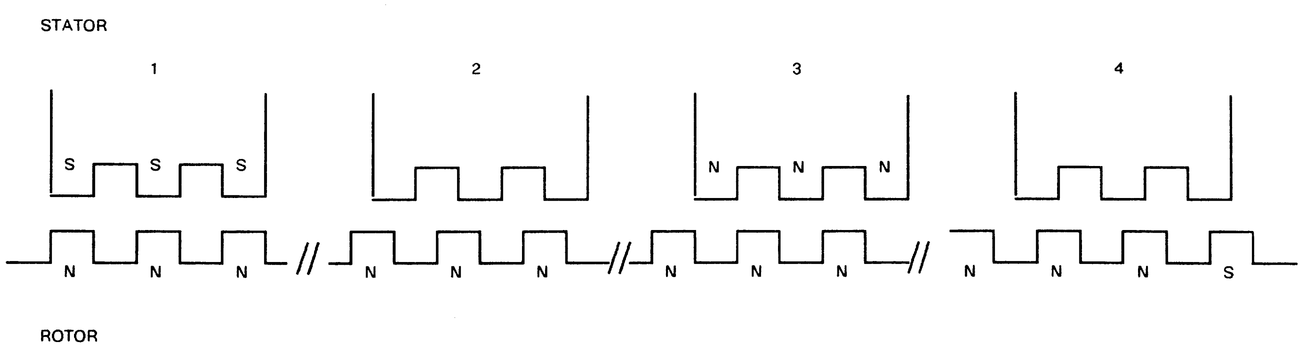


CURRENT SWITCHING TO GENERATE ROTATING MAGNETIC FIELD

Figure 2.11. 4-pole Stepper Motor



(a) STATOR WINDINGS



(b) RELATIVE POLE POSITIONS FOR STATOR AND ROTOR

Figure 2.12. Multiple Pole Stepper Motor

2.3.7 Automatic Gain Control, A.G.C.

The first step in reading data from either servo or user data surfaces is to equalise the gain from all tracks. Because the disk rotation is the same for all tracks, the head to disk speed, which is proportional to disk radius, is higher on the outer tracks, generating a larger amplitude signal in the winding when over these tracks, as in Fig. 2.13. This is undesirable, as the off track signal (from the servo surface) uses voltage differences for head positioning, and the read data measures rate of change of voltage in a differentiator, for decoding.

To equalise the signal strength, signal peaks are sampled, by charging up a capacitor, and the sampled peak compared with a reference voltage at a differential amplifier, as shown in Fig. 2.13. The output is fed back to the data pre-amplifier with polarity selected so as to reduce the gain on the outer tracks to that of the inner tracks. This is automatic gain control, A.G.C.

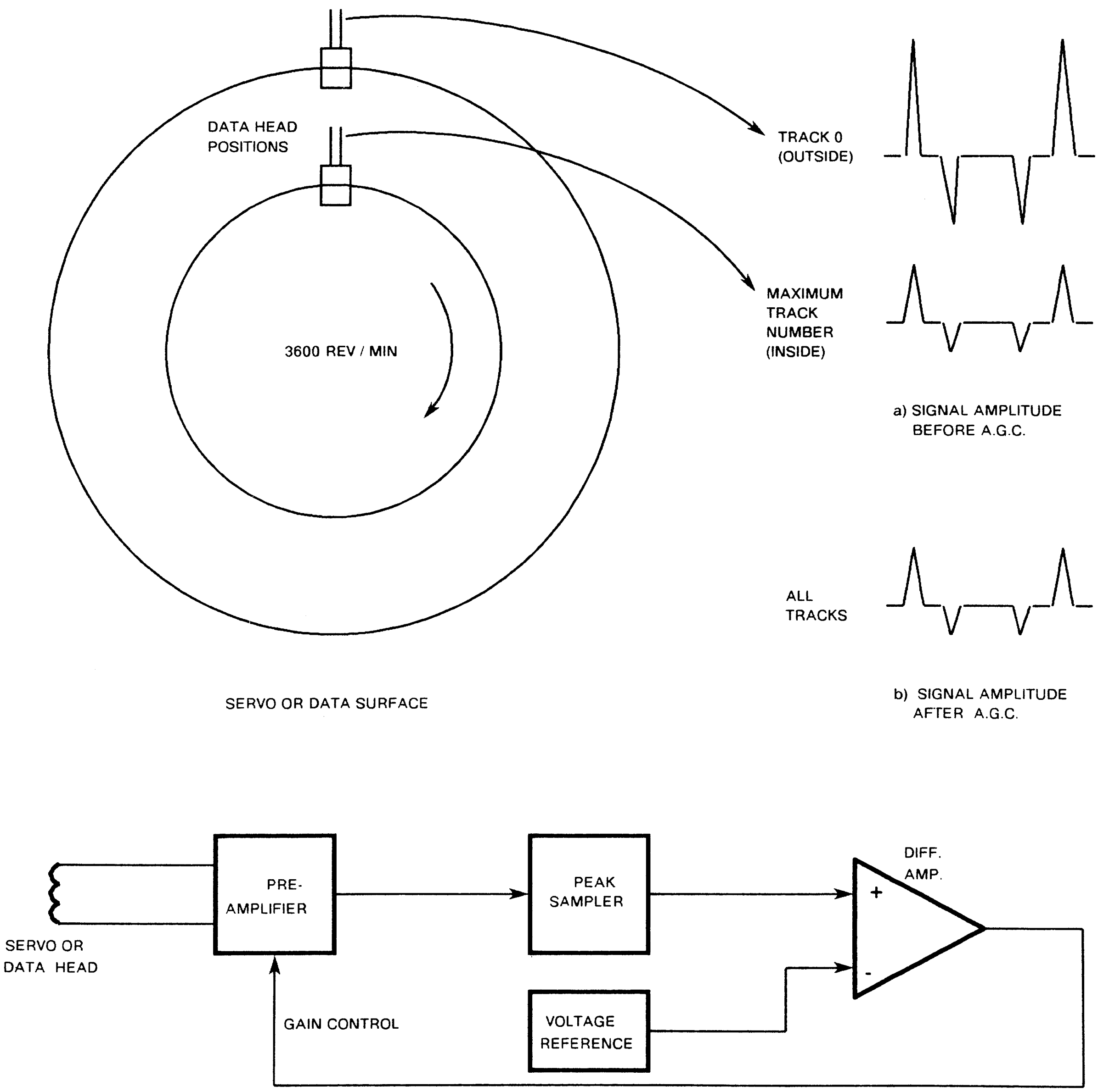


Figure 2.13 Principle Of A.G.C.

2.3.8 Timing with the Phase Locked Loop (PLL)

Drive timing clocks are obtained from the servo disk, as listed in section 2.3.2. A phase locked loop, PLL, is used because:-

(a) output clocks from the PLL vary with the input (reference) to the PLL
(b) high frequency outputs can be generated from a low frequency reference clock

Components of a PLL are shown in Fig. 2.14. The voltage controlled oscillator, V.C.O., also called variable frequency oscillator, V.F.O., has an output frequency which varies in proportion to a **d.c.** input voltage. The charge pump is a capacitor charged by pulses from the phase comparator which measures the difference in timing between reference and feedback clock,as shown in Fig. 2.14. The feedback frequency is divided down so that it has the same frequency as the average frequency of the reference. If the reference increases, charge pump voltage increases, and the output of the V.C.O. The new balance is reached when the feedback increases to the same frequency as the reference. Similarly, if the reference frequency decreases, so do the V.C.O. output frequency and feedback frequency.

Drives which use a voice coil with closed loop head control use a PLL with synchronisation pulses from the servo disk as reference. The PLL is always enabled. Output clock functions are given in section 2.3.2.

Drives also use a PLL for generating a read clock. For drives with ST 506 interface, and for floppy drives, which do not decode read data, this PLL is on the drive controller, external to the drive itself. For this PLL, there are two reference inputs, pulsed modified frequency mopdulation, MFM (or frequency modulation, FM) read data when reading, and a synchronising clock when writing, which for drives with a servo disk, is derived from the servo sync pulses. For reading MFM data, which has a varying frequency, the phase comparator is enabled only when a data pulse is present, to prevent changes in the V.C.O. output frequency due to "missing" data bits. When changing from reading to writing, the PLL is synchronised to read data, using the all "1's", or all "0's" pattern of the sync data fields at the start of the identifier and user data fields (shown in Fig. 1.2.).

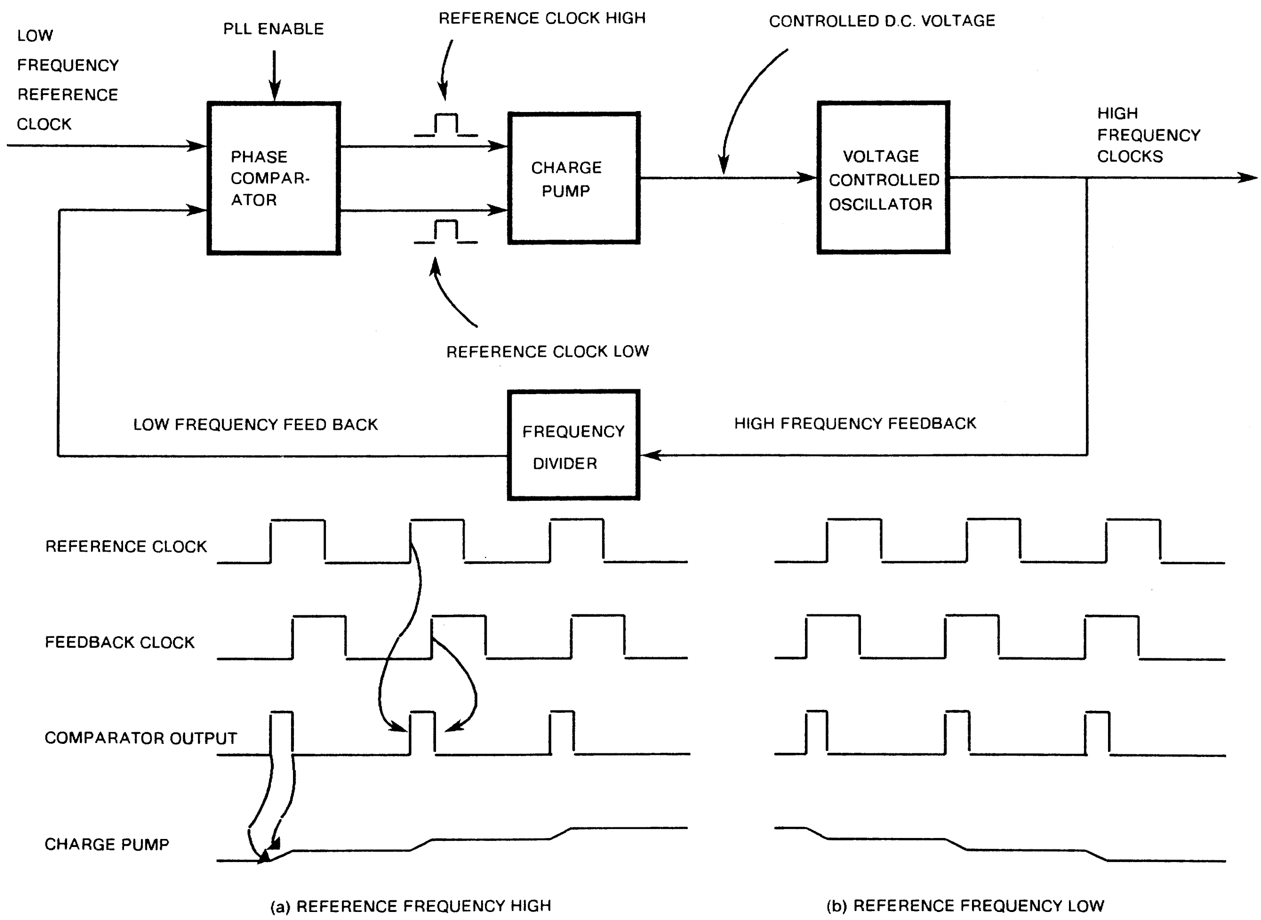


Figure 2.14. Principle of the Phase Locked Loop

2.4 READ AND WRITE

2.4.1 Principle

The basic concept , common to all electromagnetic recording, is shown in Fig. 2.15.
During data write, the magnetic field generated by a current in the read / write winding is completed in the magnetic recording media via the air gap, which is made small to generate the strongest field possible (enabling floppy disks, with head-to-disk contact, and no air gap, to use small read and write currents). The direction of polarisation on the disk is reversed by toggling the bistable to switch the winding energised.
When reading, changes in polarisation of the disk when moving under the head induce an alternating voltage in the winding, which, when decoded, is read data and read clock.
Because NRZ data from the host can have long periods without transitions in data levels (all "0's" or all "1's" patterns), this code cannot be used at the heads. During read, transitions must occur at time intervals of not more than a few bit cell periods (a bit cell is the period of time for one data bit), if read clock is not to be lost. Frequency modulation,FM, or modified frequency modulation, MFM, coding is normally used. With these codes, a transition occurs at least once per bit cell, for FM, or once every second bit cell, for MFM.

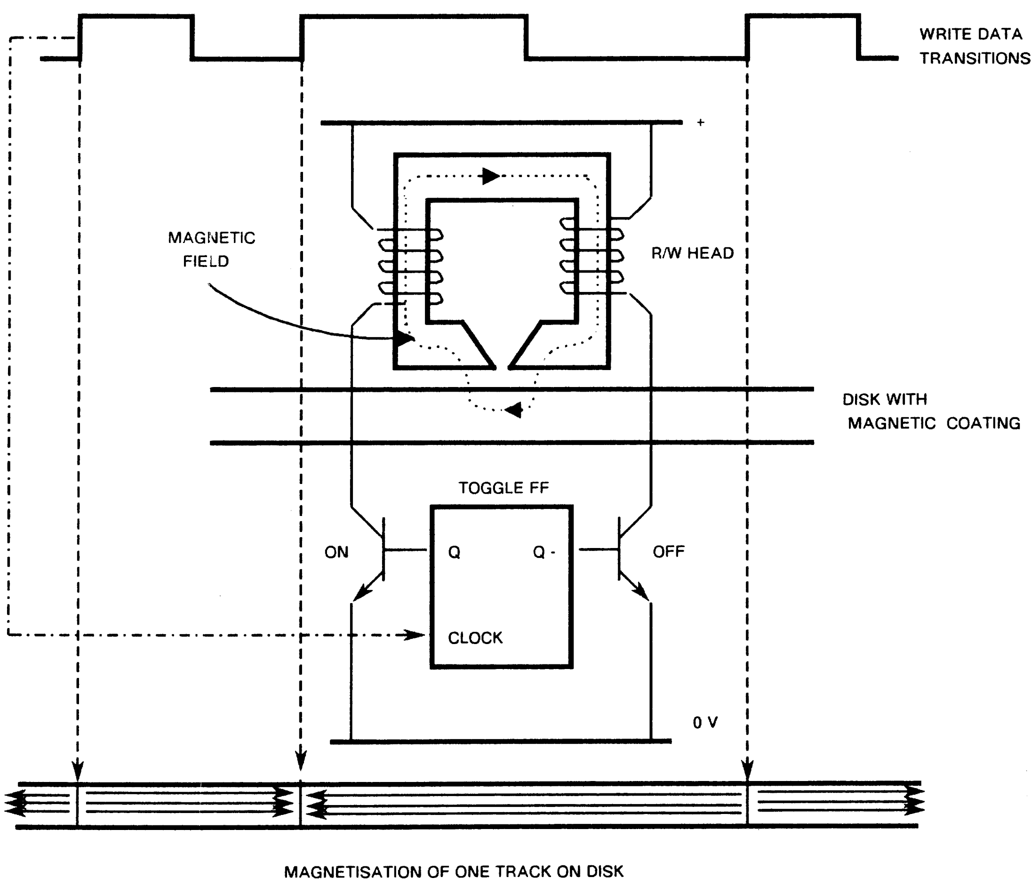


Figure 2.15. Principle of Magnetic Recording

2.4.2 Data Coding

FREQUENCY MODULATION,FM (usually known as single density recording, see section 4.8.2.)
Frequency modulation splits the data stream up into bit cells separated by a clock. The rules for encoding are:-

(a) A data "1" is represented by a change in logic levels at mid cell
(b) A data "0" is represented by no change in logic level
(c) A clock pulse is represented by a change in logic level at the start of each bit cell

This coding is used only on floppy drives. An example of FM encoding is shown in Fig. 2.16.

MODIFIED FREQUENCY MODULATION, MFM (double density recording)

A more efficient code, enabling higher average bit densities on disk, is MFM. This is used on most high capacity drives. The rules for data encoding are:-

(a) A data "1" is represented by a change in logic levels at the centre of a bit cell
(b) A data "0", followed by another data "0", is represented by a change in logic levels at the end of a bit cell
(c) A data "0", followed by a data "1" does not change logic levels

The coding requires a maximum of one flux change per bit cell, compared with two for FM, as there are no flux changes for the clock, which must be generated from the data transitions. This means that for the maximum flux changes per inch which the drive heads can handle, bit cells will be smaller for MFM than FM. Data decoding however is more complicated with MFM, a Phase Locked Loop being required to generate read clock. An example of MFM encoding is shown in Fig. 2.17.

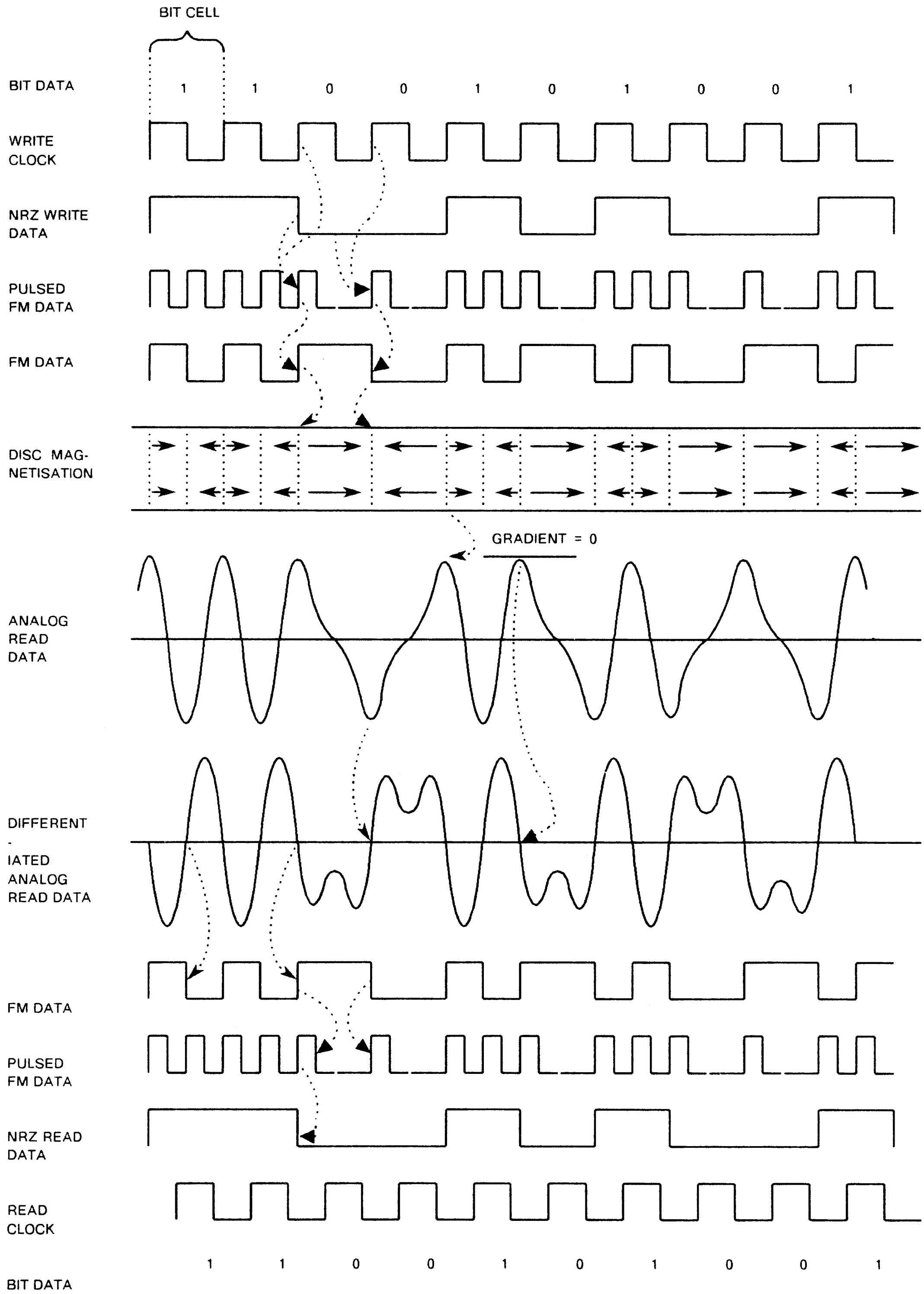


Figure 2.16. Write and Read Using FM Coded Data

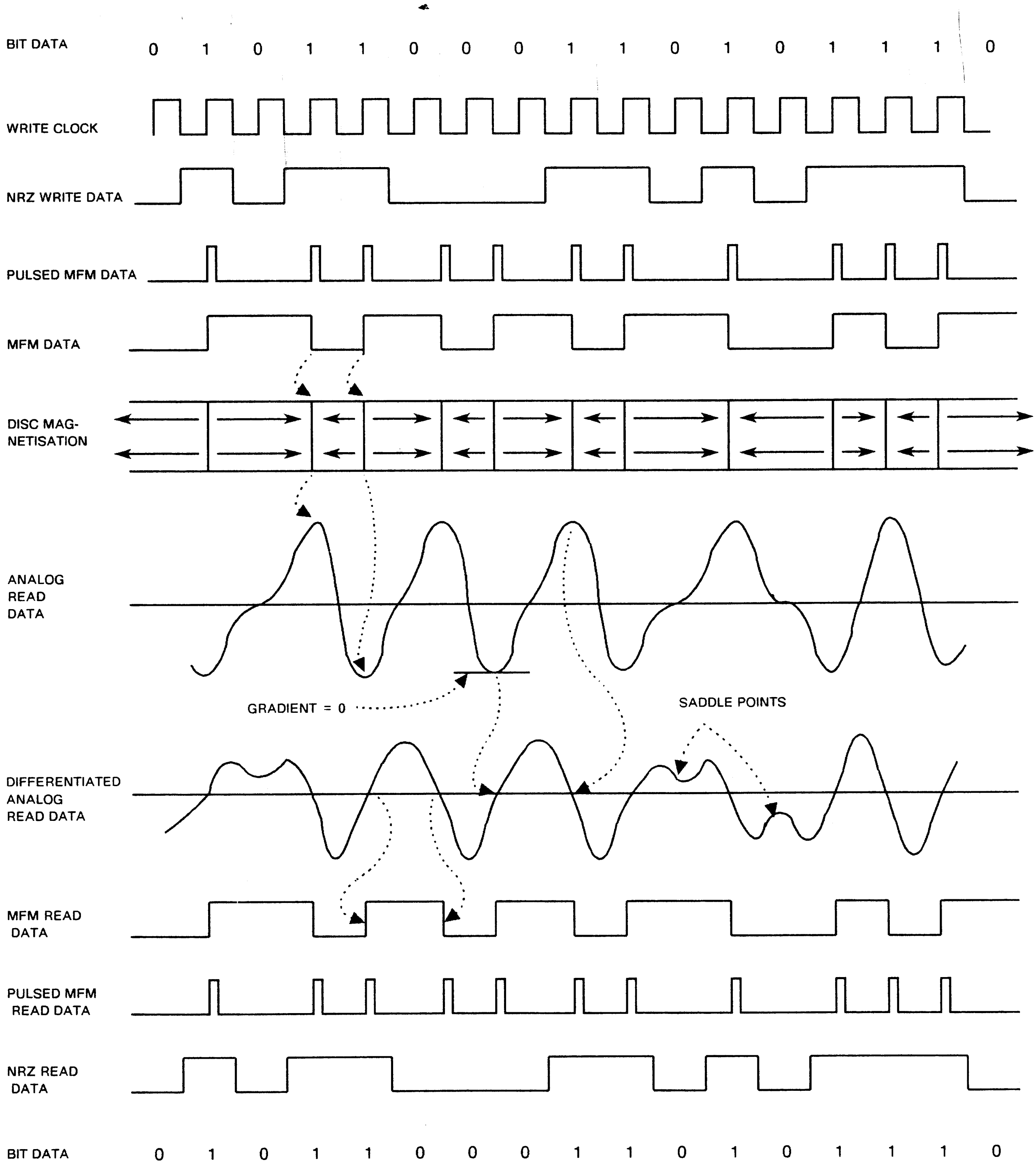


Figure 2.17. Write and Read Using MFM Coded Data

2.4.3 Write

A block diagram of the write circuits for the 8 inch and 14 inch intelligent drives (e.g. with SMD interface) is shown in Fig. 2.18. Head selection is the same for read and write.
Write logic is enabled, and the write process started by the controller issuing WRITE GATE at the interface. This generates the d.c. write current in the selected data head, which is larger than for read. At this time the read logic is disabled with READ GATE false. Write waveforms are shown in Fig. 2.17. Pulsed MFM data is generated from NRZ data, and converted to MFM data to remove the high frequency pulses. Any hardware fault during write disables write gate to protect data already on the disk. Write faults are listed in section 3.2.(d).
In addition to data encoding, the drive logic **may** also:-

(a) Select the size of write current. Inner tracks on the drive have higher data density, as total bytes / track is fixed. Small current changes are faster than reversing large currents, so on the inner tracks, write current is often reduced.

(b) Generate write compensation. The constantly changing frequencies of FM and MFM cause timing errors on readback. A decreasing frequency, e.g. a data pattern of 110 for MFM, causes a data delay of a few ns. during read, whereas an increasing frequency, e.g. 100, causes data transitions earlier than expected. To avoid this, some write circuits look at the incoming data pattern from the host ,and add write compensation, i.e. increasing frequencies are slowed down, and decreasing frequencies speeded up, before being written on the disk.

For hard disk drives with the ST506 interface, pulsed MFM data is transferred across the interface, and for floppy drives, either FM or MFM data, so that the encoding circuits are in the controller.

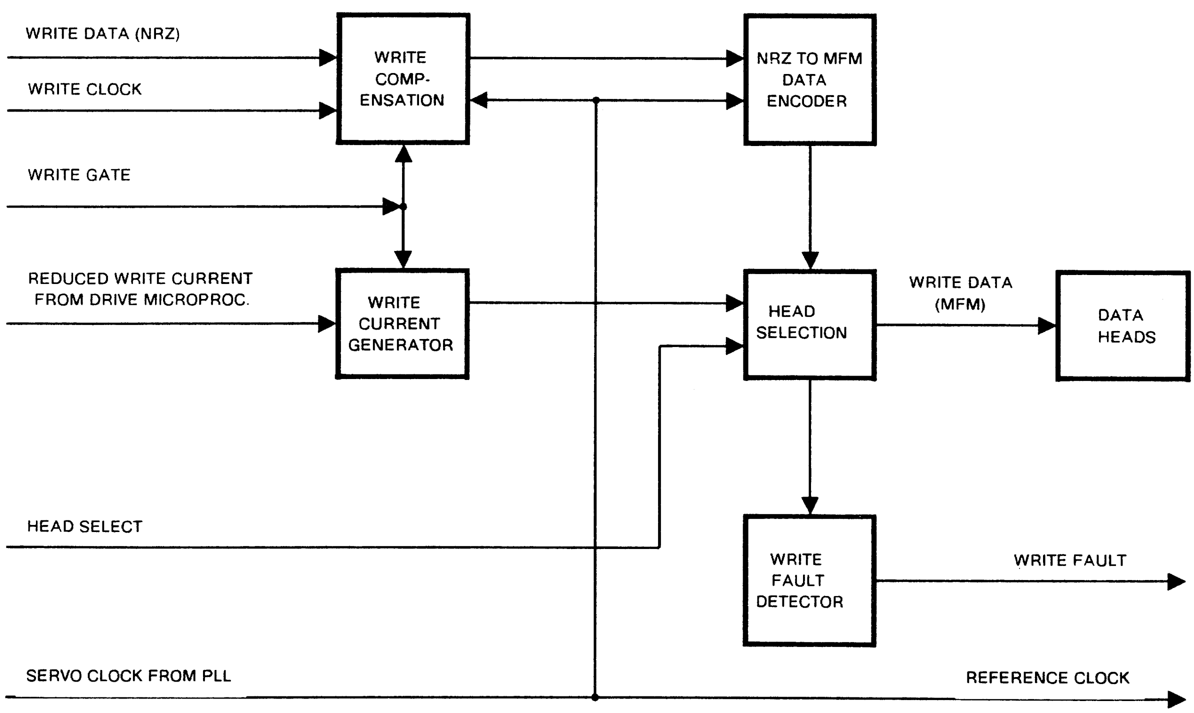


Figure 2.18. Head Selection and Write Circuits

2.4.4 Read

A block diagram of the read circuits for intelligent drives is shown in Fig, 2.19. For read, READ GATE is true, WRITE GATE false. Read waveforms are shown in Fig. 2.17.
For decoding the read signal, it is necessary to detect the **timing** of the analog peaks, which correspond to the data FM or MFM transitions. The usual way is to use a differentiator, which measures the slope of the read data. As the analog peaks have zero slope, the differentiator outputs zero volts at these peaks, which can be detected by a digital comparator set to switch levels at zero volts (a zero crossing detector). This is often followed by a data verifier.
Some data patterns, e.g. 10101, generate saddle points in the differentiated waveform, which can cause incorrect zero crossing points. As these are higher frequency than the fastest read data frequency, the method of removing them is to use a filter and delay line to generate a read data enable (time domain filter) as shown in Fig.2.20. The MFM data in the low resolution path has the false high frequency zero crossing points filtered out, and is delayed. This means that the clock for the bistable contains only transitions for valid data, and clocks the bistable only when the false data pulses in the high resolution path have ended.
The read circuits in addition to decoding the data, have to perform automatic gain control, A.G.C. (see section 2.3.7), and separate read clock from read data, using a PLL (see section 2.3.8).
As for write, section 2.4.3., FM or MFM is transferred across the interface for non-intelligent hard and floppy drives, and an external controller decodes to NRZ data, and also generates read clock from a PLL. .

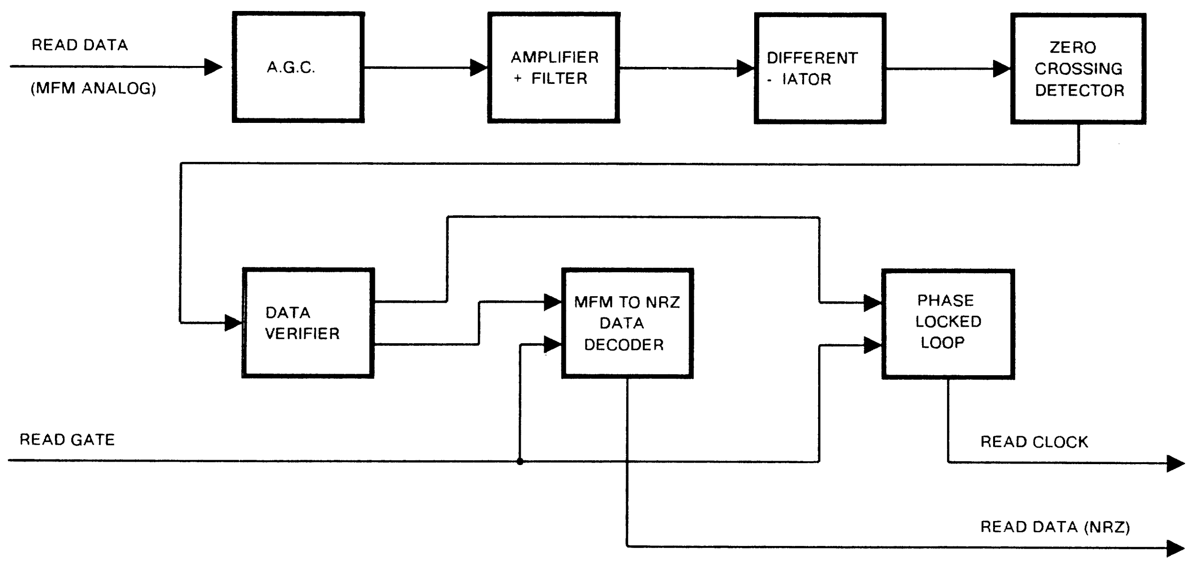


Figure 2.19. Read Data Circuits

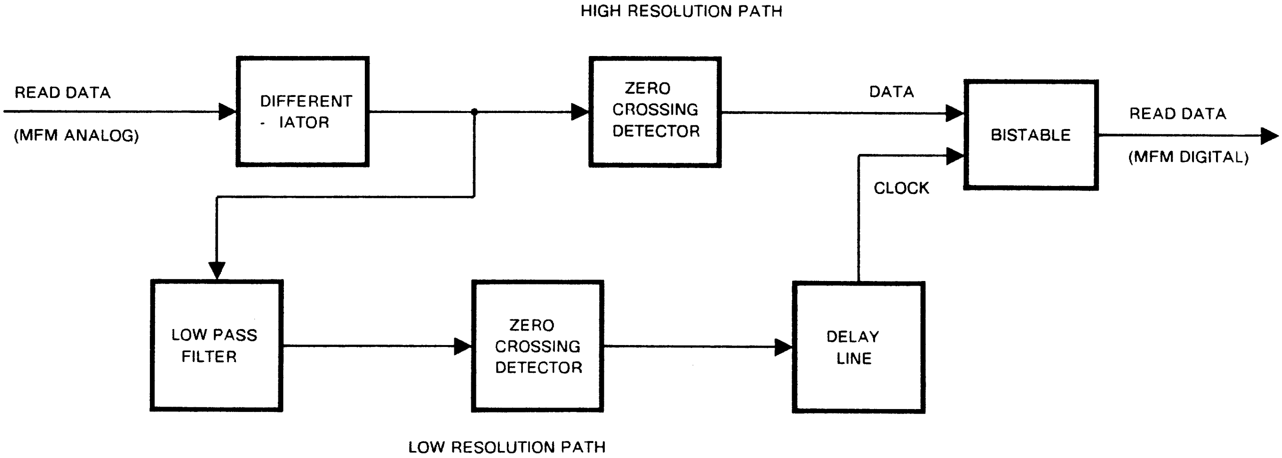


Figure 2.20. Data Verifier

2.4.5 Floppy Drive Capacities

Table 2.2. shows how floppy drive capacities are increased by changing the drive properties. Drive capacity is doubled by:-

(a) changing from single density recording (FM) to double density (MFM)
(b) using two R/W heads and therefore both disk surfaces
(c) doubling the track density from 48 tpi. to 96 tpi.
(d) doubling the data density i.e. flux changes per inch, fcpi, on each track, by improving the quality of the magnetic recording media (this is not necessarily a **doubling** of fcpi.).

From the table, it can be seen that the capacity of FD 55G using MFM is approx. 16 times that of FD 55A using FM, by using (a) to (d) above.

Model	**A**		**B**		**E**		**F**		**G**	
	FM	**MFM**	**FM**	**MFM**	**FM**	**MFM**	**FM**	**MFM**	**FM**	**MFM**
Capacity (KB)	82	164	164	328	164	328	328	655	591	1183
Tracks	40	40	80	80	80	80	160	160		
Track density	48	48	48	48	96	96	96	96	96	96
Fcpi. (max.)	2768	5536	2938	5876	2788	5578	2961	5922	4823	9646

Table 2.2. Example of varying floppy disc capacities (TEAC FD 55)

2.4.6 Floppy Drive Data Heads

To prevent data from one track interfering with data being read from the next track, tracks are separated by a gap. Immediately after a track is written, erase heads with a d.c. current in the winding only, trim the track width as shown in Fig. 2.21.

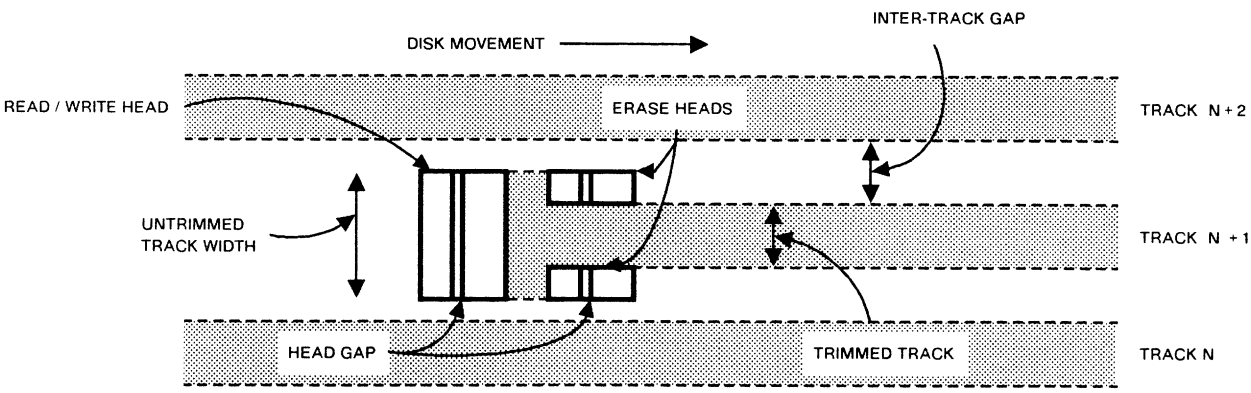


Figure 2.21. Floppy Drive Data Heads

2.4.7 Sector Pulses

For drives with hard sectoring, e.g. with SMD interface, sector pulses are used to define the start of each sector. The number of sector pulses per track is selected by the system designer. For the 8 inch and 14 inch drives used by Philips, the sector pulse generator is as shown in Fig. 2.22.

Note that :-

(a) for sectors to be of equal length, sector pulses must vary with any change in disk speed. The sector pulse generator therefore uses sync pulses from the servo disk, which has a fixed number of dibits equally spaced around each servo track, as a timing reference.

(b) sector pulse position is referenced to the fixed index pulse position, which can be used as the first sector pulse.

The required number of sectors per track is set on the drive sector switches. When the motor has been run up, the drive control microprocessor reads the sector switches. It then calculates the sector length as

$$\text{sync pulses / sector} = \frac{\text{number of dibits / track}}{\text{number of sectors / track}}$$

and writes this value to the register and thus to the counter (if this value is not exact, the remainder is ignored, leaving a longer gap at the end of the last sector). Sync pulses count down the counter, generating a borrow pulse, the sector pulse, when the count reaches zero. The borrow pulse also resets the counter, and then reloads it with sync pulses / sector from the register, to repeat the sequence. At the start of each track, the index pulse from the servo disk resets and then reloads the counter.

Drives with ST506 interface, and floppy drives use soft sectoring, described in section 2.4.8.

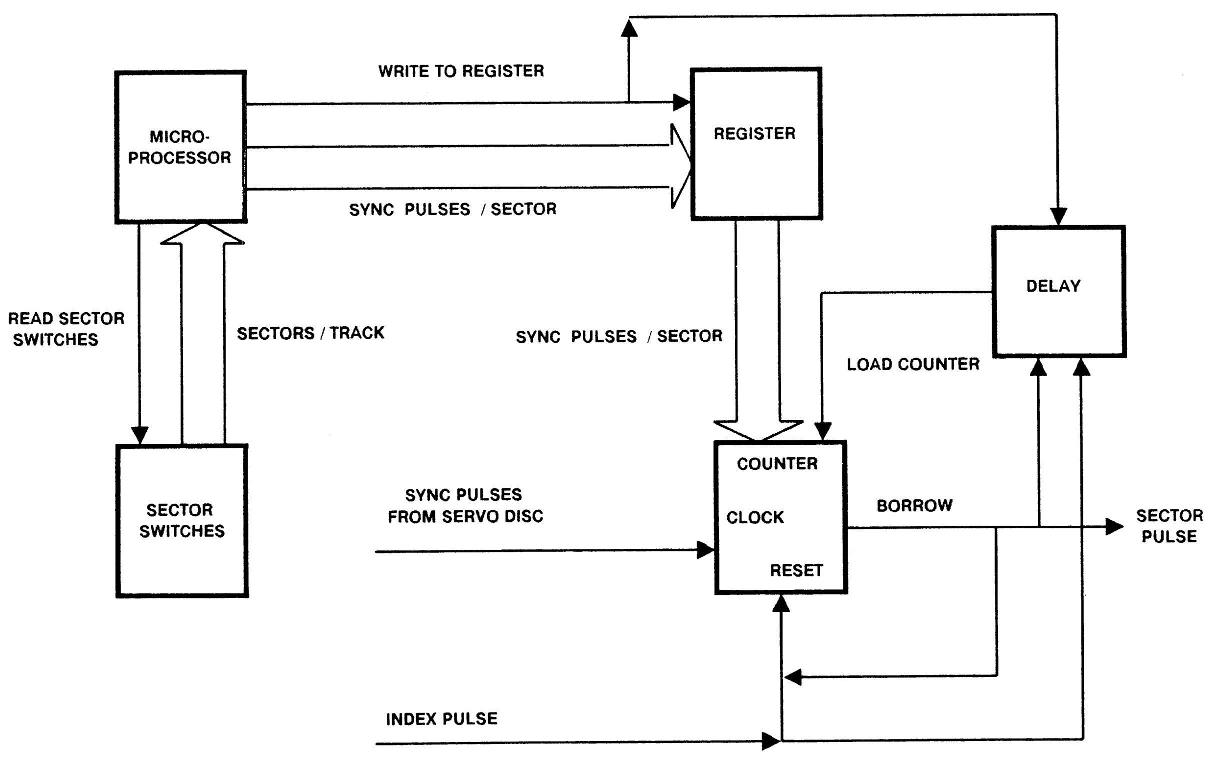


Figure 2.22. Sector Pulse Generator for 8 inch and 14 inch Drives

2.4.8 Soft Sectoring

Drives with the ST 506 interface, and floppy drives, have the number of sectors set by the system, which does not use sector pulses. This is **soft sectoring.** Sectors are separated by gaps, with sectors numbered from the index position. When formatting, changes in disk speed are ignored, so sector length may vary slightly. When reading, the controller looks for the sector address at the end of the inter-sector gap. Special data patterns identify the start of address and user fields. These patterns also form the synchronisation field for locking the PLL in the controller to read data, as shown in Fig. 1.2. When writing, the inter sector gaps prevent over-write of the next sector.

Chapter 3

Interfaces

3.1 INTERFACE TYPES

Drives can be divided into two basic groups for interfacing, depending on the number of control functions carried out by the drive intelligence. Usually:-

(a) 14 in.hard disks, with fixed or removable disk volumes, and 8 in. Winchester drives have a high level of internal drive control, including NRZ to MFM data encoding and decoding, sector pulse generation and a phase locked loop to generate master clocks. They also use closed loop head position control with a disk servo surface supplying position and timing data. An example is the SMD interface.

(b) 5.25 and 3.5 in. Winchester drives, and floppy drives, contain few internal drive control functions, and all functions listed in a) above must be carried out by the external drive controller. They use open loop head position control with a stepper motor, adequate for the lower track densities (max. of approx. 800 tpi. at mid 1987). An example of a hard disk interface is ST 506.

The sequence for read and write is given in section 1.5.1.

3.2 ST 506 INTERFACE

Refer to Tables 3.1. and 3.2.

Signals can be grouped as follows:-

(a) DRIVE SELECTION, DS 1,2,3,4 to address one drive of a daisy chain (see section 4.2.).

(b) Seek Control. DIRECTION IN determines seek inwards (towards spindle) - signal set, or outwards - signal at reset level. Each pulse at STEP causes the heads to cross one track.

(c) Read / write control.
HEAD SELECTION 2^0,2^1,2^2 for selecting one data surface.
WRITE GATE for selecting either read (signal at logic 0) or write (logic 1).
MFM WRITE DATA to the disk, or MFM READ DATA from the disk.
INDEX, defining track start position, used by the controller for soft sectoring.

(d) Status reporting from the drive.
SELECTED, in response to DRIVE SELECTION in a) above.
READY, drive is at speed, heads are loaded, no faults and ready for next controller command.
SEEK COMPLETE at end of seek requested in b) above.
TRACK0, at the end of head load, or head position recalibration, to indicate heads on track 0.
WRITE FAULT, hardware fault detected during write. Normally caused by one of the following:-
   (i) off data track centre (failure of head positioner)
   (ii) WRITE GATE missing
   (iii) no write current
   (iv) no data transitions in R/W head
   Usually generates write protection to protect data on disk.

Motor is run up and heads loaded at power on.

Connector Pin		Signal Name	Source
Signal	Ground		
2	1	Reserved	-
4	3	Head Select 2^2	Host
6	5	Write Gate	Host
8	7	Seek Complete	Drive
10	9	Track 0	Drive
12	11	Write Fault	Drive
14	13	Head Select 2^0	Host
16	15	Reserved	-
18	17	Head Select 2^1	Host
20	19	Index	Drive
22	21	Ready	Drive
24	23	Step	Host
26	25	Drive Select 1	Host
28	27	Drive Select 2	Host
30	29	Drive Select 3	Host
32	31	Drive Select 4	Host
34	33	Direction In	Host

Table 3.1. ST 506 Interface J1 Cable Signals

Connector Pin		Signal Name	Source
Signal	Ground		
1	2	Drive Selected	Drive
3-9	4-10	Reserved	-
-	11,12	Ground	-
13	-	MFM Write Data +	Host
14	-	MFM Write Data-	Host
-	15,16	Ground	-
17	-	MFM Read Data +	Drive
18	-	MFM Read Data -	Drive
-	19,20	Ground	-

Table 3.2. ST 506 Interface J2 Cable Signals

3.3 FLOPPY DISK INTERFACE

The SA 450 interface given in Table 3.3. is common to many floppy drives, with a few signals optional. It is similar to the ST 506 interface of section 3.2., with the signals in one 34 pin cable. The signals can be grouped as for the ST 506:-

(a) Drive selection - Drive Select 0 -3.
(b) Seek control - Step, Direction Select.
(c) Read / write control - Side Select, Write Gate, Write Data, Read Gate, Index.
(d) Status - Ready, Track 00.

These signals perform the same functions as in the ST 506 interface drives. There are also three extra host commands:-

MOTOR ON, to run the motor up to speed.
HEAD LOAD, to press the heads onto the disk for read / write.
IN USE, to control the activity LED on the drive front panel.

These commands enable the heads to be removed from the disk surface or the motor to be run down when the drive is idle (not reading or writing), to reduce head and disk wear.
There are also one extra status signal:-
WRITE PROTECT indicating that the write protect sensor has detected that the diskette is write protected (see section 4.8.)

Connector Pin		Signal Name	Source
Signal	Ground		
2	1	Reserved	-
4	3	Head Load / In Use	Host
6	5	Drive Select 3	Host
8	7	Index	Drive
10	9	Drive Select 0	Host
12	11	Drive Select 1	Host
14	13	Drive Select 2	Host
16	15	Motor On	Host
18	17	Direction Select	Host
20	19	Step	Host
22	21	Write Data	Host
24	23	Write Gate	Host
26	25	Track 00	Drive
28	27	Write Protect	Drive
30	29	Read Data	Drive
32	31	Side Select	Host
34	33	Ready	Drive

Table 3.3. SA 450 Floppy Disc Interface

3.4 SMD INTERFACE

Refer to Tables 3.4 to 3.6.
Similar grouping of signals to ST 506, described in section 3.2.. Uses a 10 bit data bus for transfer of head and seek addressing, and commands.

(a) UNIT SELECT, US 0,1,2,3 with strobe US TAG, drive selection, as for ST 506 (a).
(b) PICK and HOLD, sequential run up of drives (to prevent current overload of P.S.U.) and head load.
(c) Seek control. Bus BIT 0-11, with strobe signal TAG 1. The requested seek address is sent to the drive, which calculates tracks to cross, and seek direction.
(d) Read / write control:-
HEAD SELECT. Bus BIT 0-3, with strobe signal TAG 2, data surface selection, as for ST 506 (c).
INDEX, defining track start position, as for ST 506.
SECTOR, defining start positions of each sector, from the sector pulse generator.

During a write process:-
WRITE GATE (= BIT 0.TAG 3), to enable the write logic.
(NRZ) WRITE DATA, serial write data.
WRITE CLOCK, timing reference for WRITE DATA, one pulse per data bit.
SERVO CLOCK, timing reference for the controller, obtained from servo data surface, and varying. with disk speed. It enables the controller to regulate speed of WRITE DATA so that data density on the disk does not vary.

During a read process:-
READ GATE (= BIT 1. TAG 3), to enable the read logic.
(NRZ) READ DATA, serial read data.
READ CLOCK, timing reference for READ DATA, one pulse per data bit.

(e) Status reporting from the drive:-
UNIT SELECTED, in response to UNIT SELECT in (a) above.
READY, as for ST 506 (d).
FAULT, when fault detected in drive - READY disabled.
SEEK END, at end of seek requested in (c) above.
SEEK ERROR, failure to complete seek requested in (c) above.
ON CYLINDER, when on data track centre, ready to read or write.
WRITE PROTECTED, write process disabled by write protect switch or write fault.
(f) Additional commands from host:-
These use TAG 3 with selected data bus bits BIT 0-9. In addition to read, write and seek commands, used on ST 506 interface:-
RTZ, return (heads) to (track) zero for recalibration, usually after SEEK ERROR.
FAULT CLEAR, returns drive to READY state after FAULT.
SERVO OFFSET + and - enable head positioning offset from track centre during read, in an attempt to recover lost data. Only used with cartridge disk drives.

The sequence of signals across the interface is shown in Fig. 3.1.

Pins		Signal name	Source (H = host D = drive)	Pins		Signal name	Source (H = host D = drive)
Lo	Hi			Lo	Hi		
1	2	Tag 1	H	31	32	Seek error	D
3	4	Tag 2	H	33	34	On cylinder	D
5	6	Tag 3	H	35	36	Index	D
7	8	Bit 0	H	37	38	Unit ready	D
9	10	Bit 1	H	39	40	Unused	
10	12	Bit 2	H	41	42	Unused	
13	14	Bit 3	H	43	44	Unit select tag	H
15	16	Bit 4	H	45	46	Unit select 2^0	H
17	18	Bit 5	H	47	48	Unit select 2^1	H
19	20	Bit 6	H	49	50	Sector	D
21	22	Bit 7	H	51	52	Unit select 2^2	H
23	24	Bit 8	H	53	54	Unit select 2^3	H
25	26	Bit 9	H	55	56	Write protected	D
27	28	Open cable det.	D		57	Power seq. pick	H
29	30	Fault	D		58	Power seq. hold	H
				59	60	Bit 10	H

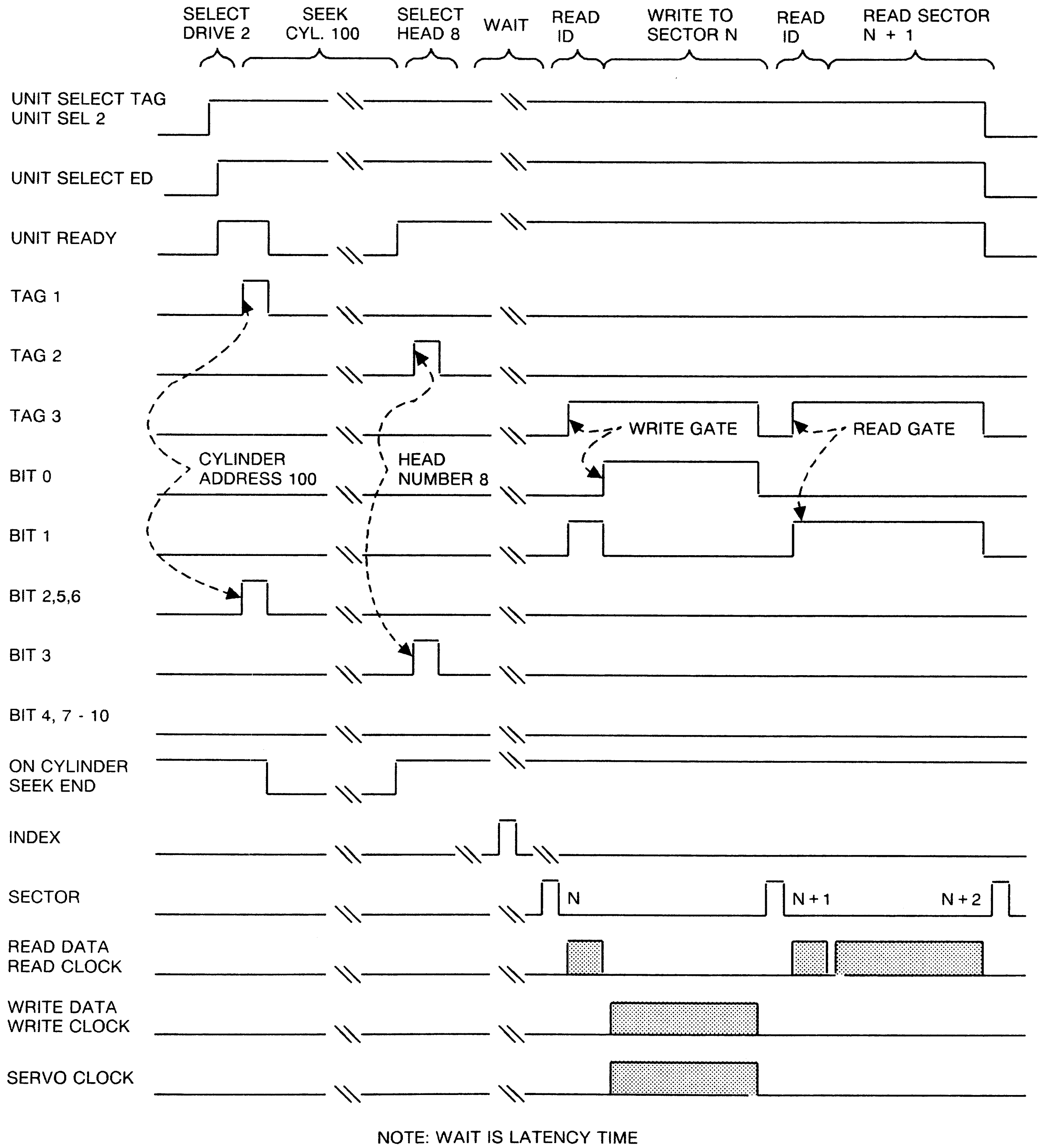
Table 3.4. SMD Interface A Cable Signals

Bus	Tag 1 Cylinder address	Tag 2 Head select	Tag 3 Control select
Bit 0	2^0	2^0	Write gate
Bit 1	2^1	2^1	Read gate
Bit 2	2^2	2^2	Servo offset +
Bit 3	2^3	2^3	Servo offset -
Bit 4	2^4	Unused	Fault clear
Bit 5	2^5	Unused	Unused
Bit 6	2^6	Unused	RTZ
Bit 7	2^7	2^{10}	Unused
Bit 8	2^8	2^{11}	Unused
Bit 9	2^9	Unused	Unused
Bit 10	2^{10}	Unused	Unused

Table 3.5 SMD Interface A Cable Decode

Signal name	Connector pins		Source (H = host D = drive)
	Lo	Hi	
Write data	15	14	H
Write clock	11	12	H
Servo clock	3	2	D
Read data	5	6	D
Read clock	9	8	D
Seek end	19	20	D
Index	23	22	D
Sector	25	26	D
Unit selected	18	17	D
Ground		rem.	

Table 3.6 SMD Interface B Cable Signals



EXAMPLE SHOWS:-
- SELECT DRI
- SEEK TRACK 100
- WRITE TO SECTOR N
- READ FROM SECTOR (N + 1)

Figure 3.1. Example of Read / Write Sequence (SMD INTERFACE)

Chapter 4

Servicing

4 SERVICING

4.1 INTRODUCTION

This chapter highlights points to be considered during installation, maintenance and repair of drives in a system. For Winchester drives, there is normally no maintenance required, and because the head - disk assembly is in a sealed unit (which it is not permitted to enter), no mechanical adjustments or repairs are possible. The complete defective assembly must be returned to the manufacturer.

4.2 MULTIPLE DRIVE SYSTEMS

A drive controller can handle more than one drive. Control cables are either directly to each drive from the controller, or one control cable can be "daisy chained" from one drive to the next. With this last configuration, signals from the controller go to each drive in turn, so that in order to select one particular drive, the unit address switches on the drives must be set to a different address for each drive. Also, to prevent the open end of the daisy chain, remote from the controller, reflecting signals back along the cable, causing data contention and thus data errors, the last drive in the chain must have a terminating resistor for each signal line (terminator). An example of a multiple drive system is shown in Fig. 4.1., using an S.M.D. interface.

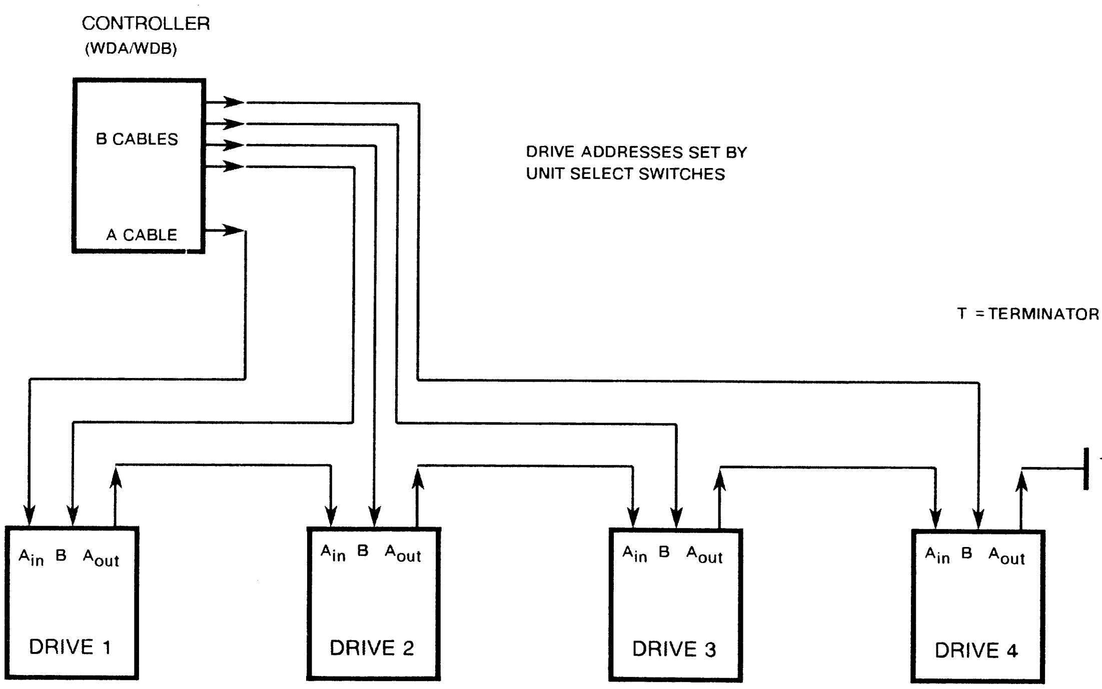


Figure 4.1. Four Drive System with SMD Interface

4.3 SECTOR SWITCHES

Drives which have a sector pulse generator, e. g. those with the S.M.D. interface, are provided with sector switches to select the number of sectors per track. This number is specified by the system, and must be set before formatting. If the sector switches are changed after formatting, it will not be possible to read data from the disk. The sector pulse generator is explained in section 2.4.7.

4.4 DEFECT MAPPING

Because of defects in manufacture, some areas on fixed disks will be defective, i.e. it will not be possible to read back data from that area. These areas are listed by the manufacturer on a printed sheet, which is kept with the drive. They may also be written on special areas of the disk pack as a defect map which is write protected.

The defective area is specified in length (bytes), and position (bytes) from the index position, of a particular track, of a particular head. With all Philips controllers, it is not possible to isolate a particular part of a track, so the whole track is not used. Where this occurs, it is normal in the identifier of the bad sector to **flag** the bad sector (as shown in Fig. 1.2.), and replace the address of the bad sector with that of a backup (alternate or reserve) sector. Some systems have a fixed number of tracks reserved as backup tracks. Other systems use any spare good tracks. Most **systems** also have a defect map which is used to prevent attempted writing to a bad track.
The manufacturers defect map includes marginally readable tracks (those giving occasional read errors) , found using a higher allowable read signal threshhold. These should not be used, even if they appear to read back without errors, as they may give more errors later, due to aging. Any extra tracks becoming defective after installation must be added to the defect map. If addresses in the identifier are lost, the complete sector will be lost (perhaps the whole file).
One cause of bad tracks in hard disks is a head crash (head to disk contact), which damages magnetic media and heads. In this case, all data on the disk will be lost, because when the damaged head is replaced, head alignment is lost (see section 4.6.). For this reason the operator is recommended to **back up** his data (make a reserve copy) at regular intervals, on a different peripheral.

Note that for Priam 806, 807 drives the orientation (positioning horizontally or vertically) when used by the operator, should be the same as when formatted. The change in weight distribution when moved from horizontal to vertical operation can cause head position offsets sufficient to give read errors.

4.5 ERROR CHECKING AND CORRECTION, ECC

Each sector identifier and user field is written with a number of check bits at the end (section 1.3.). When reading, the read data is checked with the ECC bits, using a parity checking routine, to see if any data bits are lost. Usually one or two lost data data bits are correctable with the ECC bits.

4.6 HEAD ALIGNMENT FOR CARTRIDGE DISK DRIVES

For any cartridge pack, to ensure that every disk surface can be read without data errors, write and read must be on drives which have data heads aligned directly above the servo head , i.e., there must be no head offsets. In the example of Fig. 4.2., D1 - D5 must be directly in line, above or below S.
To align the heads, a special alignment (CE) disk pack is used. For the SMD 80 MB drive, this has the normal servo surface, and servo tracks on all other (normally read / write) surfaces at the radius of data track 404. A seek is done to track 404 (using the normal servo surface), where the signal from each data head in turn is viewed and the head position adjusted radially to position the head over the centre of data track 404 (the junction of the two servo tracks on the specially written disk, at the point where the signals from the two tracks are equal in amplitude). Since all servo surfaces of CE and normal disk cartridge packs are written with the same numbered tracks having exactly the same radius, the heads are now aligned vertically.

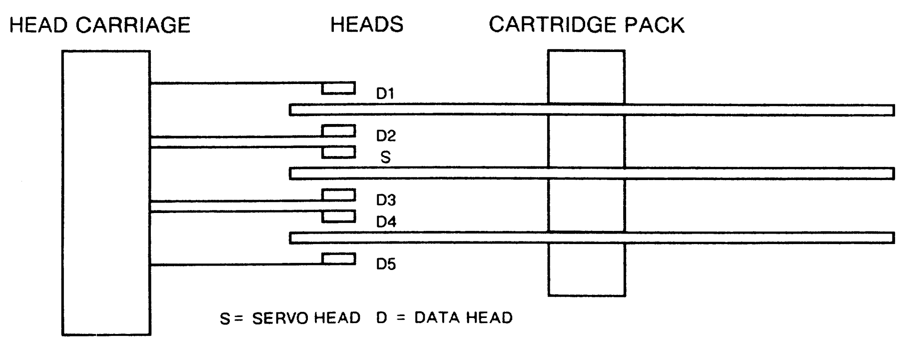


Figure 4.2. SMD 80 MB Disk Cartridge Pack

4.7 HEAD ALIGNMENT FOR FLOPPY DRIVES

Head alignment for floppy drives uses a special pre -written alignment diskette, (known as a cat's eyes disk, from the shape of waveforms seen on the oscilloscope), on which the tracks are eccentric, i.e., circular, but with centre offset from the axis of rotation, as shown in Fig. 4.3. The disk is used to align both 48tpi and 96 tpi drives. The alignment disk for each size of floppy is the same for most manufacturers. The example in this section is for 51/4 in discs using the Dysan 206 alignment diskette. There is a different version of the diskette for 48 tpi, and for 96 tpi drives.

With the correct version of the alignment disk inserted, the head(s) are sent to track 16 (for 48 tpi) or 32 (for 96 tpi). As the disk rotates, the head follows the path shown, with track TR_O giving lobe X, and TR_i, lobe Y, of the waveform. When the lobe amplitudes, X and Y, are equal, the head is correctly positioned and during each revolution moves an equal distance into Tr_i and TR_O. If the head is too far out, X will be bigger than Y, if too far in, then Y will be bigger than X. The radial position of the heads is adjusted for X and Y to be equal, by adjusting the position of the spindle motor . The ratio of X / Y or Y / X must not fall below about 70%, if data errors are to be avoided.

An extra problem is an offset introduced if the alignment disk is not clamped centrally on the drive spindle. If the centre of rotation of the alignment disk is not A, the centre of the disk, then the head position for equal width lobes is not the aligned position, but offset from it.

The read / write head for 96 tpi drives is smaller than that, for 48 tpi. The wider head reads data from one of the alignment tracks, even when the head centre is between tracks, so there is no gap between the lobes. The smaller 96 tpi head, when between alignment tracks, cannot read from either track, so that the signal is intermittant, as shown in Fig. 4.3.

Floppy drives use the track 0 position as a reference for stepping (seeking) to another track. This is a combination of stepper motor phase (which repeats every four tracks for the normal four pole stepper motors), and a detector which switches when the heads move out to tracks 1 or 2. After head alignment therefore, the position of the (track 0) detector must be checked. A wrongly positioned detector could cause the drive to set the interface TRACK 00 signal at track 3,7, or 11, even when correctly aligned.

The index to data burst is also adjusted with the alignment diskette (see section 4.9.).

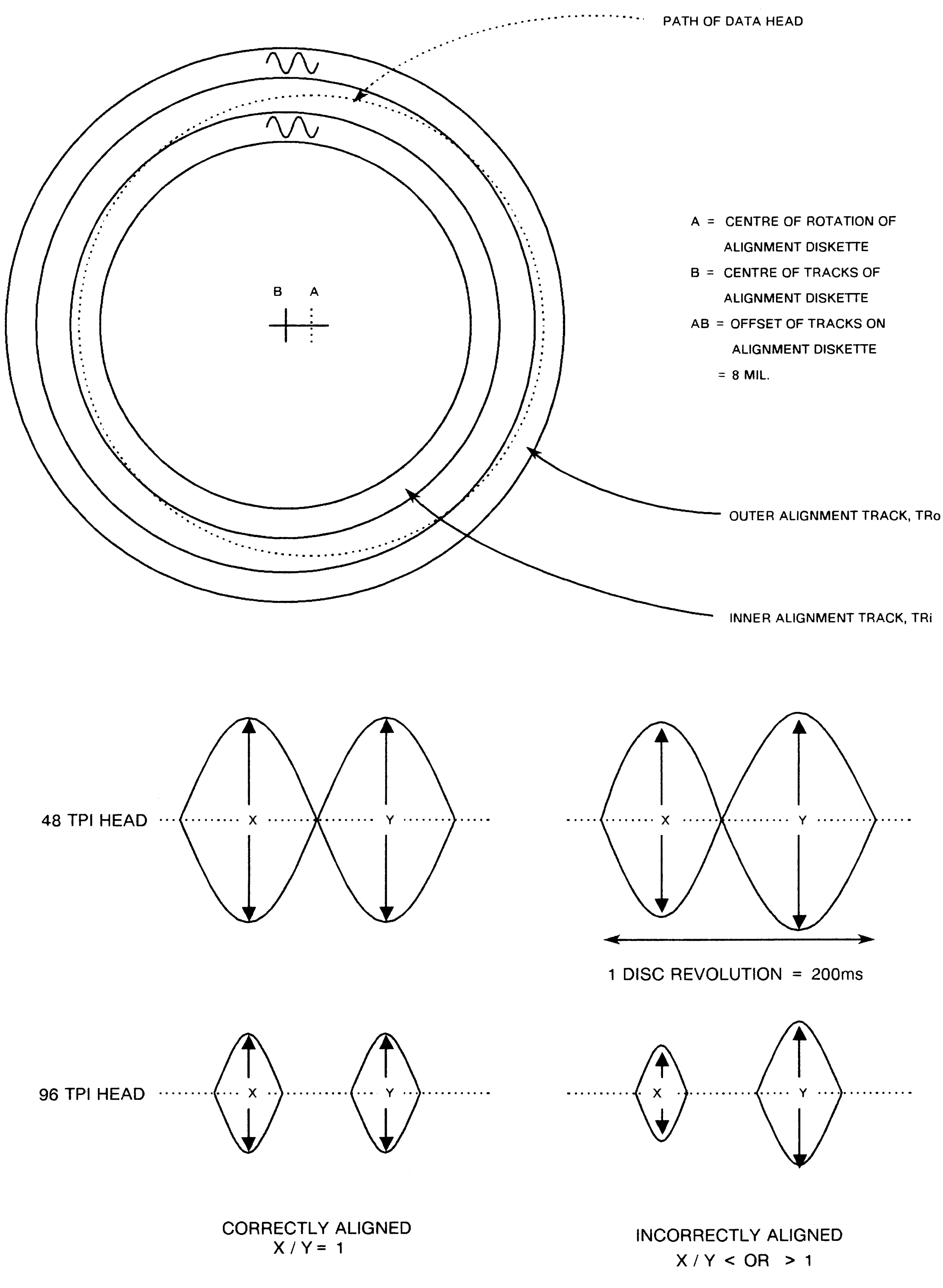


Figure 4.3. Head Alignment for Floppy Drive

4.8 FLOPPY DRIVE DETAILS

4.8.1 Single and Double Sided Disks

Drives with one head use single sided disks only. Double sided disks cannot be used because when the disk is reversed to position the second surface under the head, the position of the hole in the disk envelope, used as a window for the index hole on the disk, will not be opposite the index detector, as shown in Fig. 4.4.

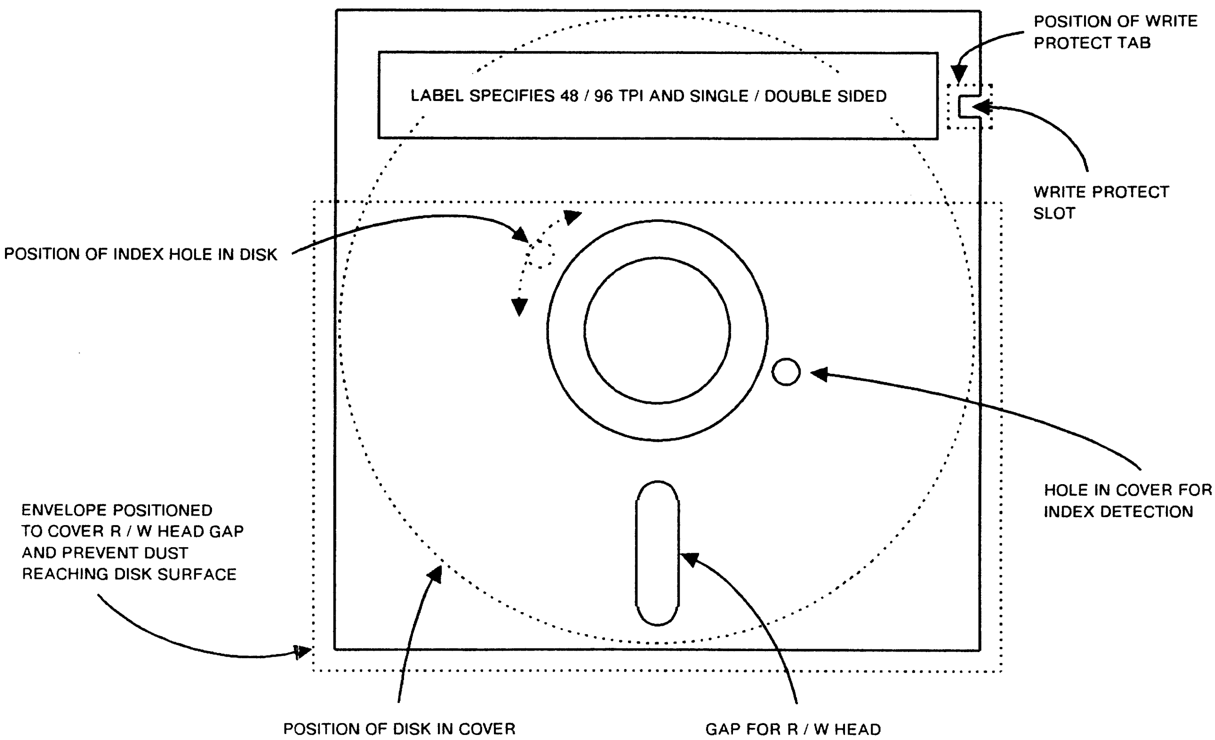


Figure 4.4. 51/4 inch Floppy Disk

4.8.2 Double Density

When the term "double density" is used, it usually means that the recording media of the disk can store twice the number of bits per inch than the standard quality media. The higher quality disk allows twice the number of flux changes per inch, fcpi. This is not the same as:-

(a) double density recording, which refers to doubling the bits per inch stored by changing from FM data coding to the more efficient MFM coding.

(b) double track density, which refers to doubling the data storage by changing from 48 tpi to 96 tpi recording. Note that a disk labelled as 48 tpi will not successfully record at 96 tpi.

4.8.3 Motor Run up and Head Load

Floppy drives differ in the conditions required for motor run up and head load. This is to reduce head and disk wear caused by friction between head and disk. On many drives switches are set to conditions required by the operator. On the SA 450 interface, two signals, HEAD LOAD and MOTOR ON, allow the system to control these functions. On drives with a mechanical head load, loading a disk in the drive causes head load. The motor need only be on when the drive is selected (for seeking, reading or writing), because the motor requires a short run up time to 300 rpm. Often, the motor is run up for a short period of time after disk insertion, in order to centre the disk on the hub, before the first read or write is attempted.

4.8.4 Write Protect Tabs

Each floppy disk has a slot in the envelope for write protection, as shown in Fig. 4.4. Light from an LED inside the drive is detected by a diode after passing through the slot of the loaded disk. The light can be interrupted by a tab over the slot, setting or resetting the WRITE PROTECT signal on the interface, and thus disabling or enabling a write operation. Write protect is set as follows:-

(a) 8 inch floppy disk - slot uncovered
(b) 5.25 inch floppy disk - slot covered
(c) 3.5 inch floppy disk - slot uncovered

4.9 FLOPPY DRIVE MAINTENANCE

The life of floppy disks is limited due to wearing out of the magnetic oxide layer caused by head to disk contact. To reduce this, operators should be instructed to regularly clean the heads with a special cleaning diskette. Disks should also be checked for scratches, to check for a damaged head. It is recommended that information on disks be "backed up" on a reserve disk.

In floppy drives there are usually a number of adjustments which are required for correct operation. The usual adjustments are:-

(a) Head load solenoid adjustment. When a HEAD LOAD command is received from the interface, a solenoid is energised to pull the heads onto the disk against the action of a spring. The spring pressure must be checked and adjusted for correct operation.

(b) Track 00 detect adjustment. A detector on the stepper motor indicates (flags) the track 00 position. The radial position of the detector is adjustable. After head alignment, described in section 4.7., carried out on, say track N, the heads should be stepped outwards by N steps (= tracks) to track 00. The sensor should switch one to two tracks before reaching track 0. When the detector is switched, track 00 is reached with a certain phasing of the currents in the four stepper motor windings. For the Dysan alignment diskette, with alignment carried out on tracks 16, for 48 tpi, or 32, for 96 tpi, track 00 will have the same phasing as the alignment track.

(c) Index to data burst. The position of the index pulse can vary between different drives, due to variation in the position of the index sensor relative to the index hole in the envelope of the disk. The Dysan alignment disk, with a special data pattern (burst) on track 1, for 48 tpi, or track 8, for 96 tpi, is used and the delay between index pulse and start of data burst, is measured. This is set to 200×10^{-6} s by adjustment of the sensor position.

4.10 POWER SUPPLIES

The 14 inch drives require only normal mains voltage (230V a.c. or 110V a.c.). They have an internal psu. for converting to d.c. voltages of 5V, 12V, 20V and 43V (for the voice coil), using transformer, bridge rectifiers and regulators.
The other drives must be provided with d.c. voltages of +5V and +12V, except for 8 inch Priam drives. For all drives, the current requirements are greatest during motor run up and head load, when the +12V supply (for most drives) current reaches several amps. For this reason, multiple drive systems often run up drives sequentially.

4.11 AIR FILTERING

For the 14 inch drives, it is important that filters are changed or cleaned regularly. Air is pumped through the drive with a blower so that incoming air first passes through one or more filters, and is then forced over the disk pack. If the filters are blocked, then the air flow is interrupted, allowing unfiltered air, containing dust particles, to cause a head crash. Air flow should be regularly checked with a pressure meter. Air flow is also used for cooling, to prevent circuit boards from overheating.
Winchester drives normally contain filtered air in the sealed head - disk assembly., which usually also contains two filters. The rotation of the disk pack generates air currents inside the HDA, and one filter is positioned so that air being sucked towards the disks passes through it first. The other filter is between the sealed HDA and the free air, to prevent a build up of pressure inside the HDA caused by heat. This would change the height at which the heads fly above the disk surfaces. It is not possible to clean or change the filters.

Chapter 5

Drive and Controller Specification

5.1 DRIVE COMPARISON

Notes on Drive Specification charts

From the specification tables, it can be seen that a number of drive properties have been standardised:-

(a) The 14 inch and 8 inch drives use a voice coil for head positioning.
The 5.25 and 3.5 inch fixed drives, and floppy drives use a stepper motor.

(b) Most 5.25 and 3.5 inch Winchester, and floppy drives require +5V and +12V voltages only.

(c) Disk speeds are 3600 rpm for hard disks and 300 rpm for floppies (although another preferred speed is 360 rpm).

(d) Floppy drive track densities are 48 tpi (single track density) or 96 tpi (double track density).

(e) The 5.25 and 3.5 inch Winchester drives use the ST 506 interface.

Other points to note :-

(a) The flux changes per inch given, fcpi., are the maximum values, i.e. on the innermost track. Since for MFM (double density recording) there is one transition per bit cell, this is also the value for bits per inch, bpi. For FM (single density recording) there are two transitions per bit cell, so that fcpi. is twice the bpi.

(b) Current requirements are average values. During motor run up, the load on the +12V rail (for small Winchester drives) is several times larger due to power required to accelerate the spindle motor. More power is also required by the voice coil or stepper motor during seeks than when reading or writing.

(c) Manufacturers often increase drive capacities by simply increasing the number of disks or track density. For example the Priam 3450 has only half the capacity of the Priam 7050 because it only uses alternate tracks. The 3450 can therefore use a HDA made to less precise specifications.

(d) Average seek time is not the average access time to start read or write. A seek ends when the heads are locked on the destination track. To obtain the access time, the **latency** time must be added, the period between lock on track and reaching the required sector. For any disk, the maximum latency time is the period required to complete one revolution, and the average latency is half that value. For a hard disk (speed = 3600 rpm), this is 8.3ms., and for a floppy (speed = 300 rpm), it is 100ms.

Manu-facturer	Type	Unform-atted capacity (MB)	Data heads	Tpi.	Tracks	Fcpi.	Speed (rpm)	Ave. seek time (ms.)	Data Xfer rate (Mb/s)	Interface	Power supply (V a.c.)	Type of head positioner
CDC	9448-96 CMD	16.3C/81.5F	1/5	384	823	6038	3600	30	9.67	SMD	230 / 120	V.C.
CDC	9762 SMD	82.9C	5	384	823	6038	3600	30	9.67	SMD	230 / 120	V.C.
CDC	9730 MMD	82.9F	5	340	823	6220	3600	30	9.67	SMD	230 / 120	V.C.
CDC	9730 MMD	165.9F	5	680	1646	6220	3600	30	9.67	SMD	230 / 120	V.C.

Table 5.1. Summary of 14 inch Hard Disk Drives (see notes at foot of Table 5.3.)

Disk size (inch)	Manu-facturer	Type	Unf. Cap. (MB)	Data heads	Tpi.	Tracks	Fcpi.	Speed (rpm)	Ave. seek time (ms.)	Data Xfer rate (Mb/s)	Interface	Power supply				Head pos.
												V	A	V	A	
8	Priam	3450 7050	35 70	5	480 960	525 1049	6670 6670	3600	42	6.4	Priam/SMD	24 -12	2.2 0.4	+ 5 -5	1.5 1.5	V.C.
8	Priam	806-13 807-11	227 344	11 11	1040 1040	1023 1152	9167 12096	3600	20 25	9.68	Priam/SMD	24 -	2.5 -	+ 5 -5	1.7 1.7	V.C.
5.25	Seagate	ST406	6.38	2	345	306	9074	3600	85	5	ST506	12	1.6	5	1.1	S.M.
5.25	Seagate	ST412	12.76	4	345	306	9074	3600	85	5	ST506	12	1.6	5	1.1	S.M.
5.25	Rodime	RO 202E	26.67	4	600	640	10,200	3600	60	5	ST506	12	2	5	0.9	S.M.
5.25	Miniscribe	3012/3212	12.8	2	588	612	10,000	3600	155/85	5	ST506	12	0.9	5	0.75	S.M.
3.5	Rodime	352	12.8	4	600	306	11,050	3600	85	5	ST506	12	0.9	5	0.53	S.M.
3.5	Miniscribe	8425	25.6	4	804	615	13,412	3600	68	5	ST506	5	0.55	12	0.7	S.M.

Table 5.2. Summary of Fixed Disk Drives (see notes at foot of Table 5.3.)

Disk size (inch)	Manu-facturer	Type	Unformatt -ed MFM capacity (KB)	Data heads	Tpi.	Tracks per Surface	Fcpi.	Speed (rpm)	Ave. seek time (ms.)	Data Xfer rate (Kb/s)	Power supply			
											V	A	V	A
8	CDC	9406	1,600	2	48	77	6536	360	96	968	24	0.1	5	1.1
5.25	Shugart	SA 455	500	2	48	40	5876	300	93	250	12	0.6	5	0.6
5.25	Philips	X3121	496	1	96	80	5876	300	147	250	12	0.9	5	0.55
5.25	Philips	X3114	1000	2	96	80	5876	300	147	250	12	0.9	5	0.55
5.25	Philips	X3133	500	1	96	80	5876	300	95	250	12	-	5	-
5.25	TEAC	FD 55E	500	1	96	80	5578	300	94	250	12	0.25	5	0.38
3.5	TEAC	FD-35F	1000	2	135	80	8717	300	94	250	12	0.08	5	0.14

Table 5.3. Summary of Floppy Disk Drives (see notes below)

Explanation of Tables

1. C = cartridge module (volume) capacity, F = fixed module capacity.
2. Tpi. = tracks per inch.
3. Fcpi. = maximum flux changes per inch (on innermost track). This equals the maximum bits per inch for MFM coded data. (all "1's" or all "0's") or twice the maximum bits per inch for FM coded data (floppy drives only) .
4. Data Xfer rate = data transfer rate.
5. Power supply requirements shows each voltage, V, with the average current, A, used by that voltage in the next column. Maximum currents, required during the start of motor run up, will be several times these values on the voltage rail supplying motor drive (usually 12V).
6. For the type of head positioner, V.C. = voice coil, and S.M. = stepper motor.

5.2 SUMMARY OF DRIVE CONTROLLERS

Controller	**Drive interface**	**Max. configuration** HD = hard disk drive FD = floppy drive	**Drives**
WDA / WDB	SMD	4 × 14 HD 4 × 8 HD with SMD I/F	CDC CMD/SMD/MMD Priam 3450 / 7050
WDC	Priam	4 × 8 HD	Priam 3450 / 7050
WDD	SCSI / ST 506	4 ×5.25HD	Rodime 202E / 204E
WDE	SCSI + FDD (SA450)	3 × 5.25HD + 2 x 5.25FD	Rodime 202E or 204E and FDD 3114 /3118
WDH	Priam	4 × 8HD (**either** 3450 / 7050 **or** 806/7)	Priam 3450 / 7050 or 806 / 807
WDI / WDK	SCSI or ST 506 + FDD (SA450)	3 ×5.25 HD+2 × 5.25FD (or +1 ×5.25FD + 1×8FD)	Rodime 202E or 204E or Vertex V185 and FDD 3114 /3118
WDJ	ESDI + SCSI	3 × HD	As for WDE

Table 5.4. Summary of Drive Controllers

Table 5.4. gives the Philips controllers used for disk control. Some controllers can handle both floppy drives and hard drives with ST 506 interface. Controllers select the interleaving factor for soft sectoring, but are not given in this Table.