TDC 4100

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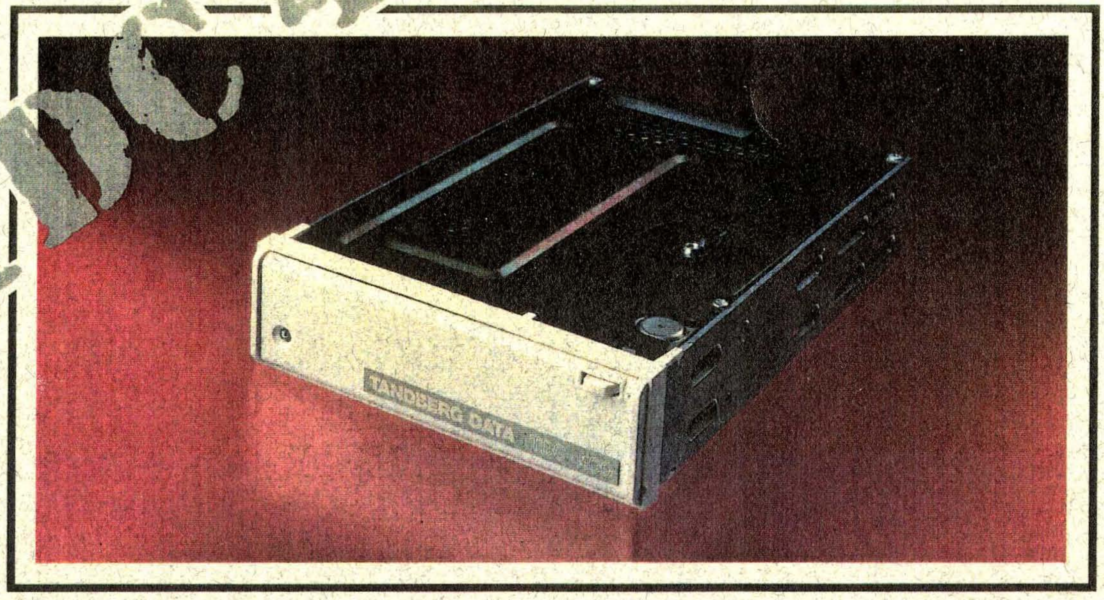
TANDBERG DATA

TDC 4100



TDC 4100 SERIES

REFERENCE MANUAL

TANDBERG DATA

TDC 4100 SERIES
REFERENCE MANUAL

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Related publications available from our Sales Department:

Publ. No.	Part No.	Title
5877	42 67 27	TDC 3800 SCSI-1 Interface - Functional Specifications
5878	42 67 30	TDC 3800 SCSI-2 Interface - Functional Specifications

We would appreciate any comments on this publication.

Table of Contents

0. Preface

This is the Reference Manual for the TDC 4100 Series (SCSI compatible) Streaming 1/4" Tape Cartridge Drive.

«TBS»

Information about some features, options or specifications concerning the TDC 4100 Series Drives are missing or not available at the time of writing (June 1991). In these cases, the abbreviation *«TBS» (To Be Supplied)* is used.

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-24, QIC-120, QIC-150, QIC-525 and QIC-1000 compatibility**

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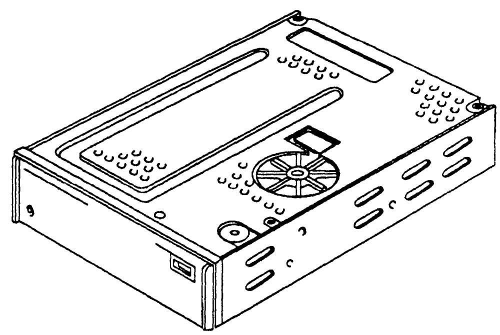
1. About this Manual

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 4100 Series 30-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 4100 Series 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 4100 Series Streaming 1/4" Tape Cartridge Drive.

The TDC 4100 Series Drive complies with the SCSI Interface Standard, and the QIC-24, QIC-120, QIC-150, QIC-525 and QIC-1000 Data Interchange Standards.

The TDC 4100 Series Drive reads and writes thirty tracks serially, running the tape at either 53.3 ips or 80 ips, *reads and writes* QIC-525 (twenty-six tracks at 120 ips), QIC-150 (eighteen tracks at 96 ips) and QIC-120 (fifteen tracks at 96 ips) and *reads* QIC-24 (nine tracks, see Section 2.2, running the tape at 96 ips).

Detailed circuit-board block diagrams, schematics and adjustment procedures are not supported by this manual. The field service technician will need the *TDC 4100 Series Maintenance Manual* and the *TDC 4100 Series Recommended Incoming Inspection Procedure* 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, 18, 26 and 30 tracks) and how the data is encoded.

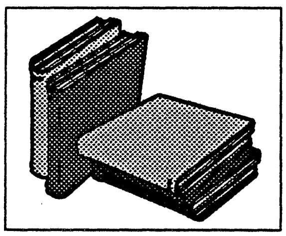
Chapter 7 describes the Drive's supported basic operational functions.

Chapter 8 describes the interface of the Drive with regards to the hardware.

Chapter 9 this section describes the major differences and special features related to the TDC 4100 Drives which are *not included* in the *TDC 3800 SCSI-1* and *TDC 3800 SCSI-2 Interface - Functional Specifications.*

Chapter 10 gives descriptions of the Drive's extensive built-in selftest possibilities and how to perform proper preventive maintenance.

1.3. Additional Documentation



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 E, April 1991*

The *QIC-150 Standard for Data Interchange, Revision J, April 1991*

The *QIC-525 Standard for Data Interchange, Revision E, April 1991*

The *QIC-1000 Standard for Data Interchange, Revision C, April 1991*

2. Introduction to the Drive

2.1. Summary

This chapter describes the basic features of the Tandberg Data TDC 4100 Series 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 4100 is a Streaming 1/4" Tape Cartridge Drive.

The TDC 4100 Series Drive reads and writes according to the following table:

QIC-1000 - 30 tracks
QIC-525 - 26 tracks
QIC-150 - 18 tracks
QIC-120 - 15 tracks
QIC-24 - 9-tracks

Tape Format	Capacity	Write	Read
QIC-1000	1.0 GByte	x	x
QIC-525	525 MByte	x	x
QIC-150	155 MByte	x	x
QIC-120	125 MByte	x	x
QIC-24	60 MByte		x

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**
- ✓ **Software distribution**

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. Too many starts and stops over a short tape distance may also reduce tape tension, which may adversely affect the recording performance.

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

Note that mounting the Drive top or bottom-flush against a flat surface will impede air flow and cause overheating of the capstan motor! This MUST be avoided!

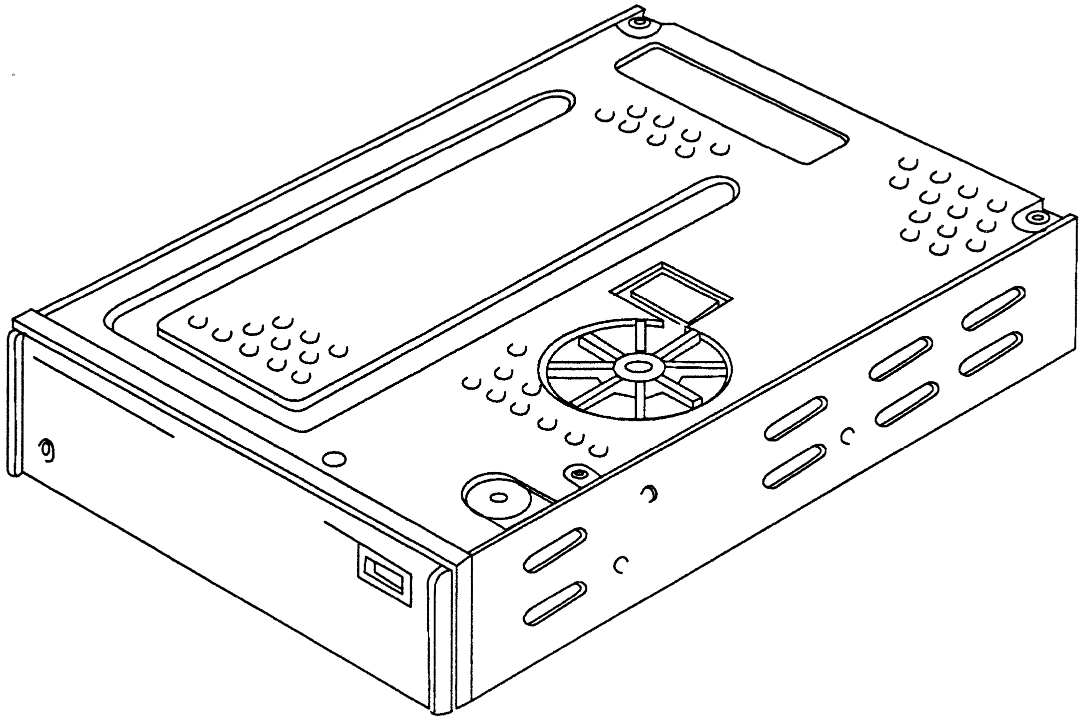


Figure 2.1 The TDC 4100 Series Drive

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

The Drive electronics comprises the 68HC11 microcomputer, the AIC-6250 SCSI Controller and two custom made Tandberg Data ASICs: one handling the Drive's formatting functions; the other handling the Buffer Controller and the ECC.
(ASIC = Application Specific Integrated Circuit).

All electronics except the opto-electronic tape hole sensors and 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 512/1024 bytes of data (1024 bytes = QIC-525 or QIC-1000). Special address and checking bytes are added to each block. The basic layout is shown in Figure 2.2.

Data Block n	Data Block (Filemark) n+1	Control Block n+2	Data Block n+3

Preamble	Data Marker	Data (512/1024 bytes)	Block Address	CRC	Postamble
Standard Data Block					

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 512/1024 bytes. The Drive adds special address and check characters to each block prior to writing the complete block on the tape. The Drive performs read-while-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 special address and check characters are removed. The data bytes are then transferred to the Host via the built-in data buffer in the Drive.
Any corrupted data will normally be corrected by the Drive (QIC-1000/-QIC-525) or the Drive will perform a reread operation (QIC-24/120/150).

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 the *Reference Bursts* as references during read operations. When changing tracks the head will always do a final movement upwards to reach the new track location. This is done to eliminate influence of backlash in the worm-gear.

Edge Seeking in Write Mode
See Chapter 7. Basic Operational Functions.

Track Seeking in Read Mode
See Chapter 7. Basic Operational Functions.

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 capstan motor operation, the sensing of the tape holes and the communication with the Host.
Figure 2.3 below shows a block diagram of the Drive.

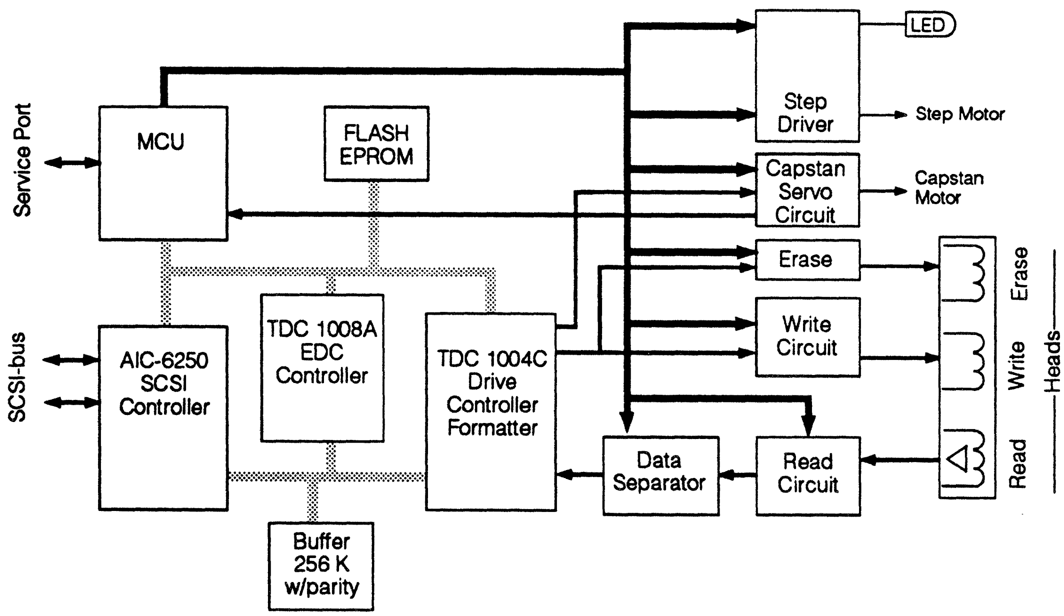


Figure 2.3 Drive block diagram

Capstan Motor System
The capstan motor speed is controlled by an analog servo and monitored by the processor. Pulse modulation of the motor voltage is used in order to reduce power dissipation in the motor drive electronics.

Head Positioning System
The head is moved up and down with a double-screw ("worm-gear") 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/Erase 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-while-write check to verify the recorded data. The head also has a full-width erase bar that erases all the tracks on the tape each time the Drive starts writing from Track 0.

Sensor System

The EOT (End of Tape), the BOT (Beginning of Tape), the LP (Load Point), the EW (Early Warning) and the Tape ID 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.

During the read/write operation, the Write current is automatically adjusted to match the actual kind of tape and format written

> NOTE:
> Use only DC9100 tape cartridges or equivalent when writing QIC-1000 tape format. Use DC6320 or DC6525 type tape cartridges only when writing QIC-525 tape format. When writing QIC-120 and QIC-150, DC6150 tapes or equal should be used.

The Read Circuit

The Read Circuit detects each flux transition from the read head and converts it to a digital pulse. Automatic Gain Control (AGC) is used to reduce the effect of the output variations from one cartridge to another. The Read Gain is automatically set to match the actual performance of each cartridge.

The Data Separator

This circuit generates the Read Clock and the Read Data pulses. A phase locked loop is used to track the Instantaneous Speed Variation (ISV) of the tape.

The MicroComputer Unit

The MCU controls and drives the operation seen from the user interfaces.
The microprocessor uses its data and address-bus to communicate with the digital circuit, and the SPI (Synchronous Pheripheral Interface) to some of the logical circuits.

The SCSI Controller

The SCSI Controller handles both the SCSI control functions and the bus-drivers and receivers.
All the SCSI Controller-circuitry is held inside the same chip, the AIC-6250 circuit.

Error Correction (ECC) and DMA Controller

This is a Tandberg Data ASIC (TDC 1008A) controlling the buffer and the DMA-channels between the digital control circuits. It also handles the error correction code (ECC).

The Tape Controller

This is a Tandberg Data ASIC (TDC 1004C) controlling the Read and Write encoding/decoding between the data-buffer and the read/write circuits.

2.5. Interface to Host

The interface to the Host conforms with the SCSI-1 and SCSI-2 standards. 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.

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.

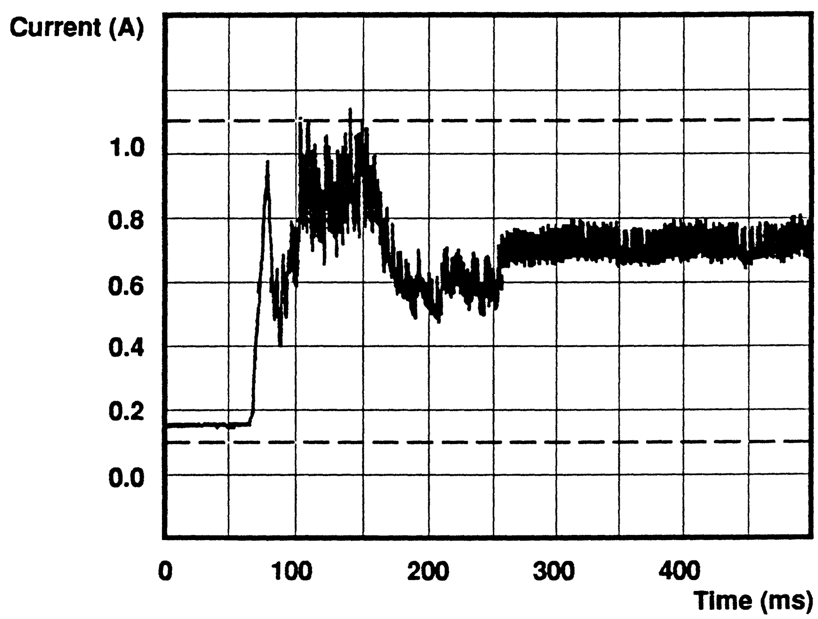
Max. dimensions
44 x 150 x 218 mm (1.732" x 5.905" x 8.583")

Weight
1.1 kg (2.4 lbs)

See Section 4.1 for mounting details and mechanical drawings.

3.2. Power Requirements

	Sleep Active		Motor Start-Up		Motor Running 120 ips Write/Erase	
	+5 V	+12 V	+5 V	+12 V	+5 V	+12 V
Typical	500 mA	80 mA	500 mA	2.0 A	500 mA	0.9 A
Maximum	700 mA	100 mA	700 mA	3.3 A	700 mA	1.45 A



Typical current curve for the +12 V power supply during capstan-motor start-up (80 ips)

Voltage variations	+5 V ± 5 %	Including ripple
	+12 V ± 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	3.5 W	Motor not running
	15.0 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.

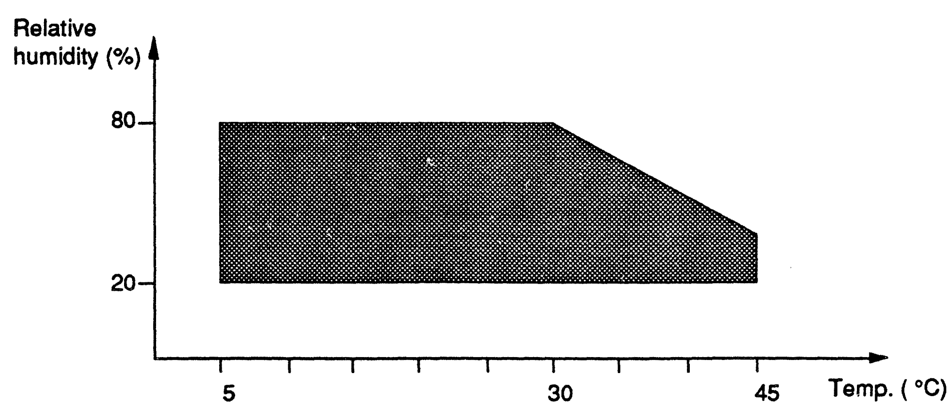
Storage The unit is unpacked and power is turned off.

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 – +45	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 5. Data Reliability).



Drive temperature and humidity limits, operating

3.3.2. Temperature Variation

Operating Maximum 10°C per hour, non-condensing

3.3.3. Atmospheric Pressure

Operating 53 - 106 kpa [maximum altitude 4 000 m (13 000 ft)]
Storage 15 - 106 kpa [maximum altitude 13 000 m (40 000 ft)]
Transport 15 - 106 kpa [maximum altitude 13 000 m (40 000 ft)]

3.3.4. Vibration

Test method EC-68-2-6

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

3.3.5. Impact and Shock

Topple Storage 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 for "single-pack" and 0.6 m for "10-pack", 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).

Shock Operating 98 m/s^2 (10 g), Half sinewave, 11 ms duration.

3.4. Product Performance Specifications

3.4.1. Audible Noise

55 dB (A). Integrated over 60 seconds, the Drive operating at 120 ips on an average cartridge. Measured at a distance of 1 m in all axes, the Drive standing free, using a cartridge with nominal noise level. Worst-case cartridges may increase this figure. When the tape and the head stepper motor are not running - none of the components in the Drive are generating any audible noise.

3.4.2. Radiated Electromagnetic Interference

The Drive complies with FCC Rules Part 15 Subpart B Class B, VDE 0871 Class B and EN55022/CISPR 22.

3.4.3. Susceptibility to Electromagnetic Interference

An electromagnetic field of 6 V/m will not cause any functional disturbance. (IEC 801-3).

3.4.4. Susceptibility to Electrostatic Discharges

The Electrostatic Discharge specification is referred to:

A: Closed front door and other parts of the Drive that are accessible from the front when the Drive is mounted in a cabinet - operating in *any* mode. Air gap discharge. Specification method: IEC 801-2, discharge network of 150 pF and 330 Ω, or 150 pF and 150 Ω.

The Drive will *not* have any hard errors at - or below 12 kV. No physical hardware errors will occur at - or below 25 kV.

B: Open front door, metal body discharge to a testpoint approximately 1 cm on the inside, the Drive in idle mode. Simulator: Schaffner NSG 432 with "Real ESD Adapter", complies approximately with ECMA TR/40.

The Drive will *not* have any hard errors at - or below 4 200 V. The Drive will operate properly when the door is closed.

3.4.5. Safety Standard

The Drive complies with EN60950/IEC 950, VDE 0805, UL 1950 and CSA C22.2 - 950M 1989.

3.4.6. Mean Time to Repair

The Drive has a MTTR of less than 0.5 hrs. 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 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 of 20.000 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, Actual "Mature" MTBF

> 80.000 POH

The actual "mature" MTBF for the electronics part, based on field experience of similar equipment, is expected to be a factor of between 4 and 5 times higher than that predicted by the model. This means that the MTBF will most probably lie in the range 80.000 POH and upwards. It is not possible to be more precise with these predictions, as the actual conditions under which the Drive is used is not under Tandberg Data's control and may vary significantly from one customer to another.

Important Notice!
The MTBF value is dependent of correct handling (f. ex.: ESD protective measures are used), installation and use of the Drive by the system installer/designer.

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 Life Time

> 5.000 POH at 100 % Duty Cycle (see NOTES 1 and 2)
> 50.000 POH at 10 % Duty Cycle (see NOTES 1 and 2)

Motor Life Time

> 10.000 POH at 100 % Duty Cycle (see NOTE 2)
> 100.000 POH at 10 % Duty Cycle (see NOTE 2)

Door Open/Close

> 15.000 open/close cycles

NOTE 1:
This figure is based on using DC9100 tapes. See also Section 3.6.3. and ***Important*** notice in Chapter 5. Data Reliability!

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. In the case of the mechanical parts, replacements must be expected as soon as the life-time is approached (see 3.5.2). This will depend on the actual usage of the Drive in each case.

Useful Life Cycle

> 10 years

3.5.4. Total Drive Reliability

Two different and independent failure mechanisms determine the failure frequency of the total Drive. These are related to the MTBF of the electronic parts alone (80.000 POH) and the limits set by the capstan motor and the magnetic head which are the most significant wear-out components.
Thus, for the total Drive, the duty cycle of tape motion versus the total amount of Power On Hours (POH) will determine the point in the life cycle where the End-Of-Life situation for a wear component is reached.

Operating the Drive inside the stable part of the so-called "bath-tub curve" - the table below illustrates the effect of the failure mechanisms:

Duty Cycle (%)	MTBF (hrs)	POH Upper Limit for the MTBF (hrs)
10	80.000	100.000
15	80.000	67.000
20	80.000	50.000
50	80.000	20.000

3.6. Functional Specifications

3.6.1. Media

Suggested types of media

3M DC6150	183 m (600-foot), cert. for 12 500 frpi
3M DC6320	183 m (600-foot), cert. for 20 000 frpi
3M DC6525	311 m (1020-foot), cert. for 20 000 frpi
3M DC9100	232 m (760-foot), cert. for 45 000 frpi

... or equivalent tapes from other manufacturers.

> NOTE:
> See ***Important*** notice in Chapter 5. Data Reliability about tape/environmental temperature and humidity restrictions.

3.6.2. Track Width and Location

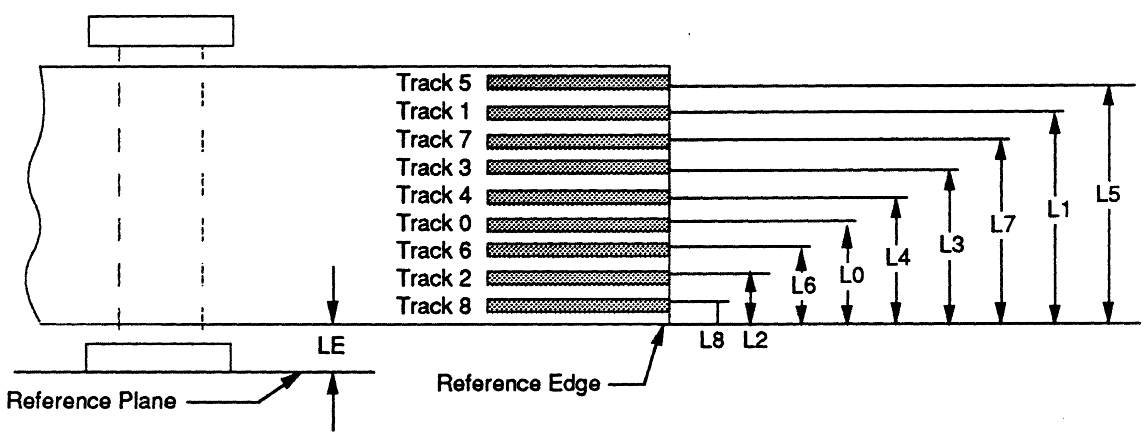
Number of recorded tracks

QIC-24:	Nine tracks - read only!
QIC-120:	Fifteen tracks
QIC-150:	Eighteen tracks
QIC-525:	Twenty-six tracks
QIC-1000:	Thirty tracks

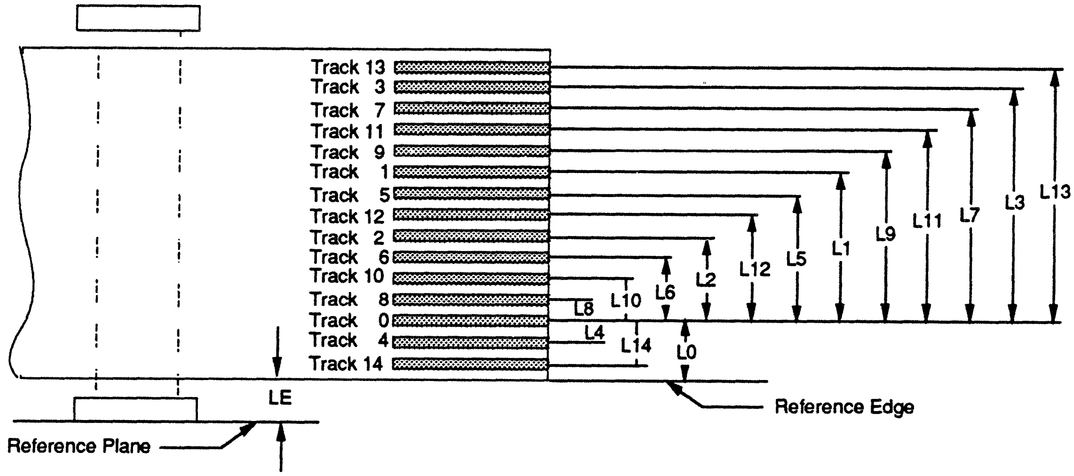
Track width

QIC-24:	0.343 mm ±0.013 mm (0.0135" ±0.0005")
QIC-120/150:	0.165 mm ±0.013 mm (0.0065" ±0.0005")
QIC-525:	0.1778 mm +0.0000/-0.0127 mm (0.0070" +0.0000"/-0.0005")
QIC-1000:	0.1778 mm ±0.00381 mm (0.0070" ±0.00015")

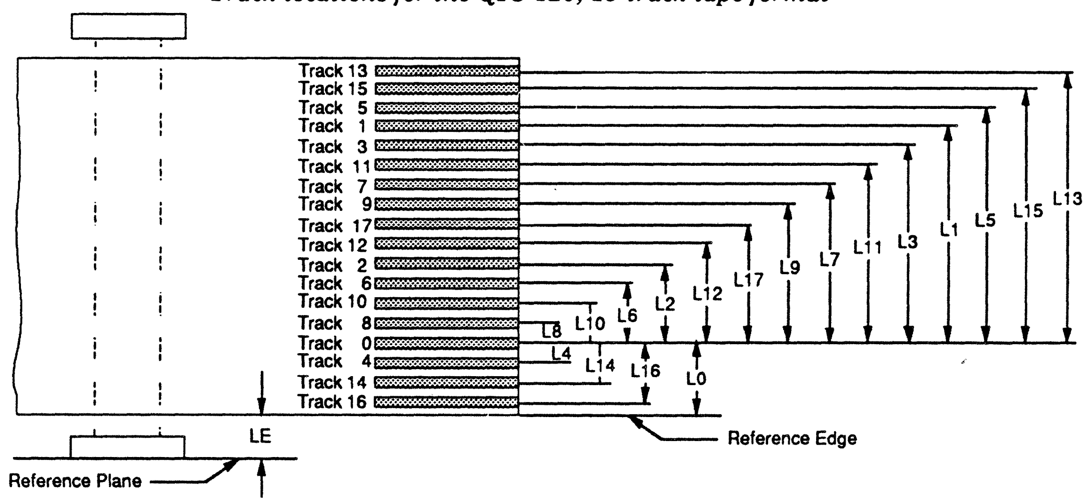
Track locations *(NOT drawn to the same scale!)* are shown below and on the following pages:



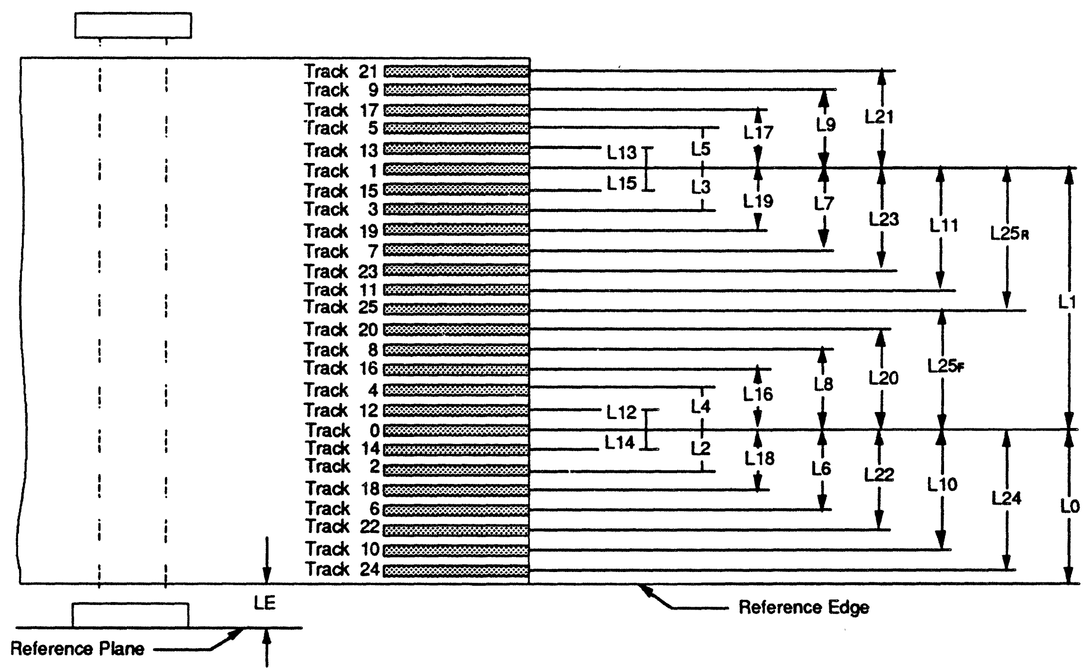
Track locations for the QIC-24, 9-track tape format



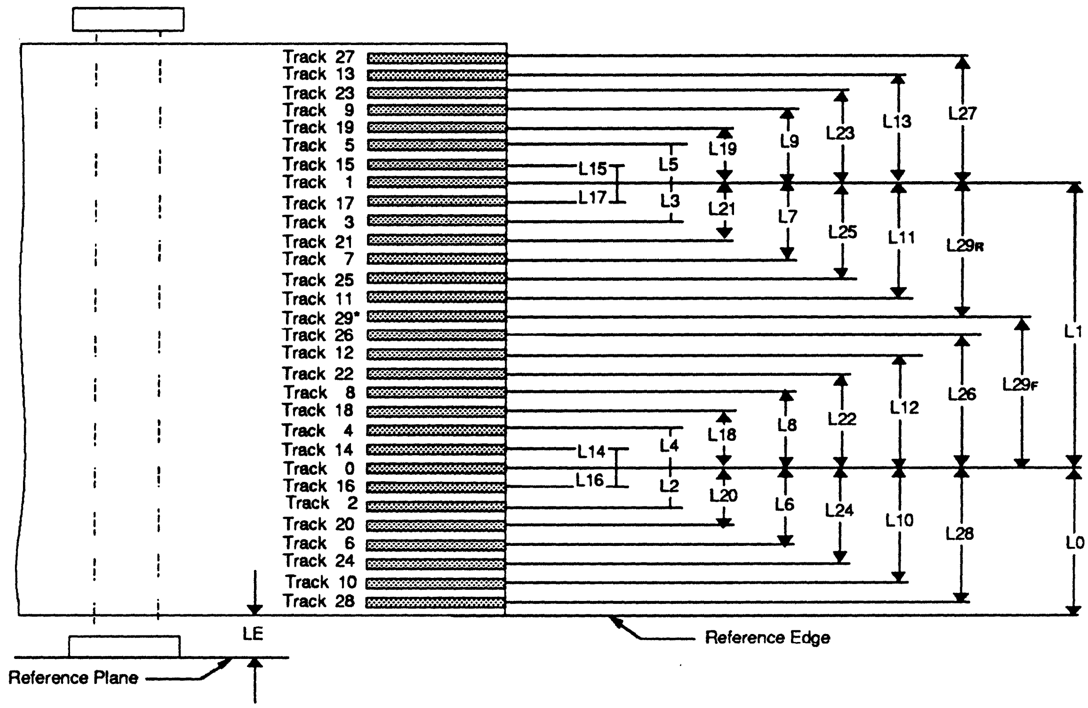
Track locations for the QIC-120, 15-track tape format



Track locations for the QIC-150, 18-track tape format



Track locations for the QIC-525, 26-track tape format



Track locations for the QIC-1000, 30-track tape format

NOTE:
A tape partitioned for Quick File Access (QFA) shall have Track 29 recorded in the forward direction, without any Reference Burst. See Figure 6.1e.

The dimensions are as follows:

QIC-24		QIC-120		QIC-150		QIC-525		QIC-1000	
LE	1.778 mm (0.070")	LE	1.778 mm (0.070")	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")	L0	1.803 mm ±0.051 mm (0.0710" ±0.0020")	L0	1.5799 mm ±0.0368 mm (0.0622" ±0.00145")
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")	L1	3.061 mm ±0.051 mm (0.1205" ±0.0020")	L1	3.0658 mm ±0.0508 mm (0.1207" ±0.0020")
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")	L2	0.457 mm ±0.033 mm (0.0180" ±0.0013")	L2	- 0.3962 mm ±0.0368 mm - (0.0156" ±0.00145")
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")	L3	0.457 mm ±0.033 mm (0.0180" ±0.0013")	L3	- 0.3962 mm ±0.0368 mm - (0.0156" ±0.00145")
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")	L4	0.457 mm ±0.033 mm (0.0180" ±0.0013")	L4	0.3962 mm ±0.0368 mm (0.0156" ±0.00145")
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")	L5	0.457 mm ±0.033 mm (0.0180" ±0.0013")	L5	0.3962 mm ±0.0368 mm (0.0156" ±0.00145")
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")	L6	0.914 mm ±0.033 mm (0.0360" ±0.0013")	L6	- 0.7925 mm ±0.0368 mm - (0.0312" ±0.00145")
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")	L7	0.914 mm ±0.033 mm (0.0360" ±0.0013")	L7	- 0.7925 mm ±0.0368 mm - (0.0312" ±0.00145")
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")	L8	0.914 mm ±0.033 mm (0.0360" ±0.0013")	L8	0.7925 mm ±0.0368 mm (0.0312" ±0.00145")
		L9	3.251 mm ±0.051 mm (0.128" ±0.002")	L9	2.380 mm ±0.051 mm (0.0937" ±0.002")	L9	0.914 mm ±0.033 mm (0.0360" ±0.0013")	L9	0.7925 mm ±0.0368 mm (0.0312" ±0.00145")
		L10	0.813 mm ±0.051 mm (0.032" ±0.002")	L10	0.680 mm ±0.051 mm (0.0268" ±0.002")	L10	1.372 mm ±0.033 mm (0.0540" ±0.0013")	L10	1.1887 mm ±0.0368 mm (0.0468" ±0.00145")
		L11	3.658 mm ±0.051 mm (0.144" ±0.002")	L11	3.060 mm ±0.051 mm (0.1205" ±0.002")	L11	1.372 mm ±0.033 mm (0.0540" ±0.0013")	L11	1.1887 mm ±0.0368 mm (0.0468" ±0.00145")
		L12	2.032 mm ±0.051 mm (0.080" ±0.002")	L12	1.700 mm ±0.051 mm (0.0669" ±0.002")	L12	0.229 mm ±0.033 mm (0.0090" ±0.0013")	L12	1.1887 mm ±0.0368 mm (0.0468" ±0.00145")
		L13	4.877 mm ±0.051 mm (0.192" ±0.002")	L13	4.760 mm ±0.051 mm (0.1874" ±0.002")	L13	0.229 mm ±0.033 mm (0.0090" ±0.0013")	L13	1.1887 mm ±0.0368 mm (0.0468" ±0.00145")
		L14	0.813 mm ±0.051 mm (0.032" ±0.002")	L14	0.680 mm ±0.051 mm (0.0268" ±0.002")	L14	0.229 mm ±0.033 mm (0.0090" ±0.0013")	L14	0.1981 mm ±0.0368 mm (0.0078" ±0.00145")
				L15	4.420 mm ±0.051 mm (0.1740" ±0.002")	L15	0.229 mm ±0.033 mm (0.0090" ±0.0013")	L15	0.1981 mm ±0.0368 mm (0.0078" ±0.00145")
				L16	1.020 mm ±0.051 mm (0.0402" ±0.002")	L16	0.686 mm ±0.033 mm (0.0270" ±0.0013")	L16	- 0.1981 mm ±0.0368 mm - (0.0078" ±0.00145")
				L17	2.040 mm ±0.051 mm (0.0803" ±0.002")	L17	0.686 mm ±0.033 mm (0.0270" ±0.0013")	L17	- 0.1981 mm ±0.0368 mm - (0.0078" ±0.00145")
						L18	0.686 mm ±0.033 mm (0.0270" ±0.0013")	L18	0.5944 mm ±0.0368 mm (0.0234" ±0.00145")
						L19	0.686 mm ±0.033 mm (0.0270" ±0.0013")	L19	0.5944 mm ±0.0368 mm (0.0234" ±0.00145")
						L20	1.143 mm ± 0.033 mm (0.0450" ±0.0013")	L20	- 0.5944 mm ±0.0368 mm - (0.0234" ±0.00145")
						L21	1.143 mm ± 0.033 mm (0.0450" ±0.0013")	L21	- 0.5944 mm ±0.0368 mm - (0.0234" ±0.00145")
						L22	1.143 mm ± 0.033 mm (0.0450" ±0.0013")	L22	0.9906 mm ±0.0368 mm (0.0390" ±0.00145")
						L23	1.143 mm ± 0.033 mm (0.0450" ±0.0013")	L23	0.9906 mm ±0.0368 mm (0.0390" ±0.00145")
						L24	1.600 mm ±0.030 mm (0.630" ±0.0013")	L24	- 0.9906 mm ±0.0368 mm - (0.0390" ±0.00145")
					See NOTE 1 below:	L25R	1.600 mm ±0.030 mm 0.630" ±0.0013")	L25	- 0.9906 mm ±0.0368 mm - (0.0390" ±0.00145")
						L25F	1.372 mm ±0.030 mm (0.540" ±0.0013")	L26	1.3868 mm ±0.0368 mm (0.0546" ±0.00145")
								L27	1.3868 mm ±0.0368 mm (0.0546" ±0.00145")
								L28	- 1.3868 mm ±0.0368 mm - (0.0546" ±0.00145")
							See NOTE 2 below:	L29R	- 1.3868 mm ±0.0368 mm - (0.0546" ±0.00145")
								L29F	1.5850 mm ±0.0368 mm (0.0624" ±0.00145")

NOTE 1:
Track 25 may be referenced to either Track 1 ($L25_R$) when recorded in the reverse direction or to Track 0 ($L25_F$) when recorded in forward direction.

NOTE 2:
Track 29 may be referenced to either Track 1 ($L29_R$) when recorded in the reverse direction or to Track 0 ($L29_F$) when recorded in forward direction.

NOTE "-":
The "-" sign indicates that the track is located below its corresponding Reference Track.

3.6.3. Head Specifications

Head type

2-channel read-after-write for serpentine recording. Full width erase bar. Ferrite cores.

Write track width

QIC-1000:	0.1778 mm ±0.0038 mm (0.007" ±0.0015")	

Read track width

QIC-1000:	0.089 mm ±0.0038 mm (0.0035" ±0.00015")	

Erase head

Full tape width erase bar. All tracks are erased when writing from BOT on Track 0.

Alignment error between read and write sections

Maximum 0.0127 mm (0.005")

Erase and bias frequency

9.6 MHz

Azimuth, Read/Write Gaplines - not Erase

≤ 7 minutes-of-arc

Zenith, Read/Write Gaplines - not Erase

< 15 minutes-of-arc

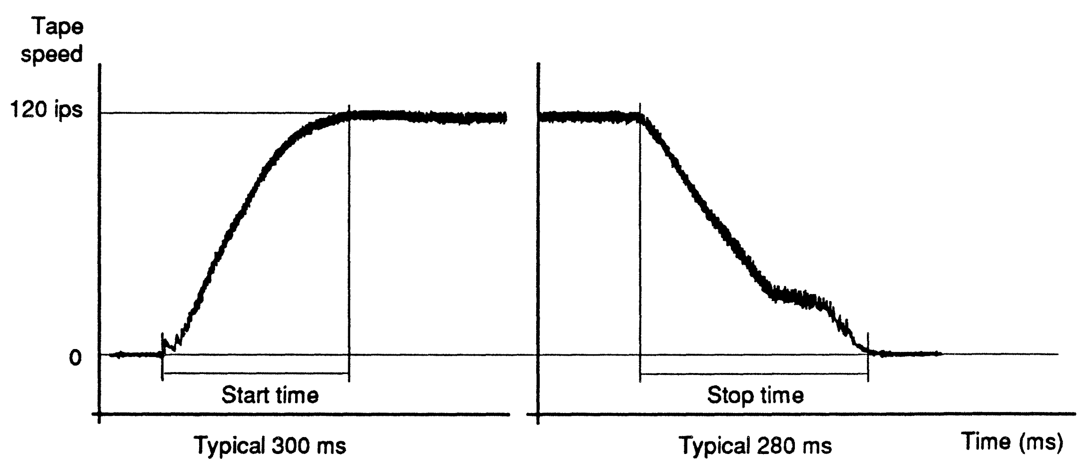
Head Life Time

> 5.000 hrs.

IMPORTANT!
The head life time specifications stated by Tandberg Data A/S assumes running tapes in an environment with an average relative humidity of a minimum of 40 % 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.
Relative humidities of less than 40 % are assumed only for a maximum of 1 hour for every 24 hurs of tape running.
The Head Life Time specifications assumes that tapes are replaced for every 2 500 passes.
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.

3.6.4. Tape Movement

Type of operation	Streaming		
Tape speed	QIC-24/120/150:	2.44 m/s (96 ips)	
	QIC-525:	3.05 m/s (120 ips)	
	QIC-1000:	1.355 m/s (53.33 ips) or 2.03 m/s (80 ips)	
Tape speed variation	Short term (1 byte):	±6 % with cartridge inserted	
	Long term (512 bytes):	±2 % with cartridge inserted	
Start/stop time	[@ 2.03 m/s (80 ips)]:	Start time typical:	200 ms
		Stop time typical:	200 ms
	[@ 1.355 m/s (53.33 ips)]:	Start time typical:	135 ms
		Stop time typical:	175 ms
	[@ 3.05 m/s (120 ips)]: (See figure)	Start time typical:	300 ms
		Stop time typical:	280 ms
	[@ 2.44 m/s (96 ips)]:	Start time typical:	240 ms
		Stop time typical:	230 ms



Typical curves for tape speed during start / stop operations

Start/stop distance	[@ 2.03 m/s (80 ips)]:	Start distance typical: Stop distance typical:	10" 7"
	[@ 1.355 m/s (53.33 ips)]:	Start distance typical: Stop distance typical:	6" 4"
	[@ 3.05 m/s (120 ips)]:	Start distance typical: Stop distance typical:	22" 15"
	[@ 2.44 m/s (96 ips)]:	Start distance typical: Stop distance typical:	15" 10"

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

QIC-24:	315 data bits per mm (8 000 data bits/inch)
QIC-120/150:	394 data bits per mm (10 000 data bits/inch)
QIC-525:	630 data bits per mm (16 000 data bits/inch)
QIC-1000:	1417 data bits per mm (36 000 data bits/inch)

Maximum flux density

QIC-24:	Maximum 394 ftpmm (10 000 ftpi)
QIC-120/150:	Maximum 492 ftpmm (12 500 ftpi)
QIC-525:	Maximum 788 ftpmm (20 000 ftpi)
QIC-1000:	Maximum 1772 ftpmm (45 000 ftpi)

Block size

QIC-24/120/150:	512 data bytes
QIC-525/1000:	1024 data bytes

Nominal overhead per block

QIC-24:	19.5 bytes (Preamble 12, Byte Marker 1, Block Addr. 4, CRC 2 and Postamble 0.5)
QIC-120/150:	23.5 bytes (Preamble 16, Byte Marker 1, Block Addr. 4, CRC 2 and Postamble 0.5)
QIC-525:	50 bytes (Preamble 40, Byte Marker 1, Block Addr. 4, CRC 4 and Postamble 1)
QIC-1000	59.5 bytes (Preamble 49.5, Byte Marker 1, Block Addr. 4, CRC 4 and Postamble 1)

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.
If QFA is implemented, writing may either commence from Track 29 (QIC-1000), Track 25 (QIC-525) or Track 0.

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.

3.6.6. Data Error Rate Definitions

Based upon QIC-1000 tape format using DC9100 tape cartridges or equivalent media under normal environmental conditions (50% rel. hum., +25°C, continuous streaming, no vibration or shock).

The various types of error rates can be divided into *four* or *five* different categories:

1) Hard Write Error Rate
2) Rewrite Error Rate
3) Soft Read Error Rate
4) Hard Read Error Rate

5) Raw Read Error Rate (only for formats with built-in ECC, see below)

In addition to this we discuss *two* main categories based on the type of drive involved:

1) Formats without built-in ECC
2) Formats with built-in ECC

3.6.6.1. Formats Without Built-in ECC

Hard Write Error Rate

This number deals with the situation where the Drive cannot write a block correctly after 16 retries.
The **Hard Write Error Rate** is expressed in the number of occurrences of this situation; divided by the total number of blocks recorded.

Rewrite Error Rate

This number deals with the situation where the Drive rewrites a block determined to be bad during the Read-While-Write control.
The **Rewrite Error Rate** is expressed as the total number of (different) rewritten blocks; divided by the total number of blocks recorded.

Soft Read Error Rate

This number deals with the situation where the Drive must perform one or several new read operations (as part of a read/retry sequence) on a block during a read-only mode.
The **Soft Read Error Rate** is expressed as the total number of (different) re-read blocks; divided by the total number of bits read.

> NOTE:
> The soft error rate counts on block numbers. According to this, the Soft Read Error Rate does not depend on how many times a block is re-read.

Hard Read Error Rate

This number deals with the situation where the Drive fails to read a block correctly after passing through the complete read/retry procedure.
The **Hard Read Error Rate** is expressed as the total number of blocks that cannot be read correctly after the complete read/retry sequence has been executed; divided by the number of bits read.

> NOTE:
> A Read error is *not* defined as "hard" until the operator has executed a head-cleaning operation, a complete retension cycle and a new (failing) Read operation when the Read operation fails on the same block.

3.6.6.2. Formats With Built-in ECC

Hard Write Error Rate Same definition as for formats without built-in ECC.

Rewrite Error Rate Same definition as for formats without built-in ECC.

Soft Read Error Rate The same definition as for formats without built-in ECC. However, the error rate now reflects the number of blocks which requires either *one or more read/retry sequences* or *an ECC operation or both* in order to be read correctly.

Hard Read Error Rate In principle the same definition as for formats without built-in ECC. However, the definition of a block with a hard error is now changed to a block which cannot be read correctly after a complete read/retry sequence has been executed *and additionally cannot be corrected by using ECC.*

NOTE:
A Read error is *not* defined as "hard" until the operator has executed a head-cleaning operation, a complete retension cycle and a new (failing) Read operation when the Read operation fails on the same block.

An additional 5th category of error rates is considered for ECC equipped drives:

Raw Read Error Rate This number deals with the amount of blocks which cannot be read correctly *without using ECC* even after a complete read/retry sequence has been performed. This number will be the same as the *Hard read Error Rate* for a format *without ECC.*

3.6.6.3. Data Error Rates

	Hard Write Error Rate	Rewrite Error Rate	Soft Read Error Rate	Raw Read Error Rate	Hard Read Error Rate
QIC-24	–	–	10^{-8}	–	10^{-11}
QIC-120/150 without ECC	See NOTE 2	0.7 %	10^{-8}	–	10^{-11}
QIC-120/150 with ECC	See NOTE 2	0.7 %	10^{-8}	10^{-11}	10^{-14}
QIC-525	See NOTE 2	0.9 %	–	3×10^{-9}	10^{-15}
QIC-1000	See NOTE 2	TBS	–	3×10^{-9}	10^{-15}

NOTES:

1) Most QIC-24 drives used 10^{-10} as the specified Hard Error Rate. The 10^{-11} specified above assumes a tape which has been recorded to meet the 10^{-11} Hard Read Error requirements.

2) The Hard Write Error Rate will be a function of factors such as operating environment, head cleaning intervals, tape changing intervals etc.
   Based upon the specified, defective density of the DC6150, DC6525 and DC9100 tapes foe QIC-120/150, QIC-525 and QIC-1000, the Hard Write Error Rates are 10^{-34}, 10^{-32} and TBS respectively. These figures assume independent Write errors. Systematic errors due to debris on the head surface, long scratches on the tape etc. are *not included.*

3) The specified Hard Read Error Rates for the formats with ECC assume independent errors.

3.6.7. *Storage Capacity*

QIC-24:	137 m (450-foot) tape: 45 MBytes *
	169 m (555-foot) tape: 55 MBytes *
	183 m (600-foot) tape: 60 MBytes *
QIC-120:	183 m (600-foot) tape: 125 MBytes *
QIC-150:	183 m (600-foot) tape: 155 MBytes *
QIC-525:	183 m (600-foot) tape: 320 MBytes *
QIC-525:	311 m (1020-foot) tape: 525 MBytes *
QIC-1000:	232 m (760-foot) tape: 1000 MBytes *

* Assuming typical tape-error performance.

3.6.8. Head Moving Mechanism

Type of mechanism Double-screw (worm-gear) 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

QIC-24:	Nominally	122 steps
QIC-120:	Nominally	81 steps
QIC-150:	Nominally	68 steps
QIC-525:	Nominally	46 steps
QIC-1000:	Nominally	40 steps

3.6.9. Capstan System

Type of capstan motor High-efficiency, brushless DC motor with built-in fan for cooling.

Servo system Analog servo-system with crystal controlled, digital reference; monitored by the microprocessor.

Capstan tachometer Hall IC outputs with 24 transitions (12 pulses) per revolution.

Commutator Solid-state, built into the motor.

3.6.10. Tape Sensor System

BOT/EOT sensor Solid state infrared transmitter and receivers. Synchronous transmitter/receiver system (digital synchronous demodulation) and digital, low-pass filtering in the microprocessor firmware for noise suppression.

Cartridge sensor Mechanical

Write protect sensor Mechanical

3.6.11. Electronics

Basic design One microcomputer (68HC11) for drive- and formatting control, one ASIC *(Application Specific Integrated Circuit)* for buffering and ECC-control and one ASIC for formatting and drive-functions. In addition there is one SCSI Controller for bus-control.
Alignment of the Read- and Write channels with A/D and D/A converter. Automatic alignment for each new tape cartridge during Read- and Write operations.

Read clock Programmable, phase-locked loop

Read/Write buffer capacity 256 KBytes with parity

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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!

Mechanical Dimensions

The Drive occupies a half-size 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")

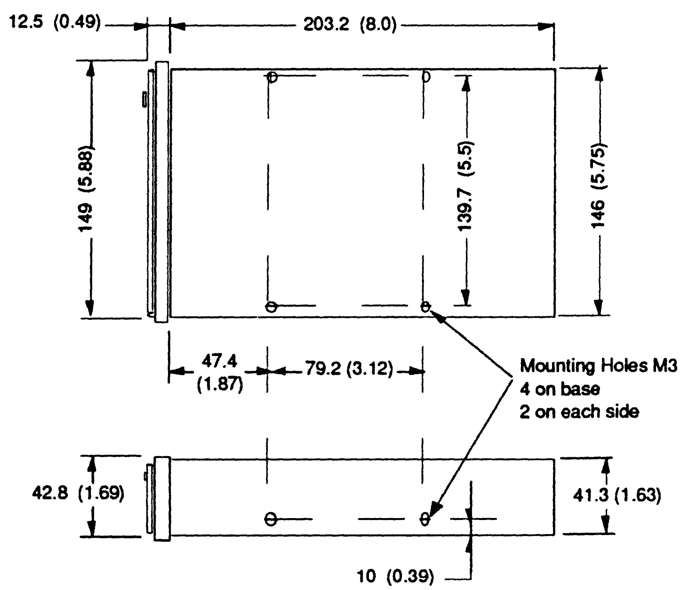


Figure 4.1 Drive Mounting Details (European Projection)

CAUTION!
It is of the utmost importance that the thickness of the mounting brackets is minimum 1.5 mm (0.59"). This to prevent the enclosed screws from penetrating into the Drive and thereby cause damage. Use for the same reason the enclosed serrated washer!

Cable Lengths

The maximum cable length from the Drive to the host-interface is 6 meters (20 feet). However, to increase system noise immunity, the cables should be kept as short as possible.

Power Connector

The power connector is AMP 172296-1 or equivalent. The mating connector is AMP 1-480424-0 or equivalent.

Chassis Grounding

The Drive-chassis must be grounded to the system-chassis through the mounting screws or by using the "fast-on" connector at the rear of the Drive, see Figure 4.2.
Correct grounding of the chassis is important to reduce radiated electromagnetic interference, and for electrostatic discharge (ESD) protection. If the Drive-chassis is *NOT* connected to the system-chassis, a Drive built-in resistor of 270 Kohm can be used to drain off the charges via the signal ground to chassis ground, provided that the signal ground is connected to the system-chassis.
However, Tandberg Data takes no responsibilities for damages which may occur if secondary arcing takes place to the Drive Mainboard. An insulation voltage is *NOT* specified.

Chassis Connection to the SCSI-bus Signal Ground

To avoid multiple, internal ground loops, the system must have only one, common point between the chassis and the signal ground. This is normally chosen where the external SCSI-bus connector is located. The DC power supply returns must therefore *NOT* be connected to the chassis. In the event of an electrostatic discharge, secondary arcing is prevented if the signal ground follows the chassis potential.

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 relevant testing standards.

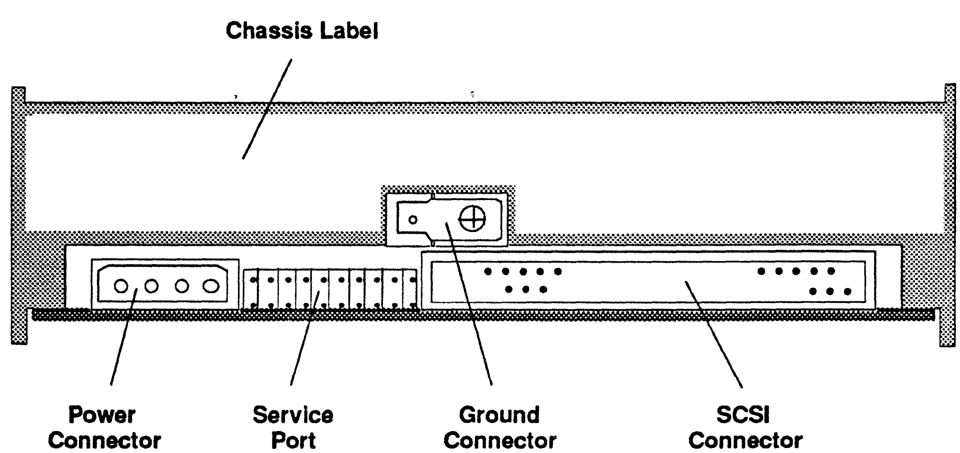


Figure 4.2 Rear View of Drive

4.2. Strap Setting/Selecting Drive Number

Most of the TDC 4100 options are controlled by the EEPROM and NOT by using the selection straps at the rear of the Drive. These options will be described in the Software Interface part of this manual.
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 (see Figure 4.3) supports the following functions:

- ✓ **Selection of Drive number**
- ✓ **Enabling/Disabling of the Parity Check**
- ✓ **Test-pins for internal, manufacturing use only**
- ✓ **Serial communication for adjustments and tests**
- ✓ **Test selection**

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

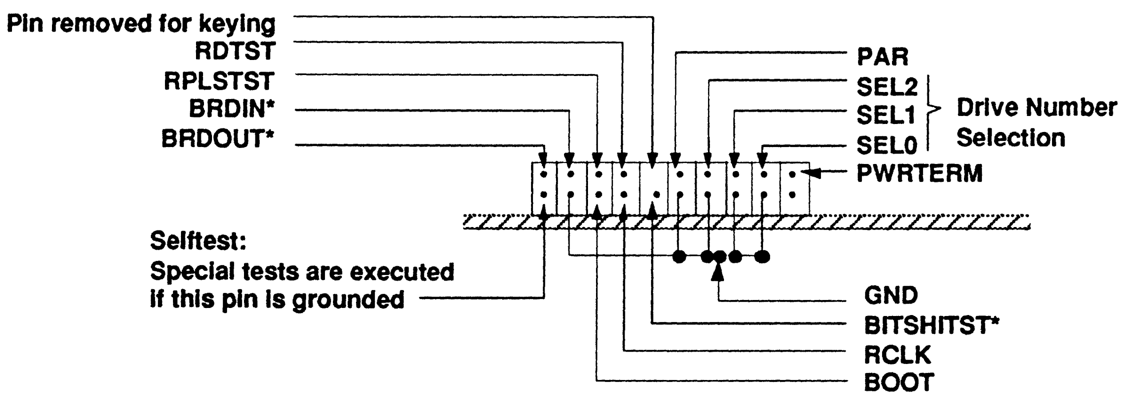


Figure 4.3 Layout of the Service Port

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 to ground 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

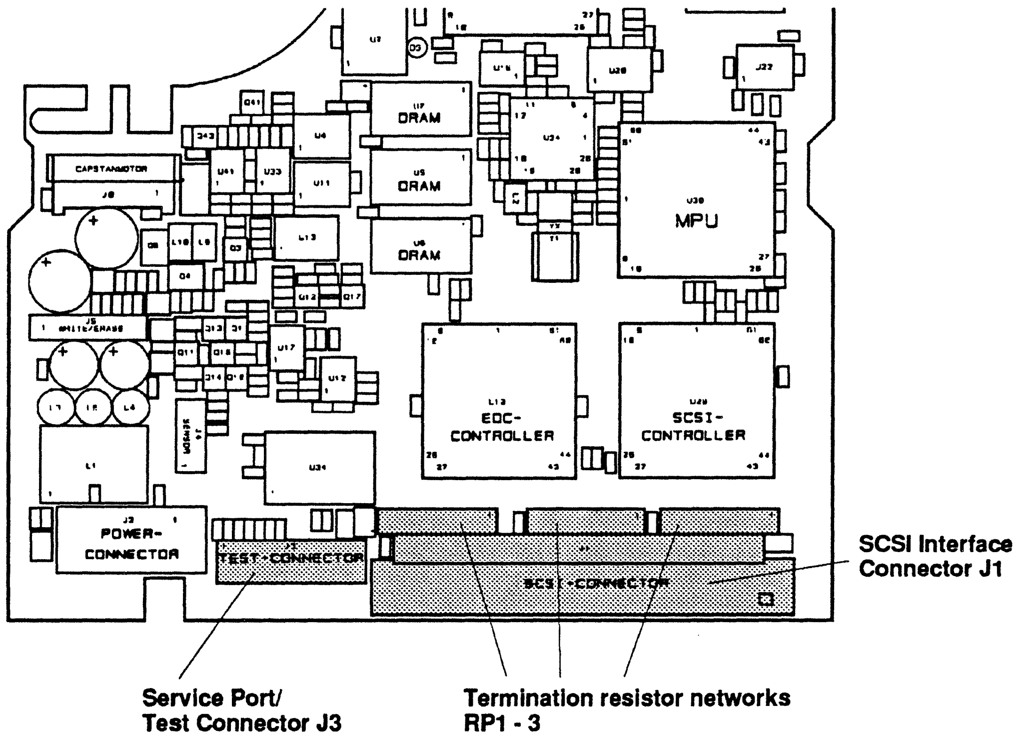
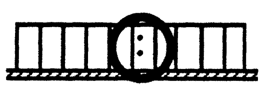


Figure 4.4 The TDC 4100 Mainboard

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).

4.2.3. *External SCSI-bus Termination*

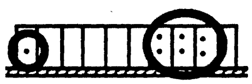
Since the data cartridge is only specified up to 45°C, we recommend that the bus termination option inside the Drive is NOT used as this will cause unnecessary heat dissipation inside the Drive.
To avoid this, the TDC 4100 Drive must be placed between other SCSI-devices on the SCSI-bus. However, if this 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 4.4 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 4120 BIRD Test System.*

4.2.5. Test Functions



The Drive has several test functions that can easily 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 is as follows:

TEST	SEL2	SEL1	SEL0	Meaning
CLOSED	OPEN	OPEN	OPEN	Burn-In
CLOSED	OPEN	OPEN	CLOSED	Selftest 2
CLOSED	OPEN	CLOSED	OPEN	Reserved
CLOSED	OPEN	CLOSED	CLOSED	Reserved
CLOSED	CLOSED	OPEN	OPEN	Reserved
CLOSED	CLOSED	OPEN	CLOSED	ERASE FWD/REV
CLOSED	CLOSED	CLOSED	OPEN	WRITE + ERASE FWD/REV
CLOSED	CLOSED	CLOSED	CLOSED	WIND/REWIND

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 4.5 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.

Temporary Host

In a SCSI-bus system (see Figure 4.5), 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 not mounted in either end of the SCSI-bus cable or if external bus termination is used.
> See Section 4.2.3. and Figure 4.4.

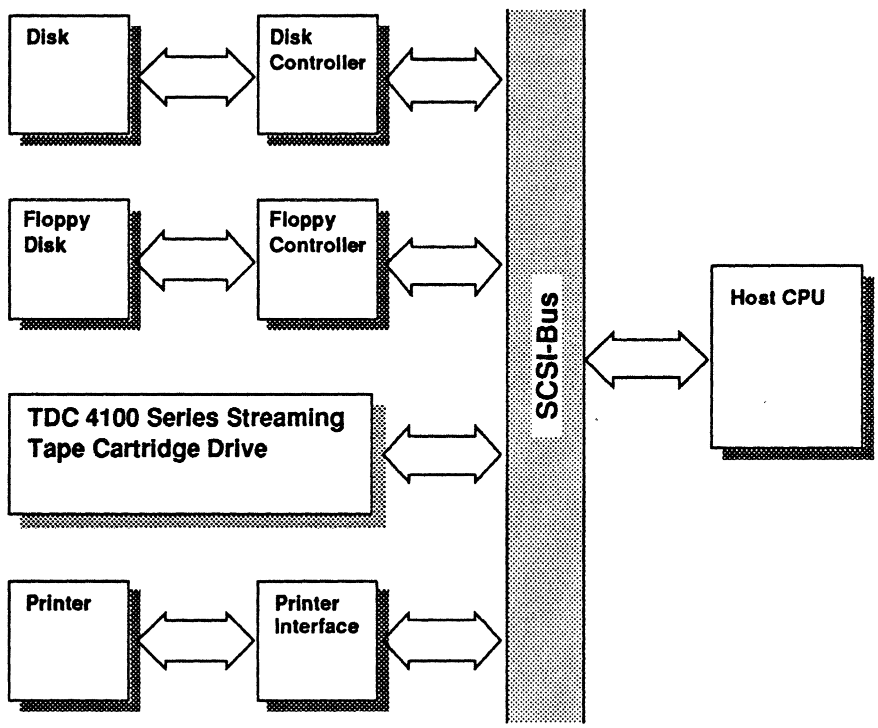


Figure 4.5 Block diagram of a system with SCSI-bus interface

4.4. Heat Dissipation

The Drive dissipates typically 15 W when running, and 3.5 W in stand-by. 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 a run of 27 minutes.

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, when designing a system, 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 not located in either of the ends of the SCSI-bus cable; 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! The Drive must NEVER be mounted or placed top or bottom-flush against a flat surface as this will impede air flow! Allow at least 10 mm (0.4") clearance to the table top if testing the Drive!

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. (Measure 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 measure the temperature inside the cartridge).**

③ **The cartridge baseplate temperature in a circle of 12.5 mm (0.5") around the center of the Drive's roller pin (= the wheel engaged with the capstan motor when a cartridge is inserted).**

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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 MEDIA 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**
- ✓ **ECC algorithm**
- ✓ **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-gear") system is able to position the head within very narrow tolerances**
- ✓ **The write and the read channels incorporate many new signal processing features which improve the recording and reading on marginal tapes**
- ✓ **A very sophisticated and intelligent retry-algorithm that includes multistep off-track alignment for reading marginal data blocks**
- ✓ **ECC algorithm (QIC-1000 and QIC-525 formats)**
- ✓ **Power shut-down when the tape is not running**
- ✓ **Switchable Read Threshold**

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 *1/4" 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. Direct sunlight should be avoided. 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/read 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 media 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 blocks transferred from the Host are written in the same sequence on the tape. There is, however, an exception for the QIC-525 and QIC-1000 formats where the data blocks are formatted into frames of 14 data/filemark blocks with two ECC blocks added before writing on the tape. The ECC blocks can be used to correct erroneous data blocks if errors are detected during Read operation.
Data is immediately verified by a read-while-write check. The read channel has stricter 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 position of each single flux transition is tested for bitshift and only accepted if within the QIC-standards.**
- **The Read signal amplitude is monitored and tested to be at least 40 % of the nominal Read amplitude.**
- **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.

> NOTE:
> Due to the narrower read head defined by the QIC-1000 format standard, the write operations of QIC-525, QIC-150 and QIC-120 formats cannot include a verification process 100 % in accordance with the specification in these standards with respect to the width of the read head during Read-While-Write (RWW) verification. This can partly be compensated for by increasing the Read Threshold (during verification) above the specified value of the standards. This is implemented in the TDC 4100 Tape Drive, where the nominal threshold value is set to 40 % (compared to the 25 % specified by QIC.
> The fact that the QIC-525 format has a powerful error correction method built into the format itself, significantly reduces any potential problems arising from the difference in the width of the read head during verification. Since the QIC-120 and QIC-150 standards do *not* have such built-in error correction methods, the user may want to utilize only the read QIC-120/150 capability (and *not* the write QIC-120/150 capability) of the TDC 4100 if a 100 % compatible RWW-verification according to the written standard is a must.

5.4. Read Mode

Retry Procedure

If a bad block is detected during Read operation there are two different operations depending on the tape-format. If Read errors are detected in QIC-24/120/150, the Drive needs to do a retry immediately, following the sequence described below. If the tape-format is QIC-525 or QIC-1000, the ECC blocks will be used to correct the faulty block. The ECC blocks are able to correct two corrupted blocks within a frame.
If *three errors* or more are detected within a frame, the Drive has to start the following retry procedure:

- **The Drive tries to read the frame containing the bad block(s) another two times.**
- **If still unable to read the faulty frame, the Drive tries to read it another two times, this time with the head moved a 1/4 track-width off center.**
- **If still unable to read the bad frame, it tries to read the bad frame 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 frame, 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, i.e. without being able to find less than 2 errors in the frame, 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.**

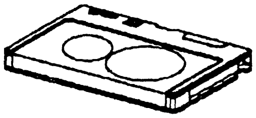
> NOTE:
> When the Drive reads QIC-525 or QIC-1000, it will make a retry procedure on a complete frame. When the retry procedure is performed on QIC-24/120/150, the Drive will search for the specific erroneous block.

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

> NOTE:
> By definition, a "Hard Read Error" occurs only when a frame cannot be read after the following sequence of operation:
>
> - 24 rereads
> - Head cleaning with the *1/4" Cleaning Cartridge Kit* (or similar cleaning equipment)
> - Complete retensioning of the tape
> - Another 24 rereads

5.5. Cartridge Conditioning

Conditioning Rules



The achieveable 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 fail on the same block before this error is classified as permanently unrecoverable.**

IMPORTANT!
Tape is a very hygroscopic media. If exposed to a high humidity environment over some period, it requires a special procedure 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 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 magnetic 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.

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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, QIC-150, QIC-525 and QIC-1000 standards for data interchange.

Tape Format Standards

See the following standards:

The QIC-24 and QIC-02 Standards, Revision D
(Part No. 402732, Publ. No. 5447, Section 3)

The QIC-120 Standard, Revision E, April 1991
The QIC-150 Standard, Revision J, April 1991
The QIC-525 Standard, Revision E, April 1991
The QIC-1000 Standard, Revision C. April 1991

The TDC 4100 Drive reads and writes the various tape formats according to the following table:

Tape Format	Write	Read
QIC-1000	X	X
QIC-525	X	X
QIC-150	X	X
QIC-120	X	X
QIC-24		X

6.2. Track Specifications

NOTE:
The illustrations are NOT drawn to the same scale!

The tape is recorded serially on nine tracks (QIC-24), fifteen tracks (QIC-120), eighteen tracks (QIC-150), twenty-six tracks (QIC-525) or on thirty tracks (QIC-1000) - one track at a time.
Figures 6.1a, 6.1b, 6.1c, 6.1d and 6.1e show the track numbering for 9-, 15-, 18-, 26-, or 30-track recorded tapes respectively.

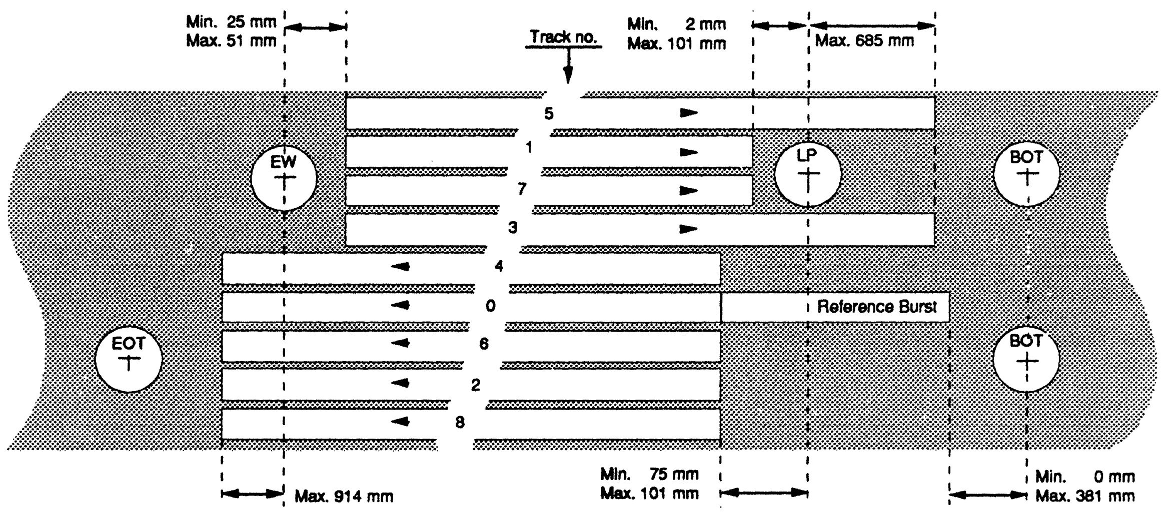


Figure 6.1a Track layout for the QIC-24, 9-track tape format

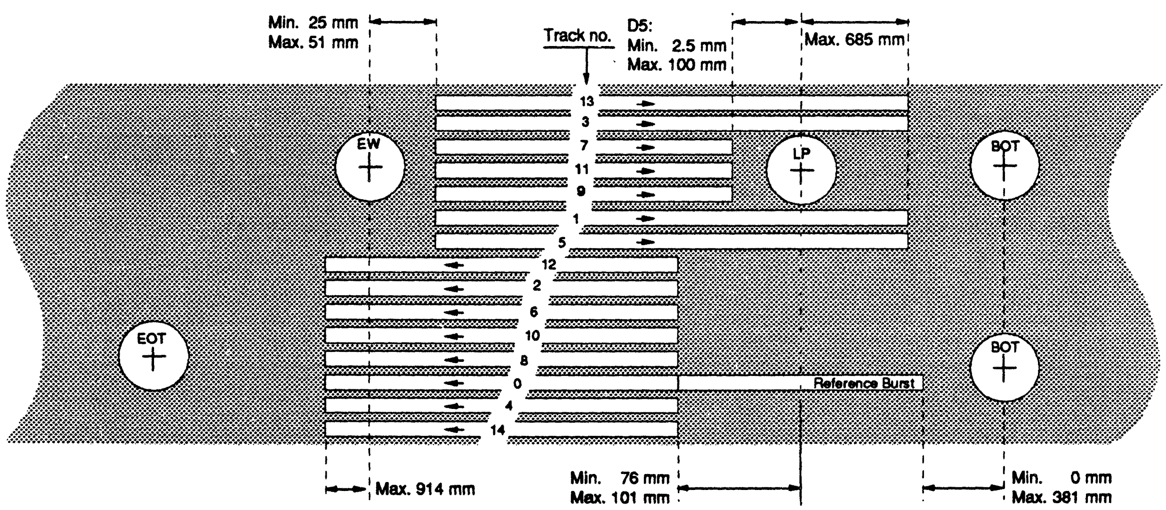
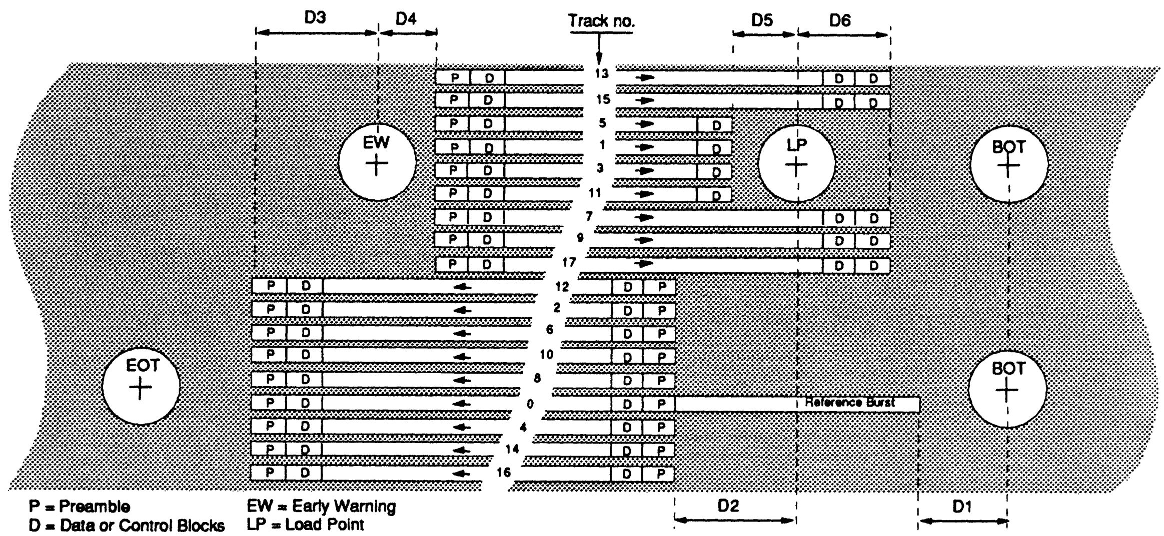


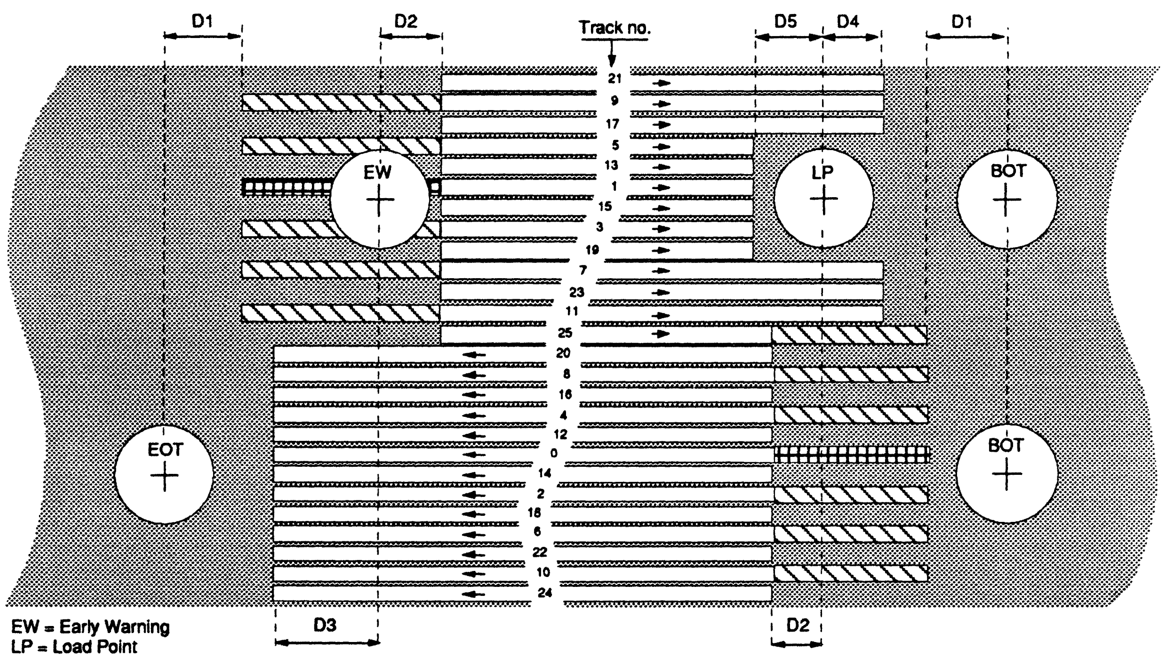
Figure 6.1b Track layout for the QIC-120, 15-track tape format

NOTE: The illustrations are NOT drawn to the same scale!



Dimension	Minimum (in.)	Maximum (in.)	Description
D1	0	15	BOT to Start of Reference Burst
D2	3	4	Load 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 Load Point on Tracks 3, 5, 11 and 13
D6	-	27	Load Point to End of Data on Tracks 1, 7, 9, 15 and 17

Figure 6.1c Track layout for the QIC-150, 18-track tape format



Dimension	Minimum (in.)	Maximum (in.)	Description
D1	0	15	BOT to Start of Reference Burst
D2	3	4	LP or EW to Start of Valid data (or Frame) area - plus LP/EW to End of Reference Burst on tracks with Reference Burst
D3	-	36	Early Warning to End of Data on Even Tracks
D4	1	27	LP to End of Data on all Odd Tracks except Tracks 1, 3, 5, 13, 15 and 19
D5	0.1	4	End of Data to LP on Tracks 1, 3, 5, 13, 15 and 19

Figure 6.1d Track layout for the QIC-525, 26-track tape format

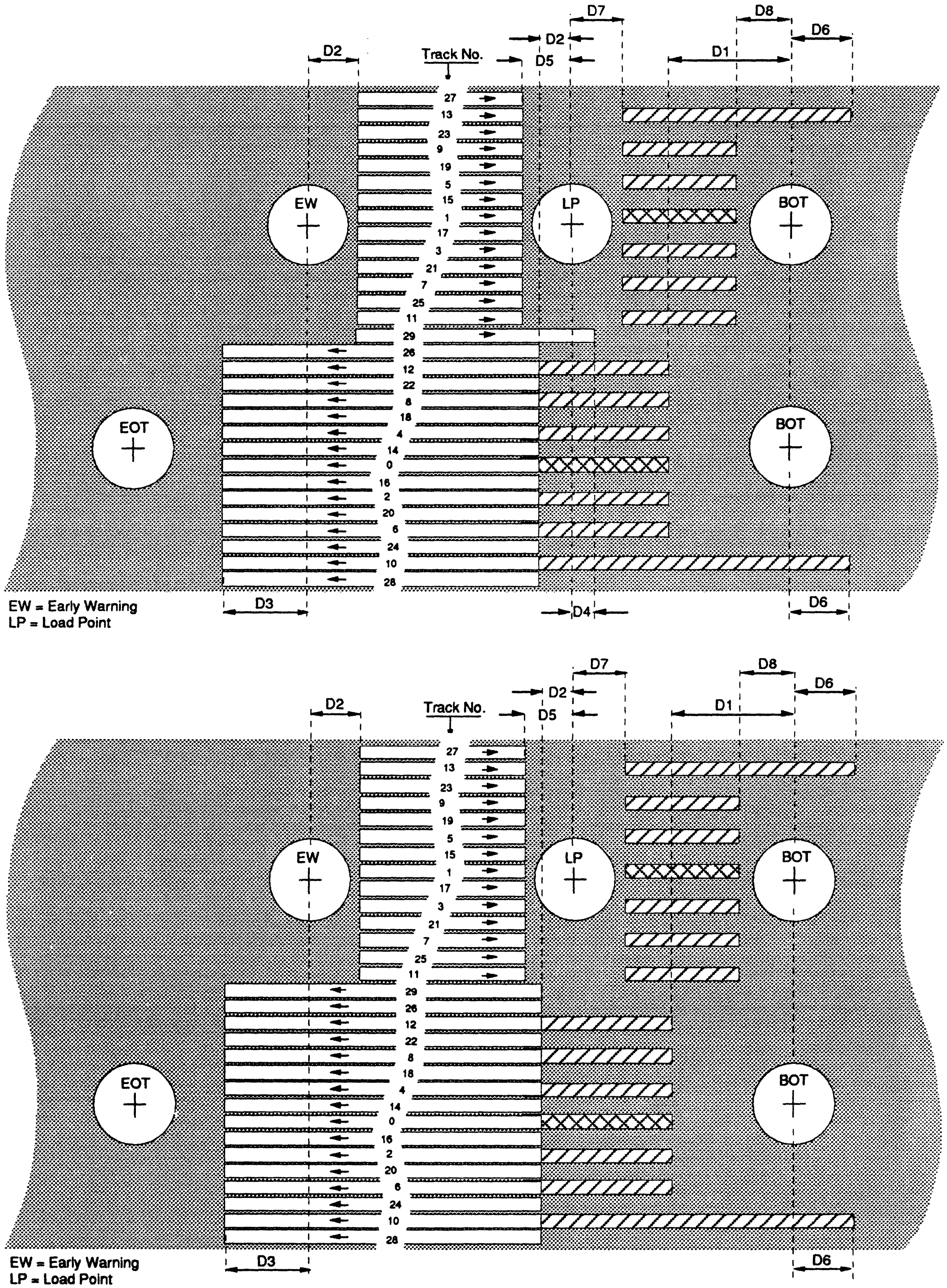


Figure 6.1e Track layouts for the QIC-1000, 30-track tape format, QFA NOT implemented (top) and QFA implemented (bottom)

Dimension	Minimum (in.)	Maximum (in.)	Description
D1	0	15	BOT to Start of Reference Burst on all Even-numbered tracks except Track 10
D2	3	4	EW to Start of Valid Data (or Frame) area
D3	–	36	EW to End of Data on all Even-numbered tracks
D4	–	1.77	LP to End of Data on Track 29
D5	0.1	4	LP to End of Data on all Odd-numbered tracks except Track 29
D6	10	15	Start of Reference Burst to Last BOT holes on Track 10 and End of Reference Burst to BOT holes on Track 13
D7	1.97	3.94	LP to Start of Reference Burst for all Odd-numbered tracks
D8	0.078	1.078	BOT to Start of Reference Burst on all Odd-numbered tracks

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 set of Reference Burst signals are recorded between LP and BOT for the QIC-1000 format, and between LP/BOT and EW/EOT for the QIC-525 format. See Figures 6.1d and 6.1e.

6.3. Track Format

6.3.1. QIC-525 and QIC-1000

The track layout is based upon *The QIC-525 Standard, Revision E, April 1991* and *The QIC-1000 Standard, Revision C, April 1991.*
Data is recorded serially on 30 tracks, one track at a time.

All blocks are organized into frames consisting of 14 data or filemark blocks followed by 2 ECC blocks.

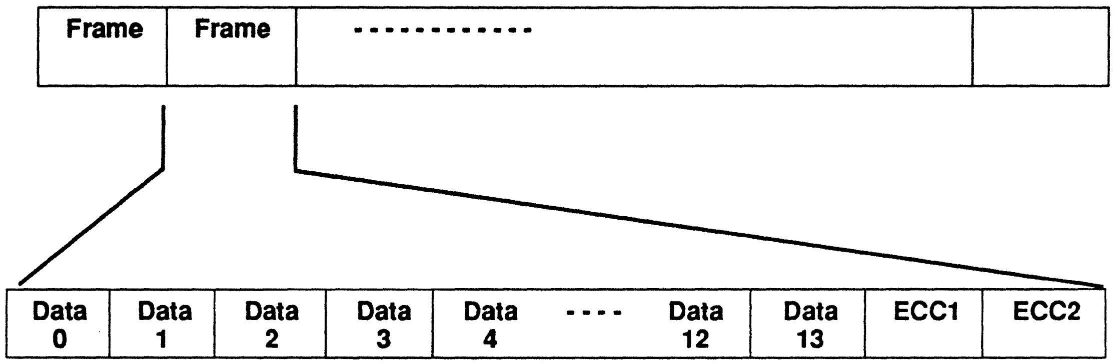


Figure 6.2 QIC-525 Track Format - organizing of one frame

6.3.2. QIC-24, QIC-120 and QIC-150

Each track contains data blocks, control blocks and possibly filemark blocks as shown in Figure 6.3.

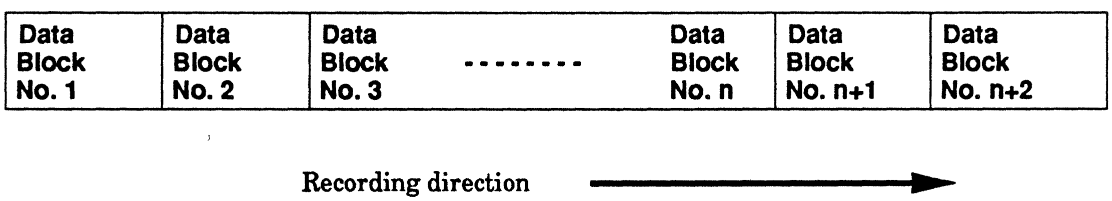


Figure 6.3 Track formats QIC-24, QIC-120 and QIC-150

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

The layout of each block is described in Section 6.4.2.

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

6.4. Block Layout

6.4.1. QIC-525 and QIC-1000

All blocks, whether it is a data block, a filemark block or a control block have the same layout, shown in Figure 6.4 below:

Pre-amble	Block Marker	Data .... Data (1024 bytes)	Control Field (4 bytes)	CRC (4 bytes)	Postamble

Recording direction →

Figure 6.4 Block layout QIC-525 / QIC-1000

6.4.1.1. Preamble

The Preamble consists of a recording at the highest recording density, nominally 787 ftpmm (20 000 ftpi) for QIC-525 and 1772 ftpmm (45 000 ftpi) for QIC-1000. 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 in a frame - Append operation**

The Normal QIC-525 Preamble consists of at least 400 but no more than 600 flux transitions recorded at the highest recording density.
The Normal QIC-1000 Preamble consists of 485 to 700 flux transitions.

Elongated Preamble

The Elongated Preamble is recorded at the beginning of the first block in a frame which is appended to already existing data on a track, and to the first block in a frame after an underrun situation. It contains a minimum of 8 800 and a maximum of 13 600 flux transitions for QIC-525 and a minimum of 8 800 and a maximum of 13 600 flux transitions for QIC-1000, recorded at the highest recording density.

Long Preamble

The Long Preamble is recorded at the beginning of the first block on every track. It contains a minimum of 24 000 and a maximum of 36 000 flux transitions for QIC-525 and a minimum of 54 000 and a maximum of 60 000 flux transitions for QIC-1000, recorded at the highest recording density.

6.4.1.2. 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.

6.4.1.3. Data

The data field in each block is fixed. It comprises 1024 bytes, encoded according to the rules given in Section 6.5. The data field is used as follows:

Data Blocks
The data field contains 1024 encoded data bytes for data interchange.

Filemark Blocks
Used to partition the tape into *Files*.

Cancel Block
Used locally to erase (cancel) Filemarks at the end of a recording when appending more data. Used also to emulate overwrite functions in the TAR-format.

Setmark Block
Used to partition the tape into *Sets*. Each *Set* can be divided into *Files*, separated by *Filemark Blocks.*

Filler
Used to fill up incomplete *Frames* so that only complete *Frames* are written to the tape. The Filler Blocks may contain "Block-Map"-information used by the Drive to allow fast positioning on the tape (FAST SPACE).

ECC
Contains error correction characters generated by the Drive.

QIC-525/QIC-1000 Identifier Block
Contains data of recording and drive serial number.

6.4.1.4. Control Field

All blocks have 4 bytes in their control field, as shown in Figure 6.5.
Control bytes 0 - 2 are always used for address and track information, regardless of block type. The use of control byte 3 depends upon the block type being recorded.

Control Byte 3	Control Byte 2	Control Byte 1	Control Byte 0

Figure 6.5 Layout of Control Field

Byte 3 is recorded first followed by Control Byte 2 and so on. All bytes are encoded according to the rules given in Chapter 8.
Figure 6.6 shows the layout of Control Byte 3:

Control Byte 3							
7	6	5	4	3	2	1	0
X	Reserved (all 0's)			Block Type			

Figure 6.6 Layout of Control Byte 3

Bits 4, 5 and 6 of Control Byte 3 are reserved and always set to 0. Bit 7 may either be set to 0 or optionally used to indicate blocks recorded past the logical Eary Warning (EW) marker.

The four least significant bits are used to indicate the type of block being recorded. The coding of these bits is shown in Table 6.3.
All combinations of the four control bits 0 - 3 not specified in the tables are reserved and shall not be used.

Control Byte 3 Bits				
3	2	1	0	Block Type
0	0	0	0	Full Data Block End variable Host Block
0	0	0	1	Full Data Block Partial variable Host Block
0	0	1	0	Full Data Block QIC-02 Compatible
0	1	0	0	Variable Data Block 1 - 255 data bytes End variable Host Block
0	1	0	1	Variable Data Block 256 - 511 data bytes End variable Host Block
0	1	1	0	Variable Data Block 512 - 767 data bytes End variable Host Block
0	1	1	1	Variable Data Block 768 - 1023 data bytes End variable Host Block
1	0	0	0	Filemark
1	0	0	1	Filler Block
1	0	1	1	Setmark
1	0	1	0	QIC-525/QIC-1000 Identifier Block
1	1	1	1	Cancel Block

Table 6.3 Encoding of Block Type Control Bits

Control Byte 3 is the only control byte covered by ECC protection.

The layout of Control Bytes 0 - 2 is shown in Figure 6.7.

Except for the 4 most significant bits of Control Byte 2, the other 20 bits contain the physical block address. This block address is independent of block type and track numbers. It starts with 00000 H(ex) for the first block on Track 0 and is incremented by one for each new block being recorded. Rewritten blocks keep their original block number. The block numbering is not reset at the start of a new track.

Control Byte 2		Control Byte 1		Control Byte 0	
7654	3210	7654	3210	7654	3210
Track Address	Physical Block Address (20 bits)				

Figure 6.7 Layout of Control Bytes 0 - 2

Track Address

The four most significant bits of Control Byte 2 contain a track address. This track address is the physical track number divided by two.

6.4.1.5. CRC (Cyclic Redundancy Check)

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

$$G(x) = x^{32} + x^{28} + x^{26} + x^{19} + x^{17} + x^{10} + x^{6} + x^{2} + 1$$

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 four CRC bytes are encoded according to the rules described in Section 6.5 and recorded with the most significant bit (bit 31) first.

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

6.4.1.6. Postamble

The Postamble is recorded at the maximum density of nominally 787 ftpmm (20 000 ftpi) for the QIC-525 format and 1772 ftpmm (45 000 ftpi) for the QIC-1000 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 10 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-525 Postamble contains a minimum of 8 800 and a maximum of 13 600 flux transitions for QIC-525 and a minimum of 14 500 and a maximum of 19 800 flux transitions for QIC-1000, recorded at the maximum flux density.
The Elongated Postamble is recorded instead of the Normal Postamble whenever an underrun situation occurs, or at the end of the last block in a recording.

6.4.2. QIC-24, QIC-120 and QIC-150

All blocks, whether it is a data block, a filemark block or a control block have the same layout, shown in Figure 6.8 below:

Pre-amble	Block Marker *(1 byte)*	Data ------- Data *(512 bytes)*	Block Address *(4 bytes)*	CRC *(2 bytes)*	Postamble

Recording direction →

Figure 6.8 Block layout QIC-24/QIC-120/QIC-150

6.4.2.1. Preamble

The Preamble consists of a recording at the highest recording density, nominally 394 ftpmm (10 000 ftpi) for QIC-24 and 492 ftpmm (12 500 ftpi) for QIC-120/150. 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 filemark**
- ✓ **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 filemark, 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.

6.4.2.2. 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.

6.4.2.3. 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.

Filemark 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

6.4.2.4. 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 6.9 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 6.9 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 7654	
0 0 0 0	Normal Data Block or Filemark Block
0 0 0 1	Normal Control Block
0 0 1 0	QIC-150 Control Block
	Tandberg Data Vendor Unique:
0 0 1 1	QIC-120 with ECC Control Block
0 1 0 0	QIC-120/150 with ECC Filemarks
0 1 0 1	QIC-120/150 with ECC Filler Blocks
0 1 1 0	QIC-150 with ECC Filler Blocks
0 1 1 1	QIC-120/150 with ECC Correction Block
1 0 0 0	QIC-120/150 with ECC Cancel Block
1 0 0 1	QIC-120/150 Map Block

The other 7 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 3 2 1 0	Byte 2 7 6 5 4	 3 2 1 0	Byte 3 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 0
Second Block	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0
.	-	-	-	-	-
.	-	-	-	-	-
Last Block	1 1 1 1	1 1 1 1	1 1 1 1	1 1 1 1	1 1 1 1

Figure 6.10 Layout of Block Number

The Block Number is encoded according to the rules given in Section 6.6.

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.

6.4.2.5. CRC (Cyclic Redundancy Check)

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

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

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.

6.4.2.6. 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.

6.5. Recording Method

The same recording technique is used for the QIC-120, QIC-150, QIC-525 and QIC-1000 tape formats...

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...).

6.6. 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 Table 6.1, 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 B3	B6 B2	B5 B1	B4 B0		E9 E4	E8 E3	E7 E2	E6 E1	E4 E0
0	0	0	0	➤	1	1	0	0	1
0	0	0	1	➤	1	1	0	1	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 E4	E9 E3	E7 E2	E6 E1	E5 E0		B7 B3	B6 B2	B5 B1	B4 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

6.7. 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.

Encoded bit positions ....567890123456789O1234....

Forward tape motion (BOT → EOT)

Resulting recording direction

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 Figures 6.11a and 6.11b.

Block n-1	Block n	Block n-+1	Block n	Block n+1	Block n+2
	First Write (bad)	First Write	First Rewrite	First Rewrite	

Recording direction →

Figure 6.11a Track layout after rewriting of bad blocks, QIC-24 / 120 / 150 / 525

Block n-1	Block n	Block n+1	Block n+2	Block n	Block n+1	Block n+2	Block n+3
OK	First Write (bad)	First Write OK	Termi-nated	First Rewrite OK	First Rewrite	First Rewrite	

Recording direction →

Figure 6.11b Track layout after rewriting of bad blocks, QIC-1000

In Figure 6.11a, 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 a certain no. of rewrites specified by the *Write Retry Count*, programmable by the Mode Select command (default = 16), and the Host is informed that a fatal write error condition has occurred (Write Abort).
For QIC-1000, see Figure 6.11b, the Drive will terminate writing block n+2 when n is bad, and rewrite blocks n, n+1 and n+2 up to a certain no. of rewrites specified by the *Write Retry Count*, programmable by the Mode Select command (default = 16).

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. Filemark and Setmark Blocks

Filemark 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 Standards also define a filemark to be recorded at the end of the recorded area. The Host should therefore issue a Write Filemark command at the end of the recording sequence.

The contents of the data fields in the filemark and setmark blocks are not transferred to the Host.

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

6.10. 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 through 6.1e, the areas not marked as tracks or reference signals are normally erased. This is especially important in the BOT area around the Reference Burst recordings.

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.

6.11. Reference Burst

One or more Reference Bursts are recorded between the BOT holes and a certain distance after the LP-hole on Track 0. (See Section 6.2 for more information).
The Reference Bursts are used during read operations to determine the exact track location.

6.12. 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", 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 motion is halted.

The Elongated Postamble will always be recorded at the end of a write operation.

6.13. Data Append

After a write underrun situation, 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, see Figure 6.12.

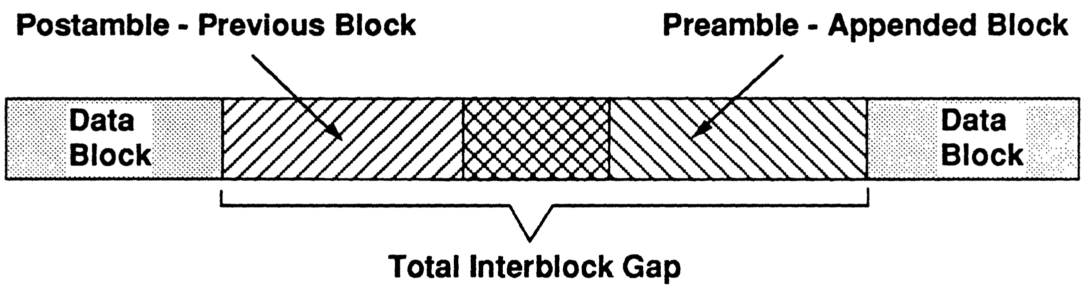


Figure 6.12 Data Append

Due to the elongated postamble after the previous last block, this ensures a minimum overlap between the postamble and the new preamble.

6.14. Recording of Even Numbered Tracks

In normal mode, all even numbered tracks are recorded in the direction from BOT to EOT. The fist block on every track is preceded by a long preamble. The Drive is also supporting Quick File Access (QFA). If this mode is selected, the last track is used as a directory track, and it is always written from BOT to EOT. (See Section 6.2).

6.15. Recording of Odd Numbered Tracks

All odd numbered tracks are recorded in the direction from EOT to BOT. The first block on every track is preceded by a long preamble.
See Section 6.2 for further information.

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7. Basic Operational Functions

7.1. Reference Tracks

During Read and Write operations the tape format defines the different track positions. When a tape is written, one or more Reference Track(s) 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(s) determines the current tape format.
Also first information on the track is used to determine the tape format (control block etc.).

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

7.1.1. Write Reference Track 0

If the tape is positioned at Beginning Of Tape, the Write Reference Track 0 function is always performed after a Write command is received. The Write Reference Track 0 is done internally in the Drive and is transparent to the Host. The Reference Track 0 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.

Refer to the Lower Tape Edge

The physical position of the Reference Track(s) 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 different Reference Tracks are known.

QIC-120/150

QIC-120/150 only has one single Reference Track located at Track 0.

QIC-525

QIC-525 has Reference Tracks for all *even tracks* up to Track 11 between BOT and LP, while all *odd tracks* up to Track 12 are written when writing in the reverse direction from EOT to EW.

QIC-1000

In the QIC-1000 mode, all tracks up to Track 14 have Reference Bursts. They are all written at the same time in the area between BOT and LP.

7.1.2. Read Reference Tracks

If the tape is positioned at Beginning Of Tape and the track position is unknown, the Read Reference Track 0 function is performed after receiving a Read command. The Read Reference Track 0 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.

Readable Tape Formats are:

QIC-24, QIC-120, QIC-150, QIC-525 and QIC-1000

During a seek Reference Track, the Drive will use the following scheme to detect the tape format:

- 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.
- From this head position the Drive will start searching for the lower edge of the Reference Track, moving the head upwards. When the lower tape edge is found, the Drive recognizes this position and starts looking for the upper edge. When it is found, the middle position is calculated, and the head adjusted accordingly.
- If no lower or/and upper edge is found, the Drive will re-adjust the approximate position and look for other tape formats.
  The same procedure is performed until the Reference Track is found.
- The Drive uses the Reference Track location to determine the current tape format.
  Due to the fact that the location of the Reference Track is very similar for some tape formats, the Drive also reads some data blocks in order to examine the tape format, and to verify that the correct track was found (by checking the recorded track information).

For QIC-120/150/525, only Reference Track 0 will be used as a reference. For QIC-1000 the Drive will first find Reference Track 0, then Reference Track 1 and finally Reference Track 12. The positions of the remaining tracks will be calculated on the basis of the found Reference Track positions. This allows for the elimination of all major mechanical tolerances and exact center track positioning.

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 current 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. Overwriting Previous Data

The QIC-standards do not allow writing to the tape except when positioned as described in the two previous sections. The Drive does, however, support *logical overwrite* at two defined places:

1) *after the first data block*

2) *before the last Filemark in front of EOR*

This makes it possible to emulate the kind of overwrite that is necessary to support the old TAR-format.
When overwriting after the 1st data block, the tape will be entirely re-written, and the first block will be written to the tape before any new data is added.

Tandberg Data Unique Filemark Cancel Block

When "overwriting" the last Filemark, the Filemark is not physically overwritten, but a Tandberg Data unique block, the so-called *Filemark Cancel Block* is written instead as the first appended block. This *Cancel Block* will, when reading logically, cancel the previous Filemark. (For more information, see the SCSI-interface documents).

7.2.4. 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.

Block Map

At this point the Drive will, if in QIC-525/1000 mode, fill incomplete frames with *Filler Blocks* to assure that only complete frames are written to the tape. The Filler Blocks will contain information in a*"Block Map"*, which is a kind of directory handled by the Drive, totally transparent to the user. It will allow fast access (seeking) to any logical block, Filemark or Setmark.

If there is not sufficient Filler Blocks in the last frame to hold the Block Map, a complete frame with only Filler Blocks will be added (if not disabled with the DTM2-bit in the Mode Select command).

In QIC-120/150 the Block Map-information will be written as Control Blocks (if not disabled with the DTM1-bit in the Mode Select command).

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.

7.2.5. 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 *TBS 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.

7.2.6. 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. 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.

7.2.7. Recoverable Write Error (Rewrite)

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

For QIC-525 →

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 7.1a Track layout after rewriting of bad blocks, QIC-120/150/525

Block n-1	Block n	Block n+1	Block n+2	Block n	Block n+1	Block n+2	Block n+3
OK	First Write (bad)	First Write OK	Termi-nated	First Rewrite OK	First Rewrite	First Rewrite	

Recording direction →

Figure 7.1b Track layout after rewriting of bad blocks, QIC-1000

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

For QIC-1000 →

For QIC-1000, see Figure 7.1b, the Drive will terminate writing block **n+2** when n is bad, and rewrite blocks **n**, **n+1** and **n+2** up to the number of times specified by the *Write Retry Count* (programmable with the Mode Select command).

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 the number of times specified by the Write Retry Count, without any action from the Host.

The Rewrite procedure is totally transparent to the Host.

7.2.8. Unrecoverable Write Error

If the Drive has tried to rewrite the same block the number of times specified by the Write Retry Count, 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/Setmarks

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 Software Manual).

Notice that data and Tapemark (Filemark/Setmark) blocks are written with separate Write commands. During Read Data, Filemarks are treated as special message blocks, and are reported with CHECK CONDITION. However, Tapemarks can be read with its own command. During Read Filemarks, datablocks are not treated as erroneous blocks, but skipped instead.

Despite that Tapemarks 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 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)

For QIC-120/150 ➔

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 the number of times specified by the Write Retry Count in the Mode Select command. 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.

For QIC-525 ➔

See Chapter 5, Section 5.4.

7.3.7. Unrecoverable Read Error

If the Drive has tried to reread the same block the number of times specified by the Write Retry Count, 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 Standard (SCSI-2), Rev. 10C, March 9, 1990.* 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 asynchronously 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 0.5 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.

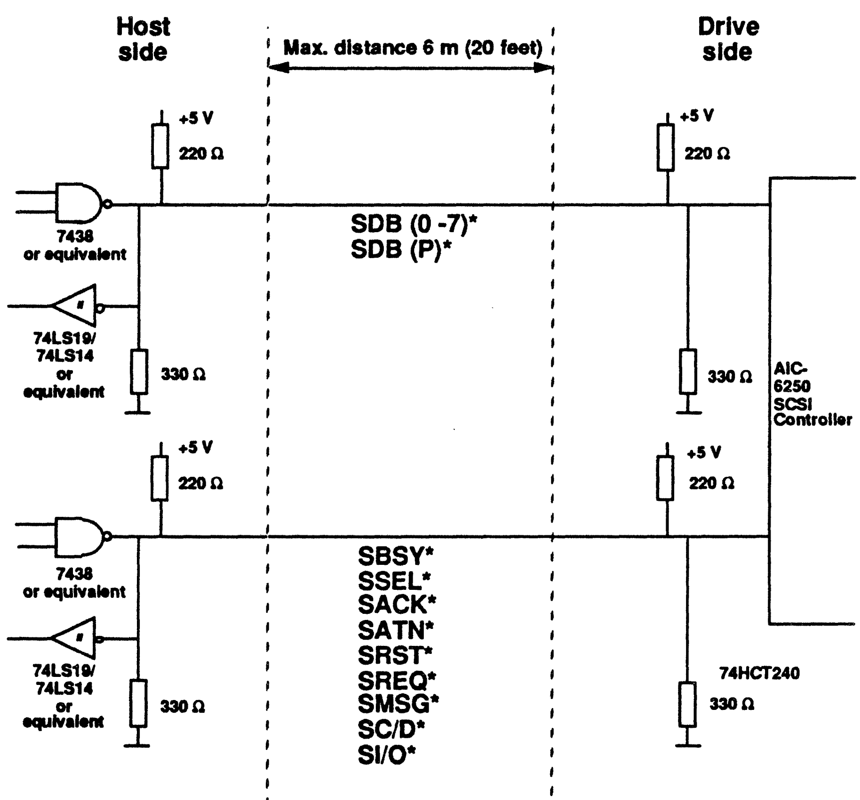

Figure 8.1 Electrical Interface Connector Specifications

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
DAT(0)	2	1	Data Bus
DAT(1)	4	3	|
DAT(2)	6	5	|
DAT(3)	8	7	|
DAT(4)	10	9	|
DAT(5)	12	11	|
DAT(6)	14	13	|
DAT(7)	16	15	Data Bus
SDATPAR	18	17	Data Bus Parity
GND		19	
GND		20	
GND		21	
GND		22	
GND		23	
GND		24	
TERMPWR	26	25	
GND		27	
GND		28	
GND		29	
GND		30	
SATN	32	31	Attention
GND		33	
GND		34	
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

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.

SATN (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.

DAT(7-0) and SDATPAR (Data Bus)
Eight data bit signals comprise the data bus. DAT(7) is the most significant bit, and has the highest priority during arbitration. SDATPAR is the data bus parity (odd). Each of the eight data signals DAT(7) through DAT(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	
✔ Data Exchange Phase	These four phases are collectively
✔ Status Phase	termed the Information Transfer Phase
✔ Message Phase	

The TDC 4100 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 µs) 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 µs), 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.

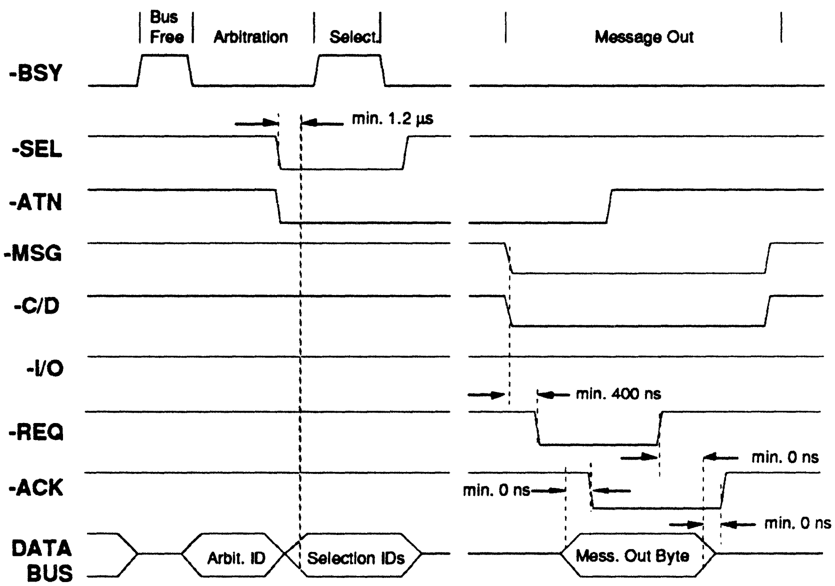

Figure 8.2 Arbitration, Selection and Message Out Phases

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.

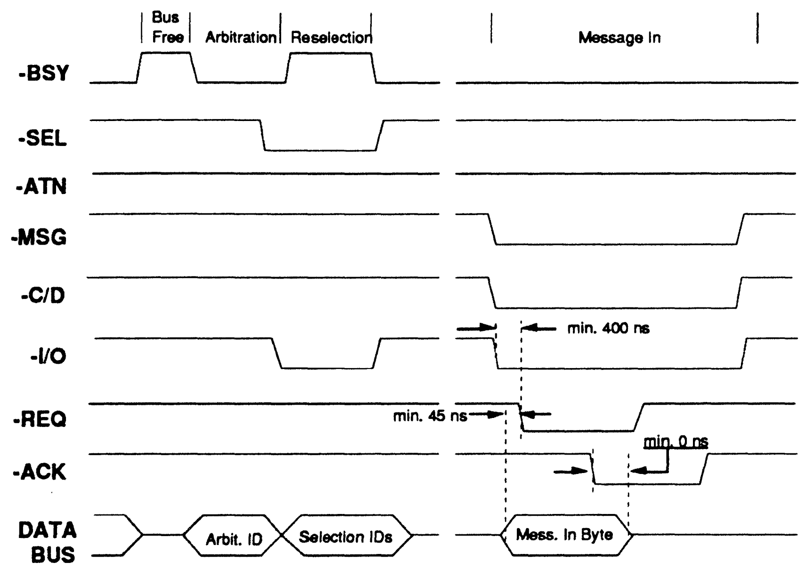

Figure 8.3 Arbitration, Reselection and Message In Phases

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.

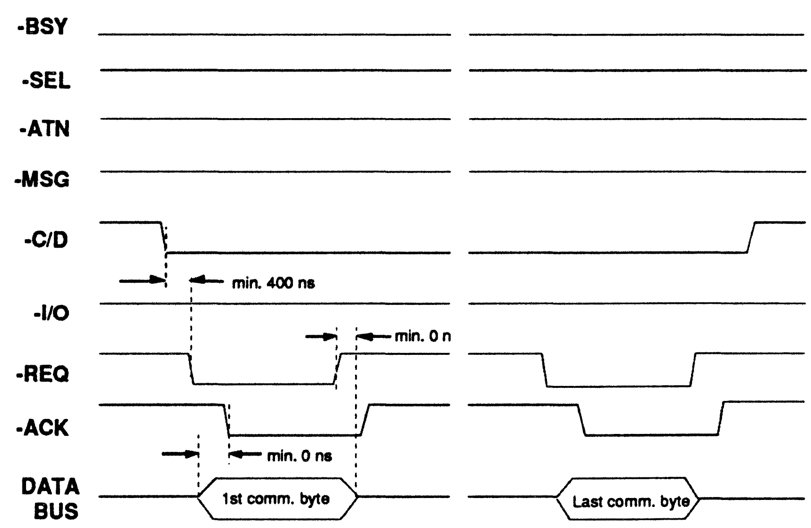

Figure 8.4 Command Phase Sequence

> NOTE:
> The data transfer for the Drive is done in hardware and has a transfer rate of about 3 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.

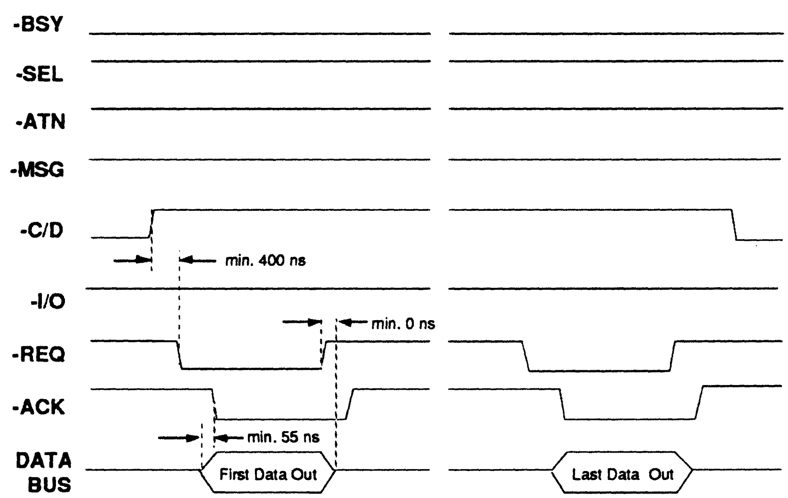

Figure 8.5 Data Out Sequence

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:

① The Target asserts I/O.

② For each byte, the Target asserts REQ.

③ The Initiator reads the byte and asserts ACK.

④ The Target releases the data bus and deasserts REQ, whereupon the Initiator deasserts ACK.

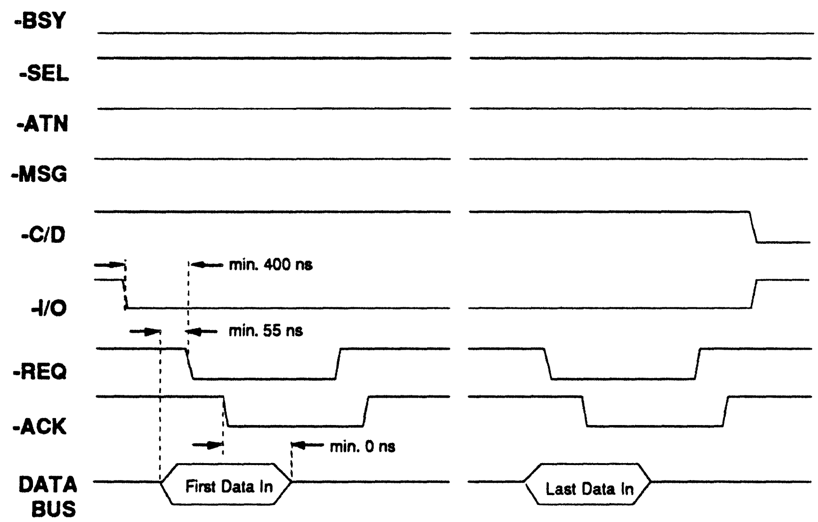

Figure 8.6 Data In Sequence

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 3 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 Drive will generate the Message In Phase by asserting the MSG, C/D and I/O lines.

② After a bus-settle delay of 400 ns the Drive puts the Message Byte on the bus and asserts the REQ signal.

③ The Initiator reads the Message Byte and asserts ACK.

④ The Drive de-asserts REQ and the Initiator can in turn de-assert ACK.

⑤ The Message In Phase terminates when the Drive de-asserts MSG.

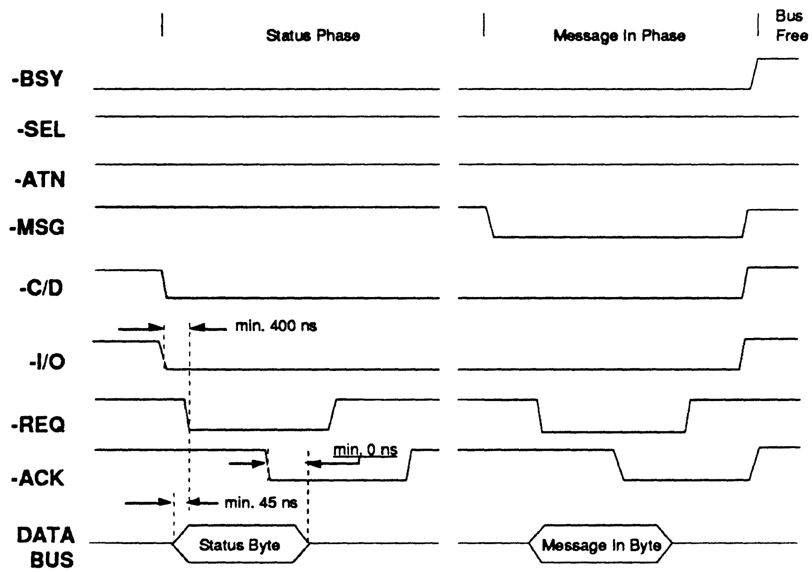

Figure 8.7 Status and Message In Phases

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 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 Out Phase terminates when the Target deasserts MSG.

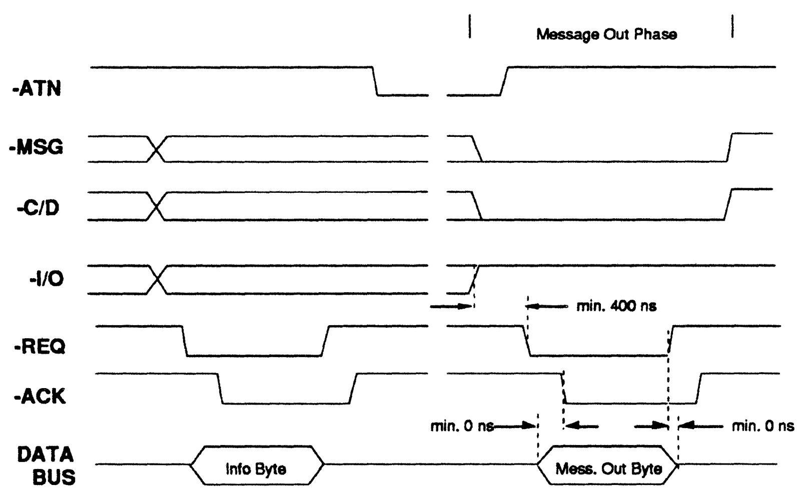

Figure 8.8 Attention Interlock and Message Out Transfer

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.
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

Table 8.2 Summary of SCSI-bus Phases

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 µs.

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:

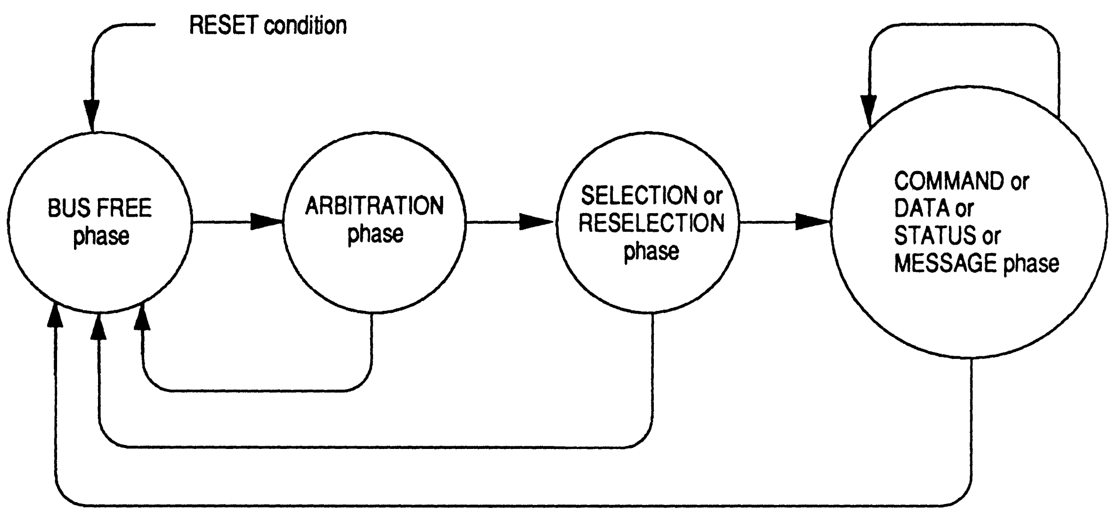

Figure 8.9 Phase Sequencing for systems using Arbitration

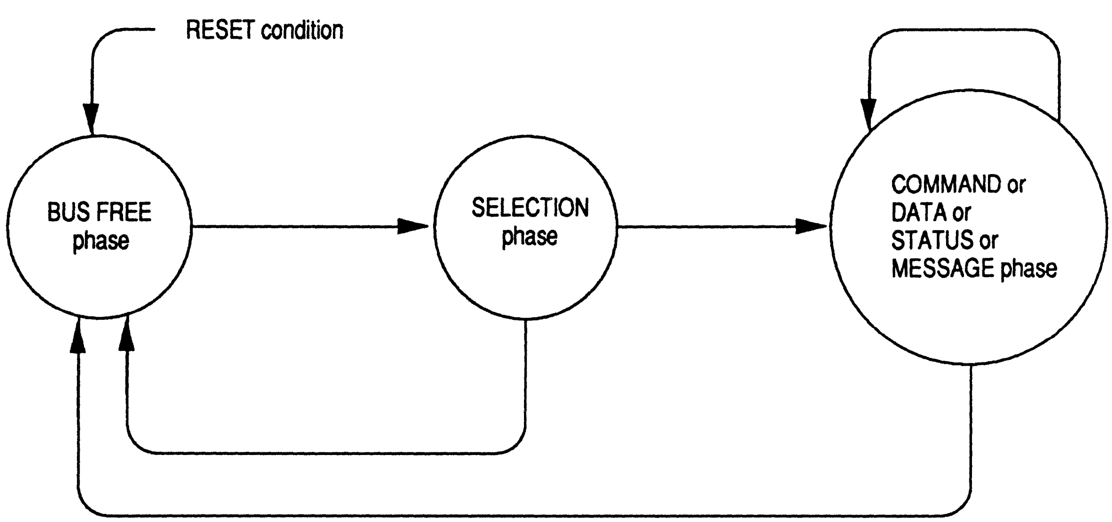

Figure 8.10 Phase Sequencing for non-arbitrating systems

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9. Software Interface

9.1. General Information

The TDC 4100 SCSI Interface, Functional Specifications are widely based on the standard TDC 3800 SCSI-1/SCSI-2 Interface manuals, both available from our Sales Department:

- *TDC 3800 Series SCSI-1 Interface, Functional Specifications, Part No. 5877, Publ. No. 41 67 27*

- *TDC 3800 Series SCSI-2 Interface, Functional Specifications, Part No. 5878, Publ. No. 41 67 30*

This chapter will describe the major differences and special features related to the TDC 4100 Drives which are *not included* in the TDC 3800 documentation.

9.1.1. Introduction of QIC-1000 Density Code and DC9100 Tape Cartridge Type in the Mode Select and Mode Sense Commands

9.1.1.1. SCSI-1, Section 12.3.2. Block Descriptor List (Mode Select)

Add the the value ***15h*** to the list of legal Density Codes:

00h : Default Density
0Dh : QIC-120 with ECC
0Eh : QIC-150 with ECC
0Fh : QIC-120
10h : QIC-150
11h : QIC-525
15h : QIC-1000
7Fh : no change (no operation)

Add the DC9100 medium to the table: *Automatic Density Codes:*

Medium	Tape Format
DC6320	*The Drive selects QIC-525 tape format (density code 11h)*
DC6525	
DC9100	**The Drive selects QIC-1000 tape format (density code 15h)**

9.1.1.2. SCSI-1, Section 13.3.1. Header List (Mode Sense)

Add the value ***17h*** under the description of Medium Type:

00h : DC300 or DC300XLP
01h : DC615 or DC600A
02h : DC6037 or DC6150 or DC6250
03h : DC6320 or DC6525
17h : DC9100

9.1.1.3. SCSI-1, Section 13.3.2. Block Descriptor List (Mode Sense)

Add the value ***15h*** to the list of possible Density Codes:

00h : Unknown
05h : QIC-24
0Dh : QIC-120 with ECC
0Eh : QIC-150 with ECC
0Fh : QIC-120
10h : QIC-150
11h : QIC-525
15h : QIC-1000

9.1.1.4. SCSI-2, Section 15.3.2. Block Descriptor List (Mode Select)

Add the value ***15h*** to the list of legal Density Codes:

00h	:	*Default Density*
0Dh	:	*QIC-120 with ECC*
0Eh	:	*QIC-150 with ECC*
0Fh	:	*QIC-120*
10h	:	*QIC-150*
11h	:	*QIC-525*
15h	**:**	**QIC-1000**
7Fh	:	*no change (no operation)*

9.1.1.5. SCSI-2, Section 16.3.1. Header List (Mode Sense)

Add the value ***17h*** under the description of Medium Type:

00h	:	*UNKNOWN*
02h	:	*DC300 or DC300XLP*
04h	:	*DC615 or DC600A*
06h	:	*DC6037 or DC6150 or DC6250*
08h	:	*DC6320 or DC6525*
17h	**:**	**DC9100**

9.1.1.3. SCSI-2, Section 16.3.2. Block Descriptor List (Mode Sense)

Add the value ***15h*** to the list of possible Density Codes:

00h	:	*Unknown*
05h	:	*QIC-24*
0Dh	:	*QIC-120 with ECC*
0Eh	:	*QIC-150 with ECC*
0Fh	:	*QIC-120*
10h	:	*QIC-150*
11h	:	*QIC-525*
15h	**:**	**QIC-1000**

9.1.2. Introduction of 53 and 80 Ips Tape Speed in the Mode Select and Mode Sense Commands

9.1.2.1. SCSI-1, Section 12.3.1. Header List (Mode Select) and SCSI-2, Section 15.3.1. Header List (Mode Select)

Replace the description of the *Speed-field* with the following:

Tape Speed

This field specifies the current tape speed. The following values are legal:

0h: No change

1h: Low Speed
(53 ips when the Drive is in QIC-1000 mode)

2h: High Speed
(80 ips when the Drive is in QIC-1000 mode)

See Chapter 13. Mode Sense for further description.

- Legal values are numbers in the range 0..2.
- The default (factory programmed) value is 0.
  (Default values and 53 ips for QIC-1000)

9.1.2.2. SCSI-1, Section 13.3.1. Header List (Mode Sense) and SCSI-2, Section 16.3.1. Header List (Mode Sense)

Replace the description of the *Speed-field* with the following:

Tape Speed

This field specifies the current tape speed. The following values are legal:

0h: Default
The actual speed depends on the current tape format:

Tape Format	Tape Speed
QIC-24/120/150	96 ips
QIC-525	120 ips
QIC-1000	53 ips

2h: 80 ips when the Drive is in QIC-1000 mode.

9.1.3. Support of Mode 5 in the Write Buffer Command

This description is valid for both SCSI-1 (TDC 3800 spec., Chapter 30: ***nn = 30***) and SCSI-2 (TDC 3800 spec., Chapter 32: ***nn = 32***).
Specification changes are indicated by vertical bars in the right hand margin:

nn ***means either:***

30 for SCSI-1
or
32 for SCSI-2

nn. Write Buffer

nn.1. Command Description

The WRITE BUFFER command is used in conjunction with the READ BUFFER command as a diagnostic function for testing the the Drive's data buffer and the SCSI-bus integrity. An additional mode is provided for downloading and saving of microcode.

This command will not alter the status of possible inserted cartridge when the combined header and data mode is specified

The WRITE BUFFER Parameter List will be transferred during the DATA-OUT phase of the command.

Note that the data transferred may write over other data already present in the data buffer (read-ahead data after a READ command or data not written after a WRITE command).

If disconnection is allowed, the Drive may disconnect when executing this command. When transferring data, the total data transfer will be split into smaller bursts with a maximum size. The maximum burst size (the amount of data transferred between reconnects/disconnects) will be controlled by the bus ratio/threshold parameters set up by the MODE SELECT command (just as for the WRITE command).

nn.2. Command Descriptor Block

BYTE	BIT 7	6	5	4	3	2	1	0
00	0	0	1	1	1	0	1	1
01	Logical Unit Number (LUN)			RESERVED		Mode		
02	Buffer ID							
03 04 05	Buffer Offset							
06 07 08	Transfer Length							
09	Control Byte							

Table: WRITE BUFFER Command Block

Mode This field specifies the Write Buffer Mode:

Mode	Description
0	Write combined Header and Data
5	Download Microcode and Save

Buffer ID This field MUST be set to zero for Mode 0. This field is ignored for Mode 5.

Buffer Offset The Buffer Offset field is reserved in Mode 0 and MUST be set to zero. This field is ignored for Mode 5.

Transfer Length Mode 0: This number includes four bytes of header, so the data length to be stored in the Drive's buffer is the Transfer Length minus four (note that the Transfer Length specifies the sum of Header and Data bytes). If the Transfer Length is zero, the Drive will not transfer any header or data. The buffer size is 245756 (not including Header).

Mode 5: The number includes 128 KByte with PROM-data, plus a 4-byte CRC polynomial. The total Transfer Length will be 131076 bytes.

nn.3. Combined Header and Data Mode

In this mode, data to be transferred is preceded by a four-byte header.

nn.3.1. Header List

BYTE	BIT 7	6	5	4	3	2	1	0
00	RESERVED							
01	RESERVED							
02	RESERVED							
03	RESERVED							

Table: WRITE BUFFER Header List

nn.3.2. Data List

Following the WRITE BUFFER Header, the Drive will transfer data to its data buffer. The first byte transferred will be the byte to be written at buffer address 4 (bytes 0...3 are occupied by the Header List data).

nn.4. Download Microcode and Save Mode

Programming the FLASH PROM

When the "Download and Save Microcode" option is issued, the Drive will *not* respond to any SCSI-activities during the saving of new microcode (programming the FLASH PROM).
After receiving the data, the Drive will send the COMMAND COMPLETED message and then enter the BUS FREE phase when saving the microcode. When the Download Microcode and Save command has completed successfully, the Drive will generate an Unit Attention condition, due to an internal Drive Reset after the programming. If an error occur during programming the FLASH PROM, the Drive will indicate the error by a blinking front LED (as in Selftest).

No selection of the Drive must be attempted during saving of the microcode.

Time for saving of the Microcode:
Typical: TBS
Maximum: TBS

The LINK-bit option in the CDB is *not allowed* in Mode 5.

nn.5. Exception Handling

See sections on Error Conditions For All Commands, Deferred Errors and Buffer Parity Errors.

If the Mode, Buffer ID or Buffer Offset fields are not set to zero for Mode 0, the Drive will terminate the command with CHECK CONDITION. No data will be transferred. The Error Code will be set to E$STE_IFIC.

If the Transfer Length exceeds the available length plus four in Mode 0, then the Drive will return CHECK CONDITION status and the Error Code will be set to E$STE_IFIC..

If the Transfer Length is different from 128 KBytes + 4 bytes (131076) in Mode 5, then the Drive will return CHECK CONDITION status and the Error Code will be set to E$STE_IFIC.

The LINK-bit option in CDB is not allowed in Mode 5. If Mode equal to 5 and the LINK-bit is set, the Drive will return CHECK CONDITION status and the Error Code will be set to E$STE_IFIC.

If the RESERVED bits in the Header List is not set to zero, the Drive will return CHECK CONDITION status after having transferred all data (header and data). The Error Code will be set to E$STE_IFIP. Note that in this case the transferred data after the erroneous header will overwrite data already in the data buffer.

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10. Selftest and Preventive Maintenance

10.1. Selftests

The Drive supports extensive selftest possibilities which will simplify the testing of the Drive. Different types of selftest procedures are provided, plus additional tests for use in the production process, can be executed:

① Power-Up Test
② Reset Test
③ Selftest 2 (Customer Incoming Inspection)
④ QA-Test

In addition:

⑤ Burn-In Test (For Production Use)
⑥ Drive Acceptance Test (For Production Use)

10.2. Test Operations

10.2.1. Power-Up Test

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.

① **Flash-Memory Test**
The complete 128 KByte, so-called FLASH MEMORY, is tested by a check-sum test. All bytes are added together and compared by a 32-bit check-sum in the memory. Time consumption is approximately 600 ms.

② **CPU Test**
Most of the instruction-set for the microprocessor is tested. The test is divided into an arithmetic, a logical and a data-move test.
A fixed sequence of instructions is executed, then the result is checked against a pre-calculated answer.

③ **Scratch Pad RAM (Static RAM) Test**
The static RAM is tested by writing and reading 55H and AAH data patterns to/from all RAM-cells.

④ **Drive Controller Test**
The hardware for Write- and Read formatting will be tested. The Drive Controller chip is placed in digital loopback mode and 1 data-block is fed into the Write Sequencer by the DMA0 channel. The last 8 bytes in the block + CRC are read back from the Read Sequencer and compared. CRC is also checked, both for the QIC-120/QIC-150 and QIC-525/QIC-1000 formats.

⑤ **SCSI Controller Test**

Data is transferred from the microprocessor to the SCSI Controller and then transferred to the buffer via the EDC Controller.
The data is then sent back in the opposite direction and checked by the microprocessor.

⑥ **EDC Controller Test**

The following tests will be performed at Power-Up:

6.1 Test of DMA0

A data block is sent to the Drive Controller (in Test Mode) then read back and checked.

6.2 Test of DMA1

A block is copied in the Data Buffer, read back and checked.

6.3 Test of the ECC Channel

14 blocks (the data-part of a frame) are written to the Data Buffer. ECC is generated and checked.
After this, one byte in the data-part is "bombed". Then the ECC Channel should regenerate the bad block which in turn is read back and checked.

6.4 MPU Transfer

Data is written to the Data Buffer - then read back and checked.

6.5 Data Buffer Test (Dynamic RAM)

The Buffer is tested with Write and Read using the DMA1 in the EDC Controller. The data pattern is 55H and AAH. Time consumption is approximately 350 ms.
The entire 256 KByte buffer is filled with the test pattern, then read back and compared. Both Parity and Compare Errors are checked.

10.2.2. Reset Test

Each time the Drive is reset it will go through a fast and simple selftest routine before it will be accessible to the Host-system. Most of the digital hardware circuitry tested in the Power-Up Test will be tested, but the degree of fault-coverage for the tests are much lower.

10.2.3. Selftest 2 (Customer Incoming Inspection)

Test Activation

Selftest 2 is activated either by a jumper setting on the Service Port (see Section 10.3) or by a SCSI command (see also Chapters 4 and 9).

Test Description

The test is a Write/Read test. Two tracks are written in files of 800 blocks (50 frames of sixteen 1 KByte blocks) for the QIC-1000 format. 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.

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 % is the total limit).

If the number of rewrites is above the limit, the test is aborted and the RED front LED is blinking an STM-Error Code (customer dependent).

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 "hard" 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 is blinking an STM-Error Code (customer dependent).

NOTE: The ECC function is turned OFF during Read.

If no rereads occur during the second Read test it is considered a "soft" error and no error is reported when the test returns.
If the test fails again, it is aborted, and the RED front LED is blinking an STM-Error Code (customer dependent).

Test OK!

If the test run OK, the GREEN front LED will be blinking (customer dependent).

See the list of STM Error Codes in Appendix A.

10.2.4. QA Test

① **Wind/Rewind Test**
This test will do a continuous WIND and REWIND between BOT and EOT with head-cycling until power is turned off.
The front LED is set to steady GREEN during this test.

No Error Checking is performed.

② **Erase FWD/REV Test**
This test will run the tape continuously forward and reverse between BOT and EOT with the erase-current ON in both directions until power is turned off.
The front LED is set to steady RED during this test.

No Error Checking is performed.

③ **Write and Erase FWD/REV Test**
This test will run the tape continuously forward and reverse between BOT and EOT with the Erase- and Write-current ON in both directions until power is turned off.
The front LED is blinking GREEN during this test.

No Error Checking is performed.

Important Notice!
Tests 2 and 3 will NOT step the Head up and down!

10.2.5. Burn-In Test (For Production Use)

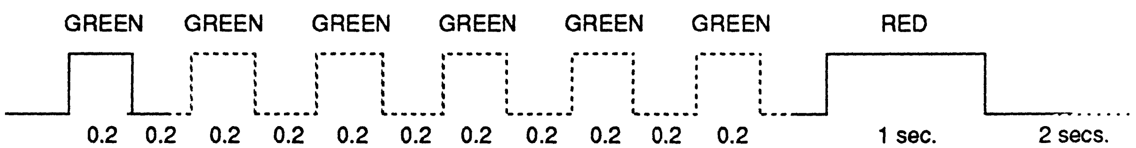
The Burn-In Test is designed as an internal production test tool. Normally this test is disabled for customers by a cell in the EEPROM. It is looping the same test for approximately 12 seconds, then it returns. A Burn-In counter located in the EEPROM is then upgraded. The Burn-In Test should be run in a test environment which cycles the power supply continuously on/off (15 sec. ON, 15 sec. OFF).

The test is divided into 6 phases depending on the value of the *Burn-In Counter.*
Phases 1 – 3 will do a write/read test of the whole EEPROM, while the phases 4 – 6 will perform "normal" tests, not including the EEPROM.

The 6 test phases for Burn-In are shown in the following table:

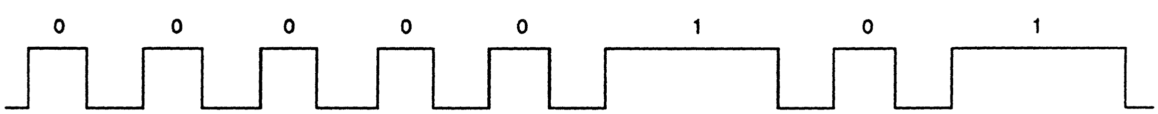
Phase	Burn-In Counter on Entry	Time	Tests	OK Blink Sequence
1	0 ($0000)	0– 15 s	Hardware, EEPROM Address and Label Test run	1 short GREEN 1 long RED
2	1...512 ($0001–$0200)	15 s– 4h17	Hardware, EEPROM Data Test run	2 short GREEN 1 long RED
3	513 ($0201)	4h17– 4h17	Hardware, EEPROM Initialize Test run	3 short GREEN 1 long RED
4	514...2880 ($0202–$0B40)	4h17– 24h00	Hardware Test run	4 short GREEN 1 long RED
5	2881...9999 ($0B41...$270F)	24h00– 83h20	Hardware Test run, 24 hour exceded	5 short GREEN 1 long RED
6	10000 ($2710)	> 83h20	Hardware Test run, EEPROM re-programmed 10 000 times	6 short GREEN 1 long RED

If the test is executed successfully, the LED located on the Drive's front panel will blink the OK-sequence according to the phase.
The number of *short GREEN blinks* will relate to the phase number:



If the test is failing, the RED front LED will blink an eight-bit STM Error Code Message. The most significant bit will be blinked first (a short blink equals logical'0', a long blink equals logical '1').

Example: The STM Error Code E$EDC (05 Hex) will blink the following code:



See the list of STM Error Codes in Appendix A.

> NOTE:
> If the Burn-In Test is run with constant power, it will only test the hardware for approximately 12 sec.

10.2.6. Drive Acceptance Test (For Production Use)

The Drive Acceptance Test is the final (and only) test of the complete drive during the production process.

The test consists of two main parts:

- **Adjustments and calibrations**
- **Performance tests**

① The following adjustments and calibrations are done fully automatically by the Drive:

- ✓ Write Current adjustment
- ✓ Write Balance adjustment
- ✓ Read Gain adjustment
- ✓ Pulse Slimming adjustment
- ✓ Read Clock Frequency adjustment
- ✓ Head Calibration

The ***Write Current Adjustment*** adjusts the Write current to the specified optimal saturation points for the different tape formats.

The ***Write Balance Adjustment*** adjusts the Write Balance to optimal symmetry in the Read-channel.

The ***Read Gain Adjustment*** adjusts the Read-channel gain to obtain the specified output from the Read-channel.

The ***Pulse Slimming Adjustment*** is adjusted to compensate for the variation in resolution of different read heads.

The ***Read Clock Frequency*** is adjusted to match the different tape format and speed combinations.

The ***Head Calibration*** executes a normal head-calibration and stores the step count in the EEPROM.

② The following performance tests are done:

- ✓ Read/Write test
- ✓ Erase and Noise tests
- ✓ Crossfeed test
- ✓ Track Alignment test
- ✓ Bitshift Performance Control

The ***Read/Write Test*** performs normal reading and writing while the performance of the Drive is carefully monitored.

The ***Erase and Noise Test*** checks if the Erase performance is inside the specifications and that the noise in the Read-channel is lower than the specified limit (motor running).

The ***Crossfeed Test*** tests if the Head crossfeed is inside the specifications.

The ***Track Alignment Test*** checks the Track-Seek function.

The ***Bitshift Performance Control*** tests that the bitshift is inside the specified limits.

10.3. How to Activate the Manual Tests

10.3.1. Jumper Test Interface

Depending on the Address Jumper setting, the corresponding test will be performed if the Selftest Jumper is installed:

Function Name	Test Jmp.	Address	SEL2	SEL1	SEL0
Burn-In Test	X	0			
Selftest 2	X	1			X
Reserved	X	2		X	
Reserved	X	3		X	X
Reserved	X	4	X		
Erase FWD/REV Test	X	5	X		X
Write & Erase FWD/REV Test	X	6	X	X	
Wind/Rewind Test	X	7	X	X	X

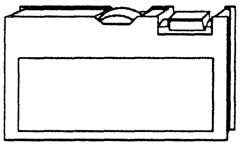
"X" indicates jumper installed.

If a “Reserved”-test is selected, the front LED will immediately be set to steady GREEN, and the Drive will be locked.

10.4. 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 ...

1/4" 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. The Head should also be immediately cleaned if "hard" or Write errors occur.

Use only certified quality cartridges for the TDC 4100 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.

App. A: STM Error Codes

This Appendix lists the various STM Error Codes which are divided into two major categories:

1) Selftest Error Codes for External Use
2) Selftest Error Codes for Internal Use Only

These two categories are split into different groups:

1) Selftest Error Codes for External Use
    - Group 0: Selftest Errors
    - Group 1: Tape Read/Write Errors
    - Group 2: Tape Status Errors
    - Group 3: Cartridge Related Errors

2) Selftest Error Codes for Internal Use Only
    - Group 4: Copy Related Errors
    - Group 5: Bus Related Errors
    - Group 6: Acceptance Test Related Errors
    - Group 7: Miscellaneous Errors

A.1. Selftest Error Codes for External Use

The following Error Codes may occur when Selftest 2 is run and are supported for customers:

A.1.1. Group 0: Selftest Errors

STM Error Code	Includes E$xxx	Description
$00	E$OK	No Error
$01	E$STM_CPU	Microprocessor CPU Error
$02	E$STM_INTRAM	Internal RAM Error
$03	E$STM_EXTRAM	External RAM Error
$04	E$STM_BUFFER	Data Buffer Error
$05	E$STM_EDC	EDC Controller Error
$06	E$STM_DRVCON	Drive Controller Error
$07	E$STM_SCSI	SCSI Controller Error
$08	E$STM_READ	Read Error
$09	E$STM_WRITE	Write Error
$0A	E$TCM_SAF1	SAFE* was high when it should be low
$0B	E$TCM_SAF0	SAFE* was low when it should be high
$0C	E$TCM_VLT1	WRVOLT was high when it should be low
$0D	E$TCM_VLT0	WRVOLT was low when it should be high
$0E	E$TCM_ERN1	EREN_IN was high when it should be low
$0F	E$TCM_ERN0	EREN_IN was low when it should be high

A.1.2. Group 1: Tape Read/Write Errors

STM Error Code	Includes E$xxx	Description
$20	E$BTD_RTRY	Read Retries Exhausted
$21	E$WRT_APFAIL	Append Failure
$22	E$WRT_EOM	End of Media Detected
$23	E$WRT_REWRITE	Maximum number of Rewrites
$24	E$BTD_APUF	Write Append uncompleted Frame detected
$25	E$BTD_CFMT	Incompatible Media Type
$26	E$BTD_TFMT	Incompatible Tape Format
$27	E$STE_ILLN	Illegal Length Error

A.1.3. Group 2: Tape Status Errors

STM Error Code	Includes E$xxx	Description
$40	E$BTD_FIMK	Filemark detected during Read/Space
$41	E$BTD_PSEW	PSEW detected on current Partition
$42	E$BTD_RDWR	Read Command after Write Command
$43	E$BTD_WRRD	Write Command after Read Command (Append)
$44	E$TEM_EOR	End of Recorded Area detected on current Partition
$45	E$TEM_EOREW	EOR at Early Warning detected
$46	E$TEM_PEOP	Physical End of Partition detected
$47	E$BTD_SEMK	Setmark detected during Read/Space
$48	E$BTD_IWSD	Illegal Write Sequence in Dual Partition Mode
$49	E$BTD_SEMK	PSEW detected on current Partition, Read

A.1.4. Group 3: Cartridge Related Errors

STM Error Code	Includes E$xxx	Description
$60	E$TCM_CFST	Fast Cartridge
$61	E$TCM_CRMD	Cartridge removed
$62	E$TCM_CSLW	Slow Cartridge
$63	E$TCM_CSTK	Stuck Cartridge
$64	E$TCM_NODATA	No Data found (blank cartridge)
$65	E$TCM_NTEF	No Tape Edge found
$66	E$TCM_SENS	Illegal Sensor condition
$67	E$TCM_TIME	Operation takes too long time
$68	E$TCM_TRUN	Tape Run-out
$69	E$BTD_WPRO	Cartridge Write Protected
$6A	E$STE_NCAR	Cartridge not Present
$6B	E$TCM_MEDERR	Signal detected between BOT and LP, but not a legal Reference Burst
$6C	E$TCM_NSIG	No signal from tape during Write

A.2. Selftest Error Codes for Internal Use Only

The following Error Codes are for Tandberg Data internal use only. These Error Codes should normally *not* occur during Selftest 2.

A.2.1. Group 4: Copy Related Errors

STM Error Code	Includes E$xxx	Description
$80	E$SIE_CILC	Cannot Execute since Host cannot Disconnect
$81	E$SIE_CHDF	Illegal Function
$82	E$SIE_CHDI	Bad Header
$83	E$SIE_CHDN	Truncated Header
$84	E$SIE_CODD	Inexact Segment, Odd number of Blocks
$85	E$SIE_CPDT	Internal Data Transfer Error
$86	E$SIE_CRES	Inexact Segment, Tape Residual
$87	E$SIE_CSGA	Address Out of Range
$88	E$SIE_CSGI	Bad ID or LUN
$89	E$SIE_CSGP	Truncated Descriptor
$8A	E$SIP_CIBS	Target Status Not GOOD STATUS or CHECK CONDITION
$8B	E$SIP_CICH	Target Status is CHECK CONDITION
$8C	E$SIP_CIDT	Parity Error in Data
$8D	E$SIP_CIDP	Parity Error in Parameter
$8E	E$SIP_CILB	Target Illegal Block Size
$8F	E$SIP_CISE	Target Selection Timeout
$90	E$SIP_CISQ	Target Phase.Sequence Error

A.2.2. Group 5: Bus Related Errors

STM Error Code	Includes E$xxx	Description
$A0	E$STE_BADC	Bad Command Block (Unspecified)
$A1	E$STE_BADP	Bad Parameter Block (Unspecified)
$A2	E$STE_CSEQ	Command Sequence Error (Unspecified)
$A3	E$STE_ICOP	Invalid Command Operation Code
$A4	E$STE_IFIC	Invalid Field in CDB
$A5	E$STE_IFIP	Invalid Field in Parameter List
$A6	E$STE_LBOR	Logical Block Address Out of Range
$A7	E$STE_LPCH	Log Parameters have been Changed
$A8	E$STE_MPCH	Mode Parameters have been Changed
$A9	E$STE_OLAP	Overlapped Commands Attempted
$AA	E$STE_PLEN	Parameter List Length Error
$AB	E$STE_PNSP	Parameter NOT Supported
$AC	E$STE_UATT	Unit Attention
$AD	E$STE_ULUN	Unsupported LUN
$AE	E$STP_ABRT	Abort Message Received
$AF	E$STP_COMP	SCSI Parity Error, Command Block
$B0	E$STP_DTAP	SCSI Parity Error, Data Block
$B1	E$STP_IBII	Invalid Bits in IDENTITY Message
$B2	E$STP_IDMR	INITIATOR DETECTED ERROR Message Received
$B3	E$STP_MERR	Message Error
$B4	E$STP_MSGP	SCSI Parity Error, Message
$B5	E$STP_PARP	SCSI Parity Error, Parameter Block
$B6	E$STP_SRFL	Select/Reselect Failure
$B7	E$STP_SYNC	Synchronous Data Transfer Error
$B8	E$STP_ABRT2	BH1 must be aborted by BH2

A.2.3. Group 6: Acceptance Test Related Errors

STM Error Code	Includes E$xxx	Description
$C0	E$CSM_ADJTAB_MISS	Impossible to Create Legal Address to ADJTAB
$C1	E$CSM_BAD_ERASE	Erased Tape Signal Too High
$C2	E$CSM_BIAS_UNSTABLE	Bias Value Unstable
$C3	E$CSM_BITSHIFT	Bitshift Limit Exceeded
$C4	E$CSM_CROSSFEED	Crossfeed Limit Exceeded
$C5	E$CSM_GAIN_RANGE	Cannot Exceed the Gain Range
$C6	E$CSM_END_OF_TRACK	End of Track Detected
$C7	E$CSM_ILLEGAL_TAPE	Adjustment allowed only on DC6320 Cartridge
$C8	E$CSM_MISALIGNMENT	Misalignment Exceeded Limit
$C9	E$CSM_NOISE	Motor and/or Read Channel Noise
$CA	E$CSM_PAST_BAL_RETRIES	Maximum Number of Retries during Balance Adjustment Exceeded
$CB	E$CSM_PAST_MAX_SAMPLES	Maximum Number of samples Exceeded
$CC	E$CSM_PAST_MAX_STEPDIFF	Maximum Difference between Head-top Values Exceeded
$CD	E$CSM_PAST_MAX_TURNS	Maximum Number of Turns Exceeded
$CE	E$CSM_PAST_MAX_UNBAL	Maximum Unbalance Value Exceeded
$CF	E$CSM_READCH_NOISE	Read Channel Noise Exceeded Limit
$D0	E$CSM_REREAD	Maximum Number of Rereads Exceeded
$D1	E$CSM_REWRITE	Maximum Number of Rewrites Exceeded
$D2	E$CSM_WRITE_PROTECTED	Cartridge Write Protected
$D3	E$CSM_WRITE_UNSTABLE	Write Value Unstable

A.2.4. Group 7: Miscellaneous Errors

STM Error Code	Includes E$xxx	Description
$E0	E$BHI_PARITY	Parity Error from Buffer to Bus
$E1	E$BTD_PBOP	Space to beginning of current Partition
$E2	E$BTD_VRFY	Data Compare Error on Verify
$E3	E$HMK_NPRC	No Process is running
$E4	E$HMK_OVFW	Stack Overflow
$E5	E$STE_BUSY	Drive is busy
$E6	E$STE_DFNN	Diagnostic failure on Component NN
$E7	E$STE_NLOD	Cartridge not Loaded
$E8	E$STE_NRRT	Cartridge has been changed
$E9	E$STE_RECV	Recovered Error
$EA	E$STE_REOB	Recover End of Buffer
$EB	E$STE_RESC	Reservation Conflict
$EC	E$STE_RNDP	Rounded Parameter
$ED	E$STE_SREV	Read Retries exhausted in Space Reverse
$EE	E$STP_MEMP	Memory Parity Error
$EF	E$STM_EEPROM	EEPROM Error
$F0	E$STM_EPROM	EPROM Error
$F1	E$STM_ILLPAR	Illegal Parameter when calling the Self-test Module
$F2	E$STM_REWIND	Rewind Error
$F3	E$STM_WIND	Wind Error
$F4	E$TEM_ILTERM	Illegal termination of Read data
$F5	E$THI_PARITY	Parity error from Buffer to Tape

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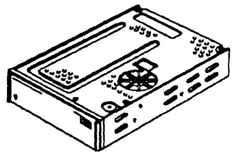
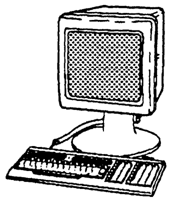
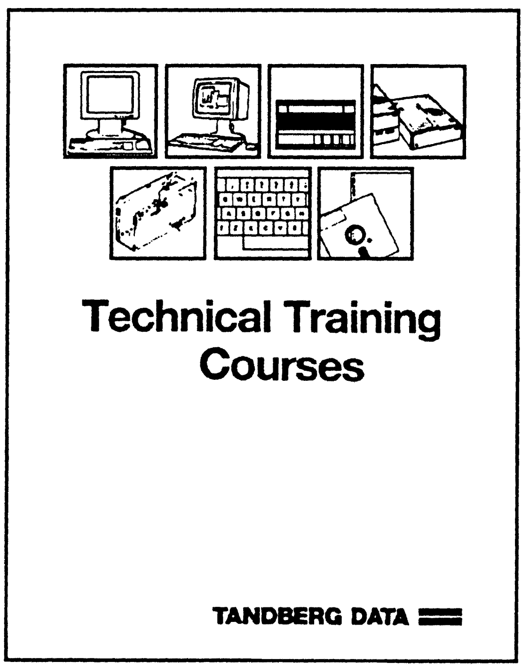


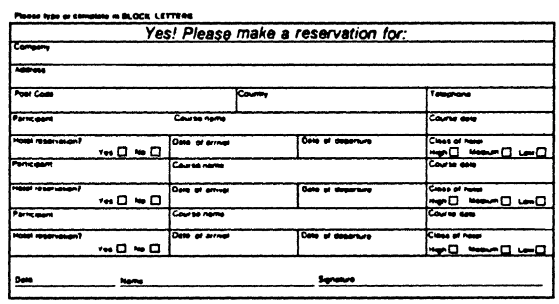
Technical Training Courses

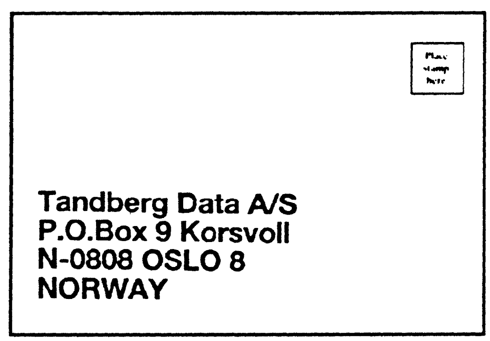
For details of our wide range of technical training courses for all Tandberg Data products please contact Tandberg Data A/S, Oslo, Norway, or our local subsidiary company.

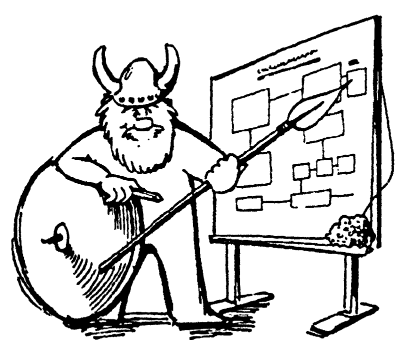


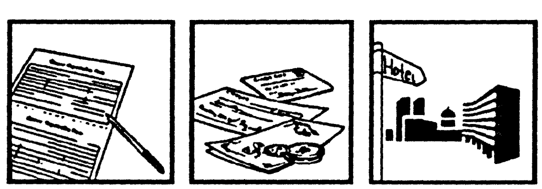
Refer to the last page of this publication for addresses and telephone numbers.











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