

TANDBERG DATA

TDC 3600 SERIES

STREAMING TAPE CARTRIDGE DRIVES

TDC 3620/3640/3660 Reference Manual

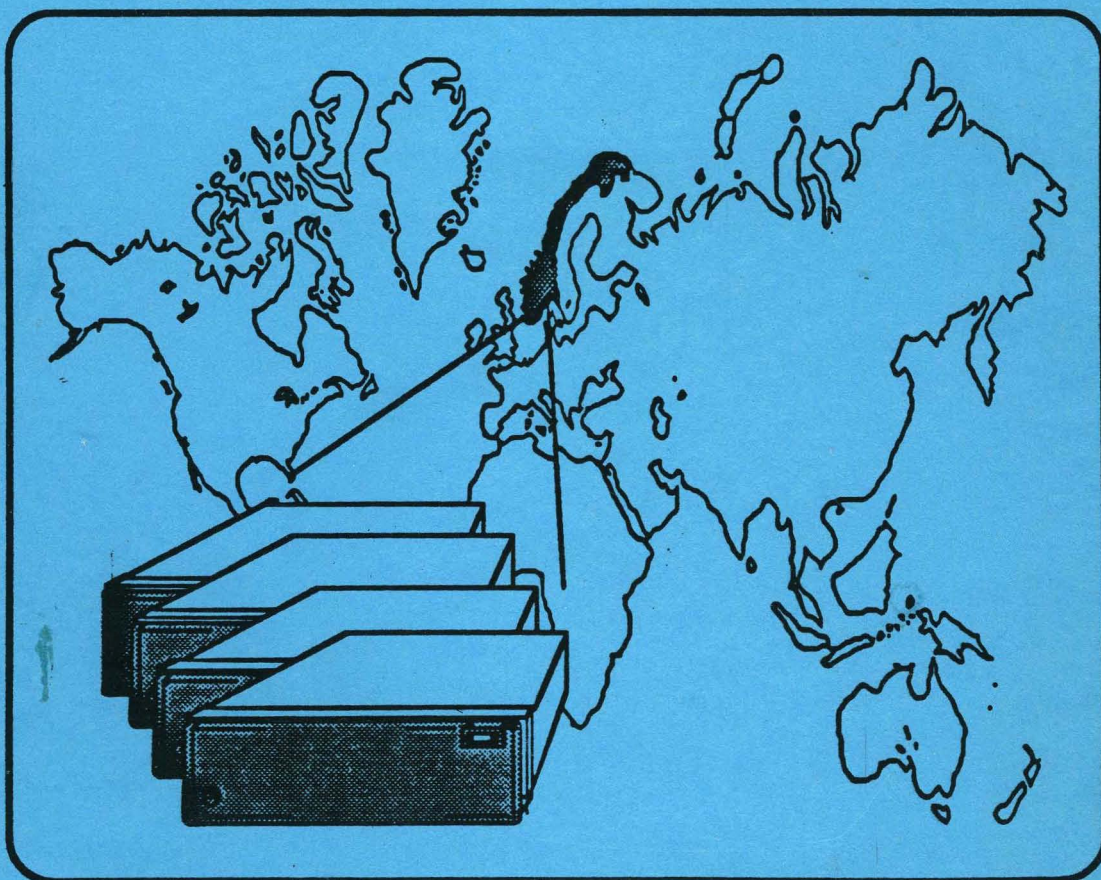


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0. Preface

This is the reference manual for the TDC 3620/3640/3660 SCSI ("Small Computer System Interface") compatible streaming 1/4" tape cartridge drive.

Tandberg Data will appreciate any comments on this publication regarding:

- discrepancies between specification and product
- Inconsistency of definitions
- lack of clarity in the definitions
- QIC-11, QIC-24, QIC-120 and QIC-150 compatibility
- QIC-104 compatibility
- SCSI Command Set compatibility to ANSI, Revision 17B
- Emulex MT03 Controller compatibility where this is not in conflict with ANSI Revision 17B

Incompatibilities to MT03 are as follows:

The Copy Command supports only copy between Direct Access and a Sequential Access Drive.

The Mode Select command does NOT support the EMULEX Vendor Unique bits:

DEA: Disable Area Ahead
AUI: Auto Load Inhibit
SEC: Soft Error Count

The following Extended Sense Status Bytes have changed position:

ERCL/ERCD: Moved from byte 08 to byte 14
Number Of Recoverable Errors: Moved from bytes 09 and 10 to bytes 12 and 13.

The TDC3620/40/60 Drive does NOT support the command:

Read Revision Level

The IMED (Immediate) bit for the Verify command is NOT supported as the TDC3620/40/60 Drive handles this as a Read-type command.

The TDC3620/40/60 Drive requires a File Mark written as the last block of every recording. Failure to this will cause 24 rereads and Unrecoverable Data Error during the Read command.

IMPORTANT!

Tape is a very hygroscopic media. If exposed to a high humidity environment over some period, it may require several days to bring a cartridge back to normal humidity condition, even if the humidity level during this "dry-out" period is kept very low. An environment with a high humidity like this may not only occur in areas with a natural high humidity.

A typical example may be a cartridge placed in its packaging box and cooled down during transportation. The relative humidity inside the box may increase; and over time affect the relative humidity of the tape itself.

Running high humidity tapes over a long period of time may severely reduce the life time of the drive's Read/Write head. It may also drastically reduce the life time of the tape.

If in doubt, always let a cartridge "dry out" in a normal humidity environment (< 50-65 % rel. hum. at +20°C) for at least 3-4 days prior to use.

The head life time specifications stated by Tandberg Data A/S assumes running tapes in an environment with an average rel. hum. of not more than 50 % and a maximum of not more than 65 %; all at a temperature of not more than +30°C outside the cartridge.

Relative humidities up to 80 % are assumed only for a maximum of 1 hour for every 24 hours of tape running. Maximum relative humidity of the environments shall not be more than 50 % averaged over the life cycle test, and never more than 65 %, averaged over 200 running hours.

The head life time specifications given for this product is not valid if the drive has been used in environments - or with tapes - that cannot meet the specifications above.

Tandberg Data A/S does not warrant against failure of any tape drive product that has directly or indirectly been exposed to conditions outside the specifications given above.

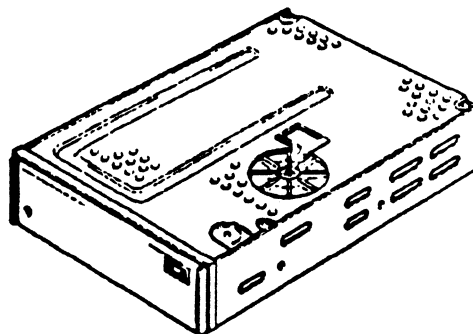
1. About this Manual

1.1. Definitions

The following two terms are widely used throughout this manual:

"The Drive"

Refers to the half-height SCSI ("Small Computer System Interface") compatible TDC 3620 9-track, TDC 3640 15-track and TDC 3660 18-track Drive.



"The Host"

Refers to the host computer that supports the SCSI hardware and software specifications, and thus is able to control the SCSI compatible TDC 3620/40/60 Drive.

1.2. Introduction to this Manual

This manual is intended to be the main reference document for users, system programmers and system integrators of the TDC 3620/40/60 streaming 1/4" tape cartridge drive.

The TDC 3620 Drive complies with the SCSI Interface Standard, and the QIC-24 Data Interchange Standard.

The TDC 3640 and the TDC 3660 Drives comply respectively with the QIC-120 or the QIC-150 Data Interchange Standards in addition to the SCSI specifications.

The TDC 3620, the TDC 3640 and the TDC 3660 reads and writes nine, fifteen or eighteen tracks serially, running the tape at 90 ips or 72 ips respectively.

Detailed circuit-board block diagrams, schematics and adjustment procedures are not supported by this manual. The field service technician will need the *TDC 3600 Series SCSI Maintenance Manual*, in addition to this reference manual, in order to have the complete service documentation at hand.

Chapter 2

describes the basic features of the Drive accompanied by a block diagram.

Chapter 3

gives the technical specifications in detail.

Chapter 4

contains mounting specifications.

Chapter 5

describes data reliability and tape conditioning.

- Chapter 6** describes the tape formats (9, 15 and 18 tracks) and how the data is encoded.
- Chapter 7** describes the Drive's supported basic operational functions.
- Chapter 8** describes the interface of the Drive with regards to the hardware.
- Chapter 9** is a comprehensive description of the interface to the Drive regarding software and/or system. It describes the command set and the behavior of the Drive in various situations.



1.3. Additional Documentation

SCSI (Small Computer System Interface manual) ANSI X3.131 Standard, Revision 17B, 1986.

The QIC-24 and QIC-02 Standards, Revision D, (Part no. 402732, Publ.no.5447), available from our Sales Department.

The QIC-120 Standard for Data Interchange, Revision D, February 11, 1987.

The QIC-150 Standard for Data Interchange, Revision I, May 12, 1987.

2. Introduction to the Drive

2.1. Summary

This chapter describes the basic features of the Tandberg Data TDC 3620/40/60 streaming tape cartridge drive. After a general introduction, a description of the mechanical and electrical drive design is given.

2.2. General Drive Description

The Tandberg Data TDC 3620/40/60 is a streaming 1/4" tape cartridge drive.

The TDC 3620

The TDC 3620 records and reads serially on 9 tracks and can store 45 Mbytes on a 137 m (450-foot) cartridge. With the 169 m (555-foot) cartridge the capacity is increased to 55 Mbytes. The 183 m (600-foot) cartridge gives a capacity of up to 60 Mbytes.

The TDC 3640

The TDC 3640 records and reads serially on 15 tracks and can store 125 Mbytes on a 183 m (600-foot) cartridge.

The TDC 3660

The TDC 3660 records and reads serially on 18 tracks and can store 155 Mbytes on a 183 m (600-foot) cartridge.

Drive Application

The Drive is well suited for a variety of applications:

- Winchester back-up
- Archival storage
- Low cost background mass-storage system
- Data logging
- Replacing the floppy disk for data interchanges

Streaming

The mode of operation is streaming, i.e. the Drive is designed to run the whole length of the tape, normally without any interruption. Unnecessary start and stop operations in the middle of the tapes will slow down the system considerably.

Basic Mechanical Building Blocks

The Drive mechanism is built inside a rigid casting. The mechanism includes a direct-drive capstan motor, a door-locking and ejection system and a head-moving ("worm-wheel/gear") system. Figure 2.1 illustrates the Drive's mechanical outline.

Note that mounting the drive top-flush against a flat surface will impede air flow and may obstruct the rubber impeller-fan mounted on the capstan-motor axle.

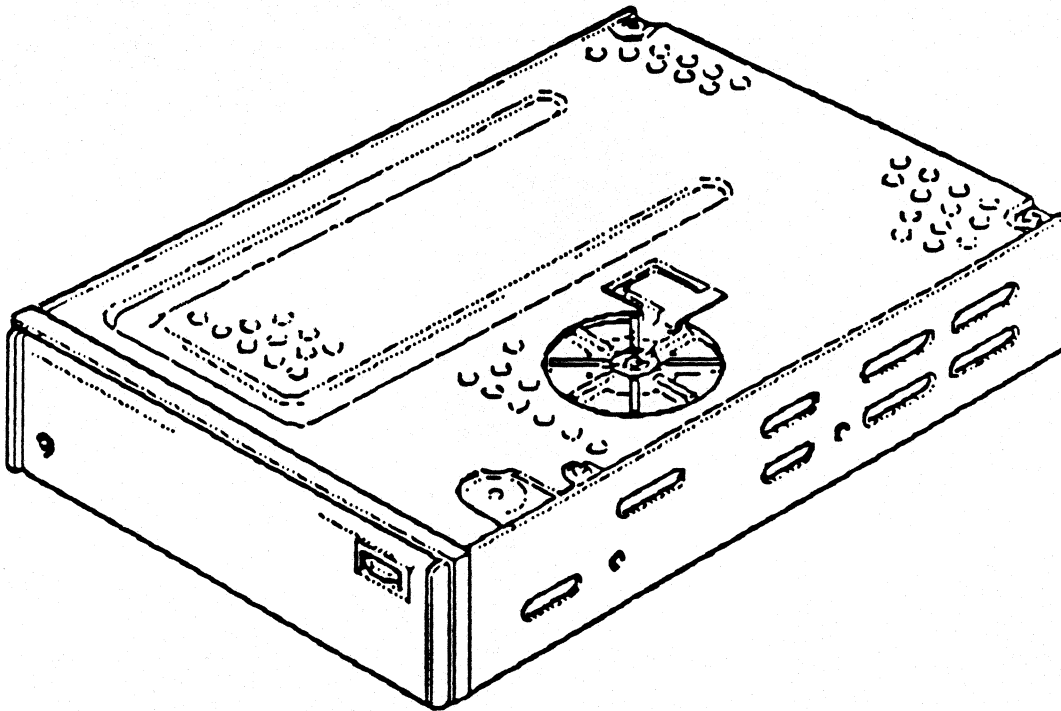


Figure 2.1 The Drive

The Electronics

The electronics are contained on two printed circuit boards: The Mainboard and the Sensorboard.

The Drive electronics comprises the 68 HC11 microcomputer and two custom made Tandberg Data ASIC-circuits: one handling the Drive's formatting functions and the other handling the buffer and bus-interface circuitry.

All electronics except the opto-electronic tape hole sensors, the mechanical "cartridge-in-place" and "write protected" switches are situated on the Mainboard. The exceptions mentioned are located on the Sensorboard.

2.3. Tape Format and Drive Operation

Data is formatted into small blocks, each block containing 512 bytes of data. Special address and checking bytes are added to each block. The basic layout is shown in Figure 2.2. The overhead per block is very small, nominally 19.5 bytes.

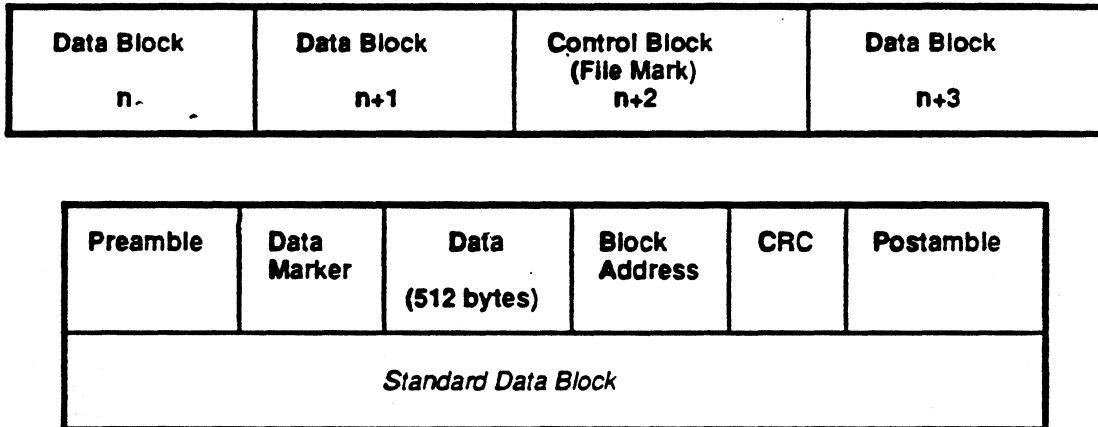


Figure 2.2 Track format

Write Operation

The data bytes are transferred from the Host to the Drive and stored in the Drive's data buffer. The data is assembled into blocks of 512 bytes. The Drive adds special address and check characters to each block prior to writing the complete block on the tape. The blocks are written without the traditional long interblock gaps. The Drive performs read-after-write checking, and blocks with errors are automatically rewritten further down the tape.

Read Operation

In read mode, data is read from the tape and the formatter-ASIC strips off the special address and check characters. The data bytes are then transferred to the Host via the built-in data buffer in the Drive.

Edge/Reference Track Seeking

In order to improve the track-location accuracy and to ensure data interchangeability between cartridges, the Drive uses the edge of the tape as the basic reference during write mode and special reference signals as references during read operations. When changing tracks the head will always move upwards when the new track is entered. This is done to eliminate influence of so-called "backlash" in the "worm-gear".

Track Seeking In Write Mode

When the Drive has received the write command, it steps the head down until the forward (lower) recording channel is right above the lower tape edge. The tape is at BOT. Then the Drive starts moving the tape forward, and at the same time stepping the head downwards very slowly. It also starts writing a fixed high-frequency (preamble) pattern.

A special detector circuit monitors the output from the read head. As soon as the read head reaches the lower edge of the tape, the read signal disappears and the edge detector informs the microcomputer that the edge is detected. The head is then stepped 50 steps downwards and then again upwards until the detector circuit once more senses the tape edge. This position is marked as the tape Edge, and the tracks further written are aligned with reference to this position.

The microprocessor will remember this position as long as the cartridge is inserted (and power is on), and it will step the head to the accurate track locations due to the high resolution of the stepping system.

Track Seeking In Read Mode

When reading, the Drive will not look for the edge of the tape. No write operation is allowed in read mode. Instead, the microcomputer will look for the long preamble on the first track, using the same edge detector circuit as in write mode. The Drive will sense the upper and lower edge of the reference track and then the microcomputer will calculate the correct center position of the reference track. In this way it is able to find the actual track locations even if the tracks were not recorded in the correct position.

The edge seeking (or reference signal seeking) is performed only between BOT and LP. Normally, the Drive has to move the tape backwards and forwards a few times before the head has moved enough to detect the tape edge (or reference signal).

If a cartridge that has been written in another format than the "native" one is read - like QIC-24 format on a TDC 3640 or -60 - the Drive may need several passes to determine the correct starting-point on the tape.

Due to the number of differences in recording and positioning in the QIC-11 format, the Drive may in extreme cases be unable to read these tapes. See Section 6.1.

2.4. Drive Block Diagram with Description

All drive operations are controlled by the 68HC11 microcomputer on the Mainboard. This includes the stepping and positioning of the head, the control of the capstan motor speed, the sensing of the tape holes and the communication with the Host.

Figure 2.3 below shows a block diagram of the Drive.

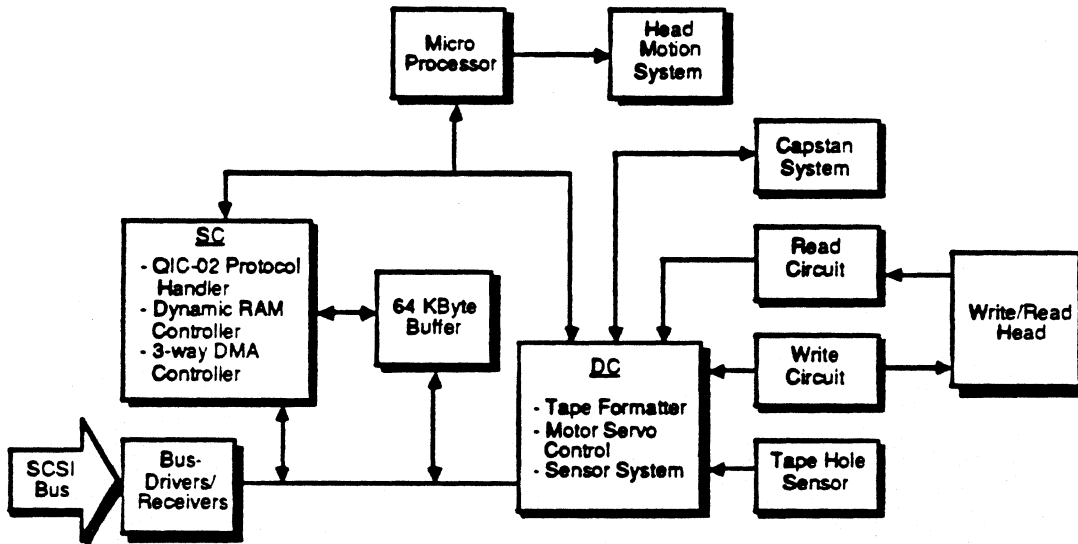


Figure 2.3 Block diagram of the Drive

Capstan System

The capstan motor is controlled by a software controlled and monitored servo system. Pulse modulation of the motor current is used in order to reduce power dissipation in the motor.

Head Motion System

The head is moved up and down with a double-screw ("worm-wheel") system, controlled by a stepper motor. The microcomputer supplies the pulses to the stepper motor. The microcomputer is also able to detect either the edge of the tape or the edge of the reference signals by employing the tape edge sensor electronics.

The Write/Read Head

The head has two recording channels designed for serpentine recording. Each channel contains a write and a read section. When writing, the Drive runs a read-after-write check to verify the recorded data. The head also has a full-width erase part that erases all the tracks on the tape each time the Drive starts writing from Track 0.

Tape Hole Sensors

The EOT (End of Tape), the BOT (Beginning of Tape), the LP (Load Point) and the EW (Early Warning) holes in the tape are detected by the Mainboard microprocessor using the Tape Hole Sensor circuit. The detection system includes a sophisticated, synchronously clocked hardware system to avoid malfunction and tape run-out.

The Write Circuit

This circuit performs the actual writing on the tape. Information about the data to be written is received from the Write Sequencer. The write circuit adapts itself to the type of tape used (DC300XL, DC600A or DC600XTD).

NOTE:

For recording, the TDC 3640 should use DC600A or DC600XTD tapes and the TDC 3660 should only use the DC600XTD tape or equivalent from other manufacturers.

The Read Circuit

The Read Circuit detects each flux transition from the read head and converts it to a digital pulse. The circuit is optimized to read weak signals, thus improving the total system error rate.

The Read Clock Generator

This circuit generates a clock signal which follows the long term variations in the data signal read back from the tape. A phase locked loop is used to control the generation. The circuit is optimized for GCR encoded data.

2.5. The Formatter Functions

The Formatter comprises:

- Communication microprocessor (68HC11)
- Data buffer
- Control circuits for data conversion
- DMA controller
- Host Interface controller

The Data Buffer is designed for optimal performance in disk back-up applications. The operation is described in detail in Section 2.7.

The microprocessor controls both the basic and the formatter functions in the Drive. It controls the Data buffer via the custom designed two channel DMA controller and it controls data Read and Write operations. It also handles the decoding of host commands.

2.6. Interface to Host

The interface to the Host conforms with the SCSI standard, revision 17B. Communication between the Drive and the host system is undertaken via a 9-bit bidirectional bus and nine bidirectional control lines.

The Drive accepts commands from the Host. The Host may read the Drive status by asking for the transfer of special status bytes from the Drive. See Chapter 9 for a complete list of available commands. During read and write operations, the data bytes are transferred via the Host Bus. The transfer of each data byte is supervised by the control lines in a handshake operation to minimize timing burden on the host controller.

For a detailed description of the hardware and software interface to the Host, see Chapters 8 and 9.

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3. Product Specifications

This section contains a comprehensive set of specifications for the Drive.

3.1. Mechanical Dimensions and Weight

Standard drive mounting

Fits in 5 1/4" half-height ("slim-line") enclosure for diskette or disk drive. Standard mounting holes for a half-height drive.

Max. dimensions

44 x 150 x 218 mm (1.732" x 5.905" x 8.583")

Weight

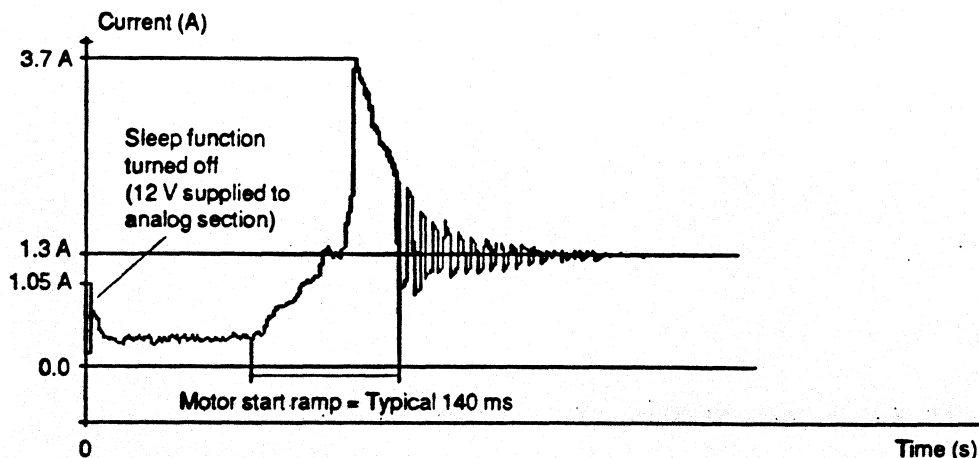
1.1 kg (2.4 lbs)

See Section 4.1 for mounting details and mechanical drawings.

3.2. Power Requirements

Voltage	Current
+5 V	250 mA *
+12 V motor not running	100 mA
+12 V motor running with tape	1.2 A **
+12 V peak value (start-up)	3.9 A ***

- * Excl. the bus termination resistor network.
- ** Nominal value. Actual value depends on cartridge friction.
- *** Assuming cartridge meeting 3M™ spec. for torque and friction



Typical current curve for +12 V during motor start-up
(Cartridge: Worst case 3M™ inside spec.)

Voltage variations	+5 V \pm 5 %	Including ripple
	+12 V \pm 10 %	Including ripple (No restrictions on the turn-on sequence).
Ripple on +5 V and +12 V	Maximum 200 mV Peak-to-Peak.	
Power dissipation	2.25 W	Motor not running.
	15.00 W	Typical, motor running with cartridge inserted.

3.3. Environmental Specifications

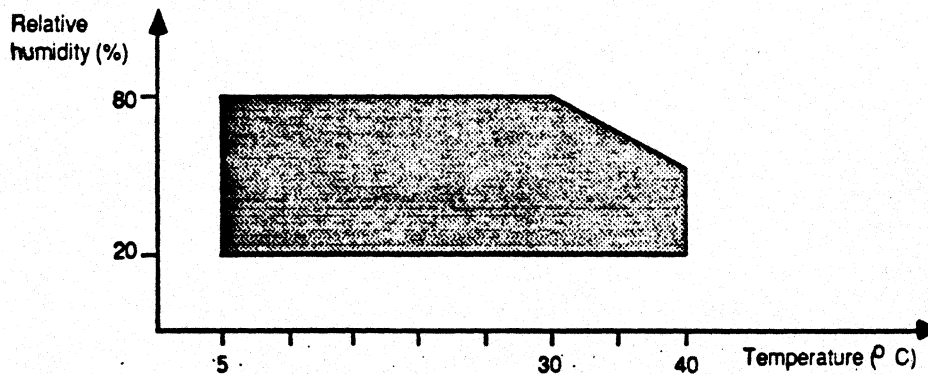
The following definitions are used in this section:

Operating	The unit is unpacked and power is turned on.
Storage	The unit is unpacked and power is turned off.
Transport	The unit is packed in original package as when ready for shipment from factory.

3.3.1. Temperature and Relative Humidity

Mode	Temperature (°C)	Rel. humidity (%)
Operating *	+5 - +40	20 - 80
Storage	-30 - +60	10 - 90
Transport	-30 - +60	10 - 90

* In operating mode these figures are limited by the media. Due to additional heating coming from internal friction in the cartridge, the maximum surrounding temperature should not exceed 40°C in order not to violate the maximum temperature rating for the tape cartridges which is 45°C. Maximum Wet Bulb temperature is 26°C operating. (See figure below and IMPORTANT-notice in Chapter 0. Preface).



Drive temperature and humidity limits, operating

Operating	3.3.2. Temperature Variation
	Maximum 6°C per hour, non-condensing
Operating Storage Transport	3.3.3. Atmospheric Pressure
	53 - 106 kpa [maximum altitude 4 000 m (13 000 ft)]
	15 - 106 kpa [maximum altitude 13 000 m (40 000 ft)]
Test method	3.3.4. Vibration
	EC-68-2-6

Mode	Frequency	Peak Displacement	Acceleration
Operating	5 - 60 Hz	0.035 mm ±10 %	-
	60 - 500 Hz	-	0.5 G
Storage	5 - 58 Hz	0.150 mm ±10 %	-
	58 - 500 Hz	-	2.0 G
Transport	5 - 12 Hz	3.5 mm ±10 %	-
	12 - 500 Hz	-	2.0 G

Topple Storage	3.3.5. Impact and Shock
	Lifted 50 mm and allowed to fall on to each of the four bottom edges and corners. (Horizontal position see section 4.1). (IEC-68-2-31).
Shock Transport	Lifted 1.0 m and allowed to fall freely on to a hard, rigid surface. Fall sequence includes all 6 sides and the most critical edge and corner. (IEC-68-2-32).
	Shock Storage
	392 m/s ² (40 G), Half sinewave, 11 ms duration. (IEC-68-2-27).

3.4. Product Performance Specifications

3.4.1. Audible Noise

55 dB (A). Integrated over 60 seconds. Measured at a distance of 1 m in all axes. The Drive free standing. Worst-case cartridges may increase this figure.

3.4.2. Radiated Electromagnetic Interference

The Drive complies with FCC Rules Part 15 Subpart J Class B and VDE 0871 Class B.

3.4.3. Susceptibility to Electromagnetic Interference

An electromagnetic field of 6 V/m will not cause any functional disturbance. (MIL-STD 462, method RS03, 14 kHz - 1 GHz).

3.4.4. Static Discharge

The Static Discharge is referred to the front door and other parts of the Drive that are accessible from the front when the Drive is mounted in a cabinet. The Drive will withstand a discharge of 15 kV from a capacitor of 150 pF via a 150 Ω resistor without malfunction or loss of data. Normal retries are allowed.

3.4.5. Safety Standard

The Drive complies with IEC 380, VDE 0805, UL 478 and CSA C22.2 - 220m 1986.

3.4.6. Mean Time to Repair

The Drive has a MTTR of less than 0.5 h. The MTTR is based on exchange of complete module assemblies. The head assembly can be exchanged in the field without the use of special alignment tools.

3.5. Product Reliability

The predicted reliability of the Drive must be expressed in two parts that will cover the expected random Mean Time Between Failures (MTBF) for the Drive electronics based on the Power On Hours (POH) and the Mean Time to Failure (MTTF) for the mechanical parts based on the POH *and* the Duty Cycle.

3.5.1. Electronics MTBF

The predicted MTBF has been calculated using a conservative Parts Count Model based on data from MIL-STD-217E. This gives a value for the "mature" MTBF for POH > 1.000 hours. The expected Early Life Failures can be estimated by reducing the MTBF by a factor of 3 (three) for 0 - 500 POH and by 2 (two) for 500 - 1.000 POH.

Predicted
"mature" MTBF

The predicted "mature" MTBF for the electronics part of the TDC 3600 Series Drives is:

> 20.000 POH

3.5.2. Mechanics MTTF

The failure rate for these parts is related to how often the Drive is actually used. In the case of the most critical components which are the head and the capstan motor, the reliability is specified as the Mean Time to Failure (MTTF) based on the POH and the Duty Cycle. The MTTR-values are not accumulative as the wear takes place in parallel.

Head Wear

> 2.000 POH at 100 % Duty Cycle (see NOTE 1)
> 20.000 POH at 10 % Duty Cycle (see NOTE 1)

Motor

> 2.000 POH at 100 % Duty Cycle (see NOTE 2)
> 20.000 POH at 10 % Duty Cycle (see NOTE 2)

Door open/close

> 15.000 open/close cycles

NOTE 1:

This figure is based on using DC300XL tapes.

NOTE 2:

Streaming operation, NOT extensive start/stop operations.

3.5.3. Useful Life Cycle

This is the period during which the Drive is serviceable either by adjustment or replacement of defective parts.

Useful Life Cycle

> 10 years

3.6. Functional Specifications

3.6.1. Media

Suggested
type of
media

3M DC 300XL	137 m (450-foot), cert. for min. 6400 frpi *
3M DC 300XLP	137 m (450-foot), cert. for 10 000 frpi
3M DC 600A	183 m (600-foot), cert. for 12 500 frpi
3M DC 600XTD	183 m (600-foot), cert. for 12 500 frpi **
DEI	137 m (450-foot), cert. for 10 000 frpi
DEI	169 m (555-foot), cert. for 10 000 frpi
DEI Ser. II	
Gold Plus	169 m (600-foot), cert. for 12 500 frpi

Or equivalent tapes from other manufacturers.

* We strongly recommend using tapes certified for 10 000 frpi or better for QIC-24 recordings. Only tapes certified for 12 500 frpi should be used for QIC-120/150 recordings.

** When you are recording, use DC600A or DC600XTD tapes - or similar makes with equal mechanical tolerances - for the TDC 3640 15-track QIC-120 version. For the TDC 3660 18-track QIC-150 version; use DC600XTD tape only! See also IMPORTANT-notice in Chapter 0. about tape/environmental temperature and humidity restrictions.

3.6.2. Track Width and Location

Number of
recorded
tracks

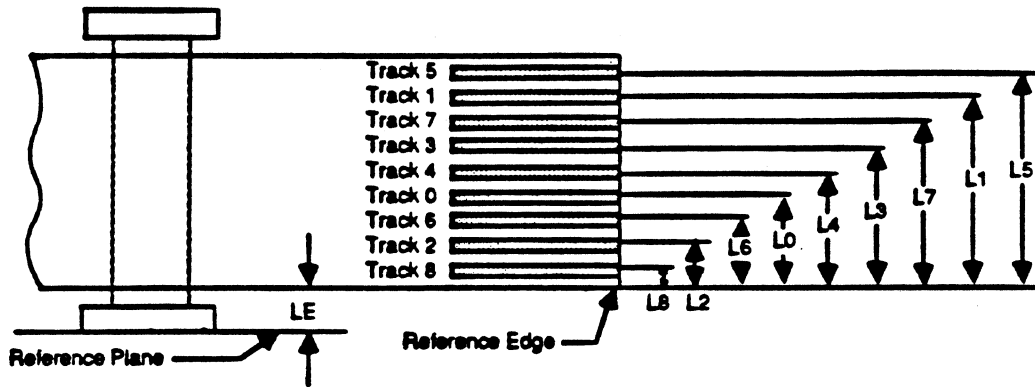
TDC 3620:	Nine tracks
TDC 3640:	Fifteen tracks
TDC 3660:	Eighteen tracks

Track
width

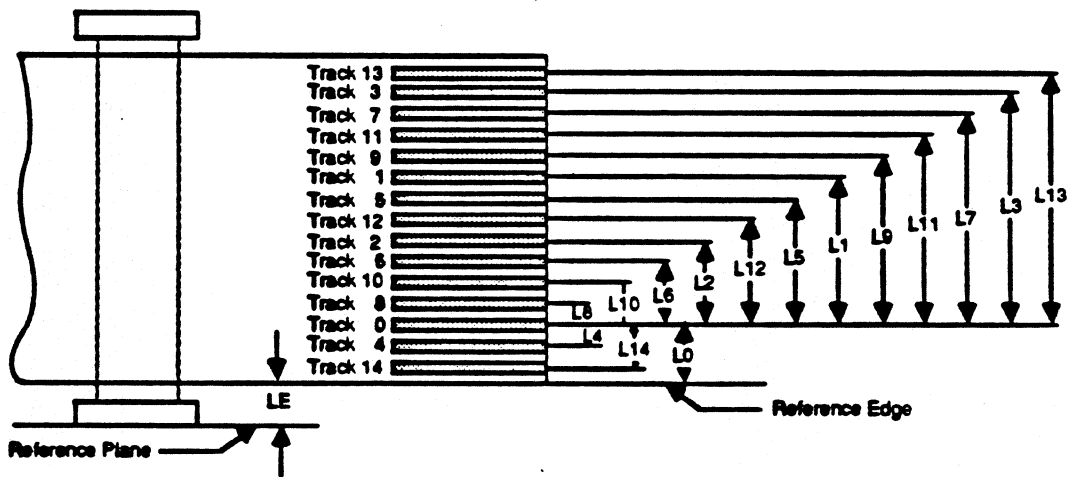
TDC 3620:	0.343 mm \pm 0.013 mm (0.0135" \pm 0.0005")
TDC 3640:	0.165 mm \pm 0.013 mm (0.0065" \pm 0.0005")
TDC 3660:	0.165 mm \pm 0.013 mm (0.0065" \pm 0.0005")

Track locations for the TDC 3620-, the TDC 3640- and the TDC 3660 Drives are shown on the next page:

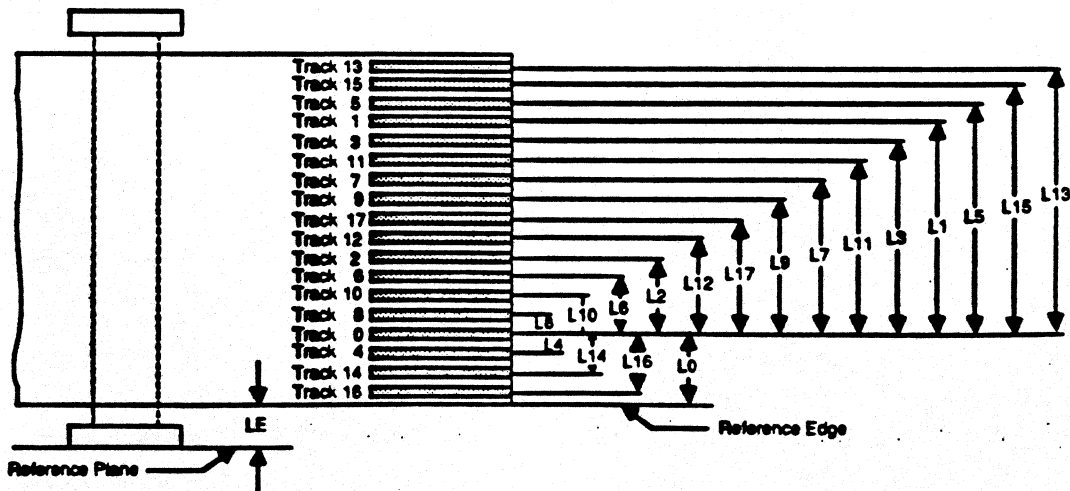
Dimension values are listed on the following page.



Track Locations for the TDC 3620/QIC-24 9-track Drive



Track Locations for the TDC 3640/QIC-120 15-track Drive



Track Locations for the TDC 3660/QIC-150 18-track Drive

[The dimensions are as follows:

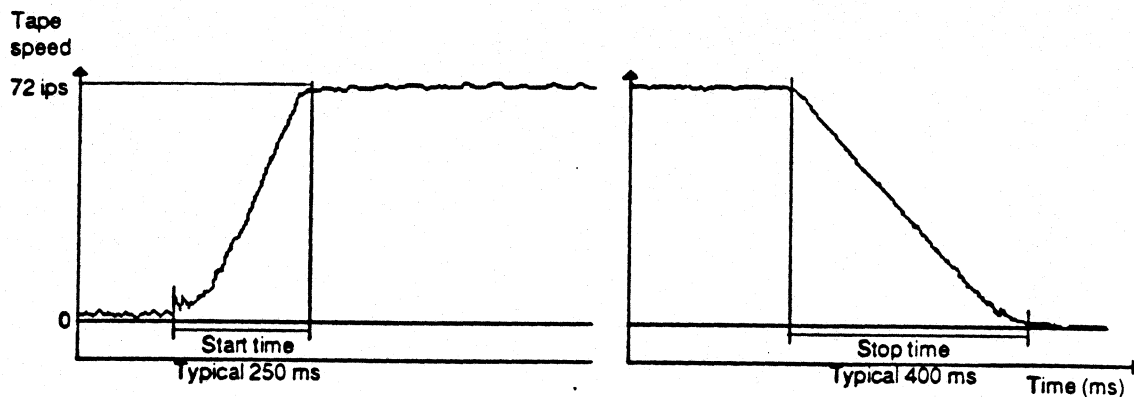
	TDC 3620/QIC-24		TDC 3640/QIC-120		TDC 3660/QIC-150
LE	1.778 mm (0.070")	LE	1.778 mm (0.070")	LE	1.778 mm (0.070")
L0	2.59 mm ±0.107 mm (0.102" ±0.0042")	L0	1.092 mm ±0.076 mm (0.043" ±0.002")	L0	1.255 mm ±0.076 mm (0.0494" ±0.003")
L1	5.03 mm ±0.107 mm (0.198" ±0.0042")	L1	2.845 mm ±0.051 mm (0.112" ±0.002")	L1	3.740 mm ±0.051 mm (0.1472" ±0.002")
L2	1.37 mm ±0.107 mm (0.054" ±0.0042")	L2	1.626 mm ±0.051 mm (0.064" ±0.002")	L2	1.360 mm ±0.051 mm (0.0535" ±0.002")
L3	3.81 mm ±0.107 mm (0.150" ±0.0042")	L3	4.470 mm ±0.051 mm (0.176" ±0.002")	L3	3.400 mm ±0.051 mm (0.1339" ±0.002")
L4	3.20 mm ±0.107 mm (0.126" ±0.0042")	L4	0.406 mm ±0.051 mm (0.016" ±0.002")	L4	0.340 mm ±0.051 mm (0.0134" ±0.002")
L5	5.64 mm ±0.107 mm (0.222" ±0.0042")	L5	2.438 mm ±0.051 mm (0.096" ±0.002")	L5	4.080 mm ±0.051 mm (0.1606" ±0.002")
L6	1.98 mm ±0.107 mm (0.078" ±0.0042")	L6	1.219 mm ±0.051 mm (0.048" ±0.002")	L6	1.020 mm ±0.051 mm (0.0402" ±0.002")
L7	4.42 mm ±0.107 mm (0.174" ±0.0042")	L7	4.064 mm ±0.051 mm (0.160" ±0.002")	L7	2.720 mm ±0.051 mm (0.1071" ±0.002")
L8	0.76 mm ±0.107 mm (0.030" ±0.0042")	L8	0.406 mm ±0.051 mm (0.016" ±0.002")	L8	0.340 mm ±0.051 mm (0.0134" ±0.002")
L9		L9	3.251 mm ±0.051 mm (0.128" ±0.002")	L9	2.380 mm ±0.051 mm (0.0937" ±0.002")
L10		L10	0.813 mm ±0.051 mm (0.032" ±0.002")	L10	0.680 mm ±0.051 mm (0.0268" ±0.002")
L11		L11	3.658 mm ±0.051 mm (0.144" ±0.002")	L11	3.060 mm ±0.051 mm (0.1205" ±0.002")
L12		L12	2.032 mm ±0.051 mm (0.080" ±0.002")	L12	1.700 mm ±0.051 mm (0.0669" ±0.002")
L13		L13	4.877 mm ±0.051 mm (0.192" ±0.002")	L13	4.760 mm ±0.051 mm (0.1874" ±0.002")
L14		L14	0.813 mm ±0.051 mm (0.032" ±0.002")	L14	0.680 mm ±0.051 mm (0.0268" ±0.002")
L15		L15		L15	4.420 mm ±0.051 mm (0.1740" ±0.002")
L16		L16		L16	1.020 mm ±0.051 mm (0.0402" ±0.002")
L17		L17		L17	2.040 mm ±0.051 mm (0.0803" ±0.002")

3.6.3. Head Specifications

Head type	2-channel read-after-write for serpentine recording. Separately mounted erase bar.
Write channel width	TDC 3610: 0.343 mm \pm 0.013 mm (0.0135" \pm 0.0005"). TDC 3630: 0.165 mm \pm 0.013 mm (0.0065" \pm 0.0005"). TDC 3650: 0.165 mm \pm 0.013 mm (0.0065" \pm 0.0005").
Read channel width	TDC 3620: 0.423 mm \pm 0.013 mm (0.0167" \pm 0.0005"). TDC 3540: 0.267 mm \pm 0.013 mm (0.0105" \pm 0.0005"). TDC 3660: 0.267 mm \pm 0.013 mm (0.0105" \pm 0.0005").
Erase head	Full tape width erase bar. All tracks are erased when writing from BOT on Track 0.
Alignment between read and write sections	TDC 3620: Maximum 0.025 mm (0.01"). TDC 3660: Maximum 0.015 mm (0.006").
Erase frequency	3.6 MHz
Azimuth	TDC 3620: < 7 minutes-of-arc. (According to ECMA/ANSI). TDC 3540: < 7 minutes-of-arc. (According to ECMA/ANSI). TDC 3660: < 7 minutes-of-arc. (According to ECMA/ANSI).
Zenith	< 15 minutes-of-arc

3.6.4. Tape Movement

Type of operation	Streaming
Tape speed standard	TDC 3620: 2.29 m/s (90 ips) TDC 3540: 1.83 m/s (72 ips) TDC 3660: 1.83 m/s (72 ips)
Tape speed variation	Short term (1 Byte): \pm 6 % with cartridge inserted. Long term (512 Bytes): \pm 2 % with cartridge inserted.
Start/stop time	[@ 2.29 m/s (90 ips)]: Start time typical: 200 ms Stop time typical: 450 ms [@ 1.83 m/s (72 ips)]: Start time typical: 250 ms (See figure) Stop time typical: 400 ms
Start/stop distance	[@ 2.29 m/s (90 ips)]: Start distance typical: 250 mm (9.8") Stop distance typical: 250 mm (9.8") [@ 1.83 m/s (72 ips)]: Start distance typical: 300 mm (12.0") Stop distance typical: 200 mm (7.8").



Typical curve for tape speed during start/stop operations

3.6.5. Recording Specifications

Recording method	NRZ1 (NON-RETURN to ZERO, change on ONEs) with data encoded according to the 0,2 GCR rules.
Recording density	TDC 3620: Maximum 315 data bits per mm (8 000 data bits per inch). TDC 3640/60: Maximum 394 data bits per mm (10 000 data bits per inch).
Maximum flux density	TDC 3620: Maximum 394 ftpmm (10 000 ftpi). TDC 3640/60: Maximum 492 ftpmm (12 500 ftpi).
Block size	TDC 3620/40/60: 512 data bytes.
Nominal overhead	TDC 3620: 19.5 Bytes (Preamble 12, Byte Marker 1, Block Addr. 4, CRC 2 and Postamble 0.5). TDC 3640/60: 23.5 Bytes (Preamble 16, Byte Marker 1, Block Addr. 4, CRC 2 and Postamble 0.5).
Write procedure	Writing always starts from the beginning of Track 0, except when the Host tells the Drive to start writing from the last block recorded. All tracks are erased when writing from BOT on Track 0. Tracks are written in an evenly rising order, i.e. 0, 1, 2 etc.
Read procedure	Reading always starts from the beginning of Track 0 and is performed in an evenly rising order, i.e. 0, 1, 2, etc.
Recoverable soft error rate	Media dependent, typically $> 10^8$ data bits per error.
Non-recoverable hard error rate	$> 10^{11}$ data bits per error when using DC600XTD or equivalent media certified for 12 500 frpi and tested under nominal conditions (50 % rel. hum., +25YC, continuous streaming).

NOTE:

By definition a "hard" error has occurred only if the Drive cannot read a particular block on the tape, even after going through the following sequence: 24 retries, head-cleaning with approved cleaning cartridge, complete tape-retensioning and another 24 retries.

3.6.6. Storage Capacity

TDC 3620:	137 m (450-foot) tape: 45 MBytes *
	169 m (555-foot) tape: 55 MBytes *
	183 m (600-foot) tape: 60 MBytes *
TDC 3640:	183 m (600-foot) tape: 125 MBytes *
TDC 3660:	183 m (600-foot) tape: 155 MBytes *

* Assuming typical tape-error performance.

3.6.7. Head Moving Mechanism

Type of mechanism	Double-screw ("worm-wheel") mechanism controlled by a stepper motor.
Head movement per step	0.005 mm (0.0002") per step, non-accumulating.
	Tolerance on maximum operating head travel: 0.03 mm (0.0012") maximum.
Number of steps between adjacent tracks	TDC 3620: Nominally 122 steps. TDC 3640: Nominally 81 steps. TDC 3660: Nominally 68 steps.

3.6.8. Capstan System

Type of capstan motor	High-inertia coreless DC motor.
Servo system	Dual feedback system using an optical tachometer. Speed variations are continually controlled by a digital servo system.
Capstan tachometer	Optical with 64 pulses per revolution.

3.6.9. Tape Sensor System

BOT/EOT sensor	Solid state infrared transmitter and receivers. Synchronous transmitter/receiver system and digital filtering in drive micro-processor firmware for noise suppression.
Cartridge sensor	Mechanical
Write protect sensor	Mechanical

3.6.10. Electronics

Basic design	One microcomputer (68HC11) for drive- and formatting control, one ASIC-circuit for buffer- and bus-control and one ASIC-circuit for formatter- and drive-functions. Tape-speed and all write data timing are referred to crystal controlled clocks.
Read clock	TDC 3620/40/60: Phase-Locked loop, nominally 900 KHz, designed to operate with the GCR-code.
Read/Write buffer capacity	64 KBytes standard.

4. Mounting Specifications

4.1. General Mounting Information

Mounting positions

Recommended mounting position is either horizontal with the indicator to the left, or vertical with the indicator down. The Drive must not be mounted in such a way that the cartridge is operated upside down.

IMPORTANT!

It is of the utmost importance to observe that the aluminum chassis is not bent or twisted in any way when tightening the mounting screws! Note that mounting the drive top-flush against a flat surface may obstruct the rubber impeller-fan mounted on the capstan-motor axle.

Mechanical dimensions

The Drive occupies a half-size (or "slim-line") 5 1/4" slot with two standard holes for 3 mm mounting screws on both sides of the Drive chassis.

In addition, four 3 mm standard mounting holes are located at the bottom of the Drive (drive mounted horizontally).

See Figure 4.1 for the mechanical dimensions of the Drive. Make sure to leave sufficient external free space to obtain easy open/close operation of the front door when mounting the Drive.

Dimensions in mm.
(Dimensions inside brackets in inches).

General tolerances:
+/-0.5 mm (+/-0.02")

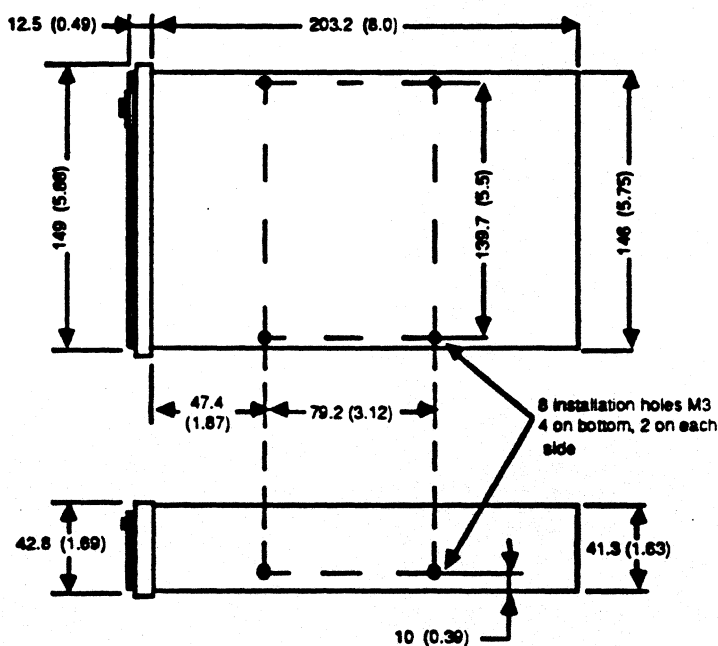


Figure 4.1 Drive Mechanical dimensions

Cable lengths

The maximum cable length from the Drive to the host-interface is 3 meters (10 feet). However, to increase system noise immunity, the cables should be kept as short as possible. The power connector is AMP 172296-1 or equivalent. The mating connector is AMP 1-480424-0 or equivalent.

Chassis grounding

The signal ground is connected to the Drive's chassis through a 1 nF capacitor located on the Mainboard. The Drive chassis may be connected to the system chassis through a "fast-on" connector at the rear of the Drive. This is only necessary if the Drive chassis is not adequately grounded to the system chassis through the mounting screws. (See Figure 4.2). Correct grounding of the chassis is important in order to reduce radiated electromagnetic interference.

The Drive operated as a stand-alone unit complies with FCC class B for radiated noise. However, incorrect grounding may violate this at the system level. As a rule of the thumb, the system should have only one common point between chassis and signal ground.

IMPORTANT!
As system-mounting and grounding are outside our control, Tandberg Data cannot be held responsible for any problems due to systems not meeting the FCC rules.

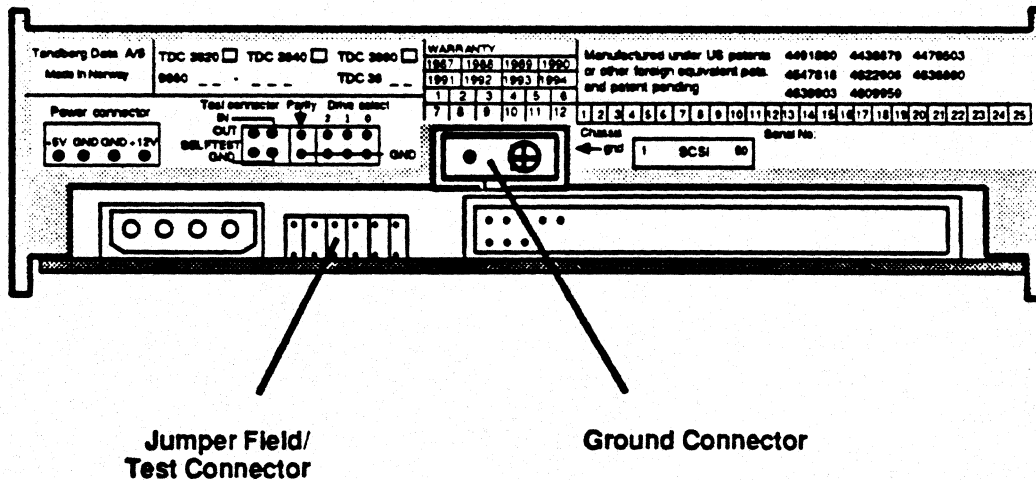


Figure 4.2 Rear View of Drive showing the Chassis Ground- and the Jumper Field/Test Connectors

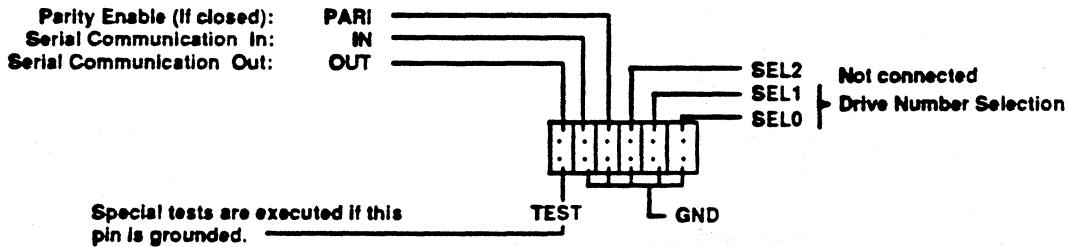
4.2. Strap Setting/Selecting Drive Number

Most of the TDC 3620/40/60 options are controlled by the EEROM and NOT by using the selection straps at the rear of the Drive. These options are described in the Software Interface part of this manual. (See Chapter 9, Section 9.3.5 Mode Select).

Only the functions and options which are unpractical to handle in this way are controlled by strap settings. The "multi-function" jumper field located at the Drive's rear end supports the following functions:

- Selection of Drive number
- Enabling/Disabling of the Parity Check
- Serial communication for adjustments and tests
- Test selection

The layout of the jumper/strap connector is shown below:



4.2.1. Selecting Drive Number

The factory default drive number setting is Drive 0. If the Drive has to be set up as a different unit number, the straps have to be connected according to the following table (Strap connected = CLOSED):

TEST	SEL2	SEL1	SEL0	Meaning
OPEN	OPEN	OPEN	OPEN	Select Drive 0
OPEN	OPEN	OPEN	CLOSED	Select Drive 1
OPEN	OPEN	CLOSED	OPEN	Select Drive 2
OPEN	OPEN	CLOSED	CLOSED	Select Drive 3
OPEN	CLOSED	OPEN	OPEN	Select Drive 4
OPEN	CLOSED	OPEN	CLOSED	Select Drive 5
OPEN	CLOSED	CLOSED	OPEN	Select Drive 6
OPEN	CLOSED	CLOSED	CLOSED	Select Drive 7

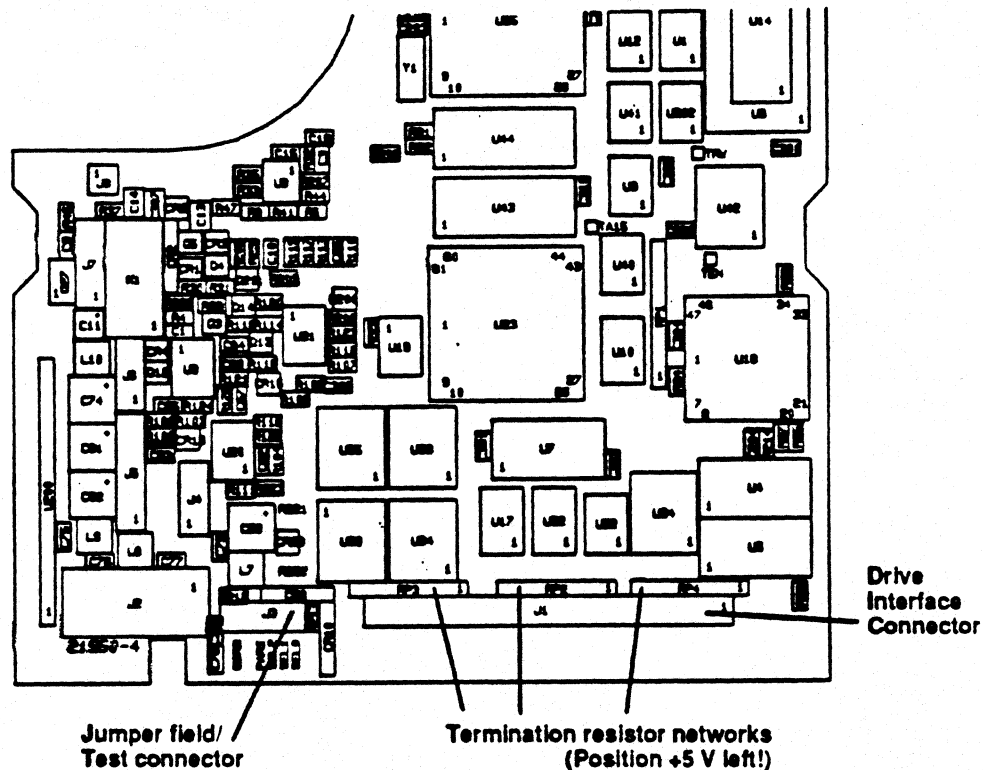


Figure 4.3 The TDC 3600 SCSI-Mainboard



4.2.2. Enable/Disable Bus Parity Checking

The Drive Parity Checking is enabled/disabled by means of a strap between the PARI-pin and GND (Ground). For more information see Section 9.7. Parity Error Handling.

4.2.3. External SCSI-bus Termination

Since the data cartridge is only specified up to 45°C, we recommend that the bus termination option inside the Drive is NOT used as this will cause unnecessary heat dissipation inside the Drive.

To avoid this, try to place the TDC 3620/40/60 Drive between other SCSI-devices on the SCSI-bus. However, if this is not possible, we suggest that the bus is terminated with a special flat-ribbon bus terminator which can be mounted at the end of the cable.

IMPORTANT!

Remember to remove the three single-in-line resistor networks inside the Drive when the Drive is NOT mounted at the end of the SCSI-bus or when external SCSI-bus termination is used! (See Figure 4.3 above).



4.2.4. Serial In/Out Communication

The IN and OUT signal pins are used to connect the Drive to certain test tools. In particular the serial communication is used for adjusting the Drive with the *TDT 370 BIRD Test System*.



4.2.5. Test Functions

The Drive has several test functions that easily can be started by setting up a specific code on the select straps (SEL0 - SEL2), and by grounding the TEST-pin during drive power-up. The coding are as follows:

TEST	SEL2	SEL1	SEL0	Meaning
CLOSED	OPEN	OPEN	OPEN	Drive without Sensor Bd.: Burn-In Test Complete Drive: Run-In Test
CLOSED	OPEN	OPEN	CLOSED	Acceptance Test/Selftest 2
CLOSED	OPEN	CLOSED	OPEN	Reserved for future use
CLOSED	OPEN	CLOSED	CLOSED	Reserved for future use
CLOSED	CLOSED	OPEN	OPEN	Reserved for future use
CLOSED	CLOSED	OPEN	CLOSED	Reserved for future use
CLOSED	CLOSED	CLOSED	OPEN	Production QA Reliability Test
CLOSED	CLOSED	CLOSED	CLOSED	Prod. QA Head and Motor Wear Test

The different tests are described in detail in Chapter 10, Section 10.1.2. The Manually Activated Selftests.

4.3. SCSI-Bus Interface Configuration

Figure 4.4 shows a typical SCSI-bus configuration making use of the Drive. In this system, each peripheral device has either a separate or an embedded interface-controller to make it compatible with the SCSI-bus specifications. The whole bus is connected to the Host via a special interface to allow other host operations while the SCSI-bus is busy.

In a SCSI-bus system (see Figure 4.4), the Host will activate a particular peripheral device when necessary. However, when needed, one of the other peripheral devices may take over the bus, acting as a temporary host until that particular operation is completed.

NOTE:

The Drive has built-in termination resistor network. This network **MUST** be REMOVED if the Drive is mounted in the middle of the SCSI-bus cable or if external bus termination is used. See Section 4.2.3. and Figure 4.3.

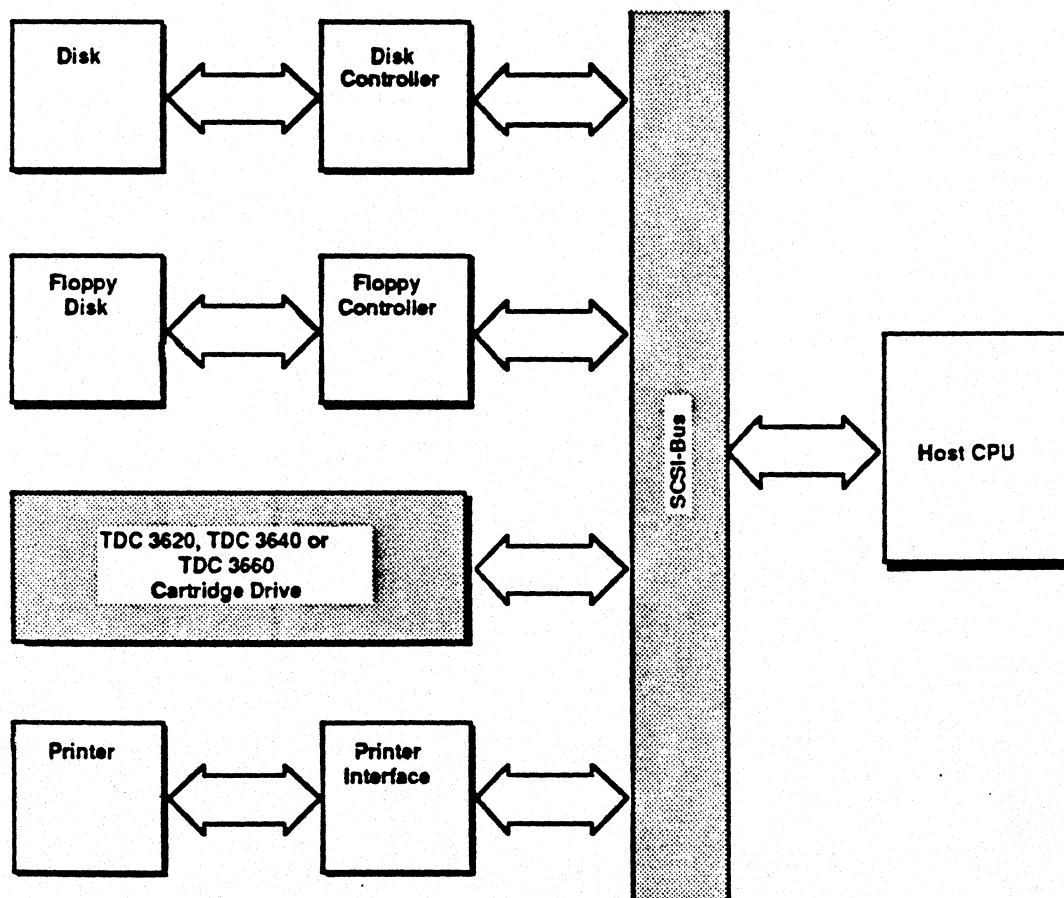


Figure 4.4 Block diagram of a system with SCSI-bus interface

4.4. Heat Dissipation

The Drive dissipates typically 15 W when running, and 2.25 W in stand-by. A part of this energy is dissipated in the cartridge itself while the tape is running. As a rule of the thumb, the base-plate temperature of a typical cartridge will increase about 7°C during the 10 minutes it takes to read or write a 450 feet tape at 90 ips.

NOTE:

To avoid unnecessary temperature build-up when the Drive is in the idle mode, i.e. when the tape is not running, power to the write- and read-circuitry is turned off.

The maximum allowed internal temperature in the Drive in operating mode is limited by the media. The specifications for the 3M cartridge is 5 - 45°C, humidity at 20 - 80 %, and maximum Wet Bulb temperature is set to 26°C. (See also Section 3.3.1).

Care should be taken at system level to provide sufficient cooling possibilities to meet the cartridge specifications above. It is of course of importance not to terminate the SCSI-bus inside the Drive as this will dissipate unwanted heat inside the drive unit. We recommend that the SCSI Drive is located in the middle position of the SCSI-bus; in which case NO Drive termination circuitry is required. See Section 4.2.3.

It is also possible to use specially designed bus-terminators on the cable itself.

IMPORTANT!

Do NOT cover the ventilation holes in the chassis when mounting the Drive! Note that mounting the drive top-flush against a flat surface will impede air flow!

It should be noted that in some applications it may be necessary to provide forced ventilation.

It is important that the cartridge operating specifications are not violated. Thus, when testing at system level the two following control points are recommended for temperature measurements:

1. **The air surrounding the head. (Close to the point where the tape touches the head-surface).**
2. **The air inside the cartridge. (Drill a small hole in the cartridge's plastic cover and insert the thermistor inside the cartridge).**

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5. Data Reliability

5.1. Summary

This chapter deals with data reliability. It starts with a general introduction including important points for the system designer, and then goes on to describe the algorithm employed during write- and read- operations when errors occur. The important message is that **ERRORS WILL OCCUR**, even in the best designed system, and the Drive is designed to deal with these errors in a very efficient way.

5.2. General Introduction

Data reliability

Data reliability is a function of many variables such as:

- **Tape and cartridge quality**
- **Head quality**
- **The design of the read- and write-electronics, including read clock circuit**
- **Capstan quality**
- **Capstan motor and servo system**
- **Quality of the mechanical locking system, the cartridge-guides and the head positioning system**
- **Quality of tape handling**
- **Drive mounting in the host chassis**
- **Cleaning and maintenance**
- **Cleanness of the air surrounding the Drive and tape**
- **Quality of the power-supply connected to the Drive**
- **Quality of the way data-errors are treated by the formatter**
- **Operating and storage environments**

Features given special attention

The Drive is designed and constructed for optimal quality to ensure a low error rate. Here are some of the features that have been given special attention:

- **The Drive mechanism is mounted on a rigid casting**
- **The locking mechanism ensures that the cartridge always locks in the same position**
- **The head screw ("worm-wheel") system is able to position the head within very narrow tolerances**
- **The write and the read channels incorporate many new features which improve the recording and reading on marginal tapes**
- **A very sophisticated and intelligent retry-algorithm that includes off-track alignment for reading marginal data blocks**
- **Power shut-down when the tape is not running**

Reduce the possibility of errors

However, it is very important that the system in which the Drive is to be mounted also is designed to reduce the possibility of errors:

- **Reliable mounting (no vibration)**
- **Good shielding and grounding to reduce influence from external electromagnetic fields**
- **Adequate ventilation**
- **Easy access to the head for cleaning purposes (preferably using the Tandberg Data TDC Cleaning Cartridge Kit)**

It is also very important that only high quality tapes are used. When they are not used, the tape cartridges should be stored in a place where temperature and humidity are within specifications. Avoid direct sunlight. A new tape or a tape that has been stored for a long time should always be run to EW and rewound to Load Point before the first write operation takes place. For best results, it is recommended that a wind/rewind operation is performed on all cartridges immediately after insertion. The Drive can be programmed to do this automatically. Prior to use, a cartridge should be kept for at least 24 hours in climatic conditions similar to those in which the Drive operates. (See also Section 5.5, Cartridge Conditioning and IMPORTANT-notice in Chapter 0).

With all these points in mind, it is important to remember that errors still occur, even on certified tape. The Drive is designed to handle these errors in the way described in the following paragraphs:

5.3. Write Mode

Data is immediately verified by a read-after-write check. The read channel has higher acceptance levels during this operation to detect marginal recordings. The Drive will verify that each block has got the correct Block Address, Block Marker and CRC character. The complete block is checked by using the CRC generator.

Checking list

The complete list of data checking is:

- **A CRC check is performed on each data block. The CRC polynomial has the following form:**

$$G(x) = x^{16} + x^{12} + x^5 + 1$$

Any single error burst of 16 bits length or less is detected by this code. 99.997 % of bursts of 17 bits length and 99.9985 % of bursts longer than 17 bits are also detected.

- **A minimum distance of 0.5 bit cells is required between adjacent flux transitions.**
- **A maximum distance of 4.0 bit cells is allowed between adjacent flux transitions.**

- All read data is checked against the coding table for GCR encoding. Any deviation from this table is marked as an error.
- For every block the Drive verifies (by reading) that the Block Marker and the Block Address is correctly recorded.

If blocks with errors are detected, the Drive tries to rewrite the bad blocks, up to 16 times if necessary, to eliminate the error. The bad blocks are not marked in any way, and may be detected as good blocks when read later. This procedure is described in detail in Section 6.8.

5.4. Read Mode

If a bad block is detected during read mode, the Drive first reads the two good blocks that follow to see if the first block has been rewritten. If it has, the bad block is just skipped.

Retry procedure

If a bad block is detected and the two good blocks that follow have higher block numbers, the retry procedure is employed:

- The Drive tries to read the bad block another two times.
- If still unable to read the bad block, it tries to read the bad block another two times, this time with the head moved a 1/4 track-width off center.
- If still unable to read the bad block, it tries to read the bad block another two times, this time with the head moved a 1/4 track-width off center in the opposite direction.
- If still unable to read the bad block, this whole procedure is repeated four times, i.e. the total number of Read Retries is 24 times, 8 times in center track position, 8 times in a 1/4 track-width off center position upwards and 8 times in a 1/4 track-width off center downwards.
- After 24 Read Retries without success, the Drive stops reading and reports a "Hard error". (Unrecoverable data).
- If the Read Retry procedure above succeeds with the head in a 1/4 track-width off center position, reading in this position is continued until End Of Track or until a new Read Retry sequence is started.

Only blocks which cannot be read after this procedure (24 retries) are marked as bad blocks.

NOTE:

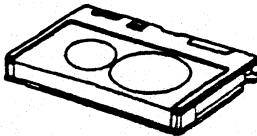
By definition, a "Hard Read Error" occurs only when a block cannot be read after the following sequence of operation:

- 24 rereads
- Head cleaning with the *TDC Cleaning Cartridge Kit* (or similar cleaning equipment)
- Complete retensioning of the tape
- Another 24 rereads

If two (or more) good blocks with the same block number are detected during read-mode (blocks which have been rewritten during write-mode), the data from the first good block is transferred to the Host. The contents of the other blocks with the same block number are just skipped.

5.5. Cartridge Conditioning

Conditioning rules



The achievable data reliability is depending on the tape and cartridge quality. In order to obtain the lowest error rate possible on a given cartridge, the cartridge should be conditioned according to the following rules before being used:

- **Before use the cartridge shall be conditioned by exposure to the actual operating environments for at least 4 hours. (Refer to Section 3.3.1 for the operating environment specifications).**
- **In Write Mode: Each time the cartridge is inserted in the Drive, the tape should be run one complete end-to-end pass (retension), prior to start of the write operation.**
- **In Read Mode: If an "Unrecoverable Read Error" occurs, the magnetic head should be cleaned, the tape should be run one complete end-to-end pass, and the read operation started once more and fall on the same block before this error is classified as permanently unrecoverable. (See also IMPORTANT-notice in Chapter 0).**

6. Track, Tape-format and Encoding Specifications

6.1. Summary

This chapter describes tape format, layout of each track, type of recording, and type of data encoding employed. Information about rewrite operations are included. The tape format conforms with the QIC-24, QIC-120 and QIC-150 Standards for data interchange. See *The QIC-24 and QIC-02 Standards, Revision D*, Part no. 402732, Publ. no. 5447, Section 3, *The QIC-120 Standard, Revision D*, February 11, 1987 and *The QIC-150 Standard, Revision I*, May 12, 1987.

NOTE:

The different drive versions reads (R) and writes (W) the various tape formats according to the following table:

	QIC-11*		QIC-24		QIC-120		QIC-150	
TDC 3620	R	W	R	W	-	-	-	-
TDC 3640	R	-	R	-	R	W	-	-
TDC 3660	R	-	R	-	R	W	R	W

* See IMPORTANT-notice below!

In this section the Industrial Standard QIC-24, QIC-120 and QIC-150 tape formats are described. QIC-24, QIC-120 and QIC-150 are the standard tape formats for the TDC 3620/40/60 Drives. Normally, the optional QIC-11 format is used only when it is necessary to read old QIC-11 formatted tapes. The main differences between the QIC-24/QIC-120/QIC-150 and the QIC-11 format are:

- No reference track is written on Track 0
- Only 1 byte available for block addressing (only 256 different block addresses)
- It is legal to terminate writing without a file mark as the last block

*** IMPORTANT!**

QIC-11 is NOT an Industry Standard and exists only in some - to a certain extent - incompatible versions. Although an (optional) extensive program is provided to allow reading of such tapes, the lack of standards makes it impossible for Tandberg Data to give any definite warranties regarding this optional QIC-11 read-compatibility. Depending on the actual QIC-11 version recorded on the tape - the TDC 3600 Series Drives may report higher error rates than specified for QIC-24/120/150 formatted tapes.

6.2. Track Specifications

The tape is recorded serially on nine tracks (TDC 3620/QIC-24) on fifteen tracks (TDC 3640/QIC-120) or on eighteen tracks (TDC 3660/QIC-150), one at a time.

Figures 6.1a, 6.1b and 6.1c show the track numbering for 9-, 5- and 18-track recorded tapes respectively.

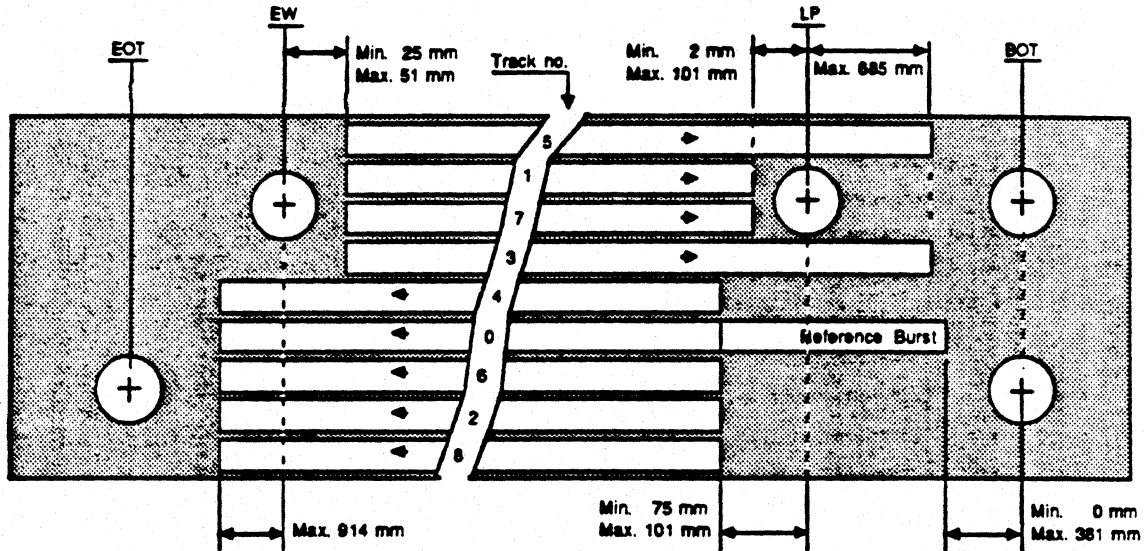


Figure 6.1a Track layout for the TDC 3620 Drive

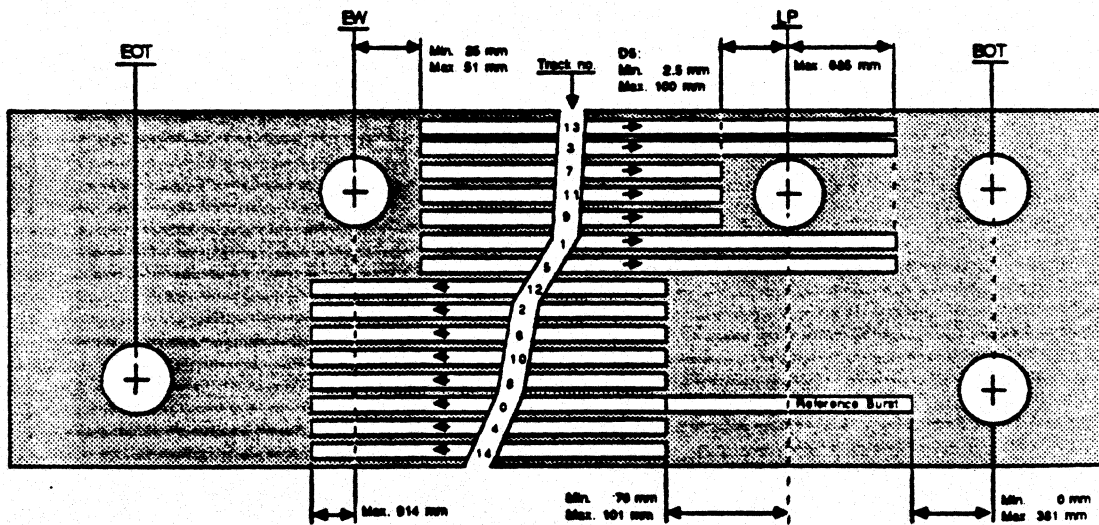
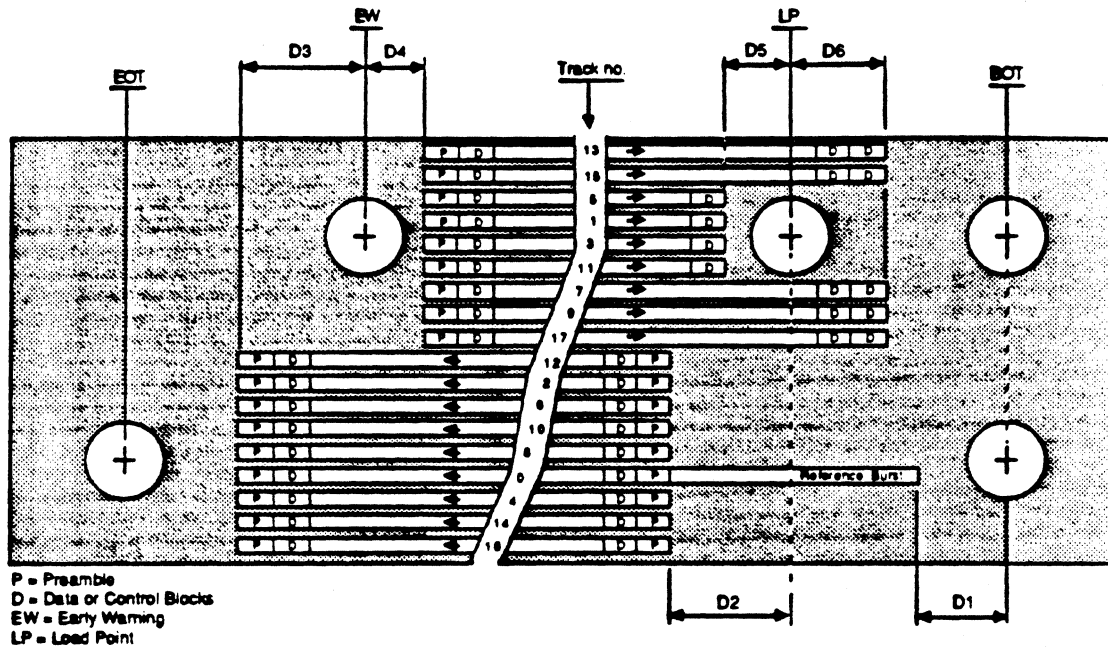


Figure 6.1b Track layout for the TDC 3640 Drive



Dimension	Minimum (Inches)	Maximum (Inches)	Description
D1	0	15	BOT to Start of Track Reference Burst
D2	3	4	Lead Point to End of Track Reference Burst and Start of Preamble on Even Tracks
D3	-	36	Early Warning to End of Data on Even Tracks
D4	1	2	Early Warning to Start of Preamble on Odd Tracks
D5	0.1	4	End of Data to Lead Point on Tracks 3, 5, 11 & 13
D6	-	27	Lead Point to End of Data on Tracks 1, 7, 9, 15 & 17

Figure 6.1c Track layout for the TDC 3660 Drive

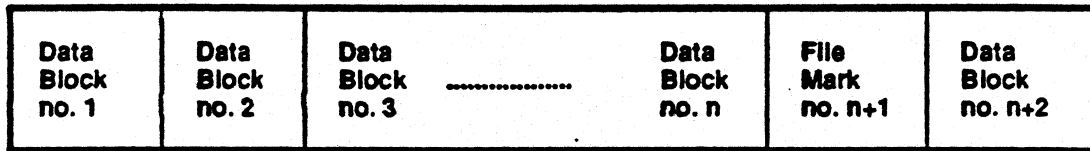
Recording is done serially on one track at a time, starting with Track 0. Even numbered tracks (0, 2, etc.) are recorded from BOT (Beginning Of Tape) towards EOT (End Of Tape), while odd numbered tracks (1, 3, etc.) are recorded from EOT towards BOT.

When writing from BOT on Track 0, all tracks are simultaneously erased.

A Reference Burst Signal is recorded between BOT and a fixed distance beyond the LP-hole on Track 0.

6.3. Track Format. QIC-24, QIC-120 and QIC-150

Each track contains data blocks, control blocks and possibly file mark blocks as shown in Figure 6.2. (The QIC-120 Standard does not allow control blocks to be written on the tape).



Recording direction 

Figure 6.2 Track formats QIC-24, QIC-120 and QIC-150

Each data block contains 512 bytes of encoded data. A file mark block contains 512 bytes of a unique data pattern.

The layout of each block is described in Section 6.7.

Data-, control- and filemark blocks are recorded without the usual interblock gaps employed in normal block-mode tape recording.

6.4. Recording Method

Information is recorded on the tape using the NRZ1 (NON-RETURN to ZERO, change on ONES) method where each "1" bit is recorded as a flux reversal. "0" bits give no flux transitions on the tape, but are detected by measuring the distance between "1" bits (flux reversals). To avoid long distances on the tape without any flux changes (strings of "0" bits only), the information to be recorded is encoded according to the 0,2 GCR rules. This ensures that the maximum distance between two flux reversals is three bit cells (...1001...).

6.5. Data Encoding; 0,2 GCR Rules

Prior to the recording, the information to be recorded is encoded according to the 0,2 GCR (Group Coded Recording) rules. The operation is as follows:

- A byte is defined as eight bits, numbered from B0 to B7. B7 is the most significant bit.
- Each byte is separated into two nibbles, each nibble containing four bits.
- Nibble 1 contains the four least significant bits, from B0 to B3.

- Nibble 2 contains the four most significant bits, from B4 to B7.

Byte: B7 B6 B5 B4 B3 B2 B1 B0

Nibbles: Nibble 2 Nibble 1

- Each nibble is then encoded into a 5-bit word according to table 6.1.

Thus, by using this table, each byte of information is translated into a 10-bit word consisting of bits E0 to E9.

Information byte: B7 B6 B5 B4 B3 B2 B1 B0

Translated to: E9 E8 E7 E6 E5 E4 E3 E2 E1 E0

Table 6.2 shows the conversion from GCR to normal data nibbles.

Nibbles 1 and 2					Encoded Information				
B7	B6	B5	B4		E9	E8	E7	E6	E5
B3	B2	B1	B0		E4	E3	E2	E1	E0
0	0	0	0	->	1	1	0	0	1
0	0	0	1	->	1	1	0	0	1
0	0	1	0	->	1	0	0	1	0
0	0	1	1	->	1	0	0	1	1
0	1	0	0	->	1	1	1	0	1
0	1	0	1	->	1	0	1	0	1
0	1	1	0	->	1	0	1	1	0
0	1	1	1	->	1	0	1	1	1
1	0	0	0	->	1	1	0	1	0
1	0	0	1	->	0	1	0	0	1
1	0	1	0	->	0	1	0	1	0
1	0	1	1	->	0	1	0	1	1
1	1	0	0	->	1	1	1	1	0
1	1	0	1	->	0	1	1	0	1
1	1	1	0	->	0	1	1	1	0
1	1	1	1	->	0	1	1	1	1

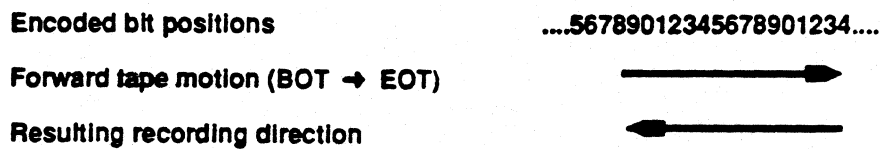
Table 6.1 GCR encoding table

Encoded Information					Nibbles 1 and 2				Hex Value	
E9	E8	E7	E6	E5	B7	B6	B5	B4		
E4	E3	E2	E1	E0	B3	B2	B1	B0		
0	0	1	0	1	->	Data Field, File Mk. Blks.				
0	0	1	1	1	->	Block Marker (E4-E0)				
0	1	0	0	1	->	1	0	0	1	9H
0	1	0	1	0	->	1	0	1	0	AH
0	1	0	1	1	->	1	0	1	1	BH
0	1	1	0	1	->	1	1	0	1	DH
0	1	1	1	0	->	1	1	1	0	EH
0	1	1	1	1	->	1	1	1	1	FH
1	0	0	1	0	->	0	0	1	0	2H
1	0	0	1	1	->	0	0	1	1	3H
1	0	1	0	1	->	0	1	0	1	5H
1	0	1	1	0	->	0	1	1	0	6H
1	0	1	1	1	->	0	1	1	1	7H
1	1	0	0	1	->	0	0	0	0	0H
1	1	0	1	0	->	1	0	0	0	8H
1	1	0	1	1	->	0	0	0	1	1H
1	1	1	0	1	->	0	1	0	0	4H
1	1	1	1	0	->	1	1	0	0	CH
1	1	1	1	1	->	Block Marker (E9-E5)				

Table 6.2 GCR to data nibble conversion

6.6. Recording Sequence

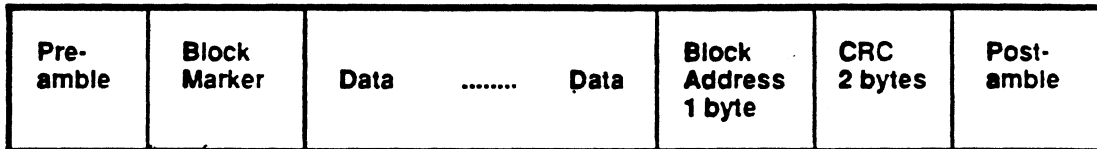
The encoded information is recorded serially by encoded bit and by character, starting with bit E9 in each character. Tracks are recorded in a sequential order, starting with Track 0.



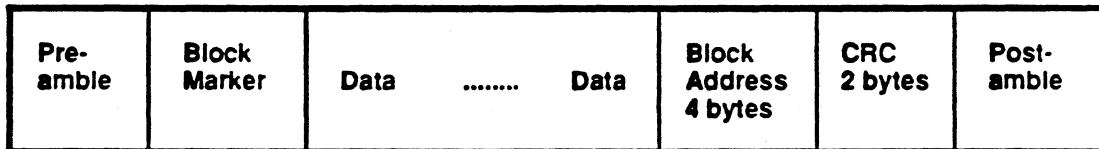
6.7. Block Layout QIC-11 and QIC-24/QIC-120/QIC-150

All blocks, whether it is a data block, a file mark block or a control block have the same layout, shown in Figure 6.3 below:

QIC-11:



QIC-24/QIC-120/QIC-150:



Recording direction 

Figure 6.3 Block layout

6.7.1. Preamble

The Preamble consists of a recording at the highest recording density, nominally 394 fipmm (10 000 fpi). The Preamble is used to synchronize the VCO (Voltage Control Oscillator) in the read electronics with the data frequency. Three preamble types are recorded: Normal, Elongated, and Long.

Normal Preamble

The Normal Preamble is recorded at the beginning of every block on the track, except for:

- The first block on the track
- The first data block on a track
- The first block after a file mark
- The first block after a buffer underrun or data append situation

The Normal QIC-24 Preamble consists of at least 120 but no more than 300 flux transitions recorded at the highest recording density. QIC-120/150: Min. 160, max. 300 flux transitions.

Elongated Preamble The Elongated Preamble is recorded at the beginning of a block following a file mark, control block or the first block after an underrun or a data append sequence. It contains a minimum of 3 500 and a maximum of 7 500 flux transitions for QIC-24, recorded at the highest recording density. For QIC-120/150: Min. 5 500, max. 8 500 flux transitions.

Long Preamble The Long Preamble is recorded at the beginning of the first block on every track. It contains a minimum of 15 000 and a maximum of 30 000 flux transitions, recorded at the highest recording density.

6.7.2. Block Marker

The Block Marker identifies the end of the preamble and the beginning of the data field on every block. It consists of a fixed bit pattern:

E9	E8	E7	E6	E5	E4	E3	E2	E1	E0
1	1	1	1	1	0	0	1	1	1

Bit E9 is recorded first.

6.7.3. Data

The data field in each block is fixed. It comprises 512 bytes, encoded according to the rules given in Section 6.5. The data field is used as follows:

Data Blocks The data field contains 512 encoded data bytes for data interchange.

File Mark Blocks The data field contains 512 bytes with a fixed encoding as follows:

E9	E8	E7	E6	E5	E4	E3	E2	E1	E0
0	0	1	0	1	0	0	1	0	1

6.7.4. Block Address

The Block Address contains four bytes, encoded according to the rules given in Section 6.5. The layout of the Block Address is shown in Figure 6.4 below.

Byte 0 contains the Track Number. Byte 1 is split into two nibbles. The most significant of these two nibbles (bits 7, 6, 5, and 4) contains the Control Nibble. The least significant of the two nibbles is the most significant nibble of the Block Number. Byte 2 and Byte 3 contain the rest of the Block Number, Byte 3 being the least significant byte.

Byte 0	Byte 1	Byte 2	Byte 3
Track Number	Control Nibble	Block Number	

Figure 6.4 Block address layout

Track Number

The Track Number is a binary number, encoded according to the rules given in Section 6.5.

Control Nibble

This is the most significant nibble of byte 1 in the Block Address. It is encoded according to the rules given in Section 6.5:

The control nibble has the following layout:

Byte 1	
7 6 5 4	
0 0 0 0	Normal Data Block or File Mark Block
0 0 0 1	Normal Control Block
0 0 1 0	QIC-150 Control Block

The other 12 bit combinations are reserved for future use.

Block Number

The Block Number is a 20-bit binary number (least significant nibble of byte 1, byte 2, and byte 3). The first block on the tape is numbered 0 0 1 and the following blocks are numbered sequentially. The numbering system is not reset at the end of each track and it is independent of the type of block being recorded.

The layout of the Block Number bits is as follows:

	Byte 1	Byte 2		Byte 3	
	3 2 1 0	7 6 5 4	3 2 1 0	7 6 5 4	3 2 1 0
First Block	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 1
Second Block	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 1 0
...
Last Block	1 1 1 1	1 1 1 1	1 1 1 1	1 1 1 1	1 1 1 1

Figure 6.5 Layout of Block Number

The Block Number is encoded according to the rules given in Section 6.5.

The Block Number is incremented by one for each block written on the tape. The only exception to this rule is when a block has to be rewritten. That block will then keep the same number; regardless of how many times it is rewritten.
See Section 6.8.

6.7.5. CRC (Cyclic Redundancy Check)

Immediately following the Block Address, a Cyclic Redundancy Check (CRC) character is recorded, using the following polynomial:

$$G(x) = x^{16} + x^{12} + x^5 + 1$$

The CRC generation is performed prior to the byte encoding starting with the most significant bit in the first byte in the Data field, ending with the least significant bit of the Block Number.

The two CRC bytes are encoded according to the rules described in Section 6.5 and recorded with the most significant bit (bit 15) first.

All CRC bits are set to "1" prior to the generation.

6.7.6. Postamble

The Postamble is recorded at the maximum density of nominally 394 ftpmm (10 000 ftpi) for the QIC-11/24 format and 492 ftpmm (12 500 ftpi) for the QIC-120 format.

Two different versions of Postamble may be recorded: The Normal Postamble or the Elongated Postamble.

The Normal Postamble

The Normal Postamble contains a minimum of 5 and a maximum of 20 flux transitions, recorded at the maximum flux density. The Normal Postamble is recorded immediately after the CRC character in every block, except for those blocks where an Elongated Postamble has to be recorded.

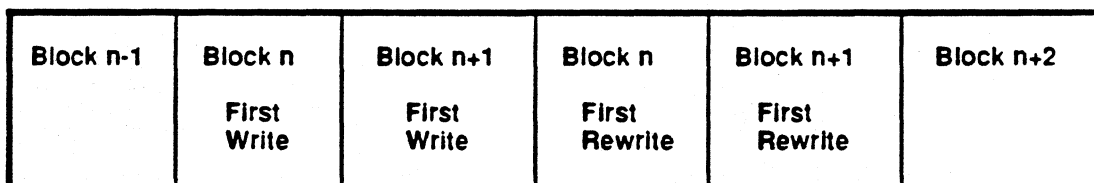
The Elongated Postamble

The Elongated QIC-24 Postamble contains a minimum of 3 500 and a maximum of 7 000 flux transitions, recorded at the maximum flux density. For QIC-120/150: Min. 5 500, max. 8 500 flux transitions.

The Elongated Postamble is recorded instead of the Normal Postamble whenever an underrun situation occurs.

6.8. Rewriting of Blocks

During write operations, the Drive performs a read-while-write test on the recorded data, using more stringent acceptance rules than for a read-only operation. Due to bad spots on the tape or other errors, some blocks may be detected as bad (one or more flux reversals not detected correctly). These bad blocks are automatically rewritten further down the tape as shown in Figure 6.6.



Recording direction 

Figure 6.6 Track layout after rewriting of bad blocks

In Figure 6.6, let us assume that block n is found to be bad. This will happen while the Drive is writing block n+1. The Drive completes this block, and then rewrites block n and n+1. The system proceeds as usual if the new block n is accepted by the read verification logic. If not, the operation is repeated up to 16 times if necessary. The Drive stops writing if it has not been able to record a block correctly after 16 retries, and the Host is informed that a fatal write error condition has occurred (Write Abort).

If the Drive, while writing a block, finds out that the block is bad, the block will immediately be rewritten (without completing the writing of the next block). This will normally only happen when errors occur at the beginning of the block.

Thus, any blocks detected as bad means that one or two blocks are rewritten, either the bad block and the following one, or only the bad block. A system may be able to read correctly blocks which have previously been rejected and rewritten. This does not cause problems since the Drive has complete control over each block by reading the Block Address. If two or more good blocks with the same block number are detected, the Drive will only transfer the data contents of the first of these blocks to the Host.

6.9. File Mark Blocks

File Mark Blocks are used to separate logically different sections of data. This is controlled from the Host. The QIC-24, the QIC-120 and the QIC-150 proposals also define a file mark to be recorded at the end of the recorded area. The Host should issue a Write File Mark command at the end of the recording sequence.

The contents of the data field in the file mark block is not transferred to the Host.

File marks are numbered, verified and (if necessary) rewritten in the same way as all the other block types.

6.10. Control Blocks

The Drive handles two different types of Control Blocks:

Normal Control Block (Control nibble = 1)

This vendor-unique Control Block will only be written if both the following cases are present:

- * A Copy Command is issued for backup of data.

and

- * An odd number of 256-byte blocks is requested from the hard-disk.

The Variable Block length Control Block is used to inform the Drive during Read or Restore that the following 512 byte data-block has only 256 valid bytes. The remaining 256 bytes will have been filled with zeroes during Write and will be ignored during Read.

QIC-150 Control Block (Control nibble = 2)

Track 0 is almost in the same physical position on the tape for both QIC-120 and QIC-150 formatted tapes. To make the Drive able to differentiate between the two (15- or 18 tracks), a unique Control Block will always be written as the first block on all QIC-150 (18 track) formatted tapes.

This is done by the Drive when it is selected to write 18 tracks. It is redundant to the Host and it is used by the Drive only during reading. The Control Block is NEVER transferred to the Host.

NOTE:

The Host can NOT write any control blocks. They are written by the Drive firmware and used only internally by the Drive.

6.11. Gaps

Except for the areas around the BOT, LP, EW, and EOT holes, no erased gaps are generated as part of the tape format. After completing the postamble of one block, the recording of the preamble of the next block is started immediately.

In Figures 6.1a and 6.1b, the areas not marked as tracks or reference signals are normally erased. This is especially important in the BOT area below the Reference Burst signal.

Erased areas may occur on a track due to defects on the tape, write current turn-on or turn-off, etc. These gaps are treated by the formatter in the same manner as drop-outs.

6.12. Reference Burst

A Reference Burst is recorded between the BOT holes and a certain distance after the LP-hole on Track 0. It is recorded at the maximum flux density (nominally 394 fpmmm or 10.000 ftpi). It starts at minimum 0 mm, maximum 380 mm (15") after the BOT holes and its extent is minimum 75 mm (3"), maximum 100 mm (4") beyond the LP hole. The Reference Bursts are used during read operations to determine the exact track location.

6.13. Termination after Underrun

During write operations, situations may occur where the Host is not able to keep up streaming.

When the buffer is empty and the Drive is not configured for "forced streaming" (see Mode Select, Section 9.3.5), the Drive will complete the writing and verification of the last block and then write an Elongated Postamble. Then the tape motion is stopped.

If the "forced streaming" option is used, the last block will be rewritten until new data is ready in the buffer, or until the limit for rewrites is reached. In this case an Elongated Postamble is written and the tape is halted.

The Elongated Postamble will always be recorded at the end of a write operation, also after the last File Mark.

6.14. Data Append

After a write underrun situation (see Section 6.13), or when the Host wants to append data to a recorded cartridge, the Drive will start the operation by looking for the last block. Then the recording will start with an elongated preamble. For QIC-24 the recording starts a minimum of 3 000 and a maximum of 3 500 flux transitions from the end of the CRC-character in the last block. Due to the elongated postamble after the previous last block, this ensures a minimum overlap between the postamble and the new preamble. For QIC-120/150: Min. 4 000, max. 5 000 flux transitions.

6.15. Recording of Even Numbered Tracks

All even numbered tracks are recorded in the direction from BOT to EOT. The recording starts somewhere between 75 mm (3") and 100 mm (4") after the LP-hole. The first block on every track is preceded by a long preamble.

No data for interchange will be recorded beyond a point 914 mm (36") past the EW-hole.

6.16. Recording of Odd Numbered Tracks

All odd numbered tracks are recorded in the direction from EOT to BOT. The recording starts somewhere between 25 mm (1") and 50 mm (2") after the detection of the EW-hole. The first block on every track is preceded by a long preamble.

On Tracks 1 and 7 no data for interchange is recorded past the LP-hole. The last block of data for interchange written on these tracks prior to switching to the next track is recorded somewhere between 2.5 mm (0.1") and 100 mm (4") before the LP-hole measured from the center of the hole.

On Tracks 3 and 5, data may be recorded past the LP-holes. No data for interchange will be recorded beyond a point 685 mm (27") past the LP-hole.

For the QIC-120 format, the distance D5, from End of Data to Load Point on the reverse Tracks 13, 3, 7, 11, 9, 1 and 5 is shown in paragraph 6.2 Track Specifications, Figure 6.1b: D5 may vary from 0.1" (2.5 mm) to 4" (100 mm).

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7. Basic Operational Functions

7.1. Reference Track

During Read and Write operations the tape format defines the different track positions. When a tape is written, a Reference Track and the track positions are always written according to one of the standards the Drive is able to write. When a tape is read, the current tape format is always detected before the Drive can position the head at Track 0 and start the Read operation.

The position and size of the Reference Track determines the current tape format. For those formats without Reference Track, the Drive will search the data area for datablocks. The size and position of datablocks will set the current format.

Usually the TDC 3600 Series Drive is able to read more tape formats than it is able to write.

The TDC 3620 the TDC 3640 and the TDC 3660 are equipped with different read/write heads. This makes it impossible for all drives to both read and write all tape formats.

Writing of- and searching for the Reference Track are done internally in the Drive. Both functions are completely transparent to the Host.

7.1.1. Write Reference Track

If the tape is positioned at Beginning Of Tape, the Write Reference Track function is always performed after a Write command is received. The Write Reference Track is done internally in the Drive and is transparent to the Host. The Reference Track is placed between the BOT (Beginning Of Tape) holes and the LP (Load Point) holes and can later be used during Read to detect the tape format and position of Track 0. For the QIC-150 tape format the Drive will also write a unique control block as the first block on the tape.

The physical position of the Reference Track is referred to the *lower tape edge*. To find the tape edge, the Drive will perform a "Seek Tape Edge" function. This function is based upon the fact that data is written and read simultaneously. If the head is moved up to the tape edge from a lower position, the signal from the Write Channel will be detected in the Read Channel when the read/write head enters the tape edge. From this position the offset to the Reference Track is known.

The standard followed by the the Drive during Write Reference Track is determined by type of drive and the selected tape format:

- The TDC 3630 can write only QIC-24 tape format
- The TDC 3640 can write only QIC-120 tape format
- The TDC 3660 can write both QIC-120 and QIC-150 tape formats

Different
Read/Write
Heads

Refer to the Lower
Tape Edge

QIC-24, QIC-120 or
QIC-150 Standard

7.1.2. Read Reference Track

If the tape is positioned at Beginning Of Tape, the Read Reference Track function is always performed after receiving a Read command. The Read Reference Track is done internally in the Drive and is transparent to the Host. The position and size of the Reference Track will determine the tape format.

Compared to the Write Reference Track, the Read Reference Track is quite more complex. This is due to the various tape formats that can be read by one drive. Furthermore, for the QIC-11 format, both 4 and 9 track tapes are written without a Reference Track. For these tape formats, it is necessary for the Drive to read datablocks to determine if it is one of these tape formats.

Readable Tape
Formats are:

TDC 3620: QIC-11 (4 or 9 tracks) + QIC-24

TDC 3640: QIC-11 (4 or 9 tracks) + QIC-24 + QIC-120 (+ QIC-150)

TDC 3660: QIC-11 (4 or 9 tracks) + QIC-24 + QIC-120 + QIC-150

TDC 3620

A TDC 3620 Drive can read neither QIC-120 nor QIC-150 tape formats because of the physical size of the read head.

TDC 3640

A TDC 3640 Drive may be able to read QIC-150 format, but because of different tolerance in head position there will be no guarantee that the QIC-150 actually can be read.

During a seek Reference Track, the Drive will use the following scheme to detect the tape format (See NOTE *):

- After power-up the Drive will calibrate the head position by entering the highest possible position. From this position the offset to any tape position can be calculated relatively accurate. Before any Read operation is performed, the head can be positioned approximately at the position where the Reference Track should be.
- If the Drive is a 15 or 18 track drive, and the cartridge is at least 600 ft. long, the Drive will start looking for the QIC-120 and QIC-150 Reference Track. (The QIC-120 and QIC-150 tape formats have the Reference Track in the same position. Only a unique *Control Block* - positioned as the first block on the QIC-150 tape - separates the two).
- If not a QIC-120 or QIC-150 tape, the Drive will search for a QIC-24 Reference Track.
- If not QIC-24, the Drive will search for data located after the LP (Load Point) holes on the tape. If data is found, it must be QIC-11 format. Depending on track position and width it is either 4 or 9 track tape format.

NOTE *):

Internally the TDC 3620, TDC 3640 and TDC 3660 Drives are equipped with the same firmware. Only the head type determines the drive functionality.

7.2. Write Data and Filemarks

The positions in which data or Filemarks can be written will be explained in the following sections. Normally a Write Data or Write Filemark command can not be performed in other positions than those described.

The Drive will have to position correctly and write at least one block after having performed either a Write Data or a Write Filemark command. Datablocks and Filemarks are equal in size. According to this - both Write Data and Write Filemark commands are treated equally.

7.2.1. Write From Beginning of Tape

If the Drive is positioned at Beginning Of Tape, and receives a Write command, the following functions will be performed internally in the Drive:

- First the Drive will assure that a cartridge is inserted. The cartridge can not be write-protected, and must be of a quality that can be written on the actual drive.
- A Reference Track - according to the type of drive and the chosen tape format - is written on the tape.
- Because the Drive will write data on the first track (Track 0), the Drive also enables the Erase function. This assures that old data on the tape is erased in front of the write head.
- The number of datablocks according to the Write command is written when the data is received into the drives internal data buffer.
- After the Drive have finished writing the first track on the tape, the Erase function is disabled. (This is done because the Erase function will erase all tracks in the first pass).
- The Drive may continue to write data on the following tracks.
- All track changes are transparent to the Host.

7.2.2. Write From a Position on the Tape

When Write Data or Filemark commands are continuously given from Beginning Of Tape, the Drive will write data and Filemarks continuously. No extra handling is necessary.

If the cartridge is not written continuously from Beginning Of Tape, but data is to be appended to an already written tape, the following must be performed:

- The Host must position the tape at EORA (End Of Recorded Area) before the Write function can be executed.

Positioning the tape at EORA means that the Drive has read past all the datablocks and Filemarks in front of the EORA, and also read past this position, resulting in the CHECK CONDITION with BLANK CHECK in the Sense Key.

7.2.3. Terminate Write From a Position on the Tape

A single- or sequences of Write Data or Write Filemark commands can be terminated at any position on the tape.

A termination is true if any other command that repositions the tape - except new Write commands - is performed.

If the termination is on the first track, the Drive will automatically erase 45 inches of tape after the last written block before executing the next command. This is done transparently to the Host and assures that the End Of Recorded Area can be detected unambiguously at Read time, even if the tape contained data before the Write operation.

7.2.4. Terminate Write at Physical End Of Tape

During Write Data or Write Filemark, the tape may enter the Physical End Of Tape. The Write operations must be terminated and the situation must be handled according to the following procedure:

- If the tape passes the position denoted as "Pseudo Early Warning" (PEW), the Drive will inform the Host by a CHECK CONDITION. The PEW-point is a position calculated to be approximately 50 inches in front of the Early Warning hole on the tape.
- At the PEW-position, the Host can be sure that all data transferred to the Drive will be correctly written to the tape. This position must be regarded as the absolute limit for normal Write operations.
- However, the Host may continue to write a few datablocks or Filemarks on the tape. This termination can consist of specific data blocks or Filemark combinations containing tape identification, directories etc. Even not required by the Drive according to the QIC-24, QIC-120 and QIC-150 tape formats, a tape must always be terminated with at least one Filemark.
- At the position between PEW and Physical End Of Tape the Drive will report CHECK CONDITION and Sense Key = INSUFFICIENT CAPACITY after each Write command even if the Write command was executed properly.
- If the Host continues to give Write commands, the Drive will sooner or later reach the Physical End Of Tape. In this position the Drive will report CHECK CONDITION with Sense Key = MEDIUM ERROR and no more data can be written.
- Theoretically there might be room for at least 200 KBytes of data from the Pseudo Early Warning (PEW) point to the Physical End Of Tape.

7.2.5. Terminate Write at Physical End Of Tape - Executing the Copy Command

During execution of the Copy command the Drive operates as an Initiator towards the direct access device. If backup is performed, the flow of data runs *from* the direct access device *to* the Drive. The Drive will therefore not send Read Data commands to the direct access device that the Drive is not able to read. The following procedure is used during the Copy command backup:

- The Drive detects the direct access device block size (see Section 9.3.1. Copy command). Then the Drive issues Read Data commands. These commands will not transfer more than 32 KByte of data in each batch. The size of each transfer is configured by the Copy Threshold.
- If the Pseudo Early Warning (PEW) point is passed during execution of a Read command, the Drive will continue the current Read operation until all datablocks have been read. At this point the Copy command is aborted and the Drive informs the Host with CHECK CONDITION.

7.2.6. Recoverable Write Error (Rewrite)

During Write, defective blocks may be written. These erroneous blocks are detected by the Drive's built-in Read After Write function.

Errors are detected by using the so-called CRC (Cyclic Redundancy Check) algorithm during Read. This CRC result is compared with a CRC value - written on the tape during Write.

Due to the physical position of the read head, the Write error will not be detected until after the Drive has started to write the next block. The block containing the error will not be written before after the current block is written.

If Block N is written with an error, the following blocks will be written to the tape:

Block N-1	Block N	Block N+1	Block N	Block N+1	Block N+2
	First Write - Contains Error	Ordinary Write	First Rewrite	Next Continuous Block No.	

Recording direction

Figure 7.1 Track layout after rewriting of bad blocks

According to the QIC-standards the tape must always contain good blocks in an increasing order. This is why Block N+1 (see Figure 7.1) has to be written once more after Block N has been correctly written.

Due to the nature of the Recoverable Write Error, this is in fact *not an error*, but should be referred to as a Rewrite.

One specific block may be rewritten 16 times without any action from the Host.

The Rewrite procedure is totally transparent to the Host.

7.2.7. Unrecoverable Write Error

If the Drive has tried to rewrite the same block 16 times without succeeding, the Drive will abort the Write command and send CHECK CONDITION.

This should be treated as a fatal error situation where either the Drive or the tape-cartridge is failing due to damage.

7.3. Read Data and Filemarks

A brief overview of the functionality of the Read command will be given in this section. For more details about error situations and error messages (see Section 9.3.8. Read).

Please notice that data and Filemark blocks are written with separate Write commands. During Read Data, Filemarks are treated as special message blocks, and are reported with CHECK CONDITION. However, Filemarks can be read with its own command (see Section 9.3.19. Space). During Read Filemarks, datablocks are not treated as erroneous blocks, but skipped instead.

Despite that Filemarks are reported with CHECK CONDITION, detection of Filemarks is not to be regarded as an error situation.

7.3.1. Read From Beginning of Tape

If a Read command is performed from the beginning of the tape, the Drive will always start with Seek Reference Track. If a Reference Track or QIC-11 tape format is found, the Drive will start reading according to the current tape format. See further details about the Seek Reference Track operation in Section 7.1.2. Read Reference Track. This seek operation is fully transparent to the Host.

7.3.2. Read From a Position on the Tape

A Read command can be executed from any position on the tape.

At any position - except Beginning Of Tape - the track position is known from the previous commands. A new Seek Reference Track is not necessary and will not be performed.

7.3.3. Read Until Logical End Of Tape

The Read Data commands can be given continuously until the tape enters the Logical End Of Tape position. This is a situation that will occur if the tape was not completely filled up, but terminated before the Physical End Of Tape.

The Logical End of Media is the point where no more data is present, and the tape contains at least 45 inches of erased tape following the last block.

The Logical End Of Tape is reported with a CHECK CONDITION.

7.3.4. Read Until Physical End Of Tape

If a tape has been written to Physical End Of Tape, the same tape can be read to Physical End Of Tape. At this point no more data can be read.

The Host will not be informed when reading past the Pseudo Early Warning (PEW) or Early Warning (EW) point.

The Physical End Of Tape is reported with CHECK CONDITION.

7.3.5. Read Until Physical End Of Tape - Executing the Copy Command

Unlike the Write Data to Tape during Copy backup, the Read Data from the tape during Copy restore do not have to handle the possible problem that all data in the Data Buffer must be written on the tape.

A number of blocks will be read correctly if they were correctly written. No special care or action has to be taken.

This situation is equal to the one described in Section 7.3.4. Read Until Physical End Of Tape.

7.3.6. Recoverable Read Error (Reread)

During Read, the Drive may read a block containing a CRC error. Because this block may be rewritten, the Drive will continue to search for this block. If the block is rewritten due to an error detected during Write, the block will be read correctly and the Read routine will continue.

If the block is not detected - and the block numbers are increased showing that the block is not rewritten - the following Reread algorithm is performed:

- The Drive will reposition and try to read the same block twice.
- The Drive will move the head 1/4 track-width upwards and try to read the same block twice.
- The Drive will position the head 1/4 track-width downwards and try to read the same block two times.

This procedure can be repeated 4 times, resulting in up to 24 retries on the same block. Once the block is read without any error, the Drive will continue to read the following blocks.

The Reread procedure is totally transparent to the Host.

7.3.7. Unrecoverable Read Error

If the Drive has tried to reread the same block 24 times, see Section 7.3.6., it will abort the Read command and send CHECK CONDITION. This should be treated as a fatal error situation where the tape is either not correctly written, is damaged in some way, or the Drive is not operating properly.

8. Hardware Interface

8.1. Power Interface

Power for the Drive is provided through a 4-pin connector. The connector type is AMP 172296-1 or equivalent. The same type is used as power connectors for 5 1/4" diskette drives and 5 1/4" fixed disk drives. The recommended mating connector is AMP 1-480424-0 using AMP 60619-1 or equivalent.

It is not necessary to keep the Reset line active during power-on, since an internal power-on reset signal is generated automatically. However, the Reset line should be active during power-up if spurious commands may be issued from the host interface during the power-on period.

8.2. Introduction to the Signal Interface

The Drive interfaces to a host adapter according to the proposed ANSI X3.131 Standard (SCSI), Rev. 17B, 1986. The SCSI-bus consists of 18 signal lines. Nine control the bus; nine are used for an eight-bit bidirectional data interface with odd parity. All communication on the bus is performed synchronously by means of the REQ/ACK-handshake. The Drive should be connected to the bus with a 50-pin flat-ribbon connector. Single ended drivers and receivers allow a maximum cable length of six meters (20 feet). The SCSI Hard Reset option is implemented.

8.3. Definition of Terms

The following terms are widely used:

Asserted Signal	A signal which is driven to the logical 1 state. In this document an asserted signal is always shown in "high level".
Bus Device	A host computer or peripheral CONTROLLER which can be attached to the SCSI-bus.
CDB	Command Descriptor Block.
Connect (Select)	This function occurs when an INITIATOR selects a TARGET to start an operation.
Controller	A SCSI-BUS DEVICE (a typical TARGET) which controls one or more PERIPHERAL DEVICES.
Deasserted Signal	A signal which is driven to the logical-0 state.
Disconnect	This function occurs when a TARGET releases control of the SCSI-bus, allowing the bus to become free.
Initiator	A BUS DEVICE which requests an operation to be performed by another BUS DEVICE.
LUN	Logical Unit Number within a device.

Peripheral Device	An I/O Device such as a disk, printer or streaming tape unit.
Reconnect	This function occurs when a TARGET selects (Reselect) an INITIATOR to continue an operation after a DISCONNECT.
Target	A BUS DEVICE which performs an operation requested by an INITIATOR.

8.4. Electrical Interface

All signals are active low and use open collector drivers. The bus should be terminated in both ends with 220 ohms to +5 V and 330 ohms to ground. (See NOTE in Section 4.3).

The signals from the Drive to the controller have the following output characteristics:

- Signal assertion (logical 1): Signal between 0.0 and 0.4 V with 48 mA sinking capability.
- Signal deassertion (logical 0): Signal between 2.5 and 5.25 V.

The signals from the Initiator to the Drive must have the following characteristics:

- Signal assertion (logical 1): Signal between 0.0 and 0.8 V with 0.4 mA input load.
- Signal deassertion (logical 0): Signal between 2.0 and 5.25 V.

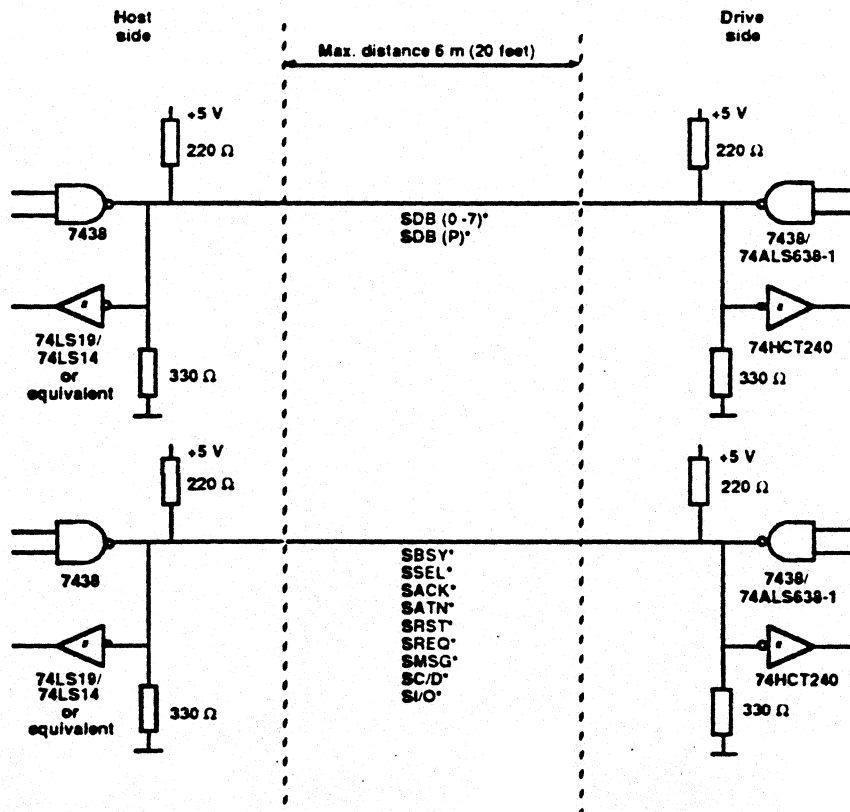


Figure 8.1 Electrical Interface Connector Specifications

8.4.1. Drive Interface Connector Layout

The Drive is connected to the SCSI-bus with a 50-pin ribbon cable. The single ended option is used. The signal pin-numbers and names are listed below:

Signal Mnem.	Pin	GND Return Pin	Signal Name
DB(0)	2	1	Data Bus
DB(1)	4	3	-
DB(2)	6	5	-
DB(3)	8	7	-
DB(4)	10	9	-
DB(5)	12	11	-
DB(6)	14	13	-
DB(7)	16	15	Data Bus
DB(P)	18	17	Data Bus Parity
SPARE	20	21	
SPARE	24	23	
SPARE	26 *)	25	
SPARE	28	27	
SPARE	30	29	
ATN	32	31	Attention
SPARE	34	33	
BSY	36	35	Busy
ACK	38	37	Acknowledge
RST	40	39	Reset
MSG	42	41	Message
SEL	44	43	Select
C/D	46	45	Control/Data
REQ	48	47	Request
I/O	50	49	Input/Output

NOTE *):
Optional for termination power.

Table 8.1 Signal pin Layout

8.4.2. Bus Signals

The nine control and nine data signals are listed below:

BSY (Busy)	An "or-tied" signal which indicates that the bus is occupied.
SEL (Select)	An "or-tied" signal which is used by an Initiator to select a Target, or by a Target to reselect an Initiator.
C/D (Control/Data)	A signal driven by the Target to signal whether control or data information is on the bus. Assertion indicates control.
I/O (Input/Output)	A signal driven by the Target to control the direction of the data bus with respect to the Initiator. Assertion indicates input to the Initiator.
MSG (Message)	A signal driven by the Target indicating the message phase.
REQ (Request)	A signal driven from the Target indicating a request for an REQ/ACK handshake.
ACK (Acknowledge)	A signal driven by an Initiator to indicate acknowledgement of an REQ/ACK handshake.
ATN (Attention)	A signal driven by an Initiator indicating that a message is available for the Target.
RST (Reset)	An "or-tied" signal which indicates the reset condition.
DB(7-0,P) (Data Bus)	Eight data bit signals comprise the data bus. DB(7) is the most significant bit, and has the highest priority during arbitration. DB(P) is the data bus parity (odd). Each of the eight data signals DB(7) through DB(0) is uniquely assigned as a target or initiator bus address (i.e. SCSI DEVICE ID). This identification is normally assigned and strapped during system configuration.

8.5. Bus Phases

The communication and data-exchange on the SCSI-bus are based on a well defined protocol with eight distinct operational phases. The bus can never handle more than one phase at a time. The phases are:

- | | |
|---------------------|---------------------------------|
| - Bus Free Phase | |
| - Arbitration Phase | (Optional in the SCSI-standard) |
| - Selection Phase | |
| - Reselection Phase | (Optional in the SCSI-standard) |

- | | |
|-----------------------|--|
| - Command Phase | These four phases are collectively termed the Information Transfer Phase |
| - Data Exchange Phase | |
| - Status Phase | |
| - Message Phase | |

The TDC 3600 Series SCSI Drives support the Arbitration and Reselection features which are optional features in the SCSI-standard.

8.5.1. Bus Free Phase

The Bus Free Phase, indicating that the bus is free for use, is invoked by all signal lines being deasserted. All devices must release their bus signals (within a bus-clear delay of maximum 800 ns) after deassertion of BSY and SEL. To recognize the Bus Free Phase, devices have to test that both BSY and SEL are not asserted (simultaneously within a deskew delay), and that the Reset condition is not active.

8.5.2. Arbitration Phase (Optional)

The SCSI-bus allows multiple host configurations. To avoid bus-crash situations in a configuration like this, the devices have to arbitrate for the bus. If more than one device is requesting the bus simultaneously, the one with the highest priority (highest SCSI ID no.) will win the bus. To arbitrate, the device has to test that the bus is in the Bus Free Phase. (See Section 8.5.1). Then it waits for a bus-free delay of minimum 800 ns before it asserts BSY, and the data-bit corresponding to the SCSI ID number, on the bus. The device will then wait for the arbitration delay (min. 2.2 μ s) before testing if the arbitration was won. If so, it asserts SEL to claim the bus, and enters the Selection Phase. All devices that have lost the arbitration (devices that recognize a higher address on the bus than their own), should immediately deassert BSY and their bus address bit. Parity is not valid during the arbitration phase.

8.5.3. Selection Phase

For single host systems, the Selection Phase can be entered after having detected the Bus Free Phase. The Initiator will assert its own device address and the device address of the wanted Target on the bus. After a 90 ns delay, it also asserts SEL. The Target will respond by asserting BSY and the Initiator should then deassert SEL.

For systems using arbitration, the following must be done - in this order:

- 1) SEL must be asserted when going from Arbitration to Selection phase.
- 2) When the Initiator asserts SEL, all other arbitrating devices must leave the bus within a bus-clear delay (maximum 800 ns).
- 3) After one bus-clear + one bus-settle delay (min. 1.2 μ s), the Initiator can put its own address and that of the Target on the bus.
- 4) The Initiator should wait at least two deskew delays, then release BSY.
- 5) When the Initiator recognizes that BSY is asserted again (by the Target), it must wait at least 1 bus settle delay (400 ns), and then deassert SEL.

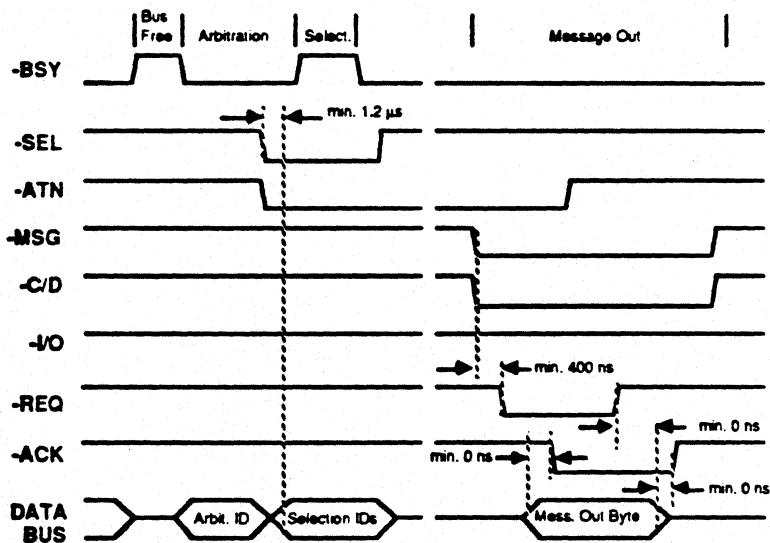


Figure 8.2 Arbitration, Selection and Message Out Phases

Parity is valid for this phase. If a parity error is detected during selection or if more than two SCSI IDs are on the bus, the Target will not respond by asserting BSY. The Initiator should detect this as a timeout.

Optionally after selection, the Initiator may initiate the Message Out phase by setting ATN along with SEL. This will inform the Target that a Message Out Phase is expected. In this Phase the Initiator will then send an Identify Message to the Target. This will establish a logical path between the two and enable the Initiator to inform the Target that it supports deselection. See Section 8.5.9. Message Out Phase.

8.5.4. Reselection Phase (Optional)

Disconnection is used by the Target to let other devices use the SCSI-bus during time consuming operations. The Reselect option is activated if the Initiator issues an Identify message immediately following the Selection Phase. (See Section 8.5.3). Hereby the Initiator signals that it can handle deselection. If the Target decides that a particular command will consume a lot of time, it will send the Deselect Message In, and release the bus. When the Target wants contact again, it will have to go through the Reselection Phase. This Phase is similar to the Selection Phase, except that the I/O line is asserted.

Before the Target can reselect, it must first go through the Arbitration Phase to gain control of the bus. Then the following sequence takes place:

- 1) Having gained control of the bus, the Target can enter the Reselection Phase by asserting SEL and I/O.
- 2) The Initiator responds to the reselection by asserting BSY.
- 3) Then the Initiator waits for the Target to deassert SEL before it again deasserts BSY.

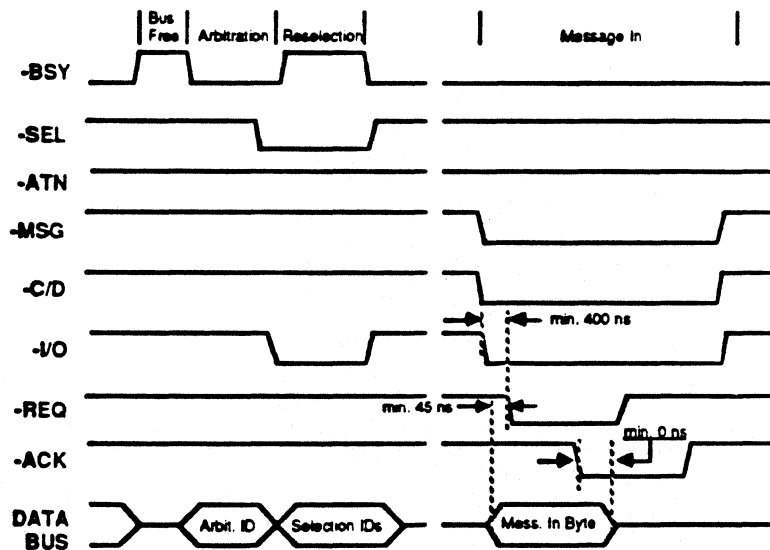


Figure 8.3 Arbitration, Reselection and Message In Phases

Since the Target will assert BSY before it deasserts SEL, the "or-tied" BSY line remains asserted, even if the Initiator deasserts BSY.

The Reselection Phase will always be followed by a Message In Phase that will report Identify Message. This helps the Initiator to see which device that reselects if the Initiator should have issued commands to more than one device.

8.5.5. Command Phase

The Command Phase follows directly after Selection or Identify Message Out. It allows the Target to obtain command information from the Initiator.

The Command Phase is entered with BSY and C/D asserted and SEL, ATN and I/O deasserted. After a bus settling delay of at least 400 ns the Target requests the first byte in the Command Descriptor Block by asserting REQ. The Initiator responds by placing the first byte on the bus and asserting ACK. The Target notices this and deasserts REQ. The Initiator should then deassert ACK.

The first byte is now transferred. The Target will continue ask for additional bytes until the entire Command Descriptor Block is transferred, and the Command Phase is ended.

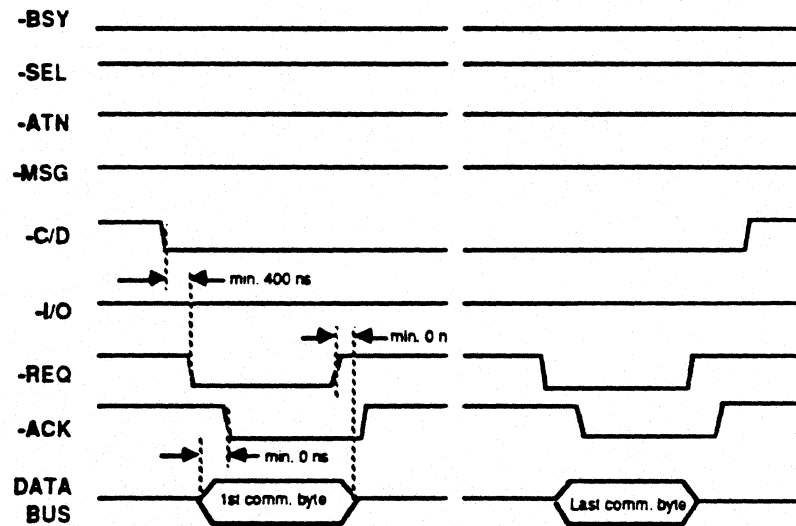


Figure 8.4 Command Phase Sequence

NOTE:

The data transfer for the Drive is done in hardware and has a transfer rate of about 1.5 Mbytes/sec.

8.5.6. Data Exchange Phase

The Data Exchange Phase includes both the Data Out Phase and the Data In Phase. In both cases the C/D and MSG lines will be deasserted, and BSY asserted.

The Data Out Phase allows data to be transferred from the Initiator to the Target in the following way:

- 1) The Target deasserts I/O.
- 2) For each byte, the Target asserts REQ.
- 3) The Initiator responds by placing data on the bus and then asserting ACK.
- 4) The Target reads the byte and deasserts REQ, whereupon the Initiator deasserts ACK.

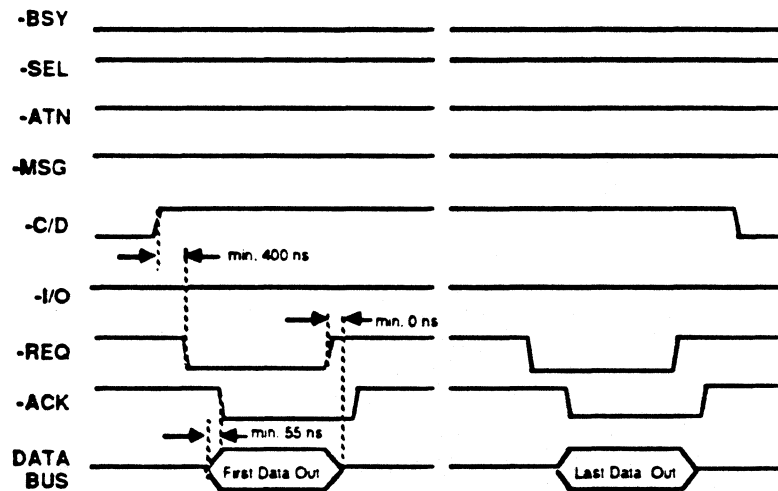


Figure 8.5 Data Out Sequence

This completes the byte transfer. This cycle is repeated until the last data byte has been transferred.

The Data In Phase allows data to be transferred from the Target to the Initiator in the following way:

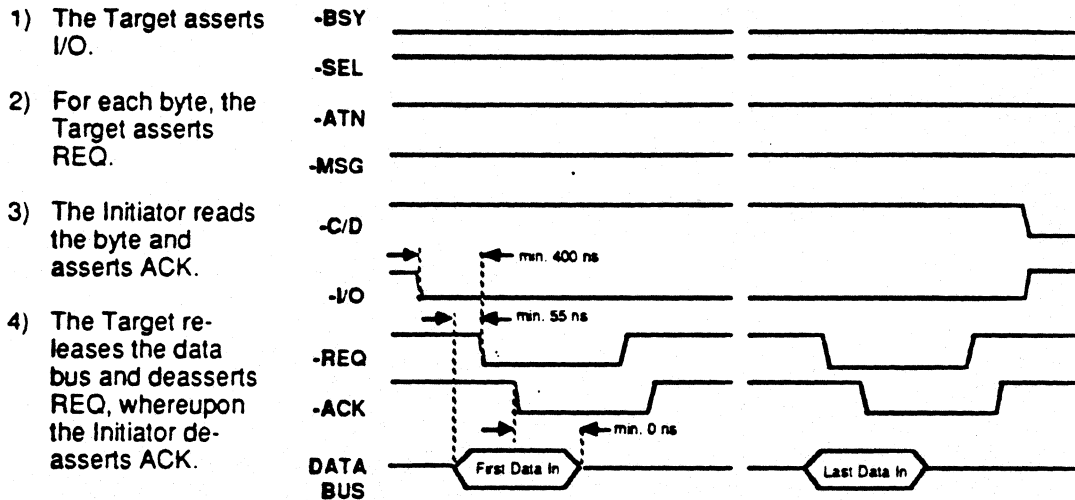


Figure 8.6 Data In Sequence

This completes the byte transfer. This cycle is repeated until the last data byte has been transferred.

NOTE:

The data transfer for the Drive is done in hardware and has a transfer rate of about 1.5 Mbytes/sec.

8.5.7. Status Phase

The Status Phase is entered when the Drive has completed a command execution, or if a non-recoverable error has occurred. In this phase BSY, C/D and I/O will be asserted and SEL and MSG deasserted. After a bus settle delay of at least 400 ns, the Drive puts the status byte on the bus and asserts REQ. The Initiator should read the byte and assert ACK. This causes the Target to deassert REQ, whereupon the Initiator can deassert ACK.

8.5.8. Message In Phase

The Message In Phase is used in three ways:

- 1) The Initiator starts by asserting the ATN line.

The handshake protocol for the Identify Message is like the one described in Section 8.5.3, Selection Phase.

- 2) The assertion of ATN enables the Target to know which transfer the message refers to.
- 3) When the Drive detects that ATN is asserted, it enters the Message In Phase by asserting MSG and C/D while deasserting I/O.
- 4) After a bus settling delay of at least 400 ns, the Target asserts REQ.
- 5) The the Initiator places the message byte on the bus and asserts ACK.
- 6) The Target then deassert REQ, and the Initiator can deassert ACK.
- 7) The Message In Phase terminates when the Target deasserts MSG.

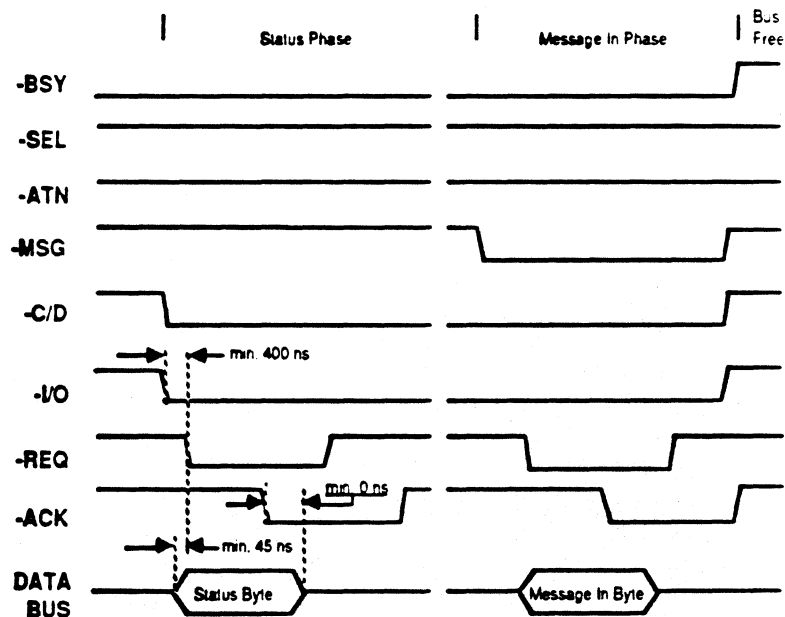


Figure 8.7 Status and Message In Phases

The Drive will generate the Message In Phase by asserting the MSG, C/D and I/O lines. After a bus settle delay of 400 ns it puts the Message byte on the bus and asserts the REQ signal. The Initiator should then read the byte and assert ACK, whereupon the Drive deasserts REQ and the Initiator can in turn deassert ACK. The Message In Phase terminates when the Drive deasserts MSG.

8.5.9. Message Out Phase

The Message Out Phase is used in the following way:

- 1) When an Initiator signals that it supports deselection.
- 2) When an Initiator has detected a parity error.
- 3) When it aborts a command.
- 4) When it resets a Target without resetting the whole bus.

The Message Out Phase has the following sequence:

- 1) The Initiator starts by asserting the ATN line.

The handshake protocol for the Identify Message is like the one described in Section 8.5.3, Selection Phase.

- 2) The assertion of ATN enables the Target to know which transfer the message refers to.
- 3) When the Drive detects that ATN is asserted, it enters the Message Out Phase by asserting MSG and C/D while deasserting I/O.
- 4) After a bus settling delay of at least 400 ns, the Target asserts REQ.
- 5) The Initiator places the message byte on the bus and asserts ACK.
- 6) The Target then deasserts REQ, and the Initiator can deassert ACK.
- 7) The Message Out Phase terminates when the Target deasserts MSG.

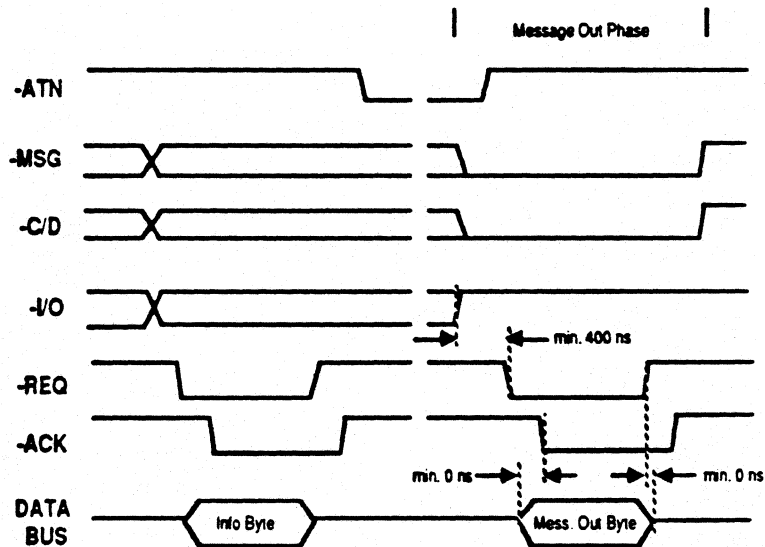


Figure 8.8 Attention Interlock and Message Out Transfer

8.5.10. Summary of SCSI-bus Phases

The SCSI-bus has several distinct bus phases. Each phase is denoted by the BSY, SEL, MSG, C/D and I/O-lines.

During the ARBITRATION and SELECTION/RESELECTION-phases, the BSY and SEL lines will change, and this is marked with - 0/1 - in Table 8.2 below.

The ARBITRATION and SELECTION-phases are controlled by the Initiator.

After the Target is selected, it should select the correct bus phases.

The ARBITRATION and RESELECTION-phases are controlled by the Target.

Bus Phase	BSY	SEL	MSG	C/D	I/O
Bus Free	0	0	0	0	0
Arbitration	1	0/1	0	0	0
Selection	0/1	1	0	0	0
Reselection	0/1	1	0	0	1
Command	1	0	0	1	0
Data Out	1	0	0	0	0
Data In	1	0	0	0	1
Status	1	0	0	1	1
Message Out	1	0	1	1	0
Message In	1	0	1	1	1

8.6. Bus Conditions

The bus has three asynchronous conditions:

- Attention Condition
- Unit Attention Condition
- Reset Condition

These conditions cause certain bus device actions and can alter the bus phase.

8.6.1. Attention Condition

The Attention Condition allows an Initiator to inform a Target that it has a message ready. The Target may respond by invoking the Message Out Phase.

The Initiator can set the Attention Condition by asserting ATN at any time except during the Bus Free or the Arbitration Phase. The Attention condition can be cleared by deasserting ATN at any time except while ACK is asserted during a Message Out Phase.

8.6.2. Unit Attention Condition

The Drive issues a Unit Attention Condition which alerts all Initiators that the operating condition of the tape cartridge may have changed.

The tape cartridge is logically unloaded from the tape drive when the Drive detects the Unit Attention Condition.

The first command sent by each Initiator to the Drive after a SCSI-bus reset condition, causes the Drive to send a Check Condition status message. The Drive also sets the Sense key in the Extended Sense Byte to UNIT ATTENTION.

Before removing the tape cartridge, the Initiator should issue an Unload command which positions the tape at EOT or BOT. If a cartridge is removed before issuing an Unload command, all drive-accessing commands cause the Drive to send a Check Condition status message and to set the Sense Key in the Extended Sense Byte to NOT READY. If a cartridge is then loaded, the first command sent by all Initiators will cause the Drive to send a Check Condition status message and to set the Sense key in the Extended Sense Byte to UNIT ATTENTION.

8.6.3. Reset Condition

The Reset Condition occurs when one of the devices on the SCSI-bus asserts RST. It is used to immediately clear all devices from the bus, and reset their associated equipment. Regardless of prior bus phase, the bus enters the Bus Free Phase. The Reset Condition must last at least 25 μ s.

8.6.4. Phase Sequencing

The bus phases follow a prescribed sequence. However, the Reset Condition can abort any phase and force the bus to the Bus Free Phase. The Phase Sequence for systems with or without Arbitration are shown in the figures below:

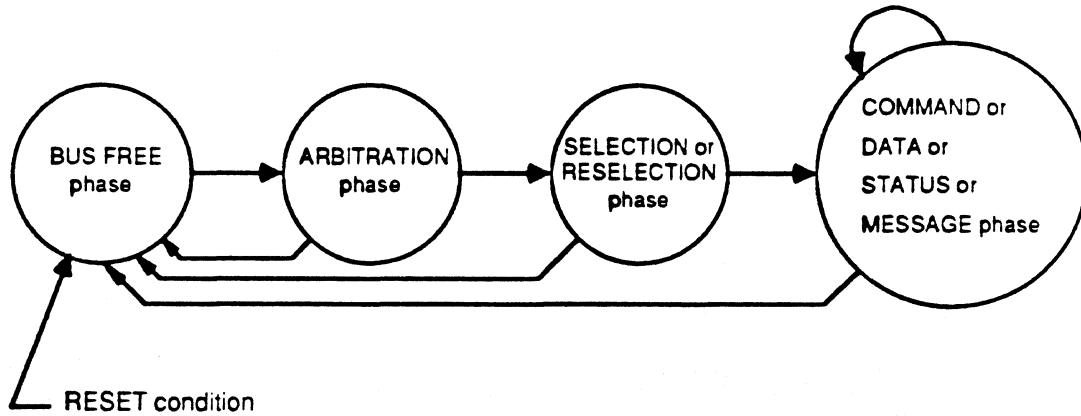


Figure 8.9 Phase Sequencing for systems using Arbitration

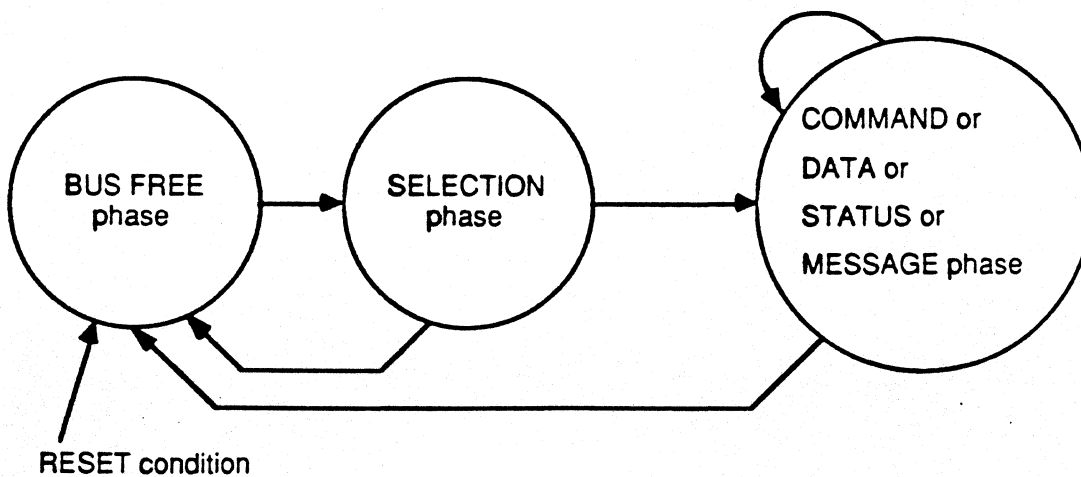


Figure 8.10 Phase Sequencing for non-arbitrating systems

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9. Software Interface

9.1. Introduction

The Drive will be a Target for all commands except the Copy command. In the following sections where the command set and the status information are described, the Drive is always a Target. The only exception is for the Copy command description, where the Drive's reactions as Initiator are also described. All commands are given by means of Command Descriptor Blocks, and all commands terminate with one byte of status information. The commands are described in alphabetical order. Error status is listed in the description for the Request Sense command. However, error conditions which are typical for one particular command are also mentioned in the description of this command.

9.2. Command Descriptor Block

All commands are initiated by means of a six-byte Command Descriptor Block (CDB) containing the command code and in most cases the necessary parameters to execute the command. The basic format of the CDB is shown in Table 9.1. The particular CDB format of each command is described in the following sections. When more parameters are needed than there is space for in the CDB, the parameters will be sent to the Drive as data.

BYTE	BIT 7	6	5	4	3	2	1	0
00	Command Class			Command Operation Code				
01	Logical Unit Number			Command Parameters				
02	Command Parameters							
03	Command Parameters							
04	Command Parameters							
05	Vendor Unique		Reserved			Flag	Link	

Table 9.1 Basic Command Descriptor Format

Command Class	The Drive uses only Command Class 0, so that these bits will always be zeroes - 000.
Command Operation Code	These bits specify the selected command.
Logical Unit Number	Since no other basic drives can be connected to the Drive these bits will always be zeroes - 000.
Vendor Unique	These two bits are not tested unless particularly specified. These bits will be marked with <i>Xes</i> in the control block descriptions when NOT tested!

Flag, Link	These two bits are used to control the ability to link commands in a sequence and to notify the Initiator that a particular command step has been completed.
Link	The use of the Link bit is optional. If the Link bit is set, an automatic link to the next command is made at a successful completion of the current command from the Initiator. Status is returned for each command executed.
Flag	The Flag bit is only meaningful when the Link bit is set. If both bits are set, a LINKED COMMAND COMPLETE WITH FLAG message is requested for this command in a group of linked commands. If only the Link bit is set the LINKED COMMAND COMPLETE message will be used instead.

In many cases the specific CDBs will contain reserved bits and bytes. Those bits are reserved for future extensions and should be set to zero. This allows upward expansion of host software to devices which may use these bits or bytes for special functions. If these bits, the Command Class or the Logical Unit Number are not zero in the commands to the Drive, the Check Condition Status will be sent, and the Sense Key in the Sense Block will be set to ILLEGAL REQUEST.

9.3. Drive Command Set

The following Common Command Set for sequential access devices are defined and standard for the Drive.

Description	Type	OP Code (Hex)
Copy	O	18
Erase	O	19
Inquiry	E	12
Load/Unload	O	1B
Mode Select	O	15
Mode Sense	O	1A
Prevent/Allow Media Removal	O	1E
Read	M	08
Read Block Limits	E	05
Read Data Buffer	O	3B
Recover Buffered Data	O	14
Release Unit	O	17
Request Block Address	V	02
Request Sense	M	03
Receive Diagnostic Results *)	O	1C
Reserve Unit	O	16
Rewind	M	01
Seek Block	V	0C
Send Diagnostic	O	1D
Space	O	11
Test Unit Ready	O	00
Verify	O	13
Write	M	0A
Write Data Buffer	O	3C
Write Filemark	M	10

NOTE *)

This command is implemented for Tandberg Data internal use only!

Type definition in the proposed SCSI Common Command Set:

Mandatory (M)

These commands are the minimum requirements and should be handled by the Host.

Optional (O)

Can be used if wanted.

Extended (E)

These commands are required for systems supporting device-independent self-configuring software.

Vendor Unique (V)

These are vendor unique commands.

9.3.1. Copy (18H)

Introduction

The Copy command is used for copying data directly between the TDC 3620/40/60 Drive and another SCSI device. The original Initiator initiates the Copy operation, but the actual data transfer will take place without further Initiator intervention.

When executing the Copy command the Drive takes two roles, one managing the copy operation and one handling the actual data transfer. The management part reads and checks the Copy Parameter Block, takes care of error handling etc. The management part operates as an Initiator for the other SCSI device and also for the internal data transfer part. The data transfer part operates much similar to the Drive when executing normal Read and Write commands.

Typically the Copy command is used to move data to or from a hard-disk. The Drive can then manage a full BACKUP or RESTORE operation.

Some Copy command features are:

- Sequential Access to Direct Access Device Copy (RESTORE)
- Direct Access To Sequential Access Device Copy (BACKUP)
- 256 Segment Descriptors
- Several Direct Access Device block sizes supported: 256, 512, 1024, 2048 or 4096 bytes.
- Buffered Mode Copy
- Configured Target Sense Handling
- The TDC 3620/40/60 Drive issues only 6-byte READ and WRITE command blocks
- No Target disconnects during a Copy command

9.3.1.1. Command and Parameter Blocks

The Command Block

BYTE	BIT 7	6	5	4	3	2	1	0
00	0	0	0	1	1	0	0	0
01	Logical Unit Number			Reserved				
02	Length of Parameter Block (MSB)							
03	Length of Parameter Block							
04	Length of Parameter Block (LSB)							
05	X	X	Reserved			Flag	Link	

Length of Parameter Block

Total length of the Parameter Block including the Copy Header Block and all Segment Descriptors. A zero value means: copy no data. For an active Copy operation the length must be equal to or larger than 4 (at least the Copy Header Block must be transferred). The maximum value is 3076. This corresponds to 256 Segment Descriptors (12 bytes long) and a single Header.

Flag, Link

These two bits have their usual meaning.

The Parameter Block

The Parameter Block has two parts. First there is a four-byte header block which contains the Copy Function Code. One or more Segment Descriptors are provided after the Header. Up to 256 Segment Descriptors are supported. The Segment Descriptors are identified with ascending numbers, starting at zero - 0.

The Copy Header Block

The Copy Header Block controls the direction of the Copy operation (BACKUP or RESTORE).

The Copy Header Block format:

BYTE	BIT 7	6	5	4	3	2	1	0
00	Copy Function					0	0	0
01	Reserved							
02	Reserved							
03	Reserved							

The following Copy Functions are supported by the Drive:

- 00: Direct To Sequential Access Device (BACKUP)
- 01: Sequential To Direct Access Device (RESTORE)

The Segment Descriptor Block

Each Segment Descriptor describes a single Copy operation. Both the Direct Access Block Address and the Number of Blocks are specified. The Source and Destination ID (and LUN) are also specified in each Segment Descriptor. This means that a single Copy command can transfer data to/from several Direct Access Devices. Note however that either the Source (RESTORE) or Destination (BACKUP) device always must be the TDC 3620/40/60 Drive executing the Copy command.

BYTE	BIT 7	6	5	4	3	2	1	0
00	Source Controller ID			Reserved			Source LUN	
01	Dest. Controller ID			Reserved			Dest. LUN	
02	Sequential Access Device Block Size (MSB) (=02)							
03	Sequential Access Device Block Size (LSB) (=00)							
04	Direct Access Device Number of Blocks (MSB)							
05	Direct Access Device Number of Blocks							
06	Direct Access Device Number of Blocks							
07	Direct Access Device Number of Blocks (LSB)							
08	Direct Access Device Logical Block Address (MSB)							
09	Direct Access Device Logical Block Address							
0A	Direct Access Device Logical Block Address							
0B	Direct Access Device Logical Block Address (LSB)							

**Source
Controller ID**

The ID number (0..7) of the Source Device.

**Destination
Controller ID**

The ID number (0..7) of the Destination Device.

Source LUN

The Logical Unit Number (0..7) of the Source Device

Destination LUN

The Logical Unit Number (0..7) of the Destination Device

**Sequential Access
Device Block Size**

The block size of the Sequential Access Device. Since the Drive always is the sequential access device in a Copy operation, this parameter must be set to 200 Hex (512 bytes).

Direct Access Device Number of Blocks	This is the number of data blocks to be transferred for this Segment. Depending on the current Direct Access Device Block Size this will correspond to a variable number of data blocks. A Block Size of 1024 bytes will lead to a 1:2 relationship between number of Direct Access Device block counts and the Drive block counts etc. A zero value means: copy no data for this Segment.
Direct Access Device Logical Block Address	This is the address of the first block on the Direct Access Device to be copied. Note that the address must fit into the 21 bits of the standard 6-byte Read/Write command blocks used. This means that the maximum value for the Logical Block Address is $2^{21}-1$.

9.3.1.2. Copy Operation

The Copy operation starts when the Copy command and the Copy Parameter Block has been transferred to the Drive. Note that the whole Parameter Block is transferred in one single transfer. The Drive will then disconnect from the Initiator. This means that the Initiator must support disconnection for the Copy command to work. If this is not so the Drive will abort the Copy command with Check Condition Status (see Section 9.3.1.4. Error Handling).

The Drive will process all Segment Descriptors (or until an error has been detected) before reconnecting to the original Initiator.

When a Copy operation leads to reading or writing from beginning of the Drive media, the Drive will position the tape and the head as if a normal Read or Write operation has started.

If the tape operation is started from another position than BOM, it is the responsibility of the Initiator to position the tape before issuing the Copy command. Any necessary error recovery procedures for any device are also the responsibility of the Initiator (see also Auto Sense and 9.3.1.4. Error Handling)

To allow the Drive to work with less sophisticated hard disk controllers, only standard 6-byte Read and Write commands are used. When processing a Segment Descriptor the TDC 3620/-40/60 Drive will issue a sequence of Read/Write commands to the direct access device. The Drive will request only small amounts of data at a time, data already in the Drive's data buffer or data with reserved space in the buffer. This means that the direct access device does not have to support disconnection. It also means that the Drive will control the SCSI bus (the direct access device is only selected when the Drive is ready for a data transfer). This makes sense because a streaming tape device like the Drive usually has a much lower average data transfer rate than most direct access devices (typically a hard-disk).

For every Segment Descriptor in the Parameter Block the sequence will be like this:

- 1) The Drive issues a Read Capacity command to establish the current direct access device block size (see also Section 9.3.1.3. Block Sizes).
- 2) The Drive issues a 6-byte Read or Write command. The number of blocks requested for transfer is controlled by the Copy Threshold parameter in the Mode Select Block (default is normally 8 blocks). The Logical Block Address in the first Command Descriptor Block is copied from the Segment Descriptor. The Logical Block Address for the following command blocks are incremented by the number of transferred blocks .
- 3) The data is transferred to/from the direct access device from/to the data buffer in the Drive. From here it goes from/to the tape.

- 4) Points 2 and 3 are repeated until the total number of blocks specified in the current Segment Descriptor Block has been transferred (this will sometimes mean that the last Read/Write command will request less blocks than indicated by the Copy Threshold).
- 5) Points 1, 2, 3 and 4 are repeated for each Segment Descriptor in the Segment Descriptor List.

NOTE:

In future firmware releases the TDC 3620/40/60 Drive may not check the block length for every Segment Descriptor as long as the direct access ID and LUN are the same as for previous Segments.

9.3.1.3. Block Sizes

The block size used on the Drive tape is always 512 bytes. This is as defined by the tape standards (QIC-24, QIC-120 and QIC-150). However, with some restrictions the Drive is able to copy data to/from direct access devices with block sizes different from 512.

The following block sizes are supported:

- 256 bytes
- 512 bytes
- 1024 bytes
- 2048 bytes
- 4096 bytes

The TDC 3620/40/60 Drive uses a "double method" to determine the actual block size of the direct access device. Before processing a new Segment Descriptor, the Drive first issues a Read Capacity (25H) command. If the direct access device supports this command it will respond by sending 8 bytes of parameter data back to the Drive. The last 4 bytes hold the block size in bytes. This block size is used for all data transfers for the current segment. If however the direct access device does not support the Read Capacity command it will terminate this command with a Check Condition status. The Drive will then use the second method to determine the block size.

First any pending sense information are cleared by issuing a Request Sense command. 4 bytes of sense data are requested. Then a Read command with the Transfer Length set to 1 (read 1 block) is sent to the direct access device (the logical address used is 0). The Drive will transfer one data block and then count the number of bytes transferred.

Regardless of the method used, the Drive will check if the block size found is legal (256, 512, 1024, 2048 or 4096 bytes).

The TDC 3620/40/60 Drive does not support Inexact Segments. This means that for every Segment Descriptor the total amount of data transferred must be an integral number of blocks on both the direct access device and the Drive. the Drive handles inexact segment errors in two different ways depending on what side the error occurred (see also Section 9.3.1.4. Error Handling). When an inexact segment error has been detected the entire Copy operation is aborted.

9.3.1.4. Error Handling

Two classes of error conditions may occur during a Copy operation; Management Errors and Data Transfer (or Target) Errors.

Management Errors

These errors are detected by the management part of the Drive. The management part are responsible for checking the Copy command and parameter blocks. It is the management part that interprets and splits the Segment Descriptors into multiple Read/Write commands. When a Management Error has been detected, the Drive reacts in the following way:

- 1) Terminates the Copy command with Check Condition Status.
- 2) Sets the VADD bit. Sets the Sense Key in the Extended Sense Block to the code that describes the error condition.
- 3) Sets the Segment Number in the Extended Sense byte 01 to the number of the segment where the error occurred.
- 4) Updates the Information Bytes with the difference between the requested and the actually processed blocks/-bytes for the current segment.

Description	Sense Key	Error Class	Ext. Error
Bad Command Block	05	20	02
Illegal Parameter List Length	05	20	03
No Disconnect Allowed	05	20	0E
Illegal Copy Function	05	20	23
Bad Header	05	20	24
Header Too Short	05	20	25
Logical Address Too Large	05	20	26
Bad ID or LUN	05	20	27
Partial Descriptor Received	05	20	28
Parity Error in Parameter/Data	04	00	2B
Target Selection Timeout	04	00	2C

Table to be continued on the next page:

Description	Sense Key	Error Class	Ext. Error
Target Phase Sequence Error	04	00	2D
Target Illegal Block Size	05	00	2E
Inexact Segment: Odd Number	05	20	47
Inexact Segment: Tape Residual	05	20	48

Inexact Segment Errors can be detected for both direct access block counts and tape block counts.

When the current block size is 256 and the number of blocks requested for copy is odd, the Drive will flag an Inexact Segment Error by immediately terminating the Copy operation. This can take place both during BACKUP and RESTORE. No data is transferred for the erroneous segment. Check Condition Status is sent to the original Initiator. The Sense Key will read Illegal Request (05H).

When the block size is larger than 512, an Inexact Segment Error will be flagged if the residual number of blocks on the tape is too small to fill a complete direct access block. This can only happen during RESTORE if the data transfer part of the Drive encounters an unexpected Filemark, End of Recorded Area (BLANK CHECK) or a Bad Block. All data up to the last residual block(s) will be transferred to/from the direct access device. The last incomplete block is not transferred. Check Condition Status is sent to the original Initiator. The Sense Key will read Illegal Request. The tape position will be immediately after the last transferred tape block. This means that there will be one or more (max. 7) tape blocks left on the tape. It is up to the Initiator to recover these blocks. The real cause of error can then be discovered.

NOTE:

It is up to the original Initiator to generate tapes (to end a tape Write operation or write Filemarks) so that an Inexact Segment Error like this does not occur. Normally this is no problem as long as the direct access device used during RESTORE has the same block size as the one used during BACKUP for a particular tape.

Data Transfer Errors

These errors are detected by the data transfer part of the Drive. The data transfer part takes care of the actual tape Read- and Write processes.

When a Data Transfer Error has been detected, the Drive reacts by:

- 1) Requesting/generating Target Sense Data.
- 2) Terminating the Copy command with Check Condition Status.
- 3) Setting the VADD bit. (The Sense Key is set to Copy Aborted).
- 4) Updating the Segment Number.
- 5) Updating the Information Bytes with the difference between the requested number of blocks and the actual number of blocks transferred for the current segment.
- 6) Updating the Additional Sense Length to indicate the amount of additional sense data available. (As a minimum a Target Status Byte will be available). The Additional Sense Length is then set to 18 (17 normal additional sense bytes plus the Target Status Byte). If Target Sense Data is available, the Additional Sense Length indicates the number of bytes available like this:
$$\text{Target Sense Bytes} = (\text{Additional Sense Length}) - 18$$
- 7) Updating the Source Sense Pointer to indicate the source Target Status Byte. This pointer is relative to the first byte of the Extended Status Block. Possible source Target Sense Data follows immediately after the Target Status Byte. A zero value Source Sense Pointer indicates that no source Target Status or Sense are available for the source logical unit.
- 8) Updating the Destination Sense Pointer to indicate the destination Target Status Byte. This pointer is relative to the first byte of the Extended Status Block. Possible destination Target Sense Data follows immediately after the Target Status Byte. A zero value Destination Sense Pointer indicates that no destination Target Status or Sense are available for the destination logical unit.

The direct access device notifies the Drive of an error by terminating the current Read or Write command with a Status Byte different from GOOD Status. If the Status Byte received is a Check Condition Status, the action taken by the Drive depends on the current Auto Sense Mode (see also Section 9.3.1.4. Error Handling). Normally the Auto Sense Mode is on. The Drive will then issue a standard 6-byte Request Sense command to the direct access device. The number of bytes requested for transfer is controlled by the Copy Sense Allocation parameter in the Mode Select parameter block. The default is normally 4 bytes. The Sense Data is then transferred into a buffer in the Drive.

If the last Status Byte from the direct access device is not Check Condition, the Drive will not request any Sense Data.

The whole Copy operation is then aborted (even if there are more Segment Descriptors). The management part of the Drive sends Check Condition Status to the original Initiator. The Initiator should then Request Extended Sense Data from the Drive. The Sense Key will read Copy Aborted. The Sense Data Block will have an unmodified copy of the direct access device Status Byte and Sense Data (if available).

The action taken by the TDC 3620/40/60 Drive in case of an error detected in the Drive itself is very similar. The data transfer part (target part) of the Drive generates a Status Byte and Sense Data internally, and the Copy operation is aborted. The management part of the Drive sends Check Condition Status to the original Initiator. The Initiator should then Request Extended Sense Data from the Drive. The Sense Key will read Copy Aborted. The Sense Data Block will have a copy of the internally generated Status Byte and Sense Data. The Status Byte will always be Check Condition. The Sense Data can be in either Standard Format or Extended Format. This is controlled by the Copy Sense Allocation parameter.

Description	Sense Key	Error Code	Ext. Error
TDC 3620/40/60 Drive Data Transfer Error	0A	00	09
Target Status Not GOOD STATUS	0A	00	29
Target Status = CHECK CONDITION	0A	00	2A

| 9.3.2. Erase (19H)

BYTE	BIT 7	6	5	4	3	2	1	0
00	0	0	0	1	1	0	0	1
01	Logical Unit Number			Reserved			LONG	
02	Reserved							
03	Reserved							
04	Reserved							
05	X	X	Reserved			Flag		Link

LONG

This bit must be set to 1 (bit 0 in byte 1). If not, the Drive will return Check Condition status. The Sense Key will read Illegal Request .

The Erase command causes the Drive to erase the entire tape. When finished the tape will be positioned at BOT.

The Drive may disconnect during the execution of this command.

| 9.3.3. Inquiry (12H)

BYTE	BIT 7	6	5	4	3	2	1	0
00	0	0	0	1	0	0	1	0
01	Logical Unit Number			Reserved				
02	Reserved							
03	Reserved							
04	Allocation Length							
05	X	X	Reserved			Flag		Link

This command requests that information regarding parameters of the Drive to be sent to the Initiator.

The Allocation Length specifies the number of bytes that the Initiator has allocated for returned Inquiry Data. An Allocation Length of zero indicates that no Inquiry Data will be transferred. This condition will not be considered as an error.

Any other value indicates the maximum number of bytes that will be transferred. The Drive will terminate the Data-In phase when allocation length bytes have been transferred or when all available Inquiry Data have been transferred to the Initiator, whichever is less.

A Check Condition status will never be reported for this command.

If an Inquiry command is received from an Initiator with a pending Unit Attention Condition, the Drive will perform the Inquiry command and will not clear the Unit Attention Condition.

The Inquiry Data table below and on the next page contains a five-byte header, followed by the Vendor Unique parameters:

BYTE	BIT 7	6	5	4	3	2	1	0
00	Peripheral Device Type Code (=01)							
01	RMB = 1	Device Type Qualifier (=00)						
02	ISO Version		ECMA Version			ANSI Version		
03	Reserved							
04	Additional Length (=46)							

Table to be continued on the next page:

BYTE	BIT 7	6	5	4	3	2	1	0
Vendor Unique Common Command Set Parameters:								
05	Reserved							
06	Reserved							
07	Reserved							
08	Vendor Identification: = T							
09	Vendor Identification: = A							
10	Vendor Identification: = N							
11	Vendor Identification: = D							
12	Vendor Identification: = B							
13	Vendor Identification: = E							
14	Vendor Identification: = R							
15	Vendor Identification: = G							
16	Product Identification:							
17	Product Identification: = T							
18	Product Identification: = D							
19	Product Identification: = C							
20	Product Identification:							
21	Product Identification: = 3							
22	Product Identification: = 6							
23	Product Identification: = 0							
24	Product Identification: = 0							
25	Product Identification:							
26	Product Identification:							
27	Product Identification:							
28	Product Identification:							
29	Product Identification:							
30	Product Identification:							

Table to be continued on the next page:

Common Command Set Parameters continued:

BYTE	BIT 7	6	5	4	3	2	1	0
31	Product Identification:							
32	Product Revision Level				(MSB)			
33	Product Revision Level							
34	Product Revision Level							
35	Product Revision Level				(LSB)			
36	Option Level				(MSB)			
37	Option Level				(LSB)			
38	Software Identification:				= C			
39	Software Identification:				= R			
40	Software Identification:				= E			
41	Software Identification:				= A			
42	Software Identification:				= T			
43	Software Identification:				= E			
44	Software Identification:				= D			
45	Month:				= (MSB)			
46	Month:				= (LSB)			
47	Day:				= (MSB)			
48	Day:				= (LSB)			
49	Year:				= (MSB)			
50	Year:				= (LSB)			

Option Level

These two bytes denote the option level of the software (ASCII coded), i.e. a customer-specific firmware will have an option level < > 0. (The standard software will have Option Level = 0).

Increment

These three bits count the decimal part of the revision level.

Revision Level

These bytes show the integer part of the revision level (ASCII coded). Together with "Increment" above, it forms the complete rev. level code of the Drive.

| 9.3.4. Load/Unload (1BH)

BYTE	BIT 7	6	5	4	3	2	1	0
00	0	0	0	1	1	0	1	1
01	Logical Unit Number			Reserved			IMED	
02	Reserved							
03	Reserved							
04	Reserved						RET	Load
05	EOT	X	Reserved			Flag	Link	

The LOAD command tells the Drive to position a newly loaded tape cartridge at BOT. The UNLOAD command tells the Drive to prepare a tape cartridge for removal.

The Drive may be configured to perform either a Auto Load or a Auto Retension operation by using the Mode Select command, see 9.3.5. This means that the Drive will automatically execute a LOAD or a RETENSION command every time a new cartridge is inserted. The GREEN LED indicates that the cartridge has been inserted in the Drive.

IMED (Immediate)

If this bit is set, the Drive returns status as soon as the command has been received. Otherwise status shall be returned after command execution. If the IMED bit is set the LINK bit must be zero - 0 - or else a Check Condition Status will be returned with the Sense Key set to Illegal Request and the Sense Code to Invalid Command.

RET (Retension)

When this bit is set and the EOT bit is not set, the Drive performs a retension pass before the LOAD or UNLOAD command is completed. If the EOT bit is set the retension option is ignored. Retensioning means moving the tape to EOT and then back to BOT. The purpose is to remove possible tape tensions that may have built up.

Load

When the LOAD bit is set the Drive will position the tape at BOT and the GREEN front LED (Light Emitting Diode) lights. When the bit is cleared the tape is positioned for removal either to BOT or EOT dependent of whether the EOT bit is set or not, and the LED is turned off.

NOTE:

The LED is also controlled with the Prevent/Allow Media Removal command. The Unload command will not turn the LED off if the Prevent Media Removal command has been issued.

EOT (End Of Tape)

If this bit is set the UNLOAD command will position the tape at EOT. This tape position enables the Drive to perform a retension at a minimum of time when the tape is loaded. When the bit is cleared, the tape will be positioned at BOT after an UNLOAD command is issued.

The Drive may disconnect for this command.

| 9.3.5. Mode Select (15H)

BYTE	BIT 7	6	5	4	3	2	1	0
00	0	0	0	1	0	1	0	1
01	Logical Unit Number			Reserved				
02	Reserved							
03	Reserved							
04	Length of Parameter List							
05	X	SMP	Reserved			Flag	Link	

This command configures the Drive. The parameter list is passed as data. The number of bytes requested is specified in the Length of Parameter List byte (Byte 04), above.

SMP (Save Mode Parameters)

If this bit is set, the selected mode is permanent; i.e. the Drive will also remember the configuration during power-down and reset.

The parameter list contains of a four-byte header followed by one Block Descriptor page of 8 bytes and 12 bytes of additional Mode Select Parameters, in total 24 bytes. The Parameter List is specified as follows:

BYTE	BIT 7	6	5	4	3	2	1	0
00	00							
01	00							
02	00		BM	00				
03	Block Descriptor Length (=08 or 00)							
Block Descriptor(s)								
00	Density Code							
01	00							
02	00							
03	00							
04	00							
05	00							
06	Block Size		(MSB)	(=02)				
07	Block Size		(LSB)	(=00)				

Table to be continued on the next page:

Vendor Unique Parameters	
00	Vendor Unique Page Code (=00)
01	Write Threshold (WRTTRH)
02	Read Threshold (REDTRH)
03	Buffer Size
04	Forced Streaming Count (MSB)
05	Forced Streaming Count (LSB)
06	Bus Threshold
07	Copy Threshold
08	Normal Sense Threshold
09	Copy Sense Allocation
10	Load Function
11	Power-Up Auto Load/Retension Delay

BM (Buffered Mode)

Default = 1

The BM bit is used to tell whether the Drive is to report good status or not as soon as the data has been transferred into the Drive's Data Buffer (cache) for the write and verify commands. BM set indicates that good status should be reported at this time. If BM is not set, the Drive will only return good status after the data blocks have been actually written or verified.

To achieve streaming mode operation, Buffered Mode must be used. The Copy command supports Buffered Mode when performing a Copy from a direct access device to the Drive (BACKUP).

The Buffered Mode is always active when moving from one Segment Descriptor to the next. This means that the Drive will start processing a new Segment Descriptor as soon as the data from the previous Segment Descriptor has been transferred into the data buffer.

When the entire Copy operation has been completed (all data from the last Segment Descriptor has been transferred into the buffer), the Buffered Mode operation is controlled by the Buffered Mode (BM) bit in byte 02 of the Mode Select parameter block - exactly in the same way as for Write operations. When the BM bit is not set, the Drive will not reconnect and send Status before all data in the buffer has been written to the tape. If the BM bit is set, the Drive reconnects and reports GOOD Status as soon as the last data byte of the last Segment Descriptor is transferred into the buffer.

Block Descriptor Length

Specifies the length in bytes of the following block descriptor. Since only the Block Descriptor is supported, this byte should be set to 08. A Block Descriptor Length of zero indicates that no block descriptors are included in the parameter list. This condition is not considered as an error.

Density Code
Default = 0

This byte specifies the tape format that should be used when writing the tape.

Format	Code
Default	00
QIC-11 4-track	04 (Not valid)
QIC-24 9-track	05 (Only valid for TDC 3620)
QIC-120 15-track	0F (Only valid for TDC 3640 & 3660)
QIC-150 18-track	10 (Only valid for TDC 3660)
QIC-11 9-track	84 (Only valid for TDC 3620)

The TDC 3640 can only write the QIC-120 tape format. The density code should therefore be set to the default value (=00) or to QIC-120 (=0F) for that Drive version.

The TDC 3660 can write both the QIC-120 and the QIC-150 format. The density code should therefore be set to the default value (=00), to QIC-120 (=0F) or to QIC-150 (=10) for that Drive version.

The TDC 3620 can write both QIC-11 and QIC-24 tape formats.

The default tape format is the format used at Power-up/Reset. This is controlled by the saved Mode Select parameters in the EEPROM.

Use the SMP bit in the Mode Select command to save (make permanent) the selected tape format.

Write Threshold
Default = 2

Number of blocks in the buffer before tape write starts. The Write Threshold specifies the number of blocks that should be ready in the buffer before the tape starts and the actual Write operation can commence.

Read Threshold
Default = 2

Number of free blocks in the buffer before tape read starts. The Read Threshold specifies the number of blocks that should be free in the buffer before the tape starts and the actual Read operation can begin.

Buffer Size
Default = Max. physical RAM-size = 4 KByte
Default for a Drive with 64 KByte buffer = 120

The Buffer Size option is used to set the virtual buffer size in number of blocks. The minimum buffer size is 6, while the maximum size depends on the hardware configuration of the Drive.

A Drive with 16 or 64 kbytes buffer chips offers a max. buffer size of 32 or 128 blocks respectively.

If you try to specify a buffer size larger than allowed by the hardware, the Drive will set the buffer size to the upper size limit. No check is made on the lower size limit.

Forced Streaming Count
Default = 0

Normally, when the data buffer becomes empty during a Write operation, the Drive will enter the Underrun Mode and stop the tape motion.

When new data is entered (from Host), the tape is restarted and streaming continues for as long as data is available. This applies when the Forced Streaming Count is set to 0 (zero).

By setting the Forced Streaming Count to a value different from 0, the Drive will rewrite the last block before entering the Underrun Mode (and stopping the tape). The number of rewrites is specified by the Forced Streaming Count byte. If the last written block was a filemark, Forced Streaming will not be enabled.

Bus Threshold
Default = 8

When the Drive has disconnected during Read, Write or Verify operation, a reconnection is performed when a certain number of blocks (the Bus Threshold) is ready for transfer to/from the Host CPU.

The Bus Threshold byte can be set between 1 and Bus Threshold - 6 blocks. No check is made for out-of-range values.

Copy Threshold
Default = 8

The Copy Threshold controls the number of blocks requested for transfer to/from the direct access device in each Read/Write command issued from the Drive during Copy. The minimum value is 1. The maximum value depends on the block size of the direct access device. Not more than 32 KBytes of data should be transferred during a single Read/Write command. This corresponds to a maximum Copy Threshold of 128 for 256-byte blocks, 64 for 512-byte block, 32 for 1024-byte blocks, 16 for 2048-byte blocks and 8 for 4096-byte blocks.

If the total number of blocks to transfer (given by the current Copy Segment Descriptor) exceeds the current Copy Threshold, the Drive will issue as many Read/Write commands as necessary to transfer the total number of blocks.

Normal Sense Threshold
Default = 0

When the Drive responds to a Request Sense command, the value of the Normal Sense Threshold byte will be used together with the number of bytes allocated (byte 04 in the Request Sense command Control Block) to determine if Normal Sense- or Extended Sense format should be returned.

The Normal Sense Threshold is the maximum number of bytes that can be specified in the No. of Bytes Allocated (see above) before Request Sense data is returned in Extended Sense format. If the value for the Normal Sense Threshold is 0 (zero), i.e. Extended Sense will be reported for No. of Bytes Allocated different from 0.

Copy Sense Allocation
Default = 4

The Copy Sense Allocation controls the Sense Data handling of both the Target direct access device and the data transfer part of the Drive in case of an error.

BIT 7	6	5	4	3	2	1	0
ASI	EXT	Target Sense Length					

ASI	The Auto Sense Inhibit controls the action taken by the Drive when Check Condition has been signalled by the direct access device. If the ASI bit is set to zero, the Drive will automatically issue a Request Sense command when the direct access device terminates a command with a Check Condition Status. If the ASI bit is set to one, the Drive will not issue any Request Sense command.
EXT	<p>The Extended Sense bit controls the Sense Data format generated by the data transfer part of the Drive when the data transfer part has detected an error during Copy (i.e. Cartridge Removed, Filemark, Bad Block etc.).</p> <p>If the EXT bit is set to zero, the Sense Data will be in Standard 4-byte format. The first byte holds the Error Class/Error Code. The VADD bit is set to zero. Byte 01 and byte 02 (Information Bytes) is also set to zero. The last byte (byte 03) holds the TDC 3620/40/60 Drive Extended Error Code (EXERCD).</p> <p>If the EXT bit is set to one, the Sense Data will be in Extended format. The VADD bit is zero. The Segment Number is zero. Byte 02 holds the FM and EOM bits and also the Sense Key. All Information Bytes will be zero. The Additional Sense Length is set to 8. Byte 14 holds the Error Class/Error Code. Byte 15 holds the TDC 3620/40/60 Drive Extended Error Code (EXERCD). All other bytes will be set to zero.</p>
Target Sense Length	This field controls the Transfer Length byte in the Request Sense command sent to the direct access device when Auto Sense is enabled (see also the ASI bit). The minimum value is 0. The maximum value is 24 (there is only a 24-byte buffer internally in the Drive for Target Sense data). If the direct access device transfers more than 24 bytes, the additional bytes will wrap around and start writing over the first bytes received.
<div style="border: 1px solid black; padding: 2px;"> Load Function Default = 00 </div>	<p>This function specifies if the Drive shall perform Auto Load or Auto Retension after insertion of a cartridge. The functions are:</p> <p style="text-align: center;"> 00: Auto Load 01: Auto Retension </p>
<div style="border: 1px solid black; padding: 2px;"> Power Up Auto-Load/Auto Retension Delay Default = 00 </div>	<p>This byte specifies the delay that should be applied before an Auto Load or an Auto Retension is started after Power Up; given in increments of 100 ms.</p> <p>The purpose is to enable OEM customers to reduce the inrush current in the system by means of controlling the time for each device to start.</p>

| 9.3.6. Mode Sense (1AH)

BYTE	BIT 7	6	5	4	3	2	1	0
00	0	0	0	1	1	0	1	0
01	Logical Unit Number			Reserved				
02	Reserved							
03	Reserved							
04	Length of Data List							
05	X	X	Reserved			Flag		Link

This command makes it possible for the Initiator to read the Drive's configuration. The configuration data are sent as data with this format:

BYTE	BIT 7	6	5	4	3	2	1	0
00	Sense Data Length							
01	00							MDTY
02	WP	Reserved	BM	Speed Code (=00)				
03	Length of Extended Descriptor List (=08)							
Block Descriptor(s)								
00	Density Code							
01	Reserved							
02	00							
03	00							
04	Reserved							
05	Reserved							
06	Block Size (MSB)				(=02)			
07	Block Size (LSB)				(=00)			
Additional Mode Select Parameters								
00	Vendor Unique Page Code (=00)							
01	Write Threshold				(WRTTRH)			
02	Read Threshold				(REDTRH)			

Table to be continued on the next page:

BYTE	BIT 7	6	5	4	3	2	1	0
03	Buffer Size							
04	Forced Streaming Count (MSB)							
05	Forced Streaming Count (LSB)							
06	Bus Threshold							
07	Copy Threshold							
08	Normal Sense Threshold							
09	Copy Sense Allocation							
10	Load Function							
11	Power-Up Auto Load/Retension Delay							

MDTY (Media Type)	This bit is cleared when a 600 foot cartridge is used. When the bit is set, the media type is either unknown or 450 feet.
WP (Write Protected Cartridge)	This bit is set when the cartridge is write protected.
BM (Buffered Mode)	The BM bit is used to tell whether the Drive is to report good status or not as soon as the data has been transferred into the Drive's Data Buffer (cache) for the write and verify commands. BM set indicates that good status should be reported at this time. If BM is not set, the Drive will only return good status after the data blocks have been actually written or verified.
Density Code	This byte specifies the tape format that has been found on the last tape read. If, however, the last tape operation was NOT a read operation, the configured format is reported. If the tape format is unknown and the Drive has not been configured to any format, Default format will be returned.

The hexadecimal codes are as follows:

Format	Code
Default	00
QIC-11 4-track	04
QIC-24 9-track	05
QIC-120 15-track	0F
QIC-150 18-track	10
QIC-11 9-track	84

Write Threshold

Read Threshold

Buffer Size

**Forced Streaming
Count**

Bus Threshold

Copy Threshold

**Normal Sense
Threshold**

For the description of these bytes see Section
9.3.5 Mode Select!

**Copy Sense
Allocation**

Load Function

**Power Up Auto-
Load/Auto Re-
tension Delay**

| 9.3.7. Prevent/Allow Media Removal (1EH)

BYTE	BIT 7	6	5	4	3	2	1	0
00	0	0	0	1	1	1	1	0
01	Logical Unit Number			Reserved				
02	Reserved							
03	Reserved							
04	Reserved							PREV
05	0	0	Reserved				Flag	Link

Since the Drive has got no mechanical lock mechanism, the front LED (Light Emitting Diode) will be used to indicate Cartridge in Use. By issuing this command with the PREV bit set (Prevent Media Removal), the green front LED will be lit.

When issuing the command with the PREV bit cleared, the LED is turned off unless the tape cartridge is loaded. The LED is turned off when the Drive is reset.

A Load/Unload command issued after a Prevent Media Removal command does NOT change the state of the front LED.

NOTE:

The Load command also activates the LED.

| 9.3.8. Read (08H)

BYTE	BIT 7	6	5	4	3	2	1	0
00	0	0	0	0	1	0	0	0
01	Logical Unit Number			Reserved				1
02	No. of Blocks to Transfer (MSB)							
03	No. of Blocks to Transfer							
04	No. of Blocks to Transfer (LSB)							
05	X	X	Reserved				Flag	Link

This command transfers the number of blocks specified in bytes 02 to 04.

If the cartridge has not been read or written after power-up or reset, the Drive automatically searches for the Reference Burst before it starts reading data from BOT.

If, on the other hand, the cartridge has been used for read- or write-operations, the current tape position is known, and data will be read from this position.

If a filemark is detected before the transfer is finished, the Drive sends the Check Condition to inform the Initiator. In the Extended Sense status the Filemark bit will be set to 1, and the Sense Key to NO SENSE. If all the requested data blocks are not read, the Valid Address bit will be set, and the difference between the requested and the actually read number of blocks will be set in the Information Bytes.

If logical End Of Media (EOM) is detected during the read operation, the Drive sends the Check Condition to inform the Initiator. In the Extended Sense Status the Error Class/Error Code will indicate READ EOM, and the Sense Key indicates BLANK CHECK. If all requested data blocks are not read, the Valid Address bit will be set and the difference between the requested and the actually read number of blocks will be set in the Information Bytes.

If physical End Of Media (EOM) is detected during the read operation, the Drive sends the Check Condition to inform the Initiator. In the Extended Sense Status the Sense key will be set to MEDIA ERROR, the Error Class/Error Code to READ EOM, and the Valid Address bit will be set. The difference between the requested and the actually read number of blocks will be set in the Information Bytes.

If an unrecoverable error occurs during the read operation, the Drive terminates the read command and sends the Check Condition to inform the Initiator. In the Extended Sense Status Byte the Sense Key will be set to MEDIA ERROR, the Valid Address bit will be set and the difference between the requested and the actually read number of blocks will be set in the Information Bytes.

If a new Read command is issued after a read error has occurred, the read operation will begin with the block following the erroneous block.

If the disconnect option is enabled, the Drive may disconnect from the Initiator during the execution of this command.

9.3.8.1. Read Command Error Conditions

General error conditions during tape operations are listed and described in Appendix B.

Sense Key	Error Class/Error Code	Read Error
Blank Check (08)	Read EOM (34)	The TDC 3620/40/60 Drive detected a logical End-Of-Recorded-Area condition
Illegal Request (05)	Read EOM (34)	A Read command was issued after a Write command, but no intervening rewind operation occurred
No Sense (00)	File Mark (1C)	The TDC 3620/40/60 Drive detected a File Mark. The FM bit in the Extended Sense Byte is set to 1
No Sense (00)	Read EOM (34)	The TDC 3620/40/60 Drive detected a Physical End-Of-Media

9.3.9. Read Block Limits (05H)

BYTE	BIT 7	6	5	4	3	2	1	0
00	0	0	0	0	0	1	0	1
01	Logical Unit Number			Reserved				
02	Reserved							
03	Reserved							
04	Reserved							
05	X	X	Reserved			Flag		Link

The Drive does not disconnect for this command.

The requested block length will be delivered as six data bytes. Since the block length is fixed to 512 bytes for QIC-11, QIC-24, QIC-120 and QIC-150, the command will always return 200 hex for maximum and minimum block length.

The layout of the data-bytes is:

BYTE	
00	Reserved
01	Maximum Block Length (MSB) (=00)
02	Maximum Block Length (=02)
03	Maximum Block Length (LSB) (=00)
04	Minimum Block Length (MSB) (=02)
05	Minimum Block Length (LSB) (=00)

| 9.3.10. Read Data Buffer (3BH)

BYTE	BIT 7	6	5	4	3	2	1	0
00	0	0	1	1	1	0	1	1
01	Logical Unit Number				Reserved			
02	Reserved							
03	Reserved							
04	Reserved							
05	Reserved							
06	Reserved							
07	Allocation Length				(MSB)			
08	Allocation Length				(LSB)			
09	X	X	Reserved				Flag	Link

The Read Data Buffer command is used in conjunction with the Write Data Buffer command as a diagnostic function for testing the Drive's data buffer memory and the SCSI-bus integrity. The medium will not be accessed during the execution of this command.

The Allocation Length specifies the number of bytes that the Initiator has allocated for returned Read Data Buffer data. An Allocation Length of zero indicates that no Read Data Buffer data will be transferred. This condition will not create the Check Condition status. Any other value indicates the maximum number of bytes to be transferred. This data is to be used by the Initiator for comparison with the data pattern sent during the Write Data Buffer command. Up to 65.535 bytes may be requested to be transferred, consisting of four bytes of header and up to 65.531 bytes of data.

If the Allocation Length is greater than the available Length (from the Read Data Buffer Header), only the Available Length will be transferred to the Initiator.

It is not considered as an error to request an Allocation Length less than the Available Length. The layout of the data-bytes is:

BYTE	
00	Reserved (=00)
01	Reserved (=00)
02	Available Length (MSB)
03	Available Length (LSB)
04-n	Buffer Data Bytes

To avoid corruption of data due to interference from other Initiators, it is recommended that the Initiator does one of the following:

- 1) Issues the Reserve Unit command prior to the Write Data Buffer command and issues the Release Unit command after the Read Data Buffer command.
- 2) Selects without allowing disconnection, and links the Write Data Buffer and the Read Data Buffer commands together.

The Available Length of data bytes returned by the Drive may be up to 65.531 bytes (64 Kbytes minus a 4-byte header), or the Drive's maximum buffer size, whichever is less.

If the Allocation Length of CDB is too small to transfer all of the Available Length, the Available Length will not be adjusted to reflect the truncation.

| 9.3.11. Recover Buffered Data (14H)

BYTE	BIT 7	6	5	4	3	2	1	0
00	0	0	0	1	0	1	0	0
01	Logical Unit Number				Reserved			1
02	No. of Blocks (MSB) (=00)							
03	No. of Blocks (=00)							
04	No. of Blocks (LSB)							
05	X	X	Reserved				Flag	Link

This command is similar to the Read command, but is used to read data from the Drive's Data Buffer, not from the tape. This can be of interest in a situation where it is impossible to write more data on the tape. In this case the Initiator can retrieve the non-written data from the Drive's Data Buffer. The data will be presented in the same order as they were written into the buffer.

If the buffer contains less than the specified number of blocks, the Check Condition will be returned. In the Extended Status Block the EOM and the VADD bits will be set, and the Information Bytes will tell the difference between the wanted number of blocks, and the blocks actually read.

The Drive does not disconnect during the execution of this command.

9.3.12. Release Unit (17H)

BYTE	BIT 7	6	5	4	3	2	1	0
00	0	0	0	1	0	1	1	1
01	Logical Unit Number			THPR	Third Party ID			0
02	Reserved							
03	Reserved							
04	Reserved							
05	X	X	Reserved			Flag	Link	

This command releases the Drive from the requesting Initiator. If the Drive was not reserved for any Initiator, this is not treated as an error.

If this command is sent when the Drive is reserved by another Initiator, the command will be ignored and GOOD status returned.

THPR (Third Party Reservation Release Option)

Releasing the Third Party Reservation Release requires the following conditions:

- 1) The THP option (see Reserve Unit, Section 9.3.14) must be used.
- 2) The same Initiator must request the release.
- 3) The Third Party Reservation Release option (Byte 1, bits 1 - 3) must be set.
- 4) The device to be released must be the one specified in the Third Party Device ID field. (Byte 1, bits 1 - 3).

Third Party ID (TPID)

Byte 1, bits 1 - 3 specify the SCSI-bus ID for which the Initiator reserved the Drive. THPR must be set.

The Drive does not disconnect during the execution of this command.

| 9.3.13. Request Block Address (02H)

BYTE	BIT 7	6	5	4	3	2	1	0
00	0	0	0	0	0	0	1	0
01	Logical Unit Number				Reserved			
02	Reserved							
03	Reserved							
04	No. of Bytes Allocated							
05	X	X	Reserved				Flag	Link

Allocation Length

The Request Block Address command requests the Drive to transfer the current tape block address to the Initiator.

An Allocation Length of zero indicates the command's default length is to be used. When non-zero, the number of bytes specified in Allocation Length (up to a maximum of 3 bytes) will be transferred.

Request Block Address Data Format is shown in the table below:

BYTE	BIT 7	6	5	4	3	2	1	0
00	0	0	0	0	Block Address (MSB)			
01	Block Address							
02	Block Address (LSB)							

| Block addresses begin with block number 1.

| 9.3.14. Request Sense (03H)

BYTE	BIT 7	6	5	4	3	2	1	0
00	0	0	0	0	0	0	1	1
01	Logical Unit Number				Reserved			
02	Reserved							
03	Reserved							
04	No. of Bytes Allocated							
05	X	X	Reserved			Flag	Link	

Condition has occurred. The Request Sense command may be issued at any time, whether an error has occurred or not. The Sense Data will be valid for a Check Condition status returned on the prior command. This Sense Data will be preserved by the Drive for the Initiator until retrieved by the Request Sense command or until the receipt of any other command from the Initiator that issued the command resulting in the Check Condition status. Sense Data will be cleared upon receipt of any subsequent command from the Initiator receiving the Check Condition status.

The Drive is able to report Sense Data both in the Normal Sense- and the Extended Sense formats. This is controlled by byte 04 in the command block and the Normal Sense Threshold stored in the EEPROM.

If the No. of Bytes Allocated (byte 04 in the command block) has a higher number than the one stored in the Normal Sense Threshold (see Mode Select), Extended Sense format will be returned.

If the value of No. of Bytes Allocated is equal or less the one stored in the Normal Sense Threshold, Normal Sense format will be returned.

The default value for the Normal Sense Threshold is 0, i.e. Extended Sense will be reported for No. of Bytes Allocated different from 0 (zero). If no byte is requested; 4 bytes of Normal Sense will be reported.

The Normal- and the Extended Sense Data Blocks are returned as data. The layout and coding of these blocks are described in the next section.

The Request Sense command will return the Check Condition status only to report fatal errors for the Request Sense command. For example:

- 1) The Drive receives a non-zero reserved bit in the command descriptor block.
- 2) A parity error occurs on the Data-Bus.
- 3) A Drive malfunction prevents return of the Sense Data.

If any non-fatal error occurs during execution of Request Sense, the Drive will return Sense Data with GOOD status. Following a fatal error on a Request Sense command, Sense data may be invalid.

The Drive does not disconnect for this command.

Default Normal Sense Threshold = 0

9.3.14.1. Standard Sense Status Block

The Drive supports both the Standard and the Extended Sense formats. The Standard Sense format will be returned if byte 04 in the Request Sense CDB is equal to, or less than the Normal Sense Threshold specified in the Mode Select parameter data.

The layout of the Standard Sense Block is:

BYTE	BIT 7	6	5	4	3	2	1	0
00	VADD	ERCL			ERCD			
01	0	0	0	Information Byte 1 (MSB)				
02	Information Byte 2							
03	Information Byte 3 (LSB)							

The meaning of this block is:

VADD

This bit is set if the Information Bytes contain valid information.

ERCL

This field specifies the Error Class:

Bits			Error Class
6	5	4	
0	0	0	Drive errors
0	0	1	Drive errors
0	1	0	System related errors
0	1	1	Vendor unique error conditions

ERCD

This field specifies one out of four Error Codes

Class 0 Errors are Drive Errors:		
Code	Error	Description
00	No sense	The Drive detected no errors during execution of the previous command.
02	Hardware error	A non-recoverable hardware error was detected
04	Drive not ready	The tape drive is not ready
09	Media not loaded	The tape cartridge is not inserted in the tape drive.
0A	Insufficient capacity	There is insufficient space on the tape to accept additional data from the Initiator.

Class 1 Errors are Target Errors:		
Code	Error	Description
11	Uncorrectable data error	A block could not be written after 16 retry attempts.
14	No record found	There is no data on the cartridge.
17	Write protected	The media cartridge is write protected. The outstanding write command has been aborted.
19	Bad block found	A block could not be read correctly after 24 retry attempts.
1C	File Mark detected	A File Mark block was encountered during a read operation. The outstanding read and verify commands are terminated and the tape is repositioned just after the File Mark block.
1D	Compare error	One or more bytes did not compare when the verify command was issued.

Class 2 Errors are System Related Errors:		
Code	Error	Description
20	Invalid command	The issued command is not implemented.

Class 3 Errors are Vendor Unique Error Conditions:		
Code	Error	Description
30	Unit attention	A Unit Attention condition (see Section 7.5.2) indicates that the cartridge has been changed and a Load command given; or the Drive may have been reset (by the Bus Device Reset message) since the last issued command. This error is reported when a new command is issued after the condition is detected. The requested command is then not performed. This condition is cleared when the next I/O is issued by the same Initiator. Unit Attention is reported to all SCSI-devices that subsequently issue a command to the Drive.
33	Append error	A Write operation was attempted before End-Of-Recorded-Area was reached.
34	Read End-Of-Media	A read operation past the EOM position was attempted on the tape drive.

9.3.14.2. Extended Sense Status Block

The Drive supports both the Standard and the Extended Sense Status formats. The Extended Sense Status format will be used if the "No. of bytes allocated" (Byte 04 in the CDB) in the Request Sense command is set to a value higher than the one specified in the Normal Sense Threshold in the Mode Select parameter data. The Extended Sense Block is transferred to the Initiator as data after the Initiator first having issued the Request Sense command, see Section 9.3.14. This Block will report all necessary information about errors and parameters before letting the Initiator perform adequate error handling.

The layout of the Sense Data Block is as follows:

BYTE	BIT 7	6	5	4	3	2	1	0
00	VADD	1	1	1	0	0	0	0
01	Segment Number							
02	FM	EOM	0	0	Sense Key			
03	Information Byte 1 (MSB)							
04	Information Byte 2							
05	Information Byte 3							
06	Information Byte 4 (LSB)							
07	Additional Sense Length							
08	Source Sense Pointer (Copy only)							
09	Destination Sense Pointer (Copy only)							
10	Reserved							
11	Reserved							
12	Number Of Recoverable Errors (MSB)							
13	Number Of Recoverable Errors (LSB)							
14	ERCL				ERCD			
15	EXERCD (Extended Error Code)							
16	Block Counter (MSB)							
17	Block Counter							
18	Block Counter (LSB)							

Table to be continued on the next page:

Extended Sense Status Block layout continued:

BYTE	BIT 7	6	5	4	3	2	1	0
19	Filemark Counter (MSB)							
20	Filemark Counter (LSB)							
21	Underrun Counter (MSB)							
22	Underrun Counter (LSB)							
23	Marginal Counter							
24	Remaining Counter							
25	Source/Destination Status Byte							
26	Source/Destination Sense Byte 00							
↓	↓							
26+(n-1)*	Source/Destination Sense Byte 00+(n-1)							

***) NOTE:**

n is the number of bytes given in the Copy Sense Allocation byte, see 9.3.5 Mode Select.

Except for operations initiated by the Copy command, the Additional Sense Block (bytes 08 - 0D) will have the meaning shown above. The meaning of these bytes under the Copy command are described in Section 9.3.1 Copy command.

The meaning of the Extended Sense Block is:

VADD

This bit is set if the information bytes contain valid information.

Segment No.

Contains the current segment number if the Extended Sense information is in response to a Copy command. Up to 256 segments are supported.

FM

This bit is set when a filemark is detected.

EOM

This bit is set when End of Media is detected.

Sense Key

This four bit code define different conditions of the aborted command. Meaning described on the following page.

Information bytes

These bytes specify the difference (residue) of the requested and the actually transferred data blocks.

Additional Sense Length	<p>This byte specifies the number of additional sense bytes which has valid information. There are four possibilities:</p> <ul style="list-style-type: none">17: This is the normal (non-Copy) case.18: A status other than GOOD-status or CHECK CONDITION-status received from the Target during a Copy operation.18+n: CHECK CONDITION-status received from the Target during Copy. The number - n - of sense bytes is specified in the Copy Sense Allocation byte, see 9.3.5 Mode Select.29: Data Transfer Error is detected by the TDC 3620/40/60 Drive during the execution of a Copy command. 18 sense bytes in the Extended Sense format will follow from byte 26.
Source Sense Pointer	<p>This byte specifies the byte number relative to the first byte of Sense Data, related to the beginning of the Source Status Byte and Sense Data. A zero - 0 - value indicates that no status byte or sense is returned for the source logical unit. When non-zero, this byte will read 25.</p>
Destination Sense Pointer:	<p>This byte specifies the byte number relative to the first byte of Sense Data related to the beginning of the Destination Status Byte and Sense Data. A zero - 0 - value indicates that no status byte or sense is returned for the destination logical unit. When non-zero, this byte will read 25.</p>
EXERCD	<p>Extended Error Code is internal to the Drive and reflects all possible errors. See Appendix A.</p>
Block Counter	<p>This is a 24-bit counter of blocks received from the Host (during Write or Verify operations) or sent to the Host (during Read operations). The counter is cleared when a transition is made from one mode (Read, Write or Position) to Read or Write mode.</p>
Filemark Counter	<p>The Filemark counter is a 16-bit counter of filemarks received from the Host (during Write operations) or sent to the Host (as a Check Condition Status when a filemark has been detected on the tape). This counter is cleared when a transition is made from one mode (Read, Write or Position) to Read or Write mode.</p>
Underrun Counter	<p>This counter counts Underruns during Write operations or Overruns during Read or Verify operations. The counter is cleared when a transition is made from one mode (Read, Write or Position) to Read or Write mode.</p>

Number of Recoverable Errors	<p>This counter counts Rewrites during Write operations or Rereads during Read or Verify operations. The counter is incremented by 1 for every block that is rewritten (1 to 16 times) or for each block that is re-read (1 to 24 times).</p> <p>This counter is cleared when a transition is made from one mode (Read, Write or Position) to Read or Write mode.</p>
Marginal Counter	<p>This counter is incremented by 1 for every block that is re-read more than 8 times.</p> <p>This counter is cleared when a transition is made from one mode (Read, Write or Position) to Read or Write mode.</p>
Remaining Blocks	<p>This is the number of unwritten blocks left in the data buffer after a fatal error has occurred during a Write operation.</p>
Source/Destination Status Byte	<p>This status byte is returned from the source or destination device when a data transfer error has been detected during a Copy operation.</p> <p>In case the Copy operation is performed by a TDC 3620/40/60 Drive, this byte will always read 02H (Check Condition).</p>
Source/Destination Sense Bytes	<p>These are the Sense Bytes returned from the source or destination device when a data transfer error has been detected during a Copy operation.</p> <p>In case this device is the Target, the Sense Bytes are the bytes transferred from the Target in response to a Request Sense command issued by the Drive.</p> <p>The Sense bytes will be in the Standard Sense format when the Copy operation is performed by a TDC 3620/40/60 Drive.</p> <p>The VADD-bit is set to zero - 0 -.</p> <p>The information bytes are also set to 0, except for the least significant byte (byte 27), which holds the Drive's Extended Error Code.</p>

The hexadecimal Sense Key Code is defined as follows:

Sense Key Code	Meaning	Description
0	NO SENSE	There is no specific information. This could be the case if Sense is requested because of File Mark or End Of Media detected. In these cases the FM or EOM bits will be set.
1	Reserved	
2	NOT READY	Reports that the cartridge is not inserted and/or loaded.
3	MEDIA ERROR	Unrecoverable data error occurred.
4	HARDWARE ERROR	Power-up Selftest failed, or parity error detected.
5	ILLEGAL REQUEST	Illegal parameter detected in the Command Descriptor Block or in additional parameters supplied as data.
6	UNIT ATTENTION	A Unit Attention Condition occurred. (See Section 7.5.2). This status indicates that the cartridge has been removed since the last command. It is returned the first time a command is given after the cartridge has been removed. The condition is cleared for the next command from the same Initiator. Unit Attention is given to all SCSI-devices that subsequently issue a command to the Drive.
7	DATA PROTECT	Returned if writing is requested to a write protected cartridge.
8	BLANK CHECK	the logical End Of Media (end of recorded area) is detected.
9	Reserved	
A	COPY ABORTED	A Copy command was aborted because an error condition was detected on the source or destination device.
B	ABORTED COMMAND	The Drive aborted the command. The Initiator may recover by trying the command again.
C	Reserved	

Table to be continued on the next page:

Sense Key Code Table continued:

Sense Key Code	Meaning	Description
D	VOLUME OVERFLOW	This condition can occur if additional data blocks are appended after the Drive has reported EOM, and there is not sufficient space left. If this error situation occurs, the non written blocks can be reclaimed by issuing the Recover Buffered Data command.
E	MISCOMPARE	Used by the Verify command to indicate that source data did not match the data read from the tape.
F	Reserved	

| 9.3.15. Reserve Unit (16H)

BYTE	BIT 7	6	5	4	3	2	1	0
00	0	0	0	1	0	1	1	0
01	Logical Unit Number			THP	Third Party ID			0
02	Reserved							
03	Reserved							
04	Reserved							
05	X	X	Reserved			Flag		Link

This command reserves the Drive for the requesting Initiator until a Release Unit command from the same Initiator occurs. During this time no other Initiator can use this drive.

If a command is received from another Initiator while the Drive is reserved for one Initiator, the Drive will send a RESERVATION CONFLICT status and disconnect from the requesting Initiator.

THP (Third Party Reservation option)

The Third Party Reservation option (Byte 1, Bit 4) allows a LUN to be reserved for another device. If this bit is set, an Initiator is allowed to reserve the Drive for the SCSI-bus device specified in the Third Party ID field (Byte 1, Bits 1 to 3). This option is intended for multiple-host environments where the Copy command is used. The Drive stays reserved until it is released by the same Initiator that reserved it.

Third Party ID

The three bits (Byte 1, Bit 1 to 3) specify the SCSI-bus device ID.

The Drive does not disconnect during the execution of this command.

| 9.3.16. Rewind (01H)

BYTE	BIT 7	6	5	4	3	2	1	0
00	0	0	0	0	0	0	0	1
01	Logical Unit Number			Reserved				IMED
02	Reserved							
03	Reserved							
04	Reserved							
05	X	X	Reserved				Flag	Link

This command will rewind the tape to BOT.

IMED

If the IMED bit is set the command will return status as soon as the rewind is initiated. If IMED is not set, status will not be returned until the tape has stopped at BOT. If the IMED option is used and a new command is received during the rewind operation, that command will be executed immediately after the rewind is completed. If the IMED bit is set the LINK bit must be zero - 0 - or else a Check Condition Status will be returned with the Sense Key set to Illegal Request and the Sense Code to Invalid Command.

The Drive may disconnect during the execution of this command.

| 9.3.17. Seek Block (0CH)

BYTE	BIT 7	6	5	4	3	2	1	0
00	0	0	0	0	1	1	0	0
01	Logical Unit Number				Reserved			IMED
02	Reserved				Block Address (MSB)			
03	Block Address							
04	Block Address (LSB)							
05	X	X	Reserved				Flag	Link

The Seek Block command causes the Drive to position the tape at the specified block address. No data is transferred.

The Initiator may obtain block addresses via the Request Block Address command as part of its tape write procedures. The block address can, in turn, be recorded in a user-defined directory. Typically, this directory is located at the end-of-recorded-data and is used to rapidly position at the beginning of specific files on the tape. The Space command can be used to position the tape at the End of Recorded Area - and then by issuing Space Reverse One File Mark - to the position in front of any directory blocks.

A block address if zero - 0 - will cause Check Condition Status with the Sense Key set to Illegal Request and the Error Code to Invalid Command.

If the specified block address is not found on the tape, a Check Condition Status is returned and the Sense Key will report Blank Check while the Error Code will be set to No Record Found.

IMED (Immediate)

The IMED bit is used to request that status be returned as soon as the operation is initiated. When the IMED bit is not set, status will be returned after the tape is positioned at the specified block. If the IMED bit is set the LINK bit must be zero - 0 - or else a Check Condition Status will be returned with the Sense Key set to Illegal Request and the Sense Code to Invalid Command.

The Drive may disconnect during the execution of this command.

9.3.18. Send Diagnostics (1DH)

BYTE	BIT 7	6	5	4	3	2	1	0
00	0	0	0	1	1	1	0	1
01	LUN = 0			0		STest	DevOfI	UniOfI
02	Reserved							
03	Parameter List Length				(MSB)			
04	Parameter List Length				(LSB)			
05	X	X	Reserved				Flag	Link

The Send Diagnostics command requests the Drive to perform diagnostic tests on itself (so-called Selftests). Two different types - Selftest 1 and Selftest 2 - may be requested:

- Default Selftest 1 is similar to the Power-on Selftest and involves no tape Read- or Write operations. See Section 10.1.1 for test description.
- Default Selftest 2 - which is identical to the Acceptance Test - is a more thorough selftest involving both Read- and Write operations. See Section 10.1.2 for a test description. Selftest 2 may be run with default parameters or with special parameters sent to the Drive as a Parameter Block. To run this test an unprotected cartridge must be inserted and loaded.

The command will return with GOOD status if no errors occurs. Else, Check Condition will be set. By issuing a Request Sense command, the Extended Sense Block will give information about the problem. The EXERCD-byte will support the detailed information. See Appendix A for explanation of the different EXERCD-error codes.

STest (Selftest)

When the STest bit is set to ONE, - 1 - , the Drive will perform one out of two possible selftests (Selftest 1 or 2) using default test parameters.

If the STest bit is set to ZERO, - 0 - , the Drive will expect a parameter list with parameters for Selftest 2. If there is no parameter list, no operation is performed.

**DevOfI and UniOfI
(Device Offline and
Unit Offline)**

When STest default is set, either one of DevOfI or will select one out of the two selftests with parameters:

- 1) If both DevOfI and UniOfI are set to ONE, the default Selftest 2 is selected.
- 2) If either DevOfI or UniOfI are set to ZERO, the default Selftest 1 is selected.

When STest is set to ZERO, both DevOfI and UniOfI must be set to ONE. If not, the Drive will respond with Check Condition status with the Sense Key set to Illegal Request.

Parameter List Length

The Parameter List Length specifies the length of the optional parameter list - for Selftest 2 - in bytes.
 If STest is set to ONE, the Parameter List Length should always be equal to 0.
 When STest is set to ZERO, the Parameter List Length must be 0 or 8. If the length is 0, no operation is performed.

NOTE 1:
 Both Selftest 1 and 2 will alter the contents of the Data Buffer.

NOTE 2:
 The Selftests are described in detail in Chapter 10. Selftest and Preventive Maintenance.

The table below shows the Parameter Block:

BYTE	BIT 7	6	5	4	3	2	1	0
00	LLD	Operation Type = 00						
01	No. of Tracks to test							
02	No. of Blocks pr. file (MSB)							
03	No. of Blocks pr. file (LSB)							
04	File Rewrite Limit							
05	Total Rewrite Limit							
06	File Reread Limit							
07	Total Reread Limit							

LLD (Low Level Debugging)

This bit is reserved for TD internal use, and should always be set to zero - 0!

NOTE:
 Acceptance Test/Selftest 2 can be run with changed parameters. This is basically the same test as the Selftest 2 described in Section 10.1.2. The difference is that it is possible to alter the test parameters in the Parameter Block above. The parameters that can be changed are:

- No. of Tracks to test Range: > 0 < 255 Default = 2
- No. of Blocks per file Range: > 0 < 65535 Default = 700
- File Rewrite Limit Range: > 0 < 100 (%) Default = 10 %
- Total Rewrite Limit Range: > 0 < 100 (%) Default = 2 %
- File Reread Limit Range: > 0 < 255 Default = 0
- Total Reread Limit Range: > 0 < 255 Default = 0

| 9.3.19. Space (11H)

BYTE	BIT 7	6	5	4	3	2	1	0
00	0	0	0	1	0	0	0	1
01	Logical Unit Number			Reserved			Code	
02	0	Count (MSB)						
03	Count							
04	Count (LSB)							
05	X	X	Reserved				Flag	Link

This command causes the Drive to perform different search operations. Both logical forward (towards End Of Media) and reverse (towards Beginning Of Media) positioning are provided.

The code is defined as follows:

Code	Description
00	Blocks
01	File Marks
02	Sequential File Marks
03	Logical End Of Media

**Codes 00 and 01:
Space over n Blocks
or File Marks**

When spacing over blocks or filemarks, the Count field specifies the number of blocks or filemarks to be spaced over. A positive value *n* in the Count field causes forward tape movement over *n* blocks or filemarks ending on the End Of Media side of the last block or filemark. A zero - 0 - value in the Count field causes no tape movement. A negative value -*n* (2's complement notation) in the Count field causes reverse tape movement over *n* blocks or filemarks ending on the Beginning Of Media side of the last block or filemark.

If a filemark is encountered while spacing over blocks, tape movement is stopped. The tape is positioned on the End Of Media side of the filemark if movement was in the forward direction and on the Beginning Of Media side of the filemark if movement was in the reverse direction. A Check Condition Status will be sent to the Initiator and the filemark and Valid bits in Extended Sense are set to one - 1. The residual length is the difference in the requested count and the actual number of blocks spaced over (not including the filemark).

If the End Of Recorded Data is encountered while spacing forward over blocks or filemarks, the Drive will return a Check Condition Status to the Initiator. The Sense Key is set to Blank Check. The Valid bit is set to one - 1 - and the actual number of blocks or filemarks spaced over.

If the Beginning Of Media is encountered while spacing over blocks or filemarks in the reverse direction, the Drive returns a Check Condition Status to the Initiator and sets the EOM bit in Extended Sense to one - 1. The Sense Key is set to No Sense. The Valid bit is set to one - 1 - and the residual length is the difference between the requested count and the actual number of blocks or filemarks spaced over.

If the physical End Of Media is encountered while spacing forward over blocks or filemarks, the Drive will return a Check Condition Status to the Initiator and will set the End Of Media (EOM) bit in Extended Sense to one - 1. The Sense Key shall be set to Media Error. The Drive will set the Valid bit to one - 1 - and the information bytes to the difference (residue) between the requested count and the actual number of blocks or filemarks spaced over.

If an unrecoverable data error is found, except when spacing to the End Of Recorded Data, the Drive shall return Check Condition with a Sense Key of Media Error. The Valid bit is set to one - 1 - and the information bytes set to the difference (residue) between the requested count and the actual number of blocks or filemarks spaced over.

**Code 02: Space over
n Sequential File
Marks**

The Drive will move the tape forwards from the current position until detection of n Sequential filemarks. n = 0 causes no tape movement. Only logical forward (towards End of Media) search operations are permitted. A negative value (2's complement) specified in the count-byte will cause a Check Condition. In the Sense bytes, "Illegal Request" will be reported. If the logical End Of Media (EOM) is detected during the search operation, the Drive will return Check Condition. In the Extended Sense Status the EOM bit will be set, the Sense Code set to READ EOM and the Sense Key set to BLANK CHECK.

Detecting the physical End Of Media (EOM) will also cause Check Condition. In the Extended Sense Status the EOM bit will be set, the Sense Code set to READ EOM, and the Sense Key to NO SENSE.

**Code 03: Space to
Logical End of Media**

This command will cause the Drive to search for the logical End Of Media (end of recorded area). The value of n is ignored for this command. The Drive will use a special fast-search algorithm to find EOM in the shortest time possible, and will NOT run in the Normal Streaming Mode.

The "Space to Logical End of Media" command can be used to get rapidly to a user-defined directory which is the last recorded block.

If the physical End Of Media (EOM) is detected during the search operation, this will cause Check Condition. In the Extended Sense Status the EOM bit will be set, the Sense Code set to READ EOM, and the Sense Key to NO SENSE.

The Drive may disconnect during the execution of this command.

| 9.3.20. Test Unit Ready (00H)

BYTE	BIT 7	6	5	4	3	2	1	0
00	0	0	0	0	0	0	0	0
01	Logical Unit Number			Reserved				
02	Reserved							
03	Reserved							
04	Reserved							
05	X	X	Reserved			Flag		Link

This command tests whether the requested unit is ready or not. This is not a Selftest request command. If the Drive is ready for a correct medium access command - without returning Check Condition Status - this command will return GOOD status. If not, Check Condition will be returned. A Request Sense command can be issued to obtain detailed information why the Drive is not ready.

The Drive does not disconnect during the execution of this command.

9.3.21. Verify (13H)

BYTE	BIT 7	6	5	4	3	2	1	0
00	0	0	0	1	0	0	1	1
01	Logical Unit Number			Reserved			BC	1
02	Length of Verification (MSB)							
03	Length of Verification							
04	Length of Verification (LSB)							
05	X	X	Reserved			Flag	Link	

This command enables verification of written data through byte-by-byte comparison or by CRC check without byte transfer from the Initiator. The number of blocks specified in bytes 02 - 04 will be tested. After completion, the tape will be positioned at the end of the last verified block. By immediately issuing the Request Sense command after this command, the number of rereads can be read.

If a filemark is found the command will be terminated, and the Check Condition will be sent. In the Extended Sense Bytes the VADD and the FM bits will be set, the Sense Code will be set to FILE MARK, and the Sense Key to NO SENSE. The number of unverified blocks will be available in the Information bytes. The tape will stop after the filemark in this case.

In case of a mismatch, the Drive terminates the Verify command and informs the Initiator by setting Check Condition. In the Extended Sense Bytes the VADD bit will be set, the Sense Code will be set to MISCOMPARE, and the Sense Key to MISCOMPARE. The number of unverified blocks will be available in the Information bytes. The tape will in this case stop after the faulty block.

If an uncorrectable data error occurs, the Drive terminates the Verify command and informs the Initiator by setting Check Condition. In the Extended Sense Bytes the VADD bit will be set, the Sense Code will be set to UNCORRECTABLE ERROR, and the Sense Key to MEDIA ERROR. The number of unverified block will be available in the Information bytes. The tape will stop after the erroneous block in this case.

If an additional Verify command is issued after a verify error has occurred, the Verify operation begins with the block that follows the erroneous block.

BC (Byte Compare)

If this bit is set, data is transferred from the Initiator to the Drive as for the write command. The data bytes will be compared byte-by-byte with the next data read from the tape. If a compare error occurs, the Verify command will be terminated with the Check Condition status.

In the Extended Sense Bytes the VADD bit will be set, the Sense Code will be set to MISCOMPARE, and the Sense Key to MISCOMPARE. The number of unverified blocks will be available in the Information bytes.

The tape will stop after the erroneous block in this case. If the BC bit is not set, only a CRC check will be performed and no data will be transferred from the Initiator to the Drive. CRC errors have higher priority than mismatch errors.

The execution of the Verify command is not affected by the BM-bit in the Mode Select parameter block. This is because the actual Byte Compare is done on the bus-side of the Drive's data buffer. The Drive handles the Verify command very much like a Read command except for the transfer of data which runs in the opposite direction (from Initiator to Drive).

This means that a "buffered mode effect" is always present when the Drive executes a Verify command.

The Drive may disconnect during the execution of this command.

9.3.21.1. Verify Command Error Conditions

General error conditions during tape operations are listed and described in Appendix B.

Sense Key	Error Class/Error Code	Error
Blank Check (08)	Read EOM (34)	The TDC3620/40/60 Drive detected a logical End-Of-Recorded Area condition
No Error (00)	File Mark (1C)	The TDC 3620/40/60 Drive detected a filemark
Miscompare (0E)	Miscompare (1D)	A data miscompare condition occurred during the Verify operation
Media Error (03)	Uncorrectable Error (11)	A CRC error occurred during the Verify operation
Illegal Request (05)	Invalid Command (20)	The last command issued was a Write command or it was a Verify CRC command following a Verify data command in the immediate mode

| 9.3.22. Write (OAH)

BYTE	BIT 7	6	5	4	3	2	1	0
00	0	0	0	0	1	0	1	0
01	Logical Unit Number				Reserved			1
02	No. of Blocks to Transfer (MSB)							
03	No. of Blocks to Transfer							
04	No. of Blocks to Transfer (LSB)							
05	X	X	Reserved				Flag	Link

This command transfers the number of blocks specified in bytes 02 to 04 from the Initiator's memory to the tape from the current tape position. If writing is started from Beginning Of Media, the Drive will automatically search for the tape edge and then reposition the head at Track 0. There a Reference Burst will be written before the actual data is recorded. As long as data is recorded on Track 0, the tape will be erased. All this is transparent to the user.

If the Drive writes past the "Pseudo Early Warning" (PEW) point - calculated to be 50 feet in front of the physical Early Warning (EW) hole - the Drive stops transferring data and reports CHECK CONDITION. All received data will be written to the tape.

In the Extended Sense the EOM and VADD bits will be set, the Sense Key will be set to NO SENSE, and the Sense Code to INSUFFICIENT CAPACITY. In addition the difference between the requested number of blocks and the number of blocks actually written will arrive in the Information Bytes. Due to the above described feature, the Drive's data buffer will be empty. It is therefore no need to perform the Recover Data Buffer command.

After the Drive has reported EW on the last track, as described above, the Initiator may continue to write blocks on the tape until the physical End Of Media (EOM) is encountered.

Between "Pseudo Early Warning" and the physical End Of Tape, the Drive will normally be able to write 200 KBytes of data. This allows the Initiator to terminate the recording with a filemark or particular data blocks (volume labels). An attempt to write past the EOM will result in a Check Condition status and the error code INSUFFICIENT CAPACITY. In the Extended Sense the VADD bit will be set; the Sense code and the Sense key will be set to INSUFFICIENT CAPACITY and VOLUME OVERFLOW respectively.

If an unrecoverable error occurs during the write operation, the Drive will terminate the Write command and send the Check Condition to inform the Initiator. Additional information about the problem is available in the Extended Sense Status. The VADD bit will be set, and the difference between the requested and the actually written number of blocks is given in the Information Bytes.

If an additional Write command is issued after a write error has occurred, this is an illegal condition which will cause the Drive to inform the Initiator with a Check Condition. In the Extended Status the Sense Code will be set to UNRECOVERABLE ERROR and the Sense Key will be set to MEDIA ERROR.

If the Drive is configured for Buffered Mode, it will return status to the Initiator as soon as the requested number of blocks are written into the Drive's Data Buffer. Errors that occur while the writing data can not be reported before the next command is issued, or if a Request Sense command is issued. It is recommended to add a Write Filemark command with the IMED bit cleared (see 9.3.24 Write Filemark) to assure that all data are written correctly. If the Drive is in the Non-buffered Mode, status will not be returned until the data are written on the tape or if a Check Condition has occurred. For Mode configuration see 9.3.5, Mode Select.

NOTE 1:

To be compatible with the QIC-24/QIC-120/QIC-150 tape formats, it is recommended to terminate a recording with a filemark!

NOTE 2:

To achieve streaming operation, the Drive has to work in Buffered Mode (see Mode Select, Section 9.3.5).

If the disconnect option is activated, the Drive may disconnect during the execution of this command.

9.3.22.1. Write Command Error Conditions

General error conditions during tape operations are listed and described in Appendix B.

Sense Key	Error Class/Error Code	Write Error
Volume Overflow (0D)	Insufficient Capacity (0A)	The TDC 3620/40/60 Drive encountered a physical End-Of-Tape
Illegal Request (05)	Append Error (33)	An attempt to append data occurred when the tape was not at the End-Of-Recorded-Media
No Sense (00)	Insufficient Capacity (0A)	The TDC 3620/40/60 Drive performed a normal Write EOM operation

| 9.3.23. Write Data Buffer (3CH)

BYTE	BIT 7	6	5	4	3	2	1	0
00	0	0	1	1	1	1	0	0
01	Logical Unit Number				Reserved			
02	Reserved							
03	Reserved							
04	Reserved							
05	Reserved							
06	Reserved							
07	Byte Transfer Length				(MSB)			
08	Byte Transfer Length				(LSB)			
09	Reserved						Flag	Link

The Write Data Buffer command is used in conjunction with the Read Data Buffer command as a diagnostic function for testing the Drive's data buffer memory and the SCSI-bus integrity. The medium will not be accessed during the execution of this command.

The Byte Transfer Length includes a four-byte header and the Write Data Buffer data. Up to 66.535 bytes may be transferred, consisting of four bytes of header and up to 65.531 bytes of data. A transfer length of zero indicates that no data transfer will take place.

This condition will not create the Check Condition status. If the transfer length is greater than the Available Length reported by the Read Data Buffer header, the Drive creates the Check Condition status with the Sense Key of Illegal Request. In this case no data will be transferred from the Initiator.

The layout of the data-bytes is:

BYTE	
00	Reserved
01	Reserved
02	Reserved
03	Reserved
04-n	Buffer Data Bytes

| 9.3.24. Write File Mark (10H)

BYTE	BIT 7	6	5	4	3	2	1	0
00	0	0	0	1	0	0	0	0
01	Logical Unit Number				Reserved			
02	No. of File Marks (MSB)							
03	No. of File Marks							
04	No. of File Marks							
05	X	IMED	Reserved			Flag	Link	

This command causes the Drive to write the data remaining in the Drive's data buffer to the tape, and then to append the number of filemarks specified in bytes 02 - 04. If zero is specified, no filemark will be written. This can be used to force the contents of the Drive's data buffer to be written to the tape.

IMED (Immediate)

This bit is valid if the Drive is in the Buffered Mode (see 9.3.5 Mode Select).

When this bit is set and the Drive is in Buffered Mode, the Write Filemark command will return Completion Status immediately after being received. This makes it possible to write filemarks in streaming mode. If the IMED bit is cleared Completion status will not be returned until the filemark(s) is(are) actually written on the tape, even if the Drive is set to Buffered Mode. If the IMED bit is set the LINK bit must be zero - 0 - or else a Check Condition Status will be returned with the Sense Key set to Illegal Request and the Sense Code to Invalid Command.

9.4. Completion Status Byte

Status is always sent when a command is completed. Any abnormal condition which occurred during the execution of the command will cause termination and Completion Status with the Check Bit set. If a new command is issued before the Drive has finished the execution of the previous command, Completion Status will be sent with the Busy Bit set.

The Completion Status Byte layout is:

BIT 7	6	5	4	3	2	1	0
Reserved (=00)			Status Code			Reserved	

The coding is as follows:

Bits				Meaning
4	3	2	1	
0	0	0	0	Good Status; the requested operation was completed successfully.
0	0	0	1	Check Condition; an abnormal condition has occurred. The Initiator should issue the Request Sense command to get further information. See Section 9.3.14.
0	1	0	0	Busy Status; the Drive is busy executing a command. (For instance the Rewind command when the IMED option has been used).
1	0	0	0	Intermediate Status. Sent for every command in series of linked commands, unless a Check Condition or Reservation Conflict status is detected.
1	1	0	0	Reservation Conflict; sent to an Initiator that attempts to access the Drive when it is reserved for another Initiator.

9.5. The Message-In Byte

The messages which can be sent from the Drive to the Initiator are listed below:

Command Complete (00)

This message indicates that the Drive has completed a requested command and sent valid status to the Initiator. The Drive will then release the bus by deasserting BSY. The Command Complete message is sent when:

- a) Good Status has been sent; the command has been completed ok.
- b) Check Condition has been sent; something went wrong during command execution.
- c) Busy Status has been sent; the requested command is not accepted because the Drive is busy executing the previous command.
- d) Reservation Conflict has been sent; the requested command is not accepted because the Drive is reserved by another Initiator.

Disconnect (04)

This code is used to inform the Initiator that the Drive will release the bus as for the Command Completed message. However, now the Drive will reconnect later in order to complete the operation. (See Section 7.4.4 for the Reselection Phase). A Save Data Pointers message is always sent prior to this message.

Identify (80)

This message is used in the Reconnection Phase to inform the Initiator that the Drive has reconnected.

Linked Command Complete (0A)

This message is used to indicate the completion of a linked command. It is sent after the Intermediate Status byte.

Linked Command Complete With Flag (0B)

This message is used to indicate the completion of a linked command that had the Flag bit set. It is sent after the Intermediate Status byte.

Message Reject (07)

This message indicates that the last message issued by the Initiator was not valid. Possible reasons are:

- a) The Identify message is received in phases other than the Selection Phase.
- b) Message Parity Error is received when no message is sent.
- c) Initiator Detected Error when the data transfer was from the Initiator.
- d) For all other messages than those mentioned on the preceding page, except for Abort and Reset.

Save Data Pointers (02)

This message tells the Initiator that it must save its data buffer pointers. It is always sent prior to the Disconnect message.

9.6. The Message-Out Byte

The messages which can be sent from the Initiator to the Drive are listed below:

Abort (06)	This message will cause the Drive to abort a command and get off the bus.
Bus Device Reset (0C)	This message tells the Drive to reset itself. It has the same effect for the Drive as if the RST line should be asserted.
Identify (80 to FF)	<p>This message is used to establish a connection to a particular LUN. The Drive is always LUN 0. If a LUN other than 0 is specified, The Drive will immediately send Check Condition status and COMMAND COMPLETE message. The Sense information will indicate ILLEGAL REQUEST. The IDENTIFY message will also indicate if the Initiator supports deselection or not. The following bits have a special meaning:</p> <ul style="list-style-type: none">Bit 7: Always setBit 6: Set if the Initiator can support Disconnection and ReconnectionBits 0-2: Specifies the LUN address of the Drive <p>The IDENTIFY message is only valid during the Selection Phase.</p>
Initiator Detected Error	The Initiator has detected a parity error during the information transfer phase. This will cause the Drive to terminate the current operation with Check Condition status. In the Extended Sense the Sense Code will be set to DEVICE NOT READY, and the Sense Key to HARDWARE ERROR.
Message Parity Error (09)	The last message sent by the Drive had a parity error. This will cause the Drive to terminate the current operation with Check Condition status. In the Extended Sense the Sense Code will be set to DEVICE NOT READY, and the Sense Key to HARDWARE ERROR.
Message Reject (07)	The last message sent by the Drive was not valid. The Drive will respond by sending a Message Reject message, except if the received MESSAGE REJECT was in response to a SAVE DATA POINTERS message. In this case the message is ignored.



9.7. Parity Error Handling

Grounding the PARI-pin on the SCSI Mainboard (see Section 4.2 for location) will enable the Parity Controller. The SCSI-Bus parity line supports odd parity if the PARI-pin is connected to ground (GND) when the Drive is driving the bus.

The Drive supports only "hard" parity error handling, i.e. no recovery sequence will be performed.

Parity errors are handled in the following way:

- If a parity error is detected during selection, the selection will be ignored.
- If a parity error is detected during transfer of a Command Descriptor Block, the total contents of the block will be transferred before Check Condition is set.
- During data transfer, parity will be checked for each n blocks, where n is equal to the Bus Threshold selectable by the Mode Select command.
If a parity error has occurred, the data transfer will be terminated and Check Condition Status sent.
The Request Sense block will tell the number of blocks NOT transferred to the buffer. If the number of blocks in a data transfer sequence is less than n, parity will be checked and reported at the end of the transfer.

9.7.1. General Information

When reading data on the bus, the Drive will check for a parity error if the PARI-pin is grounded.

If the Drive detects parity error when reading the bus, this will result in a Check Condition. In the Extended Sense Status block; the Sense Key will be set to Hardware Error.

If the Drive receives a "Message Parity Error", this will also cause a Check Condition. In the Extended Sense Status block the; Sense Key will be set to Hardware Error.

The probability of a Parity Error should be relatively low in a well designed system. If parity errors are a frequent problem in a system, this must first be solved by reducing noise and crosstalk on the signal transmission cables on system level. Frequent Parity Error situations are not acceptable to the user, regardless of the implemented error recovery routine!

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10. Selftest and Preventive Maintenance

10.1. Selftest

The Drive supports extensive selftest possibilities which will simplify the testing of the Drive. Three different types of selftest procedures can be executed:

- 1) Power-Up Selftest
- 2) The manually activated selftests
- 3) The Host activated selftests

10.1.1. Power-Up Selftest/Selftest 1

Each time the power is turned on, the Drive will go through a power-up selftest routine before it will be accessible to the Host system. This test will check most of the digital hardware.

NOTE:

The same test may also be performed with the manually or Host activated selftests. It will be referred to as Selftest 1, but then with an extended Buffer Test. See 5) in the following test description:

Test Description

1) **EPROM Checksum Test**

2) **Scratch Pad RAM (Static RAM) Test**

The static RAM is tested by writing and reading 55H and AAH data patterns to all RAM-cells.

3) **Drive Controller Test**

The hardware for Write- and Read formatting will be tested. The Drive Controller chip is placed in digital loopback mode and 16 bytes of data is fed into the Write Sequencer through the microprocessor data-port. The data is read and compared with the original data when received from the Read Sequencer. CRC is also checked.

4) **SCSI Controller Test**

Both DMA channels are tested with 55H and AAH data patterns.

DMA0 is tested using the Drive Controller in loopback mode. The data is sent from the buffer to the Drive Controller by means of DMA0. The data received from the Drive Controller Read Sequencer is checked.

DMA1 is tested transferring a block of data from the microprocessor port to the buffer using DMA1 in Copy mode. This data block is compared with the data in the microprocessor port using DMA1 in Verify mode.

Power-Up	5) Data Buffer Test (Dynamic RAM) The Buffer is tested with Write and Read using the DMA. The data pattern is 55H and AAH. Time consumption is approximately 5 ms.
Manually- or Host activated (Selftest 1)	First the buffer is tested with Write- and Check Read operations: Data 55H and AAH is sent to all buffer cells using the DRAM Controller in the SCSI Controller chip and the Bank select function. This test will fail if the DRAM refresh is not working properly. Time consumption is about 35 sec. if a 64 KByte buffer is supported. Next the RAM addressing is checked: The buffer is filled with 00H and one byte is loaded with FFH. The rest of the buffer is compared with 00H. If an error is detected, the buffer is tested again to find out if the error is located in the high or the low nibble.
	Other digital circuitry like the Address Decoding logic and the CPU are not tested separately, but have to be in perfect working order to perform Selftest 1 successfully.
	Selftest 1 is not testing the following functions: <ul style="list-style-type: none">* Analog circuits like the Read- and Write channels* Bus Interface circuits* Capstan and Stepper Motor circuits* Sensor circuitry

10.1.2. The Manually Activated Selftests

These selftests are invoked by using the straps located at the rear of the Drive. (See Section 4.2 Strap Setting/Selecting Drive Number in Chapter 4).

Test Description

1) **Production BURN-IN Test. (For Internal use only!)**

This test is used in the production in order to exercise the hardware during the Burn-In period for the Mainboard. The test will discover most errors in the digital hardware.

When the Burn-In test is started, the Drive's GREEN front LED is turned on. This test repeats the Drive's Power-Up Selftest until power is turned off or an error occurs.

The Drive's power-up test checks most drive hardware like the Drive Controller VLSI, the SCSI Controller VLSI, the Buffer RAM and the System RAM. The SCSI Controller handshake test is testing the internal SCSI VLSI-circuit bus-handshake input and output drivers.

If an error should be detected, the RED front LED will blink an error message code (see NOTE below and Appendix A). If an error has occurred once, the error information will be stored in the EEPROM so that it can be reported even after power-off. A new Burn-In test can only be started after this information has been cleared. This can be done with special equipment only!

NOTE:

Only error messages 56 to 61 will be reported during the Burn-In test.

2) **Production RUN-IN Test. (For Internal use only!)**

This test is used to exercise complete drives during Run-In in the production. It will discover premature faults in the Drive, but is no good for testing the drive quality!

When the Run-In test is started, the GREEN front LED is lit and the tape is loaded. If the Run-In test is completed without any errors, the GREEN LED will blink. (Blinking rate is approximately 0.5 Hz). A complete Run-In test takes about 90 minutes.

The test program first runs an Erase Tape command. This is done to exercise the Erase circuitry and to retension the tape.

In order to exercise the Head Servo and to test the Read circuitry, a Recalibrate Head Position command (HDTOP) and a Seek Tape Edge command is issued 4 times. The HDTOP function both recalibrates the Head Servo and runs a Seek Tape Edge. As a result of this there will be two Seek Tape Edge operations between each head servo recalibration.

Next a Write test and a Capstan Servo exercise is performed. A specific 29H data pattern is loaded into the buffer RAM and written on the tape in sections of 1000 blocks. Between each section, the data transfer is stopped. The tape is halted and backspaced. After a short delay the data transfer is restarted and 1000 new blocks are transferred. This is repeated until EOT (End Of Tape) is reached. The tape is then rewound to BOT (Begin Of Tape) and the test is started over again with an Erase command.

For this Write test, the built-in "Read After Write" function is performed. During Write, single Write errors are ignored, but fatal Write errors (Rewrite the same block 16 times with errors. Error message: E\$16RW, see Appendix A) will abort the Write test and the Run-In test starts again with an Erase command. After 4 fatal Write errors the test is aborted and an E\$16RW error message is blinked on the RED front LED.

All other errors will abort the Run-In test and the error message is blinked with the RED front LED.

3) Acceptance Test/Selftest 2

First the Selftest 1 (see Section 10.1.1) is run.

Next test is a Write/Read test. Two tracks are written in files of 700 blocks. Between each file the tape stops and backspaces before a new file is appended. Data Append is included to test the Erase circuitry.

The data pattern in each block alternates between three patterns. One block is written with a block count pattern, the next with 29H pattern and the last with 60H pattern. This sequence is then repeated. These patterns are "worst-case" patterns and will help to determine both Write- and Read quality.

After each file and when all files are written, the number of rewrites is compared to the corresponding rewrite limit. (10 % rewrites are allowed per file. 2 % are the total limit).

If there are too many rewrites the test is aborted and the RED front LED blinks with an error code, see NOTE on the next page. (See Appendix A for explanation of the error messages).

After the Write test the tape is rewound to BOT.

If the Write test detects no errors, a Read test is performed. Here the data is read file-by-file from the tape in streaming mode.

During the Read test NO rereads are allowed. If rereads should occur the Read test will be performed again. If the rereads still occur it is considered to be a "hard" error and the test is aborted. The RED front LED will blink the corresponding error message code, see NOTE. (See Appendix A).

If no rereads occur during the second Read test it is considered a "soft" error and no error is reported when the test returns.

During the Read operation a data compare is performed in addition to the built-in CRC check. If the compare fails the test is also aborted while the front LED blinks an error code (see NOTE below) according to Appendix A.

4) Production QA Reliability Test (For Internal use only!)

This test is specified by QA. A specific data pattern of 29H is written on all tracks in streaming mode. When the tape reaches EOM it is rewound to BOT and a new Write operation is started. This test runs until power is turned off or until an error occurs.

Single rewrites is ignored but fatal rewrites (Error code: E\$16RW) will abort the test and an error is reported by the RED front LED.

5) Production QA Head and Motor Wear Test (For Internal use only!)

The purpose of this test is to control TDC 3620/40/60 Drive Head and Motor wear. When the test is started the tape is loaded and the Head is positioned on Track 0. The tape moves for about 5 seconds and stops. After about 1 second delay the tape starts to move again. This sequence is repeated indefinitely. At EOT and BOT the tape move direction is reversed.

Every time the tape stops the Head is moved about half a track width up or down in order to spread the head wear evenly over the head surface. For every 10th track the head position is recalibrated.

This test will run until the power is turned off or until an error occurs. If an error is detected the test is aborted and the RED front LED blinks the corresponding error message code. (See Appendix A).

NOTE:

If the test is activated by using the Send Diagnostics command (see Section 9.3.18), errors will be reported via the Completion Status Byte.

10.1.3. The Host Activated Selftests

Selftest 1 and Selftest 2 may be activated from the Host side by using the Send Diagnostics command. (This command is described in Section 9.3.18).

The tests are the same as the Power-Up Selftest and the Acceptance Test but are referred to as Selftest 1 and Selftest 2 respectively.

10.2. Preventive Maintenance

The only maintenance normally required is to clean the read/write head. It may be cleaned through the cartridge slot.

Recommended equipment for head cleaning is:

The Tandberg Data
TDC Cleaning Cartridge Kit

**IMPORTANT!**

Do not use any hard or sharp objects that might scratch the surface of the head! Even small scratches may damage the head permanently.

Always clean the head immediately after using a new cartridge, and if large numbers of rewrite- or reread operations are performed.

Use only certified quality cartridges for the TDC 3620/40/60 Drive. Do not use worn or audibly noisy cartridges. Cartridges which repeatedly require rewriting of large numbers of blocks per track should also be rejected. The rewrite counter, bytes 19 and 20 in the Extended Sense Status Block (see Section 9.3.14.2) may be used as an indicator to the cartridge quality.

Appendix A: Extended Error Code Messages

The extended error code EXERCDC reflects all possible error types that can be detected by the Drive. Normally the user will only have use of the Error Code or the Sense Key in the Normal or Extended Sense Status Blocks. If more detailed information is wanted, byte 15 (EXERCDC) in the Extended Sense Status Block will offer this.

If an error occurs during the Power-up Selftest, the error message is given with a sequence of short and long blinks with the *RED* front LED.

The blink-code is a 6 bit binary code where a long blink means a "one"- and a short blink a "zero" level. The blink-code starts with the most significant bit.

The table below shows the TDC 3620/40/60 Drive's error messages accompanied by the EXERCDC Hex-codes (1), the LED blink codes, the Error Class Hex-codes (2) and the Sense Key Hex-codes (3):

Mnemonic	1	LED Blink-code *	2	3	Meaning	Fatal Error
E\$OK	00	S S S S S S	00	00	No Error	
E\$APPN	01	S S S S S L	33	05	Append Error	
E\$BADC	02	S S S S L S	20	05	Bad command block	
E\$BADP	03	S S S S L L	20	05	Bad param. block	
E\$BUSP	04	S S S L S S	00	04	Bus parity Error	
E\$BUSY	05	S S S L S L	04	02	Busy	
E\$CAPS	06	S S S L L S	04	04	Capst. servo Error	B
E\$CART	07	S S S L L L	09	CB	Cartridge removed	
E\$COMP	08	S S L S S S	1D	0E	Compare Error	
E\$CPDT	09	S S L S S L	00	0A	Copy data Error	
E\$CPMN	0A	S S L S L S	00	05	Copy managem. Err.	
E\$FIMK	0B	S S L S L L	1C	80	File Mark Error	
E\$HEAD	0C	S S L L S S	04	04	Head Servo Error	B
E\$ILCM	0D	S S L L S L	20	05	Illegal command	
E\$ILCP	0E	S S L L L S	20	05	Illegal copy	
E\$ILLN	0F	S S L L L L	20	20	Illegal length	
E\$INAP	10	S L S S S S	20	05	Inappropriate req.	
E\$LERR	11	S L S S S L	04	04	Latch Error	A
E\$NCAR	12	S L S S L S	09	02	No cartridge	
E\$NL0D	13	S L S S L L	09	02	Not loaded	
E\$POWR	14	S L S L S S	00	00	Power-on request	
E\$QRND	15	S L S L S L	14	03	QIC.No data detect.	
E\$RDWR	16	S L S L L S	34	05	Rd.after Wrt.Error	
E\$REOL	17	S L S L L L	34	08	Read EOM logical	
E\$REOP	18	S L L S S S	34	40	Read EOM physical	
E\$RESC	19	S L L S S L	00	00	Reserv. conflict	
E\$SENS	1A	S L L S L S	04	04	Sensor Error	B
E\$STRUN	1B	S L L S L L	04	04	Tape runout	B
E\$UATT	1C	S L L L S S	30	06	Unit attention	
E\$WEOW	1D	S L L L S L	0A	00	Write EOM warning	

Error Message table continued ...

Mnemonic	1	LED Blink-code *	2	3	Meaning	Fatal Error
E\$WEOM	1E	S L L L L S	0A	00	Write EOM	
E\$WPRO	1F	S L L L L L	17	07	Cart. write prot.	
E\$16RW	20	L S S S S S	11	03	16 rewrite errors	
E\$24RF	21	L S S S S L	19	03	24rereads.Blk.fnd.	
E\$24RE	22	L S S S L S	19	03	24rereads.Not fnd.	
E\$CHDF	23	L S S S L L	20	05	Illeg.Copy Function	
E\$CHDI	24	L S S L S S	20	05	Illegal Header	
E\$CHDN	25	L S S L S L	20	05	No Header	
E\$CSGA	26	L S S L L S	20	05	Too Large Address	
E\$CSGI	27	L S S L L L	20	05	Bad ID or LUN	
E\$CSGP	28	L S L S S S	20	05	Partial Description	
E\$CIBS	29	L S L S S L	00	0A	Bad Target Status	
E\$CICH	2A	L S L S L S	00	0A	Check Condition	
E\$CIDT	2B	L S L S L L	00	05	Data Transf. Error	
E\$CISE	2C	L S L L S S	00	0B	Selection Failure	
E\$CISQ	2D	L S L L S L	00	CB	Sequence Error	
E\$CILB	2E	L S L L L S	20	0B	Illegal Block Size	
-	2F	-	-	-	-	
-	30	-	-	-	-	
E\$SBSZ	31	L L S S S L	04	02	Buffer Size Error	A
E\$SRRD	32	L L S S L S	04	02	Rereads Outsd.Limts	
E\$SRWR	33	L L S S L L	04	02	Rewrts. Outsd.Limts	
E\$SLBF	34	L L S L S S	04	02	Buff.Err.Low Nibble	A
E\$SHBF	35	L L S L S L	04	02	Buff.Err.High Nibb.	A
E\$SFAT	36	L L S L L S	04	02	Unspec.Fatal Error	
E\$STMO	37	L L S L L L	04	02	Timeout Error	B
E\$SBUF	38	L L L S S S	04	02	Buffer RAM Error	A
E\$SDCN	39	L L L S S L	04	02	Drive contr. Error	A
E\$SEEP	3A	L L L S L S	04	02	EEPROM verific.	A
E\$SEPR	3B	L L L S L L	04	02	EEPROM Error	A
E\$SRAM	3C	L L L L S S	04	02	External RAM Error	A
E\$SSCN	3D	L L L L S L	04	02	SCSI contr. Error	A
E\$XINT	3E	L L L L L S	04	02	Spurious interrupt	B
E\$XOVF	3F	L L L L L L	04	02	Stack overflow	B

- * The abbreviation "S" means a Short blink.
- * The abbreviation "L" means a Long blink.

Fatal Error

- Type A) This error can NOT be reset. Once occurred, the Drive will continue to report the error with a blinking code. CALL FOR SERVICE!
- Type B) These errors could be failures in the Drive or in the data cartridge. The error situation is cleared by RESET, but the error information is saved in the EEROM for service purposes.

Appendix B: General Error Conditions

General media-related error conditions that occur during TDC3620/40/60 Drive operations are listed and described in the table below:

Sense Key	Error Class/Error Code	Error
Hardware Error (04)	Hardware Error (04)	A drive related or controller-related hardware error occurred
Aborted Command (0B)	Media Not Loaded (09)	The tape cartridge was removed during the execution of the command
Media Error (03)	Unrecoverable Error (11)	The TDC3620/40/60 Drive performed the maximum number of retries on the block (16 for Write or 24 for Read)
Not Ready (02)	Media Not Loaded (09)	The tape cartridge was not loaded before a command was issued
Unit Attention (06)	Unit Attention (30)	The tape cartridge was removed and then installed before the execution of a command began
Recoverable Error (01)	Correctable Data Check (18)	A recoverable error occurred during the execution of a command



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Appendix C: Application Notes

C.1. How to Achieve Streaming Mode Operation

The TDC 3620/40/60 Drive is basically designed for streaming mode operation, i.e. writing and reading data without stopping the tape.

The data capacity and the back-up performance will be optimal when running in streaming mode.

The system integrator should be aware of this fact and always try to optimize the surroundings so that streaming mode can be achieved.

The main concern is to make sure that an average data transfer rate of 90 Kbytes/sec. can be achieved.

The following items may have an impact on the average data rate:

Number of Blocks per Command

The data transfer part of the command execution is significantly faster than that of the command phase. This is because the first operation is done in hardware while the latter is done in software.

The command block will also have to be processed (decoded) before any action can be taken; which again is time consuming.

Accordingly: Increased "No. of blocks per command" gives increased bus performance.

Hard-disk Interleave Factor

The most common way of utilizing the TDC 3620/40/60 Drive is to transfer data between the Drive itself and a hard-disk. This could be done either directly (by using the Copy command) or indirectly via the Host Adapter Buffer.

The overall bus performance depends primarily on the hard-disk interleave factor. (Interleave factor = no. of disk-spindle revolutions made to read a complete disk track). Typically the interleave factor has to be less than 5 if the average transfer rate of the hard-disk should be greater than 90 Kbytes/sec.

Hard-disk Seek Time

The most time consuming operation of the hard-disk is normally the Seek operation from one track to another. If the data which should be read or written is spread all over the disk, this will involve a whole lot of Seek operations and it will be impossible to get sufficient throughput on the bus. This means that file-by-file backup - where the data usually is spread at random - can be difficult to achieve in streaming mode.

For high efficiency image backup it will be advisable to access one hard-disk cylinder (i.e. tracks on different hard-disks with same distance from the centre) at a time; as this can be done without any Seek operations.

This can be achieved by setting the Bus Threshold in Mode Select (see Section 9.3.5) to the number of blocks contained in one cylinder.

Buffered Mode Operation

The normal SCSI requirement is that each command shall be executed and terminated with Status before a new command can be issued.

This is very unfortunate for tape streamers as it makes it impossible to achieve streaming mode operation. This is because each data transfer to the Drive has to be written and verified before Status can be returned. At this time there will be no new data available in the buffer and the Drive will have to stop and wait.

To avoid this problem it is possible to specify "Buffered Mode" (see Section 9.3.5 Mode Select).

When Buffered Mode is chosen, the Drive will return Status as soon as all data are transferred into the data buffer. This makes it possible for the Host to issue a new Write command before the buffer is empty; and in this way it is possible to obtain streaming mode operation.

When working in this mode the Completion Status only tells if the data is transferred correctly (or incorrectly) into the Drive's data buffer. The verification of the written data will appear after a short delay.

If problems occur during writing, this has to be reported when the next command is issued.

Buffered Mode can also be useful to systems that do not support the "Deselect" function. It can be used to achieve early release of the SCSI-bus so that it can be used for other tasks instead of waiting for the tape to complete the Write process.

C.2. If Streaming Mode can not be Achieved**Read and Write Threshold**

If the Drive has frequent start or stops due to low bus transfer rate, this will increase the backup or restore time. The tape capacity will be reduced as a result of this as each start/stop will use approximately the space of 1.5 data-blocks for writing elongated gaps. In the extreme case where underrun occurs for each block of data, the capacity will be reduced by a factor of about 200!

In order to minimize this problem the Drive has configurable Read- and Write Thresholds.

The tape Write Threshold specifies the amount of blocks that must be ready in the buffer during backup before the tape starts (default = 2 blocks).

During restore the tape Read Threshold specifies how many data blocks there are capacity for in the buffer before the tape starts (default = 2 blocks).

In case of the example mentioned above, it would be advisable to set the Write Threshold to a high value (maximum 120). This means that the tape start will be delayed until 120 blocks are ready in the buffer. If the maximum value 120 is chosen, the Drive will have sufficient data in the buffer to be able to run for about 1.5 seconds.

The Host has most likely been able to transfer more data to the buffer during this time interval, and the Drive will be able to run even longer before underrun occurs, may be even after each 300 data blocks.

The loss of capacity will then have been reduced by only 0.5 % instead of 60 %. The backup time will be less than 10 times the time for streaming mode; compared to 200 times!

During Read operations the tape Read Threshold can be used in a similar way to avoid frequent repositionings due to overflow in the data buffer.

The Read- and Write Thresholds can be altered by means of the Mode Select command (see Section 9.3.5).

Forced Streaming

If a system suffers from too low bus transfer rate to maintain streaming mode operation, and lack of capacity is less important compared to short backup time, "Forced Streaming" mode should be used.

If the Drive operates in this mode and the buffer gets empty during Write, the last data block will be rewritten until more data is available. In this way it is possible to achieve streaming mode operation.

However, the tape capacity (the effective bus transfer rate) will be reduced by a factor of 90 Kbytes/sec.

See Section 9.3.5 Mode Select for more information.

C.3. How to Optimize SCSI Performance

The SCSI system allows "multitask" operation on one common resource, the physical SCSI-bus.

In order to optimize system performance, it is essential that all devices using the shared resource (SCSI-bus), should use it only when data or control information can be transferred. This means that such information should be buffered in the devices and only be transferred in bursts at the highest obtainable transfer rate.

The SCSI-bus should be released for other tasks as soon as the burst transfer is completed.

Normally, the performance of the total system will depend very much on the performance of each device connected to the bus. Thus, it is difficult to design a device able to work in the most optimal way independent of the surrounding system. It will be useful to "tailor" the performance of the system in each case.

The factors that might have some influence are:

- 1) Number of blocks per command
- 2) Interleave factor of the hard-disk
- 3) Seek time for the hard-disk
- 4) Buffered Mode operation
- 5) Deselect/reselect bus thresholds

Items 1 - 4 are described in application note B.1: "How to Achieve Streaming Mode Operation" and will not be dealt with here.

Deselect/Reselect Bus Thresholds

High performance SCSI systems will support the "deselect/reselect" option to allow "multitask" operations.

All communication on the bus will then take place as "high speed bursts", each burst containing control information or a certain number of data blocks.

The amount of blocks transferred in each burst may influence the overall system performance.

In order to help optimizing the performance, the TDC 3620/40/60 Drive has selectable bus thresholds (see Mode Select). The bus thresholds specifies the no. of blocks that should be transferred in each data burst.

If the Initiator supports DISCONNECT, the Drive will disconnect/reconnect between each data burst.

Appendix D: Internal Buffer Operation

Internally the Drive is equipped with RAM-chips forming the Data Buffer. The physical size is either 16 or 64 KBytes.

FIFO Queue

The buffer operates as a FIFO (First In First Out) queue, compensating for the different transfer rates on the SCSI-bus and the tape. This buffer lets the Drive use the *Disconnect - Reconnect* functions on the SCSI-bus. With approximately a 1.5 MByte data transfer-rate on the SCSI-bus and approximately 88 KByte data transfer-rate to or from the tape, the Drive will be connected to the SCSI-bus only a fraction of the total execution time during Read or Write commands.

Multiple Levels

D.1. Data Buffer Design Goal

The buffer management is controlled in "multiple levels", with each level depending on the size and functions of the layer above. To fully understand this operation, the buffer management can be explained from the following figure, showing the five layers:



PHYSICAL SIZE
MAX SIZE
CURRENT SIZE
DYNAMIC SIZE
ACTUAL SIZE

Each of the five layers is diverted from the layer above. The result of this is that a layer cannot be larger than maximum the size of the layer above.

The use of each layer is as follows (all figures are in number of blocks = 512 bytes):



- **PHYSICAL SIZE:** This is the maximum physical buffer memory in the Drive.



- **MAX SIZE:** This is the maximum available memory for buffer operations. The difference between **PHYSICAL SIZE** and **MAX SIZE** comes from the fact that the Drive has reserved 4 KBytes of data for the entire Segment Descriptor Block used by the Copy command. The maximum value of **MAX SIZE** is **PHYSICAL SIZE - 8**.



- **CURRENT SIZE:** This is the value of the Buffer Size in the Mode Sense and Mode Select commands. The maximum value is equal to **MAX SIZE**.



- **DYNAMIC SIZE:** This is the maximum available size for data transfer to or from the buffer. The maximum value for Write operations is **CURRENT SIZE - 3**, and maximum value for Read operations is **CURRENT SIZE - 5**. The extra space is required for rewrites and rereads.



• **ACTUAL SIZE:** This is the buffer size actually used. Because the Drive transfers data in bursts, where the size of each burst is controlled by the value of the Bus Threshold, only a multiple number of Bus Threshold datablocks will be transferred to the buffer during each burst. The ACTUAL SIZE is the maximum multiple of the Bus Threshold, limited to be equal or less than the DYNAMIC SIZE.

The value of BUS THRESHOLD controls the number of datablocks in each burst between the SCSI-bus and the Drive. During a Write command - no transfer of data will be initiated until the Data Buffer can accept at least the number of datablocks given by the BUS THRESHOLD. During a Read command no transfer of data will be initiated before at least BUS THRESHOLD number of blocks are available in the Data Buffer.

During a Copy command the COPY THRESHOLD will control the size of the Read and Write commands the Drive sends to the Target, and thereby also inflict on the SCSI-bus performance.

The value of the READ THRESHOLD and the WRITE THRESHOLD controls the flow of data between the buffer and the tape. During a Write Data command, no data will be written on the tape before at least WRITE THRESHOLD number of datablocks are available in the buffer. During a Read command no data will be read from the tape before the buffer can accept at least READ THRESHOLD number of blocks.

With the given functionality of the buffer and the configuration variables, it is possible to configure the Drive so that it will not operate at all. For example - for a Drive with a 64 KByte buffer, having the WRITE THRESHOLD set to 100 and the BUS THRESHOLD set to 80, large Write commands will enter the Drive in a deadlock situation. First the Drive will burst over 80 (BUS THRESHOLD) blocks. No more data can be written into the buffer because the free space is less than 80 (BUS THRESHOLD) blocks. Furthermore, no data will be written to the tape because the number of blocks in the buffer is less than WRITE THRESHOLD.

The conclusion must be that the user should be careful when selecting new values for BUFFER SIZE or READ AND WRITE THRESHOLD, thus avoiding unwanted deadlock situations.

D.2. Data Buffer Operation

This section will explain the practical operation of the First In First Out (FIFO) Data Buffer. Having the Data Buffer design goal in mind will make it easier to understand the buffer operation.

Only the transfer of data on the SCSI-bus will be explained in this section. (The goal of this section is not to explain the internal drive operation).

The FIFO-buffer is made as a circular buffer in the data RAM. This construction will result in a so-called "Wrap Around" effect. This happens when the queue handling routines have to move the queue pointers between high and low physical RAM addresses. The effect can be recognized by looking at the transfer rate on the SCSI-bus. For every "Wrap Around", an additional delay of not more than 100 μ s can be noticed between two datablocks.

The following theoretical example can visualize the operation.

A Write Data command with 1000 datablocks as parameter is given when the tape is positioned at BOT. The Drive is configured as follows:

Bus Threshold		= 64 (32 KBytes)
Write Threshold		= 2
ACTUAL SIZE	= 128 - 8 - 3	= 117 (58.5 KBytes)

After the command is transferred, the Drive will look for space for at least Bus Threshold blocks = 64 blocks in the buffer. This will be true, and data transfer is initiated. (At this moment, when at least Write Threshold = 2 blocks have entered the buffer, the Write Data to Tape is initiated.) After transfer of the first 64 blocks, the Write Data to Tape has not started to empty the buffer because of the relatively long time it takes to write the Reference Track.

At this moment, the buffer will contain 64 blocks of data. There is a free space of 117 - 64 = 53 blocks. Because this is less than the Bus Threshold value, a new data transfer is not immediately started.

After some time the tape will fetch data from the buffer. When at least 11 blocks are written to the tape, the data buffer can accept 64 new blocks from the Host. At this moment a new burst of 64 blocks is transferred from Host to Drive.

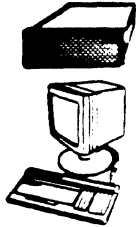
During this second burst of data it is possible to measure the "Wrap Around" effect. First 53 blocks are transferred. Then the buffer management routines will have to "recalculate" some of the buffer pointers before the Drive can transfer the last 11 blocks. The "Wrap Around" delay will be less than 100 μ s.

The Drive will continue to use this method until all data blocks have been written to the tape.

During execution of Read commands, no data will be transferred to the Host until at least Bus Threshold blocks are ready to be transferred from the buffer to the Host. The "Wrap Around" effect will be the same as for the Write operation.

Between the bursts of data (each with a size equal to the Bus Threshold) the Drive may disconnect from the SCSI-bus.

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