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OMTI 5000 SERIES
SCSI INTELLIGENT
DATA CONTROLLERS
REFERENCE MANUAL
August   1985

Scientific Micro Systems, Inc.

OMTI 5000 SERIES
SCSI INTELLIGENT
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INTELLIGENT DATA CONTROLLERS

REFERENCE MANUAL

Models:

OMTI 5100 Winchester only

OMTI 5200 Winchester & Floppy

OMTI 5300 Winchester & Tape

OMTI 5400 Winchester & Tape & Floppy

Significance of vertical bars in the left margin.

- Single bar indicates an editorial change from document
  Revision A.
- Double bars indicate a substantial improvement in the
  products since the hardware and firmware revision levels
  equivalent to the document Revision A.
- Triple bar indicates an editorial change from document Revision
  B.

Applicability of this document: Valid for the minimum firmware
revision levels as listed below:

OMTI 5100	Rev. N
OMTI 5200	Rev. E
OMTI 5204	Rev. B
OMTI 5300	Rev. D
OMTI 5400	Rev. C

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ABBREVIATIONS/MNEMONICS

ACK	Acknowledge
ADDR	Address
AM	Address Mark
ANSI	American National Standard Institute
ATN	Attention
BSY	Busy
C/D	Control Data
CDB	Command Descriptor Block
Cm	Centimeter
CRC	Cyclic Redundancy Check
CYL	Cylinder
DB	Data Bit
DP	Data Parity
DRVR	Driver
ECC	Error Correcting Code
EOD	End of Data
EPROM	Eraseable Programmable Read Only Memory
FDC	Flexible Disk Controller
HD	Head
ID	Identification
I/O	Input/Output
Kg	Kilogram
LOG	Logical
LSB	Least Significant Bit
LSTTL	Low-Power Schottky Transistor-Transistor Logic
LUN	Logical Unit Number

ABBREVIATIONS/MNEMONICS (continued)

MFM	Modified Frequency Modulation
MHz	Megahertz
Ms	Millisecond
MSB	Most Significant Bit
MSG	Message
MTBF	Mean Time Between Failures
MTTR	Mean Time To Repair
ns	Nanosecond
NRZ	Non-Return to Zero
PHY	Physical
QIC-02	Quarter Inch Cartridge (Tape Interface)
RAM	Random Access Memory
RCVR	Receiver
REQ	Request
RST	Reset
SASI	Shugart Associates System Interface
SCSI	Small Computer System Interface
SEC	Sector
SEL	Select
TPI	Track Per Inch
TRK	Track
TTL	Transistor Transistor Logic
us	Microsecond
VCO	Voltage Control Oscillator
VLSI	Very Large Scale Integration
WSI	Equivalent to: Reduced Write Current
XCVR	Transceiver

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF FIGURES

SECTION 1

INTRODUCTION

1.1 PURPOSE

This manual introduces the user to the OMTI 5000 Series SCSI
(Small Computer System Interface) Data Controllers. It
provides the information needed to install, configure, program,
operate, and maintain the OMTI 5000 Series Data Controllers.
The manual is a reference source for OEM engineers, system
integrators, service and maintenance technicians.

1.2 GENERAL

The OMTI 5000 is a series of intelligent, multi-functional data
controllers contained on a 5-1/4" PCB, which mounts directly to
the disk drive or chassis. The controllers interface with
Winchester Disk Drives, Flexible Disk Drives, and Streaming
Tape Drives.

The Winchester drives can be either 3-1/2 inch or 5-1/4 inch,
fixed, fixed removable, or removable disk drives. Each drive
can have up to 16 heads and 65,536 cylinders. The controllers
support a ST506/412 compatible, 5 MBit/sec data transfer rate.

The Flexible disk drives can be any industry-standard, 5-1/4
inch, or 8 inch drives with a transfer rate of either 250 KBit
or 500 KBits. These drives can be single or double density, and
single or double sided drives with an industry- standard
interface.

The Streaming Tape Drive can be any QIC-02 interface
compatible, 1/4 inch tape drive.

The 5000 Series SCSI Data Controllers use OMTI's advanced VLSI
chip sets to provide state-of-the-art data management. A single
chip data separator circuit ensures data integrity with
Winchester disk drives. Efficient error detection/correction is
accomplished by a powerful "computer generated" 32-bit error
correction code polynomial.

The host interface is the industry-standard 8-bit parallel
bidirectional Small Computer Systems Interface (SCSI).

1.3 MODEL DESCRIPTION

The OMTI 5000 Series data controllers are designed to attach any ST506/412 type Winchester disk (5-1/4 or 3-1/2inch), Flexible disk (5-1/4 or 8 inch), or QIC-02 (Quarter Inch Cartridge) Streaming tape drive to a variety of host computer systems through the industry standard SCSI (Small Computer System Interface). All models support up to four Logical Units. Model numbers identify the combination of drives that can be supported. (W = Winchester, F= Flexible, T = Tape).

OMTI 5100 (W). This model supports any combination of up to two 5-1/4 or 3-1/2 inch Fixed, Removable, or Fixed/Removable Winchester disk drives. Each disk can have up to 16 heads and 65,536 cylinders.

OMTI 5200, 5204 (W + F). These models support up to four drives, of which up to two may be 5-1/4 or 3-1/2 inch Winchester disk drives, and up to four may be any combination of industry-standard 5-1/4 or 8 inch Flexible disk drives. The Flexible disk interface can support a data transfer rate of 250 or 500 kilobits, single or double density, and single or double sided drives. The OMTI 5200 defaults at initialization (POWER ON or RESET) to 5 1/4 inch interface Flexible Disk drive parameters while the OMTI 5204 model defaults to 8 inch interface Flexible Disk drive parameters. Both the OMTI 5200 and OMTI 5204 support all Flexible disk types listed above.

OMTI 5300 (W + T). This model supports up to three drives, of which up to two may be 5-1/4 or 3-1/2 inch Winchester disk drives, and one Streaming tape drive with the QIC_02 Tape Interface.

OMTI 5400 (W + F + T). This model supports up to four drives, of which up to two may be 5-1/4 or 3-1/2 inch Winchester disk drives, up to three may be 5-1/4 or 8 inch Flexible disk drives, and one may be a QIC-02 Streaming tape drive.

Note: All models handle the Winchester disk drives similarly, with the same performance, same format, and same command set. The 5200, 5204 and 5400 models handle the Flexible disk drives similarly and the 5300 and 5400 models handle the Streaming tape similarly. Disk and/or tape media written by one model can be read by the other models.

SCSI CONTROLLERS

KEY:

△ = Termination
☐ = SCSI ID ADDRESS
W = Winchester
F = Flexible Disk
T = Tape
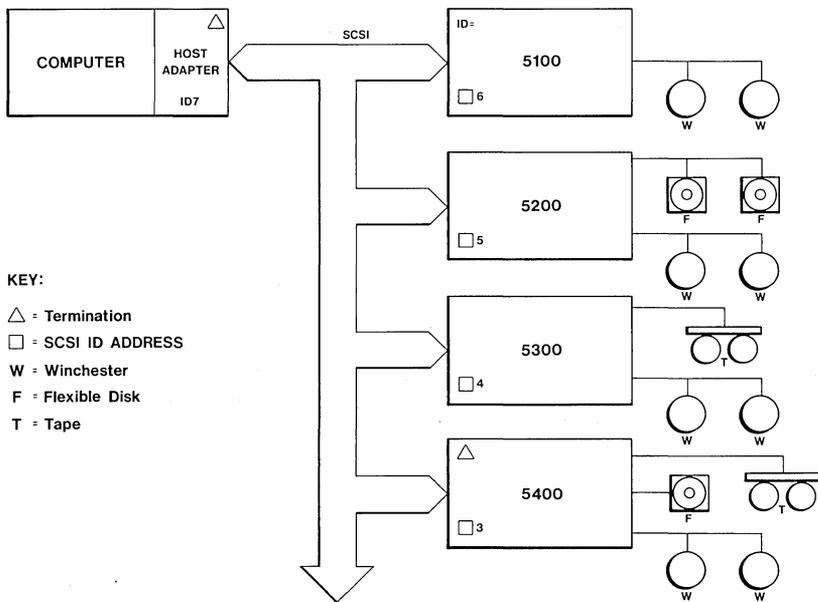
Figure 1.1 SCSI Configuration

1.4 FUNCTIONAL ORGANIZATION

Figure 1-2 is the functional block diagram for the OMTI 5000 Series Data Controller. This block diagram illustrates all of the possible functions of the controller. Functions that are available only on certain models are identified.

1.4.1 Host Interface

The SCSI host interface is a bi-directional bus interface that provides the computer with device independence so that disk drives, tape drives, printers, communication devices, processor devices, and other devices can be added to the system configuation without requiring modifications to system hardware.

1.4.2 Microprocessor

The controller board contains a 12MHz ROMless Zilog Z8 Microcomputer. The Z8 provides a powerful instruction set, simplified system expansion off chip, and flexible serial and parallel I/O capabilities. It contains a 16-bit program counter and a separate 16-bit stack pointer. The Z8 has 128 internal registers. Sixty-four registers are used for drive status and drive parameters for up to four LUNs. The remaining registers are used for system status and command parameters.

1.4.3 Four-Channel Memory Controller

Data control functions are handled by the OMTI 5060 Four-Channel Memory Controller. The Memory Controller manages the flow of block-level information between buffer memory and host and/or byte-oriented peripheral interfaces.

1.4.4 Buffer Memory

The controllers include a static 8Kbytes RAM data buffer. The buffer is used only to store blocks of data; but not used to store parameters. Buffer operations are independent of firmware constants and variables.

1.4.5 Data Sequencer

Disk data function is handled by the OMTI 5050 Data Sequencer chip. The Sequencer manages the flow of block-level information between serial device interfaces and a memory controller. The OMTI 5050 handles SERDES (Serialize, Deserialize) functions to and from NRZ data, format operations, and ECC generation and checking.

1.4.6 VCO/Encode/Decode

These functions are handled by the OMTI 5070 VCO/Encode/Decode chip. This is a fifth-generation data separator that converts MFM serial data to NRZ data and clock translations.

1.4.7 Flexible Disk Controller

Flexible Disk control is provided by an LSI flexible disk
controller chip (NEC 765), with control functions for
interfacing a processor and flexible disk drives. It supports
either IBM 3740 single density format or IBM System 34 double-
density format, including double-side recording.

5000-SERIES BLOCK DIAGRAM
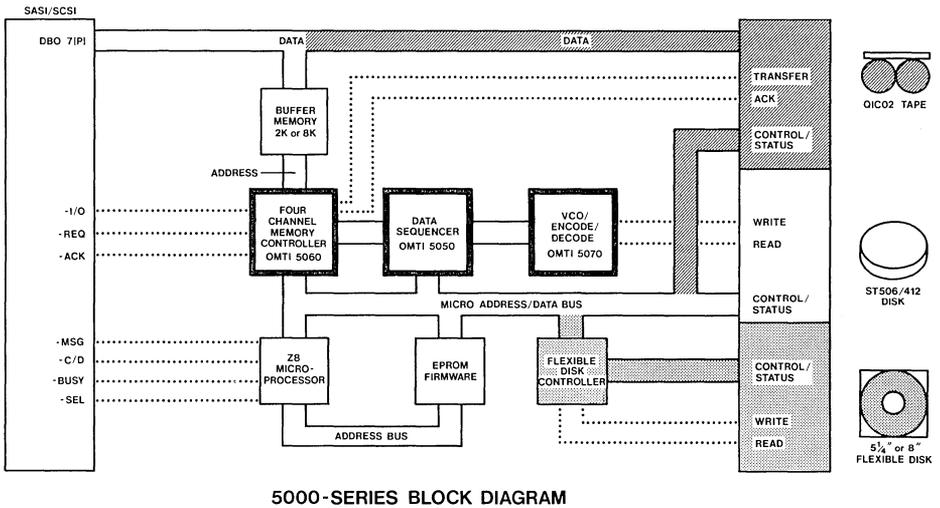
Figure 1-2. Functional Block Diagram, OMTI 5000 Series
SCSI Controllers

1.5 BUFFERING SCHEME

The controllers include a static 8KBytes RAM data buffer. The
buffer is used only to store blocks of data; it is not used
to store parameters.   Buffer operations are independent of
firmware constants and variables.

If the block size on disk is 1024 Bytes, the 8K buffer will
hold up to eight blocks; if the block size is 512 Bytes, the
buffer will hold up to sixteen blocks; if the block size is 256
Bytes, the buffer will hold thirty-two blocks.   The buffer is
used as a ring buffer, controlled by an OMTI VLSI chip, called
"Memory buffer controller chip" (5060 Model).   The chip
includes four channels (ports).   Each channel has its own
separate address and byte count register. The channels operate
simultaneously, allowing   read   and write operations to the
buffer from various data paths at the same time.

Of these channels
      - one is connected to the SCSI bus,
      - one is dedicated to the "OMTI Sequencer chip" (5050
        Model),
      - one is connected to the Tape bus (valid for 5300 and
        5400 Models).
      - the fourth channel is dedicated to the Z8 Microprocessor
        for specific applications, such as load and read data for
        an alternate track, with the automatic handling of media
        defects.

EXAMPLE OF BUFFER USE:

The following case is a multi-block READ command from the disk:

      - the first logical block, specified as starting block
        address in the SCSI command is read from the disk and
        written into the buffer, (controlled by the "Sequencer
        chip" channel of the 5060 chip).
      - when the ECC is calculated, the data block is available
        for transfer to the host bus;
      - the data block is then transferred asynchronously at the
        host memory speed (Handshake Timing).
      - the next block on the disk is stored in the buffer (at
        the address, in the buffer, below the previous block),
        as soon as it is read, independently of the access from
        the host.   Reading of data from the Disk, and sending
        data to the Host are independent, and take place at the
        same time.

- blocks are stored below each other in the buffer, until
  the maximum address is reached; then the channel wraps
  around to the first address in the buffer (assuming that
  the first block has already been transferred to the
  Host).
- if the host is too slow to empty all data blocks stored
  in the buffer, from the disk, and another block is ready
  to be stored into the buffer, with no space available,
  an overrun situation occurs. In this case, the
  controller will stop reading from the disk, wait for one
  block size to be available to start reading again. This
  will occur only if the host transfer rate is much slower
  than the 5 Mbits/sec rate, at which data is stored into
  the buffer from the disk.

- The controller allows switching Heads without losing a
  disk revolution during READ or WRITE operations. Only
  when a HEAD carriage step is required (SEEK), will disk
  revolutions be lost while the controller waits for the
  drive to return Seek Complete.

BACKUP AND RESTORE IMPLEMENTATION:

The BACKUP and RESTORE commands use the buffer as described
above. The host channel is replaced either by the Tape channel
or by the "Sequencer chip" channel, depending on the command
and its implicit data path direction.

COPY IMPLEMENTATION:

The COPY command uses the buffer differently. The COPY command
involves the disks only (Winchester and/or flexible disks).
Block sizes have to be identical on the source and the
destination devices. The COPY command first reads as much data
as it can from the Source LUN into the buffer using the
following rules, then writes all the data from the buffer to
the Destination LUN.

When using the buffer, the controller considers the following
parameters:

- number of sectors left to read on the track (limited to
  track boundary);
- number of sectors that the buffer will hold (depending
  on block count);
- total number of sectors left to transfer.

With the COPY command, only one "buffer chip" channel is used
at a time. For copy between Winchesters, the "Sequencer
Chip" channel is used. If floppy is involved, the operation is
processor bound during floppy data transfers.

1.6 SPECIFICATIONS

Table 1-2 lists the specifications for the OMTI 5000 Series Data Controllers. Included are environmental and power requirements, as well as mounting, and dimensional characteristics.

1.6.1 Physical Specifications

```
Width   - All:          5.75 inches (14.6 cm)
Length  - OMTI 5100:    7.85 inches (19.9 cm)
        - OMTI 5200:    8.00 inches (21.6 cm)
        - OMTI 5204:    8.00 inches (21.6 cm)
        - OMTI 5300:    8.00 inches (21.6 cm)
        - OMTI 5400:    8.00 inches (21.6 cm)
Height  - All:          0.75 inches (1.3 cm)
Weight  - All:          9.0 ozs (0.25 kg)
```

See Figures 3-4 and 3-5 for mounting hole locations.

1.6.2 Environmental Specifications

	Operating	Storage
Temperature	0 to 50C	-40 to 75C
Relative Humidity	10% to 95%	10% to 95%
Max. Wet Bulb	30C	Noncondensing
Altitude	0-10000 ft	0-15000 ft

1.6.3 Power Requirements

The OMTI 5000 Series requires +5 V (+/- 5%) power only. The maximum ripple and noise (P/P) is 100 mV. The maximum current drawn by each model is:

Model	Maximum Current
OMTI 5100	1.5 Amp
OMTI 5200,5204	1.8 Amp
OMTI 5300	1.8 Amp
OMTI 5400	2.0 Amp

SECTION 2

STANDARD FEATURES

2.1 GENERAL

This section contains a list of the standard features for the
OMTI 5000 Series Data Controller. Each feature has a brief
description. Sections 3 through Section 8 of this manual
contain more detailed information.

HOST INTERFACE   SCSI (Small Computer System Interface)

MULTIFUNCTION   Support Winchester Disks + Flexible Disks +
                          Streaming Tape. Supports up to 4 LUNs.

SCSI BUS TRANSFER   Up to 1.5 MBytes per second in asynchronous
RATE   mode.

SCSI BUS PARITY   Jumper selectable. On all data transfers,
                          odd parity is generated and, unless
                          disabled, is checked.

COMPACT BOARD   The 5000 Series Controllers are single
                          5-3/4 by 8.0 inch printed circuit boards
                          (ST506/412 form factor). All controllers
                          use identical mounting holes (similar
                          to OMTI 20 Series)

MULTIPLE   The SCSI bus allows up to eight
CONTROLLERS   controllers, in any combination, to be
                          attached to the host. All devices are
                          daisy-chain connected with a 50-pin cable.
                          Each controller is selectable to be one
                          of the eight devices with the Selection
                          address of 0 to 7. Various OMTI 5000
                          Series controllers can be connected to
                          the same SCSI bus.

COMMAND LINKING   Upon successful completion of a command,
                          chaining of commands is allowed, and
                          prevents the entering of a new Selection
                          phase.

ERROR RETRY   Error retry on SEEK or READ errors is
                          performed automatically unless disabled.

2-1

BUFFER	8 KBytes Ring Buffer (wraps around) on all models with 4 independent ports.
POWER	2 Amps Maximum. Requires 5 Volts only.
LIMITED PART COUNT	Featuring OMTI VLSI Chips, supporting Winchester and Tape disk drives.

2.2 WINCHESTER DISK SPECIFIC FEATURES
(All Models)

TRANSFER RATE	5 Megabits/Second
INTERFACE	ST506/412 Compatible
MULTIPLE DRIVE TYPES SUPPORTED	The 5000 Series Controllers support any combination of Fixed, Removable, or Fixed/Removable Winchester disk drives. The Fixed/Removable drives occupy two LUNs.
CONSECUTIVE SECTOR TRANSFER	Can transfer a Full Track in a single disk revolution. Allows switching HEADS without losing a disk revolution during READ and WRITE operations.
SECTOR INTERLEAVING	One to One or programmable
PROGRAMABLE DISK PARAMETERS	The disk parameters for both the Fixed disks and the Flexible disks can be passed to the controller with the ASSIGN DISK PARAMETERS command.
SECTORING	Hard or soft
NUMBER OF HEADS	Up to 16 heads supported
NUMBER OF CYLINDERS	Up to 65,533 cylinders supported
TRACK FORMAT	Compatible with the OMTI 20 Series.
BLOCK OR SECTOR SIZE	Jumper selectable; 256, 512, or 1024 bytes per sector or block
IMPLIED SEEK	Supported, with all data transfer commands
LOGICAL BLOCK ADDRESSING	All data transfer commands.
AUTOMATIC HEAD OR CYLINDER SWITCHING	Supported on multi-block data transfers
MULTI-BLOCK TRANSFER	Up to 256 Blocks per command (any block size listed above).

AUTOMATIC READ RETRIES	User selectable.
AUTOMATIC HANDLING OF MEDIA DEFECTS	Supported at track level with Alternate Track assignment
OVERLAPPED SEEK	Allows multiple drives to be positioned simultaneously. While a seek is being performed on one drive, other operations can be performed on other LUNs.
ECC	For header and data fields. Uses a 32 bit "Computer Generated" Polynomial (x31+x24+x23+x20+x17+x16+x13+x7+x0) Correction capability – 5 Bits Detection capability – 19 Bits
STEP RATE	Accepts a minimum of 14 microseconds between leading edges of two consecutive pulses.
SECTORS PER TRACK	Programmable, supported through the ASSIGN DISK PARAMETERS Command.
COPY COMMAND	Between disks (of any type). Uses the internal controller buffer.
COMMAND SET	Compatible with the OMTI 20 Series with added commands.

2.3 FLEXIBLE DISK DRIVE SPECIFIC FEATURES
(Models 5200, 5204 and 5400)

5-1/4" or 3-1/2" (250KBits)	Supported.
8 Inch Drive (500KBits)	An optional 34 Pin to 50 Pin Adapter (OMTI 528) Interface is needed to connect 8 Inch Flexible drives to the controllers (available from SMS).
5-1/4" (500KBITS)	Models 5200 and 5400 support the new generation of half height, high capacity, 5-1/4" Flexible disk drives with the same transfer rate as the 8" (500 KBits) Drives.
SECTOR SIZE	Programmable – 128, 256, 512, or 1024 bytes per sector.
NUMBER OF SECTORS/TRACKS	Programmable. Complies to the track and sector format. Gaps are fixed (set by the controller).

2-3

IBM FORMAT	Supported, 3740 SD, System 34 2S2D.
IBM PC FORMAT	Supported. (512 Bytes/sector, 9 sectors per track)
CRC	On header and data fields.

2.4 TAPE DRIVE SPECIFIC FEATURES
     (Models 5300 and 5400)

DRIVE TYPE	Streaming tape drives only.
INTERFACE	QIC 02 – Intelligent 1/4 inch cartridge interface.
NUMBER OF DRIVES	One drive is supported.
LUN	Addressed by LUN 3 only.
QIC 02 PARITY	Supported. Jumper selectable.
BACKUP AND RESTORE	To and from disk by specific Commands; host not involved.
DISK DEFECTS HANDLING DURING BACKUP & RESTORE	Handled through the automatic disk media defect scheme. Only valid blocks are backed up. BACKUP and RESTORE commands do not access defective blocks.
STREAMING MODE	Continuously maintained. Utilizes the controller's 8K Bytes of Buffer.
DATA PATHS	Three data paths are available: – Host To/From Tape – Host To/From Disk – Disk To/From Tape.
SPACING FORWARD	Three modes: – By blocks – By File' Marks – To end of data (EOD)
TAPE RETENTION	Supported.
ERASE TAPE	Supported.
VERIFY MEDIA INTEGRITY	Supported.

2.5 COMPATIBILITY WITH OMTI 20 SERIES CONTROLLERS

The OMTI 5000 Series Controllers conform to the same format as the OMTI 20 Series, with the same track architecture, and the same ECC. This allows disks formatted and written by one series to be read and updated by the other. The command sets are also compatible, thus the same software may be used for both. The OMTI 20 Series Controllers use a bit slice processor while the 5000 Series use a Z8 Microcomputer. In the 5000 Series, different microprocessor cycle times create longer timings in some of the bus phases than the OMTI 20 Series. However, the 5000 Series Controllers offer higher performance in multi-block transfers, allowing consecutive sector transfers, which the OMTI 20 Series lack.

As an example, the 5000 Series Controllers perform a Self test upon Power-On that the OMTI 20 series did not execute. By accomplishing this, the OMTI 5000 Series does not respond to the Select Signal on the SCSI bus for a period of 400 milliseconds. Software implementations expecting the assertion of BUSY within less than 400 ms, will fail to initiate dialog with the 5000 Series Controller, unless software modification is applied to allow longer delay.

(Mounting hole locations on the 5000 Series are identical to those of the OMTI 20 Series. Connector locations are slightly different).

2.6 COMMAND SET SUMMARY

COMMAND	DRIVE TYPE	CODE (HEX)	LENGTH OF CMD in BYTES(b)	CMD/DATA in BLOCKS(B)	CONTROLLER MODEL(S)
			GROUP 0		
TEST UNIT READY	W,F,T	00	6	0	all
RECALIBRATE	W,F	01	6	0	all
REWIND	T	01	6	0	5300, 5400
RETENTION *1	T	02	6	0	5300, 5400
REQUEST SENSE	W,F,T	03	6	4/12(b)	all
FORMAT UNIT	W,F	04	6	0	all
CHECK TRACK FORMAT *3	W	05	6	0	all
FORMAT TRACK *3	W,F	06	6	0	all
FORMAT BAD TRACK *3	W	07	6	0	all
READ	W,F	08	6	0-256(B)	all
READ	T	08	6	0-16M(B)	5300, 5400
WRITE	W,F	0A	6	0-256(B)	all
WRITE	T	0A	6	0-16M(B)	5300, 5400
SEEK	W,F	0B	6	0	all
ASSIGN ALT. TRK.	W	0E	6	4(b)	all
WRITE FILE MARK	T	10	6	0	5300, 5400
SPACE FORWARD	T	11	6	0	5300, 5400
VERIFY *2	T	13	6	0	5300, 5400
ERASE	T	19	6	0	5300, 5400
CHANGE CARTRIDGE	W	1B	6	0	all
			GROUP 1		
COPY	W,F	20	10	prog.(B)	all
BACKUP	T,W	22	10	prog.(B)	5300, 5400
RESTORE	T,W	23	10	prog.(B)	5300, 5400
BACKUP WITH HEADER *3	T,W	24	10	prog.(B)	5300, 5400
RESTORE CONTINUE *3	T,W	26	12	prog.(B)	5300, 5400
			GROUP 2		
RETENTION TAPE *1	T	44	6	0	5300, 5400
VERIFY TAPE *2	T	45	6	0	5300, 5400
READ SENSE *3	T	46	6	8(b)	5300, 5400
WRITE HEADER *3	T	48	6	512(b)	5300, 5400
READ HEADER *3	T	49	6	512(b)	5300, 5400
WRITE BLOCKS *3	T	4A	6	0-256(B)	5300, 5400
READ BLOCKS *3	T	4B	6	0-256(B)	5300, 5400

Continued Next Page

COMMAND SET SUMMARY (continued)

COMMAND	DRIVE TYPE	CODE (HEX)	LENGTH in BYTES(b)	of CMD/DATA in BLOCKS(B)	CONTROLLER MODEL(S)
			GROUP 6		
DEFINE FLEXIBLE DISK FORMAT	F	C0	6	10(b)	5200, 5400
ASSIGN DISK PARAMETERS	W,F	C2	6	10(b)	all
			GROUP 7		
RAM DIAGNOSTICS	–	E0	6	0	all
WRITE ECC	W	E1	6	1(B)+4(b)	all
READ ID	W,F	E2	6	4(b)	all
READ DATA BUFFER	–	EC	6	1 sector	all
WRITE DATA BUFFER	–	EF	6	1 sector	all

*1,*2 Different Code – = No Drive involved   A11 = 5100, 5200,
but similar command W = Winchester   5204, 5300, and 5400
execution   F = Flexible Disk
                     T = Tape

*3 These commands are compatible with earlier controller models,
and are recommended not to be used in new software design.

SECTION 3

INSTALLATION

3.1 UNPACKING AND INSPECTION

Upon receipt of your OMTI 5000 Series Data Controller, inspect the
packaging for evidence of damage during transit. Open the package
and inspect the controller board for visible damage such as
scratches, loose components, or broken connectors. If there is
damage, immediately notify the carrier's agent and your Scientific
Micro Systems' customer service representative.

Compare the items listed on your original Purchase Order to the
actual contents of the package and the packing list. If
discrepencies exist, notify your Scientific Micro Systems'
customer service representative.

Retain the shipping container and packing material for examination
(if there are signs of damage), or for reuse when returning the
controller board to the factory.

3.2 BOARD PREPARATION

Figures 3-1 and 3-2 illustrate the appropriate board layout, the
connector locations, and the jumper locations for each model in
the 5000 Series. Consult section 4.3 for the various jumper
selectable controller functions and ensure that the factory
installed jumpers are correctly in place. It is also possible to
install optional jumpers to tailor the controller's functions to
the specific requirements of your system.

Figure 3-1. Model 5100 Connector and Jumper Locations
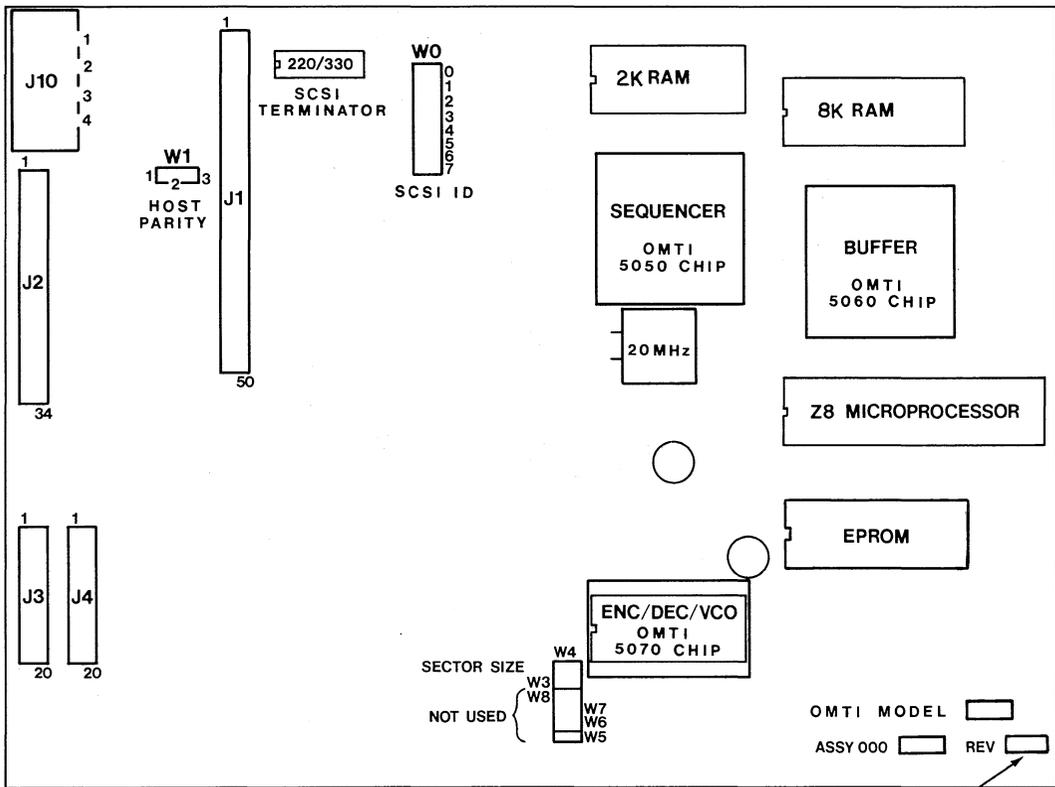
NOTE: THE FABRICATION REVISION
IS ON THE SOLDER SIDE OF
THE CONTROLLER

Figure 3-2. Model 5200/5204/5300/5400 Connector and Jumper Location.
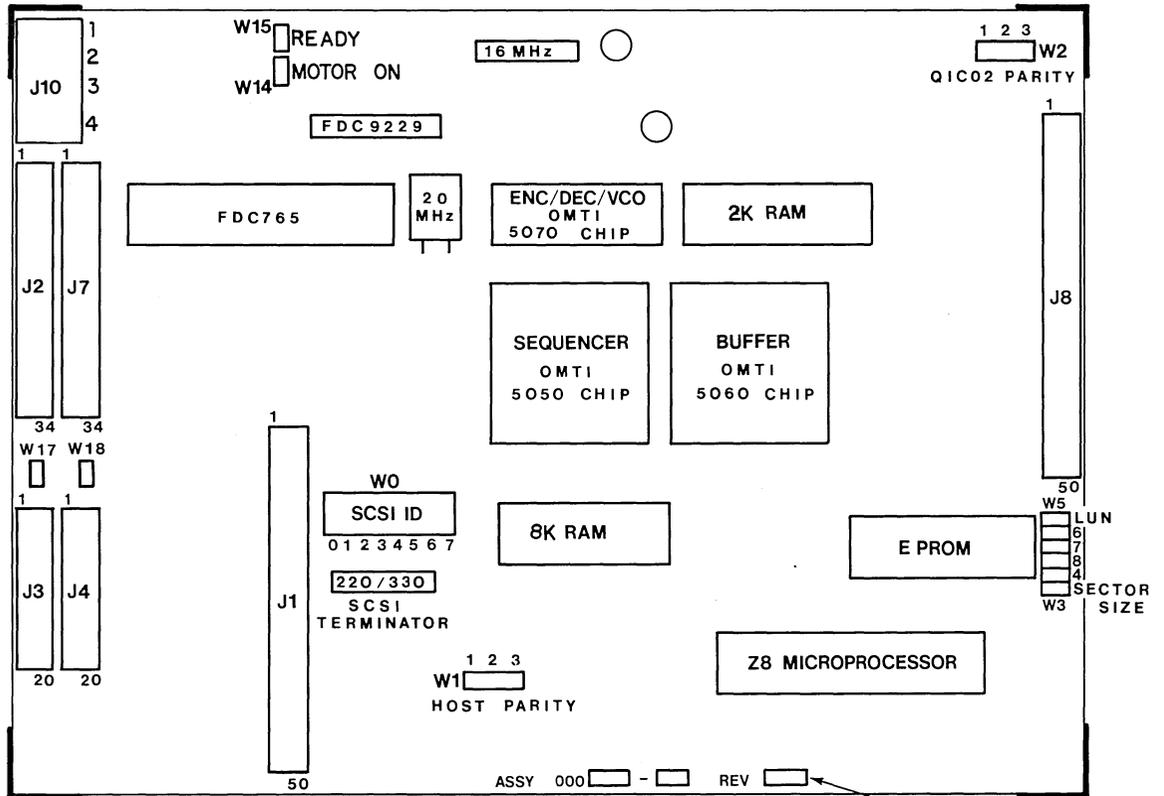
NOTE: THE FABRICATION REVISION
IS ON THE SOLDER SIDE OF
THE CONTROLLER

3.3 BOARD MOUNTING

Holes for mounting your controller board are dimensionally located
in Figure 3-3 (Model 5100) and Figure 3-4 (Models 5200, 5204,
5300, and 5400). These holes mate with the four mounting holes
provided on ST506/412 Type drives. If desired, the controller
can be mounted in a location other than on the disk itself. An
important consideration is that air be allowed to freely pass by
the board.

3.4 CABLE CONNECTIONS

After your board is mounted, connect the DC power cord and the
cables to the disk drive and host computer. Refer to the
appropriate Connector and Jumper Location drawing (Figure 3-1, and
3-2) for the location of connectors on your board. The System
Configuration drawings (Figures 4-1 and 4-2) presented in the next
section will also help in identifying the cable hookup for your
particular system.

Pin 1 on all connectors is specified by a square solder pad,
visible on the soldered side of the board.

OMTI 5100
(CIRCUIT SIDE)

.125

8 x .166

POWER
CONNECTOR

5.75

5.50

4.60

1.720   3.120

.600

.125

.450   6.60

Figure 3-3. Model 5100 Mounting Hole Locations

(CIRCUIT SIDE)

8 x .166

POWER
CONNECTOR

5.75

4.600

1.625   3.120

.600

.125

.500   6.600

8.00
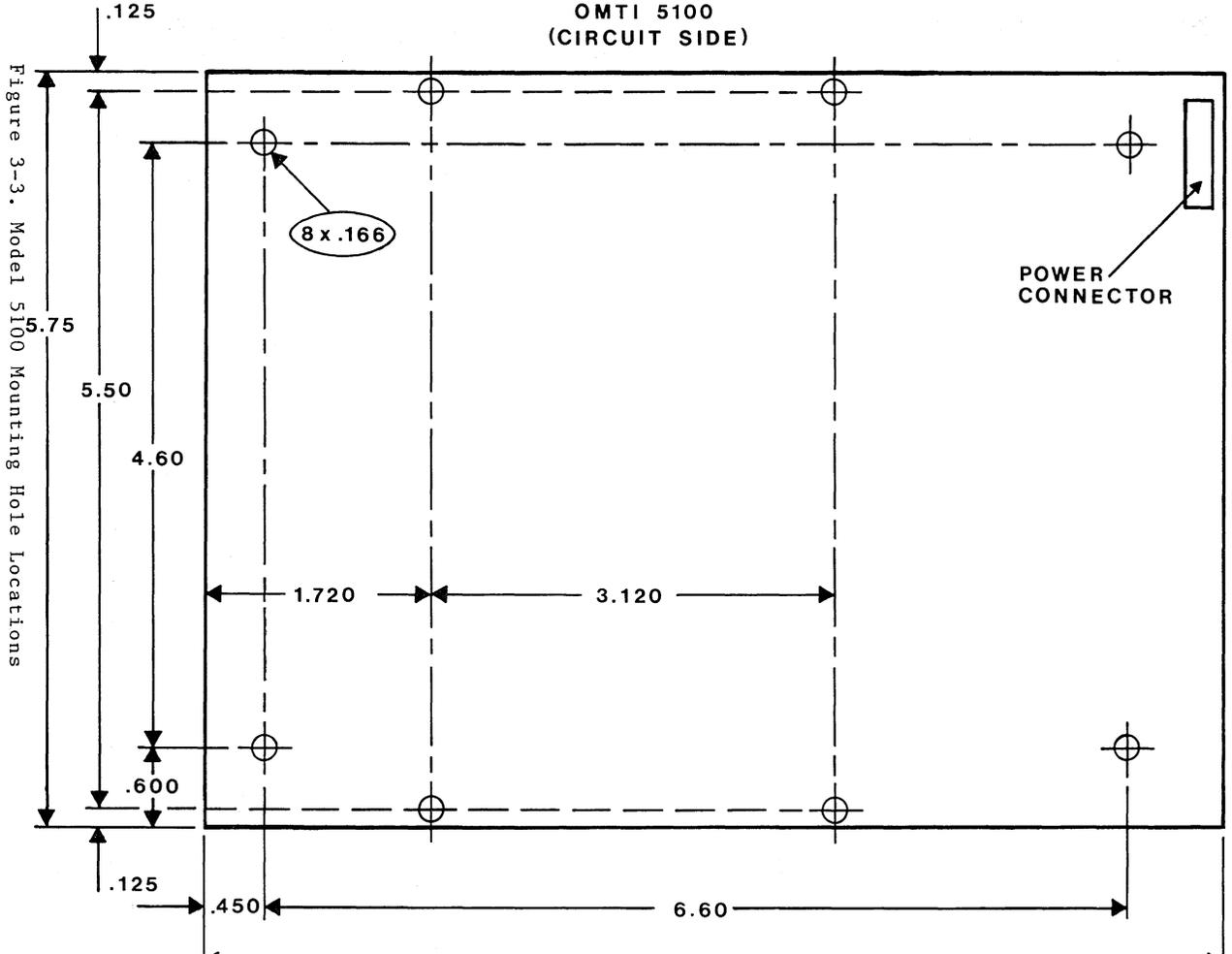
Figure 3-4. Model 5200/5204/5300/5400 Mounting Hole Locations

3-6
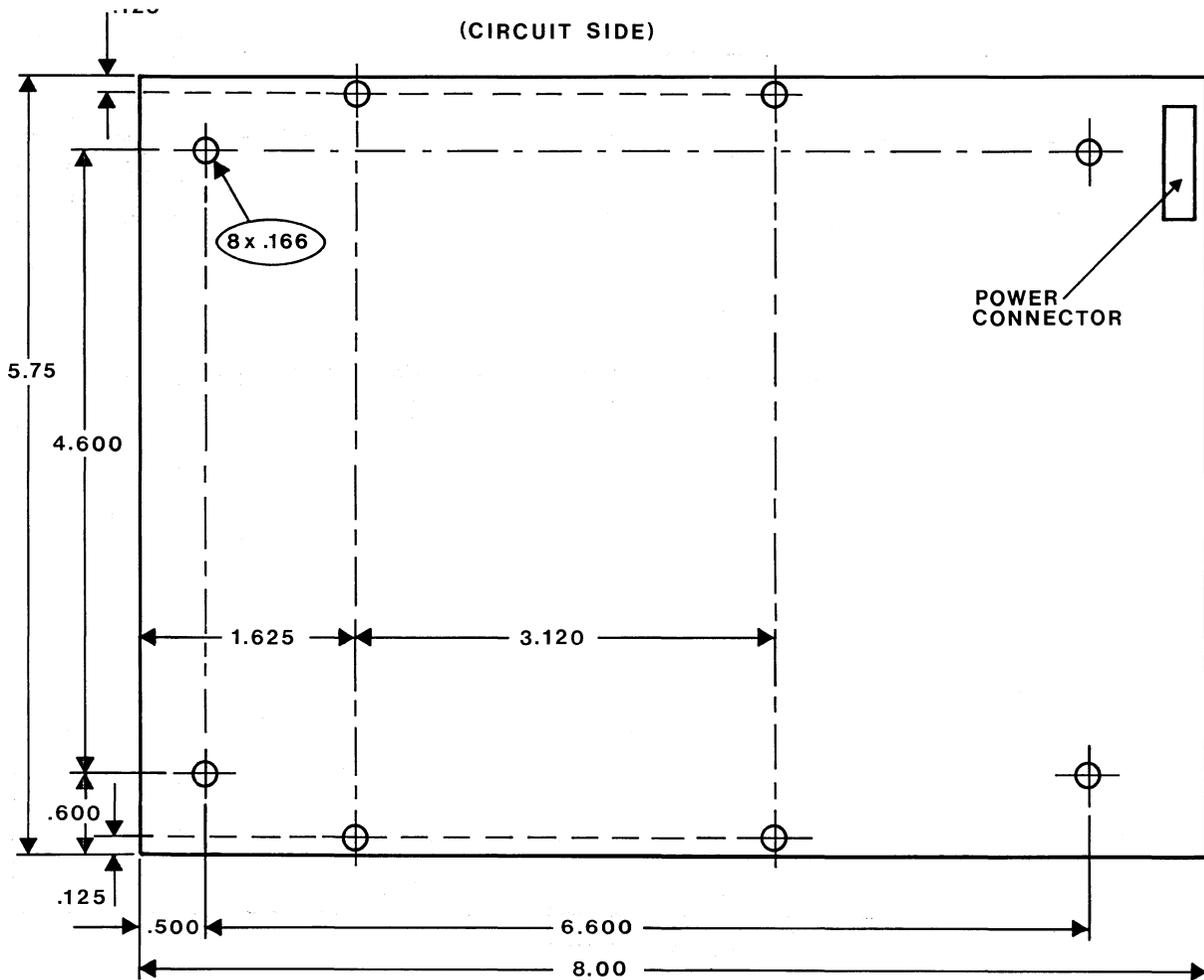
SECTION 4

SYSTEM CONFIGURATION

4.1 GENERAL

The interface between the host computer and the OMTI 5000 Series controllers is a 50-pin cable. This cable is connected to J1 on the controller. The length of the host interface cable should not exceed 20 feet (6 meters), from the first to the last device (up to eight devices) on the bus. The recommended mating connector for J1 is the AMP ribbon connector.

The Winchester Disk drive's interface to the 5000 Series controller is via connectors J2, J3, and J4. J2 is a 34-pin header type connector that connects all Winchester Disk drives in a daisy-chain configuration. This cable carries the control signals. J3 and J4 are 20-pin header type connectors used to radially connect the disk drive data lines to the controller. The length of the cables should not exceed 20 feet (6 meters) or drive manufacturer's limit, whichever is less.

The Flexible Disk drive's interface to the controller is via J7, a 34-pin header type connector. This cable carries data and control signals. The maximum cable length should not exceed 20 feet (6 meters) or the drive manufacturer's limit, whichever is less. Connect 8 inch Flexible Disk drives with a 50 pin connector to the 34-pin Controller connector, through an optional 34-pin to 50-pin adaptor.

The QIC-02 interface compatible Streaming Tape Drive's connection to the controller is via J8, a 50-pin header type connector. This length of this cable should not exceed 20 feet (6 meters) or the drive manufacturer's limit, whichever is less.

Typical OMTI 5000 Series system configurations are presented in block diagram form in Figures 4-1 and 4-2.

The recommended connector part numbers are as follows:

J1 and J8 - AMP P/N 1-499956-0
J2 and J7 - AMP P/N 1-499956-7
J3 and J4 - AMP P/N 1-499956-4

4-1
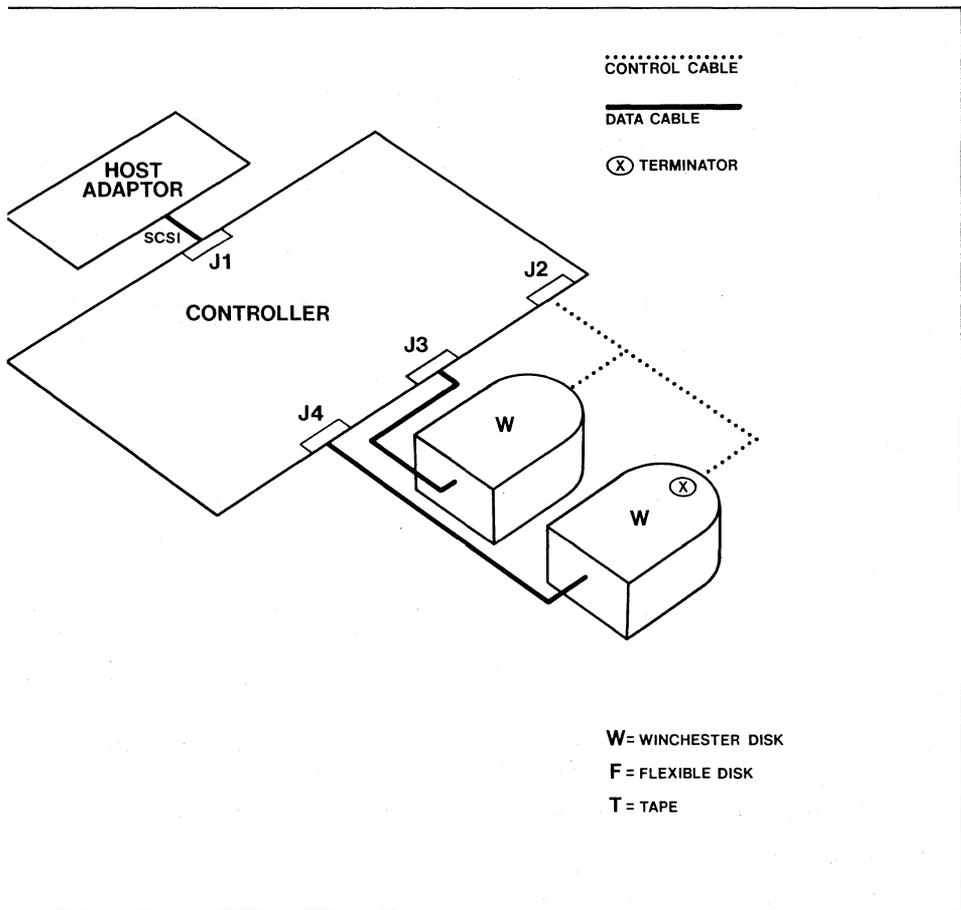
Figure 4-1. Model 5100 System Configuration
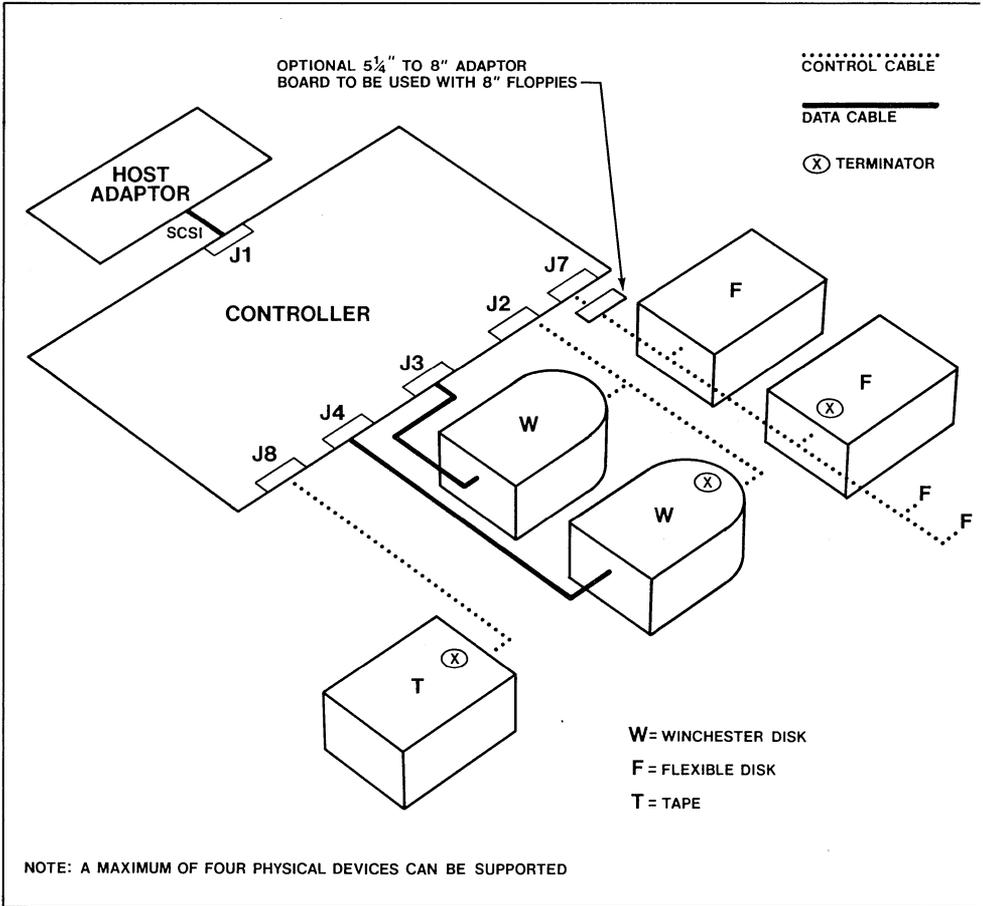
Figure 4-2. Model 5200/5204/5300/5400 System Configuration

4.2 PIN ASSIGNMENTS

4.2.1 Winchester Disk Drive Interface

The following tables define the various Winchester Disk Drive's pin assignments .

WINCHESTER DISK CONTROL SIGNAL CONNECTOR (J2). CHAINED.

	PINS	FIXED	DRIVE TYPE REMOVABLE & FIXED/REMOVABLE
GND	1 2	HEAD SELECT 3/WSI	CHANGE CARTRIDGE
	3 4	HEAD SELECT 2	
	5 6	WRITE GATE	
	7 8	SEEK COMPLETE	
	9 10	TRACK 000	
	11 12	WRITE FAULT	
	13 14	HEAD SELECT 0	
	15 16	RESERVED	SECTOR PULSE
	17 18	HEAD SELECT 1	
	19 20	INDEX	
	21 22	READY	
	23 24	STEP	
	25 26	DRIVE SELECT 1	
	27 28	DRIVE SELECT 2	
	29 30	DRIVE SELECT 3	
	31 32	DRIVE SELECT 4	
GND	33 34	DIRECTION SELECT	

WINCHESTER DISK DATA SIGNAL CONNECTOR (J3 & J4). RADIAL.

| PINS | DRIVE TYPE | |
	FIXED	REMOVABLE & FIXED/REMOVABLE
1	DRIVE SELECTED	
2	GROUND	
3	RESERVED	
4	GROUND	
5	RESERVED	WRITE PROTECTED
6	GROUND	
7	RESERVED	
8	GROUND	
9	RESERVED	CARTRIDGE CHANGED
10	RESERVED	
11	GROUND	
12	GROUND	
13	+MFM WRITE DATA	
14	−MFM WRITE DATA	
15	GROUND	
16	GROUND	
17	+MFM READ DATA	
18	−MFM READ DATA	
19	GROUND	
20	GROUND	

4.2.2 Flexible Disk Drive Interface (5-1/4 inch)

The following tables define the pin assignments for the 5-1/4"
flexible disk drives.

```
+-----------------------------------------------------------------+
| FLEXIBLE DISK CONTROL SIGNAL CONNECTOR (J7)                     |
+---------------------------+-------------------------------------+
|      GND   1  2           |  (OPEN)                             |
|            3  4           |  (OPEN)                             |
|            5  6           |  DRIVE SELECT 4                     |
|            7  8           |  INDEX                              |
|            9 10           |  DRIVE SELECT 1                     |
|           11 12           |  DRIVE SELECT 2                     |
|           13 14           |  DRIVE SELECT 3                     |
|           15 16           |  MOTOR ON                           |
|           17 18           |  DIRECTION SELECT                   |
|           19 20           |  STEP                               |
|           21 22           |  WRITE DATA                         |
|           23 24           |  WRITE GATE                         |
|           25 26           |  TRACK 00                           |
|           27 28           |  WRITE PROTECT                      |
|           29 30           |  READ DATA                          |
|           31 32           |  SIDE SELECT                        |
|      GND  33 34           |  DRIVE STATUS                       |
+---------------------------+-------------------------------------+
```

An optional 34-pin to 50-pin adaptor board, Model OMTI 528,
connects the 8 inch Flexible Disk drive to the Controller
connector, J7.

```
OPTIONAL ADAPTOR BOARD (OMTI 528 Paddle Board) CONNECTIONS

   34-pin conn.    50-pin conn.    Signal Name
------------------------------------------------------------------
      1               1            GROUND
      2               2            WSI
      3               -            -
      4               -            -
      5               -            -
      6              32            DRIVE SELECT 4
      7               -            -
      8              20            INDEX
      9               -            -
     10              26            DRIVE SELECT 1
     11               -            -
     12              28            DRIVE SELECT 2
     13               -            -
     14              30            DRIVE SELECT 3
     15               -            -
     16               -            -
     17               -            -
     18              34            DIRECTION SELECT
     19               -            -
     20              36            STEP
     21               -            -
     22              38            WRITE DATA
     23               -            -
     24              40            WRITE GATE
     25               -            -
     26              42            TRACK 00
     27               -            -
     28              44            WRITE PROTECT
     29               -            -
     30              46            READ DATA
     31               -            -
     32              14            SIDE SELECT
     33               -            -
     34              22            DRIVE ST + 5 VDC PIN 4
```

4.2.3 Power Connector

Power is applied to the controller via J10 which is a 4-pin AMP
connector.   The recommended mating connector,   P10,   is an AMP
P/N 1-480424-0 using AMP pins, P/N 60617-4, or equivalent.

J10 POWER CONNECTOR

NC	PIN 1
NC	PIN 2
+5 RTN	PIN 3
+5 VDC	PIN 4

|||

NOTE: Pin 1 is not connected to + 12VDC and pin 2 is not
connected to ground as in the OMTI 20 series controllers.

4.2.4 QIC-02 1/4 Inch Cartridge Streaming Tape Interface |||

The following table defines the pin assignments for QIC-02 1/4
inch Cartridge Streaming Tape drive.

TAPE DRIVE CONNECTOR (J8)

GND	1 2		NOT USED
	3 4		NOT USED
	5 6		NOT USED
	7 8		NOT USED
	9 10		-PARITY
	11 12		-DATA BIT 7
	13 14		-DATA BIT 6
	15 16		-DATA BIT 5
	17 18		-DATA BIT 4
	19 20		-DATA BIT 3
	21 22		-DATA BIT 2
	23 24		-DATA BIT 1
	25 26		-DATA BIT 0
	27 28		-ON LINE
	29 30		-REQUEST
	31 32		-RESET
	33 34		-TRANSFER
	35 36		-ACKNOWLEDGE
	37 38		-READY
	39 40		-EXCEPTION
	41 42		-DIRECTION
	43 44		NOT USED
	45 46		NOT USED
	47 48		NOT USED
GND	49 50		NOT USED

4.3 JUMPER ALLOCATION

The OMTI 5000 Series Controllers allow the user to select the various controller functions listed below:

(W0) SCSI CONTROLLER ID.   Defines the SCSI device priority. ID 7 is the highest priority in a multi controller configuration.

```
        *     0 SHORTED ID = 0
              1 SHORTED ID = 1
              2 SHORTED ID = 2
              3 SHORTED ID = 3
              4 SHORTED ID = 4
              5 SHORTED ID = 5
              6 SHORTED ID = 6
              7 SHORTED ID = 7
```

(W1) HOST PARITY

```
        *     PINS 1 - 2 JUMPERED = PARITY ENABLED
              PINS 2 - 3 JUMPERED = PARITY DISABLED
```

(W2) QIC-02 PARITY (5300 & 5400 only)

```
        *     PINS 1 - 2 JUMPERED = PARITY ENABLED
              PINS 2 - 3 JUMPERED = PARITY DISABLED
```

(W3 & W4) WINCHESTER DISK SECTOR SIZE

```
        W3        W4
  **    Open      Open      = 18 X 512 BYTES PER SECTOR
  *     Shorted   Open      = 32 X 256 BYTES PER SECTOR
        Open      Shorted   = 17 X 512 BYTES PER SECTOR
        Shorted   Shorted   = 9 X 1024 BYTES PER SECTOR
```

(W5 - W8) LUN ASSIGNMENT.   W5 through W8 allows the ability to jumper select the default LUN assignment for Winchester, Flexible Disk, and Tape drives.

(W9) NOT ON BOARD

(W10 - W11) RESERVED

(W12 - W13) NOT ON BOARD

```
*   As shipped.
**  Recommended  for  use  only on  drives  with  +/- 1%  speed
    regulation.
```

Refer to the LUN Assignment table below for the models 5200, 5204, 5300 and 5400 jumper selections. (The Model 5100 jumpers are not alnalyzed).

LOGICAL UNIT NUMBER (LUN) ASSIGNMENT

Jumpers (W5, W6, W7, W8)

LUN	JUMPER	OPEN	SHORTED	MODEL
0	W5	* Winchester * Winchester * Winchester	Flexible Reserved Flexible	5400 5300 5200,5204
1	W6	* Winchester * Winchester * Winchester	Flexible Reserved Flexible	5400 5300 5200,5204
2	W7	Winchester * Winchester Winchester	* Flexible Reserved * Flexible	5400 5300 5200,5204
3	W8	* Tape * Tape * Winchester	Flexible Winchester Flexible	5400 5300 5200,5204

* As shipped.

Note: The ASSIGN DISK PARAMETERS command (C2 Hex), if issued, may override these jumper allocations. Tape, however, remains LUN 3.

NUMBER AND TYPE OF DRIVES SUPPORTED

Model	5100	5200,5204	5300	5400
Number of drives Number of LUNs Winchesters Flexible disks Tape	2 max 4 up to 2 0 0	4 max 4 up to 2 up to 4 0	3 max 4 up to 2 0 1	4 max 4 up to 2 up to 4 1

Note: A Fixed/Removable Winchester occupies two LUNs. Connecting such a drive, limits the number of remaining LUNs from four to two, and limits the number of other drives that may be connected as well.

```
(W14) Motor On Override (5200, 5204 and 5400 only)

Installed:  The  Motor On signal will always be asserted.   This
overrides  bit  6  of  byte 09  in  the  ASSIGN  FLEXIBLE  DISK
PARAMETERS command.

Removed:   The  Motor  On  signal  is  asserted  or  deasserted
according  to  bit  6 of byte 09 in the  ASSIGN  FLEXIBLE  DISK
PARAMETERS command.

After  the  last completed command issued to  the  floppy,  the
controller  keeps  the drive selected with motor ON  for  seven
seconds.
```
```
(W15) READY OVERRIDE (5200, 5204 and 5400 only)

Installed: The Flexible drive is considered to always be ready.
This  jumper  must be in place for Flexible drives that do  not
support a READY signal.

Removed:  This  jumper  should  not  be  in  place  for  drives
supporting a drive READY signal.
```
```
(W16) Reserved (5200, 5204, 5300, 5400 only)
(W17, W18) Reserved (5100 only)
```

4.4 DEFAULT PARAMETERS

4.4.1 Winchester Disk Drives

Upon power-on or any Reset operation, the controller defaults
to the following parameters:

The Byte number and the HEX values refer to the parameter list
of the ASSIGN DISK PARAMETER command (See Paragraph 7.7.2
Winchester Parameter List).

```
BYTE 1    STEP PULSE WIDTH          9 MICROSECONDS (HEX 09)
BYTE 2    STEP PULSE PERIOD         3 MILLISECONDS (HEX 3C)
BYTE 3    STEP MODE(Buffered)       0              (HEX 00)
BYTE 4    NUMBER OF HEADS           4              (HEX 03)
BYTE 5    CYLINDER ADDRESS HIGH     0              (HEX 00)
BYTE 6    CYLINDER ADDRESS LOW      153            (HEX 98)
BYTE 7    REDUCED WRITE CURRENT     128            (HEX 80)
BYTE 8    FIXED DISK, SOFT SECTORED 0              (HEX 00)
BYTE 9    NUMBER OF SECTORS/TRACK   BASED ON JUMPERS W3, W4
                                    18 X 512       (HEX 11)
                                    32 X 256       (HEX 1F)
                                    17 X 512       (HEX 10)
                                    9 X 1024       (HEX 08)
BYTE 10   RESERVED                                 (HEX 00)
```

4.4.2 Flexible Disk Drives

Upon power-on or any Reset operation, the controller defaults to the following parameters.

The Hex values refer to the parameter list of the ASSIGN DISK PARAMETER command. (See Paragraph 7.7.2 Flexible Disk Drive Parameters).

Model 5200 Default Values

```
BYTE 1    STEP PULSE WIDTH                              (HEX 00)
BYTE 2    STEP PERIOD                  7 MILLISECONDS   (HEX 07)
BYTE 3    MAXIMUM CYLINDER ADDRESS     80 CYLINDERS     (HEX 4F)
BYTE 4    HEAD SETTLING DELAY          44 MILLISECONDS  (HEX 0B)
BYTE 5    RESERVED                                      (HEX 00)
BYTE 6    RESERVED                                      (HEX 00)
BYTE 7    RESERVED                                      (HEX 00)
BYTE 8    FLEXIBLE DRIVE                                (HEX 80)
BYTE 9    FLEXIBLE DISK TYPE           STANDARD 5 1/4"  (HEX 00)
BYTE 10   START WRITE PRECOMPENSATION  DISABLED         (HEX 00)
```

The default track format is as follows:

(side 0, cylinder 0 = FM recording, 16 sectors per track, 128 bytes per sector; all other tracks = MFM recording, 16 sectors per track, 256 bytes per sector.) This is the same as code 06 of the DEFINE FLEXIBLE DISK FORMAT Command.

Model 5204 Default Values

```
BYTE 1    STEP PULSE WIDTH                                    (HEX 00)
BYTE 2    STEP PERIOD                  8 MILLISECONDS         (HEX 08)
BYTE 3    MAXIMUM CYLINDER ADDRESS     76 CYLINDERS           (HEX 4C)
BYTE 4    HEAD SETTLING DELAY          22 MILLISECONDS        (HEX 0B)
BYTE 5    RESERVED                                            (HEX 00)
BYTE 6    RESERVED                                            (HEX 00)
BYTE 7    RESERVED                                            (HEX 00)
BYTE 8    FLEXIBLE DRIVE                                      (HEX 80)
BYTE 9    FLEXIBLE DISK TYPE           STANDARD 8" DRIVE      (HEX 80)
BYTE 10   START WRITE PRECOMP CYLINDER                        (HEX 00)
```

The default track format is as follows:

(side 0, cylinder 0 = FM recording, 26 sectors per track, 128 bytes per sector; all other tracks = MFM recording, 26 sectors per track, 256 bytes per sector.) This is the same as code 06 of the DEFINE FLEXIBLE DISK FORMAT Command.

SECTION 5

TRACK AND SECTOR FORMAT

5.1   WINCHESTER DISK TRACK FORMAT

5.1.1 Track Format

The standard track format for hard and soft sectored Winchester
Disk drives is organized into numbered data segments, or
sectors (See Figure 5-1 and 5-2). The nominal Winchester Disk
capacity is 10,416 Bytes. The minimum track capacity is 10,103
Bytes (based on a three percent speed variation). The method of
encoding used is Modified Frequency Modulation (MFM).

```
------------------------------------------------------------------
|INDEX GAP | GAP1 | ID FIELD | GAP2 | DATA FIELD | GAP3 | GAP4|
------------------------------------------------------------------
          |<------------------1 SECTOR---------------->|
                        (repeated n times)
```
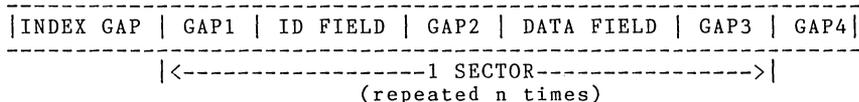
Figure 5-1 Winchester Disk Soft Sector Track Format

```
          -----------------------------------------------
          | GAP1 | ID FIELD | GAP2 | DATA FIELD | GAP3 |
          -----------------------------------------------
          |<------------------1 SECTOR---------------->|
                        (repeated n times)
```
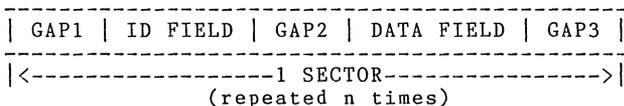
Figure 5-2 Winchester Disk Hard Sector Track Format

5.1.2 Sector ID Field

The beginning of each sector is defined by a prewritten
identification (ID) field. This field is registered during the
Format operation, and contains the Cylinder Address (MSB),
Cylinder Address (LSB), Head Address (and flags), and the
Sector Address (See Figure 5-3).

```
     BYTE #   1     A1 Address Mark (Drop Clock Bit)
              2     FE Address Mark
              3     Cylinder (MSB)
              4     Cylinder (LSB)
              5     Head and Flags
              6     Sector
              7-10  ECC (32 Bits)
              11-12 00
```

Figure 5-3 Sector ID Field

5.1.3 Sector or Block Data Field

The second field contains the user data bytes, selectable as 256, 512, or 1024 Bytes per sector or block. The format for this field varies with the field size (See Figure 5-4).

256 BYTE DATA FIELD

```
BYTE       1        A1*
           2        F8
           3-258    User Data Field (256 Bytes)
           259-262  ECC (32 Bits)
           263-264  00
```

512 BYTE DATA FIELD

```
BYTE       1        A1*
           2        F8
           3-514    User Data Field (512 Bytes)
           515-518  ECC (32 Bits)
           519-520  00
```

1024 BYTE DATA FIELD

```
           1         A1*
           2         F8
           3-1026    User Data Field (1024 Bytes)
           1027-1030 ECC (32 Bits)
           1031-1032 00
```

* = Drop Clock Bit

Figure 5-4 Sector or Block Data Field

5.1.4 Winchester Hard and Soft Sectored Gaps

Each Winchester sector track format begins with an Index gap and ends with a Speed Tolerance gap. Each sector contains three gaps. Hard sectored tracks have only the sector gaps and do not have either the Index or Speed Tolerance gaps (See Figure 5-5).

```
INDEX GAP = 11 Bytes of 4E Head Switching Recovery Period
GAP 1     = 12 Bytes of 00 Sync for ID Field
GAP 2     = 12 Bytes of 00 Write Update Splice and Sync for
                             Data Field
GAP 3     = xx Bytes of 4E Speed Tolerance for the sector
          = 14 Bytes of 4E (256 and 512 Bytes/Sector)
          = 22 Bytes of 4E (1024 Bytes/Sector)
GAP 4     = xxx Bytes of the Speed Tolerance for the track
          = 325 Bytes of 4E (256 Bytes/Sector)
          = 698 Bytes of 4E (512 Bytes/Sector, 17 Sectors/Track)
          = 148 Bytes of 4E (512 Bytes/Sector, 18 Sectors/Track)
          = 667 Bytes OF 4E (1024 Bytes/Sector)
```

Figure 5-5 Winchester Soft Sector Gaps

5.1.5 Defective Track Format

If a track is found to be defective, the host can assign an alternate track for the defective track. When the controller encounters a defective track that has been assigned an alternate track address, the alternate track will be accessed. The address of the alternate track is contained in the first three bytes of the data field in all sectors of the defective track. The ID fields of the defective track contain a flag indicating that the track has been alternated. The ID fields of the alternate track are formatted with a flag indicating that the track has been assigned as an alternate.

5.2 FLEXIBLE DISK TRACK FORMAT

5.2.1 Track Format

Figure 5-6 illustrates the standard track format for Flexible Disk drives. The track is organized into numbered data segments, or sectors.

```
----------------------------------------------------------------
|INDEX GAP | GAP1 | ID FIELD | GAP2 | DATA FIELD | GAP3 | GAP4|
----------------------------------------------------------------
          |<------------------1 SECTOR----------------->|
                        (repeated n times)
```
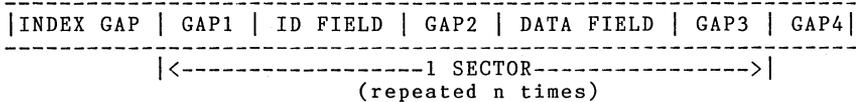
Figure 5-6 Standard Flexible Disk Track Format

5.2.2 Sector ID Field

The beginning of each sector is defined by a prewritten identification (ID) field, registered during Format operation (See Figure 5-7).

```
BYTE      1 Cylinder - 00-FE
          2 Side - 00=Side 0; 01=Side 1
          3 Sector - (See below)
          4 Sector Size
```

BYTE 3 - Number of Sectors:

250 KBit Format	500 KBit Format
01-10 at 128 Byte/Sec	01-1A at 128 Byte/Sec
01-10 at 256	01-1A at 256
01-09 at 512	01-10 at 512
01-04 at 1024	01-08 at 1024

The default number of sectors for 250 KBit format is 8 (01-08), however, a 9 sector format (01-09) is possible and can be programmed by issuing a DEFINE FLEXIBLE DISK FORMAT command (HEX CO) with BYTE 5 set to 09 (HEX).

The default number of sectors for 500 KBit format is 15 (01-OF), however, a 16 sector format (01-10) is possible and can be programmed by issuing a DEFINE FLEXIBLE FORMAT command (HEX CO) with BYTE 5 set to 10 (HEX).

Figure 5-7 Sector ID Field

5.2.3 Sector Data Field

The second field contains the user data bytes, selectable as
128, 256, 512, or 1024 Bytes per sector (See Figure 5-8).

```
 128 BYTE DATA FIELD                256 BYTE DATA FIELD
 ------------------                 ------------------
BYTE 1-3        Address Mark        1-3        Address Mark
     4          FB                  4          FB
     5-132      User Data Field     5-260      User Data Field
     133-134    CRC                 261-262    CRC


 512 BYTE DATA FIELD                1024 BYTE DATA FIELD
 ------------------                 ------------------
BYTE 1-3        Address Mark        1-3        Address Mark
     4          FB                  4          FB
     5-516      User Data Field     5-1028     User Data Field
     517-518    CRC                 1029-1030  CRC
```

Figure 5-8 Sector Data Field

5.2.4   INTER-SECTOR GAPS

Flexible Disk drives are either in 250 KBit or 500 KBit
transfer rate format. The spacing between sectors varies with
the transfer rate (See Figure 5-9).

```
 250 KBit Format                    500 KBit Format
 ---------------                    ---------------
 25 Bytes at 128 Byte/Sec           27 Bytes at 128 Byte/Sec
 50 Bytes at 256                    54 Bytes at 255
 50 Bytes at 512                    54 Bytes at 512
 240 Bytes at 1024                  116 Bytes at 1024
```

Figure 5-9 Spacing Between Sectors

SECTION 6

FUNCTIONAL DESCRIPTION

6.1 GENERAL

The OMTI 5000 Series host-controller interface is the Small
Computer Systems Interface (SCSI) general purpose 8-bit
bidirectional bus.

All commands are issued to the controller over the host bus
using a predefined protocol. The host always initiates a
command sequence by first selecting the controller. After the
controller accepts selection, it takes control of the bus and
requests the appropriate command bytes.

For data transfers, a multiple sector buffer is provided to
eliminate any possibility of data overruns. Upon command
completion (either successful or not), the controller will
issue completion status to the host. Sense Status information
is provided through the REQUEST SENSE command.

6.2 ELECTRICAL INTERFACE

All host computer interface signals are negative true. The
signals are "ASSERTED" or active at 0 to 0.4 VDC and
"DEASSERTED" or inactive at 2.5 to 5.25 VDC.

6.3 INTERFACE TERMINATION

As shipped, all assigned received interface signal lines are
terminated with a removable 220/330 ohm resistor network. The
first device and the last device (Host or Controller) on the
daisy-chain SCSI bus must be terminated. Remove the terminators
from the devices in between. For instance, if the Controller is
in the middle of the string, remove its terminators. The host
adapter should be terminated in a similar fashion.

The devices driving the controller inputs should be open
collector devices capable of sinking at least 48 milliamps at a
voltage level of less than 0.5 Vdc (7438 or equivalent).

Devices receiving the controller outputs should be of "SCHMITT"
trigger type to improve noise immunity, 74LS14, 74LS240 or
equivalent. The host adapter should not load the bus with more
than one standard LSTTL input load per line, and should
terminate the controller output signals with 220/330 ohm
terminators.

6.4 SIGNAL INTERFACE

The host computer interface signals are as shown below. All
signals are low true.

```
            GND        1    2       DATA BIT 0   ( DBO )
                       3    4       DATA BIT 1   ( DB1 )
                       5    6       DATA BIT 2   ( DB2 )
                       7    8       DATA BIT 3   ( DB3 )
                       9   10       DATA BIT 4   ( DB4 )
                      11   12       DATA BIT 5   ( DB5 )
                      13   14       DATA BIT 6   ( DB6 )
                      15   16       DATA BIT 7   ( DB7 )
                      17   18       DATA PARITY  ( DBP )
                      19   20       OPEN
                      21   22       OPEN
                      23   24       OPEN
                      25   26       OPEN
                      27   28       OPEN
                      29   30       OPEN
                      31   32       OPEN
                      33   34       OPEN
                      35   36       BUSY ( BSY )
                      37   38       ACKNOWLEDGE ( ACK )
                      39   40       RESET ( RST )
                      41   42       MESSAGE ( MSG )
                      43   44       SELECT ( SEL )
                      45   46       CONTROL / DATA ( C/D )
                      47   48       REQUEST ( REQ )
            GND       49   50       INPUT / OUTPUT ( I/0 )
```

6.5 SIGNAL DEFINITION

RESET (RST)

"OR Tied" signal asserted by the host, causes the controller to
cease all operations and return to the idle condition. This
signal is normally used during a power up sequence. A RESET
during a write operation would cause incorrect data to be
written on the disk. The RESET pulse should be at least twenty-
five microseconds wide to allow the controller's microprocessor
to execute this function properly.

SELECT (SEL)

Asserted by the host, along with a single controller address
bit (0 through 7), causes the appropriate controller to be
selected. The SELECT line must be deasserted by the host after
the controller asserts the BUSY line in response to a proper
selection. See NOTE in paragraph 6.7.

BUSY (BSY)

"OR Tied" signal asserted by the controller indicates that the
bus is being used.

  CONTROL / DATA (C/D)

Signal asserted by the controller indicates that command or
completion status information is to be transferred on the data
bus. Deassertion of this line indicates that data information
is to be transferred on the data bus.

  INPUT / OUTPUT (I/O)

Signal asserted by the controller indicates that information
will   be   transferred to the host from the   controller.
Deassertion indicates that information will be transferred to
the controller from the host.

  REQUEST (REQ)

Signal asserted by the controller indicates that an 8-bit byte
is to be transferred on the data bus. REQUEST is deasserted
following assertion of the ACKNOWLEDGE line.

  ACKNOWLEDGE (ACK)

Signal asserted by the host indicates data has been accepted by
the host or that data is ready to be transferred from the host
to the controller.

  MESSAGE (MSG)

Signal asserted by the controller indicates that the previous
byte transferred was the Completion Status byte. When the
MESSAGE signal is asserted, indicating a Message phase, REQUEST
is asserted by the controller in order to transfer an 8-bit
byte indicating the end of the operation. When this REQ/ACK
handshake is complete, the controller will deassert all
interface signal lines and return to the idle state, with BUSY
deasserted.

  DATA BITS 0-7 (DB0-7) & PARITY

The 8 bidirectional data and odd parity lines are used to
transfer 8-bit parallel data to/from the host computer. Bit 7
is the most significant bit.

6.6 HOST INTERFACE PROTOCOL

For detailed information about the Host Interface Protocol,
refer to the SCSI specifications as per ANSC X3T9.2/82-2,
Revision 8 minimum.

The Host interface includes eight distinct operational phases
as follows:

1.   Bus Free phase (BSY deasserted)
2.   Arbitration phase (Optional. To be used either with
     a Multi Host configuration or with the SCSI
     Disconnect/Reconnect feature; neither one supported
     by the OMTI 5000 Series controllers.)
3.   Selection phase
4.   Re-Selection phase (not implemented in the OMTI
     5000 Series controllers)
5.   Command phase
6.   Data In or Out phase
7.   Status phase
8.   Message In or Out phase (Message Out phase is not
     implemented in the OMTI 5000 Series controllers)

The Host bus can never be in more than one phase at any given
time.

The order in which SCSI bus phases are used on the bus follows
a prescribed sequence. The Reset condition can interrupt any
phase and is always followed by the Bus Free phase.

The controller follows a normal progression from the Bus Free
phase to Selection phase, to one or more of the following
Information Transfer phases (Command, Data In or Out, or
directly to Status phase). The Message In phase is always the
last phase before returning to the Bus Free phase.

6.7   SELECTION PHASE

In order to gain the attention of the controller, it is
necessary to perform the following selection sequence: The host
must first test BSY to determine if the bus is available. If
BSY and all other I/O lines are deasserted, the host will
assert one of the data lines (DBX = controller ID) and then
assert SEL. The appropriate controller will then respond by
asserting BSY. At this point the host must deassert SEL and
DBX. The controller responds to SEL deasserted by asserting the
C/D line. I/O remains deasserted throughout the selection
sequence.

NOTE: Upon power on reset the controller will execute a
comprehensive self test. During this test the controller will
not respond to a Selection sequence (SEL signal asserted by the
Host) for a period of 400 msec. The controller will not respond
and will not assert BSY during this time.

The following timings, for all phases (paragraphs 6.7 to
6.10), are valid with:
- 5100 FAB Rev. C
- 5200, 5204, 5300, 5400 FAB Rev. D
- the OMTI 20506-2 Memory Buffer Controller chip (not the 20506
  part).
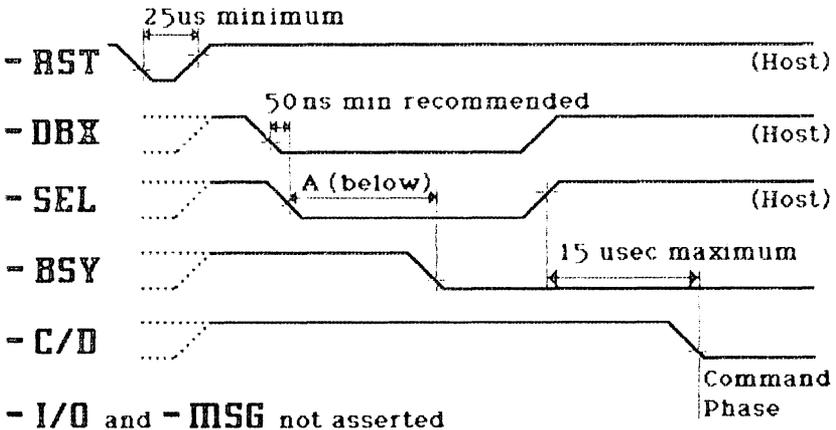
A = 400 milliseconds at Power On Sequence (self test).
A = 14 us max after a Reset with non Tape commands.
A = 60 us max with Tape commands (5300 & 5400).

Figure 6.1 Selection Phase Timing Chart

6.8 COMMAND PHASE

After being selected, the controller asserts C/D, indicating
the command phase, and REQ, requesting the first byte of
command. The host must then place the first byte of the command
descriptor block on the data bus and assert ACK. The
controller responds by picking up the byte on the data bus by
deasserting REQ. The host must then deassert ACK to begin the
next REQ/ACK handshake. The handshake continues in this phase
until all bytes of the command have been transferred.
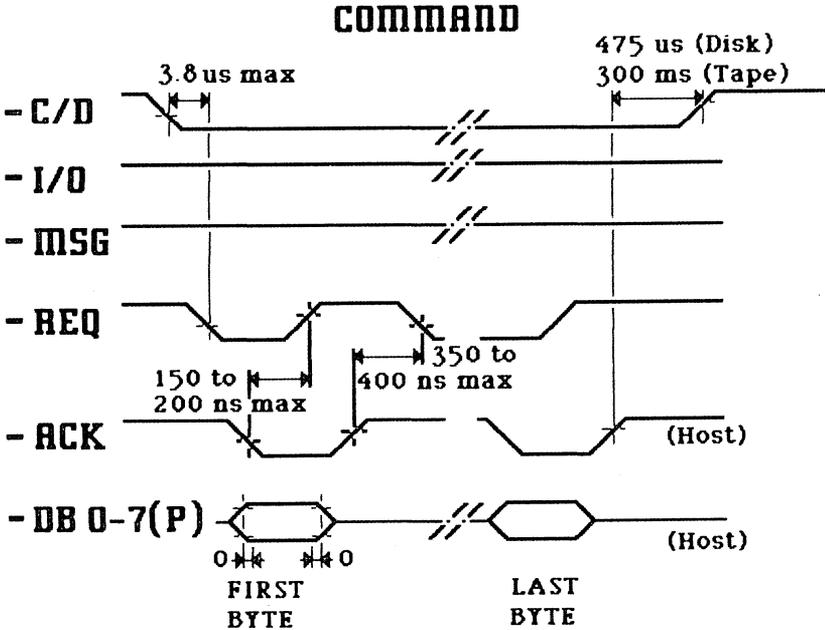
COMMAND

Assuming 50 ns response time by the host for asserting and
deasserting -ACK, the controllers can handshake one byte in 600
to 700 nanoseconds.

Figure 6.2 Command Phase Timing Chart

6.9 DATA IN OR OUT PHASE

If the command sent to the controller involves a data transfer,
the controller deasserts C/D. If the data transfer is from the
controller to the host (READ), the I/O line is asserted. If the
data transfer is from the host to the controller (WRITE), I/O
is deasserted. The controller then asserts REQ to request a
byte transfer. The host places a byte on the data bus, and
asserts ACK. The controller deasserts REQ, then the host must
deassert ACK in order to complete the byte transfer. This
handshake continues until all data bytes have been transferred
for the block count requested.

DATA IN READ
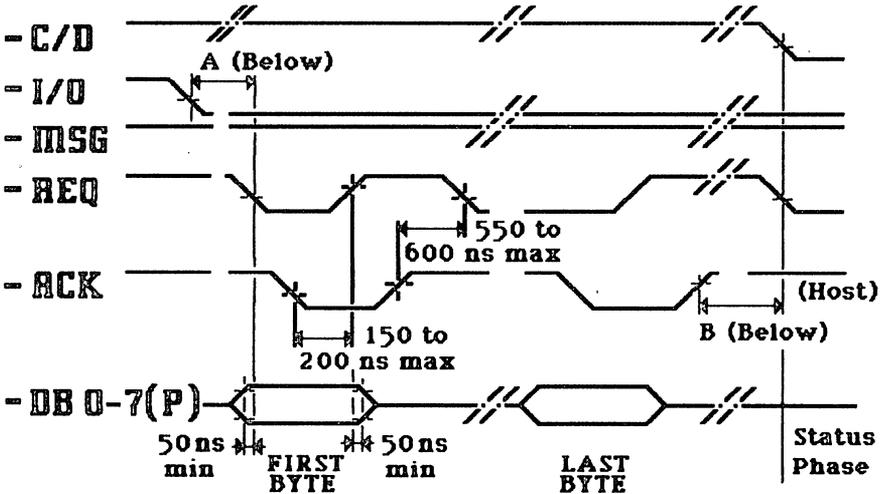
A = 1 us typical with READ commands.
A = 150 us for Disk with REQUEST SENSE command.
A = 225 us for Tape with REQUEST SENSE command.
B = 2 us typical for Disk.
B = 230 us for Tape if READ terminates with File Mark detected.

Assuming 50 ns response time from the host for the assertion
and deassertion of -ACK, the controllers can handshake one byte
in 800 to 900 nanoseconds.
In multi block transfers there may be a contention in access to
the buffer from channel zero (the sequencer port) of the OMTI
5060 chip. This may create a 500 to 600 nanosecond pause
between the deassertion of ACK and the assertion of the next
REQ.

Figure 6.3 Data In Phase Timing Chart

DATA OUT WRITE
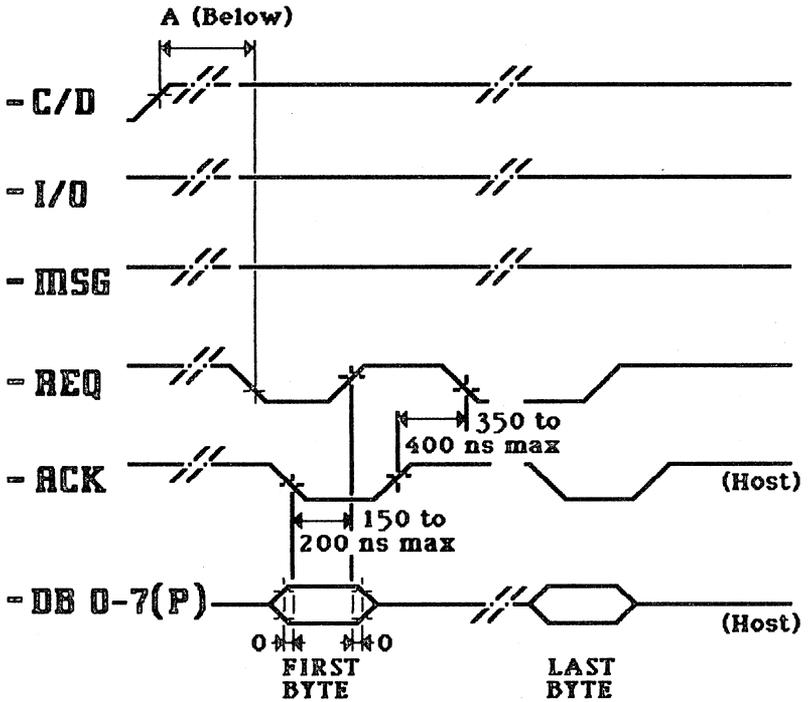
A = x   us   to x ms for Winchester Disks or x   ms   for   Floppies
    depending on Seek and latency delays.
A = x seconds for the search of the first block on Tape.

Assuming   50ns   response time from the host for   assertion   and
deassertion of -ACK,   the controllers can handshake one byte in
600 to 700 nanoseconds.

In multi block transfers there may be a contention in access to
the   buffer from channel zero (the sequencer port) of the   OMTI
5060 chip.   This may create an 800 nanosecond pause between the
deassertion of ACK and the assertion of the next REQ.

Figure 6.4   Data Out Phase Timing Chart

6.10 STATUS AND MESSAGE PHASES

Following a command or data transfer, the controller will generate a Completion Status byte and a Message In byte. To send the Completion Status byte, the controller asserts C/D, I/O, and the completion status byte on the data bus, then asserts REQ. The host must then accept the status byte on the data bus by asserting ACK. The controller will then deassert REQ and the host deasserts ACK. Following the Completion Status byte transfer, a message byte will be transferred to indicate that the command is completed. The controller asserts MSG, with C/D, I/O, and the message byte on the data bus and then asserts REQ. The host accepts the "Command Complete" message byte on the data bus by asserting ACK. The controller then responds by deasserting REQ, and the host by deasserting ACK. At this point BSY and all other control signals are deasserted and the controller returns to an idle state. SEL remains deasserted throughout this phase.

STATUS and MESSAGE
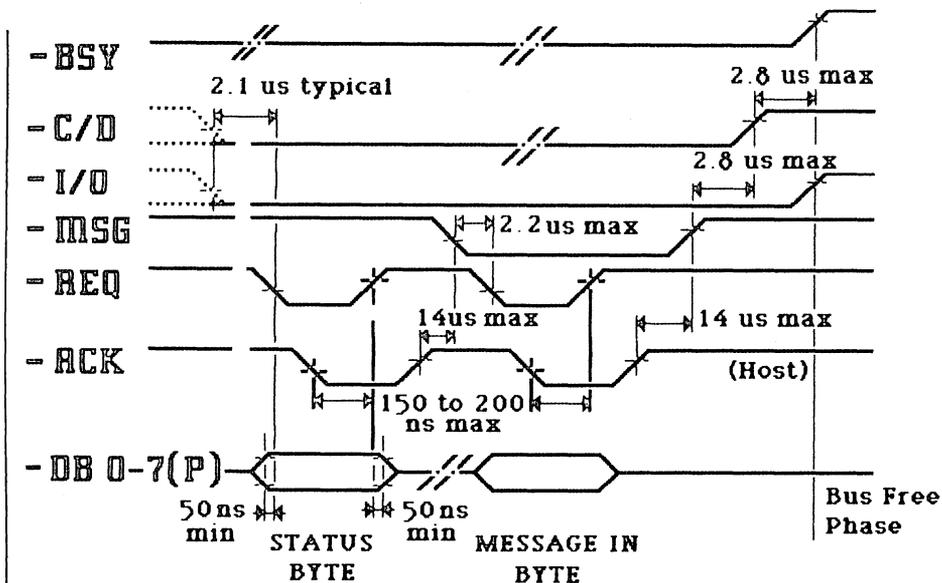
Figure 6.5 Status and Message Phase Timing Chart

SECTION 7

DISK COMMANDS

7.1 GENERAL

Following the Selection phase, the controller requests a
command descriptor block (CDB) from the host, the length of
which is either six, ten, or twelve bytes. The first byte of
the CDB contains the command code. The remaining bytes describe
the commands.

The controller checks all incoming CDB's validity and, unless
disabled, will check both CDB and data for odd parity. An error
in the command structure will terminate the command and cause a
"check condition" status to occur.

7.2 COMMAND DESCRIPTOR DEFINITION

In the following command tables, all bits specified as
"Reserved" or "Not Used" should be programmed zero value.

Command Descriptor Block

	7	6	5	4	3	2	1	0
BYTE 1	COMMAND CODE							
BYTE 2	0	LUN		LOGICAL BLOCK ADDR 2 (MSB)				
BYTE 3	LOGICAL BLOCK ADDRESS 1							
BYTE 4	LOGICAL BLOCK ADDRESS 0 (LSB)							
BYTE 5	BLOCK COUNT/INTERLEAVE FACTOR							
BYTE 6	CONTROL BYTE							

7.2.1 Command Code

Refer to Paragraph 2.6, Command Set Summary.

7.2.2 Logical Unit Number

LUN (BYTE 2 - BITS 5, and 6) is the Logical Unit Number for the
drive.

Fixed, Removable, or Flexible Drives	Fixed/Removable Drives
DRIVE SELECT 1 = LUN 0	DRIVE SELECT 1 = LUN 0
DRIVE SELECT 2 = LUN 1	DRIVE SELECT 1 = LUN 1
DRIVE SELECT 3 = LUN 2	DRIVE SELECT 3 = LUN 2
DRIVE SELECT 4 = LUN 3	DRIVE SELECT 3 = LUN 3

7.2.3 Logical Block Address

The logical block address is a 21 bit address located in Byte two (Bits 4-0)(MSB), Byte three, and Byte four (LSB). The logical block address relates to a physical address, typically defined in terms of cylinder-head-sector.

The logical block address zero relates to cylinder 0, head 0, sector 0 for Winchester Disk drives. Flexible disk drives start at sector one. Logical block addresses continue through all the sectors on the track, then continue to sector 0 on the next head, continuing through all the heads on the cylinder, and then continue to the next cylinder.

For Disk Drives, the logical block address is computed using the following formula:

```
LOGICAL  BLOCK  ADDRESS=(CYLADR * HDCYL + HDADR)  *  SECTRK  +
SECNUM
```

	Where:	CYLADR	=	Cylinder address
		HDCYL	=	Number of Heads per Cylinder
		HDADR	=	Head address
		SECTRK	=	Number of Sectors per Track
		SECNUM	=	Sector Number

Byte 3, if non zero, in the FORMAT UNIT command, is used as the Data Field Pattern.

7.2.4 Block Count/Interleave Factor

The Block Count or Transfer Length specifies the number of blocks to be transferred per command. A value of 0 will result in a transfer of 256 blocks.

This byte also specifies the interleave factor for the FORMAT command. An interleave factor of 0 will default to an interleave factor of 1. The scheme to calculate interleaving is compatible with the OMTI 20 Series.

An example of the interleave scheme for a track with 32 sectors and an interleave factor of 10 is shown below:

PHY. SEC.	0	1	2	3	4	5	6	7	8	9	10
LOG. BLK.	0	10	20	30	1	11	21	31	2	12	22
PHY. SEC.	11	12	13	14	15	16	17	18	19	20	21
LOG. BLK.	3	13	23	4	14	24	5	15	25	6	16
PHY. SEC.	22	23	24	25	26	27	28	29	30	31	
LOG. BLK.	26	7	17	27	8	18	28	9	19	29	

Refer to the Appendix for a complete Interleave Table.

7.2.5   Control Byte (Last byte in all commands)

Control Byte Format

```
7      6      5      4      3      2      1      0
┌─────────────────────────────────────────────────┐
│ X      X      0      0      0      0      0    X  │
└─────────────────────────────────────────────────┘
  .      .                                      .
  .      .                     LINK COMMAND = 1
  .      .
  .      .
  .      DISABLE ERROR CORRECTION = 1
  .
DISABLE RETRY = 1
```

Should a read error occur with the Retry bit (7) of the control
byte enabled, the controller will attempt to read the sector up
to eight (8) times. ID field errors will recalibrate and reseek
after four (4) rereads.

Should a correctable data error occur with the Error Correction
bit (6) enabled, the controller will correct the data prior to
transferring it to the host.

If both Retry and Error Correction are not disabled, the retry
sequence will be attempted prior to error correction.

If the LINK command bit of the Control Byte is enabled, and the
current command is executed successfully, the controller will
bypass the Status and Message In phases, and the Selection
phase of the next command. The controller will then request the
next command descriptor block.

7.3 COMPLETION STATUS BYTE

At termination of a command or following an error, the controller
will cause a status byte to be transferred from the controller to
the host. The completion status byte will report that a CHECK
CONDITION occurred, not the type of error. To obtain the sense
code a REQUEST SENSE command must be issued (03 Hex). Bit 0 will
be set to 1 if a Parity error is detected. Bit 1 will be set to 1
if the controller detects a sense condition during command
execution. Bits 5 and 6 represent the LUN of the device causing
the error. If no error occurs, bits 0 - 4 will be set to 0.

Completion Status Byte Format

```
 7    6    5    4    3    2    1    0
 _____
| 0  |   LUN   | 0    0    0  | X    X |
 -----------------------------------
              CHECK CONDITION = 1.......
                                         .
        SCSI BUS PARITY ERROR = 1............
```

BIT 0	SCSI BUS Parity error
BIT 1	Error occurred during command execution
BIT 2-4	Spare (Set to 0)
BIT 5-6	Logical Unit Number of the drive
BIT 7	Set to 0

7.4 MESSAGE IN BYTE

Following the transfer of the completion status byte, the
controller asserts the MSG line to indicate a Message In phase.
This message consists of a single byte transfer, with all bits
set to 0, indicating Command Complete.

7.5 TYPE O COMMANDS

7.5.1 TEST DRIVE UNIT Command (HEX 00)

The command selects the LUN specified and returns a Zero Status
during the Status phase of the command execution, to indicate
that Winchester drives are selected, ready, SEEK complete,
or that flexible drives are ready. In the case of a unit with
a Removable Disk drive, Zero Status also indicates that a
cartridge is installed.

```
          TEST DRIVE UNIT Command Descriptor Block
               7     6     5     4     3     2     1     0
BYTE 1     | 0     0     0     0     0     0     0     0 |
BYTE 2     | 0    LUN        |        NOT USED           |
BYTE 3     |            NOT USED                         |
BYTE 4     |            NOT USED                         |
BYTE 5     |            NOT USED                         |
BYTE 6     |            CONTROL BYTE                     |
```

VALID ERROR CODES

Drive not ready	(HEX 04)
Drive not selected	(HEX 05)
Multiple drives selected	(HEX 07)
Cartridge Changed	(HEX 09)
Operation in progress	(HEX 0D)

7.5.2 RECALIBRATE Command (HEX 01)

The drive specified by the LUN is stepped toward the outside cylinder until either:

        1. Track 0 signal is detected or
        2. 2048 step pulses have been issued.

The controller issues one step pulse, waits for SEEK complete (if Winchester), and tests the track 000 signal until track 000 is true.

RECALIBRATE Command Descriptor Block

	7	6	5	4	3	2	1	0
BYTE 1	0	0	0	0	0	0	0	1
BYTE 2	0	LUN			NOT USED			
BYTE 3	NOT USED							
BYTE 4	NOT USED							
BYTE 5	NOT USED							
BYTE 6	CONTROL BYTE							

VALID ERROR CODES

No seek complete	(HEX 02)
Drive not ready	(HEX 04)
Drive not selected	(HEX 05)
No track 0 found	(HEX 06)
Multiple drives selected	(HEX 07)
Cartridge Changed	(HEX 09)
Power up diagnostic error	(HEX 30)

7.5.3 REQUEST SENSE Command (HEX 03)

Following a Check Condition status from the Completion Status byte of the previous command, the host should perform REQUEST SENSE command, to obtain more detailed information about the error. (Each command description contains a list of valid error codes.)

REQUEST SENSE Command Descriptor Block

	7	6	5	4	3	2	1	0
BYTE 1	0	0	0	0	0	0	1	1
BYTE 2	0	LUN			NOT USED			
BYTE 3	NOT USED							
BYTE 4	NOT USED							
BYTE 5	NOT USED							
BYTE 6	CONTROL BYTE							

Sense Bytes: Refer to Section 8 for the Sense bytes reported for a Tape Drive.

The following four bytes are returned to the host during the Data In phase of the command execution.

SENSE BYTES FORMAT

	7	6	5	4	3	2	1	0
BYTE 1	SENSE CODE							
BYTE 2	0	LUN		LOGICAL BLOCK ADDR 2 (MSB)				
BYTE 3	LOGICAL BLOCK ADDRESS 1							
BYTE 4	LOGICAL BLOCK ADDRESS 0 (LSB)							

Sense Byte 1

SENSE CODE FORMAT

BITS	7	6	5	4	3	2	1	0
	AV	0	TYPE		CODE			

AV: When set to one, the Logical Block address reported in Bytes 2 to 4 is a valid address.

7-7

SENSE CODE SUMMARY (SENSE ·BYTE 1)

SENSE DESCRIPTION	CODE (HEX)
No error	00
No index signal	01
No seek complete	02
Write fault	03
Drive not ready	04
Drive not selected	05
No track zero found	06
Multiple drives selected	07
Not Used	08
Cartridge changed	09
Not used	0A to 0C
Operation in progress	0D
Not Used	0E to 0F
Tape exception (Tape Only)	10
Uncorrectable error in data field	11 & 91
Not Used	12 & 92
No address mark in data field	13 & 93
No record found	14 & 94
Seek error	15 & 95
Not used	16 & 96
Write protected	17 & 97
Correctable ECC error	18 & 98
Bad Track flag set	19 & 99
Incorrect interleave factor	1A & 9A
Not Used	1B & 9B
Unable to read alternate track data	1C & 9C
Not Used	1D & 9D
Illegal direct access to alternate track	1E & 9E
Tape drive failure (Tape Only)	1F
Invalid command	20
Illegal parameters	21
Illegal Function for drive type	22
Volume Overflow	23
Not Used	24 to 2F
Power Up Diagnostic error	30
FDC 765 error (5200/5204/5400 only)	31
Not used	32 through 90
Not used	A0 through FF

Note: Code 10 for Tape Exception is not necessarily an error.
For example, in the case of a File Mark Detected, the Tape
Exception condition is created by the Tape Drive in order to
report the event.

ERROR CODE DEFINITIONS (SENSE BYTE 1)

00   No error or no sense information. Indicates that there is
no specific sense information to be reported for the designated
Logical Unit Number.   This is the case for the successful
completion of the previous command.

01   No Index signal from the disk drive. The drive is ready
but the controller does not detect the Index signal coming from
the drive interface control cable indicating the beginning of
the track. The controller waited at least three seconds. This
error may occur during the following commands: FORMAT DRIVE,
FORMAT TRACK,   FORMAT BAD TRACK,   ALTERNATE TRACK, and CHECK
TRACK   FORMAT.   Verify   the cable and connector   before
investigating drive or controller problems.

02 No Seek Complete. The controller did not receive the Seek
Complete signal from the drive, which indicates that the step
function issued has been completed.   The controller waits at
least three seconds before reporting this error.

03   Write Fault received from the drive.   The Write Fault
signal is sampled before turning on Write Gate and after
turning off Write Gate. Consult the disk drive specifications
for all possible conditions reporting this error.   Check the
drive power supply voltage and drive connector.

04   Drive Not Ready. This status occurs when the selected
drive is not ready. The drive may not be at its optimum speed.
Absence of cartridge or media in the drive will also cause this
status.   During the drive selection sequence of flexible disk
drives,   if the DRIVE READY signal is not asserted the
controller will de-select the drive, re-select the drive, and
monitor the READY line for up to two seconds.   If the READY
signal is still not asserted after this de-select/re-select
process, the controller will post a DRIVE NOT READY error.
Check the drive power supply and drive connector if this status
persists.   In the case of Flexible disk drive, check that the
diskette is in place in the proper orientation and the door is
closed.

05   Drive Not Selected. The controller attempted to select a
drive and this drive did not assert its selected signal.
Ensure that any drive connected to the controller has its
address (selected by jumpers on the drive) matching the LUN
address of the command. Ensure that the drive data and control
cables are in place.   There is no relation between this error
code and the SCSI bus selection process.

06 No Track zero found. During a RECALIBRATE command the controller issues steps and checks if the drive reached Track zero after every step. This error occurs if the controller issues 2048 steps and does not detect the Track zero signal from the drive.

07 Multiple drives selected. More than one drive asserted its Drive Selected signal on its Data cable. Ensure that each drive connected has a unique address selected by jumper (on the drive). Check cables and connectors.

08 Not used.

09 Cartridge Changed.
For Winchester Type Drives:
The controller received the Cartridge Changed signal indicating that the door was opened and closed (with the possibility that the cartridge was changed). This Cartridge changed condition will likely be asserted on the first selection of a Removable Winchester disk drive at Power On Sequence.

For Flexible Disk Drives:
During the drive selection sequence for flexible disk drives, if the DRIVE READY signal is not asserted the controller will de-select the drive, re-select the drive, and monitor the READY line for up to two seconds. If the READY signal then becomes asserted, the controller will post a Cartridge Changed error. If the READY signal is still not asserted after this de-select/re-select process, the controller will post a DRIVE NOT READY error.

0A through 0C Not used.

0D Operation in Progress.
For Disk Drives:
This code is returned only in response to a TEST UNIT READY (00) command. The disk drive is busy seeking to the location defined by the previous SEEK command. This error code is to be expected after overlapping seeks are issued. The controller will keep reporting this code until the disk drive sends the Seek Complete signal.

For Tape Drives:
This code is returned whenever a command is issued that the QIC-02 Tape formatter cannot perform because it is still in Read or Write Mode and the command would violate the current mode. The command which most often causes this error code is a REQUEST SENSE command issued after a READ or a WRITE command was completed with no Tape Exception condition, or after a WRITE command which was not terminated by writing an implied File Mark.

Explanation of the OD Status with Tape: Once a Tape data
transfer command is completed, the QIC-02 interface remains
either in READ or WRITE mode depending upon the command. The
only conditions for which the interface would get out of these
modes is by:
 - an Exception condition.
 - a Rewind command.
 - or in WRITE mode, by a WRITE FILE MARK operation.
Prior to getting out of the above modes, if a TEST UNIT READY
command is issued, the controller will report a check condition
status. If a REQUEST SENSE command is issued, from another or the
same Host, the controller will report "Operation in progress",
code OD.

OE through OF Not used.

10 Tape Exception. The controller received the Exception
signal from the QIC-02 Tape drive, during a command to that
drive, indicating a condition detected by the Tape formatter
which may be either for an error or for a physical event
encountered such as File Mark, BOT, EOT etc...

11 and 91 Uncorrectable Data error. The controller detected a
data field error that could not be corrected by the ECC. The
burst error length might be over the limits of capability of the
ECC, or the error might have involved a multiple burst. The data
block is not transferred to the host. The command stops its
execution when encountering this condition, and does not exhaust
the block count. The last data block sent to the host was the
last good block for which no error was encountered. The Sense
Bytes of the REQUEST SENSE command sent following this error will
report the Logical Block address at which the error occurred. The
data block that contains the error can be accessed by a Read Data
Buffer command. The Read Data Buffer will return the block in
error provided that no data transfer commands (READs or WRITEs)
have been issued since the Uncorrectable Data error occurred.

12 and 92 Not used.

13 and 93 No Address Mark in Data Field. The controller did
not detect the AM bytes (A1, F8) when trying to access a
formatted disk. The disk may have a flaw in this particular
location.

14 and 94 No Record found. The controller was able to read at
least one ID Field and determined that it was on the right
track, but could not find the specified ID Field because it
could not find the ID Field Address Mark (A1, FE), it detected
an ID Field ECC error, or the specified ID does not exist or it
could not read any ID fields.

15 and 95 Seek error. The controller could not find the
specified ID Field, and there was a miscompare of the cylinder
or head address between the recorded and the target ID Fields.

7-11

16 and 96 Not Used.

17 and 97 Write Protected. During WRITE commands, the drive sent the Write Protect signal to the controller, indicating that the media is protected for write operations.

18 and 98 Correctable ECC error. This error can only be encountered if correction is disabled in the control byte of the command, except with the CHECK TRACK FORMAT command which does not attempt to correct errors regardless of the bit setting in the control byte. It indicates that the block which contains an error can be corrected by the ECC algorithm. The data block involved is not sent to the host. The command execution is stopped at this sector; the block count is not exhausted. Note that if correction is enabled and if the error was corrected by the ECC, the controller will not report any error.

19 and 99 Bad Track Flag set. The controller detected that the specified sector is on a track that has been flagged in the ID field by the FORMAT BAD TRACK command. It is not possible to access the sectors on a track flagged "bad".

1A and 9A Incorrect Interleave Factor. During the CHECK TRACK FORMAT command, the interleave factor specified in the command did not match the value with which the track had been formatted.

1B and 9B Not used.

1C and 9C Unable to read Alternate Track Data. During an access to a specified sector, the controller found a track with the "Bad Track" Flag and the "Alternate Track Assigned" Flag set in the ID field. The controller stepped the drive to the alternate track but was unable to locate the specified sector on the alternate track, found that the Alternate Track Flag was not set in the ID field, or encountered an uncorrectable data ECC error while trying to read the specified sector.

1D and 9D Not used.

1E and 9E Illegal Direct Access to Alternate Track. The controller received a command with the logical block address corresponding to an alternate track, and found the "Alternate Track" Flag set in the ID field. The tracks formatted as alternates cannot be accessed directly by a data transfer command. These tracks may be accessed only by the controller's automatic handling of media defects.

1F Tape Drive Failure. The tape drive interface handshake has failed. The tape drive must be reset before it will accept any new commands.

7-12

20 Invalid Command. The controller decoded a command code in byte one of the CDB that it does not support. Refer to the Command Set Summary.

21 Illegal Parameters. The controller received a command with a Logical Block Address beyond the capacity of the drive. Refer to the Logical Block Address computation formula, and check the number of cylinders, heads, and sector size that the drive is configured for.

22 Illegal Function for Drive Type. The controller received a command with legal bits and bytes but illegally defined for that drive type. This condition affects the command bytes as well as the bytes sent during the Data Out phase of the command execution. Refer to the appropriate command definition in its respective section of the manual. An example would be that a command valid only on Winchester drives is issued to a LUN defined as a tape drive.

23 Volume Overflow. The controller received a multiple sector command with which the Logical Block address and the block count specified created an overflow condition by trying to access space beyond the capacity of the disk. Refer to the Logical Block Address computation formula, and check the number of cylinders, head, and sector size that the drive is configured for.

24 through 2F Not Used.

30 Power Up Diagnostic error. The internal controller tests at power up detected an error condition. This error code is returned on the first command requiring drive access after power up sequence, or after a Reset condition.

31 FDC 765 Error. (5200/5204/5400 Models only). This situation occurs when the FDC 765 chip hung in an unexpected state. For more information, consult the chip documentation regarding the two lines RQM (Request for master) and DIO.

32 through 90 Not used.

A0 through FF Not used.

7.5.4 FORMAT UNIT Command (HEX 04)

This command causes the specified LUN to be formatted using the
interleave factor specified in byte 5. Formatting starts from
track 0 of cylinder 0, and proceeds until the last track of the
unit is formatted. The track is written starting with the
index. All data fields are filled with HEX E5 if byte 3 equals
zero. If byte 3 is different than zero, all data fields are
filled with the pattern defined in byte 3. The first sector
after index is always sector 0. The second sector is 0 plus the
interleave factor. An interleave factor of zero is set equal to
one. Track and cylinder overflow are handled automatically by
the controller.

NOTE: This command does not check data, and does not handle
media defects. For verification of format, see CHECK TRACK
FORMAT Command. For media defect handling, see the ASSIGN
ALTERNATE TRACK, and the FORMAT BAD TRACK Commands.

FORMAT UNIT Command Descriptor Block

	7	6	5	4	3	2	1	0
BYTE 1	0	0	0	0	0	1	0	0
BYTE 2	0	LUN			NOT USED			
BYTE 3	DATA FIELD PATTERN							
BYTE 4	NOT USED							
BYTE 5	INTERLEAVE FACTOR							
BYTE 6	CONTROL BYTE							

VALID ERROR CODES

No index	(HEX 01)
No seek complete	(HEX 02)
Write fault	(HEX 03)
Drive not ready	(HEX 04)
Drive not selected	(HEX 05)
No track 0 found	(HEX 06)
Multiple drives selected	(HEX 07)
Cartridge changed	(HEX 09)
Write protected	(HEX 97)
Illegal Function for drive type	(HEX 22)
FDC 765 error	(HEX 31)
Power Up Diagnostic error	(HEX 30)

7.5.5 CHECK TRACK FORMAT Command (HEX 05)

This command checks the integrity of the track specified by the
Logical Block address. ID fields and data fields are verified
against ECC value recorded. The command also ensures that the
interleave recorded matches the value in Byte 5 . An interleave
factor of 0 is set equal to one. No data is transferred to the
host. To specify the track address, any Logical Block address
on that track may be used. This command is not valid for LUN's
assigned as Flexible Disk drives.   Retries and ECC correction
are automatically disabled in the Control Byte.

This is a Diagnostic command, which code is compatible with
earlier   controller   models.   This   command   will   not   be
implemented with the same code in future controllers.

```
           CHECK TRACK FORMAT   Command Descriptor Block
                 7    6    5    4    3    2    1    0
        BYTE 1  ┌─0────0────0────0────0────1────0────1─┐
        BYTE 2  │ 0    │  LUN   │ LOGICAL  BLOCK  ADDR  2  (MSB)│
        BYTE 3  │    LOGICAL  BLOCK  ADDRESS  1            │
        BYTE 4  │    LOGICAL  BLOCK  ADDRESS  0  (LSB)     │
        BYTE 5  │    INTERLEAVE FACTOR                     │
        BYTE 6  │    CONTROL  BYTE                         │
                └──────────────────────────────────────────┘
```

VALID ERROR CODES

No index	(HEX 01)
No seek complete	(HEX 02)
Drive not ready	(HEX 04)
Drive not selected	(HEX 05)
Multiple drives selected	(HEX 07)
Cartridge changed	(HEX 09)
Uncorrectable data error	(HEX 91)
No address found in data field	(HEX 93)
No record found	(HEX 94)
Seek error	(HEX 95)
Correctable data error	(HEX 98)
Bad track flag set	(HEX 99)
Incorrect interleave factor	(HEX 9A)
Unable to read alternate track data	(HEX 9C)
Illegal direct access to alternate track	(HEX 9E)
Illegal sector address	(HEX 21)
Illegal function for drive type	(HEX 22)
Power Up Diagnostic error	(HEX 30)

7.5.6 FORMAT TRACK Command (HEX 06)

This command causes the track specified by the Logical Block address in bytes 2 - 4 to be formatted using the interleave factor specified in byte 5. The track is written starting with index and all data fields are filled with a HEX E5. The first sector after index is always sector 0. The second sector is 0 plus the interleave factor. Interleave factor of zero is set to one. To specify the track address, any Logical Block address on that track may be used.

FORMAT TRACK Command Descriptor Block

	7	6	5	4	3	2	1	0
BYTE 1	0	0	0	0	0	1	1	0
BYTE 2	0	LUN		LOGICAL BLOCK ADDR 2 (MSB)				
BYTE 3	LOGICAL BLOCK ADDRESS 1							
BYTE 4	LOGICAL BLOCK ADDRESS 0 (LSB)							
BYTE 5	INTERLEAVE FACTOR							
BYTE 6	CONTROL BYTE							

VALID ERROR CODES

No index	(HEX 01)
No seek complete	(HEX 02)
Write fault	(HEX 03)
Drive not ready	(HEX 04)
Drive not selected	(HEX 05)
Multiple drives selected	(HEX 07)
Cartridge changed	(HEX 09)
Write protected	(HEX 97)
Illegal Parameter	(HEX 21)
Illegal Function for drive type	(HEX 22)
Power Up Diagnostic error	(HEX 30)
FDC 765 error	(HEX 31)

7.5.7 FORMAT BAD TRACK Command (HEX 07)

This command is identical to the FORMAT TRACK command except
that the defective track flag is set in the ID field. All
subsequent accesses to the sectors on this track will result in
Bad Track Flag Set errors. To specify the track address, any
Logical Block address on that track may be used. Interleave
factor of zero is set to one. This command is not valid for
LUN'S assigned as Flexible Disk drives.

This command code is compatible with earlier controller models,
and should be avoided for new software design. In future
products, this command code will be used for a different
meaning, to the RE-ASSIGN BLOCKS command for defective sector
sparing.

FORMAT BAD TRACK Command Descriptor Block

	7	6	5	4	3	2	1	0
BYTE 1	0	0	0	0	0	1	1	1
BYTE 2	0	LUN		LOGICAL BLOCK ADDR 2 (MSB)				
BYTE 3	LOGICAL BLOCK ADDRESS 1							
BYTE 4	LOGICAL BLOCK ADDRESS 0 (LSB)							
BYTE 5	INTERLEAVE FACTOR							
BYTE 6	CONTROL BYTE							

VALID ERROR CODES

No index	(HEX 01)
No seek complete	(HEX 02)
Write fault	(HEX 03)
Drive not ready	(HEX 04)
Drive not selected	(HEX 05)
Multiple drives selected	(HEX 07)
Cartridge changed	(HEX 09)
Write protected	(HEX 97)
Illegal Parameter	(HEX 21)
Illegal Function for drive type	(HEX 22)
Power Up Diagnostic error	(HEX 30)

7-17

7.5.8 READ Command (HEX 08)

This command causes the number of blocks specified by byte 5 to
be transferred from the disk to the host. The command executes
an implied seek to the starting block specified by the Logical
Block address in bytes 2, 3, and 4. Up to 256 blocks can be
transferred with a single READ command. (If Byte 5 is equal to
zero, 256 blocks will be transferred.)

READ Command Descriptor Block

	7	6	5	4	3	2	1	0
BYTE 1	0	0	0	0	1	0	0	0
BYTE 2	0	LUN		LOGICAL BLOCK ADDR 2 (MSB)				
BYTE 3	LOGICAL BLOCK ADDRESS 1							
BYTE 4	LOGICAL BLOCK ADDRESS 0 (LSB)							
BYTE 5	BLOCK COUNT							
BYTE 6	CONTROL BYTE							

VALID ERROR CODES

No seek complete	(HEX 02)
Drive not ready	(HEX 04)
Drive not selected	(HEX 05)
Multiple drives selected	(HEX 07)
Cartridge changed	(HEX 09)
Uncorrectable error in data field	(HEX 91)
No address mark in data field	(HEX 93)
No record found	(HEX 94)
Seek error	(HEX 95)
Correctable data error	(HEX 98)
Bad track flag set	(HEX 99)
Unable to read alternate track data	(HEX 9C)
Illegal access to alternate track	(HEX 9E)
Illegal Parameter	(HEX 21)
Volume overflow	(HEX 23)
Power Up Diagnostic error	(HEX 30)
FDC 765 error	(HEX 31)

7.5.9 WRITE Command (HEX 0A)

This command causes the number of blocks specified by byte 5 to
be transferred from the host to the disk. The command executes
an implied seek to the starting block specified by the logical
block address in bytes 2, 3, and 4. Up to 256 blocks can be
transferred with a single WRITE command. (If Byte 5 is equal to
zero, the block count is set to 256 blocks.)

```
           WRITE Command Descriptor Block
           7    6    5    4    3    2    1    0
BYTE 1   | 0    0    0    0    1    0    1    0        |
BYTE 2   | 0     LUN     LOGICAL BLOCK ADDR 2 (MSB)   |
BYTE 3   |    LOGICAL BLOCK ADDRESS 1                  |
BYTE 4   |    LOGICAL BLOCK ADDRESS 0 (LSB)            |
BYTE 5   |    BLOCK COUNT                              |
BYTE 6   |    CONTROL BYTE                             |
```

VALID ERROR CODES

No seek complete	(HEX 02)
Write fault	(HEX 03)
Drive not ready	(HEX 04)
Drive not selected	(HEX 05)
Multiple drives selected	(HEX 07)
Cartridge changed	(HEX 09)
No record found	(HEX 94)
Seek error	(HEX 95)
Write protected	(HEX 97)
Bad track flag set	(HEX 99)
Unable to read alternate track data	(HEX 9C)
Illegal access to alternate track	(HEX 9E)
Illegal Parameter	(HEX 21)
Volume overflow	(HEX 23)
Power Up Diagnostic error	(HEX 30)
FDC error	(HEX 31)

7.5.10 SEEK Command (HEX 0B)

This command causes the device addressed by the LUN to be physically positioned to the cylinder as defined by the logical block address in bytes 2, 3, and 4.

No attempt to verify seek position is made until a READ or WRITE command is issued. Completion status is returned to the host immediately after issuing all required step pulses. This allows overlap seek operations. As READ and WRITE commands are issued with implied seek, the SEEK command need not be issued, unless overlap operations are desired.

```
              SEEK Command Descriptor Block
              7     6     5     4     3     2     1     0
BYTE 1      │ 0     0     0     0     1     0     1     1 │
BYTE 2      │ 0  │    LUN    │ LOGICAL BLOCK ADDR 2 (MSB) │
BYTE 3      │ LOGICAL BLOCK ADDRESS 1                     │
BYTE 4      │ LOGICAL BLOCK ADDRESS 0 (LSB)               │
BYTE 5      │ ZERO VALUE                                  │
BYTE 6      │ CONTROL BYTE                                │
```

VALID ERROR CODES

No seek complete	(HEX 02)
Drive not ready	(HEX 04)
Drive not selected	(HEX 05)
Multiple drives selected	(HEX 07)
Illegal Parameter	(HEX 21)
Illegal Function for drive type	(HEX 22)
Power Up Diagnostic error	(HEX 30)
FDC 765 error	(HEX 31)

7.5.11   ASSIGN ALTERNATE TRACK Command (HEX 0E)

This command is used to assign an alternate track to the track
specified in bytes 2 - 4, so that any future accesses to the
blocks   on the specified track causes the controller to
automatically access those blocks on the alternate track. This
command sets flags in the ID field and writes the alternate
track address in all blocks on the specified track (see
defective track format). The alternate track is then formatted
with flags set to indicate that this track has been assigned as
an alternate track.   Future direct accesses to the alternate
track will result in an error. To specify the defective track
address, any Logical Block address on that track may be used.
Interleave factor of zero is set to one. This command is not
valid for LUN's assigned as Flexible Disk drives.

ASSIGN ALTERNATE TRACK Command Descriptor Block

	7	6	5	4	3	2	1	0
BYTE 1	0	0	0	0	1	1	1	0
BYTE 2	0	LUN		LOGICAL BLOCK ADDR 2 (MSB)				
BYTE 3	LOGICAL BLOCK ADDRESS 1							
BYTE 4	LOGICAL BLOCK ADDRESS 0 (LSB)							
BYTE 5	INTERLEAVE FACTOR							
BYTE 6	CONTROL BYTE							

The alternate track address is passed to the controller during
the Data Out phase of the command execution, using the
following format (any Logical Block address on the alternate
track may be used):

ALTERNATE TRACK ADDRESS Descriptor Block

	7	6	5	4	3	2	1	0
BYTE 1	LOGICAL BLOCK ADDRESS 2 (MSB)							
BYTE 2	LOGICAL BLOCK ADDRESS 1							
BYTE 3	LOGICAL BLOCK ADDRESS 0 (LSB)							
BYTE 4	0	0	0	0	0	0	0	0

NOTE: Data written on the original track as well as on the
       alternate track will be destroyed.

The controller does not check if the track assigned as
alternate track has been previously used as alternate track for
another track.

A track reserved as alternate track may include defect(s), and
may be shifted to another alternate track.   Two levels of
alternate tracks are allowed.   But the residual block count
must be limited to the capacity of the alternate track,
otherwise the controller will not seek back to the original
track plus one.   In order to avoid this situation, it is
therefore recommended not to assign as Alternate Track, a track
known as a bad track, and keep the assignment to one level
only.

VALID ERROR CODES

No index	(HEX 01)
No seek complete	(HEX 02)
Write fault	(HEX 03)
Drive not ready	(HEX 04)
Drive not selected	(HEX 05)
Multiple drives selected	(HEX 07)
Cartridge changed	(HEX 09)
Write protected	(HEX 97)
Illegal Parameter	(HEX 21)
Illegal Function for drive type	(HEX 22)
Power Up Diagnostic error	(HEX 30)

7.5.12 CHANGE CARTRIDGE Command (HEX 1B)

This command is valid only for Removable Winchester Disks. The command causes the "Change Cartridge" line (J2-Pin 2) to be asserted for a period of one (1) millisecond.

CHANGE CARTRIDGE Command Descriptor Block

	7	6	5	4	3	2	1	0
BYTE 1	0	0	0	1	1	0	1	1
BYTE 2	0	LUN			NOT USED			
BYTE 3	ZERO VALUE							
BYTE 4	ZERO VALUE							
BYTE 5	ZERO VALUE							
BYTE 6	CONTROL BYTE							

VALID ERROR CODES

Drive not ready	(HEX 04)
Drive not selected	(HEX 05)
Multiple drives selected	(HEX 07)
Illegal function for drive type	(HEX 22)
Power Up Diagnostic error	(HEX 30)

7.6 TYPE 1 COMMANDS

7.6.1 COPY Command (HEX 20)

This command copies a specified number of blocks from a Source LUN to a Destination LUN. Source and Destination LUN'S may be the same. Block sizes on both Source and Destination LUNs must be identical. Because the controller uses its internal buffer, no data is transferred to the host.

COPY Command Descriptor Block

	7	6	5	4	3	2	1	0
BYTE 1	0	0	1	0	0	0	0	0
BYTE 2	0	SRC LUN		LOGICAL BLOCK ADDR 2 (MSB)				
BYTE 3	LOGICAL BLOCK ADDRESS 1							
BYTE 4	LOGICAL BLOCK ADDRESS 0 (LSB)							
BYTE 5	BLOCK COUNT							
BYTE 6	0	DST LUN		LOGICAL BLOCK ADDR 2 (MSB)				
BYTE 7	LOGICAL BLOCK ADDRESS 1							
BYTE 8	LOGICAL BLOCK ADDRESS 0 (LSB)							
BYTE 9	NOT USED							
BYTE 10	CONTROL BYTE							

VALID ERROR CODES

No seek complete	(HEX 02)
Write fault	(HEX 03)
Drive not ready	(HEX 04)
Drive not selected	(HEX 05)
Multiple drives selected	(HEX 07)
Cartridge changed	(HEX 09)
Uncorrectable error in data field	(HEX 91)
No address mark in data field	(HEX 93)
No record found	(HEX 94)
Seek error	(HEX 95)
Write protected	(HEX 97)
Correctable data error	(HEX 98)
Bad track flag set	(HEX 99)
Unable to read alternate track data	(HEX 9C)
Illegal access to alternate track	(HEX 9E)
Illegal parameter	(HEX 21)
Illegal function for drive type	(HEX 22)
Volume overflow	(HEX 23)
Power Up Diagnostic error	(HEX 30)
FDC 765 error	(HEX 31)

7.7 TYPE 6 COMMANDS

7.7.1 DEFINE FLEXIBLE DISK FORMAT Command (HEX CO)

This command specifies the track format to be used on a LUN
assigned as a Flexible disk drive. This command should be
issued after all power-on or reset operation if values other
than default are desired and should always be issued after
successful completion of the ASSIGN DISK PARAMETERS Command.
The default condition is HEX 06 - Single sided, Cylinder 0:Single
density, FM recording, 128 bytes per sector, 16 sectors per track.
All other tracks: Double density, MFM recording, 256 bytes per
sector, 16 sectors per track. Byte 6 specifies the Flexible disk
track format. If byte 5 is zero, the number of blocks per track
will be as described in the FDD track format byte. If byte 5 is
non-zero, the blocks per track will be as specified in byte 5.

DEFINE FLEXIBLE DISK FORMAT Command Descriptor Block

	7	6	5	4	3	2	1	0
BYTE 1	1	1	0	0	0	0	0	0
BYTE 2	0	LUN			NOT USED			
BYTE 3	NOT USED							
BYTE 4	NOT USED							
BYTE 5	SECTORS PER TRACK							
BYTE 6	FDD TRACK FORMAT							

VALID ERROR CODES

Illegal function for drive type (HEX 22)

BYTE 5: "Sectors per track" is normally to be set to zero
because the SECTOR PER TRACK is implied in the track format
code in Byte 6. Byte 5 can be used to override that value when
for example it is desired to increase by one the number of
sectors per track (See codes 8A and 8B next two pages).

HEX 00	Single density, Single sided, FM recording, 128 bytes per sector, 16 sectors per track.
HEX 01	Single density, Double sided, FM recording, 128 bytes per sector, 16 sectors per track.
HEX 06 *	Single sided, Cylinder 0: Single density, FM recording, 128 bytes per sector, 16 sectors per track. All other tracks: Double density, MFM recording, 256 bytes per sector, 16 sectors per track.
HEX 07	Side 0, Cylinder 0: Single density, Double sided, FM recording, 128 bytes per sector, 16 sectors per track. All other tracks: Double density, Double sided, MFM recording, 256 bytes per sector, 16 sectors per track.
HEX 86	Double density, Single sided, MFM recording, 256 bytes per sector, 16 sectors per track.
HEX 87	Double density, Double sided, MFM recording, 256 bytes per sector, 16 sectors per track.
HEX 8A **	Double density, Single sided, MFM recording, 512 bytes per sector, 8 sectors per track.
HEX 8B **	Double density, Double sided, MFM recording, 512 bytes per sector, 8 sectors per track.
HEX 8E	Double density, Single sided, MFM recording, 1024 bytes per sector, 4 sectors per track.
HEX 8F	Double density, Double sided, MFM recording, 1024 bytes per sector, 4 sectors per track.

* = Default
** = Also supports 9 sectors per track using Byte 5.

HEX 00	Single density, Single sided, FM recording, 128 bytes per sector, 26 sectors per track.
HEX 01	Single density, Double sided, FM recording, 128 bytes per sector, 26 sectors per track.

HEX 06 *	Single sided, Cylinder 0:
	    Single density, FM recording,
	    128 bytes per sector, 26 sectors per track.
	All other tracks:
	    Double density, MFM recording,
	    256 bytes per sector, 26 sectors per track.

HEX 07	Side 0, Cylinder 0:
	    Single density, Double sided, FM recording,
	    128 bytes per sector, 26 sector per track.
	All other tracks:
	    Double density, Double sided, MFM recording,
	    256 bytes per sector, 26 sector per track.

HEX 86	Double density, Single sided, MFM recording, 256 bytes per sector, 26 sectors per track.
HEX 87	Double density Double sided, MFM recording, 256 bytes per sector, 26 sectors per track.
HEX 8A **	Double density, Single sided, MFM recording, 512 bytes per sector, 15 sectors per track.
HEX 8B **	Double density, Double sided, MFM recording, 512 bytes per sector, 15 sectors per track.
HEX 8E	Double density, Single sided, MFM recording, 1024 bytes per sector, 8 sectors per track.
HEX 8F	Double density, Double sided, MFM recording, 1024 bytes per sector, 8 sectors per track.

** = Also supports 16 sectors per track using Byte 5.

7.7.2 ASSIGN DISK PARAMETERS Command (HEX C2)

This command allows the host to specify disk drive parameters for the specified LUN. This allows the controller to communicate with a wide variety of drives from the same or different vendors. This command should be issued after every power-up sequence or reset for each LUN unless the LUN matches the default values set at initialization.

The associated Parameter List, including all characteristics of the drive connected, is sent to the controller during the Data Out phase of the command execution. There is no access to the drive during execution of this command.

ASSIGN DISK PARAMETERS Command Descriptor Block

	7	6	5	4	3	2	1	0
BYTE 1	1	1	0	0	0	0	1	0
BYTE 2	0	LUN		0	0	0	0	0
BYTE 3	NOT USED							
BYTE 4	NOT USED							
BYTE 5	NOT USED							
BYTE 6	CONTROL BYTE							

WINCHESTER DISK DRIVE PARAMETERS

When bit 7 of byte 8 is set to zero, the following list allows connection of any, and different, ST506/412 compatible disk drives to the two Winchester ports of the controller. This applies to all models of the 5000 Series.

Winchester Disk Parameter List

	7	6	5	4	3	2	1	0
BYTE 1	STEP PULSE WIDTH							
BYTE 2	STEP PERIOD							
BYTE 3	STEP MODE							
BYTE 4	NUMBER OF HEADS (-1)							
BYTE 5	CYLINDER ADDRESS HI							
BYTE 6	CYLINDER ADDRESS LO (-1)							
BYTE 7	WSI / WRITE PRECOMPENSATION CYLINDER							
BYTE 8	0	0	TYPE		H/S	0	WSI	
BYTE 9	SECTORS PER TRACK (-1)							
BYTE 10	RESERVED							

DEFINITION OF THE WINCHESTER DISK PARAMETER BYTES

BYTE 1 - STEP PULSE WIDTH: The length of time the step pulse is asserted. The value of this byte specifies the width of the step pulse in 2.8 microsecond increments. The minimum value of the step pulse is 5 microseconds for byte values of 0 through 5.

BYTE VALUE	STEP PULSE WIDTH	INCREMENTS
0 THROUGH 5	5 MICROSECONDS	----
6 " 8	7.8 "	+ 2.8 us
9 " B	10.6 "	+ 2.8 us
C " E	13.4 "	+ 2.8 us
etc...		

BYTE 2 - STEP PERIOD: The length of time between the trailing and leading edges of step pulses. A zero value in this byte results in 9 microsecond step period. A non-zero value specifies the time in 50 microsecond increments.

BYTE 3 - STEP MODE: This byte must be set to zero (buffered or normal mode).

BYTE 4 - NUMBER OF HEADS (-1): The value of this byte specifies the number of user heads (minus one) on the disk drive. The maximum value of this byte is 15 (OF HEX). Any value greater than 07 HEX causes the reduced write current (WSI) function to be disabled. Write precompensation is not affected.

BYTES 5-6 - NUMBER OF CYLINDERS (-1): These 2 bytes specify the maximum number of user cylinders (minus one) on the disk drive. Byte 5 is the most significant byte.

The maximum number of cylinders is 65K (FF, FF HEX).

BYTE 7 (and Bits 0-1 of Byte 8) - WSI/WRITE PRECOMPENSATION CYLINDER ADDRESS: This byte specifies the cylinder address where reduced write current and/or precompensation is first applied.

Reduced Write Current:

-   A value of zero or one in byte 7 indicates that the "reduced write current" function is disabled.

-   A value different than zero or one indicates that "reduced write current" is applied to all cylinders greater than or equal to the value of the byte.

Write Precompensation:

-   A 10 bit value of zero (byte 7 and bits 0-1 of byte 8) indicates that the write precompensation function is disabled.

‖‖‖ - A 10 bit value of one indicates that write precompensation is
applied to all cylinders.

- A value different than zero or one indicates that "write
precompensation" is applied to all cylinders greater than or
equal to the 10 bit value (byte 7 and bits 0-1 of byte 8).

EXAMPLES:

Bits	BYTE 8 1 0	BYTE 7 7 6 5 4 3 2 1 0	PRECOMPENSATION
	0 0	0 0 0 0 0 0 0 0	No WSI No Precompensation
	0 0	0 0 0 0 1 1 1 1	WSI Starts at OF(HEX) Precomp. starts at 00F(HEX)
	0 1	0 0 0 0 0 0 0 0	No WSI Precomp. starts at 100(HEX)
	0 1	1 0 0 1 0 0 0 0	WSI Starts at 90(HEX) Precomp. Starts at 190(HEX)
	0 0	0 0 0 0 0 0 0 1	No WSI Precomp. applied to all cylinders

BYTE 8:
```
7   6   5   4   3   2   1   0
0   0 | TYPE | H/S | 0 | WSI |
```

Bits 7, 6, and 2 should be set to zero.

Type: Bits 5 and 4 of Byte 8:   These bits specify whether the
device is a Fixed, Removable, or Fixed/Removable Winchester
Disk drive.

TYPE	
Bit 5	Bit 4
0	0 = Fixed Disk Drive
1	0 = Fixed/Removable disk Drive
1	1 = Removable Disk Drive

H/S: Bit 3 of Byte 8 specifies whether the device is a hard or
soft sectored disk drive (0 = Soft sectored; 1=Hard sectored).

Bits 1 and 0 define WSI/Write Precompensation as MSB bits.

NOTE: A Fixed/Removable disk drive must have two LUNs
assigned. One is for the Removable disk and the other is for
the fixed disk (LUN 0 = Removable; LUN 1 = Fixed; or LUN 2 =
Removable, LUN 3 = Fixed). This command must be issued to both
LUNs.

BYTE 9 - SECTORS PER TRACK (-1): This byte specifies the number
of sectors per track (minus one). A zero value is interpreted
as 9, 17, 18 or 32 sectors per track, depending upon the
position of the sector size jumpers, W3 and W4.

FLEXIBLE DISK DRIVE PARAMETERS

When bit 7 of byte 8 of the Parameter List is set to one, the
following Flexible Disk Parameter List, allows connection of
either 5 1/4" or 8" Flexible Disk drives to the port allocated
by the 5200, 5204 and 5400 models. High-capacity, half-height 5
1/4" flexible disk drives with the 500 Kbit/sec transfer rate
are supported as well by this list.

Flexible Disk Parameter List

	7	6	5	4	3	2	1	0
BYTE 1	STEP PULSE WIDTH (not analyzed)							
BYTE 2	STEP PERIOD							
BYTE 3	MAXIMUM CYLINDER ADDRESS (-1)							
BYTE 4	HEAD SETTLING DELAY							
BYTE 5	NOT USED							
BYTE 6	NOT USED							
BYTE 7	NOT USED							
BYTE 8	1	0	0	0	0	0	0	0
BYTE 9	FLOPPY TYPE/WRITE PRECOMP							
BYTE 10	START WRITE PRECOMP CYLINDER							

DEFINITION OF FLEXIBLE DISK PARAMETER BYTES

BYTE 1 - STEP PULSE WIDTH: (HEX 00) The step pulse width is
not analyzed. A value of zero is recommended. The FDC 765
controls the step pulses. Typical values are 5 microseconds
when using 500 KBit transfer rate, and 10 microseconds when
using 250 KBit transfer rate.

BYTE 2 - STEP PERIOD: The time between two step pulses. The
value of this byte is specified with bits 3, 2, 1, and 0 only.
Since the FDC 765 controls these step pulses, the period
changes depending on the drive data rate as follows:

- For a 500Kbit/sec data transfer rate, the value is in one (1)
  millisecond increments from one to fifteen milliseconds.
  (1=1ms, 2=2ms, 3=3ms, etc...)

- For a 250Kbit/sec data transfer rate, the value is in two
  millisecond increments from two to thirty milliseconds.
  (1=2ms, 2=2ms, 3=4ms, 4=4ms etc...)

In both cases, zero specifies the maximum step rate.

BYTE 3 - NUMBER OF CYLINDERS (- 1): The maximum number of
cylinders minus one (- 1).

BYTE 4 - HEAD SETTLING DELAY: The delay required from the last step pulse to a valid read or write. The value of this byte specifies the delay in two (2) milliseconds increments for a 500 Kbit transfer rate drive, and in four (4) milliseconds increments for a 250 KBit transfer rate drive.

500 KBit	250 Kbit
0 = 258ms	0 = 516ms
1 = 2ms	1 = 4ms
2 = 4ms	2 = 8ms
3 = 6ms	3 = 12ms

BYTE 5 through 7: NOT USED. To be set to zero.

BYTE 8: This Byte should be set to HEX 80 to indicate Flexible Disks.

BYTE 9 - FLEXIBLE DISK TYPE: Specifies the type of Flexible disk.

Bit 7 = 0 for a 250 Kilobit/second data transfer rate drive

Bit 7 = 1 for a 500 Kilobit/second data transfer rate drive

Bit 6 = 0 means that Pin 16 (motor on) will be asserted.

Bit 6 = 1 means that Pin 16 (motor on) shall not be
        asserted. This bit shall be set to 1 when
        using high capacity Disk Drives (192 TPI) and
        their pre-formatted diskettes.

Bits 5 and 4 are used to specify the number of step
        pulses per cylinder. Non-zero values allow a
        drive to read a diskette formatted on a drive
        with lower TPI. For example a value of
        Bit 5 = 0, and a Bit 4 = 1 will allow a 96 TPI
        drive to access tracks on a diskette from a
        48 TPI drive.

Bit 5	Bit 4	Steps/Cyl	
0	0	1	(Normal Usage)
0	1	2	
1	1	4	

Bits 1 and 0 describe Write Precompensation values as follows:

250 KBits/second			500 KBits/second		
BIT 1	BIT 0		BIT 1	BIT 0	
0	0	= 0 NSEC	0	0 = 0 NSEC
0	1	= 125 NSEC	0	1 = 62.5 NSEC
1	0	= 250 NSEC	1	0 = 125 NSEC
1	1	= 375 NSEC	1	1 = 187.5 NSEC

BYTE 10 - STARTING WRITE PRECOMPENSATION CYLINDER: Write precompensation is applied to all cylinders greater than this value.

VALID ERROR CODES

Illegal Function for drive type   (HEX 22)

7.8 TYPE 7 COMMANDS (DIAGNOSTIC Commands)

7.8.1 RAM DIAGNOSTIC Command (HEX E0)

This command performs a pattern test on the sector buffer.

RAM DIAGNOSTIC Command Descriptor Block

	7	6	5	4	3	2	0	0
BYTE 1	1	1	1	0	0	0	0	0
BYTE 2	NOT USED							
BYTE 3	NOT USED							
BYTE 4	NOT USED							
BYTE 5	NOT USED							
BYTE 6	CONTROL BYTE							

VALID ERROR CODES

Power Up Diagnostic error   (HEX 30)

7.8.2   WRITE ECC Command (HEX E1)

This command writes a "long" data field on the disk to allow testing of the ECC logic.   This command requests the number of data bytes, as determined by the sector size, plus four (4) more data bytes. Only one sector is written. These four bytes are written where the four ECC bytes normally reside. A subsequent READ command will treat these extra four bytes as ECC.   This command is not valid for LUN's assigned to Flexible disk drives.

WRITE ECC Command Descriptor Block

	7	6	5	4	3	2	1	0
BYTE 1	1	1	1	0	0	0	0	1
BYTE 2	0	LUN		LOGICAL BLOCK ADDR 2 (MSB)				
BYTE 3	LOGICAL BLOCK ADDRESS 1							
BYTE 4	LOGICAL BLOCK ADDRESS 0 (LSB)							
BYTE 5	NOT USED							
BYTE 6	CONTROL BYTE							

A data pattern which will not result in an ECC error is as follows:

256 BYTE SECTOR		512 BYTE SECTOR		1024 BYTE SECTOR	
0-255	6C	0-511	6C	0-1023	6C
256	3C	512	77	1024	7B
257	FD	513	FB	1025	65
258	1E	514	4C	1026	BE
259	B4	515	DC	1027	79

VALID ERROR CODES

No seek complete	(HEX 02)
Write fault	(HEX 03)
Drive not ready	(HEX 04)
Drive not selected	(HEX 05)
Multiple drives selected	(HEX 07)
Cartridge changed	(HEX 09)
No record found	(HEX 94)
Seek error	(HEX 95)
Write protected	(HEX 97)
Bad track flag set	(HEX 99)
Unable to read alternate track data	(HEX 9C)
Illegal access to alternate track	(HEX 9E)
Illegal Parameter	(HEX 21)
Illegal function for drive type	(HEX 22)
Power Up Diagnostic error	(HEX 30)

7.8.3 READ IDENTIFIER Command (HEX E2)

On LUNs assigned as Winchester Disk Drives the ID field of the
sector specified by the logical sector address is transferred
to the host. Only one sector is processed. The command will
return four data bytes during the Data In phase of the command
execution. On LUNs assigned as Flexible Disk Drives the first
ID field encountered is transferred. No seek is performed.

```
                    READ  IDENTIFIER Command Descriptor Block
                     7    6    5    4    3    2    1    0
        BYTE 1     │ 1    1    1    0    0    0    1    0 │
        BYTE 2     │ 0  │   LUN    │ LOGICAL BLOCK ADDR 2 (MSB) │
        BYTE 3     │   LOGICAL BLOCK ADDRESS 1              │
        BYTE 4     │   LOGICAL BLOCK ADDRESS 0 (LSB)        │
        BYTE 5     │   NOT USED                             │
        BYTE 6     │   CONTROL BYTE                         │
```

```
                        Data Byte Format
                 7    6    5    4    3    2    1    0
        BYTE 1 │        HIGH CYLINDER NUMBER          │
        BYTE 2 │        LOW CYLINDER NUMBER           │
        BYTE 3 │           HEAD/FLAGS                 │
        BYTE 4 │      PHYSICAL SECTOR NUMBER          │
```

BYTE 3, HEAD/FLAGS bit on Winchester LUNs is as follows:

```
            Bit    0   =   Head 1
                   1   =   Head 2
                   2   =   Head 4
                   3   =   Head 8
                   4   =   0
                   5   =   Alternate track flag
                   6   =   Bad track with Alternate assigned
                   7   =   Bad track
```

VALID ERROR CODES

No seek complete	(HEX 02)
Drive not ready	(HEX 04)
Drive not selected	(HEX 05)
Multiple drives selected	(HEX 07)
Cartridge changed	(HEX 09)
No record found	(HEX 94)
Illegal Parameter	(HEX 21)
Illegal Function for drive type	(HEX 22)
Power Up Diagnostic error	(HEX 30)
FDC 765 error	(HEX 31)

7.8.4 READ DATA BUFFER Command (HEX EC)

The controller data buffer is transferred to the host as if a single sector READ had occurred. The LUN can be any number since no device participates however, the number of bytes returned is determined by the block size for the specified LUN. The host can use this command following a WRITE DATA BUFFER command to verify READ / WRITE sequences without drive participation or, on a permanent ECC error in the data field, to obtain the bad record.

```
              READ DATA BUFFER Command Descriptor Block
               7    6    5    4    3    2    1    0
       BYTE 1 | 1    1    1    0    1    1    0    0 |
       BYTE 2 | 0  |   LUN   |     NOT USED          |
       BYTE 3 |             NOT USED                 |
       BYTE 4 |             NOT USED                 |
       BYTE 5 |             NOT USED                 |
       BYTE 6 |           CONTROL BYTE               |
```

Issued after Initialization (Power ON or Reset operation), the contents of the buffer are defined as below.

VALID FOR ALL FIRMWARE REVISIONS

HEX Address	Contents
00 through 0D *	5X00 VW.W MMDDYY
0E " 0F	Undefined
10-bit 0 ***	ROM checksum error
11-bit 0 ***	Processor Register error
12-bit 0 ***	Buffer Ram error
13-bit 0 ***	Sequencer Register File Error
14-1F	Undefined
20-2F	LUN 0 Default Values **
30-3F	LUN 1 " " **
40-4F	LUN 2 " " **
50-5F	LUN 3 " " **

*   X = Model number (1, 2, 3 or 4)
    W = Revision level
    MM = Month
    DD = Day
    YY = Year

** Default Values

*** Valid only after a POWER ON or if a diagnostic error (HEX 30) occurred on the previous POWER ON or RESET.

Address	Winchester Disk		Flexible Disk	
Byte 0		00		00
" 1		00		00
" 2		00		00
" 3		00		00
" 4	Cyl. High	00		00
" 5	Cyl. Low	98	Number of Cylinders	4F or 4C (5204)
" 6	Head Count	03	Reserved	00
" 7	Sect/Track (depends on Jumpers)	?	Sect/Track	10
" 8	Write Precomp	00	Head Settling Time	0B
" 9	" "	80	Write Precomp	00
" 10	Reduce Write Curr.	00	Retry Count	00
" 11	"	80	Not Applied	00
" 12	Step High	3C	Step Rate (3ms)	04
" 13	Step Low	09	Reserved	00
" 14	Reserved	00	Reserved	00
" 15	LUN FLAG	8?	LUN FLAG	A5

LUN FLAG Byte Bit Assignment (Byte 15)

7	6	5	4	3	2	1	0

Undefined

00 = 512 Bytes/sect
     (18 sect/track)
01 = 256
10 = 512 (17 sect/track)
11 = 1024

DRIVE TYPE
00 = ST506/412
01 = Floppy
10 = Reserved
11 = Tape

0 = Soft Sector for ST506/412
0 = MFM recording for Floppies
1 = Hard Sector for ST506/412
1 = FM recording for Floppies

For ST506/412 Drives
00 = Fixed
01 = Reserved
10 = Fixed/Removable
11 = Removable

For Flexible Disk Drives
Bit 5 = 1 = Cylinder 0 side 0 FM recording
Bit 6 = 1 = 8 inch format
Bit 6 = 0 = 5 1/4 inch format

VALID ERROR CODES

NONE

7.8.5 WRITE DATA BUFFER Command (HEX EF)

This command causes data to be written from the host to the
controller data buffer.   The LUN can be any number since no
device participates however, the number of bytes written is
determined by the block size for the specified LUN.   The host
can use this command preceding a READ DATA BUFFER command to
verify a READ/WRITE sequence without device participation.

```
         WRITE DATA BUFFER  Command Descriptor Block
              7    6    5    4    3    2    1    0
   BYTE 1 |  1    1    1    0    1    1    1    1  |
   BYTE 2 |    0   |  LUN   |    NOT USED         |
   BYTE 3 |             NOT USED                  |
   BYTE 4 |             NOT USED                  |
   BYTE 5 |             NOT USED                  |
   BYTE 6 |           CONTROL BYTE                |
```

VALID ERROR CODES

NONE

7-38

SECTION 8

TAPE COMMANDS

8.1 GENERAL

The OMTI 5300 and 5400 controllers support a QIC-02 Cartridge Tape drive interface, which is an intelligent device level interface to a Streaming Tape Drive.

8.1.1 Drive Type

A streaming drive is a tape drive that is designed to maintain continuous tape motion without the requirement to start and stop within an interrecord gap. If the tape motion is interrupted for any reason, the drive must reposition the tape by moving far enough in the reverse direction to allow the tape to be brought up to speed in the forward direction before it reaches the point at which the preceding operation was terminated.

8.1.2 Data Bus

Data and commands are transferred to and from the QIC-02 device on an eight-bit bidirectional data bus with an asynchronous handshake to eliminate rigorous timing constraints. The controller includes an internal 8K buffer to optimize streaming operations during BACKUP and RESTORE commands between disk and tape.

The recording of information on the tape is performed in the Sequential mode.

Accessing information on the tape may be performed either in Sequential or, when reading, in a Direct mode. The difference between the two modes is the positioning scheme. In the Sequential mode, data is transferred from the current tape position. In the Direct mode, the controller allows the user to specify the location on the tape from which the transfer of data will take place. See Read operations (8.5).

8.1.3 Data Integrity

The ability to enable or disable the tape drive bus parity is jumper selectable.

8.1.4 Host/Controller/Drive Communication

The tape drive can be commanded by the host, through a set of
commands, to either rewind the cartridge to the BOT (beginning
of tape), erase the cartridge, write data and file marks onto
the tape, read data and/or file marks from the tape, verify the
tape, backup data from a disk, or restore data onto the disk
connected to the same controller. The host may request sense
information from the controller/tape drive to obtain status.

8.1.5 Media

The tape media is an industry-standard one quarter inch (1/4")
cartridge, recorded bi-directionally on serpentine tracks.

8.1.6 Tape Format

The minimum length of data accessible by the controller is a
block. Blocks have a fixed length of 512 bytes. A group of
blocks constitute a file. Each READ or WRITE command specifies
the number of blocks to access. Files are separated by file
marks.

A header may optionally be written at the beginning of the tape
to label a cartridge or provide for an Initial Program Load
(IPL) block.

<p align="center">TAPE FORMAT</p>
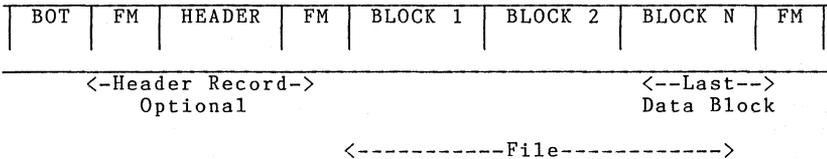
```
| BOT | FM | HEADER | FM | BLOCK 1 | BLOCK 2 | BLOCK N | FM |

        <-Header Record->                    <--Last-->
            Optional                         Data Block

                        <-----------File------------>

FM = File Mark
```

<p align="center">BLOCK FORMAT (QIC 24)</p>

```
| GAP | SYNC | 512 BYTES DATA BLOCK | BLOCK ADDRESS | CRC |
```
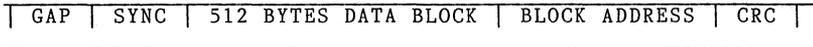
8.1.7 Header

The HEADER is an optional field that is used to identify and
label cartridges. It is written to the first 512 byte block of
the cartridge. The contents of this block are user defined.
Issuing the WRITE HEADER command rewinds the tape to BOT,
erases the entire tape, rewinds, records a File Mark then
records the header followed by a File Mark. Therefore, any
prewritten data on the cartridge is lost. The controller allows
only one header per cartridge. The host software must implement
the READ HEADER command to identify the information in a
HEADER.

A cartridge does not necessarily need a HEADER to be useable.
It is not recommended to use these two commands in new software
design.

8.1.8 Controller Block Count

Starting from BOT, if no header is recorded, or starting from
the first block after the header, the controller will increment
a counter for each block accessed in the forward direction.
Blocks and File Marks are counted in the same fashion in this
counter. This counting occurs either in Sequential or Direct
modes. See READ OPERATIONS paragraph (Section 8.3.5). The
counting also takes place with the space command.

8.1.9 Operational Warnings

o   The BACKUP and RESTORE commands will report an "ERROR 21"
     (invalid parameter), if the Disk sector size is 1024 bytes,
     and the Tape block count is odd.

o   Write Protect Status: If a cartridge was write protected,
     and the user removes it, when the cartridge is replaced,
     two consecutive REQUEST SENSE, or READ SENSE commands are
     needed to get "no write protect" status reported in the
     sense bytes.

o   Exception Condition with File Mark encountered,
     unexpectedly, with the READ and RESTORE commands: Because
     the Tape Formatter may read more blocks from the Tape
     drive than the READ or RESTORE commands ask for, an exception
     condition may be generated from the Tape Drive for a File
     Mark detected by the Tape Formatter in the block count limit
     requested. This situation is more likely to occur with tape
     formatters containing a large buffer. This should not
     be considered as an error condition.

o   When an End of Tape Exception Condition is encountered in a
     WRITE mode, one File Mark followed by one Tape Block and
     another File Mark are allowed to be written after EOT.

8.2 TAPE COMMANDS

8.2.1 Command Phase

The command process for the Tape drive is similar to the
command process for the Disk drives, except that some Tape
commands require more bytes (10 or 12) to be transferred during
the command phase.

In the tables of this section, all bits specified as "Reserved"
should be set to zero.

LUN 3

The Logical Unit Number (LUN) specified in byte 2 of all
exclusively Tape related commands is three (3), with bits 5 and
6 set to 1. All BACKUP and RESTORE commands imply the use of
LUN 3.

6 BYTE COMMAND FORMAT (Sequential Mode)

	7	6	5	4	3	2	1	0
BYTE 1	COMMAND CODE							
BYTE 2	0	1	1	0	0	0	0	0
BYTE 3	BLOCK COUNT (MSB)							
BYTE 4	BLOCK COUNT							
BYTE 5	BLOCK COUNT (LSB)							
BYTE 6	CONTROL BYTE							

These above commands offer up to 16 MegaBlocks per Command.

6 BYTE COMMAND FORMAT (Direct Read Mode)

	7	6	5	4	3	2	1	0
BYTE 1	COMMAND CODE							
BYTE 2	0	1	1	TAPE LOGICAL BLOCK ADDR (MSB)				
BYTE 3	TAPE LOGICAL BLOCK ADDRESS							
BYTE 4	TAPE LOGICAL BLOCK ADDRESS (LSB)							
BYTE 5	BLOCK COUNT							
BYTE 6	CONTROL BYTE							

The 6 byte READ commands (Direct Mode) are limited to transfer
up to 256 Blocks, and limited to 21 bit addressing.

```
                    10 BYTE COMMAND FORMAT
                  7   6   5   4   3   2   1   0
   BYTE  1 |             COMMAND CODE             |
   BYTE  2 | 0 | DISK LUN | DISK LOGICAL BLOCK ADDR (MSB)|
   BYTE  3 |         DISK LOGICAL BLOCK ADDRESS        |
   BYTE  4 |      DISK LOGICAL BLOCK ADDRESS (LSB)      |
   BYTE  5 |               ZERO VALUE                  |
   BYTE  6 |               ZERO VALUE                  |
   BYTE  7 |          TAPE BLOCK COUNT (MSB)           |
   BYTE  8 |             TAPE BLOCK COUNT              |
   BYTE  9 |          TAPE BLOCK COUNT (LSB)           |
   BYTE 10 |               CONTROL BYTE                |
```

These commands offer a Block count of 3 bytes for up to 16 Megablocks per command.

```
            12 BYTE COMMAND FORMAT (RESTORE CONTINUE)
                  7   6   5   4   3   2   1   0
   BYTE  1 |             COMMAND CODE             |
   BYTE  2 | 0 | DISK LUN | DISK LOGICAL BLOCK ADDR (MSB)|
   BYTE  3 |         DISK LOGICAL BLOCK ADDRESS        |
   BYTE  4 |      DISK LOGICAL BLOCK ADDRESS (LSB)      |
   BYTE  5 |               ZERO VALUE                  |
   BYTE  6 | TAPE STARTING LOGICAL BLOCK ADDR (MSB)     |
   BYTE  7 | TAPE STARTING LOGICAL BLOCK ADDRESS        |
   BYTE  8 | TAPE STARTING LOGICAL BLOCK ADDR (LSB)     |
   BYTE  9 |          TAPE BLOCK COUNT (MSB)           |
   BYTE 10 |             TAPE BLOCK COUNT              |
   BYTE 11 |          TAPE BLOCK COUNT (LSB)           |
   BYTE 12 |               CONTROL BYTE                |
```

This command offers a Block count of 3 bytes for a transfer of up to 16 Megablocks per command. The Tape Block size is 512 bytes. The Disk Block size may be different. The value of the Disk Block size is selected by jumpers.

CONTROL BYTE

The Control Byte is the last byte of all commands.

CONTROL BYTE FORMAT

7	6	5	4	3	2	1	0
DR	DC	SR	0	0	0	0	LK

DR - Disable Retry: Bit 7, if set to one, will disable the controller automatic retries. This bit 7 is valid for those commands involving a disk. This is only to be used for test or evaluation purposes.

DC - Disable Correction: Bit 6, if set to one, will disable the disk automatic error correction with the ECC algorithm. This is to be used only for disk media evaluation or test purposes.

SR - Sequential Record: Bit 5, if set to zero will cause a File Mark to be written when the block count of the command is exhausted; if set to one and if the command code is WRITE BLOCKS (4A), READ BLOCKS (4B), BACKUP (22), or RESTORE (23) then this flag can have two possible meanings:

- During a READ, the controller will start to read at the current tape position, therefore read the next block. This is called the Sequential Mode.

- During a WRITE, the controller will start to write at the current position, and a File Mark will not be written on the tape at completion of the WRITE or BACKUP command execution. This allows segmented Disk files to be backed up onto the Tape on a contiguous file without File Marks separating every segment of the file. When the last segment is transferred with the last command issued, the user should set bit 5 (SR) of the Control Byte to zero. This automatically records a File Mark. If Bit 5 is set to zero and an error occurs before the block count of the command is exhausted, a File Mark will _not_ be written on the tape.

LK - Link Command: Bit 0, upon successful completion of the command, if this bit is set to one, the controller will enter the command phase and request command bytes for the next linked command to be executed. Linking commands avoids entering the Selection phase again, and keeps control of the bus to the same host/controller.

WARNING: It is recommended not to link commands such as REWIND, RETENTION, or ERASE (for which the SCSI Busy line is deasserted during Tape motion) to other commands. Doing so could result in Busy status error to the linked commands. This is due to the fact that the Tape drive is performing offline mechanical functions which cause it to be busy to the controller. This could cause the drive to be busy for up to several minutes.

8.2.2 STATUS Phase

COMPLETION STATUS BYTE FORMAT

7	6	5	4	3	2	1	0
0	LUN		0	0	0	CC	PE

CC – Check Condition
PE – SCSI BUS Parity Error

Status is always sent to the host during the Status Phase, at the end of a command, in a single byte called "Completion Status Byte".

A value of zero in bits 0 (PE) and 1 (CC) indicates a successful command completion.

Any abnormal condition encountered during the command execution will cause command termination and ending status with the Check Condition (bit 1) set to one.

Any SCSI BUS Parity Error (PE, bit 0) encountered during the transfer of bytes from the host will cause command termination and ending status with the Parity error bit 0 set to one.

Bits 5 and 6 report the LUN address of the device originating the error condition or the LUN to which the command was issued. If a disk error occurs, the disk LUN is reported in the Completion Status byte, if a Tape error occurs, the tape LUN (3) is reported.

If the Check Condition status (CC, bit 1) is set, the host should issue the REQUEST SENSE command to determine the nature of the condition.

NOTE: The status byte is not the last byte transferred by the controller. The Host Adapter should not generate the Interrupt for the command when receiving this byte but instead should wait for the Command Complete message (HEX 00) issued in the next Message In phase.

8.2.3 MESSAGE IN Phase

Every command ends with the Message In phase. The 5000 series controllers send a single byte to the host during this phase, with the value of zero, indicating "Command Complete".

8.2.4 TAPE COMMAND SET SUMMARY

COMMAND TYPE	CODE (HEX)	COMMAND BYTES	DATA LENGTH
TEST UNIT READY	00	6	0
REWIND	01 & 4F	6	0
RETENTION	02 & 44	6	0
REQUEST SENSE	03	6	4 to 12 bytes
READ	08	6	up to 16 M blocks
WRITE	0A	6	up to 16 M blocks
WRITE FILE MARK	10 & 4C	6	0
SPACE FORWARD	11 & 4D	6	0
VERIFY	13 & 45	6	0
ERASE	19 & 4E	6	0
BACKUP	22	10	up to 16 M blocks
RESTORE	23	10	up to 16 M blocks
BACKUP WITH HEADER *	24	10	up to 16 M blocks
RESTORE CONTINUE *	26	12	up to 16 M blocks
READ SENSE *	46	6	8 bytes
WRITE HEADER *	48	6	512 bytes
READ HEADER *	49	6	512 bytes
WRITE BLOCKS *	4A	6	up to 256 blocks
READ BLOCKS *	4B	6	up to 256 blocks

* These commands, compatible to earlier controller models, are recommended to be avoided in new software design.

8.3 COMMAND SET

8.3.1 TEST UNIT READY Command (HEX 00)

This command returns a zero status during the Status phase of the command execution to indicate that the unit is on line and ready.

TEST UNIT READY Command Descriptor Block

	7	6	5	4	3	2	1	0
BYTE 1	0	0	0	0	0	0	0	0
BYTE 2	0	1	1	0	0	0	0	0
BYTE 3			ZERO VALUE					
BYTE 4			ZERO VALUE					
BYTE 5			ZERO VALUE					
BYTE 6	0	0	0	0	0	0	0	LK

VALID ERROR CODES

Drive not Ready	(HEX 04)
Drive not Selected	(HEX 05)
Operation in Progress	(HEX 0D)

8.3.2 REWIND Command (HEX 01) and (HEX 4F)

The unit is rewound to the beginning of tape (BOT). Status is returned as soon as the tape motion is initiated. Overlap operations with the disk drives connected to the other ports is allowed during the tape motion. If a REWIND command is issued after a WRITE command and a File Mark has not been written, the controller will automatically write a File Mark before initiating the rewind. The code (4F) provides software compatibility to an earlier controller model. It is recommended to use code 01 for new software implementation.

REWIND Command Descriptor Block

	7	6	5	4	3	2	1	0
BYTE 1	0	0	0	0	0	0	0	1
BYTE 2	0	1	1	0	0	0	0	0
BYTE 3	ZERO VALUE							
BYTE 4	ZERO VALUE							
BYTE 5	ZERO VALUE							
BYTE 6	0	0	0	0	0	0	0	LK

VALID ERROR CODES

Drive not Ready	(HEX 04)
Drive not Selected	(HEX 05)
Operation in Progress	(HEX 0D)
Tape Exception	(HEX 10)

8.3.3 RETENTION Command (HEX 02) and (HEX 44)

The unit rewinds to the beginning of tape (BOT), if not already
positioned at the load point, then moves from the BOT to the
end of tape (EOT) without transferring any data or altering
the contents of the cartridge, then rewinds to the BOT. Status
for the command is returned as soon as the tape motion is
initiated, allowing host/controller to overlap operations with
the disk drives connected to the other controller ports.   The
code (44) is provided for software compatibility with an
earlier controller model. It is recommended to use code 02 for
new software design.

RETENTION Command Descriptor Block

	7	6	5	4	3	2	1	0
BYTE 1	0	0	0	0	0	0	1	0
BYTE 2	0	1	1	0	0	0	0	0
BYTE 3	ZERO VALUE							
BYTE 4	ZERO VALUE							
BYTE 5	ZERO VALUE							
BYTE 6	0	0	0	0	0	0	0	LK

VALID ERROR CODES

Drive not Ready	(HEX 04)
Drive not Selected	(HEX 05)
Tape Exception	(HEX 10)

8.3.4 REQUEST SENSE Command (HEX 03)

The sense information returned during the Data In phase of this
command execution is valid for the Check Condition Status just
presented to the host. Sense data will be cleared upon
reception of any subsequent command issued to the LUN or
cleared by a Reset condition.

The host must be able to receive a minimum of 4 sense bytes and
a maximum of 12 bytes. Byte 5 of the CDB will specify the
number of bytes that the host has allocated for returned sense.
If byte 5 is less than or equal to four, the controller will
return four bytes of sense data, otherwise it will return the
required number of bytes between four and twelve, with the
following condition: up to 4 bytes are returned for Disks; up
to 12 bytes are returned for Tape. If more than 12 bytes are
requested in byte 5, the Data phase will stop after the 12th
byte.

REQUEST SENSE Command Descriptor Block

	7	6	5	4	3	2	1	0
BYTE 1	0	0	0	0	0	0	1	1
BYTE 2	0	1	1	0	0	0	0	0
BYTE 3	ZERO VALUE							
BYTE 4	ZERO VALUE							
BYTE 5	NUMBER OF SENSE BYTES ALLOCATED (MAX. 12)							
BYTE 6	0	0	0	0	0	0	0	LK

SENSE BYTES: The following bytes are returned to the host
during the Data In phase of the command execution.

SENSE BYTE FORMAT (Sequential Read Mode)

	7	6	5	4	3	2	1	0
BYTE 1	SENSE CODE							
BYTE 2	0	1	1	BLOCK COUNT ACCESSED (MSB)				
BYTE 3	BLOCK COUNT ACCESSED							
BYTE 4	BLOCK COUNT ACCESSED (LSB)							
BYTE 5	TAPE SENSE BYTE 0							
BYTE 6	TAPE SENSE BYTE 1							
BYTE 7	TAPE SENSE BYTE 2							
BYTE 8	TAPE SENSE BYTE 3							
BYTE 9	TAPE SENSE BYTE 4							
BYTE 10	TAPE SENSE BYTE 5							
BYTE 11	TAPE SENSE BYTE 6							
BYTE 12	TAPE SENSE BYTE 7							

SENSE BYTE FORMAT (Direct Read Mode)

```
              7    6    5    4    3    2    1    0
    BYTE  1  |           SENSE CODE              |
    BYTE  2  | 0  |   LUN   | LOGICAL  BLOCK  ADDRESS (MSB)|
    BYTE  3  |       LOGICAL BLOCK ADDRESS       |
    BYTE  4  |       LOGICAL BLOCK ADDRESS (LSB) |
    BYTE  5  |        TAPE SENSE BYTE 0          |
    BYTE  6  |        TAPE SENSE BYTE 1          |
    BYTE  7  |        TAPE SENSE BYTE 2          |
    BYTE  8  |        TAPE SENSE BYTE 3          |
    BYTE  9  |        TAPE SENSE BYTE 4          |
    BYTE 10  |        TAPE SENSE BYTE 5          |
    BYTE 11  |        TAPE SENSE BYTE 6          |
    BYTE 12  |        TAPE SENSE BYTE 7          |
```

CONTROLLER SENSE BYTE 1: SENSE CODE

```
BITS         7    6    5    4    3    2    1    0
            | AV |  0  |  TYPE   |      CODE      |
```

AV: If AV is set to one the Logical Block address reported in
     bytes 2 to 4 is a valid address.

SENSE TYPE

Bits	5	4	Meaning
	0	0	Drive Errors
	0	1	Data Errors
	1	0	Command Errors
	1	1	Diagnostic Errors

CONTROLLER SENSE CODES - TAPE DRIVE ERRORS - TYPE 0:

MEANING	HEX
NO ERROR	00
DRIVE NOT READY	04
DRIVE NOT SELECTED	05
OPERATION IN PROGRESS	0D

CONTROLLER SENSE CODES - TAPE DATA ERRORS - TYPE 1

MEANING	HEX
TAPE EXCEPTION	10
WRITE PROTECTED	17 & 97
TAPE DRIVE FAILURE	1F

Note: Tape Exception is not necessarily an error.

CONTROLLER SENSE CODES - TAPE COMMAND ERRORS - TYPE 2

MEANING	HEX
INVALID COMMAND	20
ILLEGAL FUNCTION	22
FOR DRIVE TYPE	

CONTROLLER SENSE CODES - TAPE DIAGNOSTIC ERRORS - TYPE 3

MEANING	HEX
POWER UP DIAGNOSTIC ERROR	30

SENSE BYTE 2 (Bits 6 and 5): LUN of the drive.

SENSE BYTES 2 TO 4:

- Sequential Read Mode: These bytes report the number of Blocks accessed. When requesting access to more blocks than recorded, the difference between the Block Count of the command and Sense bytes 2 through 4, computed by the host software, would provide the remaining block count requested.

- Direct Read Mode: These bytes report the address of the next Tape Block if the command completed successfully, or if it ended with an Exception Condition with "File Mark detected". If the command completed with an Exception Condition with no "File Mark detected", these bytes report the address of the erroring block.

When a File Mark is detected, the Tape drive always positions the tape so that the File Mark is past the head. Therefore, at the end of a READ BLOCKS Command terminating with "File Mark detected", the File Mark will be counted as a block and bytes 2 to 4 will report the address of the next Tape block.

- SPACE command: These bytes report the number of Blocks spaced with the Block Mode or the number of File Marks spaced with the File Mark Mode.

Note: If a permanent tape error occurs during a RESTORE command, the logical sector address points to the sector in error + 1.

8-13

TAPE SENSE BYTES

The next 6 Bytes come from the Tape Formatter, as specified in the
QIC-02 specifications. The last two Tape Sense Bytes are generated
by the controller. The Exception condition bit 7 of bytes 1,2,6,
and 7 is set to one only if this byte contains an error condition
or the tape has to report a physical event. More than one byte may
have bit 7 set to one.

Note: When Operation in Progress error (HEX 0D) is returned by a
REQUEST SENSE or READ SENSE command, only bytes 6 and 7
of the Tape Sense bytes reported are valid, and the other six Tape
Sense bytes are meaningless.

TAPE SENSE BYTE 0

BIT 7   Exception condition (at least 1 of bits 0-6 is on)
BIT 6   Cartridge not installed
BIT 5   Unselected Tape drive
BIT 4   Write Protected cartridge
BIT 3   End of media (EOT)
BIT 2   Unrecoverable data error
BIT 1   Bad block not located
BIT 0   File Mark detected

TAPE SENSE BYTE 1

BIT 7   Exception condition (at least 1 of bits 0-6 is on)
BIT 6   Illegal QIC 02 command
BIT 5   No data detected
BIT 4   Reserved
BIT 3   Beginning of media (BOT)
BIT 2   Reserved
BIT 1   Reserved
BIT 0   Power On Reset occurred

TAPE SENSE BYTES 2 and 3

- The number of blocks rewritten by the controller
recovery procedure, for WRITE and VERIFY commands.

- The number of READ retries exercised by the controller
recovery procedure.

The most significant byte is 2.

TAPE SENSE BYTES 4 and 5 (Underflow Counter)

- These bytes indicate the number of times streaming operations were interrupted due to host failure to maintain minimum throughput rate. The most significant byte is byte 4.

The following two bytes are prepared by the controller itself, not by the Tape Formatter.

TAPE SENSE BYTE 6

BIT 7   Exception Condition (at least 1 of bits 0-6 is on)
BIT 6   DMA time out during handshake on the QIC 02 bus
BIT 5   Reserved
BIT 4   No header found (only with READ HEADER command)
BIT 3   Drive disconnected
BIT 2   Reserved
BIT 1   Reserved
BIT 0   Tape Parity error

TAPE SENSE BYTE 7

BIT 7   Exception Condition (at least 1 of bits 0-6 is on)
BIT 6   Reserved
BIT 5   Reserved
BIT 4   Rewind in progress
BIT 3   End of data recorded on the tape
BIT 2   Reserved
BIT 1   See table below
BIT 0   See table below

Bits	1	0	Meaning
	0	0	Off Line
	0	1	On Line (Default to READ if Bit 1=0)
	1	0	Illegal
	1	1	Write operation in progress

8.3.5   READ OPERATIONS

The Controller offers two methods to read data from the Tape.
The user may use either:

- the READ command code (HEX 08) in the Sequential Mode, or
- the READ BLOCK(S) command code (HEX 4B) in the Direct Mode.

Comparison

- The READ command (HEX 08) reads blocks of data starting at
the current tape position, that is, the next block of the
unit. The media has to be previously positioned at the
starting block prior to issuing the READ command. The
positioning can be achieved with the SPACE command.

- The READ BLOCK(S) command (HEX 4B) accesses the blocks of
data with an implied tape search to a specified starting
logical block address, similar to a disk command with an
implied seek. The controller counts each block, counting File
Marks as blocks, and allocates a logical block address from
BOT to all blocks accessed. Therefore when receiving the READ
BLOCK(S) (4B) command, in which the user specifies the logical
block address of the starting block, the controller determines
if a rewind or forward motion is necessary to reach the first
block. If the starting block address is greater than the
current head position, the controller will rewind the tape to
BOT, then will move the tape forward counting blocks until the
specified starting block is reached. This approach allows
access to the data faster than if the tape had to be rewound
first, then spaced forward, until the starting block is
reached. The host software is to keep track of the starting
block address of the files such as the disk directories
usually do. Specific Block(s) of data inside a file may be
accessed in a Direct Mode, but cannot be accessed in a
Sequential Mode.

8.3.6   READ Command (HEX 08) (Sequential Mode only)

The READ command transfers the specified Block Count to the host, starting with the next block of the unit. Blocks are transferred until either the Block count is exhausted, or a File Mark is encountered, or the End of Tape (EOT) is encountered. The last two conditions create an Exception condition, and the Block Count read is available in the Sense Bytes. Up to 16 Megablocks can be transferred by a single command.

READ Command Descriptor Block

	7	6	5	4	3	2	1	0
BYTE 1	0	0	0	0	1	0	0	0
BYTE 2	0	1	1	0	0	0	0	0
BYTE 3	BLOCK COUNT (MSB)
BYTE 4	BLOCK COUNT
BYTE 5	BLOCK COUNT (LSB)
BYTE 6	DR	DC	0	0	0	0	0	LK

VALID ERROR CODES

Drive not ready   (HEX 04)
Drive not selected   (HEX 05)
Tape exception   (HEX 10)

8.3.7 WRITE Command (HEX 0A)

The WRITE command transfers the specified number of blocks from the host, starting at the current position, that is, the next block of the unit. The operation terminates when the number of blocks to be transferred is exhausted, or when the Tape Formatter recovery procedure of unsuccessful retries of rewrite has been exhausted, or when the end of the media (EOT) is encountered. The last two conditions create an exception condition, and the Block Count written will be available in the Sense Bytes.

WRITE Command Descriptor Block

	7	6	5	4	3	2	1	0
BYTE 1	0	0	0	0	1	0	1	0
BYTE 2	0	1	1	0	0	0	0	0
BYTE 3	BLOCK COUNT (MSB)							
BYTE 4	BLOCK COUNT							
BYTE 5	BLOCK COUNT (LSB)							
BYTE 6	DR	DC	0	0	0	0	0	LK

VALID ERROR CODES

Drive not Ready	(HEX 04)
Drive not Selected	(HEX 05)
Tape Exception	(HEX 10)
Write Protected	(HEX 17 and 97)

8.3.8   WRITE FILE MARK(S) Command (HEX 10) and (HEX 4C)

This command causes the specified number of File Marks to be written onto the cartridge. A zero value in bytes 3 to 5 indicate that no File Mark is to be written. File Marks can be searched by SPACE FORWARD commands. The code (4C) provides software compatibility to an earlier controller model. It is recommended to use the code 10 with new software design.

Note that if the Control Byte SR bit 5 had been set to zero in the previous WRITE BLOCKS (4A HEX), BACKUP (22 HEX) or BACKUP with HEADER (24 HEX) commands, a File Mark was written when the Block Count was exhausted. Therefore, if the host software issues a WRITE FILE MARK command with a File Mark count of one, two consecutive File Marks will be recorded onto the cartridge.

WRITE FILE MARK(S) Command Descriptor Block

	7	6	5	4	3	2	1	0
BYTE 1	0	0	0	1	0	0	0	0
BYTE 2	0	1	1	0	0	0	0	0
BYTE 3	FILE MARK COUNT (MSB)							
BYTE 4	FILE MARK COUNT							
BYTE 5	FILE MARK COUNT (LSB)							
BYTE 6	DR	DC	0	0	0	0	0	LK

VALID ERROR CODES

Drive not Ready	(HEX 04)
Drive not Selected	(HEX 05)
Tape Exception	(HEX 10)
Write Protected	(HEX 17 and 97)

8.3.9   SPACE FORWARD Command (HEX 11) and (HEX 4D)

This command covers three positioning modes. It moves the tape forward:

- over the subsequent data Block(s), (Block Mode),
- over the subsequent File Mark(s), (File Mark Mode), or
- to the physical end of the data (Physical End of Data Mode).

The mode must be specified in byte 2 of the command. The number of Blocks or File Marks to space is specified in bytes 3 to 5. If the value of these bytes is zero, no tape motion will be initiated. The code (4D) provides software compatibility to an earlier controller model.   It is recommended to use code 11 with new software design.

Block Mode: Up to three bytes of Block Count may be spaced. The controller will not skip more blocks after reaching a File Mark. Reaching a File Mark creates an Exception condition. The media will remain positioned after the File Mark. The sense bytes 2 to 4 will specify the number of blocks spaced, if less than the command Block Count.

File Mark Mode: Up to three bytes of File Mark Count may be spaced.   The media will remain positioned after the last File Mark spaced, or at the End of Tape, if reached. If the end of media is encountered, an Exception condition is created, and the Sense bytes 2 to 4 indicate the number of File Mark(s) spaced.

NOTE: The controller remains Busy while executing the spacing, in all three modes, except under one condition. With the File Mark Mode set, if bit 7 (SP) of the control byte is set to one, the block count is ignored, the controller will release the Busy signal of the SCSI bus right after receiving the command. The Tape will move and search for a File Mark. Repetitive SPACE FORWARD commands in this "off line" mode may be issued until no more data is recorded (EOD). The tape will then remain positioned after the last block or File Mark recorded. Writing, or Backing up new data is then allowed from this location. The Tape Sense Bytes report the Physical End of Data. The controller will not analyse bytes 3 to 5 in this mode. During the "off line" spacing operations, the winchester and/or floppy drives can be accessed for other operations.

8-20

Physical End of Data Mode: The controller will move the tape
forward, toward the end of media, until no more data is
recorded (EOD). The tape will then remain positioned after the
last block or File Mark recorded. Writing, or Backing up new
data is then allowed from this location. The Tape Sense Bytes
report the Physical End of Data. The controller will not
analyze bytes 3 to 5 in this mode.

SPACE FORWARD Command Descriptor Block

	7	6	5	4	3	2	1	0
BYTE 1	0	0	0	1	0	0	0	1
BYTE 2	0	1	1	0	0	0	CODE	
BYTE 3	BLOCK(s) or FILE MARK(s) COUNT (MSB)							
BYTE 4	BLOCK(s) or FILE MARK(s) COUNT							
BYTE 5	BLOCK(s) or FILE MARK(s) COUNT (LSB)							
BYTE 6	SP	0	0	0	0	0	0	LK

BYTE 2 CODE

Bits	1	0	Meaning
	0	0	Block Mode
	0	1	File Mark Mode
	1	1	Physical End of Data Mode

VALID ERROR CODES

Drive not Ready	(HEX 04)
Drive not Selected	(HEX 05)
Tape Exception	(HEX 10)

8.3.10 VERIFY Command (HEX 13) or (HEX 45)

This command verifies the entire media, from the beginning of tape (BOT) to the end of tape (EOT). The pattern (E5) is written. The Tape Formatter performs a CRC check on every block. When reaching the EOT, the tape rewinds. The media will be erased, from BOT to EOT. Finally, the tape is rewound. The user may then issue the REQUEST SENSE command to obtain the number of blocks rewritten during the Verify process is available in the Tape Sense bytes 2 and 3.

The code (HEX 45) provides software compatibility with an earlier controller model. It is recommended to use code 13 with new software design.

If the read after write drive function detects a bad block, rewrite will occur. If the Tape Formatter exhausts its rewrite count, and the procedure is still unsuccessful, the process stops, and an Exception condition is created.

VERIFY Command Descriptor Block

	7	6	5	4	3	2	1	0
BYTE 1	0	0	0	1	0	0	1	1
BYTE 2	0	1	1	0	0	0	0	0
BYTE 3			ZERO VALUE					
BYTE 4			ZERO VALUE					
BYTE 5			ZERO VALUE					
BYTE 6	DR	DC	0	0	0	0	0	LK

VALID ERROR CODES

Drive not Ready	(HEX 04)
Drive not Selected	(HEX 05)
Tape Exception	(HEX 10)
Write Protected	(HEX 17 and 97)

8.3.11 ERASE Command (HEX 19) and (HEX 4E)

This command erases the entire media, from BOT to EOT, then
rewinds the tape. Status for the command is returned as soon as
the tape motion is initiated, allowing host/controller to
overlap operations with the disk drives connected to the other
controller ports. The code (4E) provides software
compatibility to an earlier controller model. It is
recommended to use code 19 with new software design.

ERASE Command Descriptor Block

	7	6	5	4	3	2	1	0
BYTE 1	0	0	0	1	1	0	0	1
BYTE 2	0	1	1	0	0	0	0	0
BYTE 3			ZERO	VALUE				
BYTE 4			ZERO	VALUE				
BYTE 5			ZERO	VALUE				
BYTE 6	0	0	0	0	0	0	0	LK

VALID ERROR CODES

Drive not Ready	(HEX 04)
Drive not Selected	(HEX 05)
Tape Exception	(HEX 10)
Write Protected	(HEX 17 and 97)

8.3.12 BACKUP Command (HEX 22)

This command will backup data from the Disk Drive, as specified
by the DISK LUN, to the tape drive in a streaming fashion, and
for the specified number of blocks.
Disk:
The read operation from the disk starts at the specified
logical disk block address and continues for the specified
number of blocks. A volume overflow will stop the operation.
Only valid data is backed up from the disk. Automatic
handling of media defects, including retries (if not disabled),
ECC correction (if not disabled), and alternate track
accessing, are initiated by the controller.
Tape:
The data is written starting at the current Tape position, that
is, the next block. An End of Tape (EOT) will stop the
operation. If the tape is positioned at BOT, and if a header is
recorded, the first block will be written after the header and
its File Mark.
Whenever streaming cannot be maintained (i.e., because the disk
had to access an alternate track, the Tape Formatter will move
the tape in the reverse direction, and stop. When the disk data
buffer allows streaming again, the tape will move forward, come
up to proper speed, and will continue recording. If bit 5 SR of
the Control Byte is set to zero, when the block count is
exhausted, a File Mark is written at the current tape position.
If this bit is set to one, no File Mark is written, and the
tape remains at its current position.
The Tape Block Size is 512 bytes. The Disk Block Size may be
different, and have its value selected by jumper. If the Disk
block size is 1024 bytes, the Tape Block Count must be even, or
the controller generates an Illegal Parameter error.

BACKUP Command Descriptor Block

	7	6	5	4	3	2	1	0
BYTE 1	0	0	1	0	0	0	1	0
BYTE 2	0	DISK LUN		DISK LOGICAL BLOCK ADDR (MSB)				
BYTE 3	DISK LOGICAL BLOCK ADDRESS							
BYTE 4	DISK LOGICAL BLOCK ADDRESS (LSB)							
BYTE 5	ZERO VALUE							
BYTE 6	ZERO VALUE							
BYTE 7	TAPE BLOCK COUNT (MSB)							
BYTE 8	TAPE BLOCK COUNT							
BYTE 9	TAPE BLOCK COUNT (LSB)							
BYTE 10	DR	DC	SR	0	0	0	0	LK

VALID TAPE ERROR CODES

Drive not Ready	(HEX 04)
Drive not Selected	(HEX 05)
Tape Exception	(HEX 10)
Write Protected	(HEX 17 and 97)
Illegal Parameter	(HEX 21)

For Disk errors refer to Section 7.

8.3.13 RESTORE Command (HEX 23)

This command restores data from the Tape drive to the Disk drive specified by the DISK LUN, in a streaming fashion, and for the specified number of blocks.

Disk:
The write operation to the Disk starts at the specified logical disk block address, for a specified number of blocks. A volume overflow will stop the operation. Automatic handling of media defects, including retries (if not disabled), and alternate track addressing are initiated by the controller.

Tape:
The data is read starting at the current Tape location, that is, the next block. The access mode to the data is Sequential only. A File Mark encountered stops the operation. If the tape is positioned at BOT, and if a header is recorded, the first block will be read after the header and its File Mark.

Whenever streaming cannot be maintained (i.e., because the disk had to access an alternate track), the Tape Formatter stops the tape, moves the tape in the reverse direction, and stops. When the disk data buffer is available again for streaming, the tape will move forward, come up to proper speed, and will continue reading.

The Tape Block Size is 512 bytes. The Disk Block Size may be different, and have its value selected by jumper.

RESTORE Command Descriptor Block

	7	6	5	4	3	2	1	0
BYTE 1	0	0	1	0	0	0	1	1
BYTE 2	0	DISK	LUN	DISK	LOGICAL	BLOCK	ADDR	(MSB)
BYTE 3	DISK LOGICAL BLOCK ADDRESS							
BYTE 4	DISK LOGICAL BLOCK ADDRESS (LSB)							
BYTE 5	ZERO VALUE							
BYTE 6	ZERO VALUE							
BYTE 7	TAPE BLOCK COUNT (MSB)							
BYTE 8	TAPE BLOCK COUNT							
BYTE 9	TAPE BLOCK COUNT (LSB)							
BYTE 10	DR	DC	0	0	0	0	0	LK

VALID TAPE ERROR CODES

Drive not Ready	(HEX 04)
Drive not Selected	(HEX 05)
Tape Exception	(HEX 10)
Illegal Parameter	(HEX 21)

For Disk errors refer to Section 7.

8.3.14   BACKUP WITH HEADER Command (HEX 24)

This command is a combination of WRITE HEADER and BACKUP
commands. The tape is first rewound to BOT, then erased from
BOT to EOT, then rewound. The header is then recorded with its
File Marks similar to the WRITE HEADER command. The BACKUP
operation takes place last, in the same fashion as in the
BACKUP command. This command is compatible with an earlier
controller model. It is not recommended to use this command in
new software design.

BACKUP WITH HEADER Command Descriptor Block

	7	6	5	4	3	2	1	0
BYTE 1	0	0	1	0	0	1	0	0
BYTE 2	0	DISK LUN		DISK LOGICAL BLOCK ADDR (MSB)				
BYTE 3	DISK LOGICAL BLOCK ADDRESS							
BYTE 4	DISK LOGICAL BLOCK ADDRESS (LSB)							
BYTE 5	ZERO VALUE							
BYTE 6	ZERO VALUE							
BYTE 7	TAPE BLOCK COUNT (MSB)							
BYTE 8	TAPE BLOCK COUNT							
BYTE 9	TAPE BLOCK COUNT (LSB)							
BYTE 10	DR	DC	SR	0	0	0	0	LK

VALID TAPE ERROR CODES

Drive not Ready   (HEX 04)
Drive not Selected   (HEX 05)
Tape Exception   (HEX 10)
Write Protected   (HEX 17 and 97)
Illegal Parameter   (HEX 21)

For Disk errors refer to Section 7.

8.3.15   RESTORE CONTINUE Command (HEX 26)

This command restores data from the Tape drive to the Disk
drive, as specified by the DISK LUN, in a streaming fashion,
and for the specified number of blocks.
Rewind takes place first. Then the controller moves the tape to
the Tape starting Logical Block address, counting blocks in the
process.
This command differs from the RESTORE command in the way that
the data is read from the Tape starting at the Tape Logical
Block Address specified in the command (Direct Read Mode),
instead of starting at the current tape position.   The
operation of the command is similar to the RESTORE command
operation as far as Disk functions and error reports are
concerned.

```
            RESTORE CONTINUE Command Descriptor Block
                 7    6    5    4    3    2    1    0
       BYTE 1  | 0    0    1    0    0    1    1    0  |
       BYTE 2  | 0  | DISK LUN  | DISK LOGICAL BLOCK ADDR (MSB) |
       BYTE 3  |     DISK LOGICAL BLOCK ADDRESS               |
       BYTE 4  |     DISK LOGICAL BLOCK ADDRESS (LSB)         |
       BYTE 5  |              ZERO VALUE                      |
       BYTE 6  | TAPE STARTING LOGICAL BLOCK ADDRESS (MSB)    |
       BYTE 7  | TAPE STARTING LOGICAL BLOCK ADDRESS          |
       BYTE 8  | TAPE STARTING LOGICAL BLOCK ADDRESS (LSB)    |
       BYTE 9  | TAPE BLOCK COUNT (MSB)                       |
       BYTE 10 | TAPE BLOCK COUNT                             |
       BYTE 11 | TAPE BLOCK COUNT (LSB)                       |
       BYTE 12 | DR | DC | 0    0    0    0    0  | LK        |
```

Application: – Assuming that a Disk error occurred during a
RESTORE command, the operation stops. The Sense bytes report
the Disk logical block address. With this, the host software
computes, depending on the Disk block size, the Tape Block
Count transferred until the Disk error occured. Then the host
software determines at which Tape Starting Logical Block
Address, and starting Disk Logical Block address, and for what
remaining Tape Block count should the transfer of data
continue. This information is provided to the RESTORE CONTINUE
command. This command is compatible to an earlier controller
model. It is not recommended to use this command in new
software design.

VALID TAPE ERROR CODES

```
_____

Drive not Ready                           (HEX 04)
Drive not Selected                        (HEX 05)
Tape Exception                            (HEX 10)
Illegal Parameter                         (HEX 21)
-----------------------------------------------------------
For Disk errors refer to Section 7.
```

8.3.16 READ SENSE Command (HEX 46)

This command returns to the host 8 Tape Sense bytes. The function of this command is similar to the REQUEST SENSE command, but it reports less sense information. The Opcode and format of this command is compatible with an earlier controller model. It is recommended not to implement this command in new software design.

```
          READ SENSE Command Descriptor Block
          7    6    5    4    3    2    1    0
BYTE 1 |  0    1    0    0    0    1    1    0  |
BYTE 2 |  0    1    1    0    0    0    0    0  |
BYTE 3 |          ZERO VALUE                   |
BYTE 4 |          ZERO VALUE                   |
BYTE 5 |          ZERO VALUE                   |
BYTE 6 |  0    0    0    0    0    0    0  | LK |
```

See the REQUEST SENSE command for the format of the 8 Tape Sense Bytes (0 to 7) returned by the READ SENSE command.

8.3.17 WRITE HEADER Command (HEX 48)

This command writes a user defined block of data to the first block of the tape. Rewind takes place first. The tape is then erased from BOT to EOT, then rewound. The 512 bytes/block is then written between two File Marks at the Beginning of Tape (BOT). At the completion of this command, the tape is positioned after the second File Mark. The contents of this user defined block are not altered by a BACKUP command. The header can be overwritten, thereby destroyed, by a WRITE command (HEX 0A). This block is intended to provide cartridge labelling.
This command code is compatible to an earlier controller model. It is recommended not to use this command with new software design.

```
         WRITE HEADER Command Descriptor Block
          7    6    5    4    3    2    1    0
BYTE 1 |  0    1    0    0    1    0    0    0  |
BYTE 2 |  0    1    1    0    0    0    0    0  |
BYTE 3 |          ZERO VALUE                   |
BYTE 4 |          ZERO VALUE                   |
BYTE 5 |          ZERO VALUE                   |
BYTE 6 | DR | DC | 0    0    0    0    0  | LK |
```

VALID ERROR CODES

Drive not Ready	(HEX 04)
Drive not Selected	(HEX 05)
Tape Exception	(HEX 10)
Write Protected	(HEX 17 and 97)

8.3.18   READ HEADER Command (HEX 49)

This command reads a user defined block, located at the
Beginning of the Tape (BOT), that was written by the WRITE
HEADER command. This block is intended to provide cartridge
labelling. If no header is recorded, an Exception condition
occurs. The Tape Sense bytes report a "No header found" error;
then the tape is rewound.

At the completion of the command, if the header is found, the
media is positioned after the File Mark located behind the
header block.

This command code is compatible to an earlier controller model.
It is recommended not to use this command with new software
design.

```
              READ HEADER Command Descriptor Block
              7     6     5     4     3     2     1     0
BYTE 1  | 0     1     0     0     1     0     0     1  |
BYTE 2  | 0     1     1   | 0     0     0     0     0  |
BYTE 3  |           ZERO  VALUE                       |
BYTE 4  |           ZERO  VALUE                       |
BYTE 5  |           ZERO  VALUE                       |
BYTE 6  | DR  | DC  | 0     0     0     0     0  | LK  |
```

<center>VALID ERROR CODES</center>

Drive not Ready   (HEX 04)
Drive not Selected   (HEX 05)
Tape Exception   (HEX 10)

8.3.19 WRITE BLOCK(S) Command (HEX 4A)

The WRITE BLOCK(S) command transfers a specified number of blocks from the host to the tape. The operation terminates when the number of blocks to transfer is exhausted, or when the Tape Formatter recovery procedure of unsuccessful retries of rewrite has been exhausted, or when the end of the media (EOT) is encountered. The last two conditions cause an Exception condition to occur, and the Block Count written will be available in the Sense Bytes. Up to 256 blocks may be transferred.

- If bit 5(SR) of the Control Byte is set to one, writing begins at the current Tape position. A Header (if previously recorded) will be overwritten. A File Mark is not written at the end of the Write operation.
- If bit 5(SR) of the Control Byte is set to zero, the controller searches for EOD (End of Data), then begins writing. A header (if previously recorded) is skipped. A File Mark is written at the end of the write operation.

The code (HEX 4A) provides software compatibility to an earlier controller model. It is not recommended to use this command in new software design.

```
          WRITE BLOCK (S) Command Descriptor Block
           7    6    5    4    3    2    1    0
BYTE 1   | 0    1    0    0    1    0    1    0 |
BYTE 2   | 0    1    1    0    0    0    0    0 |
BYTE 3   |       ZERO  VALUE                    |
BYTE 4   |       ZERO  VALUE                    |
BYTE 5   |       BLOCK  COUNT                   |
BYTE 6   | DR | DC | SR | 0    0    0    0 | LK |
```

VALID ERROR CODES

Drive not Ready	(HEX 04)
Drive not Selected	(HEX 05)
Tape Exception	(HEX 10)
Write Protected	(HEX 17 and 97)

8.3.20 READ BLOCK(S) Command (HEX 4B)

This command accesses data on the tape in the direct mode and transfers the specified Block Count to the host by:

- starting at the specified Tape Logical Block address, if bit 5 (SR) of the Control Byte is set to zero, or
- starting at the current tape position, that is at the next block, if bit 5 (SR) of the Control Byte is set to one. In the last case, the Logical Block Address in bytes 2 to 4 is not analyzed.

Blocks are transferred until the block count is exhausted, a File Mark is encountered, or End of Tape (EOT) is encountered.

Up to 256 Blocks of data can be accessed. If the block count is not exhausted, an Exception condition occurs, and the Block Count read is available in the Sense bytes.

The code (HEX 4B) provides software compatibility to an earlier controller model. It is not recommended to use this command in new software design.

READ BLOCK(S) Command Descriptor Block

	7	6	5	4	3	2	1	0
BYTE 1	0	1	0	0	1	0	1	1
BYTE 2	0	1	1	TAPE LOGICAL BLOCK ADDR (MSB)				
BYTE 3	TAPE LOGICAL BLOCK ADDRESS							
BYTE 4	TAPE LOGICAL BLOCK ADDRESS (LSB)							
BYTE 5	BLOCK CLOUNT							
BYTE 6	DR	DC	SR	0	0	0	0	LK

VALID ERROR CODES

Drive not Ready	(HEX 04)
Drive not Selected	(HEX 05)
Tape Exception	(HEX 10)
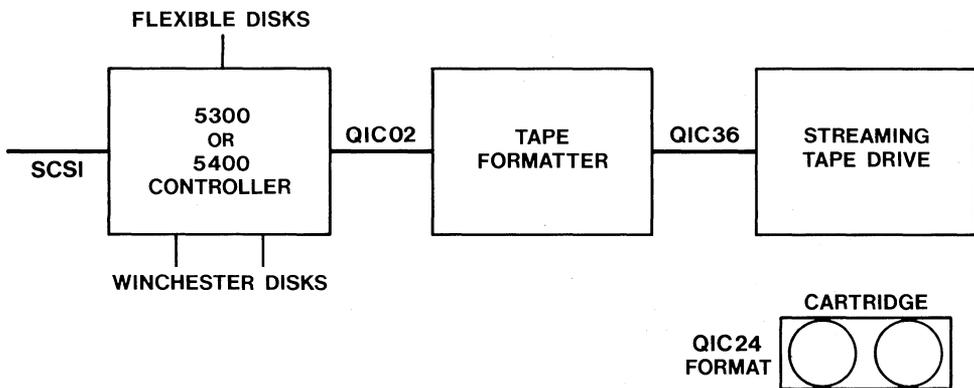
Figure 8.1 Tape Drive Configuration

APPENDIX A

INTERLEAVE SCHEME

512 BYTE SECTORS – 17 SECTORS PER TRACK

INTERLEAVE FACTOR

0/1	2	3	4	5	6	7	8

LOGICAL SECTOR NUMBERS

P H Y S I C A L	S E C T O R		0/1	2	3	4	5	6	7	8
		0	0	0	0	0	0	0	0	0
		1	1	2	3	4	5	6	7	8
		2	2	4	6	8	10	12	14	16
		3	3	6	9	12	15	1	1	1
		4	4	8	12	16	1	7	8	9
		5	5	10	15	1	6	13	15	2
		6	6	12	1	5	11	2	2	10
		7	7	14	4	9	16	8	9	3
		8	8	16	7	13	2	14	16	11
		9	9	1	10	2	7	3	3	4
		10	10	3	13	6	12	9	10	12
		11	11	5	16	10	3	15	4	5
		12	12	7	2	14	8	4	11	13
		13	13	9	5	3	13	10	5	6
		14	14	11	8	7	4	16	12	14
		15	15	13	11	11	9	5	6	7
		16	16	15	14	15	14	11	13	15

1024 BYTE SECTORS – 9 SECTORS PER TRACK

INTERLEAVE FACTOR

0/1	2	3	4

LOGICAL SECTOR NUMBERS

P H Y S I C A L	S E C T O R		0/1	2	3	4
		0	0	0	0	0
		1	1	2	3	4
		2	2	4	6	8
		3	3	6	1	1
		4	4	8	4	5
		5	5	1	7	2
		6	6	3	2	6
		7	7	5	5	10
		8	8	7	8	3

Note: Interleave factor of zero will be set to one.

Interleave factors greater than one half the total number of sectors per track are not recommended.