QIC-3220-MC
Revision A
27 Aug 97

SERIAL RECORDED MAGNETIC TAPE MINICARTRIDGE FOR INFORMATION INTERCHANGE

Streaming Mode
108 Tracks with 0.315 in (8.0 mm) Tape
Transistion Density: 79,800 ftpi (3142 ftpmm)
Data Density: 106,400 bpi (4189 bpmm)
RLL 1,7 Encoding
Reed-Solomon ECC
Preformatted: 1650 Oe Metal Particle Media
Optional Read While Write

Uncompressed Formatted Capacity:
10 GBytes (with 740 ft Minicartridge)

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(See important notices on the following page)

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REVISION HISTORY

Revision	Date	Comments
A	27 August 1997	Initial revision. Based on TRAVAN-520 revision C.

1. SCOPE AND INTRODUCTION

1.1 Scope

This Standard provides a format and recording standard for a streaming magnetic tape in a Travan mini-cartridge to be used for information interchange between information processing systems, communication systems, and associated equipment utilizing a standard code for information interchange, as agreed upon by the interchange parties. The Standard provides the following capacities of formatted data on a single Travan™ mini-cartridge with error correction codes:

With 740 ft 0.315 in (8.0 mm) tape, 108 data tracks, 10.0 GBYTES

This standard refers solely to recording on a magnetic tape mini-cartridge meeting the requirements of TRVN-521 Preformatted Mini-cartridge Standard.

1.2 Introduction

1.2.1. This standard defines the requirements of supporting test methods necessary to ensure interchange at acceptable performance levels. It is distinct from a specification in that it delineates a minimum of restrictions consistent with compatibility in interchange transactions. The standard uses a Reed Solomon error correction code to achieve a corrected bit error rate of at least 10^{-15} when data is recorded in compliance with the requirements of Section 5, given an equivalent media defect density of up to TBD DPSI.

1.2.2. The performance levels contained in this standard represent the minimum acceptable levels of performance for interchange purpose. They therefore represent the performance levels which the interchanged items should meet or surpass during their useful life and thus define end-of-life criteria for interchange purposes. The performance levels in this standard are not intended to be employed or substituted for purchase specification.

1.2.3. Wherever feasible, quantitative performance levels are specified which must be met or exceeded in order to comply with this standard. In all cases, including those in which quantitative limits for requirements falling within the scope of this standard are not stated but are left to agreement between interchange parties, standard test methods and measurement procedures shall be used to determine such quantities.

1.2.4. U.S. engineering units are the original dimensions in this standard except head dimensions are in SI units. Conversions of toleranced dimensions from customary U.S. engineering units (similar to British Imperial Units) to SI units have been done in this standard according to ANSI/IEEE STD 268-1982 and ISO 370-1975 Method A. Method A should be used for economy unless a requirement for absolute assurance of a fit justifies use of Method B. In the national standards of ISO member nations, additional rounding may be done to produce "preferred" values. These values should lie within or close to the original tolerance ranges.

1.2.5. Except as indicated in 1.2.3 above, interchange parties complying with the applicable standards should be able to achieve compatibility without need for additional exchange of technical information.

1.2.6. In this section, several references are made to QIC-121. However, this does not imply that a drive meeting this Standard must be compatible with QIC-121. This standard sets no requirements as to the interface of the drive.

1.2.7. All bits designated as Reserved shall be set to zero.

2. DEFINITIONS

For the purpose of this standard, the following definitions apply:

Bad Block: A block determined to be bad during a read operation.

Bit: A single digit in the binary system.

Bit Cell: The physical length of a recorded encoded bit along the track. In this standard, the bit cell length must be measured indirectly, by measuring the length of a minimum Transition Cell.

Block: A group of 512 consecutive data bytes plus additional control bytes recorded as a unit.

Block Marker: A group of encoded bits following the preamble and marking the start of each block.

BOP Beginning of Partition. The position at the beginning of the permissible recording region of a partition.

BOT Marker: The BOT (Beginning of Tape) Marker is a set of two holes punched side by side in the tape. There are three sets of holes provided, the innermost of which is used for identifying the storage position for the cartridge. The additional sets of holes are used to ensure reliability of detection.

Note: In the storage position, all of the permissible recording area of the tape is wound on the supply hub and is protected by at least one layer of tape not used for recording data. Cartridges to be interchanged shall be rewound to the storage position prior to interchange.

Byte: A group of 8 data bits operated on as a unit.

Cancel Mark: The Cancel Mark acts as a "negative" File Mark or Set Mark. When a Cancel Mark follows as the first block in the next frame after a File Mark or Set Mark, the drive when reading the tape will logically ignore the Cancel Mark and the File Mark or Set Mark it cancels.

Control Field: A group of 8 bytes recorded before the data area in each block, containing information about block address, track address and block type.

Compression Block Group: A group of compressed data recorded as one variable block on the tape. The Compression Block Group either contains a number of host defined logical blocks or a complete or partial host defined logical block. The Compression Block Group also contains a Compression Header recorded at the beginning of the Compression Block Group.

Compression Header:	A group of bytes recorded as uncompressed data at the beginning of a Compression Block Group. The Header contains specific information related to the Compression Block Group recorded on the tape.
CRC:	The CRC (Cyclic Redundancy Check) is a group of 4 bytes recorded at the end of each block of data for the purpose of error detection.
Data Block:	A block containing user valid data in its data field.
Data Density:	The nominal distribution of recorded data information per unit length of track, usually expressed in bits per inch (bpi) or bits per millimeter (bpmm). In this standard, the data density is higher than the transition density.
DPSI:	(Defect Per Square Inch). The DPSI number specifies the number of defects (using a defined read method) per square inch of tape.
Directory Track	The track at the centerline of the tape, identified as track 254 by its Track ID Frame.
ECC:	(Error Correction Code). Special drive generated information which may be used to correct bad blocks.
ECC Block:	A block containing drive generated ECC data in its data field and part of control field.
Encoding:	A method whereby a group of data bits is translated into a group of recording bits. In this standard, 2, 4 or 8 data bits are translated into 3, 6 or 12 recording bits.
EOD Block:	A block used to indicate end of recorded data.
EOD Frame:	A frame consisting of only EOD and ECC blocks used to indicate the end of recorded data.
EOP	End of Partition. The position at the end of the permissible recording area of a partition.
EOT Marker:	The EOT (End of Tape) Marker is a single hole punched in the tape to indicate that the usable recording area of the tape has been exceeded, and that the physical end of the tape is approaching. There are three EOT holes to ensure reliable detection.
EW Marker:	The EW (Early Warning) Marker is a single hole punched in the tape to indicate the approaching end of the usable recording area in the forward direction.
File Mark Block:	A block designated as a File Mark.

Filler Block: A block containing no valid information in its data field. The purpose of this block is to complete a frame in the case that the host cannot fill the whole frame with valid data information.

Flux Transition: A point on the magnetic tape which exhibits maximum free space flux density normal to the tape surface.

Flux Transition Spacing: A distance on the magnetic tape between flux transitions.

Frame: A group of 128 blocks forming a complete logical unit.

GByte (GB): This standard defines 1 GB to be equal to 10^9 Bytes.

Media Header Block: A unique block identifying the type of format being recorded.

KByte (KB): This standard defines 1 KB to be equal to 1024 bytes.

LP Marker: The LP (Load Point) Marker is a single hole punched in the tape to indicate the approaching start of the usable recording area in the forward direction.

Magnetic Tape Cartridge: A cartridge containing magnetic tape wound on two coplanar hubs with an internal drive belt to transport the tape between the hubs.

MByte (MB): This standard defines 1 MB to be equal to 10^6 bytes.

Postamble: A special sequence of bits recorded at the end of each block.

Preamble: A special sequence of bits recorded at the beginning of each block.

Recorded Azimuth: The angular deviation, in minutes of arc, of the recorded mean flux transition line from the line normal to the cartridge reference plane.

Reference Tape Cartridge: A tape cartridge selected for a given property for calibrating purposes.

Reserved: Reserved fields are to be written with zeros and ignored by firmware to facilitate future standard revisions.

RLL: Run Length Limited. A data encoding method where data bits are encoded so that certain constraints are met with regard to the maximum and minimum distances between flux transitions.

Secondary Reference Tape Cartridge: A tape cartridge intended for routine calibration purposes, the performance of which is known and stated in relation to that of the Reference Tape Cartridge.

Set Mark Block: A block designated as a Set Mark.

Signal Amplitude Reference Tape Cartridge: A reference cartridge selected as a standard for signal amplitude and reference field.

Standard Reference Amplitude: The average peak-to-peak signal amplitude output of the Signal Amplitude Reference Cartridge when it is recorded on a measuring system at the maximum flux density specified in this standard.

Streaming: A method of recording on magnetic tape that maintains continuous tape motion without the requirement to start and stop within an interblock gap.

Track: A longitudinal area on the tape along which magnetic signals may be serially recorded.

Track ID Block A block recorded in the Load Point and Early Warning regions to designate the track number.

Transition Cell: The physical distance between two adjacent flux transition at the maximum recording density.

Transition Density or Physical Recording Density: The number of recorded flux transitions per unit length of track, usually expressed in flux transitions per inch (ftpi) or flux transitions per millimeter (ftpmm). See also Data Density.

Underrun: A condition developed when the host transmits or receives data at a rate less than required by the device for streaming operation.

Vendor Specific: Vendor Specific fields may be used to implement unique features beyond the scope of this document.

3. REFERENCE EDGE

The Reference Edge shall be that edge of the tape which is nearest to the baseplate of the cartridge.

4. TRACK GEOMETRY

4.1 Track Positions

Each track is written referenced to servo patterns written between the BOT holes and Load Point on the BOT end of the tape, and between EOT and EW on the EOT end of the Tape. The servo pattern is written across the entire width of the tape. The Directory Track has larger guard bands on both sides to allow it to be written without interfering with its adjacent tracks.

The data tracks are divided into 4 bands with 3 sub-bands each to reduce the time required to change from track to track and to allow optional 3 channel operation. Tracks are grouped into bands according to

Table 4-1:

Band	Starting Track	Ending Track	Direction
1	0	52	Forward
2	1	53	Reverse
3	54	106	Forward
4	55	107	Reverse

Table 4-1 Single Channel Track Band Layout

The tracks and bands are arranged to allow approximately constant distance between all sequential tracks. Band 1 is located nearest the bottom edge of tape. Band 2 is located above band 1. Continuing up sequentially is band 3 and band 4 (nearest the top edge of tape). The directory track is located between bands 2 and 3.

4.2 Track Width

Head manufacturers use the units of µm for head dimensions; therefore, to prevent rounding errors the unit for specifying track width shall be µm.

The write track width is 66 µm ± 1.5 µm.

The read track width is 22 µm nominal.

4.3 Servo Bursts

Servo Bursts are written at the BOT end of the tape for locating the centerline of the forward direction tracks and at the EOT end of the tape for the reverse direction tracks. At physical BOT, they are written in the Load Point region. At physical EOT, they are written in the Early Warning region. See QIC-180-MC for more specifics on the forward and reverse Servo Burst locations.

4.4 Media Partitions

All tapes are recorded with 2 partitions. The data (or default) partition is designated 0. It shall be recorded on all tracks except the Directory track. Partition 1 shall be the directory partition and shall be recorded on the Directory track only.

5. RECORDING

5.1 Method Of Recording

The recording method shall be the Non Return to Zero Mark (NRZI) method where a ONE is represented by a change in direction of longitudinal magnetization.

The recording current shall be $1.15xI_{sat} \pm 3\%$, measured on a standard reference cartridge at $20\pm4°C$ and $50\pm10\%$ R.H., where I_{sat} is the current providing 95% of the maximum output at 79,800 ftpi (3142 ftpmm). The I_{sat} is measured on the non-saturating side of the saturation current curve.

5.2 Write Equalization

To minimize the problems due to the large transition spacing ratio (4:1) write equalization must be used. Write equalization consists of inserting narrow pulses into the written data stream in such a manner that the resultant write current waveform continues to be bi-level. In addition, when write equalization pulses are added in accordance with this specification the transfer function of the write equalizer will be linear. Refer to Appendix A for write suppression characteristics.

For every "zero" other than the first "zero" following a "one", one or more additional write equalization pulses shall be inserted into the waveform as shown in Figure 5.1 and Figure 5.2 of the inserted pulse (pulses) with reference to the bit cell shall be exactly as specified in the figures.

The width t_w of the equalization pulse (all measurements made from the 50% point of the write current waveform) shall be 1/6 of the minimum nominal transition period t_c as shown in Figure 5.2.

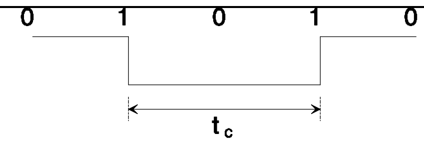


Figure 5.1.1 Pattern ..01010..

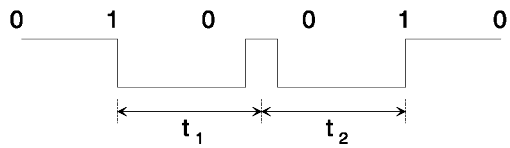


Figure 5.1.2 Pattern ..010010..

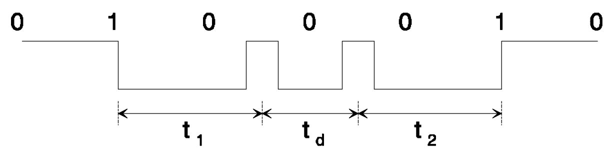


Figure 5.1.3 Pattern ..0100010..

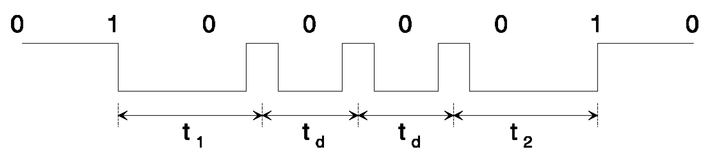


Figure 5.1.4 Pattern ..01000010..

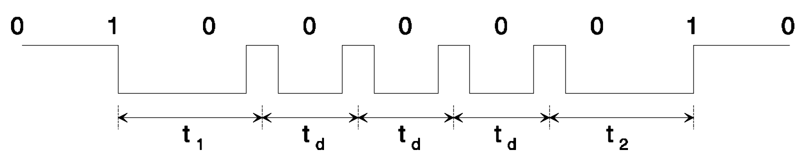


Figure 5.1.5 Pattern ..010000010..

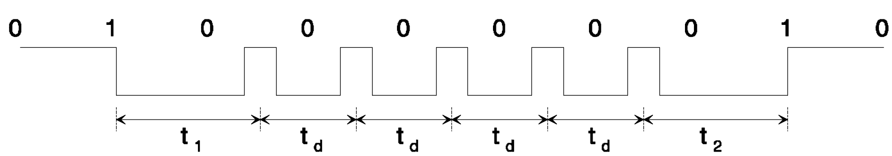


Figure 5.1.6 Pattern ..0100000010..

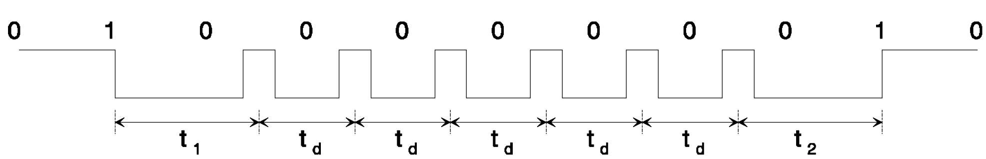
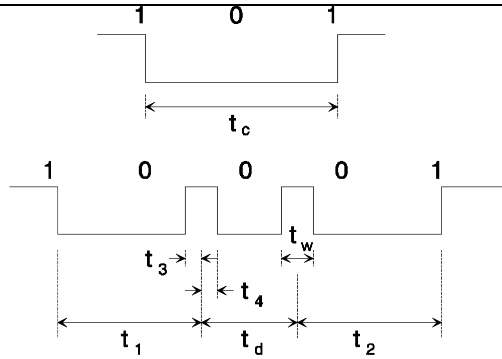


*Figure 5.1.*7 Pattern ..01000000010..

Figure 5.1 Write Waveforms and Equalization



$$t_d = \frac{t_c}{2}; \quad t_c = 2t_d$$

$$t_1 = \frac{11}{6} \times \mathrm{t_d}$$

$$t_1 + t_2 = 3t_d$$

$$t_3 = t_4 = \frac{t_w}{2}$$

$$t_w = t_3 + t_4 = \frac{t_c}{6} = \frac{t_d}{3}$$

Maximum variation of $\mathrm{t_1 + t_2}$ is $\pm 0.5\%$ from nominal value.

Maximum variation of $\mathrm{t_w}$ is $\pm 2.5\%$ from nominal value.

Figure 5.2 Timing Information, Write Equalization

5.3 Transition Densities

The nominal maximum physical recording density or transition density shall be 79,800 ftpi (3142 ftpmm). The nominal transition cell length shall be12.53 micro-inches (0.3138 µm).

With the recording method used in this Standard, seven transition densities may occur on the tape:

79,800 ftpi (3142 ftpmm)

53,200 ftpi (2094 ftpmm)

39,900 ftpi (1570 ftpmm)

31,920 ftpi (1257 ftpmm)

26,600 ftpi (1047 ftpmm)

22,800 ftpi (898 ftpmm)

19,950 ftpi (785 ftpmm)

5.4 Average Transition Cell Length Variations

5.4.1 Average Transition Cell Length

The average transition cell length is the sum of the distances between the flux transitions in n transition cells divided by (n-1). The tests referred to below may be made in any continuously recorded pattern, provided the first and the last transition cell in the pattern each contain a flux transition.

5.4.2 Long Term Average Transition Cell Length

The long term average transition cell length is the average transition cell length taken over a minimum of 3,000,000 transition cells. The long term average transition cell length shall be within ± 3% of the nominal transition cell length of 12.53 micro-inches (0.3183 µm).

5.4.3 Medium Term Average Transition Cell Length

The medium term average transition cell length is the average transition cell length taken over a minimum of 45,000 transition cells and a maximum of 51,000 transition cells. The medium term average transition cell length shall be within ± 6% of the long term average transition cell length.

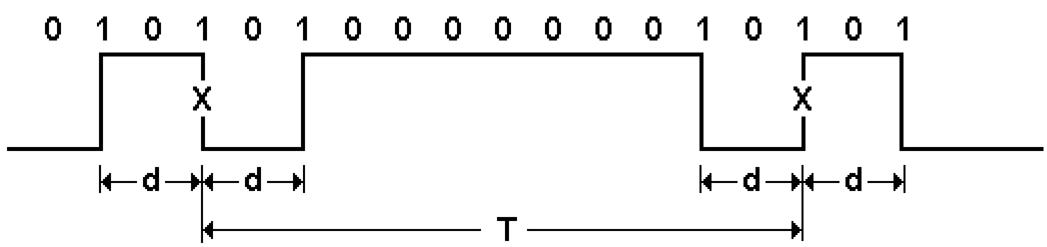
5.4.4 Short Term Average Transition Cell Length

The short term average transition cell length is the average transition cell length taken over a minimum of 57 transition cells and a maximum of 75 transition cells. The short term average transition cell length shall be within ± 2% of the medium term average transition cell length.

5.4.5 Instantaneous Flux Transition Spacing

The instantaneous spacing between flux transitions is influenced by the reading and writing process, the pattern recorded (pulse-crowding effect) and other factors. Instantaneous spacing between flux transitions shall satisfy the following conditions:

In a sequence of flux transitions defined by the encoded pattern ..010101000000010101.., the center flux transition of each group of 010101's is called a reference flux transition. The maximum displacement of flux transitions on either side of the reference flux transitions shall not exceed ± 12.5% of the transition cell length d1 averaged over the six transition cells between the reference flux transitions indicated in the bit pattern in Figure 5.3.



d1 = T/6

d1(1-0.125) < d < d1(1+0.125)

X denotes a reference flux transition.

Figure 5.3 Test Pattern for Instantaneous Flux Transition Spacing Test.

5.5 Signal Amplitude Of A Recorded Cartridge For Data Interchange

When performing the tests described below, the output or resultant signal shall be measured on the same pass for both the Standard Amplitude Reference Cartridge and the tape under test. The measurements specified in sections 5.5.1 through 5.5.3 shall be performed during the first read pass after the write pass. The same equipment shall be used for all measurements. The signal amplitude shall be measured at a point in the read channel where the signal is proportional to the head output.

After writing, the cartridge shall meet the following requirements:

5.5.1 Average Signal Amplitude at Nominal Maximum Density

At the nominal maximum physical recording density of 79,800 ftpi (3142 ftpmm), the Average Peak-to-Peak Signal Amplitude of any track on the interchange tape shall deviate no more than + 25% or - 25% from the Standard Reference Amplitude recorded at 79,800 ftpi (3142 ftpmm) measured at a temperature of 20^{o} C ± 4^{o} C. This averaging shall be made over the central 60 flux transitions of any 64 or more flux transitions recorded at nominal maximum recording density in a block and over at least 600 blocks.

5.5.2 Maximum Signal Amplitude

When interchanged, a tape shall not contain, in the valid information area, any flux transitions where the peak-to-peak signal amplitude is more than twice the Standard Reference Amplitude at 79,800 ftpi (3142 ftpmm) measured at a temperature of 20^{o} C ± 4^{o} C.

5.5.3 Minimum Signal Amplitude

When interchanged, a tape shall not contain, in its valid information area, any flux transitions where the peak-to-peak signal amplitude is less than 50% of the Standard Reference Amplitude at 79,800 ftpi (3142 ftpmm) measured at a temperature of 20^{o} C ± 4^{o} C, exclusive of media defects.

5.6 Recorded Azimuth

On any track the angle that a flux transition across the track makes with a line perpendicular to the cartridge reference plane shall not exceed 10 minutes of an arc (2.91 mrad).

5.7 TRACK POSITIONING ACCURACY

The design criteria for accuracy of positioning of the write gap to a track centerline is the term e_{bs} as defined in the QIC-3220-MC Tracking Tolerance Analysis. This value is 56.109 micro-inches. This dimension is the accuracy to which the average center of the track in the servo burst area of the tape is to be located. Note that this dimension is much smaller than the cartridge tracking repeatability and is not easily measurable.

5.8 Erasure

Erasure shall be by means of overwrite only.

5.9 Overwrite

Overwritten tracks shall not contain any components of previously recorded information whose amplitudes exceeds -26 dB relative to the amplitude of the newly recorded data.

6. USE OF TRACKS

6.1 Data Tracks

Each data track shall be written serially, one track at a time.

6.2 Track Numbering

All even numbered tracks, and the Directory track, shall be recorded in the forward direction (the direction from the BOT marker to the EOT marker). All odd numbered tracks shall be recorded in the reverse direction (the direction from the EOT marker to the BOT marker).

6.3 Minimum and Maximum Distances, Forward Tracks

On all even numbered tracks and the Directory Track, the beginning of the long preamble of the first frame shall commence a minimum distance of 1 inch (25 mm) and a maximum distance of 2 inches (51 mm) past the LP marker.

The valid data area shall terminate at least a distance of 0.1 inches (2.5 mm) before the EW marker, measured from the center of the EW hole.

Low Frequency Postamble shall be recorded from the end of the valid data area to a distance of at least 2 inches (51 mm) and at most 5 inches (128 mm) past the EW hole.

6.4 Minimum and Maximum Distances, Reverse Tracks

On all odd numbered tracks, the beginning of the long preamble of the first frame shall commence a minimum distance of 3 inches (76 mm) and a maximum distance of 4 inches (101 mm) past the EW marker.

No data shall be recorded beyond 2.5 inches (64 mm) past the LP marker. Postamble shall be recorded after the last data frame to a minimum distance of 4 inches (102 mm) and a maximum distance of 5 inches (127 mm) past the LP hole.

6.5 Track ID Frame

Following the Servo Bursts, a Track ID Frame is recorded before the LP hole on forward direction tracks, and before the EW hole for reverse direction tracks, as part of the servo writing process. The Track ID Frames are recorded in the same direction as the data for the related track. Following the Track ID Frame, Low Frequency Postamble is recorded into the Data region and then for at least 5 inches more. Part of this Postamble is recorded over the first time the tape is written.

The first block in each Track ID Frame is given the Physical Block Address of 0. The Physical Block Address increments for each block of the frame. Control Byte 0 for each of the data blocks is set to 3E Hex, indicating a Track ID block. The Track Number is recorded in Control Byte 1. The Directory Track is given a Track number of FE hex. All 128 blocks of the Track ID frame contain identical information in the data field. No ECC encoding is performed on the frame prior to recording it on the tape. See Section 9 for more information on frame construction and Section 9.2.3.3. The contents of the data field for Track ID blocks is defined in the preformatted tape document QIC-3220-MC10.

6.6 Drive Working Area

A section of the tape has been set aside as a drive working area (DWA). The drive may use this area independently of any recordings on the rest of the tape. Information recorded in this area, if any, is vendor unique, and no specification for retrieving this information will be supplied.

The area marked DWA is defined as shown in Figure 6.1. It is located in the BOT region preceding the LP region at physical BOT. It resides above the holes and extends up to the top edge of the tape.

The DWA zone may be altered by the drive on a write protected tape. To guarantee the integrity of recorded tapes, the drive manufacturer should take care to ensure that no activities in the DWA zone can go on outside the described limits.

6.7 Summary Of Requirements

Figure 6.1 shows the general tape layout including the Drive Working Area. Table 6-1 provides the dimension for the DWA.

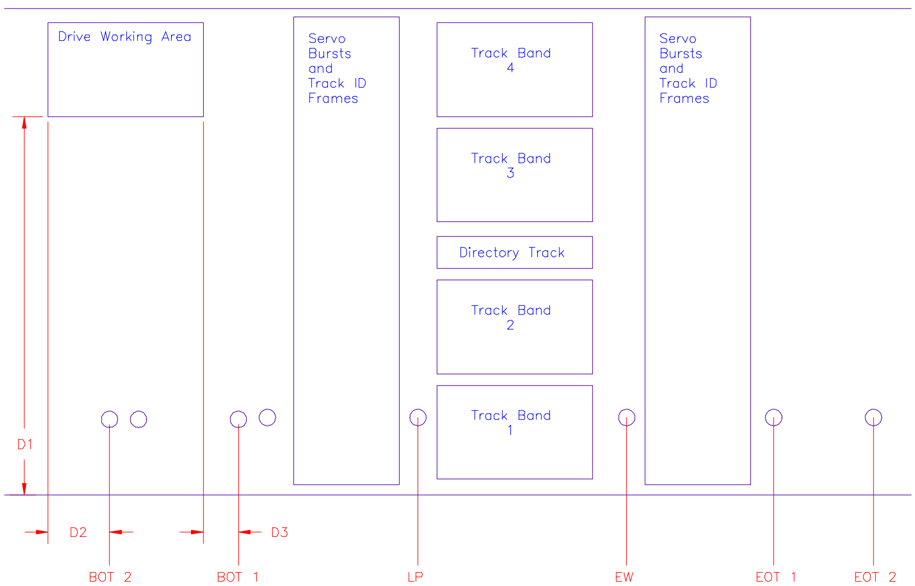


Figure 6.1 General Tape Layout and Dimensions for DWA

Dimension	Minimum	Maximum	Description
D1	0.20 inches 5.1 mm	---	Edge of Tape to lower limit of DWA
D2	---	2.0 inches 51 mm	Beginning of DWA region to centerline of first BOT2 hole
D3	0 inches 0 mm	---	End of DWA to centerline of first BOT1 hole.

Table 6-1 Dimensions for DWA

Figure 6.2 summarizes the requirements in sections 6.1 through 6.5. Table 6-2 lists the dimensions for this figure.

	Description	**Distance**
d1	First BOT1 hole to beginning of forward direction Track ID Frames.	96 to 100 inches 2.44 to 2.54 m
d2	LP to start of preamble for forward direction tracks.	1.0 to 2.0 inches 25 to 51 mm
d3	Data end before EW for forward tracks.	0.1 inch minimum 2.5 mm minimum
d4	EW hole to end of postamble for forward direction tracks.	2.0 to 5.0 inches 51 to 127 mm
d5	EOT1 hole to beginning of reverse direction Track ID Frames.	91 to 100 inches 2.44 to 2.54 m
d6	EW hole to beginning of preamble for reverse tracks.	3.0 to 4.0 inches 76 to 102 mm
d7	LP hole to end of reverse direction tracks.	2.5 inches maximum 64 mm maximum
d8	LP hole to end of postamble for reverse direction tracks.	4.0 to 5.0 inches. 102 to 127 mm

Table 6-2 Summary of Track Requirements

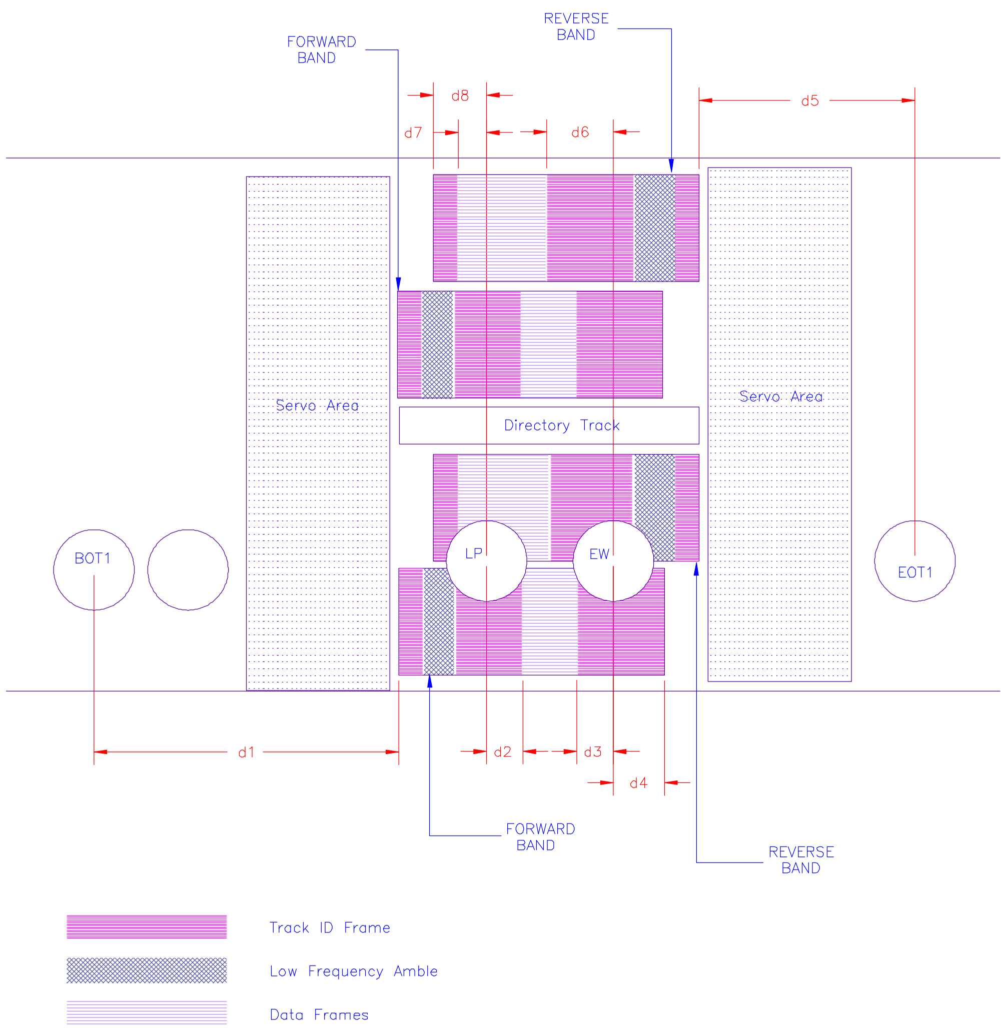


Figure 6.2 Track Requirements

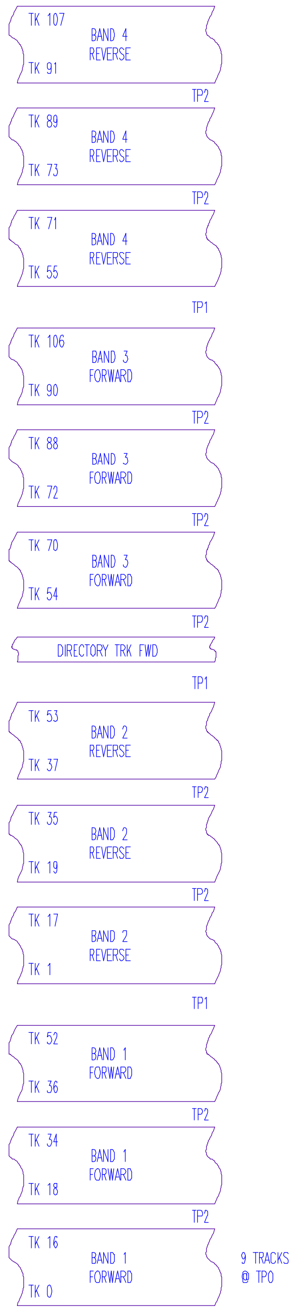


Figure 6.3 SINGLE CHANNEL TRACK LOCATIONS

NOTE: Figure 6.3 demonstrates relative placement of data and directory tracks. For detailed definitions refer to QIC-3220-MC10.

7. BYTE AND CODE REQUIREMENTS

7.1 Byte Length

The data shall be in eight-bit bytes. The 8 bits in each byte are numbered b0 to b7, b7 being the most significant bit.

8. DATA RANDOMIZING AND ENCODING

Prior to the recording of the data on the tape, the coded characters (see section 7) shall be modified by a special data randomizer circuit (see section 8.1). The randomized information shall then be encoded according to section 8.2 before being recorded on the tape.

Except when otherwise indicated in the description of the tape format, all bytes to be recorded shall be randomized and encoded as described in sections 8.1 and 8.2.

8.1 Data Randomizer

In order to reduce problems due to long strings of repetitive data with bad peak shift or amplitude characteristics, a special data randomizer algorithm shall be used on all bytes in the data and control area of each block. This data randomizing process shall take place before the data is encoded according to section 8.2.

Assuming that the data content is converted into a serial stream prior to being encoded, the data stream shall be "randomized" using the following generator polynomial:

$$g(x) = x^{12} + x^6 + x^4 + x + 1$$

Figure 8.1 shows one method to achieve this randomizer algorithm. It consists of 12 flip-flops (marked x0 to x11) organized into a twelve bit shift register. Exclusive-or gates are inserted in the data stream between register 0 and 1, between 3 and 4 and between 5 and 6. The other inputs to the exclusive-or gates are taken from the output of shift register 11. The serial data stream to be randomized (or "de-randomized" in the case of a read operation) is exclusive-or'ed with the output of register 0. The randomizer starts with the most significant bit of byte 7 in the Control area and ends up with the least significant bit of byte 511 in the data area.

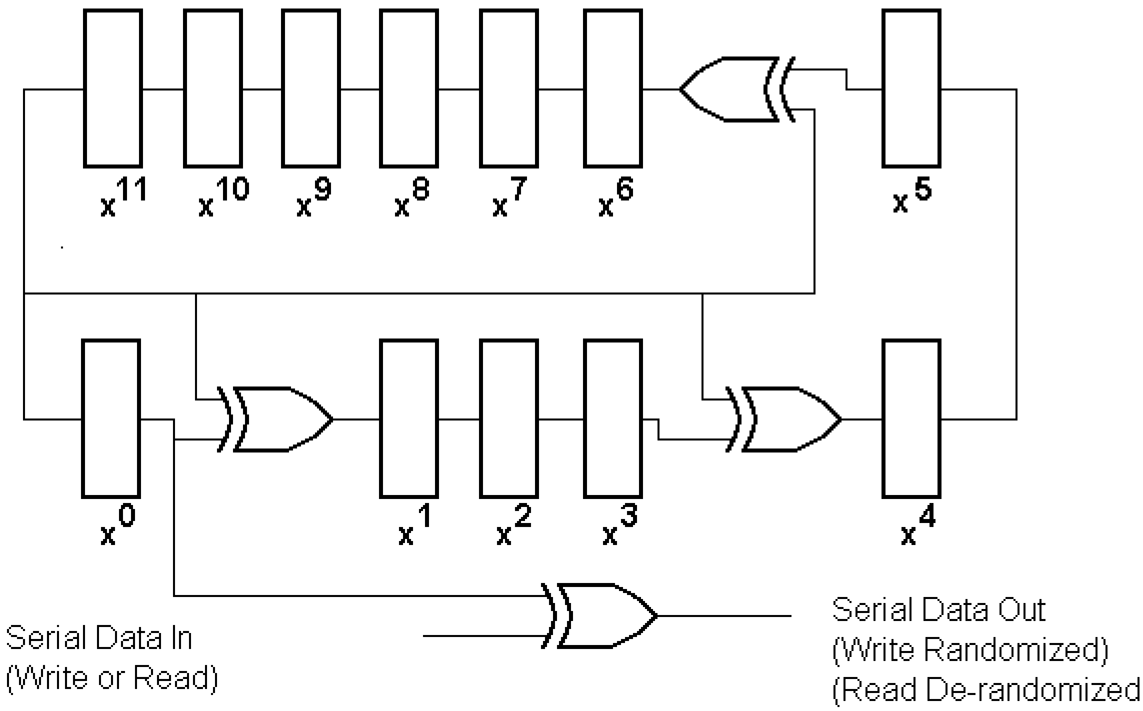


Figure 8.1 Randomizer Circuit

For every data block all 12 bits in the generator shall be set to 1 prior to the randomizer operation.

> Note that it is only the data in the 512 bytes data area and the control field that are "randomized" prior to encoding and writing. Preambles, postambles, block markers and CRC bytes shall not be randomized.

8.2 Data Encoding

Prior to the recording of the data on the tape, the randomized data and control information (plus the non-randomized CRC-bytes) shall be transformed into an encoded bit pattern according to Table 8-1 (RLL 1,7 encoding).

For each byte, the most significant two (four) bits shall be encoded first, then the next two (four) and so on. The most significant data bit is always to the left in Table 8-1. The most significant encoded bit is also to the left in the table. When recording, the most significant encoded bit in each byte is recorded first. X denotes an encoded bit which is ONE if the preceding encoded bit was a ZERO, but ZERO if the preceding encoded bit was a ONE. This encoding method will give a minimum of one "0" and a maximum of seven "0" 's between two Ones.

> Note: Table 8.1 lists two exceptions to the general encoding rules. Data bit patterns 11101110 (EEHex) and 10111011 (BBHex) shall be encoded following the rules for special patterns. Note that this is not byte related, but should be treated as a sliding encoding in steps of two or four bits. Also note that these special patterns are only used for 11101110 (EEHex) and 10111011 (BBHex) respectively. Other patterns, like 11101111 (EFHex) or 10111010 (BAHex) patterns are encoded in the normal way, using the standard table.
>
> Examples:

```
1110 1011 1110 0001 --> X01010 010101 001010 100001

1110 1110 1011 1011 --> 010000 001001 010000 001010
 | E    E | | B    B |

1001 1011 1011 1010 --> 010100 010000 001010 010010
      | B    B |

  |  E      E  |
0111 1011 1001 0000 --> X01010 000001 001000 010000

         | B      B |
1011 0110 1110 1101 --> 010101 000010 000001 010100
```

Data bits		Encoded bits
01	⇒	X00
10	⇒	010
11	⇒	X01
0001	⇒	X00 001
0010	⇒	X00 000
0011	⇒	010 001
0000	⇒	010 000

Special Patterns:

EE hex:		
1110 1110	⇒	010 000 001 001
BB hex:		
1011 1011	⇒	010 000 001 010
Normal Preamble, 1 byte repeating:		
	⇒	... 010 101 010 101 ...
Normal Postamble, 1 byte repeating:		
	⇒	... 010 101 010 101 ...
Low Frequency Preamble, 2 bytes repeating:		
	⇒	... 010 000 000 100 000 001 000 000 ...
Low Frequency Postamble, 2 bytes repeating:		
	⇒	... 010 000 000 100 000 001 000 000 ...

Table 8-1 Encoding Table, RLL 1,7 Code

Note:

When the last two bits of the last CRC byte end in 00 two additional bits (01) shall be added to the end of the last CRC byte. The encoded pattern is then followed by the Normal Postamble as usual.

Example:

Last CRC Byte		Encoded CRC		Postamble
... 1001 1100	⇒	010100 101000	001 (Extra bits)	0101010101

Examples:

Data Pattern Byte 1	Byte 2		**Encoded Pattern** Byte 1	Byte 2
0011 0111	0010 0001	⇒	010001 000101	000000 100001
1000 0000	0001 1111	⇒	010010 000010	000100 101001
1011 1011	1011 1111	⇒	010000 001010	010101 001001
1001 1011	1011 1001	⇒	010100 010000	001010 010100
1110 1011	1110 1011	⇒	X01010 010101	001010 010101
1111 1011	1011 1101	⇒	X01010 000001	001001 001000

9. TRACK FORMAT

9.1 General Information

For a single channel implementation each track is recorded sequentially, starting with track 0, then track 1, and so on. Before recording, data is grouped into blocks and blocks are then grouped into frames with 128 blocks in every frame.

This Standard operates on both a frame and a block basis. Section 9.2 gives a detailed description of frames, while section 9.3 gives a detailed description of blocks.

Two numbering methods are used to number blocks: Physical numbering and Logical numbering. Both numbers start from 0 at the beginning of each partition.

The Physical numbering relates directly to the recorded block on the tape. Each new block, regardless of its contents, is given a unique physical number. As implied by its name, the physical numbering system therefore relates directly to each recorded block on a track.

Logical numbering does not relate to the blocks physically recorded on the tape, but to the block numbering system used by the host. Very often, a host system operates with logical blocks of a different size from the fixed 512 byte blocks physically recorded on the tape. These host blocks may be either smaller or larger than the physically recorded blocks.

Host blocks may also be either fixed or variable. Fixed host blocks contain the same number of data bytes in every host block, while variable host blocks may contain a different number of data bytes for every host block.

In order to provide the host with a flexible numbering system, this standard records both a physical block number for every block recorded on the tape and a logical block number which may span more than one physical block. These two block numbers are recorded in the control field of every block.

9.2 Frames

9.2.1 General Information

On every track, data is recorded in 512 data byte blocks. 128 blocks (108 data or information blocks plus 20 ECC blocks) constitute a frame. Therefore, each track of a single channel implementation consists of sequentially recorded frames as shown in Figure 9.1.

	Frame N	Frame N + 1	Frame N + 2	Frame N + 3	Frame N + 4	Frame N + 4	Frame N + 5	

Figure 9.1 General Track Layout

Each frame contains 128 blocks, 108 are data blocks or information blocks (file marks, cancel marks, set marks, Media Header, EOD, or filler blocks), and 20 are ECC blocks.

Frames are numbered indirectly, by using the 25most significant bits of the Physical Block Address.

The frame operation is controlled by the recording drive and is normally invisible to the host. The purpose for the use of frames is to control the error correction operations.

Frames may be overwritten with new data frames or an EOD frame. Append operations may only begin at EOD (End of Data).

An underrun is not allowed in the middle of a frame, regardless of the frame type. Filler blocks may be used to complete a frame, providing they are not used interior to a logical block including a compression block group.

A frame which cannot be completed on one track shall be rewritten in its entirety at the beginning of the following track, i.e. frames will NOT be split around corner turns. When recording Reverse direction data tracks in Track Band 2 the following precautions will be taken to ensure that a complete instance of all frames exists. These requirements are necessary due to the possibility of one or both of the last two frames being written over the Early Warning hole.

a) If the Early Warning hole is detected while writing the last one-half (last 54 blocks) of a frame, rewrite that frame in its' entirety at the beginning of the next track.

b) If the Early Warning hole is detected while writing the preamble or the first one-half of frame (first 54 blocks) the current frame and the preceding frame shall be written in their entireties at the beginning of the next track.

c) It is permissible to always write both frames at the beginning of the next track when Early Warning hole is detected to simplify the implementation.

9.2.2 Frame Layout

The number of physically recorded blocks within a data frame is always 128. The first 108 of these blocks are used as Data or Information Blocks and the remaining 20 are ECC (Error Correction Code) blocks.

Each block contains 512 data or information bytes.

The general layout of a frame is shown in Figure 9.2.

Data Block 0	Data Block 1	Data Block 2	......	Data Block 107	ECC Block 0	......	ECC Block 19

Figure 9.2 General Frame Layout

9.2.3 Frame Types

There are 4 different types of frames:

- Data Frame.
- Media Header Frame.
- Track ID Frame.
- EOD Frame.

9.2.3.1 Data Frame

The Data Frame contains Data and Information blocks in addition to the normal ECC blocks.

9.2.3.2 Media Header Frame

The Media Header Frame contains only Media Header blocks and ECC blocks. This frame is recorded as the first frame on the Directory Track. The Media Header blocks contain configuration information about the recording drive, and the Volume Directory as specified in Section 9.7.

9.2.3.3 Track ID Frame

The Track ID Frame is recorded following each Servo Burst as part of the formatting process of the cartridge. These frames can easily be distinguished from other frame types because they reside entirely outside of the data region of the tape. There is an erased gap between the end of the Servo Burst and the preamble of the first block in the Track ID frame.

All 128 blocks of the Track ID Frame have the Block Type field in the Block Control Byte set to 3E Hex indicating a Track ID block. Control Byte 1 contains the track number. Control bytes 2 through 4 are reserved and shall be written with zeros. The first block in each Track ID Frame is set to Physical Block Address 0, incrementing for each block of the frame. Read-While-Write is always disabled while writing the Track ID Frames.

No ECC encoding is performed on the Track ID Frame. The Data field of all 128 blocks are identical. See QIC-180-MC for more details as to the makeup of the Track ID Frame.

9.2.3.4 End of Data Frame

The End of Data Frame is an absolute indicator of the end of the recorded data. It is recorded following the last frame containing Host data upon terminating a Write process. The EOD Frame is recorded at the end of data on each partition. The EOD Frame contains 108 EOD blocks and 20 ECC blocks only. The data fields of the EOD frame contain a Volume Directory, as defined in Section 9.8, starting from the first byte of block 2.

9.3 Block Types

There are 7 different types of blocks:

- Data Block
- Media Header Block
- CancelMark / FileMark / SetMark Block
- Filler Block
- EOD Block
- ECC Block
- Track ID Block

Information in the Block Control Byte determines the type of block being recorded, except for ECC blocks which are recognized by their block numbers (Last byte of physical block numbers x110 1100 through x111 1111). See also Table 9-2.

The Data Field of the blocks always contains 512 bytes, although the number of valid data bytes in the block may be less than 512. See Sections 9.3.9 and 9.6.

Information about the number of user data bytes available in each data block is recorded in the Block Control Byte of the block.

9.3.1 Data Block

The Data Block contains user data. A full Data Block contains 512 bytes, but data blocks may contain from 1 through 511 valid data bytes depending on the host selected logical block size (see Section 9.6).

9.3.2 Media Header Block

The first frame on the Directory Track is the Media Header Frame. This frame contains 108 Media Header Blocks (plus the normal 20 ECC blocks). The Media Header blocks contain specific host, drive and vendor information as well as the Volume Directory.

The Media Header blocks are generally invisible to the host system, but the information in the data area may be transferred to the host by special command sequences. See Section 9.2.3.2 for further details regarding the writing of the Media Header Frame.

9.3.3 Filemark Block

Filemark Blocks are physical blocks written to tape in response to a host "Write Filemarks" command. Filemarks are logical blocks with each Filemark assigned a unique logical block address.

9.3.4 Setmark Block

Setmark Blocks are physical blocks written to tape in response to a host "Write Setmarks" command. Setmarks are logical blocks with each Setmark assigned a unique logical block address. Setmarks provide a segmentation scheme hierarchically superior to Filemarks.

9.3.5 Cancelmark Block

Cancelmark Blocks are physical blocks written to tape under firmware control. Cancelmarks are used to "cancel" or negate one Filemark or Setmark when overwritten by host command. The Cancelmark must be the first block in frame immediately following the frame containing the Filemark or Setmark it cancels.

A Filemark or Setmark may be canceled only if there are no data blocks between it and EOD. A Cancel Mark cancels only the File Mark or Set Mark immediately preceding it.

The logical block number of the Cancelmark shall be the same as the Filemark or Setmark it cancels. The next logical block on tape shall also have the same logical address as the canceled Filemark or Setmark and the Cancel Mark.

9.3.6 Filler Block

Filler blocks are used to “fill” incomplete frames and contain no valid user data in the data area. Filler blocks are required when a Write Process terminating command, e.g. REWIND or UNLOAD, is issued and the data in the buffer does not end in a complete frame but does end in a complete logical (host) block. Filler blocks are given the same logical address as the previous logical data block, filemark, or setmark.

Filler blocks are not allowed within host logical blocks. Filler blocks are only allowed between the end of a host logical block, filemark, or setmark and the beginning of the beginning of the next host logical block, filemark, or setmark.

9.3.7 EOD Block

See Section 9.2.3.4 for the definition of the contents of the EOD Blocks.

9.3.8 ECC Block

The ECC Block contains error correction parity bytes which shall be used to ensure data integrity during read operations. The ECC blocks are recognized by the 7 least significant bits of the physical block number (Range 110 1100 through 111 1111).

9.3.9 Fixed and Variable Logical Blocks

(See also Section 9.6.)

From a host point of view, logical blocks may be written as fixed or variable. The sequence of commands required to write fixed blocks is different from the command sequence required to write variable blocks.

The physical recorded blocks on the tape are always fixed in length, containing 512 bytes of data. However, a logical block may contain a number of valid bytes different from 512 (either more or less). This format standard makes it possible to distinguish between logical blocks containing 512 bytes of data and logical blocks containing either less than 512 or more than 512 bytes of data.

The blocks are numbered in two ways: A physical numbering system numbering every block sequentially, regardless of block type and track number, and a logical numbering system which only numbers valid logical (host) data blocks, filemarks, and setmarks (sequentially). The physical numbering system starts with 0 for the first block in each partition, and then increments this number by one for each new block, regardless of track number and block type. The logical numbering system starts with 0 for the first valid host data block, filemark, or setmark recorded in each partition, and is then incremented by one for each new host data block, filemark, or setmark recorded in that partition, regardless of track number. Frames are numbered indirectly, by using the 25 most significant bits of the Physical Block Address.

9.4 Block Format

9.4.1 General Layout

All blocks have the same basic layout as shown in Figure 9.3:

Preamble	Block Marker	Control Field	Data	CRC	Postamble

Figure 9.3 Layout of a block

All sections of a block are recorded continuously without any erased gaps between the sections. All blocks within a frame are also recorded continuously without any erased interblock gaps. See Section 5.9 on overwrite.

Append operations and underruns are only allowed at frame boundaries.

This standard allows for the optional use of Read-While-Write verification. Any block determined to be bad by Read-While-Write verification is rewritten immediately. See Section 9.5 on block read-writes.

9.4.2 Preamble

The preamble consists of either the fixed Normal Preamble pattern (010 101 010 101) alone or a combination of the fixed Low Frequency Preamble patterns (010 000 000 100 000 001 000 000) with the fixed Normal Preamble pattern. See Table 8-1.

There are three types of preambles: NORMAL, ELONGATED, and LONG. The decoding system must be able to distinguish between a preamble and any possible combinations of data patterns.

9.4.2.1 Normal Preamble

A Normal Preamble shall contain a minimum of 13 and a maximum of 30 recordings of the normal preamble pattern (010 101 010 101) as described in Table 8-1. This preamble shall be recorded at the beginning of every block. It may be preceded by other types of preamble, depending upon the type of block or frame being recorded. To achieve maximum capacity, it is recommended to use the minimum length of 13 repetitions whenever possible.

The Normal Preamble may be recorded as the only preamble at the beginning of a block or in a combination with other types of preamble.

9.4.2.2 Elongated Preamble

An Elongated Preamble consists of 1400 to 1600 recordings of the Low Frequency Preamble pattern (010 000 000 100 000 001 000 000). It is not recorded alone, but will always be followed by a Normal Preamble. The transition between the Elongated Preamble and the following Normal Preamble shall be continuous without any erased or destroyed gaps.

The Elongated Preamble shall be recorded at the beginning of the first block in a frame which is appended to already existing data on a track or the first block in a frame after an underrun situation.

9.4.2.3 Long Preamble

The Long Preamble shall contain a minimum of 7500 and a maximum of 9500 recordings of the Low Frequency Preamble pattern (010 000 000 100 000 001 000 000). It is not recorded alone, but always followed by a Normal Preamble. This preamble shall be recorded at the beginning of the first block on every track. It is also recorded before the first Data Frame on the Directory track to separate it from the rewritable Media Header Frames and before the End Of Data frame to allow reliable appending.

9.4.3 Block Marker

The Block Marker marks the start of a new frame or block. It contains 24 encoded bits immediately following the Normal Preamble pattern:

010 101 010 000 000 100 000 010

The left bit is the most significant bit, recorded first.

9.4.4 Control Field

The control field consists of 8 bytes, numbered 0 to 7. These bytes contain information pertaining to the block they precede, or to the frame that block resides in. The organization of the control bytes are different for the first 108 blocks of each frame than for the ECC blocks.

Control bytes 0-7 are encoded according to the rules in section 8. Byte 7 is recorded first, followed by byte 6 and so on. The most significant encoded bit in each byte is recorded first.

9.4.4.1 Control Field, Data and Information blocks

Figure 9.4 shows the general layout of the control field for data and information blocks. Control byte 0 (Block Control Byte) specifies the type of block being recorded. Control bytes 1-4 specify the Logical Block Address. Control bytes 5-7 specify the least significant 3 bytes of the Physical Block Address.

Control Bytes 5-7	Control Bytes 1-4	Control Byte 0
Physical Block Number	Logical Block Address	Block Control Byte

Figure 9.4 Layout of Control Field, first 108 blocks.

9.4.4.1.1 Block Control Byte

Block Control Byte							
7	6	5	4	3	2	1	0
Comp	Reserved	BOLB	EOLB	Block Type			

Figure 9.5 Layout of Control Byte 0.

Bit 7 in the Block Control Byte indicates whether the data in the block has been formatted into Compression Block Groups as defined in Section 10.3. Bit 7 is set to 0 if the data is not formatted into Compression Block Groups. When bit 7 is set, host data is formatted into Compression Block Groups as defined in Section 10. Bits 5 and 4 indicate the beginning and end of Compression Block Groups instead of Host Logical Blocks.

Bit 6 in the Block Control Byte is reserved and shall bet set to 0.

Bits 5 and 4 in the Block Control Byte deal with Host Logical Blocks that are larger than the physical block size of 512 bytes. This is shown in Table 9-1.

Note that a host block may contain a number of data bytes different from the fixed 512 bytes in the physical blocks.

Bits 5 and 4 are used to mark the beginning and the end of Host Logical Blocks. Bit 5 (BOLB) is set to 1 in the first physical block of the host block. In the same way, bit 4 (EOLB) is set to 1 in the last physical block containing data from the same logical host block. Bits 5 and 4 shall be set to 0 for all other physical blocks within the same logical block.

Example: Logical block is 4200 bytes long.

The first physical block will contain the first 512 bytes of this logical block and have bit 5 set to 1 and bit 4 set to 0. The next 7 physical blocks will have bits 5 and 4 set to 0. The next physical block will have bit 5 set to 0 and bit 4 to 1. This block will contain the last 104 bytes of the logical block, plus 408 padding (filler) bytes.

The four least significant bits of the Block Control Byte are used to indicate the type of block being recorded. The coding of these four bits is shown in Table 9-2. There are two different codes to indicate a Full Data Block, 0000 and 1111. The code 1111 is used to indicate the entire frame is full of data, with no padding or partially filled blocks, and that every logical block in the frame is of equal size.

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

Block Control Byte, bits 4 and 5	
Bits 5 4	Description
1 0	This physical block marks the beginning of a logical host block. This block and the next physical block are part of the same logical host block.
0 0	This physical block is neither the first nor the last physical block within the logical host block. This block and the next physical block is part of the same logical block.
0 1	This physical block is the last physical block within the logical host block. It may contain a maximum of 512 valid data bytes.
1 1	This physical block marks both beginning and the end of a logical host block. The host block therefore contains a maximum of 512 valid data bytes.

Table 9-1 BOLB/EOLB Indicators.

Block Control Byte, Block Type field		
Bits 3 2 1 0	Block Type	Comments
0 0 0 0	Full Data Block	This block contains 512 bytes of valid data. This block may be all or only part of a logical host block.
1 1 1 1	Full Data Frame Block	This block contains 512 bytes of valid data. This block is used to indicate the entire frame is full of data, with no padding or partially filled blocks, and that every logical block in the frame is of equal size.
0 0 0 1	Limited 255 Byte Block.	This block contains from 1 to 255 bytes of valid data. A host logical block ends with this block. The remaining number of data bytes in the host block is between 1 and 255 (see section 9.6).
0 0 1 0	Limited 511 Byte Block.	This block contains from 256 to 511 bytes of valid data. A host logical block ends with this block. The remaining number of data bytes in the host block is between 256 and 511 (see section 9.6).
0 0 1 1	Reserved	
0 1 0 0	Filemark Block	No valid information in the data area.
0 1 0 1	Setmark Block	No valid information in the data area.
0 1 1 0	Cancel Mark Block	No valid information in the data area.
0 1 1 1	Reserved	
1 0 0 0	Filler Block	No valid information in the data area.
1 0 0 1	EOD Block	Contains special drive data. See Section 9.2.3.4.
1 0 1 0	Media Header Block	Contains special drive data. See Section 9.7.
1 0 1 1 through 1 1 0 1	Reserved	
1 1 1 0	Track ID Block	This block contains track identification information and is recorded in the LP and EW regions as specified in the document - TRAVAN 510

Table 9-2 Encoding of Block Type Control Bits.

9.4.4.1.2 Logical Block Address

Control bytes 1-4 are used to specify the Logical Block Address as shown in Figure 9.6. Byte 4 is the least significant byte of the logical address, byte 1 is the most significant byte of the logical address. This address specifies the number of logical (host) data blocks that are recorded on the tape. The address starts with 00000000Hex and is incremented by one for each new logical data block, filemark, or setmark recorded until a maximum of FFFFFFFE Hex. A logical block may consist of one or more physical blocks. See section 9.6.

Logical block numbering is only used for data blocks, filemarks, setmarks, and cancelmarks. Filler blocks are recorded with the last known logical block number. Media Header blocks are not given a unique logical block number, but are recorded with Control bytes 1, 2, 3 and 4 always set to FFFFFFFF Hex.

Logical Block Address			
Control Byte 4	Control Byte 3	Control Byte 2	Control Byte 1
LSB	Next LSB	Next MSB	MSB

Figure 9.6 Logical Block Address

9.4.4.1.3 Physical Block Address

Control Bytes 5-7 are used to specify the least significant 3 bytes of the physical block number. This is shown in Figure 9.7. The block numbering starts with 00000000 Hex and is incremented by one for each new block recorded, regardless of block type, frame type or track number. The block numbering is not reset at the start of a new track.

Physical Block Address		
Control Byte 7	Control Byte 6	Control Byte 5
LSB		MSB

Figure 9.7 Physical Block Address

9.4.4.2 Control Field, ECC blocks

Figure 9.8 shows the general layout of the control field for ECC blocks. Control byte 0 holds the codes to correct errors in the Block Control Byte of the first 108 blocks in the frame. Control byte 1 contains the track number. Control bytes 2 and 3 specify the number of times the tape has been recorded from the beginning of the tape. Control bytes 4-7 specify the complete physical block address.

Control Bytes 4-7	Control Bytes 2&3	Control Byte 1	Control Byte 0
Physical Block Number	Write Pass Count	Track Number	ECC for Block Control Bytes

Figure 9.8 Layout of Control Field, ECC blocks.

The Block Control Byte of each of the first 108 blocks in each frame is protected by ECC. The correction codes for these bytes are recorded in Control Byte 0 of the ECC blocks.

Control Bytes 2 and 3 contain the Write Pass Count (WPC). Each time a write operation is started from the Beginning of the Partition, the Write Pass Count for that partition is incremented and the new value is recorded in each frame. This distinguishes left-over frames from a previous write pass from the valid frames of a new write pass. When reading a tape, any frame with a different value in this field from the value specified in the Volume Directory Partition Table for the active partition is not a valid frame. Byte 3 holds the least significant byte of the count, byte 2 holds the most significant byte.

Control Bytes 4-7 contain the complete Physical Block Address. See Figure 9.9 for the byte ordering.

Physical Block Address			
Control Byte 7	Control Byte 6	Control Byte 5	Control Byte 4
LSB	Next LSB	Next MSB	MSB

Figure 9.9 Physical Block Address in ECC blocks

9.4.4.3 Control Field, Track ID Blocks

Table 9-3 shows the general layout of the control field for Track ID blocks. All 128 blocks of the Track ID Frame are identical except the LSB of the Physical Block Address field. The first block in each Track ID Frame is recorded as Physical Block Address 000000 hex. The Physical Block Address increments by one for each of the 128 blocks in each Track ID Frame. Byte 1 contains the track number.

Byte	Bits							
	7	6	5	4	3	2	1	0
7	(LSB)							
6	Physical Block Address							
5	(MSB)							
4 - 2	Reserved							
1	Track							
0	0	0	1	1	Block Type (0E hex)			

Table 9-3 Control Field, Track ID Blocks

9.4.5 Data Field

The Data Field contains 512 bytes of data, encoded according to the rules in Sections 8.1 and 8.2. The contents of the data field depends upon the type of block being recorded and is described in Table 9-2:

9.4.6 CRC Field

The CRC (Cyclic Redundancy Check) field consists of 4 bytes calculated over the whole data block area and control field area, starting with the most significant bit of byte 7 in the Control Field ending with the least significant bit of byte 511 in the Data Field.

All calculations are done prior to the data randomizing and encoding. All 32 bits in the CRC character shall be set to ONE prior to the start of the CRC calculation. The generating polynomial shall be:

$$x^{32} + x^{28} + x^{26} + x^{19} + x^{17} + x^{10} + x^{6} + x^{2} + 1$$

The four bytes shall be encoded according to the rules in Section 8.2 prior to the recording. No randomizing shall take place on the CRC characters. The most significant bits of the most significant byte shall be recorded first. It is a possibility that the two last bits of the last CRC byte both are 0's. In this case 01 shall be appended to the two 0's to enable correct encoding. After decoding, these two extra bits have no significance. See Sections 8.2 and 9.4.7.

9.4.7 Postamble

The postamble consists of either the fixed Normal Postamble pattern (010 101 010 101) or a combination of this pattern with the Low Frequency Postamble pattern (010 000 000 100 000 001 000 000) See Table 8-1.

The decoding system must be able to distinguish between a postamble and any possible combinations of data patterns. The Postamble is recorded at the end of each block immediately following the CRC bytes.

9.4.7.1 Normal Postamble

A Normal Postamble shall contain a minimum of 1 and a maximum of 2 bytes of the Normal Postamble pattern (010 101 010 101) as described in Table 8-1. This postamble shall always be recorded at the end of each block. It may be followed by either an Elongated Postamble, or by a normal preamble.

To achieve maximum capacity, it is recommended to use the minimum length of 1 byte whenever possible.

After writing this postamble, the following preamble or postamble shall be recorded so that there is no phase shift error or transition glitches between the end of the postamble and the beginning of the next preamble/postamble.

If the last two bits of the last CRC byte are 0, the encoding (and decoding) shall add 01 to the CRC bits before encoding. In this case the coding of the last two bits of the CRC character and the postamble will give the following pattern:

```
                        CRC |     |  Postamble |
.... ..00 Postamble --> X00 001 010 101 010 101
                                |
Inserted 01 bits encoded  ------|
```

9.4.7.2 Elongated Postamble

The Elongated Postamble shall be recorded after the second Media Header Frame. The Elongated Postamble shall consist of a minimum of 6600 recordings of the 2-byte Low Frequency Postamble pattern (010 000 000 100 000 001 000).

9.4.7.3 Long Postamble

The Long Postamble shall be recorded at the end of every write operation as described in Section 9.4.8. This Postamble shall consist of a minimum of 64K (65,536) recordings of the 2-byte Low Frequency Postamble pattern (010 000 000 100 000 001 000), except when the postamble extends beyond the EW hole for forward tracks or the LP hole for reverse tracks. If the postamble extends beyond either EW or LP holes, it shall not exceed the dimensions described in section 6.7 and listed in Table 6-2.

The Long Postamble shall be recorded following the normal postamble.

Recording Type	Preamble	Postamble
Normal Data Block in a fixed frame	Normal	Normal
Last Block before an underrun	Normal	Normal + Long[1]
First Block in an append operation	Elongated + Normal	Normal
First Block on a track	Long + Normal	Normal
First Data Block on Partition 1	Long + Normal	Normal
Last Block on a Track	Normal	Normal + Long[1]
First Block of an EOD frame	Long + Normal	Normal
Last Block of an EOD frame	Normal	Normal + Long[1]
First Block of first Media Header Frame	Long + Normal	Normal
First Block of subsequent Media Header Frame	Elongated + Normal	Normal
Last Block of last Media Header Frame	Normal	Normal + Elongated (Per Section 9.7)

Table 9-4 Summary of Preambles/Postambles Recordings

[1] *If necessary, the Long Postamble shall be truncated to comply with the hole to amble distances listed in Table 6.2.*

9.4.8 Underrun

An underrun is only allowed to occur at frame boundaries. When an underrun situation occurs data shall be terminated with a Normal Postamble and a Long Postamble.

9.4.9 EOD Frame

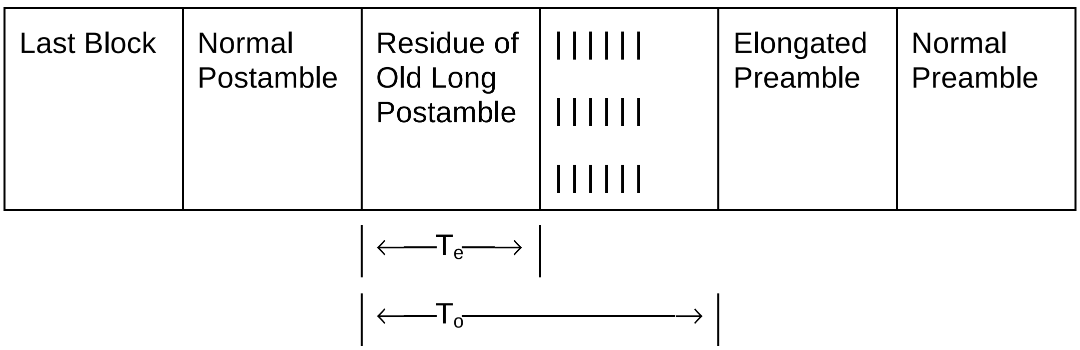
Whenever a write process is terminated, or optionally each time an underrun occurs while writing, an EOD frame shall be recorded on tape. The EOD frame is always separated from the frame immediately preceding it by a Long Preamble and is overwritten by an append operation.

The EOD frame consists of 108 blocks all with the EOD BLOCK indicator in control byte 0, and 20 ECC blocks. All of the EOD blocks have a Logical Block Address of one greater than the last logical block on tape. All of the other control bytes follow normal conventions for a data frame.

The EOD frame is always followed by a Long Postamble.

9.4.10 Erase and Append Operations at EOD

When a data frame is appended after an underrun, the recording shall begin at a point between the first 12 to 7,500 recordings of the Low Frequency Postamble Pattern. The append operation shall start with an Elongated Preamble followed by a Normal Preamble. See Figure 9.10. If an EOD Frame is present following the last frame which holds any information blocks other than EOD blocks, it shall be over-written completely by the append operation.



T_e = Minimum 12 Low Frequency Postamble Residue not overwritten by the Elongated Preamble.

T_o = Maximum 7,500 Low Frequency Postamble Residue not overwritten by the Elongated Preamble.

Figure 9.10 Postamble/Preamble Overlap after Append Operation

9.4.11 Erase and Write operation at BOP

Each time a write operation is started from the Beginning of either Partition, the Write Pass Count from the previous write on that partition is incremented. To erase all of the data on a partition, a new Media Header Frame is written at BOT of the Directory Track with the Erased bit set in the Volume Directory Partition Table for that partition. See Sections 9.7 and 9.8.2 for further details.

9.5 Block Rewrites

During write operations, read-while-write verification testing may be performed on the recorded data. The use of read-while-write verification is optional. However, all devices which support this standard must be capable of reading data which has been recorded with block re-writes as defined in this section. If read-while-write verification is used, it shall comply with the rules set forth in the following paragraphs.

When writing in the read-while-write mode a count of blocks which failed the read-while-write test shall be maintained for each ECC interleave of the frame being currently written. When the count reaches a maximum of 4 all subsequent detected bad blocks in that interleave shall be re-written as defined below. The counting process shall be re-started at the beginning of the next frame.

Any block determined to require re-writing during the read-while-write verify process shall be re-recorded. The bad block shall be re-recorded after the block currently being written has been completed. When rewriting a bad block, all blocks already recorded that succeed the bad block shall also be rewritten. The rewrite process must begin before more than seven succeeding blocks have been recorded.

Figure 9.11 shows typical block sequences resulting from rewrite operations. In Figure 9.11A block N-1 is bad, and this block plus blocks N, N+1, and N+2 must be rewritten. The number of blocks which must be rewritten depends upon the delay associated with verifying a frame that has been written. Figure 9.11B demonstrates the same scenario as Figure 9.11A but with a larger read-while-write verification delay.

In Figure 9.11C the bad block is N-2. When it is rewritten, the rewrite operation fails and a second rewrite must take place.

Figure 9.11D and Figure 9.11E show cases where bad block N is rewritten due to a rewrite operation of block N-2. For Figure 9.11D, block N is determined to be bad while being rewritten. As a result N and all block succeeding N are rewritten. For Figure 9.11E, both blocks N-2 and N are determined to be bad while being rewritten. In the second rewrite operation both blocks are determined good. No further rewrites of block N are required. Figure 9.11F show the case where blocks N-2, N-1, and N all fail to verify. While rewriting block N-2, N passes the verification test. Since N has been written correctly no further rewrites of block N are required.

Each block may be re-recorded up to 16 times after the previous block has been determined good. At the end of a write operation (including an underrun) the last ECC block shall be rewritten until it has been verified prior to writing the final postamble.

Blocks being rewritten shall be identical to the original blocks with the same Physical Block Address, Logical Block Address, data contents, etc.

During read operations, two or more good blocks with the same Block Address may be detected by the drive. Should this happen, the drive may use the data contents of any of these valid blocks. Note, however, that the last occurrence of a block is not guaranteed to be a “good block”. Figure 9.11G shows the case where block N-2 has been rewritten. Upon reading the data the first occurrence of N-2 is good and the second occurrence is bad.

It is permissible to rewrite consecutive blocks with the same Physical Block Address as shown in Figure 9.11H. This would occur if, for instance, data is being written in “forced streaming" mode. It is not necessary to rewrite a block that has previously been verified as 'good'.

The writing of blocks in a new frame may start before all blocks from the previous frame have been verified. However, if one or more blocks must be rewritten from the first frame, the rewrite operation shall follow the rules already discussed in this section and in Figure 9.11.

A:

N-3	N-2	N-1	N	N+1	N+2	N-1	N	N+1	N+2	N+3	N+4	N+5	N+6

B:

N-3	N-2	N-1	N	N+1	N+2	N+3	N-1	N	N+1	N+2	N+3	N+4	N+5

C:

N-3	N-2	N-1	N	N+1	N-2	N-1	N	N+1	N-2	N-1	N	N+1	N+2

D:

N-3	N-2	N-1	N	N+1	N-2	N-1	N	N+1	N+2	N+3	N	N+1	N+2

E:

N-3	N-2	N-1	N	N+1	N-2	N-1	N	N+1	N-2	N-1	N	N+1	N+2

F:

N-3	N-2	N-1	N	N+1	N-2	N-1	N	N+1	N+2	N-1	N	N+1	N+2

G:

N-3	N-2	N-1	N	N+1	N-2	N-1	N	N+1	N+2	N+3	N	N+1	N+2

H:

N-3	N-2	N-1	N	N+1	N+2	N+2	N+2	N+2	N+2	N+3	N+4	N+5	N+6

Figure 9.11 Examples of Possible Format Layout Variations Due to Block Rewrite Operations (Shaded Denotes a Bad Block, N Denotes a Physical Block Address)

9.6 Fixed And Variable Blocks

This standard allows for the recording of both fixed and variable host blocks. The physical blocks recorded on the tape always contain 512 data bytes, however, some of these data bytes may not be valid in every block, as provided in Sections 9.4.4 and 9.6.

9.6.1 Host Blocks of 512 Data Bytes

In this case, the host block size is the same as the size of the physical recorded block. Bits 0-3 in the Block Control Byte are set to 0Hex. All data bytes in the recorded block are valid. Bits 4 and 5 in the Block Control Byte shall be set to 1 for every physical block recorded, to indicate both the start and the end of a new host (logical) block.

9.6.2 Host Blocks of < 256 Data Bytes

In this case, the host block size is less than the size of the physical recorded block. Bits 0-3 in the Block Control Byte are set to 1Hex. The number of valid data bytes in the block is specified by the Valid Byte Counter, byte 511 of the data area. This byte contains a number from 1 to FF Hex (255Dec) depending upon the number of valid data bytes. The valid data bytes are always recorded first in the data field, then come filler bytes (no value specified in this standard) and finally, as the last byte, the Valid Byte Counter. See Figure 9.12

Bits 4 and 5 in the Block Control Byte shall be set to 1 for every physical block recorded, to indicate the start and end of a new host (logical) block.

Data Field 512 Bytes		
Valid Data Bytes	Filler Bytes (Unspecified)	Valid Byte Counter (Byte 511)

Figure 9.12 Layout of Data Field, Physical Variable Data Blocks.

9.6.3 Host Blocks of 256 to 511 Data Bytes

In this case, the host block size is still less than the size of the physical recorded block. . Bits 0-3 in the Block Control Byte are set to 2Hex. The number of valid data bytes in the block is specified as 256 plus the number specified by the Valid Byte Counter, byte 511 of the data area. This byte contains a number from 0 to FF Hex (255Dec) depending upon the number of valid data bytes. The valid data bytes are always recorded first in the data field, then come filler bytes (no value specified in this standard) and finally, as the last byte, the Valid Byte Counter. See Figure 9.12.

A host block containing 392 bytes of valid data shall therefore be recorded with bits 0-3 in Control Byte 0 set to 02Hex and byte 511 of the data field set to 88Hex (136Dec). This indicates 256 + 136 = 392 valid data bytes in the block (which means data bytes from 000 to 391 in the data area).

Bits 4 and 5 in the Block Control Byte shall be set to 1 for every physical block recorded, to indicate the start and end of a new host (logical) block.

9.6.4 Host Blocks > 512 Data Bytes in Multiples of 512

In this case, the host block size is greater than the physical block size, but the host blocks are specified as Nx512 where N is 2, 3, etc. Therefore all the physical blocks recorded to cover one host block contain only valid data bytes.

As an example, assume a host block of 2048 bytes. This will require 4 physical blocks. Bit 5 in the Block Control Byte is set to 1 for the first physical block and 0 in the next three blocks. Bit 4 is set to 0 for the first 3 blocks and to 1 for the last one. Bits 0-3 in the Block Control Byte are set to 0Hex in all four physical blocks. See Figure 9.13.

Host Block with 2048 Data Bytes			
Physical Block number N	Physical Block number N+1	Physical Block number N+2	Physical Block number N+3
Full Data Block BOLB Bits 0-3 in Control Byte 0 is 0 Hex Bit 6 = 0 Bit 5 = 1 Bit 4 = 0	Full Data Block Bits 0-3 in Control Byte 0 is 0 Hex Bit 6 = 0 Bit 5 = 0 Bit 4 = 0	Full Data Block Bits 0-3 in Control Byte 0 is 0 Hex Bit 6 = 0 Bit 5 = 0 Bit 4 = 0	Full Data Block EOLB Bits 0-3 in Control Byte 0 is 0 Hex Bit 6 = 0 Bit 5 = 0 Bit 4 = 1

Figure 9.13 Host Block with 2048 Bytes.

9.6.5 Host Blocks > 512 Data Bytes, not a multiple of 512

In this case, the host block size is greater than the physical block size, but the host blocks are specified as different from Nx512 where N is 2, 3, etc. Therefore the last of the physical blocks recorded to cover one host block contain less than 512 bytes of valid data bytes.

As an example, assume a host block of 1027 bytes. This will require 3 physical blocks. Bit 5 in the Block Control Byte is set to 1 for the first physical block and 0 in the next two.

Bit 4 is set to 0 for the first 2 blocks and 1 in the last one. Bits 0-3 in the Block Control byte are set to 0Hex in the first two physical blocks and 1Hex for the last one See Figure 9.14.

Figure 9.15 shows another example, with a block specified as 1417 bytes long.

Host Block with 1027 Data Bytes		
Physical Block number N	Physical Block number N+1	Physical Block number N+2
Full Data Block BOLB Bits 0-3 in Control Byte 0 is 0 Hex Bit 6 = 0 Bit 5 = 1 Bit 4 = 0	Full Data Block Bits 0-3 in Control Byte 0 is 0 Hex Bit 6 = 0 Bit 5 = 0 Bit 4 = 0	Variable Data Block, 1 -255 Data Bytes EOLB Bits 0-3 in Control Byte 0 is 1 Hex Last byte in Data field is 03 Hex (1027-512-512=137) Bit 6 = 0 Bit 5 = 0 Bit 4 = 1

Figure 9.14 Host Block with 1027 Bytes.

Host Block with 1417 Data Bytes		
Physical Block number N	Physical Block number N+1	Physical Block number N+2
Full Data Block BOLB Bits 0-3 in Control Byte 0 is 0 Hex Bit 6 = 0 Bit 5 = 1 Bit 4 = 0	Full Data Block Bits 0-3 in Control Byte 0 is 0 Hex Bit 6 = 0 Bit 5 = 0 Bit 4 = 0	Variable Data Block, 256 - 511 Data Bytes EOLB Bits 0-3 in Control Byte 0 is 2 Hex Last byte in Data field is 89 Hex (137 Decimal) (1417-512-512-256=137) Bit 6 = 0 Bit 5 = 0 Bit 4 = 1

Figure 9.15 Host Block with 1417 Bytes.

9.7 Media Header

The Media Header is a small rewritable volume recorded with Media Header frames at the beginning of the Directory Track. The Media Header frames shall be written according to the rules of Section 9.4. In order to facilitate improved error recovery, several identical copies of the Media Header frame should be recorded. Each copy of the Media Header frame shall be preceded by an Elongated Preamble. In order to meet the minimum requirements of this standard, at least one complete copy of the Media Header frame must be recorded in the allocated space. Drives that do not use Read While Write shall record a minimum of 2 complete copies of the Media Header frame.

Recording of the Media Header frames must be completed before the "Media Header End Position" (MHE) is reached. An Elongated Postamble is written following the Media Header frames either to the "Start Partition Position" (SPP) if writing shall continue, or to the "Media Header Update Position" (MHU) if only the Media Header should be updated.

The Media Header shall be written with initial values during the process which writes the Servo Bursts. The Media Header frames shall be rewritten with updated information at the completion of a write process which modifies any of the information.

The Media Header End Position, Start Partition Position, and the Media Header Update Position are:

Media Header End Position (MHE)	19 inches maximum from LP
Media Header Update Position (MHU)	20.5 +/-1.5 inches from LP
Start Partition Position (SPP)	23.5 +/-1.5 inches from LP

When writing from the beginning of the Directory Partition, that is, from SPP, the first block shall be preceded by 3 inches of Low Frequency Preamble followed by a Long Preamble.

9.7.1 Media Header Block 0

The first 16 bytes shall contain the Format ID. These 16 bytes shall contain the ASCII code for the characters QIC-3220-MC. The next 2 bytes shall contain the revision level of the QIC-3220-MC Serial Recorded Magnetic Tape Development Standard the writing drive was designed to meet. If only one character is required, it shall be placed in byte 17 with an ASCII space character in byte 16.

The next 8 bytes shall identify the WRITING DRIVE MANUFACTURER in accordance with table J-1 of the TRVN-521 VENDOR IDENTIFICATION list.

The Product Identification, Firmware Revision, and Drive Serial Number fields contain ASCII characters to describe the drive which last wrote on the tape. Use of these fields is at the discretion of the drive manufacturer. Unused bytes shall be filled with the ASCII space character.

The layout of Media Header Block 0 is shown in Table 9-5.

Byte	Description	Contents
0 - 15	Format ID	QIC-3220-MC
16 - 17	Format Revision	QIC-3220-MC
18 - 19	ASCII spaces	“ “
20 - 27	Manufacturer ID	Writing Drive Manufacturer.
28- 43	Product Identification	Product Name of the writing drive.
44 - 47	Firmware Revision	Firmware revision level of the writing drive.
48 - 63	Drive Serial Number	Serial Number of the writing drive.
64 - 65	Configuration Word	See Section 9.7.1.1
66 - 511	Filler	All zeros

Table 9-5 Media Header Block 0 Contents

9.7.1.1 Configuration Word

Byte 64 of Media Header Block 0 contains a configuration word. The bits in this word are defined in Table 9-6.

Byte	Bits							
	7	6	5	4	3	2	1	0
64	Update	RWW	3 CHAN	Reserved			Vendor Unique	
65	Reserved							

Table 9-6 Media Header Configuration Word

Update Set if the tape is recorded with firmware update information.

RWW Set if any data written between the beginning of the data partition and the first EOD was recorded with a Read While Write drive.

3 Chan Set if the tape has been recorded in QIC-3220-MC 3 Channel mode. Always 0 when recorded with a single channel QIC-3220-MC drive.

Reserved Set to zero, reserved for future options

Vendor Unique Set to zero, If not zero denotes Vendor Unique Attribute

9.7.2 Media Header Block 1

The 512 bytes of the data area of Media Header block 1 are filled with a copy of a track ID block for the directory track (Track FE_{Hex}).

9.7.3 Media Header Blocks 2 - 51

The data area of blocks 2 through 51 shall contain the Volume Directory as defined by Section 9.8. The Volume Directory Header Field shall begin at the first byte of block 2. The total size of the Volume Directory shall not exceed 25,600 bytes.

9.8 Volume Directory

The Volume Directory is recorded in the Media Header Frame and in the EOD Frame. It contains information that can be used by the drive to enhance the performance of some Random Access sequences. The content of the Volume Directory is compiled by the drive as an operation that is transparent to the host, and is not accessible by the host system.

The Volume Directory consists of four elements; the Header Table, Partition Table, Track Table, and Random Access Table (RAT). This data is recorded continuously, without regard to physical block boundaries. The Header Table is recorded first, at a zero byte offset from the start of the Volume Directory. Following the Header Table, the Partition Table is recorded, then the Track Table, and finally, the Random Access Table. See Table 9-7. All unused bytes in the space allocated to the Volume Directory shall be filled with 00hex. All fields that span more than one byte are recorded with the most significant byte as the first byte, and the least significant byte as the last byte.

Header Table (bytes 0 - 21)	Stores information about the Volume Directory and its organization.
Partition Table (bytes 22 - 61)	Stores information about individual partitions.
Track Table (bytes 62 - 77)	Stores information concerning individual tracks.
Random Access Table (bytes 78 - end)	Records information concerning the relationship between Physical Block Numbers, Logical Blocks Numbers, Filemarks and Setmarks.

Table 9-7 Volume Directory Layout

Note:

To avoid incompatibility with future revision of the Volume Directory, all accesses to data within the Volume Directory should be made by indexing off of the values stored in the Volume Directory Header Table.

9.8.1 Volume Directory Header Table

Table 9-8 shows the contents of the Volume Directory Header.

Bytes	Contents	Comment
0 - 6	Key	This field is used to authenticate the Volume Directory. If the proper key, "TR5 DIR" is not present, the Volume Directory is not valid.
7	Revision	This field shall be set to 00hex.
8	Maximum Number of Partitions	This field shall be set to 2.
9	Active Number of Partitions	The number of partitions into which the tape is currently divided.
10	Number of Channels per Trackset	This field is set to 1 for single channel and to 3 for 3 channel.
11	Start of Partition Table	This field specifies the number of bytes from the beginning of the Header Field to the first byte of the Partition Table. This field shall be set to 22.
12-13	Start of Track Table	This field specifies the number of bytes from the beginning of the Header Field to the first byte of the Track Table. This field shall be set to 62.
14-15	Start of Random Access Table	This field specifies the number of bytes from the beginning of the Header Field to the first byte of the Random Access Table. This field shall be set to 1790.
16	Partition Table Entry Size	This field specifies the number of bytes in each entry of the Partition Table. This field shall be set to 20.
17	Track Table Entry Size	This field specifies the number of bytes in each entry of the Track Table. This field shall be set to 16.
18	Random Access Table Entry Size	This field specifies the number of bytes in each entry of the Random Access Table. This field shall be set to 10.
19	Maximum RAT Entries Per Track	This field specifies the maximum number of RAT entries per track. The value is dependent on the tape format, tape length, and RAT Distance used. If no Random Access Table is used, this field shall be 0.
20-21	Random Access Table Distance	This field contains the number of physical blocks between entries in the RAT. This field specifies the physical address of the first block that has a RAT entry, and the distance between all succeeding entries. The value to use is dependent on tape format, tape length, and number of bytes allocated for the Volume Directory. This field shall be 0 if no RAT is used.

Table 9-8 Volume Directory Header

9.8.2 Volume Directory Partition Table

Each of the two partitions has its own Partition Table. The Partition Table for partition 0 follows immediately after the Volume Directory Header Field. The Partition Table for partition 1 follows the Partition Table for partition 0. Table 9-9 shows the content of each Partition Table.

Byte	Bit							
	7	6	5	4	3	2	1	0
0	Erased	EOP	HWE	LEW	Reserved			
1	BOP Track Number							
2	EOP Track Number							
3	EOD Track Number							
4 - 7	(MSB) EOD Physical Block Address (LSB)							
8 - 11	(MSB) EOD Logical Block Address (LSB)							
12 - 13	(MSB) Write Pass Count (LSB)							
14 - 17	(MSB) Filemark Count (LSB)							
18 - 19	(MSB) Setmark Count (LSB)							

Table 9-9 Volume Directory Partition Table

Erased Bit set if partition is logically erased. Cleared if partition contains data.

EOP Bit set if End Of Partition is reached during a write process. The HWE bit shall also be set when this bit is set.

HWE	Bit set if a Hard Write Error has occurred during a write process. When this bit is set, the EOD Physical Block Address field shall contain the Physical Block Address of the next block to be written when the hard write error occurred. The EOD Logical Block Address field is invalid when HWE is set.
LEW	This bit is set when End Of Media has been sent to the host during a write process.
BOP Track Number	Track Number for the beginning of this partition. This field is set to 0 for partition 0 and 254 for partition 1.
EOP Track Number	Track Number for the end of this partition. This field is set to 71 for partition 0 and 254 for partition 1.
EOD Track Number	This field contains the track number on which the block specified by the EOD Physical Block Address field is recorded.
EOD Physical Block Address	Physical Block Number of the last block in the last Data Frame before End Of Data.
EOD Logical Block Address	Logical Block Address of the last logical host block before End Of Data.
Write Pass Count	Write Pass Count for valid frames in the partition.
Filemark Count	This field specifies the total number of Filemarks recorded in the partition.
Setmark Count	This field specifies the total number of Setmarks recorded in the partition.

9.8.3 Volume Directory Track Table

The Volume Directory Track Table contains information pertaining to each track in Partition 0. Tracks that have no data shall have a 0 Hex value for all of the entries in their table.

Offset	Contents	Comment
0 - 1	Valid RAT Entries from this Track	This field represents the number of valid entries in the RAT for this track.
2 - 5	Starting Physical Block Address	This field contains the Physical Block Address of the first block recorded on this track.
6 - 9	Logical Block Address	This field specifies the value contained in the Logical Block Address field of the first block recorded on this track which has its BOLB bit set.
10 - 13	Filemark Count	This field specifies the number of Filemarks recorded in the partition up to but not including the first block on this track.
14 - 15	Setmark Count	This field specifies the number of Setmarks recorded in the partition up to but not including the first block on this track.

Table 9-10 Volume Directory Track Table

9.8.4 Volume Directory Random Access Table

The Random Access Table allows for increased resolution over the Track Table into the relationships between Physical Addresses, Logical Addresses, and the location of Filemarks and Setmarks. A snapshot of the Logical Address and Filemark and Setmarks counts is taken every N Physical Blocks, where N is the RAT Distance defined in the Volume Directory Header Field. The RAT Distance is chosen to optimize the relationship between minimizing the time required to position accurately to a logical block on tape, and the amount of memory space required to contain the RAT. The structure of each RAT entry is defined in Table 9-11.

Offset	Contents	Comment
0 - 3	Logical Block Address	This field specifies the value contained in the Logical Block Address field of the first block recorded at or beyond this RAT entry point which has its BOLB bit set.
4 - 7	Filemark Count	This field specifies the number of Filemarks recorded in the partition up to but not including this RAT entry point.
8 - 9	Setmark Count	This field specifies the number of Setmarks recorded in the partition up to but not including this RAT entry point.

Table 9-11 Volume Directory RAT Entry Structure

10. DATA COMPRESSION

10.1 Introduction

This Standard supports data compression as an optional feature. If hardware data compression is implemented it shall be done using the ALDC-1 algorithm in accordance with QIC-154.

It is not a requirement in this Standard that the drive must support hardware data compression to be compatible with the Standard. The Standard is designed such that drives that do support the general QIC-3220-MC Standard but do not support data compression will be able to retrieve compressed data and transfer it to the host.

10.2 General Rules

The rules for data compression are set forth below. The user should also refer to the appropriate host interface standard for additional information.

Only the data area in the data blocks may contain compressed data. All other information is uncompressed. If compression is enabled, filemarks, setmarks and cancelmarks shall be recorded without compression, as specified in section 9.3.

The data on the directory partition shall not be compressed.

If compression is enabled, all data blocks within the current partition shall be grouped into Compression Block Groups (except the directory partition, which shall be written uncompressed).

10.3 Compression Block Group

Compressed data will be grouped into Compression Block Groups. The Compression Block Group shall contain an 18 byte Compression Header as described in Section 10.6. The first data byte following the Compression Header is the beginning of compression and the last byte is the end of compressed data. . The Compression Block Group shall be limited to 64K -1 (65535) bytes of compressed and uncompressed data. That is, the size of the uncompressed data may never expand to more than 64K -1 when attempting to compress it. Each Compression Block Group shall be written to the tape as one variable logical block.

10.4 Data Compression with Fixed or Same Sized Blocks

When writing in fixed block mode, a number of same sized blocks may be grouped, compressed and recorded as one Compression Block Group on the tape.

10.5 Data Compression with Variable Blocks

When writing in variable block mode, each write data command is recorded as one or more Compression Block Groups. Variable blocks having a transfer length greater than 64K (65536) bytes shall be divided into multiple Compression Block Groups.

10.6 Compression Header

The Compression Header consist of 18 bytes of uncompressed data placed at the beginning of each Compression Block Group. See Table 10-1.

Byte	Bit							
	7	6	5	4	3	2	1	0
0	UCMP	BCBG	ECBG	Header Length				
1	QIC Compression Algorithm ID							
2 - 3	(MSB) Logical Host Block Length (LSB)							
4 - 5	(MSB) Logical Host Block Quantity (LSB)							
6 - 9	(MSB) Logical Block Address (LSB)							
10 - 11	(MSB) Net Logical Tape Block Length (LSB)							
12 - 15	(MSB) Filemark Count (LSB)							
16 - 17	(MSB) Setmark Count (LSB)							

Table 10-1 Compression Header

UCMP	The UCMP (Uncompressed) bit indicates whether the data in the Compression Block Group is compressed (CMP=0) or uncompressed (CMP=1).
BCBG	The BCBG (Beginning of Compression Block Group) bit is set to 1 to indicate if this is the first or only Compression Block Group in a series of linked Compression Block Groups. When cleared, this Compression Block Group is a continuation of a Host Logical Block which began in a previous Compression Block Group.
ECBG	The ECBG (End of Compression Block Group) bit is set to 1 to indicate if this is the last or only Compression Block Group in a series of linked Compression Block Groups. When cleared it indicates the continuation of a Host Logical Block into the next Compression Block Group.
Header Length	The Header Length indicates the length of the Compression Header. This field shall always contain 12_{Hex}.
QIC Compression Algorithm	The QIC Compression Algorithm contains the registered compression algorithm identifier. Refer to QIC-123 for more details. This field shall be zero if no compression is used.
Logical Host Block Length	This field contains the uncompressed size, in bytes, of the host block(s) in the Compression Block Group. If BCBG or ECBG is 0, this field contains the size of the uncompressed partial host block.
Logical Host Block Quantity	This field contains the number of host blocks compressed and recorded on the tape as one Compression Block Group. If a either BCBG or ECBG is zero, this field shall be set to 1.
Logical Block Address	This field contains the Logical Block Address of the first block in the Compression Block Group. If the logical block is split across multiple Compression Block Groups then the Logical Block Address will be the same in all the Compression Block Groups.
Net Logical Tape Block Length	This field contains the number of valid bytes in the Compression Block Group following the Compression Header.
Filemark Count	Contains the number of Filemarks recorded from the beginning of the partition up to the present position. Note: This count will be zero for the first Filemark.
Setmark Count	Contains the number of Setmarks recorded from the beginning of the partition up to the present position. Note: This count will be zero for the first Setmark.

When writing and reading compressed data, the Compression Block Groups are not visible to the user. The Compression Header will not be transferred to the host during decompression. If a tape which contains compressed data is read on a drive without data decompression, the complete Compression Block Group with the Compression Header and the compressed data will be transferred to the host. The host must then use the information in the Compression Header to decompress the data.

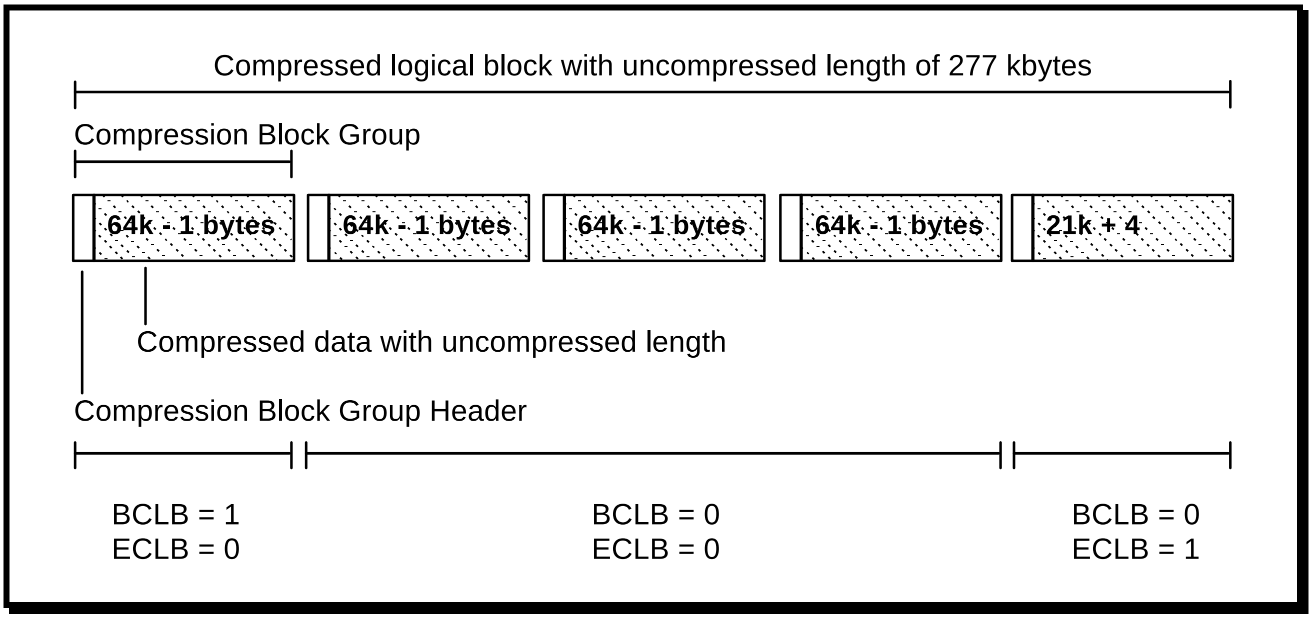


Figure 10.1 Logical block spanning multiple Compression Block Group

The ECC blocks at the end of each frame may be used during the data read operation to reconstruct blocks in error. The error correction system is based upon an interleave organization effectively separating each frame into 2 groups: one containing all of the even numbered blocks, the other one containing all of the odd numbered blocks. Each group has independent error correction. The group with the even blocks shall be referred to as the even interleave while the group containing the odd blocks shall be referred to as the odd interleave. For each of these groups, the error correction system makes it possible to correct any combination of s blocks with CRC errors (or pointers) and t blocks with CRC failures, as long as:

$$s + 2t < 11$$

10.7 Error Correction Matrix Format

A frame contains 128 blocks, 108 data blocks and 20 ECC parity blocks. Each block contains 512 data bytes and 1 Control Byte (Control Byte 0) which are covered by ECC control.

The bytes in the ECC frames are considered to be arranged in 64 blocks (rows) by 513 bytes as shown in Figure 10.1.

The even parity rows (i.e. blocks 108, 110, 112, 114, 116, 118, 120, 122, 124, and 126) shall be chosen so that each column of the even rows (i.e. blocks 0, 2, 4, ..., 104 and 106) of the matrix forms an independent Reed-Solomon codeword of redundancy ten, with 8-bit characters, as shown in Figure 10.1. Similarly, the odd parity rows (i.e. 109, 111, 113, 115, 117, 119, 121, 123, 125, and 127) shall be chosen so that each column of the odd rows (blocks 1, 3, 5, ..., 105 and 107) of the matrix forms an independent Reed-Solomon codeword of redundancy ten. See Figure 10.2. Data shall be written on the tape row by row, starting with row 0, and within each row (i.e. block) the bytes shall be written starting with column 0. This implementation gives a very effective interleaving of the data regarding ECC, although the data itself is recorded in the normal order received from the host. This implementation ensures that the influence of any error spreading over two neighbor blocks is reduced. Figure 10.4 shows the complete ECC frame format with all blocks.

	Control Byte 0	Data Bytes 0	1	...	510	511		
0							CRC	D
2							CRC	A
4							CRC	T
...								A
104							CRC	
106							CRC	
108				ECC 0			CRC	P
110				ECC 2			CRC	A
112				ECC 4			CRC	R
114				ECC 6			CRC	I
116				ECC 8			CRC	T
118				ECC 10			CRC	Y
120				ECC 12			CRC	
122				ECC 14			CRC	
124				ECC 16			CRC	
126				ECC 18			CRC	

Figure 10.1 ECC Frame Format, Even Blocks

	Control Byte 0	Data Bytes 0	1	...	510	511		
1							CRC	D
3							CRC	A
5							CRC	T
...								A
105							CRC	
107							CRC	
109				ECC 1			CRC	P
111				ECC 3			CRC	A
113				ECC 5			CRC	R
115				ECC 7			CRC	I
117				ECC 9			CRC	T
119				ECC 11			CRC	Y
121				ECC 13			CRC	
123				ECC 15			CRC	
125				ECC 17			CRC	
127				ECC 19			CRC	

Figure 10.2 ECC Frame Format, Odd Blocks

10.8 Field Representation

GF(256) is the field consisting of 256 elements. Each field element "a" has the form:

$$a = a_7x^7 + a_6x^6 + a_5x^5 + a_4x^4 + a_3x^3 + a_2x^2 + a_1x + a_0$$

where each a_i is either 0 or 1. A field element "a" shall be represented by a byte as shown in Figure 10.3.

MSB							LSB
a_7	a_6	a_5	a_4	a_3	a_2	a_1	a_0

Figure 10.3 Bit Numbering Convention

Field math operations (addition, multiplication, division) are defined to be polynomial math modulo a_n irreducible binary polynomial of degree eight, f(x), where binary addition is the logical exclusive-or operation and binary multiplication is the AND operation. The irreducible polynomial used to generate the field GF(256) shall be:

$$f(x) = x^8 + x^7 + x^2 + x + 1 .$$

	Control			Data Bytes				
	Byte 0	0	1	...	510	511		
0							CRC	D
1							CRC	A
2							CRC	T
...							...	A
106							CRC	
107							CRC	
108				ECC 0			CRC	P
109				ECC 1			CRC	A
110				ECC 2			CRC	R
...				...			CRC	I
126				ECC 18			CRC	T
127				ECC 19			CRC	Y

Figure 10.4 ECC Full Frame Format.

10.9 Code Generator Polynomial

Let r be a root of f(x); in hex notation, r=2hex. The generator polynomial for the Reed-Solomon code shall be of the form:

$$g(x) = (x+r^0)(x+r^1)(x+r^2)(x+r^3)(x+r^4)(x+r^5)(x+r^6)(x+r^7)(x+r^8)(x+r^9)$$
$$= x^{10} + F1x^9 + BEx^8 + 0Cx^7 + 45x^6 + E7x^5 + D0x^4 + B3x^3 + 1Bx^2 + E0x + 78$$

Encoding shall be accomplished as follows. In a full frame, each column contains data bytes d0 to d127, numbered as in Figure 10.4. The parity bytes d108 to d127 in each column shall be chosen so that the 2 polynomials:

$$do(x) = \sum_{I=0}^{63} d_{(127-2i)}x^i$$

and

$$do(x) = \sum_{i=0}^{63} d_{(127-2i)}x^i$$

31

(Σ = SUM)

are each divisible by g(x), using polynomial division over GF(256).

10.10 Examples Of Codewords

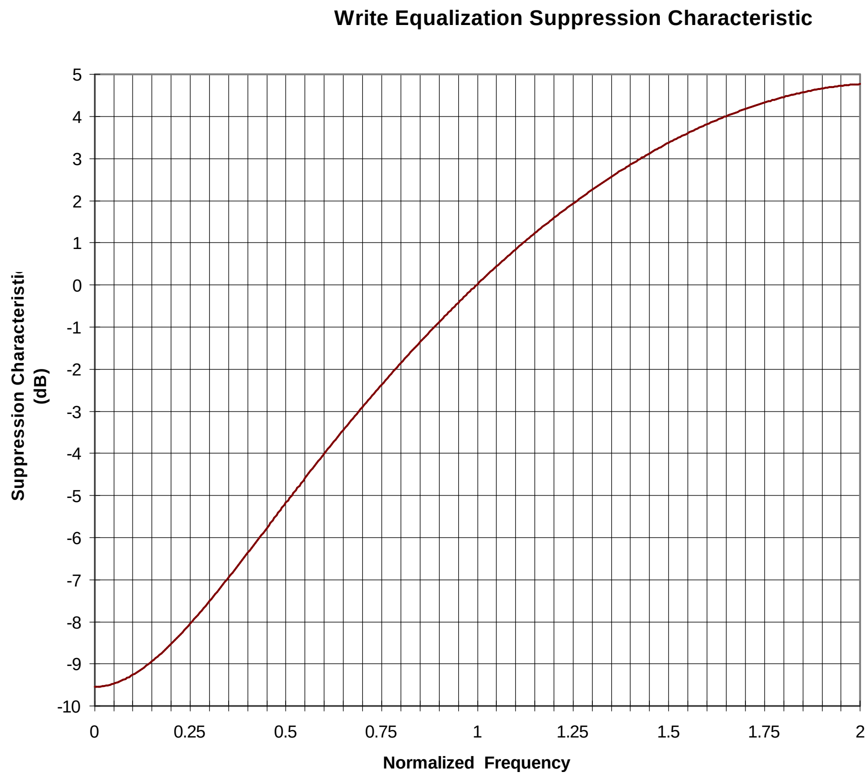
The following columns of bytes are codewords for the polynomials defined in the preceding sections, using hex notation for the field elements.

Data Block Number	Byte Number															
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
1	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
...						(all	0's)									
98	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
99	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
100	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
101	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
102	00	00	00	00	00	00	01	00	01	01	00	01	00	00	00	00
103	00	00	00	00	00	00	00	01	01	00	01	01	00	00	00	00
104	00	00	00	01	00	01	00	00	00	01	00	01	FF	00	FF	00
105	00	00	00	00	01	01	00	00	00	00	01	01	00	FF	FF	00
106	01	00	01	00	00	00	00	00	00	01	00	01	00	00	00	00
107	00	01	01	00	00	00	00	00	00	00	01	01	00	00	00	00
Parity Block Numbering	Byte Number															
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
108	F1	00	F1	0A	00	0A	1B	00	1B	E0	00	E0	1A	00	1A	00
109	00	F1	F1	00	0A	0A	00	1B	1B	00	E0	E0	00	1A	1A	00
110	BE	00	BE	6D	00	6D	85	00	85	56	00	56	73	00	73	00
111	00	BE	BE	00	6D	6D	00	85	85	00	56	56	00	73	73	00
112	0C	00	0C	9C	00	9C	3C	00	3C	AC	00	AC	7B	00	7B	00
113	00	0C	0C	00	9C	9C	00	3C	3C	00	AC	AC	00	7B	7B	00
114	45	00	45	44	00	44	C6	00	C6	C7	00	C7	E4	00	E4	00
115	00	45	45	00	44	44	00	C6	C6	00	C7	C7	00	E4	E4	00
116	E7	00	E7	ED	00	ED	50	00	50	5A	00	5A	5F	00	5F	00
117	00	E7	E7	00	ED	ED	00	50	50	00	5A	5A	00	5F	5F	00
118	D0	00	D0	BA	00	BA	E9	00	E9	83	00	83	FB	00	FB	00
119	00	D0	D0	00	BA	BA	00	E9	E9	00	83	83	00	FB	FB	00
120	B3	00	B3	52	00	52	2A	00	2A	CB	00	CB	A9	00	A9	00
121	00	B3	B3	00	52	52	00	2A	2A	00	CB	CB	00	A9	A9	00
122	1B	00	1B	41	00	41	F5	00	F5	AF	00	AF	E9	00	E9	00
123	00	1B	1B	00	41	41	00	F5	F5	00	AF	AF	00	E9	E9	00
124	E0	00	E0	1B	00	1B	3D	00	3D	C6	00	C6	23	00	23	00
125	00	E0	E0	00	1B	1B	00	3D	3D	00	C6	C6	00	23	23	00
126	78	00	78	E1	00	E1	3E	00	3E	A7	00	A7	CE	00	CE	00
127	00	78	78	00	E1	E1	00	3E	3E	00	A7	A7	00	CE	CE	00

Table 10-1 Example of Codewords

11. APPENDIX A

Suppression characteristic of the write equalizer normalized by frequency F_d.



Data Frequency	Suppression
F_d	OdB
$F_d/2$	-5.2 dB
$F_d/4$	-8.1 dB

Table A-1 Write Equalization Suppression Characteristics