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Information technology — Digitally recorded media for information interchange and storage — 120 mm Single Layer (25,0 Gbytes per disk) and Dual Layer (50,0 Gbytes per disk) BD Rewritable disk

Technologies de l'information — Supports enregistrés numériquement pour échange et stockage d'information — Disques BD réinscriptibles de 120 mm simple couche (25,0 Go par disque) et double couche (50,0 Go par disque)

Reference number
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Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO and IEC shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents) or the IEC list of patent declarations received (see patents.iec.ch).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information Technology*, Subcommittee SC 23, *Digitally recorded media for information interchange and storage*.

This third edition cancels and replaces the second edition (ISO/IEC 30192:2016), which has been technically revised. It also incorporates the Amendment ISO/IEC 30192:2016/Amd.1:2019.

The main changes compared to the previous edition is the addition of requirements for physical accesss control and reserved area of BD application.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

In March 2002, the Blu-ray Disc Founders, or BDF, came together to create optical disk formats with the large capacity and high-speed transfer rates that would be needed for recording and reproducing of high-definition video content. The first edition of Blu-ray Disc™ Rewritable Format Part 1 Version 1.0 was issued in June 2002 (capacity 23 GB with catridge).

The BDA issued Version 2.1 of the Blu-ray Disc™ Rewritable Format Part1 in October 2005 and Version 3.0 in June of 2010 (capacity 25 GB and 50 GB without cartridge).

To keep the compatibility of the removable medium in the market, just to make a standard is not enough, and it is necessary to check that the disks and devices can satisfy the specifications. The BDA conducts verification activities for both disks and devices and has established more than 10 testing Centres in Asia, Europe and the USA.

Blu-ray™ disks, players, recorders and PC drives/software based on BDA standards became popular all over the world. The BDA gave consumer applications the highest priority in the first few years. But it was known, of course, that international standardization would be required before many government entities and their contractors would be allowed to use Blu-ray Disc™. In January and February 2011, the BDA was formally requested to consider international standardization. The reason for this was to enable the inclusion of writable BDs, along with DVDs and CDs, in an International Standard specifying test methods for the estimation of lifetime of optical storage media for long-term data storage. In October 2011, the BDA responded that it had decided to pursue international standardization of the basic physical formats for the Recordable and Rewritable Blu-ray Disc™.

In December 2011, the BDA sent project proposals for international standardization of four formats. They are 120 mm Single Layer (25,0 Gbytes per disk) and Dual Layer (50,0 Gbytes per disk) BD Recordablee disks, 120 mm Single Layer (25,0 Gbytes per disk) and Dual Layer (50,0 Gbytes per disk) BD Rewritable disks, 120 mm Triple Layer (100,0 Gbytes per disk) and Quadruple Layer (128,0 Gbytes per disk) BD Recordable disks and 120 mm Triple Layer (100,0 Gbytes per disk) BD Rewritable disk.

A few additional specifications are required in order to write and read video recording applications, such as the BDMV and BDAV formats, which have been specified by the BDA for use on BD recordable disks. These specifications, which are related to the BD application, the file system and the content-protection system, are required for the disk, the generating system and the receiving system[1)].

The International Organization for Standardization (ISO) and International Electrotechnical Commission (IEC) draw attention to the fact that it is claimed that compliance with this document may involve the use of a patent.

ISO and IEC take no position concerning the evidence, validity and scope of this patent right.

The holder of this patent right has assured ISO and IEC that he/she is willing to negotiate licences under reasonable and non-discriminatory terms and conditions with applicants throughout the world. In this respect, the statement of the holder of this patent right is registered with ISO and IEC. Information may be obtained from the patent database available at www.iso.org/patents.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights other than those in the patent database. ISO and IEC shall not be held responsible for identifying any or all such patent rights.

NOTE Blu-ray™, Blu-ray Disc™ and the logos are trademarks of the Blu-ray Disc Association.

1) For more information of the BD application, the content-protection system and the additional requirements for the Blu-ray™ Format specifications, see http://www.blu-raydisc.info.

Information technology — Digitally recorded media for information interchange and storage — 120 mm Single Layer (25,0 Gbytes per disk) and Dual Layer (50,0 Gbytes per disk) BD Rewritable disk

1 Scope

This document specifies the mechanical, physical and optical characteristics of a 120 mm rewritable optical disk with a capacity of 25,0 Gbytes or 50,0 Gbytes. It specifies the quality of the recorded and unrecorded signals, the format of the data and the recording method, thereby allowing for information interchange by means of such disks. User data can be written, read and overwritten many times using a reversible method. This disk is identified as a BD rewritable disk.

This document specifies the following:

— two related but different types of this disk;

— conditions for conformance;

— environments in which the disk is to be operated and stored;

— mechanical and physical characteristics of the disk, which allow mechanical interchange between data processing systems;

— format of the information on the disk, including the physical disposition of the tracks and sectors;

— error-correcting codes and coding method used;

— characteristics of the signals recorded on the disk, which enable data processing systems to read data from the disk.

This document provides for interchange of disks between drives. Together with a standard for volume and file structure, it provides for full data interchange between data processing systems.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC 646, *Information technology — ISO 7-bit coded character set for information interchange*

ISO 9352, *Plastics — Determination of resistance to wear by abrasive wheels*

ISO 30193, *Information technology — Digitally recorded media for information interchange and storage — 120 mm Triple Layer (100,0 Gbytes per disk) BD Rewritable disk*

IEC 60068-2-2, *Environment testing — Part 2-2: Tests — Test B: Dry heat*

IEC 60068-2-30, *Environment testing — Part 2-30: Tests — Test Db: Damp heat, cyclic (12 h + 12 h cycle)*

IEC 60950-1, *Information technology equipment — Safety — Part 1: General requirements*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC 30193 apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

4 Symbol and abbreviated terms

ac	alternating current
ADIP	address in pre-groove
APC	automatic power control
AU	address unit
AUN	address unit number
BCA	burst-cutting area
BIS	burst-indicating subcode
BPF	band-pass filter
CAV	constant angular velocity
cbs	channel bits
CNR	carrier-to-noise ratio
dc	direct current
DDS	disk definition structure
DFL	defect list
DI	disk information
DL	dual layer
DMA	disk management area
DMS	disk management structure
DOW	direct overwrite
DOW(n)	the n-th overwrite
DOW(0)	the initial recording
DSV	digital-sum value
DWP	disk write protect
EB	emergency brake
ECC	error correction code
lsb	least significant bit
L_{SHD}	second harmonic distortion level
L_{SHL}	second harmonic level
LSN	logical sector number
MM	MSK mark
MSB	most significant byte
msb	most significant bit
MSK	minimum shift keying
MW	monotone wobble
NRD	non-re-allocatable defect
NRZ	non-return-to-zero
NRZI	non-return-to-zero inverting
NWL	nominal wobble length
OPU	optical pick-up unit
PAA	physical ADIP address
PAC	physical access control
PBA	possibly bad area
PIC	permanent information and control data
PLL	phase-lock loop
PoA	post-amble
PP	push-pull
pp	peak-to-peak
PrA	pre-amble
PSN	physical sector number
R_H	relative humidity

EDC	error detection code	RMTR	repeated minimum transition run length
FAA	first ADIP address (of data zone)	R-M-W	read-modify-write
FS	frame sync	RS	Reed-Solomon (code)
FWHM	full width at half maximum	R_T	relative thickness
HF	high frequency	RUB	recording unit block
HFM	high frequency modulated	SER	symbol error rate
HMW	harmonic-modulated wave	SL	single layer
HPF	high-pass filter	S/N	signal-to-noise ratio
HTL	high-to-low	SPS	start position shift
I_{NHWS}	normalized HFM-wobble signal amplitude	STW	saw-tooth wobble
I_{NWS}	normalized wobble signal amplitude	Sync	synchronization
LAA	last ADIP address (of data zone)	TP	track pitch
LDC	long-distance code	TS	transmission stack
LPF	low-pass filter	wbs	wobbles
LSB	least significant byte	WP	write protect

5 Conformance

5.1 Optical disk

A claim of conformance with this document shall specify the type implemented. An optical disk shall be in conformance with this document if it meets all mandatory requirements specified for its type.

5.2 Generating system

A generating system shall be in conformance with this document if the optical disk it generates is in accordance with 5.1.

5.3 Receiving system

A receiving system shall be in conformance with this document if it is able to handle both Types of optical disks according to 5.1.

5.4 Compatibility statement

A claim of conformance by a generating or receiving system with this document shall include a statement listing any other standards supported. This statement shall specify the numbers of the standards, the optical disk types supported (where appropriate) and whether support includes reading only or both reading and writing.

6 Conventions and notations

6.1 Levels of grouping

Many times, data is collected into that data can be collected into higher level groups. For the clarity of the grouping hierarchy, in this document, the following levels of hierarchy is used.

Frame: the lowest level of grouping. Generally, frames contain bytes of information.

Block: the second level of grouping. Generally, blocks consist of a number of frames.

Cluster: the highest level of grouping. Clusters consist of several blocks.

Fragment: a level of grouping that can be applied by the application. A certain amount of data is allocated to a (fixed) number of consecutive clusters.

6.2 Representation of numbers

A measured value $x_{measured}$ may be rounded off to the least significant digit of the corresponding specified value x before being compared with this specified value.

EXAMPLES:

— The specification is: $x = 1,26^{+0,01}_{-0,02}$:

(nominal value = 1,26 with a positive tolerance of +0,01 and a negative tolerance of −0,02)

— a measured value in the range $1,235 \leq x_{measured} < 1,275$ fulfills this specification.

— The specification is: $x \leq 0,3$:

— a measured value $x_{measured} < 0,35$ fulfills this specification (rounding off is applied for $0,30 < x_{measured} < 0,35$: $x_{rounded} = 0,3$);

— The specification is: $x < 0,3$:

— a measured value $x_{measured} = 0,299$ fulfills this specification (no rounding off needs to be applied);

— a measured value $x_{measured} = 0,3$ exactly does not fulfil this specification.

In case the specified value is given as “maximum *x* units” or “minimum *x* units”, the measured value shall not be rounded off before comparing to the specified value. Parameters given in this way shall not violate the specified limits set by the exact value of *x*.

EXAMPLES:

— The specification is maximum 0,3 mm:

— a measured value of 0,300 mm fulfills this specification;

— a measured value of 0,301 mm does not fulfil this specification;

— The specification is minimum 3 dB:

— a measured value of 3,00 dB fulfills this specification;

— a measured value of 2,99 dB does not fulfil this specification.

Numbers in decimal notation are represented by the digits 0 to 9. The decimal symbol is "," (comma). In large numbers, the " " (space) can be used as digit grouping symbol.

Numbers in hexadecimal notation are represented by the hexadecimal digits 0 to 9 and A to F in parentheses or followed by lowercase "h". The character x in hexadecimal numbers represents any digit 0 to 9 or A to F.

Numbers in binary notation and bit patterns are represented by strings of digits 0 and 1, with the most significant bit shown to the left. The character *x* in binary numbers represents a digit 0 or 1.

Negative values of numbers in binary notation are given as two's complement.

In a pattern of *n* bits, bit $b_{(n-1)}$ shall be the most significant bit (msb) and bit b_0 shall be the least significant bit (lsb). Bit $b_{(n-1)}$ shall be recorded first.

An uninterrupted sequence of *m* 0's in a bit pattern can be represented by $[0^m]$.

The setting of bits is denoted by ZERO and ONE.

In data fields composed of bytes, the data is recorded so that the most significant byte (MSB), identified as byte 0, shall be recorded first and the least significant byte (LSB) last.

In a field of 8*n* bits, bit $b_{(8n-1)}$ shall be the most significant bit (msb) and bit b_0 the least significant bit (lsb). Bit $b_{(8n-1)}$ shall be recorded first.

In data fields composed of nibbles, the data is recorded so that the most-significant nibble, identified as nibble 0, shall be recorded first and the least-significant nibble last.

In a field of 4*n* bits, bit $b_{(4n-1)}$ shall be the most significant bit (msb) and bit b_0 the least significant bit (lsb). Bit $b_{(4n-1)}$ shall be recorded first.

A range of values is indicated as $x \sim y$, where the limits *x* and *y* are included in the range.

A list of integers is indicated as *i* .. *j*. The list contains all integers between *i* and *j* as well as *i* and *j* (e.g. *k* = 0 .. 7). If the step size is different from one, this is indicated as: *i*, (*i* + step) .. *j* (e.g. *k* = 1, 4 .. 16, where step = 3).

A group of parameters is indicated as param *m* .. *n* or P_m .. P_n. The group contains all parameters with an index between *m* and *n* as well as *m* and *n* (e.g. byte 16 .. 31, bit 7 .. 4, Add0 .. Add255).

If *x* is nearly equal to *y*, then it is expressed as $x \approx y$.

6.3 Integer calculus

div(*n*,*d*) represents the integer part of the division of *n* by *d*.

mod(*n*,*d*) represents the remainder of the division of *n* by *d*: mod(*n*,*d*) = *n* – *d* × div(*n*,*d*).

EXAMPLE

div(+11,+3) = +3	div(–11,+3) = –3	div(+11,–3) = –3	div(–11,–3) = +3
mod(+11,+3) = +2	mod(–11,+3) = –2	mod(+11,–3) = +2	mod(–11,–3) = –2

7 General descriptions of disk

The 120 mm optical disk that is the subject of this document consists of a substrate of about 1,1 mm nominal thickness. clamping is performed in the clamping zone.

The recording layer of the disk uses high-to-low (HTL) technology. Recorded HTL marks have lower reflection than the unrecorded layer(s).

The recording layer of the disk may use phase-change recording technology. Recorded amorphous marks have lower reflection than the crystalline spaces of unrecorded layer(s).

This document provides for two types of disks

Type SL disk: the substrate is covered with a recording layer, consisting of several films. On top of this recording layer, a transparent cover layer of 0,1 mm is applied with precisely defined optical characteristics (see Figure 1). The capacity is 25,0 Gbytes.

Type DL disk: the substrate is covered with two recording layers, each consisting of several films. The two recording layers are separated by a transparent spacer layer of about 0,025 mm. The first recording layer seen from the read-out side of the disk shall be semi-transparent. On top of this recording layer, a transparent cover layer of about 0,075 mm is applied. Both the spacer layer and the cover layer shall have precisely defined optical characteristics (see Figure 2). The capacity is 50,0 Gbytes.

To improve scratch resistance of the disk, the cover layer optionally can be protected with an additional hard coating.

Data can be written and overwritten onto the disk with a high-power focused optical beam. The data can be read with a low-power focused optical beam, using the difference in the reflectivity of the amorphous marks and the crystalline spaces.

The recording layer(s) contain wobbled groove(s) with addresses that enable a speed control and navigation system for data to be read from or written to the recording layer concerned.

Recording and reading of the data is accomplished through the cover layer or through the total stack of cover layer, first recording layer and spacer layer, depending on which recording layer is involved.

For reference purposes, a layer that the light beam passes through when accessing a certain recording layer is called a transmission stack of that specific recording layer (see Figure 1 and Figure 2).

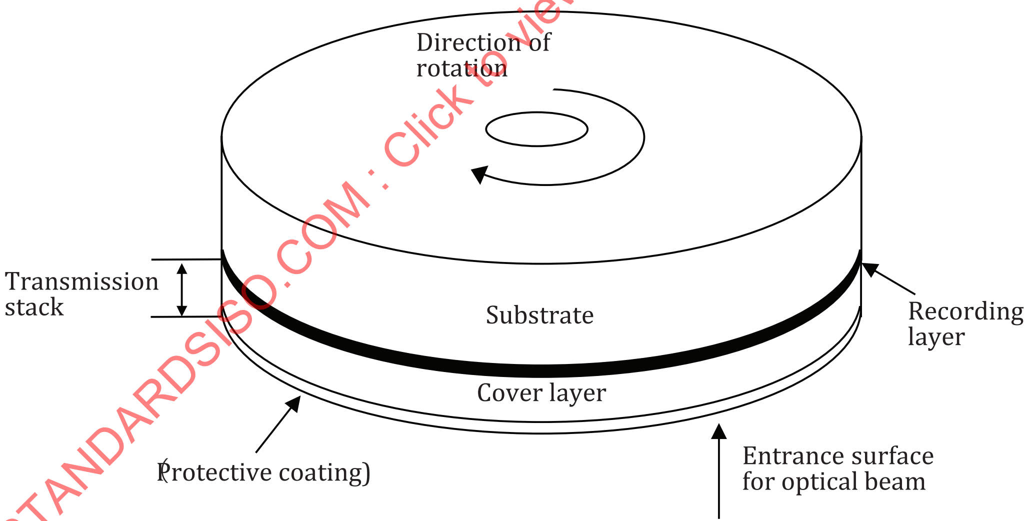


Figure 1 — Outline of type SL disk

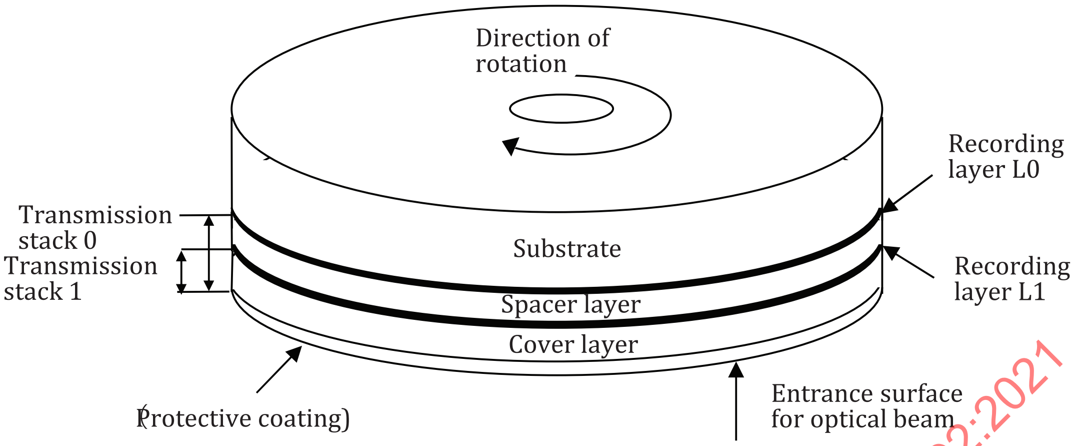


Figure 2 — Outline of type DL disk

This document specifies two kinds of recording velocity: 1x and 2x.

Figure 3 shows the recording velocity requirements for each disk type. At least one of the write strategies is reqired for each recording velocity.

Disk type	Disk type parameters		Recording velocity	
	Mark polarity	Layer type	1x	2x
Type SL	HTL	SL	M	M
Type DL	HTL	DL	M	M
M Mandatory				

Figure 3 — Recording velocity requirements for disk type

8 General requirements

8.1 Environments

8.1.1 Test environment

8.1.1.1 General

During measurements for testing conformance of a disk with this document, the disk shall be in the test environment. The test environment is the environment where the air immediately surrounding the disk shall have following properties:

— temperature, T: (23 ± 2) °C;

— relative humidity, R_H: 45 %to 55 %;

— atmospheric pressure: 86 kPa to 106 kPa.

No condensation on the disk shall occur. Before testing, the disk shall be conditioned in this environment for a sufficient time.

8.1.1.2 Test conditions for sudden changes in operating environment

Some parameters can be rather sensitive to changes in the operating environment. Where specified, the following two tests shall be performed. In both cases, the required specifications shall be fulfilled during the time it takes for the disk to acclimatize to the new environment.

a) Apply a sudden change in relative humidity, while keeping the temperature at a constant level: R_H = 90 %, T = 25 °C → R_H = 45 %, T = 25 °C (see Figure 4).

b) Apply a sudden change in temperature, while keeping the absolute humidity at a constant level (≈10,4 g/m^3): T = 25 °C, R_H = 45 % → T = 55 °C, R_H = 10 % (see Figure 4).

8.1.2 Operating environment

A disk in conformance with this document shall provide data interchange over the specified ranges of environmental parameters in the operating environment. The operating environment is the environment where the air immediately surrounding the disk shall have the following properties:

— temperature, T: 5°C to 55 °C;

— relative humidity, R_H: 3 %to 90 %;

— absolute humidity: 0,5 g/m^3 to 30 g/m^3;

— atmospheric pressure: 60 kPa to 106 kPa.

There shall be no condensation of moisture on the disk. If a disk has been exposed to conditions outside those specified above, it shall be acclimatized in an operating environment for at least 2 h before use.

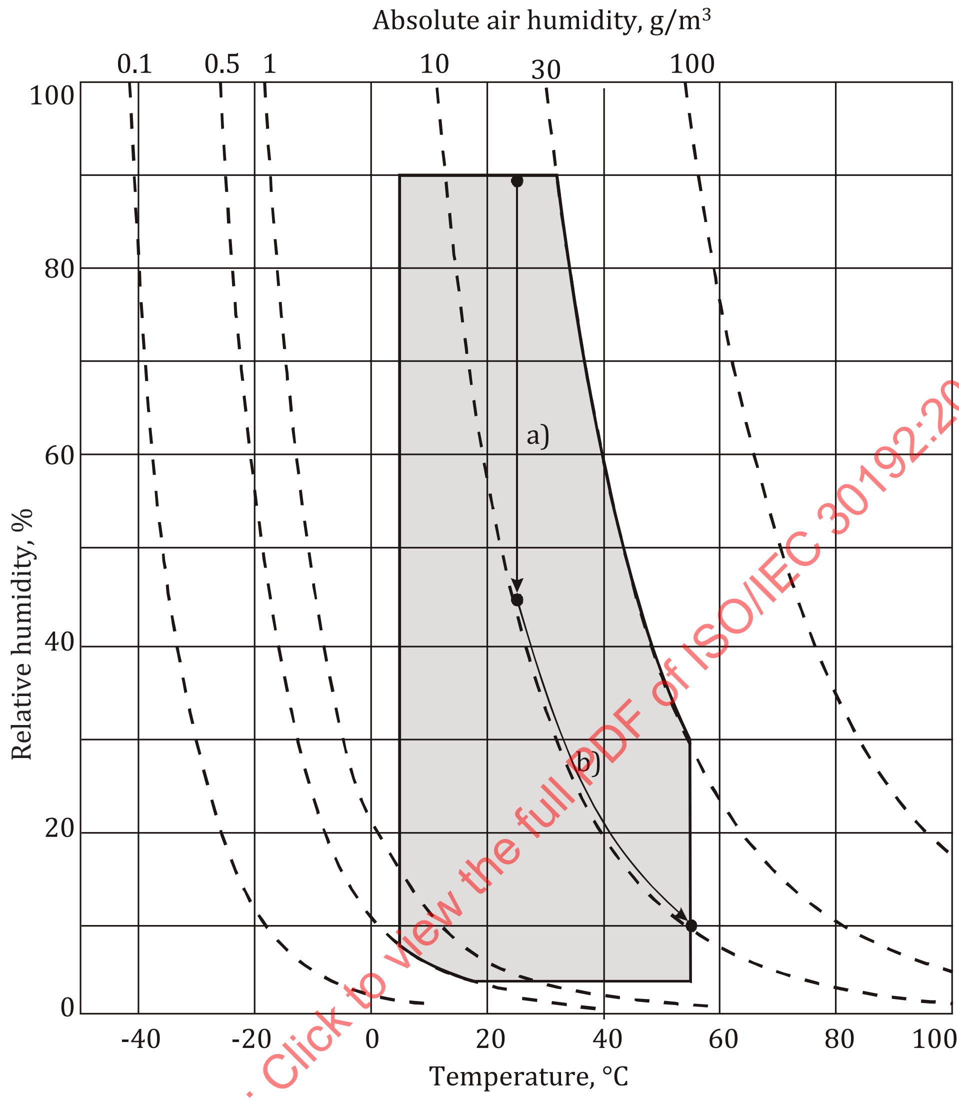


Figure 4 — Operating environment

8.1.3 Storage environment

8.1.3.1 General

The storage environment is an environment where the air immediately surrounding the optical disk shall have the following properties:

— temperature, T:	–10 °C to 55 °C;
— relative humidity, R_H:	5 %to 90 %;
— absolute humidity:	1 g/m³ to 30 g/m³;
— atmospheric pressure:	60 kPa to 106 kPa;
— maximum temperature variation:	15 °C/h;
— maximum relative humidity variation:	10 %/h.

8.1.3.2 Climatic storage tests

To check environmental stability of the disk, it shall be exposed to the following environments:

— dry heat test according to IEC 60068-2-2 Ba:

$T = 55$ °C, $R_H = 50\%$, 96 h;

— damp heat cycle test according to IEC 60068-2-30 Db:

$T_{high} = 40$ °C, $T_{low} = 25$ °C, $R_H = 95$ %, cycle time = (12 + 12) h, 6 cycles.

After exposure to these environmental conditions, one should allow for some recovery time before measuring (24 h or 48 h).

8.1.4 Transportation

8.1.4.1 General

As transportation occurs under a wide range of temperature and humidity variations, for differing periods, by many methods of transport and in all parts of the world, it is not possible to specify mandatory conditions for transportation or for packaging.

8.1.4.2 Packaging

8.1.4.2.1 General

The form of packaging should be agreed between sender and recipient or, in absence of such an agreement, is the responsibility of the sender. It should take into account the following hazards.

8.1.4.2.2 Temperature and humidity

Insulation and wrapping should be designed to maintain the conditions for storage over the estimated period of transportation.

8.1.4.2.3 Impact loads and vibrations

a) Avoid mechanical loads that would distort the shape of the disk.

b) Avoid dropping the disk.

c) Disks should be packed in a rigid box containing adequate shock-absorbent material.

d) The final box should have a clean interior and a construction that provides sealing to prevent the ingress of dirt and moisture.

8.2 Safety requirements

The disk shall satisfy the requirements of IEC 60950-1, when used in the intended manner or in any foreseeable uses in an information system.

8.3 Flammability

The disk shall be made from materials that comply with the flammability class for HB materials, or better, as specified in IEC 60950-1.

9 Reference drive

9.1 General

A reference drive shall be used for the measurement of optical and electrical signal parameters in order to confirm that a disk is in conformance with the requirements of this document. The characteristics of the critical components of this device are specified in Clause 9.

9.2 Environmental conditions

During tests, the disk shall be in a test environment as defined in 8.1.1, unless stated otherwise.

9.3 Optical system

The basic set-up of the optical system of the reference drive used for measuring specified (over)write and read parameters is shown in Figure 5. Different components and locations of components are permitted, provided that the performance remains the same as that of the set-up in Figure 5.

The optical system shall be aligned such that the focused optical beam is perpendicular to the recording layer on which the beam is focused at the radius where the measurement is to be performed.

The optical system shall be such that the detected light reflected from the entrance surface of the disk is minimized so as not to affect the accuracy of the measurements.

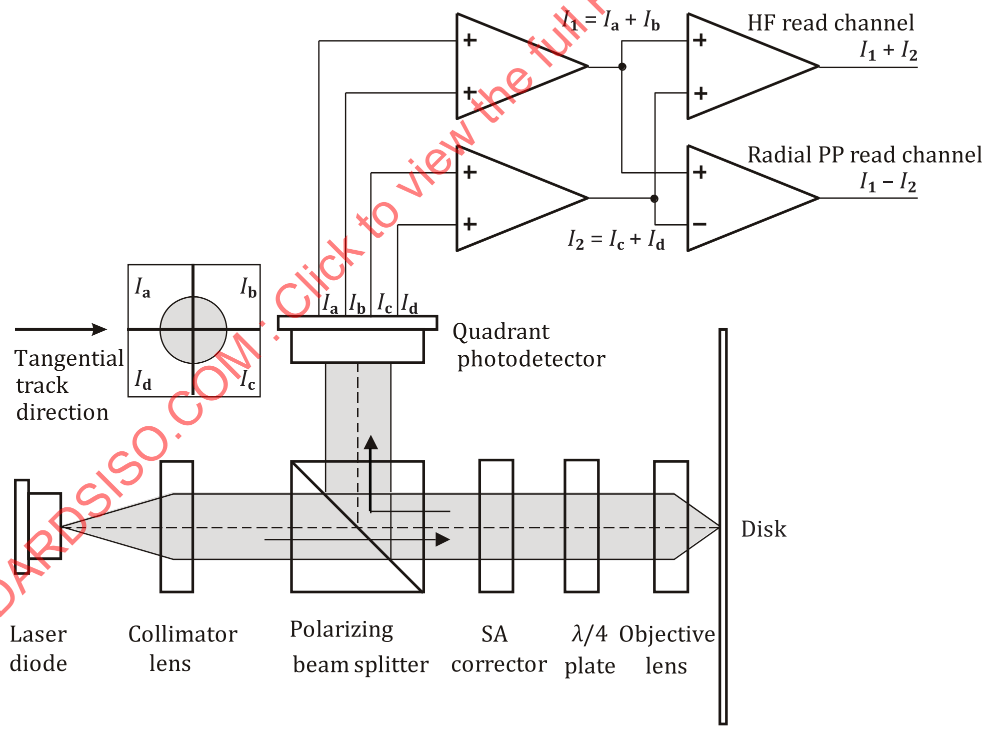


Figure 5 — Optical system of reference drive

A polarizing beam splitter and a quarter-wavelength plate shall be used to separate the entrance light beam, coming from the laser diode, and light beam reflected by the optical disk going towards the photodetector. The light beam transmitted through the splitter shall have a p:s intensity ratio of at least 100:1.

The optical beam shall be compensated for spherical aberrations (SA) such that these aberrations are minimized for the thickness of the transmission stack of the recording layer on which the beam is focused at the radius where the measurement is to be performed.

During measurements on one layer of a dual-layer disk, light reflected from the other layer can influence the measurements on the layer under investigation. To cope with these effects, the photodetector shall have limited dimensions. Its length and width shall be smaller than $M \times 5$ µm, where M is the transversal optical magnification from the disk to its conjugate plane near the quadrant photodetector.

9.4 Optical beam

The focused optical beam used for writing and reading data shall have the following properties:

— wavelength (λ) of the laser beam: (405 ± 5) nm;

— polarization: circular;

— NA: 0,85 ± 0,01;

— light intensity at the rim of the pupil of the objective lens relative to the maximum intensity:

  — in the tangential direction: (60 ± 5) %;

  — in the radial direction: (65 ± 5) %;

— maximum wave-front aberration at the recording layer(s): $0{,}033 \times \lambda$ rms;

(after correction of tilt and spherical aberrations)

— maximum relative-intensity noise of the laser diode: –125 dB/Hz;

$$\left[10 \times \lg\left(\frac{P_m}{P_{dc}}\right)\right]$$

where

P_m is the ac light density, in Hz;

P_{dc} is the dc light power.

— normalized detector size: $S/M^2 \leq 25$ µm^2

where S is the total surface of the quadrant photodetector;

— read power for disk testing (average):

  — SL disk: (0,35 ± 0,1) mW;

  — DL disk: (0,70 ± 0,1) mW;

— write power and pulse shape: For write power, see 29.4.2 for detailed specifications.

The pulse shape shall follow Annex F.

9.5 HF read channel

The HF read channel is provided to supply a signal from which user data can be retrieved. This signal is generated by summing the currents from all four elements of the photodetector ($I_a + I_b + I_c + I_d$). These currents are modulated by the user-written information due to the difference in reflectivity of the marks and spaces caused by the phase-change effects.

In the frequency range from dc to 22 MHz the HF read channel, including the photodetectors, shall have a flat amplitude response within ±1,0 dB relative to its dc gain.

The group delay variation shall be maximum 2 ns pp in the frequency range from 3 MHz to 22 MHz.

For measurement of jitter, the characteristics of the signal processing, the data slicer and the PLL, etc., are specified in Annex H.

9.6 Radial PP read channel

The radial PP read channel provides the tracking error signal to control the servo for radial tracking of the optical beam. It also provides a wobble signal from which the information modulated on the grooves can be retrieved.

The radial tracking error is generated as a signal $[(I_a + I_b) - (I_c + I_d)]$ related to the difference in the amount of light in the two halves of the exit pupil of the objective lens.

The read amplifiers including the photodetectors in the radial PP read channel shall have a flat amplitude response within ±1,0 dB relative to their dc gain from dc to 8 MHz.

9.7 Disk clamping

While its parameters are being measured, the disk shall be clamped between two concentric rings covering most of the clamping zone (see 10.6). The top clamping area shall have the same inner and outer diameters as the bottom clamping area (see Figure 6).

Clamping shall occur between d_{in} = (23,5 ± 0,5) mm and d_{out} = (32,5 ± 0,5) mm.

The total clamping force shall be F_1 = 2,0 N ± 0,5 N.

In order to prevent warping of the disk under the moment of force generated by the clamping force and the chucking force F_2, which is exerted by the tapered cone on the rim of the centre hole of the disk, F_2 shall not exceed 0,5 N (see Figure 6).

The top angle θ_a of the tapered cone for centring of the disk shall be 40,0° ± 0,5°.

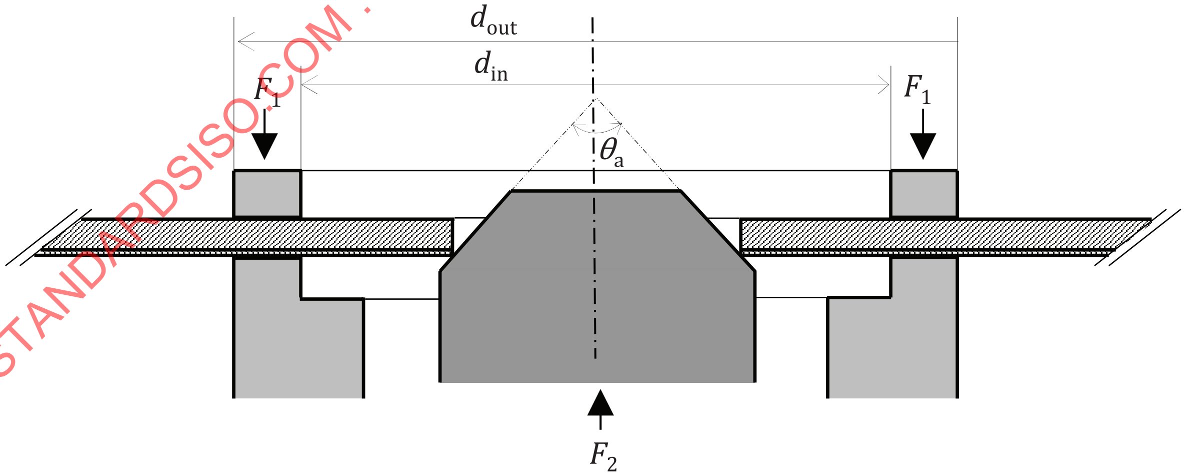


Figure 6 — Clamping conditions for measurement

9.8 Rotation of the disk and measurement velocity

The direction of rotation shall be counter-clockwise as viewed from the objective lens.

All specifications are based on a tangential speed during reading that is equal to the reference velocity. This corresponds to a constant linear velocity of 4,917 m/s.

Tests for determining the recording characteristics of BD rewritable disks shall be carried out at all velocities defined in each of the DI units that are present on the disk (see 15.8.3).

9.9 Normalized servo transfer function

In order to specify the servo systems for axial and radial tracking, a function $H_N(i\omega)$ is used. It specifies the nominal values of the open-loop transfer function H of the reference servo(s) as Formula (1):

$$H_N(i\omega)=\frac{1}{3}\times\left(\frac{\omega_0}{i\omega}\right)^2\times\frac{1+\frac{3\times i\omega}{\omega_0}}{1+\frac{i\omega}{3\times\omega_0}}\times\left(1+\frac{\omega_{int}}{i\omega}\right)^K \qquad (1)$$

where

ω = $2\pi \times f$;

ω_0 = $2\pi \times f_0$;

ω_{int} = $2\pi \times f_{int}$;

i^2 = –1;

K = order of integrator.

Here, f_0 is the 0 dB crossover frequency of the open-loop transfer function. The crossover frequencies of the lead-lag network of the servo are given by the following:

— lead break frequency: $f_1 = f_0 / 3$;

— lag break frequency: $f_2 = f_0 \times 3$.

The term $(1+\omega_{int}/i\omega)$ in the Formula (1) above represents an integrator function. Such an integrator or equivalent function is used to further reduce of low-frequency components, especially those due to deviations with frequencies equal to the rotational frequency of the disk or its harmonics.

Also, f_{int} is the 3 dB crossover frequency of the integrator function.

Another frequency of importance is the frequency f_X at which a sinusoidal displacement with an amplitude equal to the maximum allowed residual tracking error e_{max}, corresponds to the maximum expected acceleration α_{max}. This frequency can be calculated with Formula (2):

$$f_x=\frac{1}{2\pi}\sqrt{\frac{\alpha_{max}}{e_{max}}} \qquad (2)$$

Because the tracking error signals from the disk can have rather large variations, the tracking error signal fed into each reference servo loop shall be adjusted to a fixed level (effectively calibrating the total loop gain), which guarantees the specified bandwidth.

9.10 Measurement velocity and reference servo for axial tracking

Regarding the open-loop transfer function $H(f)$ of the reference servo for axial tracking, $|1 + H(f)|$ is shown schematically by the shaded area in Figure 7.

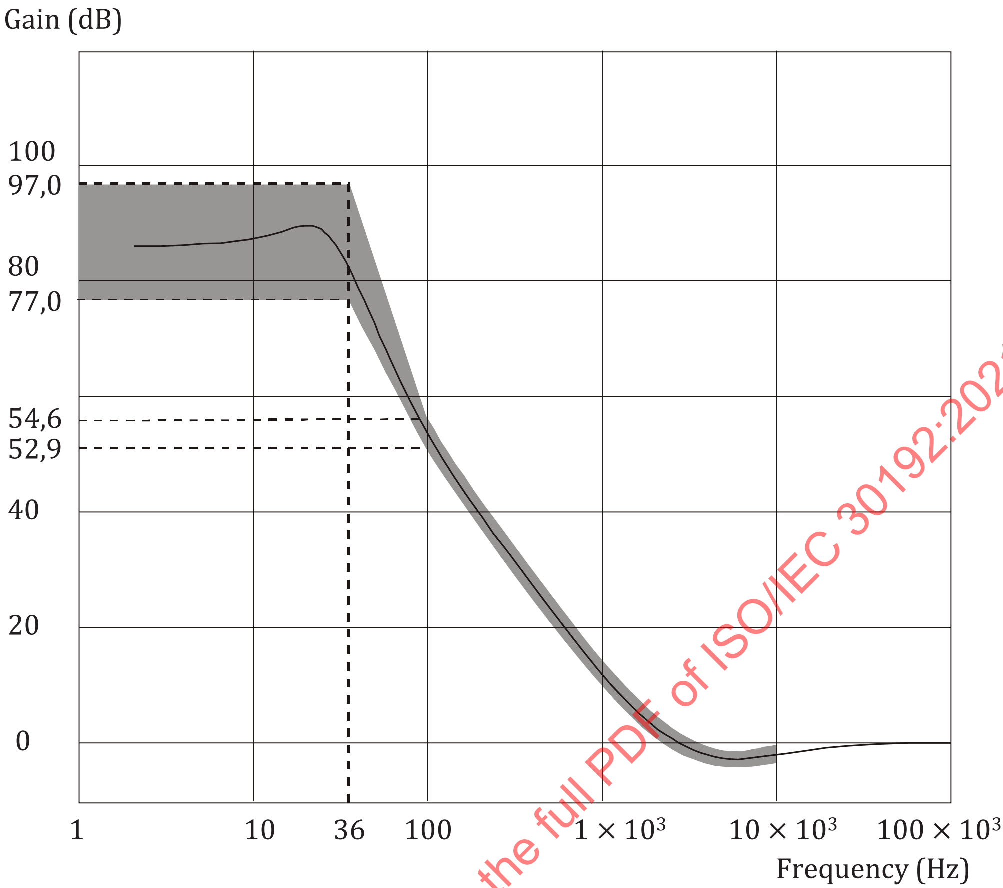


Figure 7 — Servo characteristic for axial tracking

The crossover frequency, f_0 of $H_N(f)$ (see 9.9), in kHz, used to define the limits of $|1 + H(f)|$, is specified by the Formula (3), where α_{max} = 6,0 m/s² is the maximum expected axial acceleration due to local disturbances, and α_{max} is multiplied by a factor m = 1,25 for servo margin. The tracking error e_{max}, caused by this $m \times \alpha_{max}$, shall be 55 nm. Thus, the 0 dB crossover frequency shall be as follows:

$$f_0 = \frac{1}{2\pi}\sqrt{\frac{3 \times m \times \alpha_{max}}{e_{max}}} = \frac{1}{2\pi}\sqrt{\frac{3 \times 1{,}25 \times 6{,}0}{55 \times 10^{-9}}} = 3{,}2 \qquad (3)$$

The integrator 3 dB crossover frequency shall be: f_{int} = 100 Hz.

In the frequency range 100 Hz to 10 kHz, $|1 + H(f)|$ shall be within –10 % to +10 % of $|1 + H_N(f)|$.

In the frequency range 36 Hz to 100 Hz, $|1 + H(f)|$ shall be within the limits defined by the following four points:

— 52,9 dB at 100 Hz ($|1 + H_N(f)|$ at 100 Hz – 10 %);

— 54,6 dB at 100 Hz ($|1 + H_N(f)|$ at 100 Hz + 10 %);

— 77,0 dB at 36 Hz ($|1 + H_N(f)|$ at 36 Hz – 10 %);

— 97,0 dB at 36 Hz ($|1 + H_N(f)|$ at 36 Hz – 10 % + 20 dB).

In the frequency range up to 36 Hz, $|1 + H(f)|$ shall be between 77,0 dB and 97,0 dB.

The frequency f_X, in kHz, has the value as per Formula (4):

$$f_x = \frac{1}{2\pi}\sqrt{\frac{\alpha_{max}}{e_{max}}} = \frac{1}{2\pi}\sqrt{\frac{6,0}{55\times10^{-9}}} \approx 1,6 \quad (4)$$

9.11 Measurement velocity and reference servo for radial tracking

Regarding the open-loop transfer function $H(f)$ of the reference servo for radial tracking, $|1 + H(f)|$ is shown schematically by the shaded area in Figure 8.

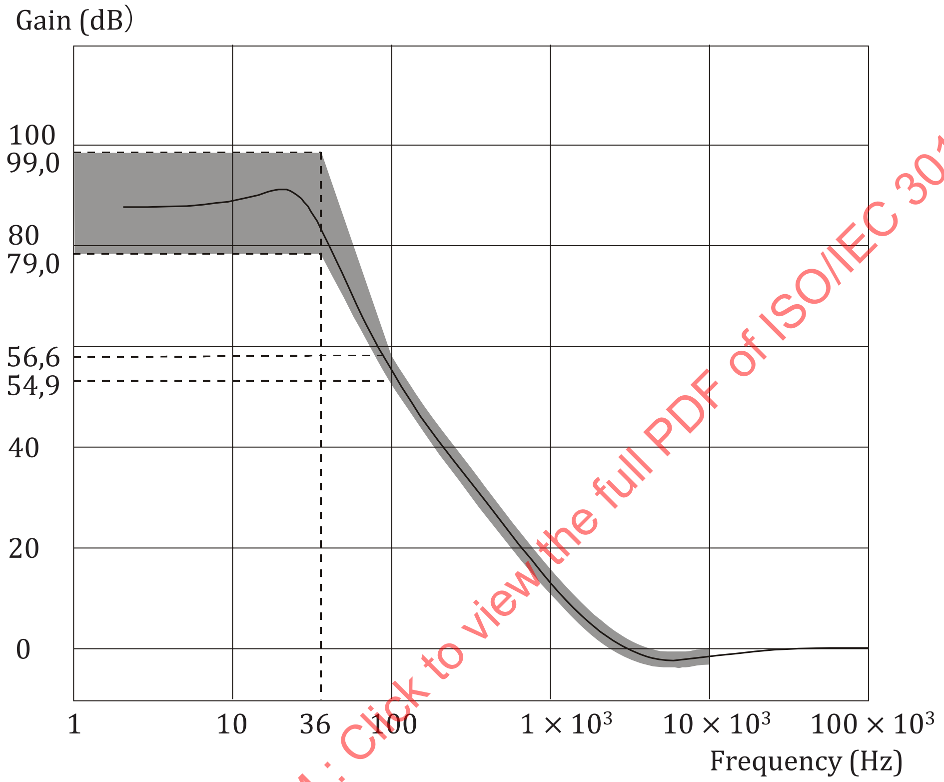


Figure 8 — Servo characteristic for radial tracking

The crossover frequency, f_0 of $H_N(f)$ (see 9.9), in kHz, which is used to define the limits of $|1 + H(f)|$, is specified by the Formula (5), where α_{max} = 2,2 m/s^2 is the worst-case maximum expected radial acceleration due to local disturbances, and α_{max} is multiplied by a factor m = 1,25 for servo margin. The tracking error e_{max}, caused by this $m \times \alpha_{max}$, shall be 16 nm. Thus, the 0-dB crossover frequency shall be as per Formula (5):

$$f_0 = \frac{1}{2\pi}\sqrt{\frac{3\times m\times\alpha_{max}}{e_{max}}} = \frac{1}{2\pi}\sqrt{\frac{3\times1,25\times2,2}{16\times10^{-9}}} = 3,6 \quad (5)$$

The integrator 3 dB crossover frequency shall be f_{int} = 100 Hz.

In the frequency range 100 Hz to 10 kHz, $|1 + H(f)|$ shall be within −10 % to +10 % of $|1 + H_N(f)|$.

In the frequency range 36 Hz to 100 Hz, $|1 + H|$ shall be within the limits defined by the following four points:

— 54,9 dB at 100 Hz ($|1 + H_N(f)|$ at 100 Hz − 10 %);

— 56,6 dB at 100 Hz ($|1 + H_N(f)|$ at 100 Hz + 10 %);

— 79,0 dB at 36 Hz ($|1 + H_N(f)|$ at 36 Hz − 10 %);

— 99,0 dB at 36 Hz (|1 + $H_N(f)$| at 36 Hz – 10 % + 20 dB).

In the frequency range up to 36 Hz, |1 + $H(f)$| shall be between 79,0 dB and 99,0 dB.

The frequency f_X, in kHz, has the value as per Formula (6):

$$f_x = \frac{1}{2\pi}\sqrt{\frac{\alpha_{max}}{e_{max}}} = \frac{1}{2\pi}\sqrt{\frac{2,2}{16\times10^{-9}}} \approx 1,8 \qquad (6)$$

10 Dimensional characteristics

10.1 General

Dimensional characteristics are specified for those parameters deemed mandatory for interchange and compatible use of the disk. Where there is freedom of design, only the functional characteristics of the elements described are indicated. Figure 9 shows the dimensional requirements in summarized form. The different parts of the disk are described from the centre hole to the outside rim.

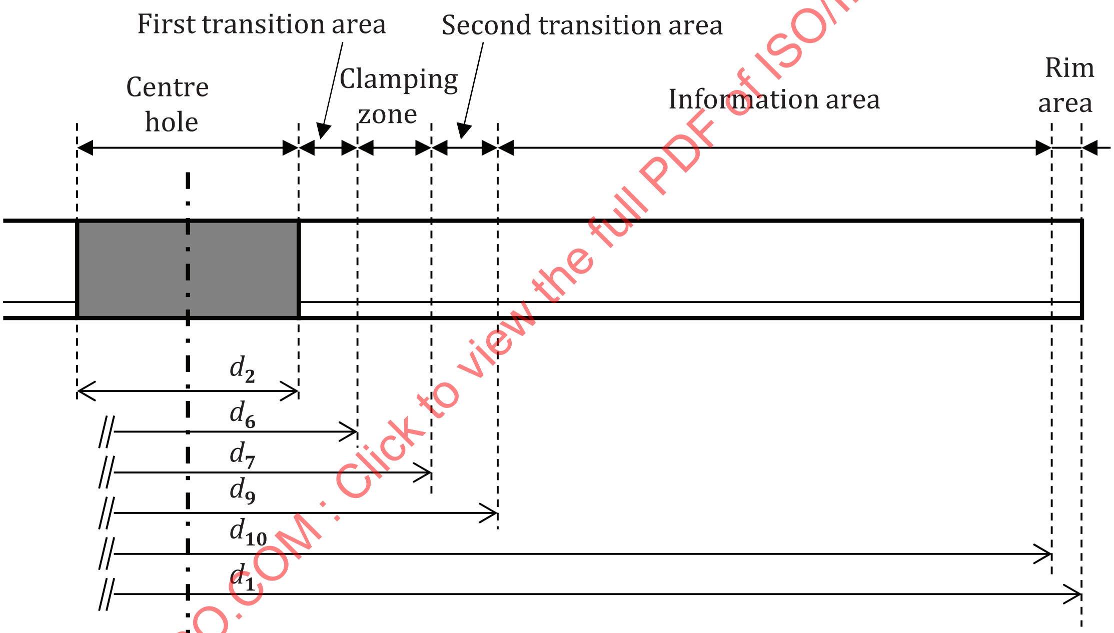


Figure 9 — Overview of disk dimensions

10.2 Disk reference planes and reference axis

For disk reference planes, see also Figure 10 and Figure 11.

The disk reference plane P is the plane determined by the surface of the clamping zone (see 10.6) at the read-out side of the disk.

The disk reference plane Q is the plane determined by the surface of the clamping zone at the substrate side of the disk.

The reference axis A is the axis through the middle of the centre hole, perpendicular to the disk reference plane P.

The disk reference plane R is a plane parallel to the disk reference plane P. The distance between disk reference plane R and disk reference plane P shall be e_4 = (100 ± 25) µm towards the inside of the disk (see Figure 10 and Figure 11).

The disk reference plane R shall intersect with recording layer L0 at layer L0's average position between radius r_a = 23 mm and r_b = 24 mm (layer L0 is the only recording layer on an SL disk or the deepest recording layer on a DL disk).

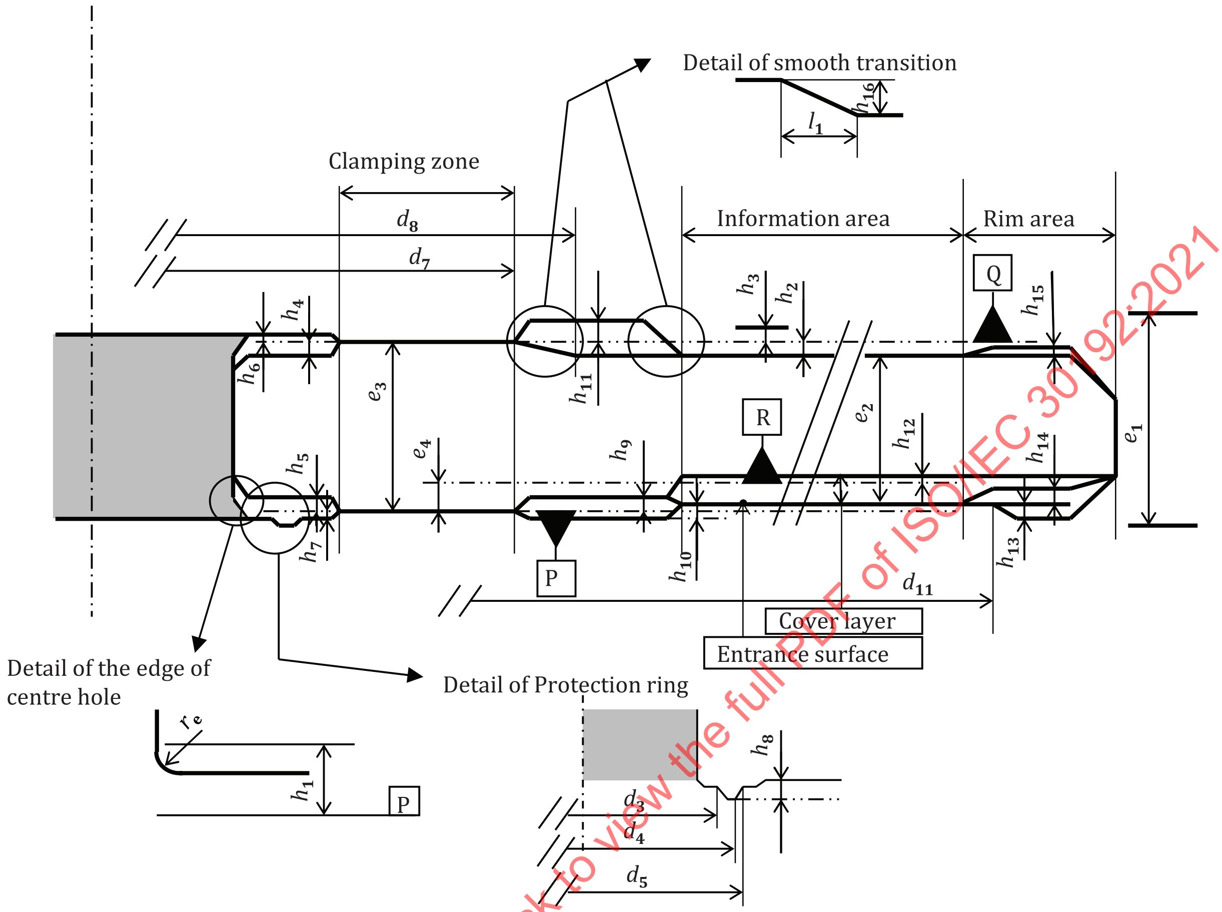


Figure 10 — Details of disk dimensions

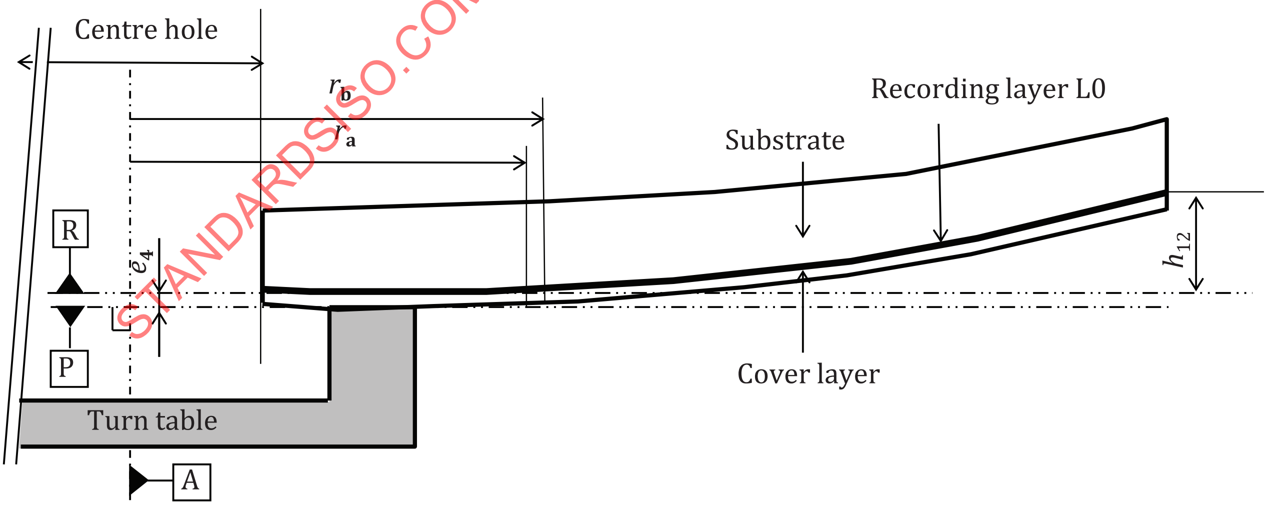


Figure 11 — Details of disk reference planes P and R and recording layer L0

10.3 Overall dimensions

The overall outer diameter of the disk shall be d_1 = (120,0 ± 0,3) mm (see Figure 9).

The diameter of the centre hole shall be $d_2 = 15{,}00^{+0{,}10}_{0{,}00}$ mm (see Figure 9).

There shall be no burr on the edge of the centre hole at the read-out side.

The edge of the centre hole at the read-out side is the reference for centring the disk and shall be rounded off or chamfered. The rounding radius shall be maximum r_e = 0,1 mm. The height of chamfer shall be maximum 0,1 mm above the bottom surface of the first transition area. The rounding or chamfer shall be maximum h_1 = 0,25 mm from disk reference plane P (see detail in Figure 10).

The maximum thickness of the disk is defined as the distance in the direction of the reference axis A between the highest structure protruding from the entrance surface of the disk and the highest structure protruding from the top surface of the disk.

Maximum thickness of the disk, including cover layer, protective coating and label printing, at any radius shall be e_1 = 1,40 mm (see Figure 10).

Minimum thickness of the disk in the information area shall be e_2 = 0,90 mm.

Outside the clamping zone, the top surface may be inside the disk reference plane Q by maximum h_2 = 0,4 mm.

Outside the clamping zone, the top surface may be outside the disk reference plane Q by maximum h_3 = 0,1 mm (see Figure 10).

10.4 First transition area

In the inner area inside the clamping zone ($d < d_6$), the surfaces may be inside the disk reference planes P and Q by maximum h_5 = 0,20 mm and maximum h_4 = 0,12 mm, respectively. These surfaces may be uneven or may have burrs up to maximum h_7 = 0,05 mm and h_6 = 0,05 mm outside the disk reference planes P and Q, respectively (see Figure 9 and Figure 10).

10.5 Protection ring

An optional ring-shaped protrusion in the inner area of the disk that can prevent full contact between the surface of the disk and a surface on which such a disk is laid down. By applying such a ring, the chance for damage to the read-out side of the disk can be minimized.

When applied, the protection ring shall be located between diameter d_3 = 17,5 mm and diameter d_5 = 21,0 mm. Between d_3 and diameter d_4 = 20,5 mm, the height of the protection ring shall be maximum 0,12 mm above the clamping surface.

Between d_4 and d_5, the height of the protection ring shall sink gradually to the surrounding surface (see Figure 10).

10.6 Clamping zone

The inner diameter of the disk clamping zone shall be $d_6 \leq 23{,}0$ mm.

The outer diameter of the disk clamping zone shall be $d_7 \geq 33{,}0$ mm (see Figure 9).

The thickness of the disk within the clamping zone shall be $e_3 = 1{,}20^{+0{,}10}_{-0{,}05}$ mm (see Figure 10).

Within the clamping zone, ($d_6 < d < d_7$), both sides of the disk shall be flat within maximum 0,1 mm.

Within the clamping zone, ($d_6 < d < d_7$), both sides of the disk shall be parallel within maximum 0,1 mm.

10.7 Second transition area

The second transition area is an area between the clamping zone and the information area: $d_7 < d < d_9$ (see Figure 9).

In the second transition area, the surface at the read-out side of the disk may be inside the reference plane P by maximum h_9 = 0,12 mm. This surface may be outside the entrance surface in the information area by maximum h_{10} = 0,01 mm (see Figure 10).

In the second transition area, the top surface of the disk may be outside the disk reference plane Q by maximum h_{11} = 0,2 mm.

The step from the top surface in the area to the top surface in the information area is h_{16}. The distance between the start and the end diameters of the step is l_1. If h_{16} > 0,2 mm, then the slope down to the top surface of the information area shall be smooth and l_1 > 1,8 mm, as indicated in Figure 10. If the top surface in the information area is stepped down from the top surface in the second transition area, then the step shall end within diameter d_8 = 40,0 mm.

10.8 Information area

10.8.1 General

The information area shall extend from diameter d_9 = 42 mm to diameter d_{10} = 117 mm (see Figure 9 and Figure 12).

On each recording layer, the data zone shall be located between inner diameter d_{DZI} and outer diameter d_{DZO}. The data zones on all recording layers shall have the same storage capacity.

The inner diameter d_{DZI} on recording layer Ln shall be $d_{DZIn} = 48{,}0^{0{,}0}_{-0{,}2}$ mm while and the outer diameter d_{DZO} on recording layer Ln shall be d_{DZOn} ≤ 116,2 mm.

The area between d_9 and d_{DZI} is called the inner zone and the area between d_{DZO} and d_{10} is called the outer zone (see Figure 12).

The total thickness of the disk in the information area is as specified in 10.3.

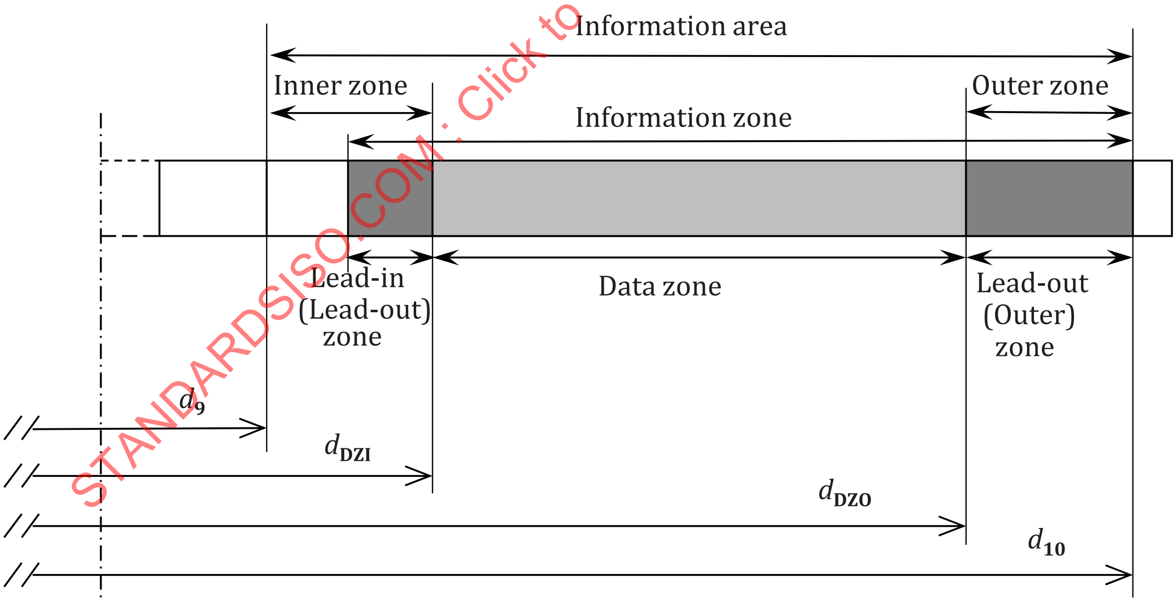


Figure 12 — Division of information area

10.8.2 Subdivisions of information zone on SL disk

The information area is used to record the information zone.

The information zone is subdivided into the following main parts (see Figure 13):

— lead-in zone (part of the inner zone);

— data zone;

— lead-out zone (outer zone).

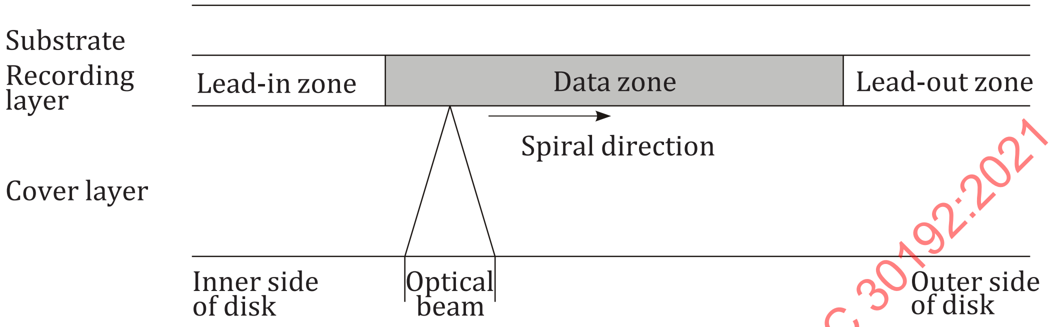


Figure 13 — Subdivision of information zone on SL disk

The lead-in zone starts in the area extending from 44,0 mm to 44,4 mm in diameter and shall end at the beginning of the data zone at diameter d_{DZI}.

The lead-out zone shall start at the end of the data zone at diameter d_{DZO} and shall end at minimum 117 mm in diameter.

10.8.3 Subdivisions of information zone on DL disks

The information area is used to record the information zone, divided over the two recording layers.

The information zone is subdivided into the following main parts (see Figure 14):

On recording layer L0:

— lead-in zone (part of the inner zone 0),

— data zone 0, and

— outer zone 0.

On recording layer L1:

— outer zone 1,

— data zone 1, and

— lead-out zone (part of the inner zone 1).

On layer L0, the spiral groove shall run from the inner side of the disk towards the outer side of the disk.

On layer L1, the spiral groove shall run from the outer side of the disk towards the inner side of the disk.

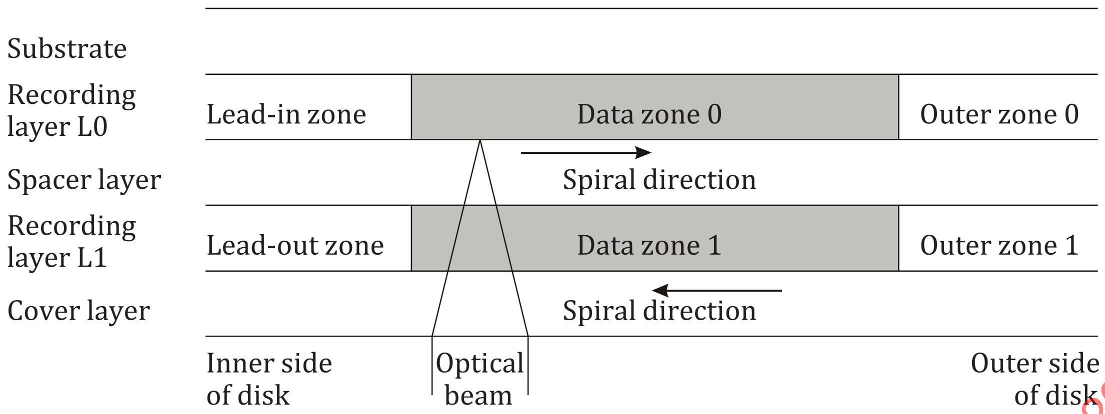


Figure 14 — Subdivision of information zone on DL disk

The lead-in zone starts in the area extending from 44,0 mm to 44,4 mm in diameter and shall end at the beginning of the data zone 0 at diameter d_{DZI0}.

The outer zone 0 shall start at the end of the data zone 0 at diameter d_{DZO0} and shall end at minimum 117 mm in diameter.

The outer zone 1 shall start at minimum 117 mm in diameter and shall end at the beginning of data zone 1 at diameter d_{DZO1}.

The lead-out zone shall start at the end of the data zone 1 at diameter d_{DZI1} and shall end in the area extending from diameter 44,0 mm to diameter 44,4 mm.

10.9 Rim area

The rim area is the area outside the information area, starting at d_{10} and extending to the outer diameter of the disk (see Figure 9).

In the first 0,5 mm of the rim area, the surface at the read-out side of the disk shall not be outside the entrance surface in the information area.

In the remainder of the rim area, the surface at the read-out side of the disk shall not be outside the entrance surface in the information area by maximum h_{13} = 0,05 mm (see Figure 10).

In the rim area, the surface at the read-out side of the disk may be inside the entrance surface in the information area by maximum h_{14} = 0,12 mm (see Figure 10).

In the rim area, the top surface of the disk shall not be outside the top surface in the information area by maximum h_{15} = 0,05 mm (see Figure 10).

11 Mechanical characteristics

11.1 Mass

The mass, m, of the disk shall be 12 g ≤ m ≤ 17 g.

11.2 Moment of inertia

The moment of inertia of the disk shall be ≤0,032 g.m^2.

11.3 Dynamic imbalance

The dynamic imbalance of the disk shall be ≤2,5 g.mm.

11.4 Axial runout

11.4.1 General

When measured by an optical system using the reference servo for axial tracking and with the disk rotating at a scanning velocity of 4,917 m/s (for all capacities), the distance between each recording layer and the disk reference plane R (see Figure 10 and Figure 11) in the direction of the reference axis A shall be maximum h_{12} = 0,3 mm over the entire disk.

Within one track (one revolution), the deviation of each recording layer from its average position in the direction of the reference axis A shall be maximum 0,1 mm.

At the inner side of the disk, rotating at a velocity of 4,917 m/s, this corresponds to a maximum acceleration of about 4,6 m/s^2, based on a sinusoidal deviation at the rotational frequency of the disk.

Due to the integrator function in the reference servo (see 9.10), this component is suppressed sufficiently such that the residual tracking errors as defined in 11.4.2 are mainly due to local disturbances.

11.4.2 Residual axial tracking error

The residual axial tracking error of each recording layer for frequencies below 1,6 kHz (equals f_X, see 9.10), measured using the reference servo for axial tracking as specified in 9.10, shall be maximum 45 nm (displacement of the objective lens needed to move the focal point of the optical beam onto the recording layer).

Spikes in the residual axial tracking error signal due to local defects, such as dust and scratches, shall be excluded.

The measuring filter shall be a Butterworth LPF, with f_{-3dB} = 1,6 kHz and slope = −60 dB/decade.

This means that, for frequencies <1,6 kHz, the maximum local acceleration of the recording layer in the direction of the reference axis A does not exceed 6,0 m/s^2.

The rms noise value of the residual error signal in the frequency band from 1,6 kHz to 10 kHz, measured with an integration time of 20 ms and using the reference servo for axial tracking, shall be at maximum 32 nm. The measuring filter shall be a Butterworth BPF, from f_{-3dB} = 1,6 kHz with slope = +60 dB/decade, to f_{-3dB} = 10 kHz with slope = −60 dB/decade.

11.5 Radial runout

11.5.1 General

The runout of the outer edge of the disk shall be maximum of 0,3 mm pp.

The radial runout of the tracks in each recording layer (including eccentricity and unroundness) shall be measured by an optical system using the reference servo for radial tracking, while the disk is rotating at a scanning velocity of 4,917 m/s (for all capacities).

The radial runout shall be maximum 75 µm pp (SL and DL disks).

At the inner side of the disk, rotating at a velocity of 4,917 m/s, this corresponds to a maximum acceleration of about 1,7 m/s^2, based on a sinusoidal deviation at the rotational frequency of the disk.

Due to the integrator function in the reference servo (see 9.11), this component is suppressed sufficiently such that the residual tracking errors as defined in 11.5.2 and 11.5.3 are mainly due to local disturbances.

The residual tracking error shall be determined by applying the radial PP read channel (I_1 − I_2) signal for both measurement and radial servo control purposes as indicated in Figure 5.

11.5.2 Residual radial tracking error on SL disks

The residual radial tracking error for frequencies below 1,8 kHz (equals f_X, see 9.11), measured using the reference servo for radial tracking as specified in 9.11, shall be a maximum of 9 nm.

Spikes in the residual radial tracking error signal due to local defects, such as dust and scratches, shall be excluded.

The measuring filter shall be a Butterworth LPF, with f_{-3dB} = 1,8 kHz and slope = 60 dB/decade.

This means that, for frequencies <1,8 kHz, the maximum local acceleration of the tracks in the radial direction does not exceed 1,5 m/s^2.

The rms noise value of the residual error signal in the frequency band from 1,8 kHz to 10 kHz, measured with an integration time of 20 ms and using the reference servo for radial tracking, shall be maximum 6,4 nm. The measuring filter shall be a Butterworth BPF, from f_{-3dB} = 1,8 kHz with slope = +60 dB/decade, to f_{-3dB} = 10 kHz with slope = −60 dB/decade.

11.5.3 Residual radial tracking error on DL disks

The residual radial tracking error in each recording layer at frequencies below 1,8 kHz (equals f_X, see 9.11), measured using the reference servo for radial tracking as specified in 9.11, shall be a maximum of 13 nm.

Spikes in the residual radial tracking error signal due to local defects, such as dust and scratches, shall be excluded.

The measuring filter shall be a Butterworth LPF, with f_{-3dB} = 1,8 kHz and slope = −60 dB/decade.

This means that for frequencies <1,8 kHz, the maximum acceleration of the tracks in the radial direction does not exceed 2,2 m/s^2.

The rms noise value of the residual error signal in the frequency band from 1,8 kHz to 10 kHz, measured with an integration time of 20 ms and using the reference servo for radial tracking, shall be a maximum of 9,2 nm. The measuring filter shall be a Butterworth BPF, from f_{-3dB} = 1,8 kHz with slope = +60 dB/decade, to f_{-3dB} = 10 kHz with slope = −60 dB/decade.

11.6 Durability of cover layer

11.6.1 Impact resistance of cover layer

To prevent excessive damage by accidential impact, the entrance surface of the disk should have a certain minimum impact resistance.

The minimum impact resistance can be tested by procedures described in Annex L.

11.6.2 Scratch resistance of cover layer

To prevent excessive scratching, the surface of the disk shall have at least a certain minimum hardness.

The scratch resistance shall be tested by a procedure described in Annex C.

11.6.3 Repulsion of fingerprints by cover layer

To prevent excessive contamination, the surface of the disk shall repel grime as much as possible.

The repulsion of grime shall be tested by a procedure described in Annex D.

12 Optical characteristics in information area

12.1 General

The following requirements shall be fulfilled within the information area of the disk.

These specifications of the transmission stacks (TS) include all possible layers on top of the recording layer concerned (such as gluing layers in case of foils, the spacer layer and the semi-transparent recording layer of layer L1 in case of TS0, the cover layer and possibly a protective coating).

12.2 Refractive index of transmission stacks (TS)

If the layers making up the total TS have different refractive indexes, then the procedure described in Annex A shall be followed.

The refractive index n of the cover layer and spacer layer of the disk shall be as per Formula (7):

$$1,45 \leq n \leq 1,70 \quad (7)$$

12.3 Thickness of transmission stack(s)

12.3.1 Thickness of transmission stack of SL disks

The average thickness between radius r_a and radius r_b is called the reference thickness of the transmission stack (TS) on the disk (see 10.2 and Figure 11).

The thickness of the TS, measured over the whole disk, shall fulfil the following two requirements.

a) The thickness of the TS, as determined by its refractive index, shall be within the upper shaded area in Figure 15 (in case of a refractive index of 1,6 the thickness shall be between 95 µm and 105 µm and the dashed line indicates the nominal thickness as a function of the refractive index).

b) The maximum deviation ΔD of the thickness of the TS from the reference thickness shall meet the requirement $|\Delta D| \leq 2,0$ µm.

12.3.2 Thickness of transmission stack of DL disks

The average thickness between radius r_a and radius r_b is called the reference thickness of the related transmission stack (TS0 or TS1) on the disk.

The thickness of TS0 and TS1, measured over the whole disk, shall fulfil the following four requirements.

a) The thickness of TS0 (all layers on top of layer L0), as determined by its refractive index, shall be within the upper shaded area in Figure 15 (in case of a refractive index of 1,6, the thickness shall be between 95 µm and 105 µm and the dashed line indicates the nominal thickness as a function of the refractive index).

b) The thickness of TS1 (all layers on top of layer L1), as determined by its refractive index, shall be within the lower shaded area in Figure 15 (in case of a refractive index of 1,6, the thickness shall be between 70 µm and 80 µm and the dashed line indicates the nominal thickness as a function of the refractive index).

c) The thickness of the spacer layer shall be between 20 µm and 30 µm.

d) The maximum deviation ΔD of the thicknesses of TS0 and TS1 from their respective reference thicknesses shall meet the requirement $|\Delta D| \leq 2,0$ µm.

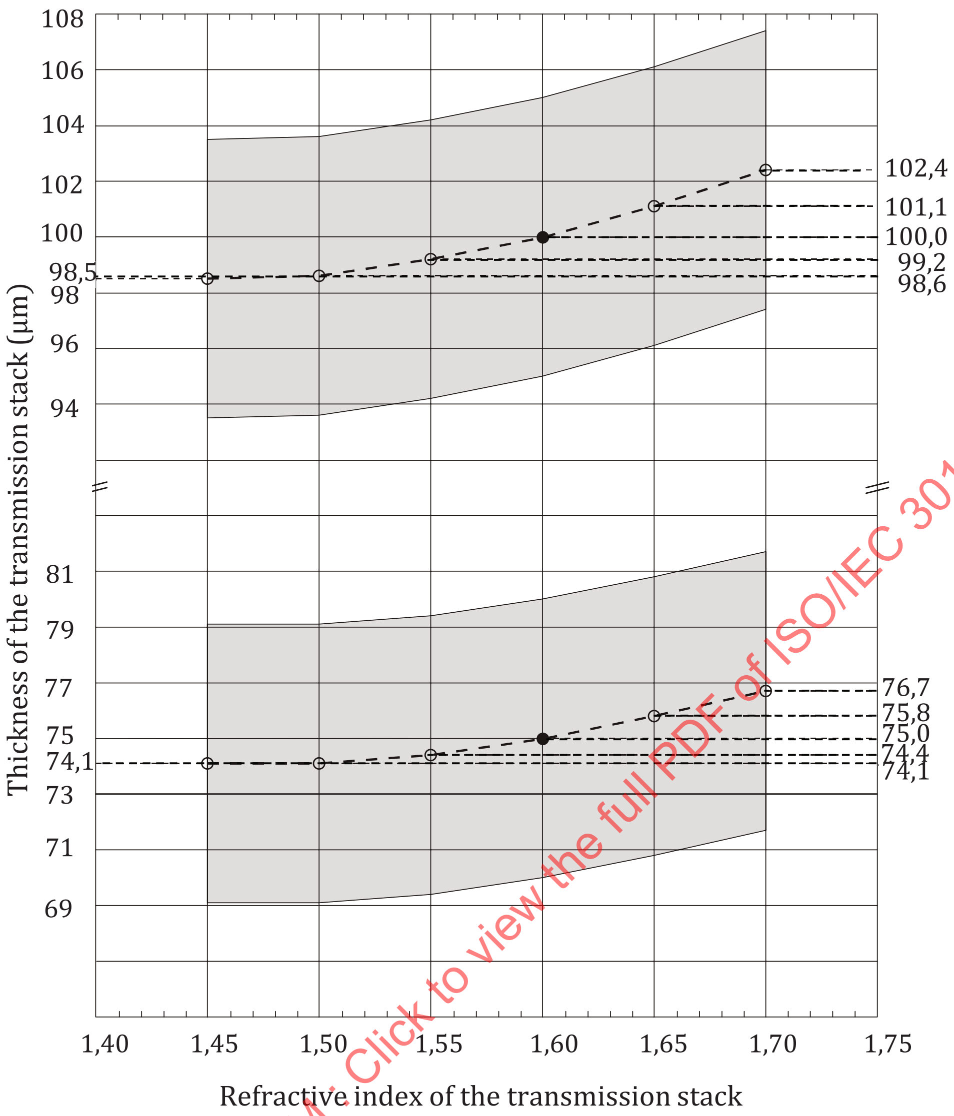


Figure 15 — Thickness of transmission stacks as function of refractive index

12.4 Reflectivity

12.4.1 Reflectivity of recording layer of SL disks

The reflectivity of the recording layer in the information zone, including transmission through the cover layer, shall fulfil the requirements of Formulae (8) to (12) under the measurement conditions of Annex B:

— in unrecorded virgin groove:

$$R_{g-v} = 12\ \% \text{ to } 24\ \% \tag{8}$$

— in unrecorded erased groove:

$$R_{g-e} = 11\ \% \text{ to } 24\ \% \tag{9}$$

— at each location on the disk;

$$0{,}75 \times R_{g-v} < R_{g-e} < 1{,}25 \times R_{g-v} \tag{10}$$

— in recorded grooves for the first ten DOW cycles:

$$R_{8H} = 11 \text{ to } 24\ \% \quad (11)$$

— at each location on the disk;

$$0{,}75 \times R_{g-v} < R_{8H} < 1{,}25 \times R_{g-v} \quad (12)$$

Written marks shall have a lower reflectivity than the unrecorded layer.

12.4.2 Reflectivity of recording layer of DL disks

The reflectivity of each recording layer in the information zone, including transmission through the transmission stack concerned, shall fulfil requirements of Formulae (13) to (17), independent of the recording status of the other recording layer (whether unrecorded, recorded or partially recorded), under the measurement conditions of Annex B:

— in unrecorded virgin grooves:

$$R_{g-v} = 4\ \% \text{ to } 8\ \% \quad (13)$$

— in unrecorded erased grooves:

$$R_{g-e} = 3{,}5\ \% \text{ to } 8\ \% \quad (14)$$

— at each location on the disk;

$$0{,}75 \times R_{g-v} < R_{g-e} < 1{,}25 \times R_{g-v} \quad (15)$$

— in recorded grooves for the first ten DOW cycles:

$$R_{8H} = 3{,}5\ \% \text{ to } 8\ \% \quad (16)$$

— at each location on the disk;

$$0{,}75 \times R_{g-v} < R_{8H} < 1{,}25 \times R_{g-v} \quad (17)$$

Written marks shall have a lower reflectivity than the unrecorded layer.

12.5 Birefringence

The in-plane birefringence of the transmission stacks shall be as per Formula (18) (see Annex J for detailed information):

$$\Delta n_{//} \leq 1{,}5 \times 10^{-4} \quad (18)$$

The perpendicular birefringence of the transmission stacks shall be as per Formula (19) (see Annex J for detailed information):

$$\Delta n_{\perp} \leq 1{,}2 \times 10^{-3} \quad (19)$$

12.6 Angular deviation

The angular deviation is the angle θ_a between a parallel incident beam perpendicular to the disk reference plane P and the reflected beam. The incident beam shall have a diameter in the range 0,3 mm to 1,0 mm. The angle θ_a includes deflections of the entrance surface and to lack of parallelism of the cover layer and/or spacer layer (see Figure 16).

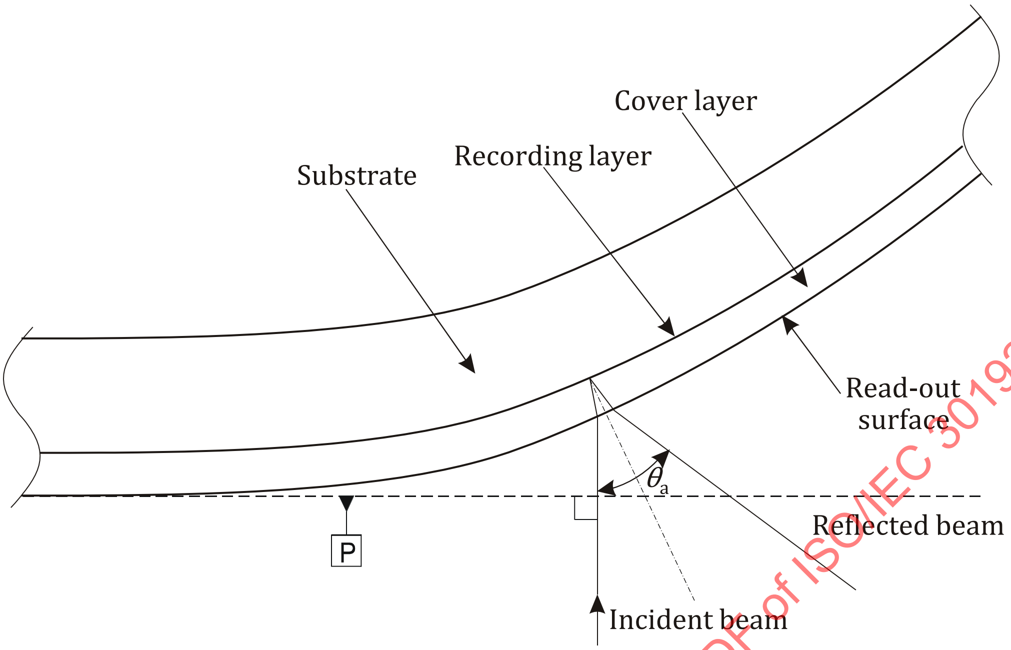


Figure 16 — Definition of angular deviation

The requirements for the angle θ_a shall be as follows:

— in the radial direction:

  — under the normal test conditions specified in 8.1.1: $|\theta_a|_{max.} = 0{,}60°$;

  — under the “sudden change” test conditions specified in 8.1.1: $|\theta_a|_{max.} = 0{,}70°$;

— in the tangential direction:

  — under the normal test conditions specified in 8.1.1: $|\theta_a|_{max.} = 0{,}30°$.

13 Data format

13.1 General

The data received from the source (application or host), called user data frames, are formatted in a number of steps before being recorded on the disk (see Figure 17).

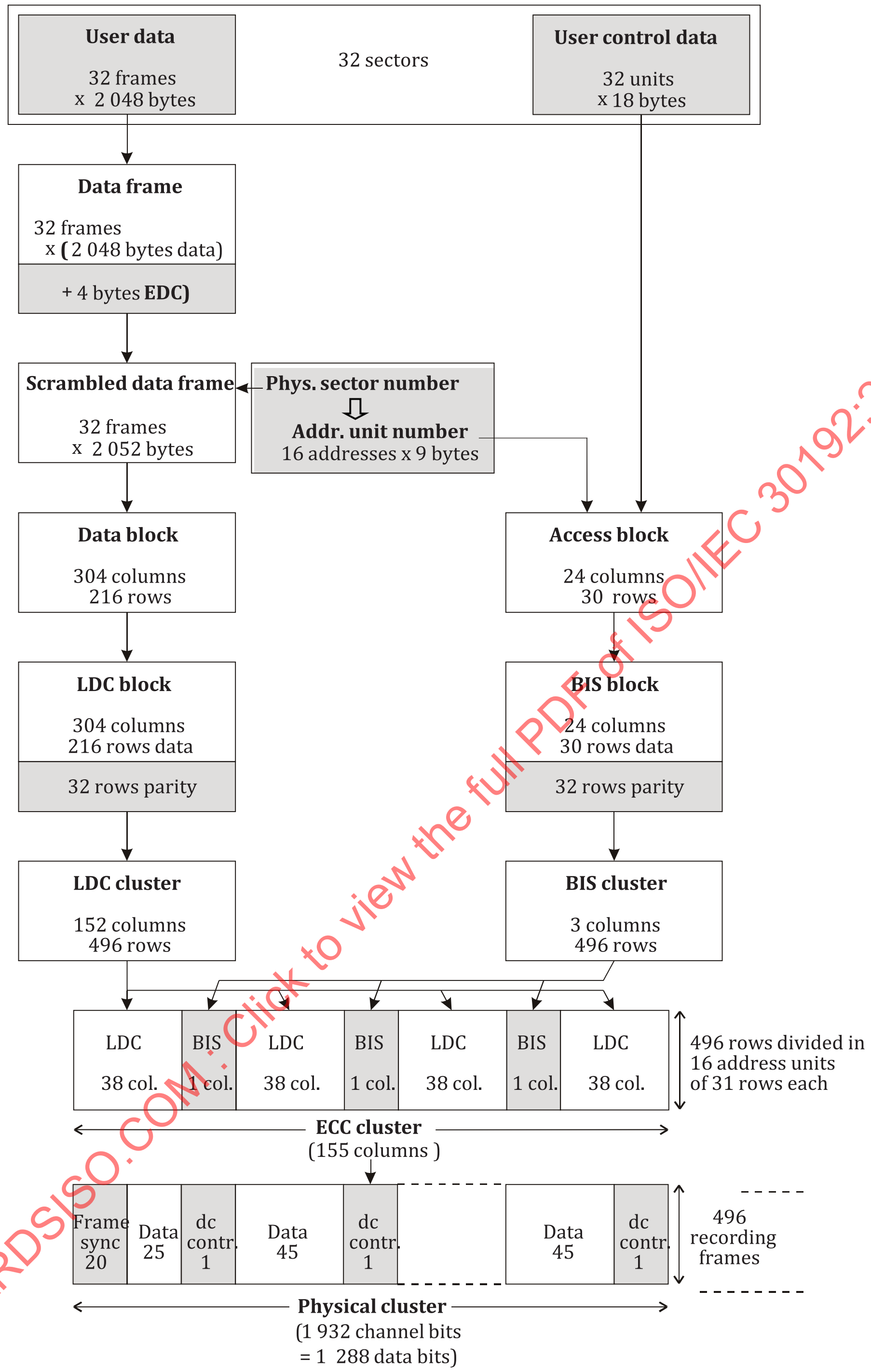


Figure 17 — Schematic representation of encoding process

They are transferred successively into data frames, scrambled data frames, a data block, an LDC block, and an LDC cluster.

The address and control data added by the BD rewritable system are transferred successively into an access block, a BIS block and a BIS cluster.

The LDC cluster and the BIS cluster are multiplexed and modulated into the following:

— an ECC cluster, subdivided into 16 address units;

— a physical cluster, consisting of 496 recording frames.

The data on BD rewritable disks is recorded in 64K partitions, called clusters, containing 32 data frames with 2 048 bytes of user data. These clusters are protected by the following two error correction mechanisms as follows.

— First, the data is protected by a long distance (LDC) error correction code, consisting of (248,216,33) Reed-Solomon (RS) code words. This code has ample parities and interleaving length with a good overall efficiency and can correct both random errors and burst errors;

— Then, the data is multiplexed with a powerful burst-indicating subcode (BIS), which consists of (62,30,33) Reed-Solomon (RS) code words. These BIS code words carry addresses for allocation purposes and control information belonging to the user data. They can also be used to indicate long burst errors, by means of which the LDC can efficiently perform erasure corrections.

The combination of these two codes is called an "LDC+BIS code" (see Figure 18).

All the data is arranged in an array as indicated in Figure 18. This array is read in the horizontal direction, row after row, and recorded on the disk after insertion of additional dc-control bits, modulation, and insertion of synchronization patterns.

The error correction codes are applied in the vertical direction, which gives a good basic break-up of burst errors on the disk. Additionally, the LDC code words have been interleaved in a diagonal direction.

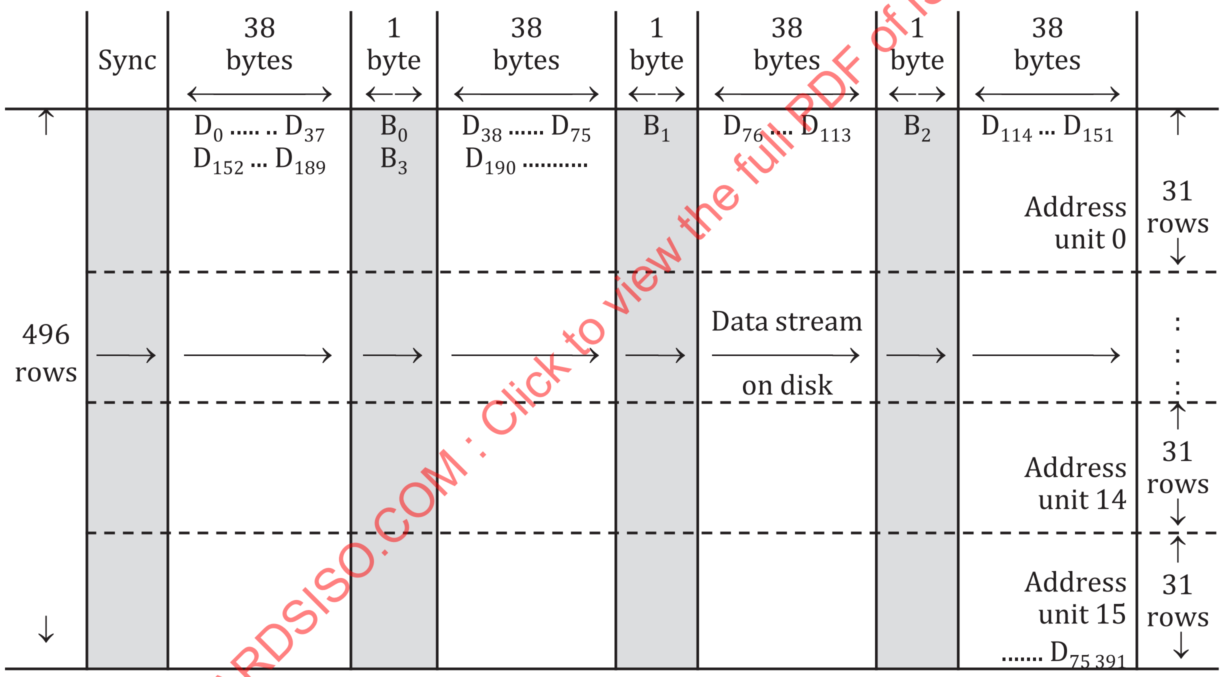


Figure 18 — Schematic representation of physical cluster on disk

Address units, physical sectors and logical sectors are defined as follows.

Address units:

For the purpose of allocating the optical pick-up to a certain position on the disk, the physical cluster is subdivided into 16 address units, each consisting of 31 consecutive rows. The address unit numbers (AUN) provide a fast addressing mechanism embedded in the written data.

Physical sectors:

A data frame accompanied by its control data is called a sector. All sectors in all physical clusters all over the disk (including the inner and outer zones) are called physical sectors. All physical sectors have a virtual number assigned, called the physical sector number (PSN). These PSNs are not recorded onto the disk; however, they are synchronized with the AUNs.

Logical sectors:

Not all physical sectors are available for storage of user data delivered by the application or host. The inner and outer zones are excluded. The remaining sectors are available for storing user data and are called logical sectors.

13.2 Data frames

A data frame consists of 2 052 bytes: 2 048 bytes of user data and 4 bytes of error detection code (EDC). The 2 048 user data bytes are identified as ud_0 to $ud_{2\,047}$ and the 4 EDC bytes as $ed_{2\,048}$ to $ed_{2\,051}$ (see Figure 19).

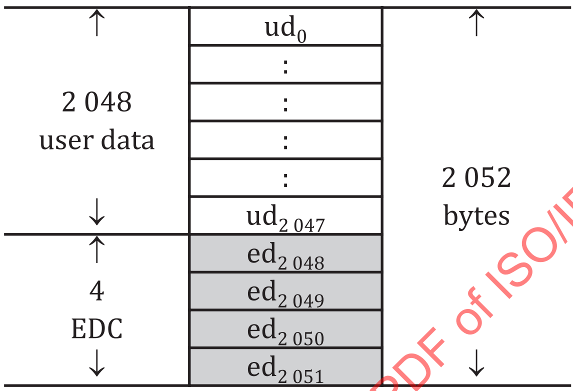


Figure 19 — Data frame

13.3 Error detection code (EDC)

The 4-byte field $ed_{2\,048}$ to $ed_{2\,051}$ shall contain an error detection code computed over the 2 048 bytes of user data.

Considering the data frame as a single-bit field, starting with the most significant bit of the first user data byte (ud_0) and ending with the least significant bit of the last EDC byte ($ed_{2\,051}$), then the msb is $b_{16\,415}$ and the lsb is b_0.

Each bit b_i of the EDC is shown as Formula (20) for i = 0 to 31:

$$EDC(x) = \sum_{i=31}^{0} b_i x^i = I(x) \bmod G(x) \tag{20}$$

where

$$I(x) = \sum_{i=16\,415}^{32} b_i x^i \text{ ; and}$$

$$G(x) = x^{32} + x^{31} + x^4 + 1 \text{ .}$$

13.4 Scrambled data frame

Each data frame consisting of 2 052 bytes of user data + EDC shall be scrambled with the output of the circuit defined in Figure 20, in which bits s_7 (msb) to s_0 (lsb) represent a scrambling byte at each 8-bit shift.

The heart of the circuit is a linear-feedback shift register (LFSR) based on the polynomial as per Formula (21):

$$\Phi(x) = x^{16} + x^{15} + x^{13} + x^{4} + 1 \qquad (21)$$

Here, s_0 to s_{15} form a 16-bit shift register. At each shift clock the content of s_n shifts to s_{n+1} (n = 0 .. 14), while s_0 is set to $s_{15} \oplus s_{14} \oplus s_{12} \oplus s_3$ ($\oplus$ stands for exclusive-or).

At the beginning of the scrambling procedure of each data frame, the shift register s_0 to s_{15} shall be preset with a value derived from the (virtual) PSN associated with the data frame (see Clause 17). The 16-bit preset value shall be composed in the following way:

— s_{15} shall be set to ONE;

— s_{14} .. s_0 shall be set to PS_{19} .. PS_5 of the PSN (see Figure 20).

The same preset value shall be used for all 32 data frames within the same cluster.

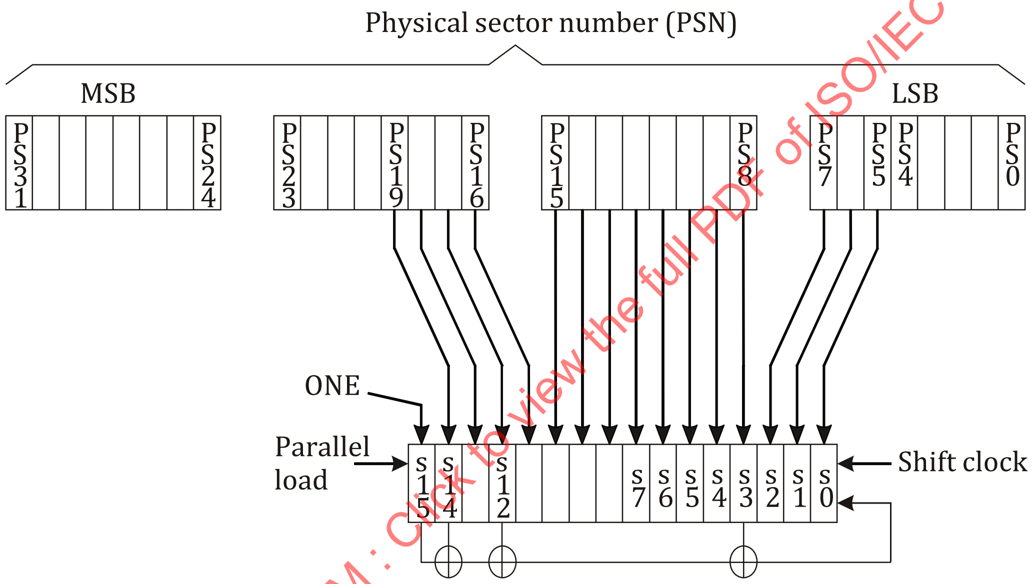


Figure 20 — Scrambler circuit

After loading the preset value, s_7 .. s_0 are taken out as scrambling byte S_0. Then, an 8-bit shift is repeated 2 051 times and the following 2 051 bytes are taken from s_7 .. s_0 as the scrambling bytes S_1 to $S_{2\,051}$.

The 2 052 bytes ud/ed_k of the data frame become scrambled bytes d_k where $d_k = ud/ed_k \oplus S_k$ for k = 0 to 2 051; ($\oplus$ stands for exclusive-or).

13.5 Data block

In the next step, 32 scrambled data frames (F = 0 .. 31) are combined into one block of data as shown in Figure 21.

	← 32 frames					→
	0	1	:	*F*	:	31
↑	$d_{0,0}$	$d_{0,1}$	:	$d_{0,F}$	:	$d_{0,31}$
	$d_{1,0}$	$d_{1,1}$	:	$d_{1,F}$	:	$d_{1,31}$
2 052	:		:	:	:	:
bytes	:		:	:	:	:
	$d_{2\,050,0}$	$d_{2\,050,1}$	:	$d_{2\,050,F}$	:	$d_{2\,050,31}$
↓	$d_{2\,051,0}$	$d_{2\,051,1}$	:	$d_{2\,051,F}$	:	$d_{2\,051,31}$

Figure 21 — 32 scrambled data frames

These data are rearranged into an array of 216 rows × 304 columns by dividing each scrambled data frame into 9,5 columns as shown in. Figure 22. This new array is called a data block. It should be noted that every even scrambled data frame ends halfway down a column and every odd scrambled data frame starts halfway down a column.

	← 304 columns									→
	0	1	:	9	10	:	18	19		303
↑	$d_{0,0}$	$d_{216,0}$	:	$d_{1\,944,0}$	$d_{108,1}$	:	$d_{1\,836,1}$	$d_{0,2}$	:	$d_{1\,836,31}$
	$d_{1,0}$	$d_{217,0}$	:	$d_{1\,945,0}$	$d_{109,1}$	:	$d_{1\,837,1}$	$d_{1,2}$	:	$d_{1\,837,31}$
	:	:	:	:	:	:	:	:	:	:
	:	:	:	$d_{2\,050,0}$	:	:	:	:	:	:
216	:	:	:	$d_{2\,051,0}$	:	:	:	:	:	:
rows	:	:	:	$d_{0,1}$	:	:	:	:	:	:
	:	:	:	$d_{1,1}$	:	:	:	:	:	:
	:	:	:	:	:	:	:	:	:	:
	:	:	:	$d_{106,1}$	:	:	:	:	:	:
↓	$d_{215,0}$	$d_{431,0}$	:	$d_{107,1}$	$d_{323,1}$	:	$d_{2\,051,1}$	$d_{215,2}$	:	$d_{2\,051,31}$

Figure 22 — Composition of data block from 32 scrambled data frames

13.6 LDC block

The bytes in each column of the data block are renumbered as shown in Figure 23 starting from the top of each column as follows: $e_{0,L}$ $e_{1,L}$ .. $e_{i,L}$ .. to $e_{215,L}$, in which *L* represents the code-word number (= the column number: 0 to 303).

The LDC block is completed by extending each of the columns with 32 parity bytes according to a (248,216,33) long-distance RS code. The parity bytes are numbered: $p_{216,L}$ $p_{217,L}$ .. $p_{j,L}$ .. to $p_{247,L}$.

		← 304 columns →						
		Code word 0	Code word 1	:	Code word *L*	:	Code word 302	Code word 303
1 LDC code word = 248 bytes	216 rows with data	$e_{0,0}$ $e_{1,0}$ $e_{2,0}$: : $e_{215,0}$	$e_{0,1}$ $e_{1,1}$: : : $e_{215,1}$	: : : : : :	$e_{0,L}$ $e_{1,L}$: : : $e_{215,L}$	: : : : : :	$e_{0,302}$ $e_{1,302}$: : : $e_{215,302}$	$e_{0,303}$ $e_{1,303}$: : : $e_{215,303}$
	32 rows with parity	$p_{216,0}$: : : : $p_{247,0}$	$p_{216,1}$: : : : $p_{247,1}$	: : : : : :	$p_{216,L}$: : : : $p_{247,L}$	: : : : : :	$p_{216,302}$: : : : $p_{247,302}$	$p_{216,303}$: : : : $p_{247,303}$

Figure 23 — Renumbering data bytes and forming LDC block by adding parities

13.7 LDC code words

The long-distance RS code is defined over the finite field GF(2^8). The non-zero elements of the finite field GF(2^8) are generated by a primitive element α, where α is a root of the primitive polynomial $p(x)$ as per Formula (22):

$$p(x) = x^8 + x^4 + x^3 + x^2 + 1 \tag{22}$$

The symbols of GF(2^8) are represented by bytes (groups of 8 bits), using the polynomial-base representation, with ($\alpha^7, \alpha^6, \alpha^5, .., \alpha^2, \alpha, 1$) as a basis. The root α is thus represented as α = 00000010.

Each LDC code word, represented by the vector l_{dc} = ($e_{0,L}$ .. $e_{i,L}$ .. $e_{215,L}$ $p_{216,L}$ .. $p_{j,L}$ .. $p_{247,L}$), is a Reed-Solomon code over GF(2^8) having 32 parity bytes and 216 information bytes. Such a code word can be represented by a polynomial $l_{dc}(x)$ of degree 247 (possibly having some coefficients equal to zero), where the highest degrees correspond to the information part of the vector ($e_{0,L}$ .., etc.) and the lowest degrees correspond to the parity part of the vector ($p_{216,L}$ .., etc.).

$l_{dc}(x)$ is a multiple of the generator polynomial $g(x)$ of the LDC code word. The generator polynomial is as per Formula (23):

$$g(x) = \prod_{i=0}^{31} (x - \alpha^i) \tag{23}$$

The LDC is systematic: the 216 information bytes appear unaltered in the highest-degree positions of each code word. For all LDC code words l_{dc} , the parity-check matrix H_{LDC} of code l_{dc} is as per Formula (24):

$$H_{LDC} \times l_{dc}^{T} = 0 \tag{24}$$

The second row h_{LDC2} of the parity-check matrix H_{LDC} corresponding to the zero α of the generator polynomial $g(x)$, defines the code-word positions to be used for error locations. This second row h_{LDC2} of the parity-check matrix H_{LDC} is given by Formula (25):

$$h_{LDC2} = (\alpha^{247}, \alpha^{246} .. \alpha^2, \alpha, 1) \tag{25}$$

13.8 LDC cluster

13.8.1 General

After generating the LDC code words, the LDC block is interleaved in a two-step process resulting in the LDC cluster.

13.8.2 First interleave step

In the first interleaving step, the 304 columns of height 248 are rearranged into a new array with 152 columns and 496 rows.

Each new column is formed by multiplexing each even column from the LDC block with the next odd column. The new column is filled by taking the first byte from the even LDC block column, then the first byte from the odd LDC block column, next the second byte from the even LDC block column, followed by the second byte from the odd LDC block column, etc. as shown in Figure 24.

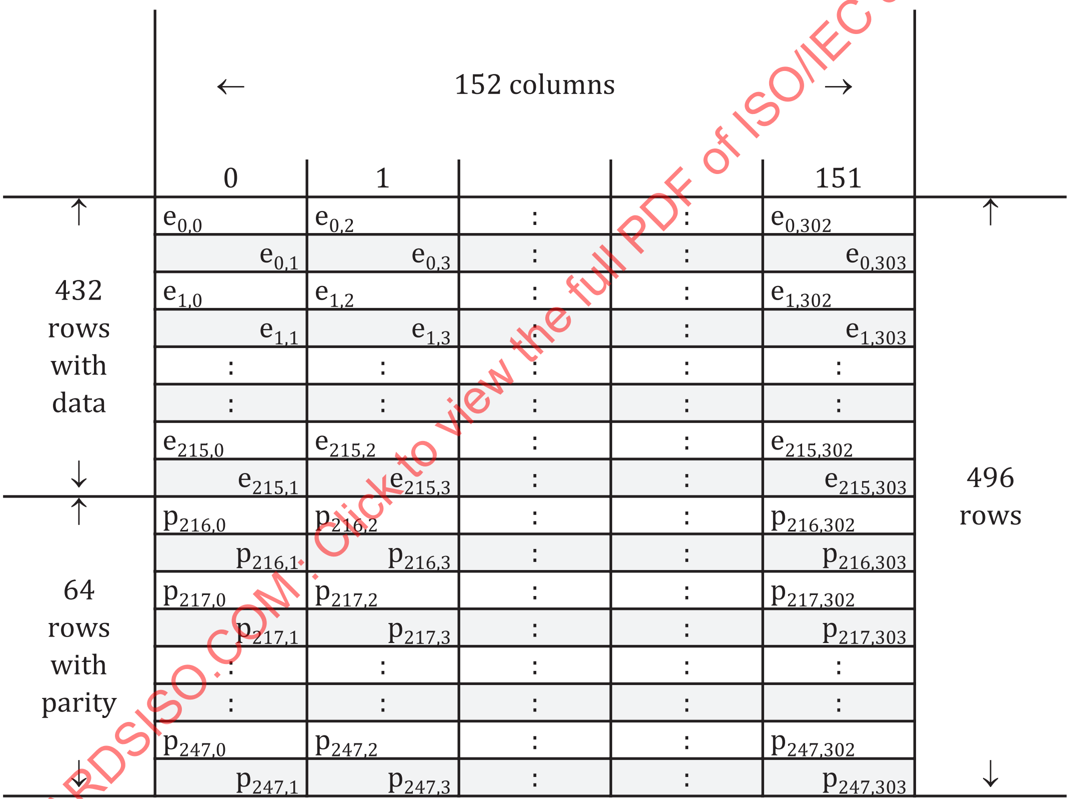


Figure 24 — First step of interleaving

13.8.3 Second interleaving step

To reduce the influence of error propagation and further improve the burst-error correcting capabilities, an additional interleaving is introduced.

All rows of an LDC block resulting from the first interleaving step, shall be shifted over mod(k × 3, 152) bytes to the left where k = div(row_number, 2), 0 ≤ row_number ≤ 495. The bytes that shift out at the left side are re-entered in the array from the right side (see Figure 25).

After this process, the bytes are renumbered in the horizontal direction through all the rows resulting in the numbering D_0 to $D_{75\,391}$ as indicated in Figure 18.

	←									152 bytes							→
← shift 0	$e_{0,0}$	$e_{0,2}$		…						…						$e_{0,300}$	$e_{0,302}$
	$e_{0,1}$	$e_{0,3}$		…						…						$e_{0,301}$	$e_{0,303}$
← shift 3	$e_{1,6}$	$e_{1,8}$		…						…			$e_{1,300}$	$e_{1,302}$	$e_{1,0}$	$e_{1,2}$	$e_{1,4}$
	$e_{1,7}$	$e_{1,9}$		…						…			$e_{1,301}$	$e_{1,303}$	$e_{1,1}$	$e_{1,3}$	$e_{1,5}$
← shift 6	$e_{2,12}$	$e_{2,14}$		…						…	$e_{2,302}$	$e_{2,0}$	$e_{2,2}$	$e_{2,4}$	$e_{2,6}$	$e_{2,8}$	$e_{2,10}$
	$e_{2,13}$	$e_{2,15}$		…						…	$e_{2,303}$	$e_{2,1}$	$e_{2,3}$	$e_{2,5}$	$e_{2,7}$	$e_{2,9}$	$e_{2,11}$
	…	…		…						…							
	…	…		…						…							
← shift 150	$e_{50,300}$	$e_{50,302}$	$e_{50,0}$	…						…							$e_{50,298}$
	$e_{50,301}$	$e_{50,303}$	$e_{50,1}$	…						…							$e_{50,299}$
← shift 1	$e_{51,2}$	$e_{51,4}$		…						…					$e_{51,300}$	$e_{51,302}$	$e_{51,0}$
	$e_{51,3}$	$e_{51,5}$		…						…					$e_{51,301}$	$e_{51,303}$	$e_{51,1}$
	…	…		…						…							
	…	…		…						…							
← shift mod(k×3, 152)	…	…		…						…							
	…	…		…						…							
	…	…		…						…							
	…	…		…						…							
← shift 130	$p_{246,260}$	$p_{246,262}$		…				$p_{246,302}$	$p_{246,0}$	…							$p_{246,258}$
	$p_{246,261}$	$p_{246,263}$		…				$p_{246,303}$	$p_{246,1}$	…							$p_{246,259}$
← shift 133	$p_{247,266}$	$p_{247,268}$		…	$p_{247,302}$	$p_{247,0}$	$p_{247,2}$	$p_{247,4}$	$p_{247,6}$	…							$p_{247,264}$
	$p_{247,267}$	$p_{247,269}$		…	$p_{247,303}$	$p_{247,1}$	$p_{247,3}$	$p_{247,5}$	$p_{247,7}$	…							$p_{247,265}$

Figure 25 — LDC cluster

13.9 Addressing and control data

13.9.1 General

For the purpose of accessing the data on the disk, addressing and control data is included.

13.9.2 Address units

13.9.2.1 General

For positioning the optical head onto the desired track, a fast addressing mechanism is implemented by subdividing the 64K physical clusters into 16 address units. Each address unit contains an address, which is placed in such a way into the BIS code words (see 13.11) that it can be accessed quickly (see Figure 26).

Each address field consists of nine bytes as follows:

— 4 bytes for the address unit number (see Clause 17);

— 1 byte for flag bits;

— 4 bytes for error correction.

		←		16 addresses			→
		0	1	:	*S*	:	15
↑	Address-unit numbers	$AF_{0,0}$	$AF_{0,1}$	:	$AF_{0,S}$	:	$AF_{0,15}$
		$AF_{1,0}$	$AF_{1,1}$	:	:	:	$AF_{1,15}$
		:	:	:	:	:	:
9		$AF_{3,0}$	$AF_{3,1}$	:	$AF_{3,S}$	:	$AF_{3,15}$
bytes	Flag bits	$AF_{4,0}$	$AF_{4,1}$	:	$AF_{4,S}$	:	$AF_{4,15}$
	Parities	$AF_{5,0}$	$AF_{5,1}$	:	$AF_{5,S}$	:	$AF_{5,15}$
		:	:	:	:	:	:
↓		$AF_{8,0}$	$AF_{8,1}$	:	$AF_{8,S}$	:	$AF_{8,15}$

Figure 26 — 16 address fields

13.9.2.2 Bytes assignments for address fields

$AF_{0,S}$: MSB of the address unit number;

$AF_{1,S}$: 2nd SB of the address unit number;

$AF_{2,S}$: 3rd SB of the address unit number;

$AF_{3,S}$: LSB of the address unit number;

$AF_{4,S}$: flag bits: These bits can be used to indicate a status of individual data frames in a cluster or can be used to hold other information, such as an address. The basic format for assigning some of these flag bits is specified in 13.9.2.4. Flag bits not used shall be set to ZERO.

$AF_{5,S}$ .. $AF_{8,S}$: parity bytes for forming an (9,5,5) RS code over the primary address field.

This RS code is defined over the finite field GF(2^8). The non-zero elements of the finite field GF(2^8) are generated by a primitive element α, where α is a root of the primitive polynomial $p(x)$ as per Formula (26):

$$p(x) = x^8 + x^4 + x^3 + x^2 + 1 \tag{26}$$

The symbols of GF(2^8) are represented by bytes (groups of 8 bits), using the polynomial-base representation, with (α^7, α^6, α^5, .., α^2, α, 1) as a basis. The root α is thus represented as α = 00000010.

Each address-field code word, represented by the vector afc = ($AF_{0,S}$ .. $AF_{i,S}$ .. $AF_{8,S}$), is a Reed-Solomon code over GF(2^8), having four parity bytes and five information bytes. Such a code word can be represented by a polynomial $afc(x)$ of degree 8 (possibly having some coefficients equal to zero), where the highest degrees correspond to the information part of the vector ($AF_{0,S}$ .., etc.) and the lowest degrees correspond to the parity part of the vector ($AF_{5,S}$ .., etc.).

$afc(x)$ is a multiple of the generator polynomial $g(x)$ of the address-field code word. The generator polynomial is as per Formula (27):

$$g(x) = \prod_{i=0}^{3} (x - \alpha^i) \tag{27}$$

The address-field code is systematic: the five information bytes appear unaltered in the highest-degree positions of each code word. For all address-field code words afc, the parity-check matrix H_{AFC} of code afc is as per Formula (28):

$$H_{AFC} \times afc^T = 0 \tag{28}$$

The second row h_{AFC2} of the parity-check matrix H_{AFC}, corresponding to the zero α of the generator polynomial $g(x)$, defines the code word positions to be used for error locations. This second row h_{AFC2} of the parity-check matrix H_{AFC} is given by Formula (29):

$$h_{AFC2} = (\alpha^8, \alpha^7 \,..\, \alpha^2, \alpha, 1) \tag{29}$$

13.9.2.3 Address unit numbers

The 16 address fields, to be recorded in the BIS columns of the physical cluster each contain a 4-bytes address unit number (AUN).

The address unit numbers shall be derived from the physical sector numbers (PSN) as defined in Figure 27. The address unit numbers increase by two for each successive address unit, for reasons of synchronization with the PSNs (see Clause 17).

The address unit number of the first address unit of each physical cluster is a multiple of 32.

The first address unit number in data zone 0 is 00 10 00 00h (1 048 576 decimal).

The last address unit number in data zone 1 is 01 EF FF FEh (32 505 854 decimal).

The bits of the address unit numbers shall be set as follows:

— AU_{31} .. AU_5 shall be a copy of PS_{31} .. PS_5 from the PSNs;

— AU_4 .. AU_1 shall count from 0 to 15 inside the physical cluster;

— AU_0 shall be reserved.

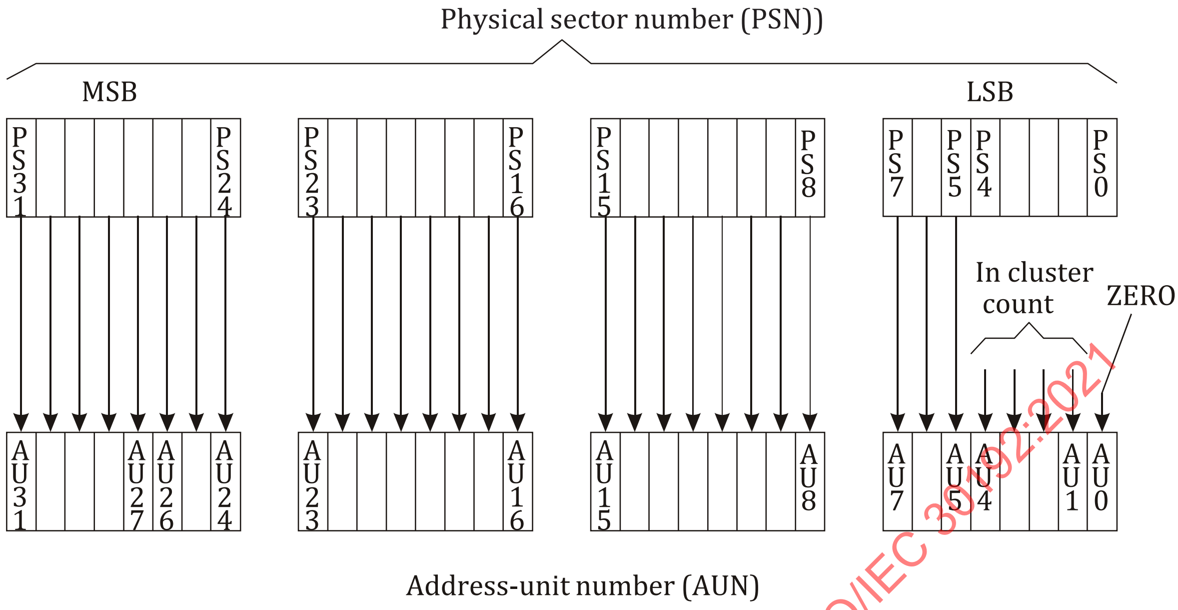


Figure 27 — Composition of AUNs from PSNs

13.9.2.4 Assignments for flag bit

Bit / Byte $AF_{4,S}$	b_7	b_6	b_5	b_4	b_3	b_2	b_1	b_0
$AF_{4,0}$	$Sa_{0,1}$	$Sa_{1,1}$	$Sa_{0,0}$	$Sa_{1,0}$	IdT_7	Rd_{15}	Rsv	Rsv
$AF_{4,1}$	$Sa_{2,1}$	$Sa_{3,1}$	$Sa_{2,0}$	$Sa_{3,0}$	IdT_6	Rd_{14}	Rsv	Rsv
$AF_{4,2}$	$Sa_{4,1}$	$Sa_{5,1}$	$Sa_{4,0}$	$Sa_{5,0}$	IdT_5	Rd_{13}	Rsv	Rsv
$AF_{4,3}$	$Sa_{6,1}$	$Sa_{7,1}$	$Sa_{6,0}$	$Sa_{7,0}$	IdT_4	Rd_{12}	Rsv	Rsv
$AF_{4,4}$	$Sa_{8,1}$	$Sa_{9,1}$	$Sa_{8,0}$	$Sa_{9,0}$	IdT_3	Rd_{11}	Rsv	Rsv
$AF_{4,5}$	$Sa_{10,1}$	$Sa_{11,1}$	$Sa_{10,0}$	$Sa_{11,0}$	IdT_2	Rd_{10}	Rsv	Rsv
$AF_{4,6}$	$Sa_{12,1}$	$Sa_{13,1}$	$Sa_{12,0}$	$Sa_{13,0}$	IdT_1	Rd_9	Rsv	Rsv
$AF_{4,7}$	$Sa_{14,1}$	$Sa_{15,1}$	$Sa_{14,0}$	$Sa_{15,0}$	IdT_0	Rd_8	Rsv	Rsv
$AF_{4,8}$	$Sa_{16,1}$	$Sa_{17,1}$	$Sa_{16,0}$	$Sa_{17,0}$	Rsv	Rd_7	Rsv	Rsv
$AF_{4,9}$	$Sa_{18,1}$	$Sa_{19,1}$	$Sa_{18,0}$	$Sa_{19,0}$	Rsv	Rd_6	Rsv	Rsv
$AF_{4,10}$	$Sa_{20,1}$	$Sa_{21,1}$	$Sa_{20,0}$	$Sa_{21,0}$	Rsv	Rd_5	Rsv	Rsv
$AF_{4,11}$	$Sa_{22,1}$	$Sa_{23,1}$	$Sa_{22,0}$	$Sa_{23,0}$	Rsv	Rd_4	Rsv	Rsv
$AF_{4,12}$	$Sa_{24,1}$	$Sa_{25,1}$	$Sa_{24,0}$	$Sa_{25,0}$	Rsv	Rd_3	Rsv	Rsv
$AF_{4,13}$	$Sa_{26,1}$	$Sa_{27,1}$	$Sa_{26,0}$	$Sa_{27,0}$	Rsv	Rd_2	Rsv	Rsv
$AF_{4,14}$	$Sa_{28,1}$	$Sa_{29,1}$	$Sa_{28,0}$	$Sa_{29,0}$	Rsv	Rd_1	Rsv	Rsv
$AF_{4,15}$	$Sa_{30,1}$	$Sa_{31,1}$	$Sa_{30,0}$	$Sa_{31,0}$	Rsv	Rd_0	Rsv	Rsv
Rsv Reserved unless otherwise specified by the BDAP.								

Figure 28 — Flag bits from 16 address fields

Status bits $Sa_{i,j}$ ($0 \le i \le 31$, $0 \le j \le 1$): Because each cluster contains 32 data frames and there are only 16 address units, each such unit shall hold the flag bits for two data frames (see Figure 28).

Bit b_7 and bit b_5 of successive flag bytes $AF_{4,S}$ are defined as status bits $Sa_{2S,1}$ and $Sa_{2S,0}$, respectively, for data frame 2*S*.

Bit b_6 and bit b_4 of successive flag bytes $AF_{4,S}$ are defined as status bits $Sa_{2S+1,1}$ and $Sa_{2S+1,0}$, respectively, for data frame $2S + 1$.

RID_tag bits IdT_i: Bits b_3 of successive flag bytes $AF_{4,0}$ to $AF_{4,7}$ shall represent the RID_tag value (see 21.4) of the recorder that has recorded the cluster containing this address unit. The msb shall be at IdT_7 (see Figure 28).

Bits b_3 of successive flag bytes $AF_{4,8}$ to $AF_{4,15}$ shall be reserved.

Recording date bits Rd_i: Bits b_2 of successive flag bytes $AF_{4,S}$ shall represent the date when the cluster containing this address unit has been recorded in the following format (see Figure 28):

Rd_{15} to Rd_9: These 7 bits shall represent the actual year – 2 000 as an unsigned binary number with Rd_{15} as the msb;

Rd_8 to Rd_5: These 4 bits shall represent the actual month as an unsigned binary number with Rd_8 as the msb;

Rd_4 to Rd_0: These 5 bits shall represent the actual day of the month as an unsigned binary number with Rd_4 as the msb.

If a drive is not able to correctly set this field, all bits Rd_i shall be set to ZERO.

13.9.2.5 Usage of status bits $Sa_{i,j}$

Each pair of status bits $Sa_{i,1}/Sa_{i,0}$ is used to indicate the status of an individual data frame in a cluster. The following settings are defined:

$Sa_{i,1}/Sa_{i,0}$:

00: data frame contains general user data;

01: data frame contains specific user data that is allowed to be discarded during read-modify-write (RMW) actions;

10: this value is reserved unless otherwise specified by the BDAP;

11: data frame contains padding data inserted by the drive to complete clusters before recording them onto the disk.

In the user data area, all status bits $Sa_{i,1}/Sa_{i,0}$ should be set to 01 in clusters being written in “streaming” mode.

Furthermore, the status bits $Sa_{i,1}/Sa_{i,0}$ shall be set to 11 in data frames that have been inserted by the drive, to complete clusters, before recording them onto the disk (padding).

In all other cases where the data for data frame *i* is supplied by the host, the status bits $Sa_{i,1}/Sa_{i,0}$ shall be set to 00.

Consequently:

— if $Sa_{i,1}/Sa_{i,0}$ is set to 00, the content of data frame *i* shall be conserved during R-M-W actions;

— if $Sa_{i,1}/Sa_{i,0}$ is set to 01 or 11, the content of data frame *i* may be discarded during R-M-W actions.

In case of doubt about the reliability of some $Sa_{i,1}/Sa_{i,0}$ bits, the content of the related data frame *i* shall be conserved during R-M-W actions ($Sa_{i,1}/Sa_{i,0}$ shall be considered as having the value 00).

13.9.3 User control data

For accessing user data, special control data can be added to each user data frame. These additional bytes can carry BDAP-dependent information. A user data frame accompanied by its user control data unit is called a sector. Each user control data unit consists of 18 bytes (see Figure 29).

	←		32 units			→
	0	1	:	S	:	31
↑	$UC_{0,0}$	$UC_{0,1}$	:	$UC_{0,S}$	:	$UC_{0,31}$
	$UC_{1,0}$	$UC_{1,1}$	:	:	:	$UC_{1,31}$
18 bytes	:	:	:	:	:	:
	:	:	:	:	:	:
↓	$UC_{17,0}$	$UC_{17,1}$	:	$UC_{17,S}$	:	$UC_{17,31}$

Figure 29 — 32 user control data units

13.9.4 Byte/bit assignments for user control data

The user control data bytes are BDAP-dependent. If this setting is not specified by the BDAP, these bytes shall be set to 00h.

13.10 Access block

The data for the address fields and user control data units is mapped into an array of 30 rows × 24 columns, that is called an access block.

Because of the need for a fast access of the address fields, the data for these address fields are mapped in a special pre-interleaved way.

The 9 bytes of each of the 16 addresses (see Figure 26) are grouped into three groups of 3 bytes.

The three groups of bytes of each of the addresses 0 to 7 are placed in the access block in a diagonal direction in the first, third and fifth row, starting with address 0 and each successive address shifted cyclically three positions to the left (see Figure 30).

The three groups of bytes of each of the addresses 8 to 15 are placed in a diagonal direction in the second, fourth and sixth row, starting with address 8 and each successive address shifted cyclically three positions to the left.

Within each group of bytes in the third and fourth rows, the bytes are shifted cyclically to the left over 1 byte position.

Within each group of bytes in the fifth and sixth rows, the bytes are shifted cyclically to the left over two byte positions.

Mathematically, this mapping of the address bytes into the access block can be represented by Formula (30). Byte $AF_{x,y}$ shall be allocated in:

row $r = 2 \times \mathrm{div}(x, 3) + \mathrm{div}(y, 8)$; and

$$\text{column } c = 3 \times \mathrm{mod}\{[\mathrm{div}(x, 3) + 16 - y], 8\} + \mathrm{mod}\{[x - \mathrm{div}(x, 3)], 3\} \quad (30)$$

The user control data unit is placed in the column direction, whereby each user control data unit only fills ¾ of a column (4 user control data units in 3 full columns, see Figure 30).

	← 24 columns →														
↑ 6 rows with physical addresses	$AF_{0,0}$	$AF_{1,0}$	$AF_{2,0}$	$AF_{0,7}$	$AF_{1,7}$	$AF_{2,7}$	$AF_{0,6}$	$AF_{1,6}$	$AF_{2,6}$	$AF_{0,5}$	:	:	$AF_{0,1}$	$AF_{1,1}$	$AF_{2,1}$
	$AF_{0,8}$	$AF_{1,8}$	$AF_{2,8}$	$AF_{0,15}$	:	:	$AF_{0,14}$	:	:	$AF_{0,13}$	:	:	$AF_{0,9}$	$AF_{1,9}$	$AF_{2,9}$
	$AF_{4,1}$	$AF_{5,1}$	$AF_{3,1}$	$AF_{4,0}$	$AF_{5,0}$	$AF_{3,0}$	$AF_{4,7}$	$AF_{5,7}$	$AF_{3,7}$	$AF_{4,6}$	:	:	$AF_{4,2}$	$AF_{5,2}$	$AF_{3,2}$
	$AF_{4,9}$	:	:	$AF_{4,8}$	$AF_{5,8}$	$AF_{3,8}$	$AF_{4,15}$	:	:	$AF_{4,14}$	:	:	$AF_{4,10}$	$AF_{5,10}$	$AF_{3,10}$
	$AF_{8,2}$	$AF_{6,2}$	$AF_{7,2}$	$AF_{8,1}$	$AF_{6,1}$	$AF_{7,1}$	$AF_{8,0}$	$AF_{6,0}$	$AF_{7,0}$	$AF_{8,7}$	:	:	$AF_{8,3}$	$AF_{6,3}$	$AF_{7,3}$
↓	$AF_{8,10}$	:	:	$AF_{8,9}$	:	:	$AF_{8,8}$	$AF_{6,8}$	$AF_{7,8}$	$AF_{8,15}$	:	:	$AF_{8,11}$	$AF_{6,11}$	$AF_{7,11}$
↑ 24 rows with user control data	$UC_{0,0}$	$UC_{6,1}$	$UC_{12,2}$	$UC_{0,4}$	:	:	:	:	:	:	:	:	:	:	$UC_{12,30}$
	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
	:	:	$UC_{17,2}$	:	:	:	:	:	:	:	:	:	:	:	$UC_{17,30}$
	:	:	$UC_{0,3}$	:	:	:	:	:	:	:	:	:	:	:	$UC_{0,31}$
	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
	:	$UC_{17,1}$	:	:	:	:	:	:	:	:	:	:	:	:	:
	:	$UC_{0,2}$	:	:	:	:	:	:	:	:	:	:	:	$UC_{0,30}$	:
	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
	$UC_{17,0}$	:	:	$UC_{17,4}$	:	:	:	:	:	:	:	:	:	:	:
	$UC_{0,1}$	:	:	$UC_{0,5}$	:	:	:	:	:	:	:	:	:	:	:
	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
↓	$UC_{5,1}$	$UC_{11,2}$	$UC_{17,3}$	:	:	:	:	:	:	:	:	:	:	$UC_{11,30}$	$UC_{17,31}$

(↑ 30 rows ↓)

Figure 30 — Composition of access block (from 16 address fields and 32 of user control data units)

13.11 BIS block

The bytes in each column of an access block are renumbered as shown in Figure 31 starting from the top of each column as follows: $b_{0,C}$ $b_{1,C}$ .. $b_{i,C}$ .. to $b_{29,C}$, where C represents the code-word number (= the column number: 0 to 23).

The BIS block is completed by extending each of the columns with 32 parity bytes according to a (62,30,33) RS code. The parity bytes are numbered: $pb_{30,C}$ $pb_{31,C}$ .. $pb_{j,C}$ .. to $pb_{61,C}$.

		←		24 columns				→
		Code word 0	Code word 1	:	Code word C	:	Code word 22	Code word 23
↑	↑	$b_{0,0}$	$b_{0,1}$	:	$b_{0,C}$	:	:	$b_{0,23}$
		$b_{1,0}$	$b_{1,1}$	:	$b_{1,C}$	:	:	$b_{1,23}$
	30 information bytes	:	:	:	:	:	:	:
1 BIS code word		:	:	:	$b_{N,C}$	:	:	:
		:	:	:	:	:	:	:
	↓	$b_{29,0}$	$b_{29,1}$	:	$b_{29,C}$	:	:	$b_{29,23}$
= 62 bytes	↑	$pb_{30,0}$	$pb_{30,1}$	:	$pb_{30,C}$	:	:	$pb_{30,23}$
	32	:	:	:	:	:	:	:
	parity bytes	:	:	:	:	:	:	:
		:	:	:	:	:	:	:
↓	↓	$pb_{61,0}$	$pb_{61,1}$	:	$pb_{61,C}$	:	:	$pb_{61,23}$

Figure 31 — Renumbering data bytes and forming BIS block by adding parities

13.12 BIS code words

The BIS RS code is defined over the finite field GF(2^8). The non-zero elements of the finite field GF(2^8) are generated by a primitive element α, where α is a root of the primitive polynomial $p(x)$ as per Formula (31):

$$p(x) = x^8 + x^4 + x^3 + x^2 + 1 \qquad (31)$$

The symbols of GF(2^8) are represented by bytes (groups of 8 bits), using the polynomial-base representation, with ($\alpha^7, \alpha^6, \alpha^5, .., \alpha^2, \alpha, 1$) as a basis. The root α is thus represented as α = 00000010.

Each BIS code word, represented by the vector bis = ($b_{0,C}$ .. $b_{i,C}$ .. $b_{29,C}$ $pb_{30,C}$ .. $pb_{j,C}$ .. $pb_{61,C}$), is a Reed-Solomon code over GF(2^8) having 32 parity bytes and 30 information bytes. Such a code word can be represented by a polynomial $bis(x)$ of degree 61 (possibly having some coefficients equal to zero), where the highest degrees correspond to the information part of the vector ($b_{0,C}$ .., etc.) and the lowest degrees correspond to the parity part of the vector ($pb_{30,C}$ .., etc.).

$bis(x)$ is a multiple of the generator polynomial $g(x)$ of the BIS code word. The generator polynomial is as per Formula (32):

$$g(x)=\prod_{i=0}^{31}(x-\alpha^i) \quad (32)$$

The BIS code is systematic: the 30 information bytes appear unaltered in the highest-degree positions of each code word. For all BIS code words *bis*, the parity-check matrix H_{BIS} of code *bis* is as per Formula (33):

$$H_{BIS} \times bis^T = 0 \quad (33)$$

The second row $h_{BIS\,2}$ of the parity-check matrix H_{BIS} corresponding to the zero α of the generator polynomial $g(x)$, defines the code word positions to be used for error locations. This second row h_{BIS2} of the parity-check matrix H_{BIS} is given by Formula (34):

$$h_{BIS2} = (\alpha^{61}, \alpha^{60} .. \alpha^2, \alpha, 1) \quad (34)$$

13.13 BIS cluster

After generating the BIS code words, the BIS block is mapped in an interleaved way into an array of 496 rows × 3 columns. This newly formed array is called a BIS cluster.

The BIS cluster is subdivided according to the address units as shown in Figure 18. The units are numbered u = 0 to 15; the rows in such a unit are numbered r = 0 to 30 and the columns are numbered e = 0 to 2 (see Figure 32).

The essentials of the BIS interleaving scheme are the following (see Figure 23, Figure 32 and the examples in Figure 33 and Figure 34):

— each row of a BIS block is split into 8 groups of 3 bytes. These 3-byte groups are each placed in one row of the BIS cluster;

— the even rows of a BIS block are mapped into units 0 to 7 and the odd rows of the BIS block are mapped into units 8 to 15;

— the 3-byte groups from an even row of the BIS block are placed each in the same row of units 0 to 7, whereby the units are used in reverse order (according to their numbering). The first 3-byte group of each successive row of the BIS block shall be placed in a unit with a number which is one higher than the start unit used for the previous row:

  — row N = 0 of the BIS block is placed on rows r = 0 of units: 0, 7, 6, 5, .., 2, 1;

  — row N = 2 of the BIS block is placed on rows r = 1 of units: 1, 0, 7, 6, .., 3, 2;

  — row N = 4 of the BIS block is placed on rows r = 2 of units: 2, 1, 0, 7, .., 4, 3.

  — this process is repeated cyclically until row N = 60, which is placed on rows r = 30 of units: 6, 5, 4, 3, .., 0, 7;

— now, within each unit, each row r is shifted cyclically to the right by mod(r, 3) positions: so row r = 0 is not shifted, row r = 1 is shifted 1, row r = 2 is shifted 2, row r = 3 is not shifted, row r = 4 is shifted 1, etc.;

— for the odd rows of a BIS block, the same kind of procedure is followed, but then using the units 8 to 15.

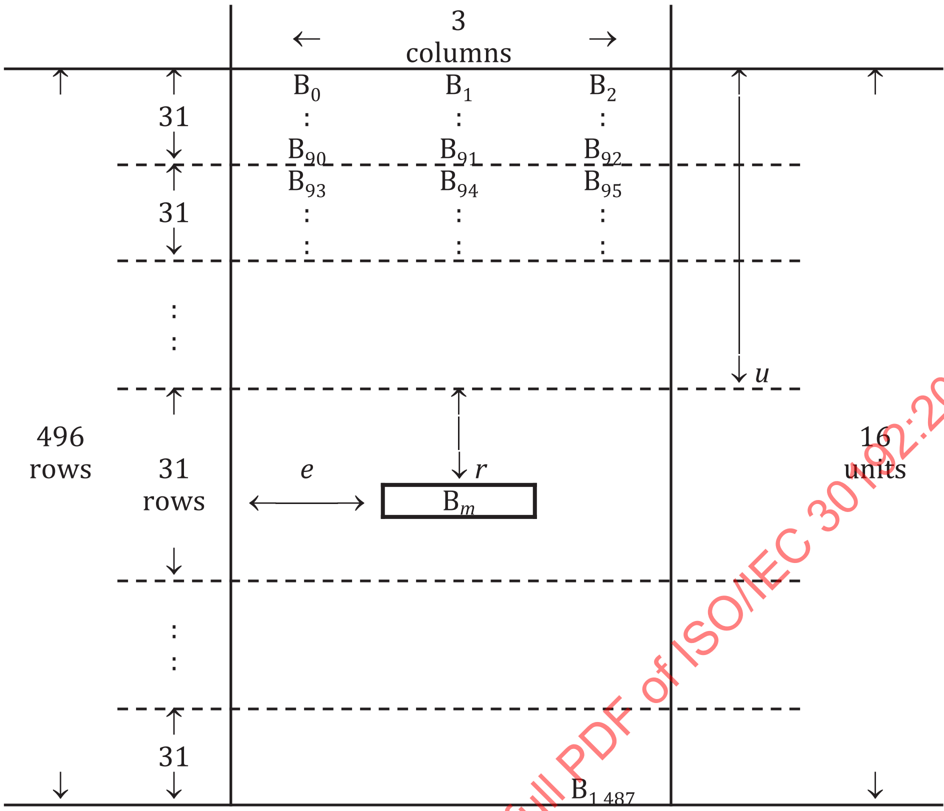


Figure 32 — BIS cluster

Mathematically, the mapping of the bytes from a BIS block into a BIS cluster can be represented by Formulae (35) to (37):

Byte $b_{N,C}$ or pb $_{N,C}$ (see Figure 31) is placed as follows:

— in unit

$$u = \text{mod}\{[\text{div}(N, 2) + 8 - \text{div}(C, 3)], 8\} + 8 \times \text{mod}(N, 2) \quad (35)$$

— on row

$$r = \text{div}(N, 2) \quad (36)$$

— in column

$$e = \text{mod}\{[C + \text{div}(N, 2)], 3\}. \quad (37)$$

The byte number m, giving the sequence number B_m as the physical cluster is written to the disk (see Figure 18), is as per Formula (38):

$$m = (u \times 31 + r) \times 3 + e \quad (38)$$

Unit *u*	Row *r*	Byte number *N,C* from BIS block, Column *e* 0	1	2	Shift right (= mod(*r*,3))	Filling in upward direction
0	0	0,0	0,1	0,2	0	Start of block row *N* = 0
	1	2,5	2,3	2,4	1	↑ Continuation of block row *N* = 2
	2	4,7	4,8	4,6	2	
	3	6,9	6,10	6,11	0	
	:					
	7	14,23	14,21	14,22	1	
	8	16,1	16,2	16,0	2	Start of block row *N* = 16
	:					
	30	60,18	60,19	60,20	0	
1	0	0,21	0,22	0,23	0	End of block row *N* = 0
	1	2,2	2,0	2,1	1	Start of block row *N* = 2
	2	4,4	4,5	4,3	2	
	3	6,6	6,7	6,8	0	
	:					
2	0	0,18	0,19	0,20	0	
	1	2,23	2,21	2,22	1	End of block row *N* = 2
	2	4,1	4,2	4,0	2	Start of block row *N* = 4
	3	6,3	6,4	6,5	0	
	:					
3	0	0,15	0,16	0,17	0	
	1	2,20	2,18	2,19	1	
	2	4,22	4,23	4,21	2	
	3	6,0	6,1	6,2	0	Start of block row *N* = 6
	:					
4	0	0,12	0,13	0,14	0	
	1	2,17	2,15	2,16	1	
	2					
	:					
5	0	0,9	0,10	0,11	0	
	1	2,14	2,12	2,13	1	
	2					
	:					
6	0	0,6	0,7	0,8	0	
	1	2,11	2,9	2,10	1	
	2	4,13	4,14	4,12	2	
	:					
7	0	0,3	0,4	0,5	0	↑ Continuation of block row *N* = 0
	1	2,8	2,6	2,7	1	↑ Continuation of block row *N* = 2
	2	4,10	4,11	4,9	2	
	:					
	7	14,2	14,0	14,1	1	Start of block row *N* = 14
	:					
	30	60,21	60,22	60,23	0	End of block row *N* = 60

Figure 33 — Example of mapping (partial) of BIS bytes into first 8 units

Unit *u*	Row *r*	**Byte number *N,C* from BIS block** Column *e* 0	1	2	Shift right (= mod(*r*,3))	Filling in upward direction
8	0	1,0	1,1	1,2	0	Start of block row *N* = 1
	1	3,5	3,3	3,4	1	
	2	5,7	5,8	5,6	2	
	3	7,9	7,10	7,11	0	
	:					
	8	17,1	17,2	17,0	2	Start of block row *N* = 17
	:					
	30	61,18	61,19	61,20		
9	0	1,21	1,22	1,23		End of block row *N* = 1
10	0	1,18	1,19	1,20		
11	0	1,15	1,16	1,17		
12	0	1,12	1,13	1,14		
13	0	1,9	1,10	1,11		
14	0	1,6	1,7	1,8		
15	0	1,3	1,4	1,5	0	↑ Continuation of block row *N* = 1
	1	3,8	3,6	3,7	1	
	2	5,10	5,11	5,9	2	
	:					
	7	15,2	15,0	15,1	1	Start of block row *N* = 15
	:					
	30	61,21	61,22	61,23	0	End of block row *N* = 61

Figure 34 — Example of mapping (partial) of BIS bytes into last 8 units

Some conclusions are as follows:

— all information bytes of a BIS block are found in the first 15 rows of each address unit;

— all parity bytes of a BIS block are found in the last 16 rows of each address unit;

— each address field is found in the first three rows of each address unit (see Figure 35).

13.14 ECC cluster

After constructing the LDC cluster and the BIS cluster, the LDC cluster is split into 4 groups of 38 columns each. In between these 4 groups, the three columns from the BIS cluster are inserted one by one. After multiplexing the BIS cluster with the LDC cluster, the ECC cluster of Figure 35 is reached.

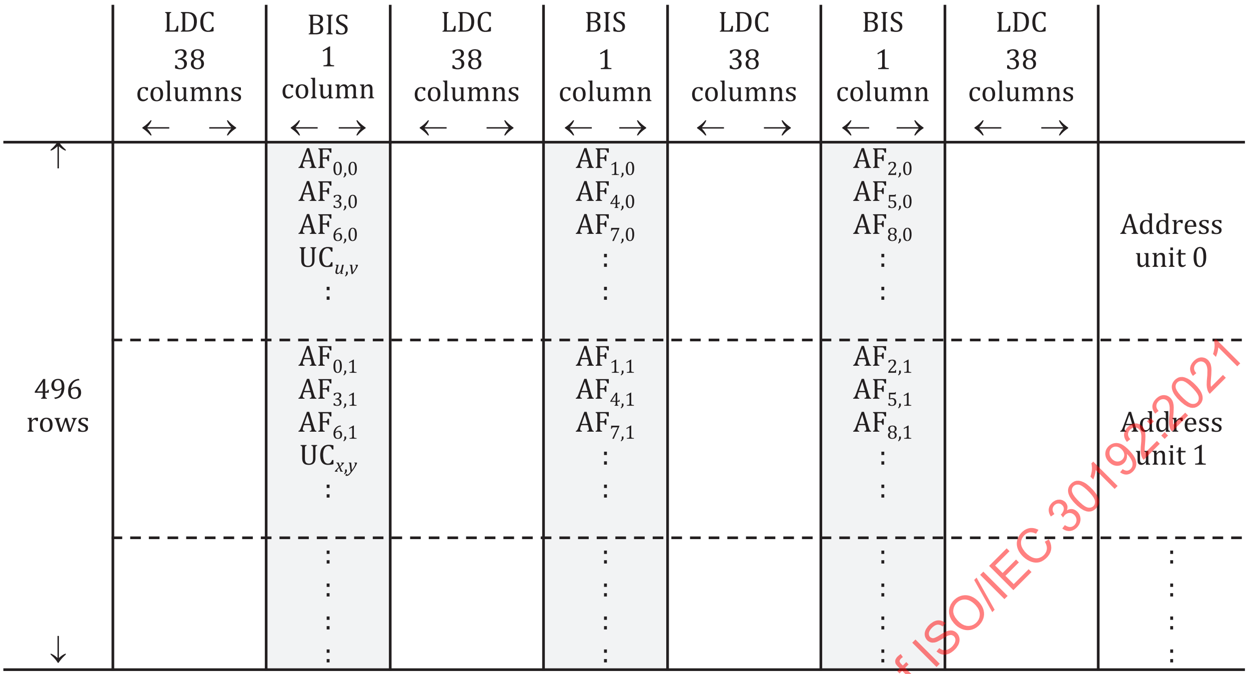


Figure 35 — ECC cluster after multiplexing of BIS cluster with LDC cluster

13.15 Recording frames

Each row of an ECC cluster is transformed into a recording frame by adding locations for frame sync bits and for the dc-control bits.

For this purpose, a stream of 1 240 data bits, which is formed by the 155 bytes of each row of the ECC cluster is divided into one group of 25 data bits and 27 groups of 45 data bits (see Figure 36), with the most significant bits of the bytes handled first.

The first group of 25 data bits is extended with 20 data-bit positions for the insertion of the frame sync, which is a special sequence of 30 modulation/channel bits.

Next, each group of 45 data bits is completed with one additional bit position to form a dc-control block.

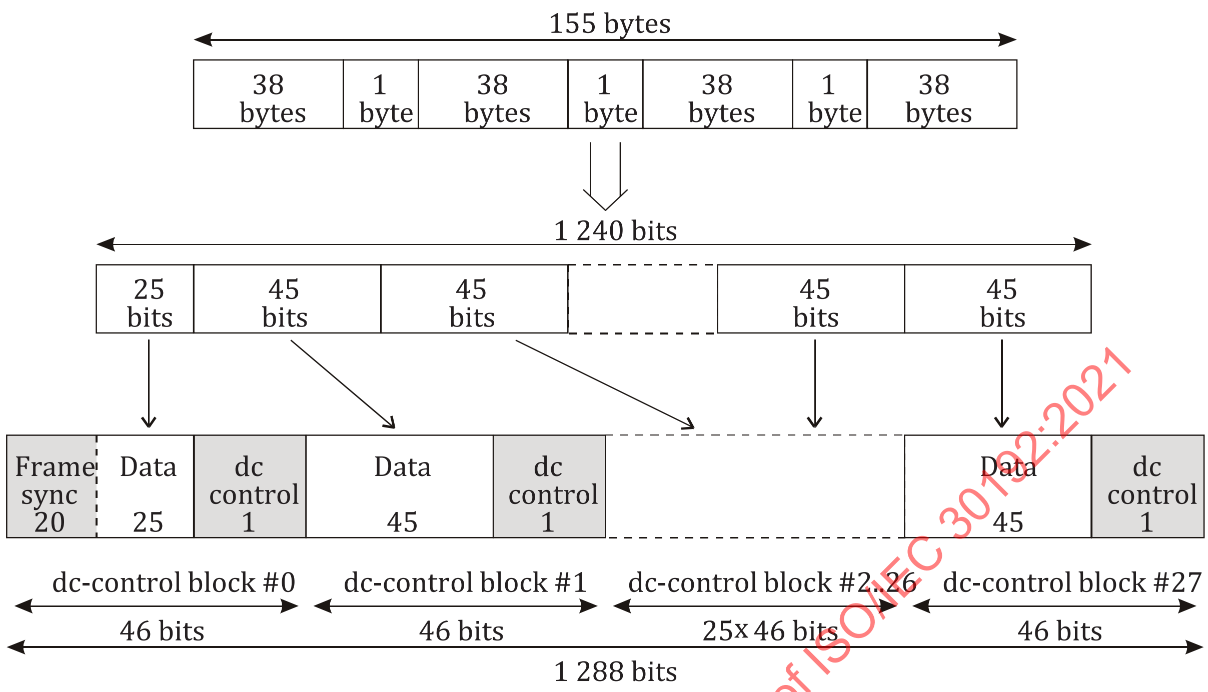


Figure 36 — Composition of recording frame

13.16 Physical cluster

The 496 rows from an ECC cluster, transformed into recording frames, are called a physical cluster.

13.17 17PP modulation for recordable data

13.17.1 General

All the bits of recording frames, except the frame sync, are converted to modulation bits according to the 17PP modulation code. This is an RLL (1,7) code with run lengths of ≥2T and ≤8T and with some special properties. PP means: parity preserve/prohibit RMTR as follows:

— Parity preserve: if the number of ONEs in the data-bit stream is even, then also the number of ONEs in the modulation-bit stream is even; if the number of ONEs in the data-bit stream is odd, then also the number of ONEs in the modulation-bit stream is odd.

  This property makes it easy to control the low-frequency content of the recorded signal efficiently (see 13.7.3).

— Prohibit RMTR: the number of consecutive minimum run lengths (2T) is limited to 6. Because of the low signal levels on minimum run lengths, this improves the read-out performance.

13.17.2 Bit conversion rules

Figure 37 defines the conversion rules from data bits to modulation bits. The data bits shall be processed from the left to the right (msb first, see Figure 36). Remaining bits at the end of the recording frame shall be encoded according to the table for terminating bits.

A ONE in the tables represents a transition in the recorded signal. The modulation-bit stream is converted to an NRZI channel-bit stream (see 13.18) and subsequently recorded onto the disk.

Data bits	Modulation bits	
00 00 00 00	010 100 100 100	
00 00 10 00	000 100 100 100	
00 00 00	010 100 000	
00 00 01	010 100 100	
00 00 10	000 100 000	
00 00 11	000 100 100	
00 01	000 100	
00 10	010 000	
00 11	010 100	
01	010	
10	001	
11	000 101	If preceding modulation bits = xx1 If preceding modulation bits = xx0

Data bit pattern to be substituted	Substituting modulation bits	Condition for substitution
11 01 11	001 000 000	If next modulation bits = 010

Terminating data bits	Terminating modulation bits	
00 00	010 100	
00	000	

Figure 37 — 17PP modulation code conversion table

13.17.3 dc-control procedure

Because a ONE in the modulation-bit stream means a transition in the recorded signal, the polarity of this signal can be inverted if an odd number of ONEs is added to the modulation-bit stream in a controlled way. Because of the parity-preserve property of the 17PP modulation code, this is possible just by inserting additional bits into the data-bit stream and setting these to ONE if an inversion is needed.

In this way, the accumulated DSV of the recorded signal shall be minimized after each dc-control block by setting the dc-control bit at the end of the previous dc-control block to ZERO or ONE (see Figure 36).

13.17.4 Frame sync

The physical clusters consist of 16 address units, where each address unit contains 31 recording frames (see Figure 18 and Figure 36).

A modulated recording frame starts with a frame sync consisting of 30 channel bits.

The main body of the frame sync is formed by a 24-bit pattern violating the 17PP modulation rules (two times run length of 9T).

The last six bits define a signature that identifies one of seven different frame sync patterns. The 6-bit signatures for the frame sync IDs are selected such that their distance with relation to transition shifts is ≥2.

If the last data bits preceding the frame sync have been coded according to the termination table (see Figure 37), then the first modulation bit of the frame sync # = ONE, else # = ZERO (see Figure 38).

The frame sync patterns are defined in terms of modulation bits. A "1" in the table represents a transition in the recorded signal. Before recording onto the disk, the frame sync codes are converted to an NRZI channel-bit stream (see 13.18).

Sync number	24-bit sync body	6-bit sync ID
FS0	#01 010 000 000 010 000 000 010	000 001
FS1	#01 010 000 000 010 000 000 010	010 010
FS2	#01 010 000 000 010 000 000 010	101 000
FS3	#01 010 000 000 010 000 000 010	100 001
FS4	#01 010 000 000 010 000 000 010	000 100
FS5	#01 010 000 000 010 000 000 010	001 001
FS6	#01 010 000 000 010 000 000 010	010 000

Figure 38 — 30-bit frame sync codes

Because seven different frame syncs are insufficient to identify 31 recording frames, each frame is identified by the combination of its own frame sync and the frame sync of one of the preceding recording frames. The mapping of these combinations can be made such that, even with missing frame syncs in 1, 2 or 3 preceding frames, a recording frame can still be identified by its own frame sync and the last present frame sync (see Figure 39).

<table>
<tr><td>Rec. frame n–4</td><td>Rec. frame n–3</td><td>Rec. frame n–2</td><td>Rec. frame n–1</td><td>Rec. frame n</td></tr>
<tr><td colspan="5">Recording frame n can be identified from the frame sync IDs of the following:
Recording frame n + recording frame n–1;
Recording frame n + recording frame n–2;
Recording frame n + recording frame n–3;
Recording frame n + recording frame n–4.</td></tr>
</table>

Figure 39 — Identification of recording frames

The first recording frame of each address unit has a unique frame sync: FS0.

The other frame syncs are mapped as specified in Figure 40.

Frame number	Frame sync	Frame number	Frame sync
0	FS0		
1	FS1	16	FS5
2	FS2	17	FS3
3	FS3	18	FS2
4	FS3	19	FS2
5	FS1	20	FS5
6	FS4	21	FS6
7	FS1	22	FS5
8	FS5	23	FS1
9	FS5	24	FS1
10	FS4	25	FS6
11	FS3	26	FS2
12	FS4	27	FS6
13	FS6	28	FS4
14	FS6	29	FS4
15	FS3	30	FS2

Figure 40 — Mapping of frame sync codes on recording frames

13.18 Modulation and NRZI conversion

Before being recorded onto the disk, data bits are converted to modulation bits that, in turn, are converted to NRZI channel bits according to the process shown in Figure 41.

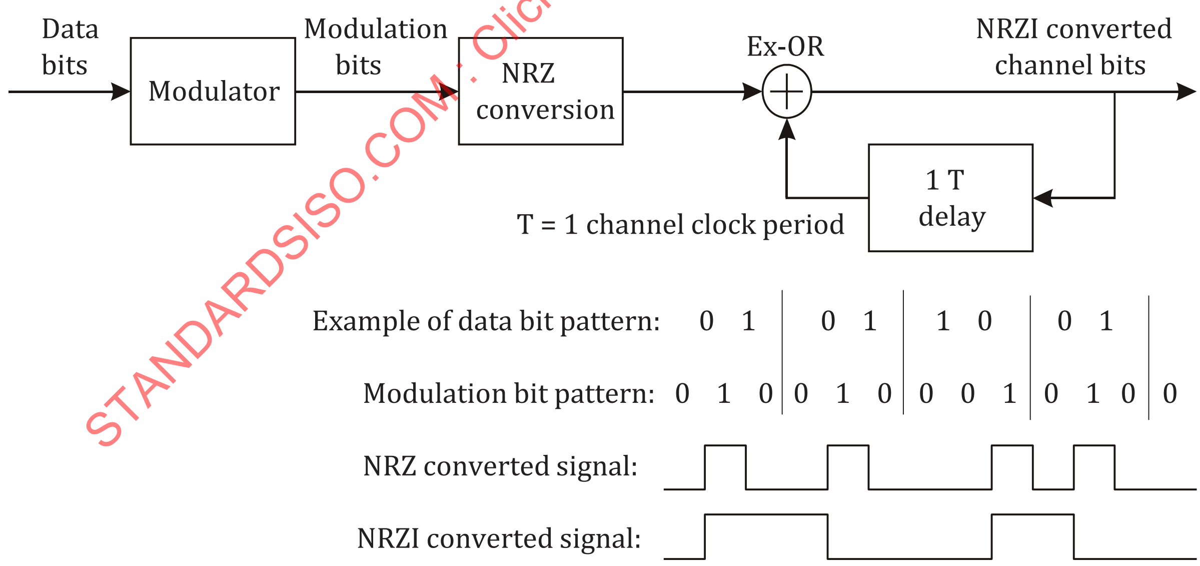


Figure 41 — Modulation and NRZI conversion

14 Physical data allocation and linking

14.1 General

The unit of recording is a recording unit block (RUB), consisting of a physical cluster preceded by a data run-in and followed by a data run-out. The run-in and run-out are offering sufficient buffering for facilitating fully random write/overwrite.

Recording unit blocks can be written one by one or in a continuous sequence of several RUBs (write_streaming).

In the rewritable areas of the disk, a wobble cycle shall correspond to 69 channel bits if the channel-bit rate is locked to the wobble frequency. This means that a modulated recording frame, which is 1 932 channel bits (= 1 288 data bits), covers exactly 28 wobble cycles. This locked case is considered to be the nominal situation.

14.2 Recording unit block (RUB)

14.2.1 General

Each RUB consists of a data run-in of 2 760 cbs (nominally 40 wobble periods), a physical cluster of 496 × 1 932 cbs (nominally 496 × 28 wobble periods) and a data run-out of 1 104 cbs (nominally 16 wobble periods) as shown in Figure 42.

Run-in	Physical cluster	Run-out	Guard_3
←40 wbs→	←496 × 28 wbs→	←16 wbs→	←8 wbs→

Figure 42 — Layout of single written recording unit block

Each single written RUB or each continuously written sequence of RUBs shall be terminated by a Guard_3 field, ensuring that no gaps (unrecorded areas) ever occurs between any 2 RUBs as shown in Figure 43.

Such a Guard_3 field shall consist of 540 cbs (nominally ≈ 8 wobble periods).

Run-in	Physical cluster	Run-out	Run-in	Physical cluster	:	Physical cluster	Run-out	Guard_3
←40 wbs→	←496 × 28 wbs→	←16 wbs→	←40 wbs→	←496 × 28 wbs→	:	←496 × 28 wbs→	←16 wbs→	←8 wbs→

Figure 43 — Layout of continuously written sequence of recording unit blocks

With the above choices, an SPS (see 14.3.2) of about ±2 wobbles maximum and a start position accuracy of about ±0,5 wobble, random writing/overwriting leads to an overlap of between 3 and 13 wobbles and a minimum length of non-overlapped data run-in of about 27 wobbles (minimum ≈ 1 recording frame).

14.2.2 Data run-in

14.2.2.1 General

The data run-in consists of the following parts as shown in Figure 44:

— Guard_1: 1 100 channel bits;

— PrA (pre-amble): 1 660 channel bits.

The PrA field is meant as a runin for signal processing (for locking and synchronization).

The Guard_1 field is meant to cope with the overlaps due to the SPS and inaccuracies in determining the start location of recording sequences.

Guard_1 1 100 cbs		PrA 1 660 cbs
Optional APC ≈ 5 wobbles	Repeated bit pattern ≈ 11 wobbles	Nominal ≈ 24 wobbles

Figure 44 — Layout of data run-in

14.2.2.2 Content of Guard_1 field

The Guard_1 field has a length of 1 100 channel bits.

The content represented in modulation bits is: 55 times repeated $01[0^2]1[0^2]10101[0^4]1[0^3]$.

These patterns result in a repeated 3T/3T/2T/2T/5T/5T sequence, which is well-suited to re-settle the electronic circuits.

14.2.2.3 Automatic power control (APC)

The first five wobbles of the Guard_1 field at the start of a recording sequence can be used for performing an automatic power-control procedure. The modulation-bit pattern to be used for such an APC procedure can be chosen freely by the recorder manufacturer and is allowed to be different from the repeated pattern as defined in 14.2.2.2.

14.2.2.4 Content of PrA field

The PrA field has a length of 1 660 channel bits.

The content of the PrA field shall be as shown in Figure 45.

77 times repeated $01[0^2]1[0^2]10101[0^4]1[0^3]$	Sync_1	2 times repeated $01[0^2]1[0^2]10101[0^4]1[0^3]$	Sync_2	$01[0^2]1[0^2]10101[0^4]1[0^3]$
←— 1 540 cbs —→	←30 cbs →	←— 40 cbs —→	←30 cbs →	←— 20 cbs —→

Figure 45 — Layout of PrA field

In general, Sync_1 shall be FS{mod[(N + 4), 7]} and Sync_2 shall be FS{mod[(N + 6), 7]}, if the first frame sync after the PrA is FS(N) (N = 0 .. 6, see 13.17.4).

This means that Sync_1 shall be FS4 and Sync_2 shall be FS6 (the first frame sync after the PrA is FS0).

The first bit of each of Sync_1, Sync_2 and the first frame sync after the PrA are allowed to be used for dc control (# = ZERO or ONE, see Figure 38).

14.2.3 Data run-out

14.2.3.1 General

The data run-out consists of the following parts, as shown in Figure 46:

— PoA (post-amble): 564 channel bits;

— Guard_2: 540 channel bits.

The PoA field is meant as a runout for signal processing.

The Guard_2 field is meant to cope with overlaps due to the SPS and inaccuracies in determining the start location of recording sequences.

PoA 564 cbs	Guard_2 540 cbs
Nominally ≈ 8 wobbles	Nominally ≈ 8 wobbles

Figure 46 — Layout of data run-out

14.2.3.2 Content of PoA field

The PoA field has a length of 564 channel bits as shown in Figure 47.

The content of the PoA field shall be as shown in Figure 47.

Sync_3	$01[0^8]1[0^8]1[0^8]1[0^8]1[0^8]1[0^7]$	24 times repeated $01[0^2]1[0^2]10101[0^4]1[0^3]$
← 30 cbs →	← 54 cbs →	← 480 cbs →

Figure 47 — Layout of PoA field

In general, Sync_3 shall be chosen such that it corresponds to a frame number $n + 1$ if the user data before the PoA ends with frame number n (see 13.17.4).

This means that Sync_3 shall be FS0.

The first bit of the Sync_3 patterns shall be used as defined in 13.17.4.

The 9T/9T/9T/9T/9T/9T pattern after Sync_3 can be used as a “stop of user data” indicator.

14.2.3.3 Content of Guard_2 field

The Guard_2 field has a length of 540 channel bits.

The content represented in modulation bits is: 27 times repeated $01[0^2]1[0^2]10101[0^4]1[0^3]$.

14.2.4 Guard_3 field

14.2.4.1 General

Guard_3 540 cbs	
Repeated bit pattern ≈ 3 wobbles	Optional APC ≈ 5 wobbles

Figure 48 — Layout of Guard_3 field

The Guard_3 field has a length of 540 channel bits as shown in Figure 48.

The content represented in modulation bits is: 27 times repeated $01[0^2]1[0^2]10101[0^4]1[0^3]$.

14.2.4.2 Automatic power control (APC)

The last five wobbles of the Guard_3 field at the end of a recording sequence can be used for performing an automatic power-control procedure. The modulation-bit pattern to be used for such an APC procedure can be chosen freely by the recorder manufacturer and is allowed to be different from the repeated pattern as defined in 14.2.4.1.

14.3 Locating data relative to wobble addresses

14.3.1 General

The nominal start positions for recordings (and single RUB as continuous sequences of several RUBs), are the locations of the middle of the wobble in NWL 25 in the reference unit between the Sync_3 unit and the first data_*x* unit of the ADIP words with a PAA of which bits AA1, AA0 = 00 (see 15.7, Figure 50 and Figure 52).

The accuracy for determining the start positions shall be better than ±34 cbs.

14.3.2 Start position shift (SPS)

To avoid excessive wear of the disk, the start of the writing of each recording sequence (one or more RUBs) shall be shifted from its nominal start position by a random number of channel bits, called the start position shift (-128 cbs $\leq T_{SPS} \leq +127$ cbs) (see Figure 49), where T_{SPS} is the shift value of SPS in cbs.

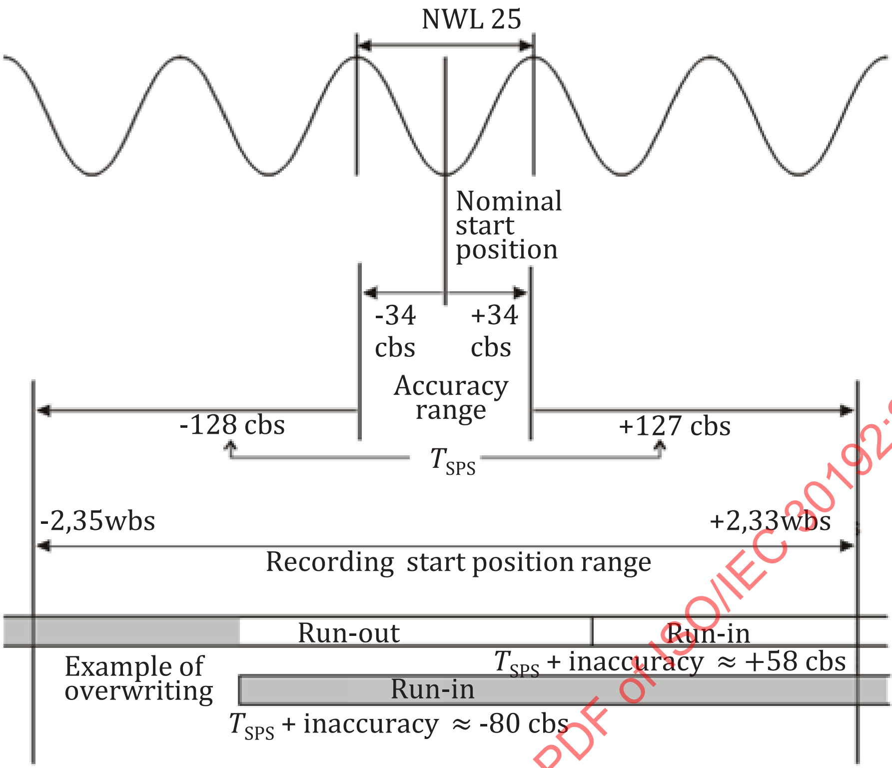


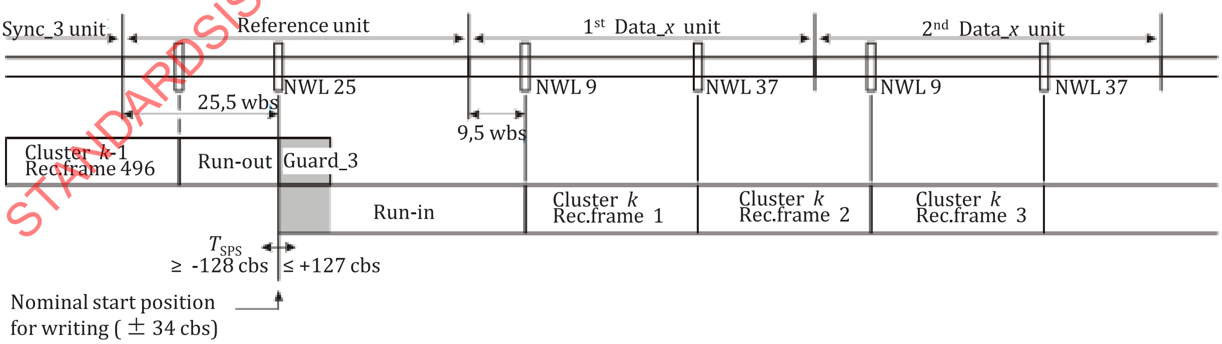
Figure 49 — Nominal start position for data recording

Figures 50 to 52 show examples of how newly written RUBs overlap with previously written RUBs.

At the start of the newly written RUB, the run-in of the newly written RUB overwrites a part of the run-out/Guard_3 of the preceding RUB (if this had been written already before).

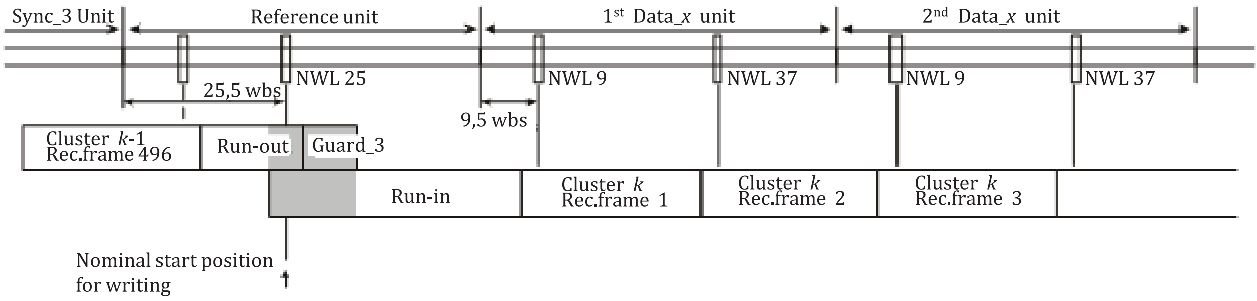
At the end of the newly written RUB, the run-out/Guard_3 of the newly written RUB overwrites a part of the run-in of the following RUB (if this had been written already before).

In all cases, sufficient run-in/run-out is left over for recapturing of the detection electronics during random access.



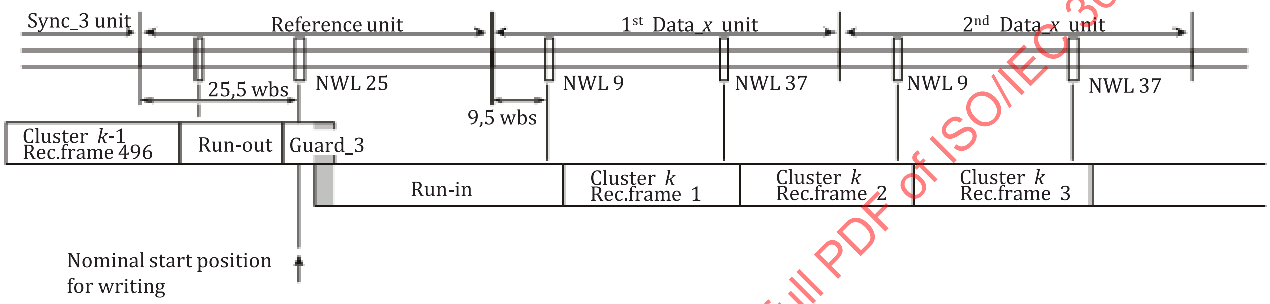
NOTE T_{SPS} + inaccuracy of previous encoding = 0 and T_{SPS} = inaccuracy of new recording = 0.

Figure 50 — Example of nominal start position for data recording



NOTE T_{SPS} + inaccuracy of previous recording = +161 and T_{SPS} + inaccuracy of new recording = −162.

Figure 51 — Example of data recording with maximum overlap



NOTE T_{SPS} + inaccuracy of previous recording = −162 and T_{SPS} + inaccuracy of new recording = +161.

Figure 52 — Example of data recording with minimum overlap

15 Track format

15.1 General

A track is formed by a 360° turn of a continuous spiral.

Each recording layer shall have the same basic tracks at about the same locations (see Figure 53). For consistency reasons, the sole recording layer on an SL disk is also called layer L0.

15.2 Track shape

The zone between radius r_1 = 21,0 mm and radius r_3 = 22,2 mm is reserved to be used for the BCA (see Clause 35). In this zone, there shall be tracks formed by a single spiral groove, starting from (on layer L0) or ending at (on layer L1) radius $21{,}0^{0{,}0}_{-0{,}1}$ mm.

Transition from one groove type to another groove type between the BCA zone and the embossed HFM area shall occur between radius r_2 = 22,0 mm and radius r_3 (see Figure 53). At this transition, the spiral groove shall be uninterrupted.

The groove tracks in the BCA zone shall be straight groove(s) (without any modulation) between radius r_1 = 21 mm and the point where the encoding of the HFM groove in the embossed HFM area starts (on layer L0) or ends (on layer L1) (see Clause 18).

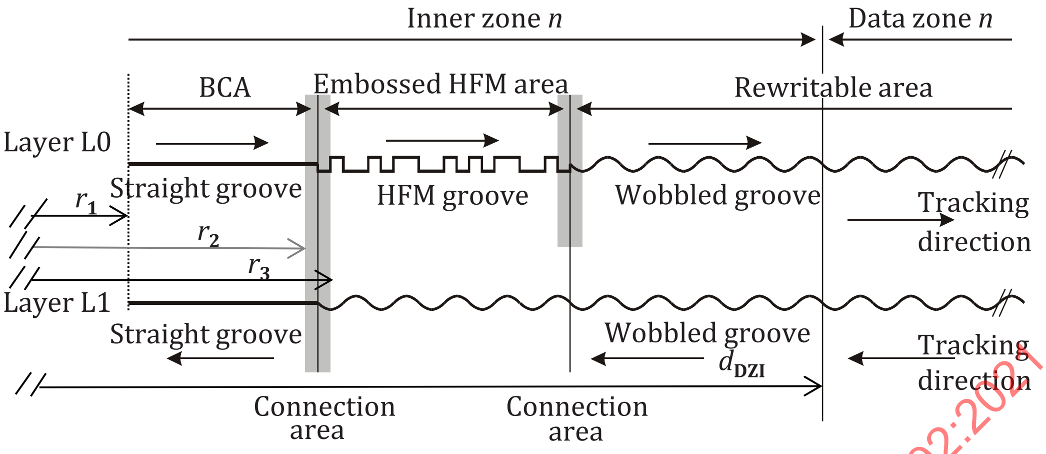


Figure 53 — Connection areas between different groove types

In the embossed HFM areas (see Clause 16), the tracks are formed by a single spiral groove, continuing uninterruptedly from the end of the groove in the BCA zone (on layer L0) or continuing uninterruptedly to the beginning of the groove in the BCA zone (on layer L1).

The groove tracks in the embossed HFM areas move with a rather high-frequency deviation in the radial direction around their nominal centrelines, providing a high bit rate/high-capacity data channel for the storage of replicated information (HFM groove).

The shape of each track is determined by the requirements in Clause 26.

In the rewritable areas (see Clause 16), the tracks are formed by a single spiral groove, starting from the end of the embossed HFM area (on layer L0) or ending at the beginning of the groove in the embossed HFM area (on layer L1).

The groove in the rewritable areas move with a mainly monotone sinusoidal deviation in the radial direction around their nominal centrelines [wobbled groove(s)]. The sinusoidal deviation is modulated by replacing some cycles at certain locations by different patterns.

The wobble can be used for speed control of the disk and synchronization of the write clock of the drive while the modulated parts represent addressing information called address in pre-groove or ADIP (see 15.7).

NOTE Although the term of "pre-groove" is not defined in this document, "ADIP" is widely used as an acronym of "address in pre-groove" in optical disk standards. The meaning of "pre-groove" is the same as that of "groove" in this document.

The shape of each track is determined by the requirements in Clause 27.

At the connection between the embossed HFM area and the rewritable area, the spiral groove shall be uninterrupted. Between the replicated information in the HFM groove and the ADIP information in the wobbled groove, it may have a groove-only part (without any modulation) for a maximum of 1 mm in the tangential direction along the track.

Groove geometry

The grooves shall be nearer to the entrance surface of the disk than the land.

The grooves shall be at the inner side of their average centreline at the start of the monotone wobbles (see Figure 54). Recordings shall be made on the grooves.

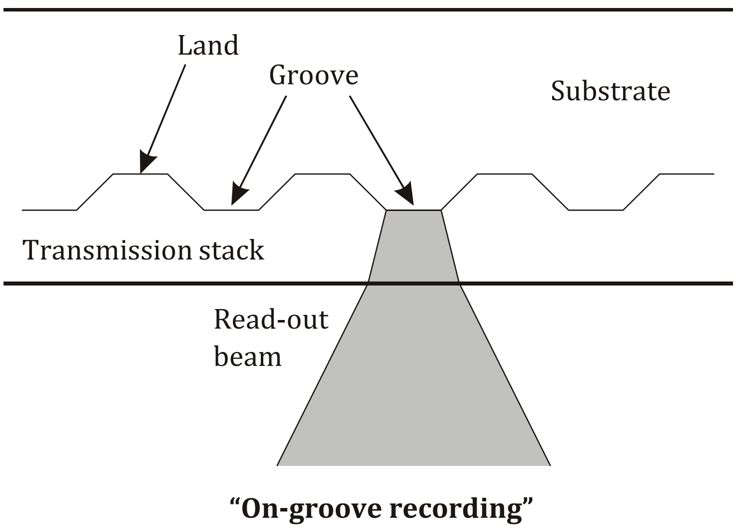


Figure 54 — Outline of groove geometry (radial cross-section of the disk)

15.3 Track path

On layer L0, the spiral shall run from the inner side of the disk towards the outer side of the disk when the disk rotates according to the specification in 9.8.

On layer L1, the spiral shall run from the outer side of the disk towards the inner side of the disk when the disk rotates according to the specification in 9.8.

On an SL disk, the tracks shall start at the beginning of the inner zone, terminate at the end of the outer zone and shall be continuous in the information zone (see Figure 12 and Figure 13).

On a DL disk, the tracks on layer L0 shall start at the beginning of the inner zone, terminate at the end of the outer zone 0 and be continuous in the information zone. On layer L1, the tracks shall start at the beginning of the outer zone 1, terminate at the end of the inner zone 1 and be continuous in the information zone (see Figure 12 and Figure 14).

15.4 Track pitch

15.4.1 Track pitch in BCA zone

The track pitch (TP) in BCA zone is the distance between the average centrelines of a groove in adjacent tracks, measured in the radial direction.

The track pitch shall be (2,0 ± 0,1) µm.

In the area between r_2 and r_3 mm, the track pitch shall change over from 2,0 µm to the track pitch of the embossed HFM area (on layer L0) or vice versa (on layer L1).

15.4.2 Track pitch in embossed HFM areas

The track pitch (TP) in embossed HFM areas is the distance between the average centrelines of an HFM groove in adjacent tracks, measured in the radial direction.

The track pitch shall be (0,350 ± 0,010) µm.

The track pitch, averaged over the embossed HFM areas, shall be (0,350 ± 0,003) µm.

15.4.3 Track pitch in rewritable areas

The track pitch (TP) in rewritable areas is the distance between the average centrelines of a wobbled groove in adjacent tracks, measured in the radial direction.

The track pitch shall be (0,320 ± 0,010) µm.

The track pitch, averaged over the rewritable areas, shall be (0,320 ± 0,003) µm.

15.4.4 Track pitch between embossed HFM area and rewritable area

The change in track pitch from 0,35 µm to 0,32 µm (on layer L0) or vice versa (on layer L1) shall be realized within maximum 100 tracks (revolutions), which tracks shall be located completely in protection zone 2 (see Figure 81).

15.5 Track layout of HFM groove

15.5.1 General

In this subclause, only the encoding format of the data is described. The locations and their content are defined in Clause 18.

The data in HFM groove is recorded in 4K partitions, called PIC clusters. Each such PIC cluster contains two data frames, each with 2 048 bytes of data. The error correction mechanisms used to protect this data and the procedures used to build up fully-formatted partitions are very similar to those described in Clause 13.

A reduced combination of an LDC + BIS code is used as shown schematically in Figure 55.

For detailed descriptions of the related processing steps and applied codes, reference is made to the descriptions in Clause 13.

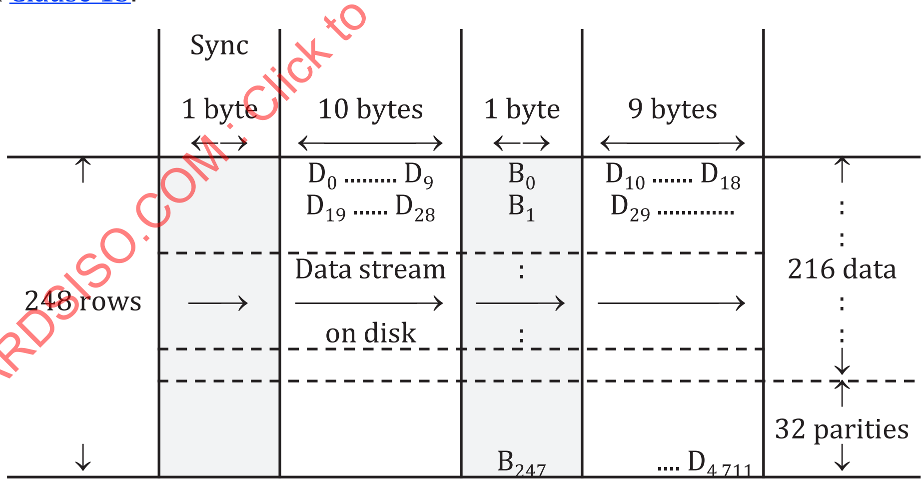


Figure 55 — Schematic representation of 4K PIC cluster on disk

15.5.2 Data format

15.5.2.1 Data frame

Each data frame is extended with a 4-byte error detection code (EDC) as described in 13.2 and 13.3.

15.5.2.2 Scrambled data frame

Each data frame with its EDC is scrambled according to the procedure described in 13.4. For the preset of the scrambler, AUN_{15} .. AUN_1 (see 15.4.1 and 13.9.2.3) shall be used instead of PS_{19} .. PS_5.

15.5.2.3 Data block

Each two scrambled data frames are mapped into an array of 216 rows × 19 columns as described in 13.5 and indicated in Figure 22 (only columns 0 .. 18).

15.5.2.4 LDC block

Next, 32 rows with error correction parities are added according to the procedure described in 13.6 and 13.7, with the difference being that there are only 19 columns (L = 0 .. 18). The result of this processing is a matrix of 248 rows × 19 columns.

15.5.2.5 Interleaving

The interleaving procedure is different from the one described in 13.8.

Only the second interleaving step, described in 13.8.3 is applied, where each successive row is shifted one more byte position to the left [shift = mod(*k*, 19), in which *k* is the row number, 0 ≤ *k* ≤ 247]. The bytes that shift out at the left side are re-entered in the array from the right side (see Figure 56).

	←			19 bytes				→	
← shift 0	$e_{0,0}$	$e_{0,1}$	...		...			$e_{0,18}$	↑
← shift 1	$e_{1,1}$	$e_{1,2}$	...		...		$e_{1,18}$	$e_{1,0}$	
← shift 2	$e_{2,2}$	$e_{2,3}$	...		...	$e_{2,18}$	$e_{2,0}$	$e_{2,1}$	
	...	...	...		...				
← shift 18	$e_{18,18}$	$e_{18,0}$	...		...			$e_{18,17}$	248
← shift 0	$e_{19,0}$	$e_{19,1}$	...		...			$e_{19,18}$	rows
	...	...	...		...				
← shift mod(*k*,19)	...	...	...		...				
	...	...	...		...				
← shift 18	$p_{246,18}$	$p_{246,0}$	...		...			$p_{246,17}$	
← shift 0	$p_{247,0}$	$p_{247,1}$	...		...			$p_{247,18}$	↓

Figure 56 — Interleaving of PIC LDC block

After this process, the bytes are renumbered in the horizontal direction through all the rows, resulting in the numbering D_0 to $D_{4\,711}$ as indicated in Figure 55.

15.5.3 Addressing and control data

15.5.3.1 General

Unlike the format in rewritable areas of the disk, a BIS block, is composed of 4 BIS code-words, and filled up with 8 addresses of nine bytes each, in 18 rows and two user control data units of 24 bytes each, in 12 rows (see Figure 57).

		4 columns				
		0	1	2	3	
↑	0	***$AF_{0,0}$***	$AF_{0,3}$	$AF_{0,2}$	$AF_{0,1}$	↑
	1	$AF_{0,4}$	$AF_{0,7}$	$AF_{0,6}$	$AF_{0,5}$	
	2	$AF_{1,1}$	***$AF_{1,0}$***	$AF_{1,3}$	$AF_{1,2}$	
	3	$AF_{1,5}$	$AF_{1,4}$	$AF_{1,7}$	$AF_{1,6}$	
	4	$AF_{2,2}$	$AF_{2,1}$	***$AF_{2,0}$***	$AF_{2,3}$	
	5	$AF_{2,6}$	$AF_{2,5}$	$AF_{2,4}$	$AF_{2,7}$	
	6	$AF_{3,3}$	$AF_{3,2}$	$AF_{3,1}$	***$AF_{3,0}$***	
	7	$AF_{3,7}$	$AF_{3,6}$	$AF_{3,5}$	$AF_{3,4}$	
	8	***$AF_{4,0}$***	:	:	$AF_{4,1}$	18 rows
	9	$AF_{4,4}$	:	:	:	addresses
	10	$AF_{5,1}$	***$AF_{5,0}$***	:	:	
	11	$AF_{5,5}$	:	:	:	
1 BIS	12	$AF_{6,2}$	$AF_{6,1}$	***$AF_{6,0}$***	:	
code-word	13	$AF_{6,6}$	:	:	:	
= 62 bytes	14	$AF_{7,3}$	:	$AF_{7,1}$	***$AF_{7,0}$***	
	15	$AF_{7,7}$	:	:	:	
	16	***$AF_{8,0}$***	:	:	$AF_{8,1}$	
	17	$AF_{8,4}$	$AF_{8,7}$	$AF_{8,6}$	$AF_{8,5}$	↓
	18	$UC_{0,0}$	$UC_{12,0}$	$UC_{0,1}$	$UC_{12,1}$	↑
	19	$UC_{1,0}$	$UC_{13,0}$	$UC_{1,1}$	$UC_{13,1}$	12 rows
	:	:	:	:	:	user control
	28	$UC_{10,0}$	$UC_{22,0}$	$UC_{10,1}$	$UC_{22,1}$	data
	29	$UC_{11,0}$	$UC_{23,0}$	$UC_{11,1}$	$UC_{23,1}$	↓
	30	$pb_{30,0}$	$pb_{30,1}$	$pb_{30,2}$	$pb_{30,3}$	↑
	31	$pb_{31,0}$	$pb_{31,1}$	$pb_{31,2}$	$pb_{31,3}$	32 rows
	:	:	:	:	:	parities
↓	61	$pb_{61,0}$	$pb_{61,1}$	$pb_{61,2}$	$pb_{61,3}$	↓
		Code word 0	Code word 1	Code word 2	Code word 3	

Figure 57 — PIC BIS block

15.5.3.2 Address field

Comparable to the rewritable areas of the disk, where each 1/16 of a 64K cluster (=4K bytes) is identified by one address unit number (see 13.9.2), each 4K PIC cluster shall be identified by one address unit number. These address unit numbers shall increase by two for each successive 4K PIC cluster.

Each PIC BIS block contains 8 repetitions (S = 0 .. 7) of the same address, where the flag bits are used to identify the repetition number as follows:

— $AF_{0,S}$ = MSB of address unit number (all the same for S = 0 .. 7);

— $AF_{1,S}$ = 2nd SB of address unit number (all the same for S = 0 .. 7);

— $AF_{2,S}$ = 3rd SB of address unit number (all the same for S = 0 .. 7);

— $AF_{3,S}$ = LSB of address unit number (all the same for S = 0 .. 7);

— $AF_{4,S}$ = flag bits:

  — bit 7 to bit 3 shall be set to reserved;

  — bit 2 to bit 0 shall be set to the binary value of S;

— $AF_{5,S}$ .. $AF_{8,S}$ = parity bytes for forming an (9,5,5) RS code over the address field.

The parity bytes shall be calculated according to the definitions given in 13.9.2.2.

The 8 addresses are mapped into the PIC BIS block in a special pre-interleaved way.

The bytes of addresses 0 to 3 are placed in a diagonal direction in the even numbered rows, starting with byte 0 of address 0 in row 0, column 0 and each successive address being shifted cyclically one more position to the left (see Figure 57).

The bytes of addresses 4 to 7 are placed in a diagonal direction in the odd numbered rows, starting with byte 0 of address 4 in row 1, column 0 and each successive address being shifted cyclically one more position to the left.

Mathematically, this mapping of the address bytes into the PIC BIS cluster can be represented by Formula (39). Byte $AF_{x,y}$ shall be allocated in:

row $r = 2 \times x + \mathrm{div}(y, 4)$; and

$$\text{column } c = \mathrm{mod}[(x + 8 - y), 4] \quad (39)$$

15.5.3.3 User control data

There are two user control data units, each consisting of 24 bytes. Bytes 0 to 11 of the first user control data unit shall be placed in column 0, rows 18 to 29 of the PIC BIS block and bytes 12 to 23 in column 1, rows 18 to 29. In the same way, bytes 0 to 11 of the second user control data unit shall be placed in column 2 and bytes 12 to 23 in column 3 (see Figure 57).

All bytes of both user control data units shall be reserved.

15.5.3.4 BIS code words

The PIC BIS block is completed by adding 32 rows with parity bytes (see Figure 57) according to the procedure described in 13.11 and 13.12, with the difference that there are only two columns (c = 0 .. 3). The result is now a matrix of 62 rows × 4 columns.

15.5.3.5 BIS cluster

Finally, the matrix of BIS code words is reconstructed into one-column of 248 bytes that can be inserted in the PIC cluster as indicated in Figure 55.

Bytes B_0 to B_{123} are filled by successively copying bytes from the even rows by going through the BIS block cyclically in a diagonal direction starting from row 0, column 0 (see Figure 58).

Bytes B_{124} to B_{247} are filled by successively copying bytes from the odd rows by going through the BIS block cyclically in a diagonal direction starting from row 1, column 0.

Mathematically, the mapping of the bytes from the PIC BIS block into the PIC BIS cluster can be represented by Formulae (40) to (42):

Let byte $b_{r,c}$ be the byte in row r and column c of the BIS block, and byte B_i is the i^{th} byte in the column of the BIS cluster. Then:

$$r = \mathrm{mod}(2 \times i, 62) + \mathrm{div}(i, 124); \quad (40)$$

$$c = \mathrm{mod}(i, 4); \tag{41}$$

And vice versa

$$i = 124 \times \mathrm{mod}(r, 2) + \mathrm{div}(r, 2) + 31 \times \mathrm{mod}\{[4 - c + \mathrm{div}(r, 2)], 4\} \tag{42}$$

As a result of this interleaving, the one-column 248-byte BIS cluster is divided into 8 groups of 31 bytes, where each 31-byte group is composed of nine address bytes, six UC data bytes, and 16 parity bytes in succession. The address bytes, due to the pre-interleaving, appear in the correct order for direct access.

	BIS block					BIS cluster	
i	*c* = 0	1	2	3		← 1 byte →	↑
r = 0	***0***	***93***	***62***	***31***		B_0	
1	124	217	186	155		:	
2	***32***	***1***	***94***	***63***		:	
3	156	125	218	187		:	
4		***33***	***2***	***95***		:	
5		157	126	219	⇒	B_i	
6			***34***	***3***		:	
7			158	127		:	
8	***4***			***35***		:	
9	128			159		:	
10		***5***				:	
11		129				B_{123}	248
12			***6***			B_{124}	rows
13			130			:	
:	:	:	:	:		:	
53				243		:	
54	***120***			***27***		:	
55	244					:	
	28	***121***			⇒	:	
57	152	245				:	
58	***60***	***29***	***122***			:	
59	184	153	246			:	
60	***92***	***61***	***30***	***123***		:	
61	216	185	154	247		B_{247}	↓

Figure 58 — Reading order for constructing PIC BIS cluster

15.5.4 Recording frames

15.5.4.1 General

In the next processing step, the 19 columns of an interleaved LDC block are multiplexed with the one-column BIS cluster and extended with a column of synchronization patterns as defined in Figure 55.

Each row of this 21-column by 248-row matrix is called a PIC recording frame.

15.5.4.2 Modulation

The 168 bits of each PIC recording frame, except some of the bits of the synchronization pattern, are converted into modulation bits by applying a biphase modulation method. In this modulation method, a bit with value ZERO is represented by a transition at the start of the bit cell and a bit with value ONE is represented by a transition at the start and in the middle of the bit cell (see example in Figure 59).

The modulation bits are recorded on the disk by a deviation of the groove from its average centreline as indicated in Figure 59. The length of each bit cell shall be 36T, where T corresponds to the length of a channel bit in the rewritable data areas.

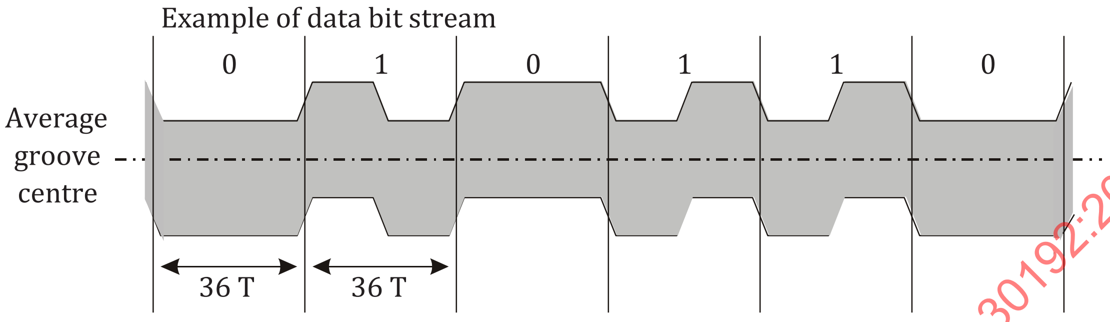


Figure 59 — Biphase modulated HFM groove

15.5.4.3 Frame sync

Each recording frame starts with a synchronization pattern equivalent to 8 data bits. The first 4 bits are replaced by 4-bit cells with a special pattern that violates the normal biphase encoding rules (see Figure 60: two possible patterns depending on the initial phase).

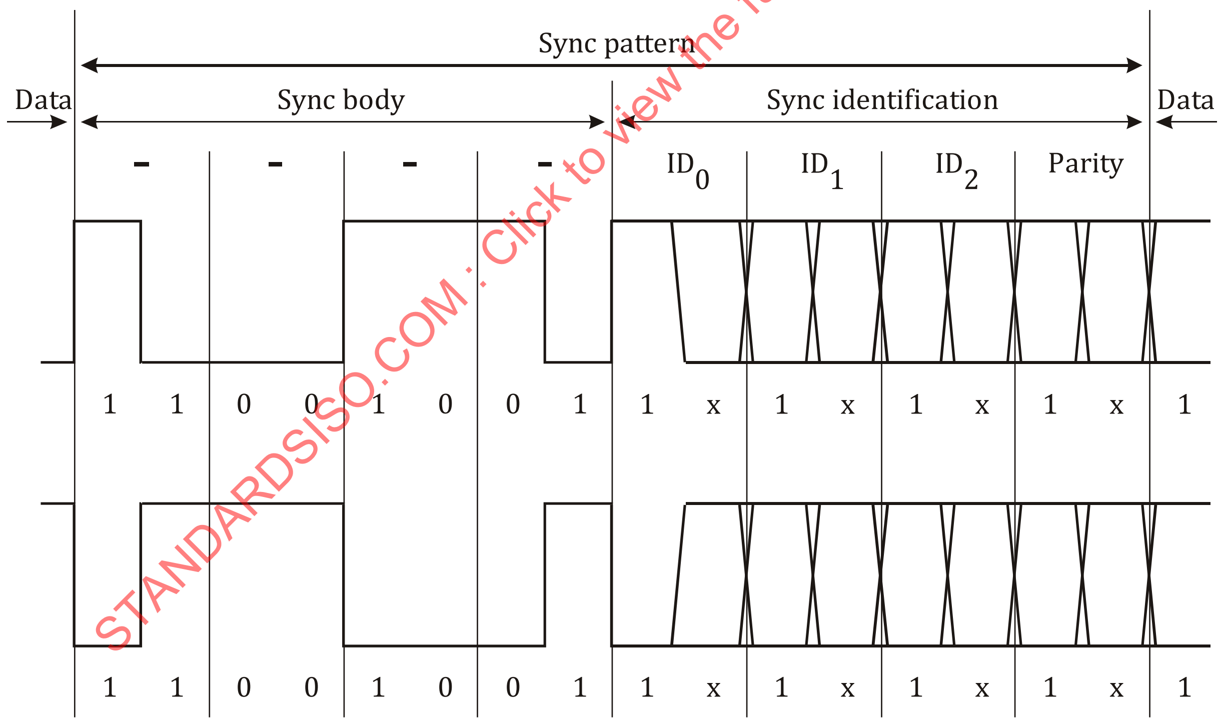


Figure 60 — Biphase synchronization pattern

Seven different sync patterns are identified by the last 4 bits: ID_0 .. ID_2 and a parity bit (see Figure 61).

Sync number	ID_0	ID_1	ID_2	Parity
FS0	0	0	0	0
FS1	0	0	1	1
FS2	0	1	0	1
FS3	0	1	1	0
FS4	1	0	0	1
FS5	1	0	1	0
FS6	1	1	0	0

Figure 61 — Sync identification

By means of the PIC BIS column, the 248 rows of a PIC cluster can be divided into 8 groups of 31 recording frames, where each group of recording frames carries an address in its first nine rows (see 15.5.3.5).

The 31 successive recording frames of each such group are identified by a special sequence of sync patterns (see also 13.17.4). The first recording frame of each group has the unique sync pattern FS0.

The other sync patterns are mapped as specified in Figure 62.

Frame number	Sync number	Frame number	Sync number
0	FS0		
1	FS1	16	FS5
2	FS2	17	FS3
3	FS3	18	FS2
4	FS3	19	FS2
5	FS1	20	FS5
6	FS4	21	FS6
7	FS1	22	FS5
8	FS5	23	FS1
9	FS5	24	FS1
10	FS4	25	FS6
11	FS3	26	FS2
12	FS4	27	FS6
13	FS6	28	FS4
14	FS6	29	FS4
15	FS3	30	FS2

Figure 62 — Mapping of sync patterns on PIC recording frames

15.6 Track layout of wobbled groove(s)

15.6.1 General

The wobble of the tracks is a more or less sinusoidal deviation from their average centrelines.

The nominal wobble length NWL (equivalent to 69 channel bits) shall be as follows:

5,140 5 µm ± 0,005 µm for a disk with a user data capacity of 25,0 GB per layer averaged over the rewritable areas.

This corresponds to a fundamental frequency f_{wob} = 956,522 kHz at the reference velocity.

15.6.2 Modulation of wobbles

15.6.2.1 General

The basic shape of the wobble is a cosine wave: cos(2π × f_{wob} × t). wobbles with this basic shape are called “monotone wobbles” (MW).

Some wobbles are modulated, and two modulation methods shall be used simultaneously as follows:

— the first modulation method is called “MSK-cos” (minimum shift keying–cosine variant); and

— the second modulation method is called “HMW” (harmonic-modulated wave).

In the protection zone 3 area in the outer zone(s) (see Clause 16 and 20.9), the groove shall be modulated by MSK-cos only and NOT by HMW.

Both modulation methods shall represent ADIP information as defined in 15.7.

15.6.2.2 MSK-cos modulation

MSK-cos modulation is applied by replacing three consecutive monotone wobbles by one MSK mark (MM). An MSK mark consists of the following three nominal wobble lengths NWL with the following wobble patterns as indicated in Figure 63:

— the first NWL starts the MSK mark with a cosine wobble with a frequency = 1,5 × f_{wob};

— the second NWL continues the MSK mark with a cosine wobble with a frequency = f_{wob};

— the third NWL terminates the MSK mark with a cosine wobble with a frequency = 1,5 × f_{wob}.

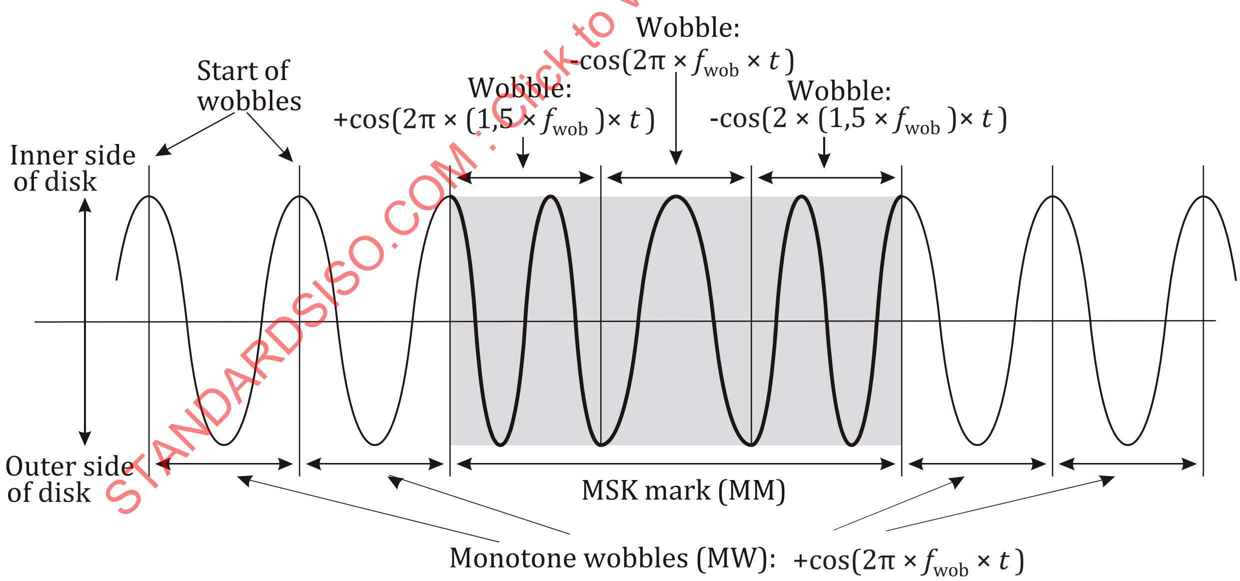


Figure 63 — Definition of MSK mark

15.6.2.3 HMW modulation

HMW modulation is applied by replacing a number of consecutive monotone wobbles with the same number of saw-tooth wobbles (STW). A saw-tooth wobble is formed by combining the basic cosine with a sine wave of twice the frequency as per Formula (43):

$$\cos(2\,\pi \times f_{wob} \times t) \pm a \times \sin[\,2\pi \times (2 \times f_{wob}) \times t\,] \tag{43}$$

where a is 0,25.

Such a combination of a cosine with the fundamental frequency and a certain amount of second harmonic represents a first-order approximation of a saw-tooth wave. The "+" or "–" sign creates a left or right inclination, where the "+" sign is used to represent the bit value ONE and the "–" sign is used to represent the bit value ZERO (see Figure 64).

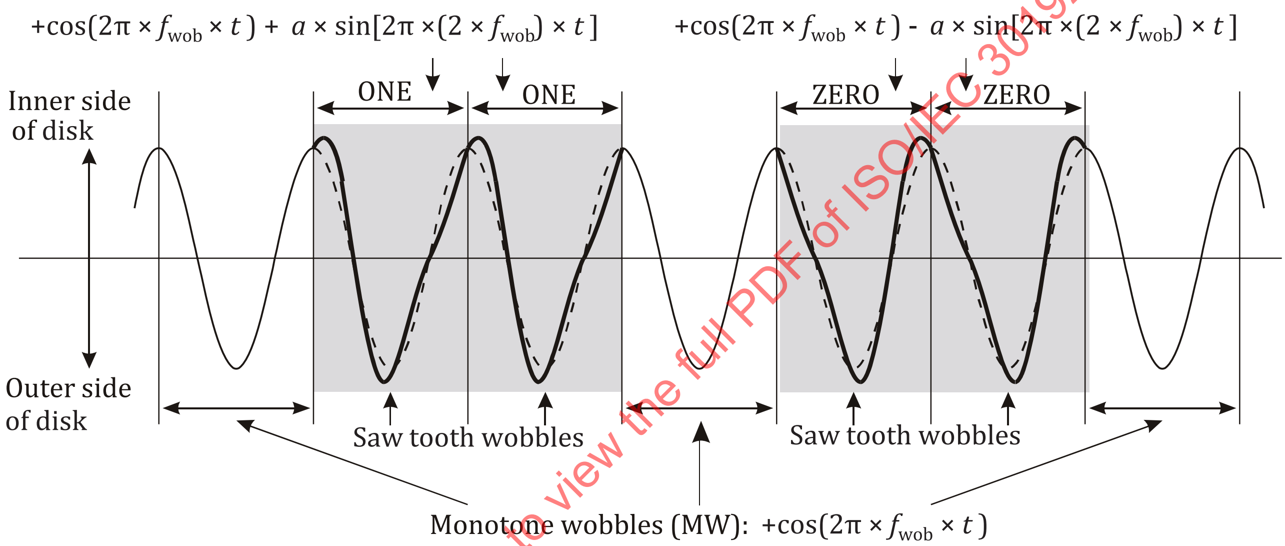


Figure 64 — Definition of saw-tooth wobbles

15.7 ADIP information

15.7.1 General

Data to be recorded onto the disk shall be aligned with the ADIP addresses modulated in the wobble. Therefore, 56 NWLs shall correspond to two recording frames (see 13.15). Each group of such 56 NWLs is called an ADIP unit (see Figure 65).

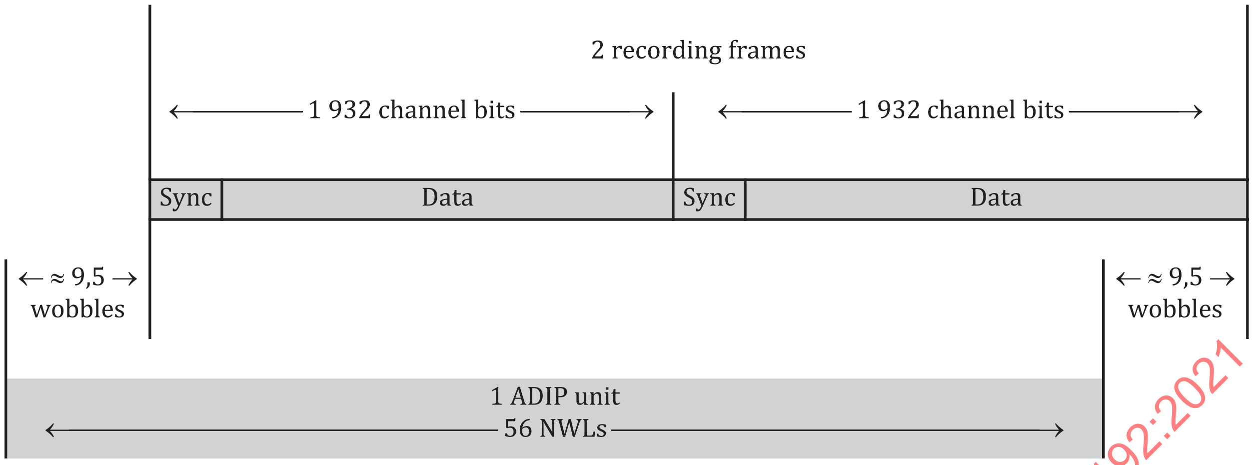


Figure 65 — General ADIP structure

15.7.2 ADIP unit types

By inserting MM's into the 56 NWLs of an ADIP unit with unique distances between adjacent MM's, different types of ADIP units can be created.

The ADIP units representing a data bit are additionally modulated with STW's.

Furthermore, a reference STW unit is defined. Each type of ADIP unit starts with an MM.

The following types of ADIP units are defined (see Figure 66):

— Monotone unit: consisting of one MM followed by 53 MWs;

— Reference unit: consisting of one MM followed by 15 MWs, 37 STWs and one MW;

— Sync_0 unit: consisting of one MM followed by 13 MWs, one MM, 7 MWs, one MM and 27 MWs;

— Sync_1 unit: consisting of one MM followed by 15 MWs, one MM, 7 MWs, one MM and 25 MWs;

— Sync_2 unit: consisting of one MM followed by 17 MWs, one MM, 7 MWs, one MM and 23 MWs;

— Sync_3 unit: consisting of one MM followed by 19 MWs, one MM, 7 MWs, one MM and 21 MWs;

— Data_*x* unit: with *x* representing ONE or ZERO:

  — Data_1 unit: consisting of one MM followed by 9 MWs, one MM, three MWs, 37 STWs and one MW;

  — Data_0 unit: consisting of one MM followed by 11 MWs, one MM, one MW, 37 STWs and one MW.

The 4 Sync units are used for synchronization purposes while the Data_1 unit is used to represent the bit value ONE and the Data_0 unit is used to represent the bit value ZERO.

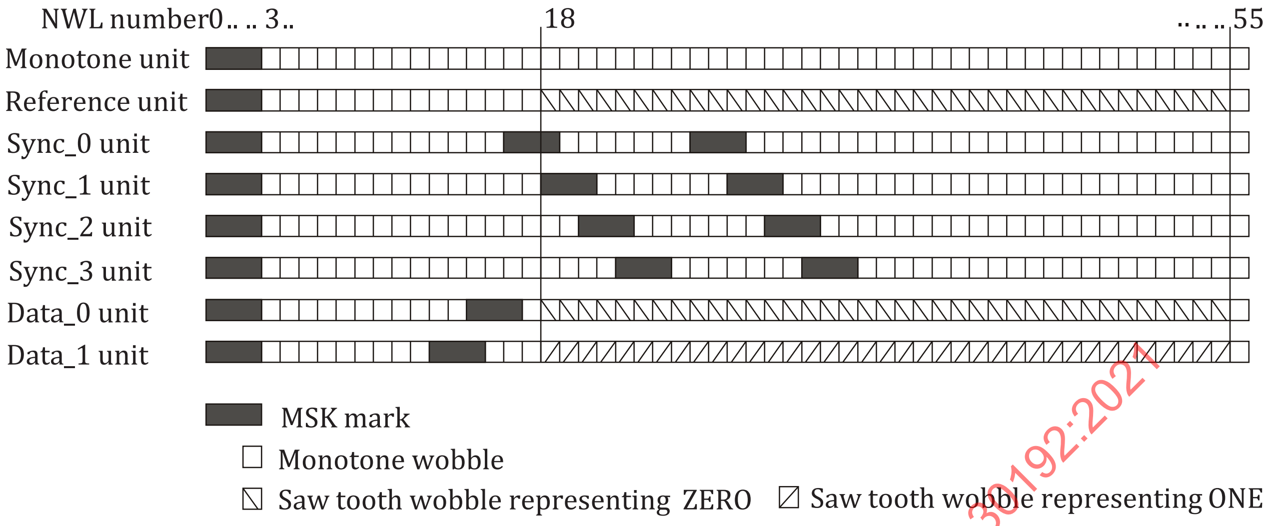


Figure 66 — ADIP unit types

15.7.3 ADIP Word structure

83 ADIP units are grouped into one ADIP word.

This means that three ADIP words correspond to 3 × 83 × 2 = 498 recording frames, which is equivalent to one recording unit block (RUB) (see 14.2).

Each ADIP word shall be constructed as indicated in Figure 67.

ADIP unit number	ADIP unit type	ADIP nibble bit number	ADIP code word nibble number
0	Monotone	—	—
1	Sync_0	—	
2	Monotone	—	
3	Sync_1	—	
4	Monotone	—	
5	Sync_2	—	
6	Monotone	—	
7	Sync_3	—	
8	Reference	—	
9	Data_*x*	b_3	c_0
10	Data_*x*	b_2	
11	Data_*x*	b_1	
12	Data_*x*	b_0	
13	Reference	—	—
14	Data_*x*	b_3	c_1
15	Data_*x*	b_2	
16	Data_*x*	b_1	
17	Data_*x*	b_0	
18	Reference	—	—
:	:	:	:
$8 + i \times 5$	Reference	—	—
$9 + i \times 5$	Data_*x*	b_3	c_i
$10 + i \times 5$	Data_*x*	b_2	
$11 + i \times 5$	Data_*x*	b_1	
$12 + i \times 5$	Data_*x*	b_0	
:	:	:	:
78	Reference	—	—
79	Data_*x*	b_3	c_{14}
80	Data_*x*	b_2	
81	Data_*x*	b_1	
82	Data_*x*	b_0	

Figure 67 — ADIP word structure

15.7.4 ADIP Data structure

15.7.4.1 General

Each ADIP word contains in a total of 60 bits, which forms a code word, according to a non-systematic Reed-Solomon error correction code. This code word is constructed from 36 information bits. Before encoding the information, the 36 information bits are ordered into 9 4-bit nibbles, n_0 to n_8, as defined in the array of Figure 68.

Nibble	b_3	b_2	b_1	b_0	
n_0	AA23	AA22	AA21	AA20	↑ 6 nibbles ADIP address
n_1	AA19	AA18	:	:	
:	:	:	:	:	
n_5	AA3	:	:	AA0	↓
n_6	AX11	:	:	:	↑ 3 nibbles Aux data
:	:	:	:	:	
n_8	AX3	:	:	AX0	↓

Figure 68 — ADIP information structure

The nibbles n_0 to n_8 are transcoded to nibbles c_0 to c_{14} by an error correction system (see 15.7.5).

Because this error correction system is non-systematic, there is no simple direct relationship between the bits in the information array and the coded bits in the ADIP unit.

15.7.4.2 ADIP information bit assignments

The information contained in the ADIP data bits shall be as follows:

— **AA2 .. A0**: These 24 bits shall contain the physical ADIP address (PAA). AA23 shall be the msb and AA0 shall be the lsb. This address shall consist of three parts:

  — **AA2 .. A21**: These 3 bits shall indicate the layer number and shall be set to: 000 on layer L0 and to 001 on layer L1. All other settings shall be reserved;

  — **AA2 .. A2**: These 19 bits shall contain a sequential number, which shall increase by one after each 3 consecutive ADIP words (synchronized to the RUB's, see 14.2);

  — **AA1,AA0**: These 2 bits shall be set to 00, 01 and 10 consecutively in 3 successive ADIP words corresponding to one RUB. The setting 11 shall not be used.

The first address in the information zone on layer L0 shall be such that the first address in the data zone, which is PAA 02 00 00h, is located at radius $24{,}0^{0{,}0}_{-0{,}1}$ mm.

The last address of the data zone on layer L0 (LAA) shall be located at a radius <58,1 mm.

The first address of the data zone on layer L1 (FAA) shall be located at a radius <58,1 mm.

The last address of the data zone on layer L1 (3D FF FEh) shall be located at a radius $24{,}0^{0{,}0}_{-0{,}1}$ mm.

— **AX1 .. X0**: These 12 bits contain auxiliary information about the disk:

  — in the data zone(s) and the outer zone(s) of the disk, the auxiliary bits shall be set to ZERO;

  — in the inner zone(s) of the disk, the auxiliary bits shall be used as follows;

    — AX1 .. X0 from 96 consecutive ADIP words (equivalent to 32 RUBs), shall form one ADIP aux frame with 144 bytes;

    — the first bits of each ADIP aux frame shall be located in an ADIP word with a PAA that is a multiple of 128 (PAA = xxxx xxxx xxxx xxxx x000 0000);

    — the content of the 144 bytes are defined in 15.8.

15.7.4.3 Relation between physical ADIP addresses on layer L0 and layer L1

There shall be a fixed relation between the PAAs on layer L0 and layer L1. The PAAs on layer L0 and layer L1 located at the same radius (having the same distance in number of ADIP words from their respective inner zone) shall have inverted bits AA20 to AA2 (see Figure 69).

In this way, the PAAs on layer L1 increase from the outer side towards the inner side of the disk, which is in the tracking direction. Simultaneously, the inverted address bits AA20 .. AA2 of PAA_1 have the same relation with the radius as the equivalent non-inverted bits on layer L0.

	Layer number	Sequence number	Intra-RUB number
PAA_0 on layer L0	AA23 .. AA21 = 000	AA20 .. AA2	AA1, AA0 = 00,01,10 from inner to outer
PAA_1 on layer L1	AA23 .. AA21 = 001	$\overline{AA20}$ .. $\overline{AA2}$	AA1, AA0 = 00,01,10 from outer to inner

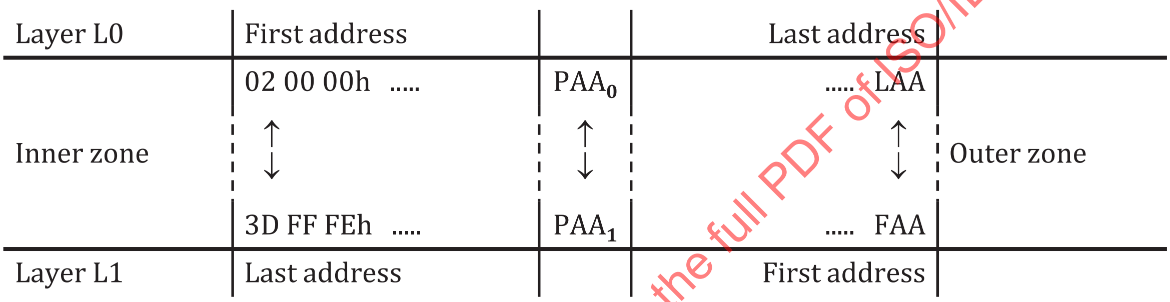


Figure 69 — Illustration of PAA relation between layer L0 and layer L1

Mathematically, this can be expressed as follows.

After adding C0 00 01h to PAA_0, all 24 bits are inverted, resulting directly in the full corresponding address PAA_1 on layer L1 as Formula (44):

$$PAA_1 = \overline{PAA_0 + C0\,00\,01h} \tag{44}$$

(The addition of 1 corrects for the order of the intra-RUB numbers, while the addition of C0 00 00h takes care of the correct layer number.)

This way, the last address of data zone 1 can be derived as Formula (45):

$$3D\,FF\,FEh = \overline{02\,00\,00h + C0\,00\,01h} \tag{45}$$

And the first address of data zone 1 is as per Formula (46):

$$FAA = \overline{LAA + C0\,00\,01h} \tag{46}$$

15.7.5 ADIP error correction

The error correction system is a nibble-based, (15,9,7) non-systematic Reed-Solomon (RS) code defined over the finite field $GF(2^4)$. The total number of nibbles in a code word is 15, the code words are calculated from nine information nibbles and the minimum distance of this code is seven.

The non-zero elements of the finite field $GF(2^4)$ are generated by a primitive element α, where α is a root of the primitive polynomial $p(x)$ as per Formula (47):

$$p(x) = x^4 + x + 1 \tag{47}$$

The symbols of $GF(2^4)$ are represented by nibbles (groups of 4 bits), using the polynomial-base representation, with $(\alpha^3, \alpha^2, \alpha, 1)$ as a basis. The root α is thus represented as $\alpha = 0010$.

The code word, represented by the vector $(c_0\ c_1\ ..\ c_{13}\ c_{14})$, can be calculated from the information symbols n_0 to n_8 with Formula (48):

$$C(x) = \sum_{i=0}^{14} c_i \times x^{14-i} = \sum_{i=0}^{7} n_i \times g^{(i)}(x) + n_8 \times g_p(x) \tag{48}$$

where $g_p(x)$ is the parent generator polynomial:

$$g_p(x) = \prod_{i=0}^{13} (x - \alpha^i)\text{; and}$$

$g^{(i)}(x)$ is a specific generator polynomial for each symbol n_i ($i = 0..7$).

$g^{(i)}(x)$ is derived from the parent generator polynomial $g_p(x)$ by removing one of the zeroes z_i of $g_p(x)$ and normalizing the result such that $g^{(i)}(z_i) = 1$. The zero z_i to be removed is given by Formula (49):

$$z_i = \alpha^{i+6} \tag{49}$$

The generator polynomials are then calculated as Formula (50):

$$g^{(i)}(x) = \frac{\tilde{g}^{(i)}(x)}{\beta_i} \tag{50}$$

where

$$\tilde{g}^{(i)}(x) = \frac{g_p(x)}{x - z_i}\text{; and}$$

$$\beta_i = \tilde{g}^{(i)}(z_i).$$

Before recording on the disk, all bits of the nibbles c_9 to c_{14} shall be inverted.

Because the code is non-systematic, an additional calculation is needed to derive the information symbols from the corrected code-word symbols after standard RS-decoding.

The information symbols n_0 to n_7 can be obtained by evaluating the corrected code word $C(x)$ in the zero corresponding to the information symbol, i.e. by calculating a syndrome as Formula (51):

$$n_i = S_{i+6} = C(\alpha^{i+6}) = \sum_{j=0}^{14} c_{14-j} \times \alpha^{(i+6)\times j} \tag{51}$$

n_8 is a systematic symbol and can be obtained from $C(x)$ directly by copying symbol c_0.

NOTE Each information symbol n_i corresponds to a ZERO in the parent generator polynomial $g_p(x)$. Figure 70 gives the corresponding zero factor for each information symbol (note that n_8 does not have a corresponding zero).

Symbol	Corresponding zero factor
	$(x - \alpha^0)$
	$(x - \alpha^1)$
	$(x - \alpha^2)$
	$(x - \alpha^3)$
	$(x - \alpha^4)$
	$(x - \alpha^5)$
n_0	$(x - \alpha^6)$
n_1	$(x - \alpha^7)$
n_2	$(x - \alpha^8)$
n_3	$(x - \alpha^9)$
n_4	$(x - \alpha^{10})$
n_5	$(x - \alpha^{11})$
n_6	$(x - \alpha^{12})$
n_7	$(x - \alpha^{13})$

Figure 70 — Corresponding zero factor for each information symbol

If an information symbol is known and its corresponding zero extends the existing series of zeroes corresponding to $(x - \alpha^0)$ .. $(x - \alpha^5)$ .., the Hamming distance increases. For instance, if n_0 is known, the Hamming distance becomes $d = 8$. If both n_0 and n_1 are known, the Hamming distance becomes $d = 9$, etc.

In other words, prior knowledge of information symbols can increase the Hamming distance of the code. Because the addresses in the ADIP increase linearly, such prior knowledge is present.

This phenomenon can be used for additional checking of the reliability of the decoding result.

15.8 Disk information in ADIP aux frame

15.8.1 General

The information nibbles from the auxiliary fields of 96 consecutive ADIP words are grouped into frames of bytes and carry several disk parameters. The nibbles are re-ordered into bytes according to Figure 71. Several disk information (DI) aux frames can be grouped into a DI block. All disk information blocks shall have the same content.

Byte number	b_7	b_6	b_5	b_4	b_3	b_2	b_1	b_0
0	AX11 word 1	AX10 word 1	AX9 word 1	AX8 word 1	AX7 word 1	AX6 word 1	AX5 word 1	AX4 word 1
1	AX3 word 1	AX2 word 1	AX1 word 1	AX0 word 1	AX11 word 2	AX10 word 2	AX9 word 2	AX8 word 2
2	AX7 word 2	AX6 word 2	AX5 word 2	AX4 word 2	AX3 word 2	AX2 word 2	AX1 word 2	AX0 word 2
3	AX11 word 3	AX10 word 3	AX9 word 3	AX8 word 3	AX7 word 3	AX6 word 3	AX5 word 3	AX4 word 3
:								
:								
141	AX11 word 95	AX10 word 95	AX9 word 95	AX8 word 95	AX7 word 95	AX6 word 95	AX5 word 95	AX4 word 95
142	AX3 word 95	AX2 word 95	AX1 word 95	AX0 word 95	AX11 word 96	AX10 word 96	AX9 word 96	AX8 word 96
143	AX7 word 96	AX6 word 96	AX5 word 96	AX4 word 96	AX3 word 96	AX2 word 96	AX1 word 96	AX0 word 96

Figure 71 — ADIP aux frame byte ordering

15.8.2 Error protection for disk information aux frames

The DI aux frames are protected by a long distance RS error correction code according to 13.7. Because such a long-distance code is built up from 248 bytes, 104 dummy bytes (not recorded on the disk) are added to complete the long distance DI aux frame code words (see Figure 72).

Bytes $e_{0,L}$ .. $e_{103,L}$ in 13.7 represent the dummy bytes (all set to FFh), bytes $e_{104,L}$ .. $e_{215,L}$ represent the disk information bytes, and bytes $p_{216,L}$ .. $p_{247,L}$ represent the parity bytes.

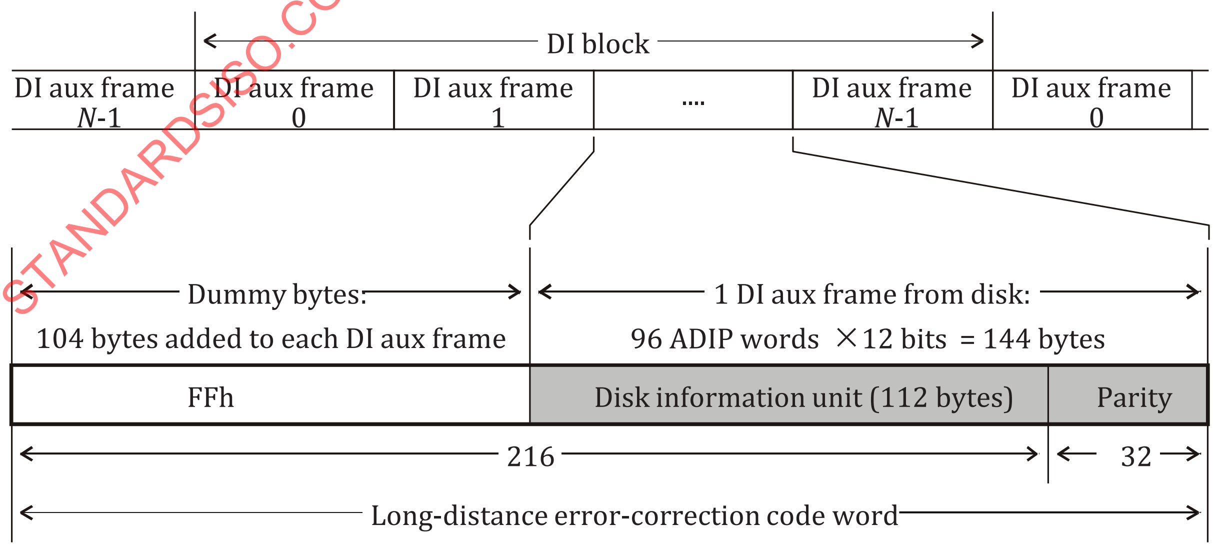


Figure 72 — Disk information structure and error correction format

15.8.3 Disk information data structure

15.8.3.1 General

A DI block can consist of a multiple of 144-byte DI aux frames (see Figure 72). If needed, additional DI aux frames, up to a maximum total of 31, can be used. Each recording layer shall carry the same DI blocks with the same DI aux frames.

The sequence of DI aux frames shall be repeated throughout the inner zones, starting with DI aux frame 0 from PAA 01 B8 00h on layer L0 and from PAA 3E 00 00h on layer L1.

In protection zone 2 (see Figure 81 and Figure 82), the auxiliary bits can be set to ZERO or can contain DI aux frames (such that the sequence is contiguous with a DI aux frame 0 at the addresses specified above).

The 112 disk information bytes in each DI aux frame are called a disk information (DI) unit. Each DI unit shall start with 8 bytes, forming the DI unit header (see 15.8.3.2).

DI units can contain different sets of parameters, such as different write strategies. To distinguish DI units that have different definitions for their content, a unique identification of such DI units is needed. Byte 2 in the DI unit header, the DI format number, shall be used for this purpose. With this byte, 256 types of DI units with different content can be distinguished.

If the number of parameters of a single set do not fit in one DI unit, such a set shall be stored in multiple consecutive DI units, in which case, bit b_7 of byte six indicates that the next DI unit in the sequence is a continuation of the actual one.

An usage of DI blocks is given in 15.8.3.7.

Whenever new DI aux frames are added, the existing ones can still be used if appropriate and in that way, backwards compatibility with existing drives can be facilitated. Each drive should check all DI aux frames present on the disk and, based on the DI format number (byte 2) and the indicated recording velocity (bytes 32 to 35), only use the ones that it is supporting (see also 15.8.3.7).

15.8.3.2 General definitions for DI unit

Each DI unit shall consist of a header, a body and a footer as depicted in Figure 73.

	Byte number	Content	Number of bytes
Header	0 to 1	Disk information identifier	2
	2	DI-format number	1
	3	Number of DI aux frames in each DI block (5 bits) Number of the layer to which this DI unit applies (3 bits)	1
	4	Legacy information	1
	5	DI-unit sequence number in DI block	1
	6	Continuation flag (1 bit) Number of DI bytes in use in this DI unit (7 bits)	1
	7	Reserved	1
Body	8 to 99	DI-unit content	92
Footer	100 to 105	Disk manufacturer ID	6
	106 to 108	Media type ID	3
	109 to 110	Time stamp	2
	111	Product revision number	1

Figure 73 — General DI unit format

Bytes 0 to 1: **Disk information identifier**

These two bytes shall be set to 44 49h, representing the characters “DI”.

Byte 2: **DI format number**

This byte shall identify the content of the DI unit or DI unit set (see description of byte 6).

For disks with BCA code the msb of this byte shall be set to ZERO.

For disks without BCA code the msb of this byte shall be set to ONE.

NOTE The DI format number only defines the content of the DI unit and has no relation with the class number and the version number as defined in byte 11.

To prevent backwards-compatibility problems of newer disks with older drives as much as possible, a class number and a version number have been introduced.

The class number is incremented if a BD layer according to the new specifications should not be accessed by legacy drives at all, neither for reading nor for writing (e.g. to prevent possible damage to the disk or to the drive). If the read compatibility can be made to conform to an existing class, no new class number is needed.

The version number is incremented if the new specifications imply an extension/change for which no class-number update is needed (read compatibility is maintained) and the new specifications result in a write-compatibility break. Although such a BD layer is carrying a higher version number, it still can contain a DI unit according to a previously defined DI format, if this layer can be recorded according to the write strategy as defined in such DI unit.

Consequently, drives should always check for the presence of a DI unit with a DI format number known to the drive. In such cases, the recording parameters (such as e.g. recording velocities, recording power, timing requirements) needed to set the related write strategy can be checked and if these are within the capabilities of the drive, the drive should accept the disk for recording.

By using the class number and version number as described above, backwards compatibility of future disks can be maximized while still preventing possible damage to disks and drives.

Each layer type (defined by bytes 8 to 10) has its own independent DI format numbering. The DI format number is also an indication for the write-strategy type, which is specified in the DI unit or DI unit set.

Byte 3: Number of DI aux frames in each DI block/Number of the layer to which this DI unit applies

Bits b_7 to b_3: These 5 bits specify the number of DI aux frames N in each DI block ($1 \le N \le 31$).

Bits b_2 to b_0: These 3 bits specify the number of the recording layer to which the specifications in this DI unit apply.

Byte 4: Legacy information

This byte shall be set to as follows:

01h on SL disks;

02h on DL disks;

00h on other disks.

Byte 5: DI unit sequence number in DI block

This byte shall specify the sequential DI unit number within the DI block.

It shall be set to a number n, where n indicates the actual number of the DI unit within the actual DI block ($0 \le n \le N - 1$).

The sequence of DI units shall be ordered (see Figure 74) first according to increasing nominal recording velocity (byte 32 to 33), second, within each sequence of DI units with the same nominal recording velocity, according to ascending layer number (byte 3) and third according to the preference of the write strategy (identified by the DI format number, but need not be in the sequence of DI format numbers).

Sequence number	Recording velocity	Layer number	Write strategy
0	v_1	0	Preferred WS
1			Alternative WS
:		1	Preferred WS
$k - 1$			Alternative WS
k		:	Preferred WS
:			Alternative WS
:		$k - 1$	Preferred WS
$2k - 1$			Alternative WS
$2k$	$v_2 > v_1$	0	Most-preferred WS
:			:
:		:	:
:		$k - 1$	:
:			Least-preferred WS
:	$v_3 > v_2$	0	:
:	:	:	:
$N - 1$	etc.	etc.	:

Figure 74 — Example of DI block sequence

Byte 6: **Continuation flag/Number of DI bytes in use in this DI unit**

Bit b_7: This bit specifies if the parameter set in this DI unit is continued in the next DI unit or if the next DI unit is the start of a new set of parameters.

It shall be set to as follows:

ZERO if the next DI unit is the start of a new set of parameters; or

ONE if the parameter set in this DI unit is continued in the next DI unit (see Figure 75).

Bits b_6 to b_0: These seven bits shall indicate the number of bytes in use in the actual DI unit up to the last unused (reserved) bytes immediately preceding the footer (see e.g. Figure 76).

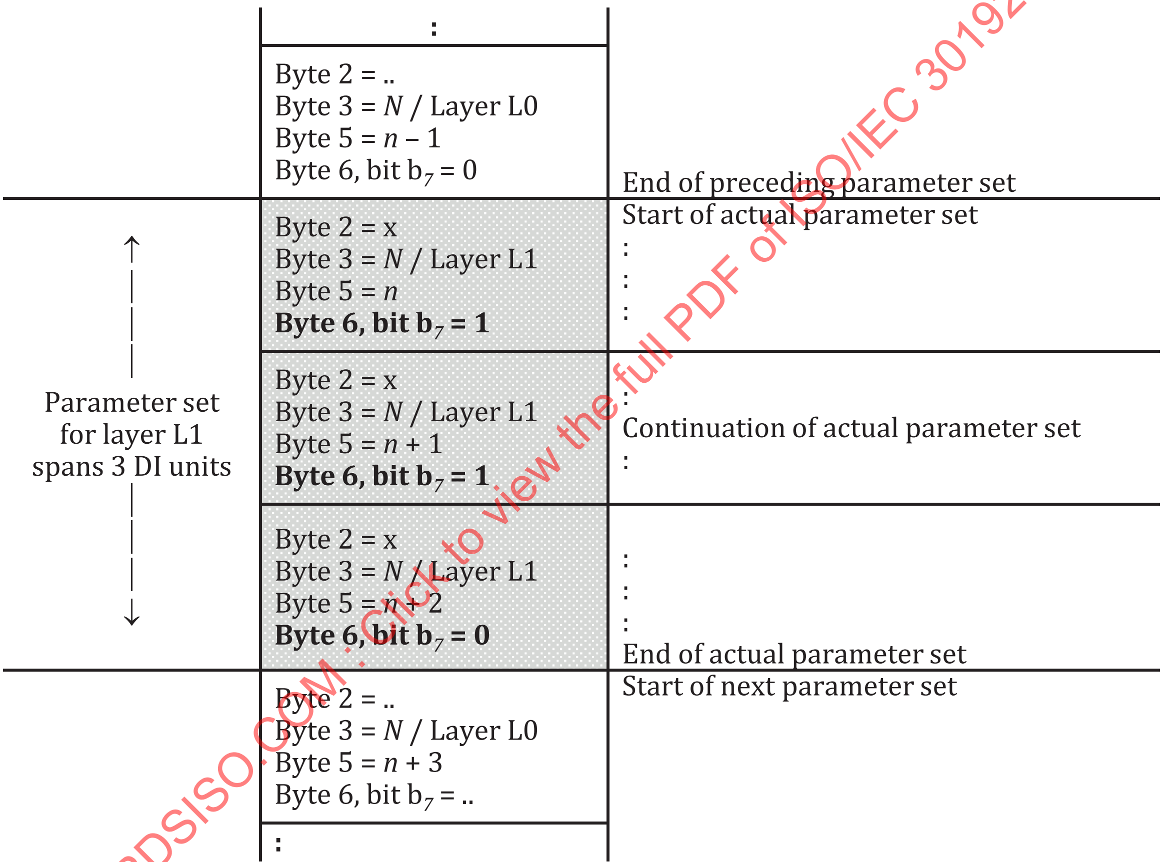


Figure 75 — Example of DI unit extension

Byte 7: **Reserved**

Bytes 8 to 99: **DI unit content**

These 92 bytes shall store the specific content of the DI unit, for example, general disk parameters, read/write powers and write strategy parameters.

Bytes 100 to 105: **Disk manufacturer ID**

The format and the content of these 6 bytes require agreement between the interchange parties, else these bytes shall be set to all 00h.

Bytes 106 to 108: **Media type ID**

The format and the content of these 3 bytes require agreement between the interchange parties, else these bytes shall be set to all 00h.

Bytes 109 to 110: **Time stamp**

These 2 bytes provide information about the production date of the master disk from which this disk has been replicated. All disks with the same disk-manufacturer ID and the same media type ID, regardless of the time stamp, shall have the same recording properties (only minor differences are allowed: the time stamp shall be irrelevant for recorders).

Bits b_7 to b_0 of byte 109 plus bits b_7 to b_4 of byte 110 shall form one 12-bit binary number representing the year of production.

Bits b_3 to b_0 of byte 110 shall form one 4-bit binary number representing the month of production.

If the time stamp is not used, both bytes shall be set 00h.

Byte 111: **Product revision number**

This byte shall identify the product revision number in binary notation. All disks with the same disk manufacturer ID and the same media type ID, regardless of the product revision numbers, shall have the same recording properties (only minor differences are allowed: product revision numbers shall be irrelevant for recorders).

The content of this byte can be chosen freely by the disk manufacturer. This document does not specify the format and the content of this byte. It shall be ignored in interchange.

15.8.3.3 Definitions for DI format 1(N-1 write strategy A)

The content of the body of DI units according to DI format 1 shall be as depicted in Figure 76.

Byte number	Content	Number of bytes
0 to 7	DI-unit header	8
8 to 10	BD layer type identifier	3
11	Disk size / Class / Version	1
12	BD structure	1
13	Channel bit length	1
14 to 15	Reserved	2
16	BCA descriptor	1
17	Maximum transfer rate	1
18 to 23	Reserved	6
24 to 31	Data zone allocation	8
32 to 35	Recording velocities	4
36 to 39	Maximum dc read powers	4
40 to 43	Maximum HF-modulated read powers	4
44 to 47	Reserved	4
48 to 55	Write power settings at nominal recording velocity	8
56 to 63	Write power settings at maximum recording velocity	8
64 to 71	Write power settings at minimum recording velocity	8
72	T_{MP} write multi-pulse duration	1
73 to 75	T_{top} first write pulse duration	3
76 to 78	dT_{top} first write pulse start time at nominal recording velocity	3
79 to 81	dT_{top} first write pulse start time at maximum recording velocity	3
82 to 84	dT_{top} first write pulse start time at minimum recording velocity	3
85 to 87	Reserved	3
88	T_E erase multi-pulse duration	1
89 to 91	dT_E first erase pulse start time at nominal recording velocity	3
92 to 94	dT_E first erase pulse start time at maximum recording velocity	3
95 to 97	dT_E first erase pulse start time at minimum recording velocity	3
98	Erase-flag bits	1
99	Unused = 00h	1
100 to 111	DI-unit footer	12

Figure 76 — Content of disk information for DI format 1

Bytes 0 to 1: **Disk information identifier**

See 15.8.3.2.

Byte 2: **DI format number**

This byte shall be set to 01h for disks with BCA code.

This byte shall be set to 81h for disks without BCA code.

Byte 3: **Number of DI aux frames in each DI/Number of the layer to which this DI unit applies**

See 15.8.3.2.

Byte 4: **Legacy information**

See 15.8.3.2.

Byte 5: **DI unit sequence number in DI block**

See 15.8.3.2.

Byte 6: **Continuation flag/Number of DI bytes in use in this DI unit**

This byte shall be set to 63h to indicate that the first 99 bytes of the DI unit are used and that there is no continuation in the next DI unit. All remaining bytes of the DI unit body (excluding the bytes in the DI unit footer) are unused and shall be set to 00h.

Byte 7: **Reserved**

See 15.8.3.2.

Bytes 8 to 10: **BD layer type identifier**

These three bytes identify the type of the BD layer to which this DI unit applies and shall be set to 42 44 57h, representing the characters “BDW”, in each rewritable layer.

Byte 11: **Disk size/Class/Version**

Bits b_7 to b_6: These two bits specify the disk size. They shall be set to 00, to indicate a 120 mm disk.

Bits b_5 to b_4: These two bits specify the class number. The class number identifies BD layers of the same layer type but with different basic specifications. BD layers according to this document shall have these bits set to 00. drives that are not familiar with a particular class of layers should not access the data zone of such layers (neither for reading nor for writing)

Bits b_3 to b_0: These 4 bits specify the version number. They shall be set to 0010, to indicate a layer according to this document.

Byte 12: **BD structure**

Bits b_7 to b_4: These 4 bits specify the total number of BD recording/recorded layers on the disk.

On SL disks they shall be set to 0001 to indicate one recording layer.

On DL disks they shall be set to 0010 to indicate two recording layers.

Bits b_3 to b_0: These 4 bits specify the type of BD recording/recorded layer to which this DI unit applies:

Bits b_3 to b_0 shall be set to 0100, to indicate a rewritable recording layer.

Byte 13: **Channel bit length**

Bits b_7 to b_4: These 4 bits shall be set to 0000.

Bits b_3 to b_0: These 4 bits specify the main data channel bit length, which shall be the same on all BD recording layers.

They shall be set to as follows:

0001: to indicate a channel-bit length of 74,5 nm (25,0 GB per layer);

other settings: reserved.

Bytes 14 to 15: Reserved

Byte 16: BCA descriptor

Bits b_7 to b_4: These 4 bits shall be reserved.

Bits b_3 to b_0: These 4 bits shall indicate the presence of a BCA code on this disk as follows:

0000: indicates that there is no BCA code;

0001: indicates that the BCA code present;

other settings: reserved.

Byte 17: Maximum transfer rate

This byte shall specify the maximum read transfer rate needed by the BDAP as a number n such that:

n = maximum read transfer rate in Mbit/s ($n \leq 255$; M = 10^6)

n shall be set to 00h, to indicate no maximum transfer rate is specified.

Bytes 18 to 23: Reserved

Bytes 24 to 31: Data zone allocation

Bytes 24 to 27: These bytes specify the first physical ADIP address of the data zone of the related layer.

In each DI unit relating to layer L0, these bytes shall be set to 00 02 00 00h to indicate PAA 131 072 as the first PAA of data zone 0.

In each DI unit relating to layer L1, these bytes shall be set to a value FAA, which shall be 00 26 B1 80h for a disk with a user data capacity of 25,0 GB per layer, to indicate FAA as the first PAA of data zone 1.

Bytes 28 to 31: These bytes specify the last physical ADIP address of the data zone of the related layer.

In each DI unit relating to layer L0, these bytes shall be set to a value LAA, which shall be 00 19 4E 7Eh for a disk with a user data capacity of 25,0 GB per layer, to indicate LAA as the last PAA of data zone 0.

In each DI unit relating to layer L1, these bytes shall be set to 00 3D FF FEh to indicate PAA 4 063 230 as the last PAA of data zone 1.

Bytes 32 to 35: Recording velocities

Bytes 32 to 33: These bytes specify the nominal recording velocity, to be used with the parameters as defined in this DI unit as a 2-byte binary number (byte 32 is MSB).

It shall specify the nominal recording velocity as a number n such that:

$$n = 100 \times V_{nom}$$

n shall be equal to 01 ECh to indicate a nominal recording velocity of 4,92 m/s.

Byte 34: This byte shall specify the maximum recording velocity, to be used with the parameters as defined in this DI unit.

It shall specify the maximum recording velocity as a number n such that:

$$n = 100 \times V_{max} / V_{nom} \ (n \geq 100)$$

Here, n shall be equal to 64 h to indicate a maximum recording velocity equal to the nominal recording velocity.

Byte 35: This byte shall specify the minimum recording velocity, to be used with the parameters as defined in this DI unit.

It shall specify the minimum recording velocity as a number n such that:

$$n = 100 \times V_{min} / V_{nom} \ (n \leq 100)$$

Here, n shall be equal to 64 h to indicate a minimum recording velocity equal to the nominal recording velocity.

If these bytes specify a velocitiy range (value of byte 34 > value of byte 35), then recording shall be possible at any velocitiy within this range. The actual values of the write strategy parameters for the velocitiy concerned, can be derived from the specified values for the minimum, nominal and maximum recording velocities by interpolation.

Bytes 36 to 39: Maximum dc read power

The maximum read power is defined as the maximum optical power on the entrance surface of the disk, at which at least 106 successive reads can be applied without degrading the recorded signals (see 30.8).

Byte 36 This byte shall specify the maximum dc read power P_r at the reference velocity, in milliwatts, as a number n such that:

$$n = 100 \times P_r$$

Byte 37 This byte shall specify the maximum dc read power P_r at the nominal recording velocity as defined in bytes 32 and 33 of this DI unit, in milliwatts, as a number n such that:

$$n = 100 \times P_r$$

Byte 38 This byte shall specify the maximum dc read power P_r at the maximum recording velocity as defined by byte 34 of this DI unit, in milliwatts, as a number n such that:

$$n = 100 \times P_r$$

Byte 39 This byte shall specify the maximum dc read power P_r at the minimum recording velocity as defined by byte 35 of this DI unit, in milliwatts, as a number n such that:

$$n = 100 \times P_r$$

NOTE For reading at lower velocities than the lowest specified velocity, a reduction of the read power can be necessary to guarantee stability of the recordings on the disk.

Bytes 40 to 43: **Maximum HF-modulated read powers**

The maximum read power is defined as the maximum optical power on, the entrance surface of the disk, at which at least 106 successive reads can be applied without degrading the recorded signals (see 30.8).

Byte 40 — This byte shall specify the maximum HF-modulated read power P_r at the reference velocity, in milliwatts, as a number n such that:

$$n = 100 \times P_r$$

Byte 41 — This byte shall specify the maximum HF-modulated read power P_r at the nominal recording velocity as defined in bytes 32 and 33 of this DI unit, in milliwatts, as a number n such that:

$$n = 100 \times P_r$$

Byte 42 — This byte shall specify the maximum HF-modulated read power P_r at the maximum recording velocity as defined by byte 34 of this DI unit, in milliwatts, as a number n such that:

$$n = 100 \times P_r$$

Byte 43 — This byte shall specify the maximum HF-modulated read power P_r at the minimum recording velocity as defined by byte 35 of this DI unit, in milliwatts, as a number n such that:

$$n = 100 \times P_r$$

NOTE For reading at lower velocities than the lowest specified velocity, a reduction of the read power can be necessary to guarantee stability of the recordings on the disk.

Bytes 44 to 47: **Reserved**

Bytes 48 to 71: **Write power settings**

For each of the byte fields f to $(f + 7)$, with $f = 48$, 56 and 64, the following values are defined at three different recording velocities:

Byte f: $\boldsymbol{P_{IND}}$: P_{IND} can be used as a starting value for the determination of P_{target} in the OPC procedure (see Annex G for detailed procedure).

This byte shall specify the indicative value P_{IND} of P_{target}, in milliwatts, as a number n such that:

$$n = 20 \times P_{IND}$$

Byte $(f + 1)$: $\boldsymbol{m_{IND}}$: m_{IND} can be used as a starting value for the determination of P_{target} in the OPC procedure (see Annex G for detailed procedure).

This byte shall specify the modulation at P_{IND} as determined by the media manufacturer as a number n such that:

$$n = 200 \times m_{IND}$$

Byte $(f + 2)$: $\boldsymbol{\rho}$: This byte shall specify the write power multiplication factor ρ, used in the OPC algorithm (see Annex G for detailed procedure), as a number n such that:

$$n = 100 \times \rho$$

Byte $(f + 3)$: $\boldsymbol{\varepsilon_{BW}}$: This byte shall specify the write bias/write-peak power ratio ε_{BW}, used in the OPC algorithm (see Annex G for detailed procedure), as a number n such that:

$$n = 200 \times \varepsilon_{BW}$$

Byte (f + 4): **ε_C:** This byte shall specify the cooling/write peak power ratio ε_C, used in the OPC algorithm (see Annex G for detailed procedure), as a number n such that:

$n = 200 \times \varepsilon_C$ = Byte (f + 3);

ε_C shall be equal to ε_{BW}

Byte (f + 5): **ε_{E1}:** This byte shall specify the erase/write peak power ratio-1, ε_{E1}, used in the OPC algorithm (see Annex G for detailed procedure) as a number n such that:

$n = 200 \times \varepsilon_{E1}$

Byte (f + 6): **ε_{E2}:** This byte shall specify the erase/write peak power ratio-2, ε_{E2}, used in the OPC algorithm (see Annex G for detailed procedure) as a number n such that:

$n = 200 \times \varepsilon_{E2}$

ε_{E2} shall be equal to ε_{E1}.

Byte (f + 7): **κ:** This byte shall specify the target value for κ, used in the OPC procedure (see Annex G for detailed procedure) as a number n such that:

$n = 20 \times \kappa$

Bytes 48 to 55: Write power settings at nominal recording velocity

Byte 48: P_{IND} at nominal recording velocity

Byte 49: m_{IND} at nominal recording velocity

Byte 50: ρ at nominal recording velocity

Byte 51: ε_{BW} at nominal recording velocity

Byte 52: ε_C at nominal recording velocity

Byte 53: ε_{E1} at nominal recording velocity

Byte 54: ε_{E2} at nominal recording velocity

Byte 55: κ at nominal recording velocity

Bytes 56 to 63: Write power settings at maximum recording velocity

Byte 56: P_{IND} at maximum recording velocity

Byte 57: m_{IND} at maximum recording velocity

Byte 58: ρ at maximum recording velocity

Byte 59: ε_{BW} at maximum recording velocity

Byte 60: ε_C at maximum recording velocity

Byte 61: ε_{E1} at maximum recording velocity

Byte 62: ε_{E2} at maximum recording velocity

Byte 63: κ at maximum recording velocity

Bytes 64 to 71: Write power settings at minimum recording velocity

Byte 64: P_{IND} at minimum recording velocity

Byte 65: m_{IND} at minimum recording velocity

Byte 66: ρ at minimum recording velocity

Byte 67: ε_{BW} at minimum recording velocity

Byte 68: ε_{C} at minimum recording velocity

Byte 69: ε_{E1} at minimum recording velocity

Byte 70: ε_{E2} at minimum recording velocity

Byte 71: κ at minimum recording velocity

Byte 72: T_{MP} write multi-pulse duration

This byte shall specify the duration of the second and higher pulses of the multi-pulse train for recording marks (see F.2 for detailed definition).

The multi-pulse duration T_{MP} consists of two contributions: a variable part and a fixed part as follows:

$$T_{MP} = T_{MP,var} + T_{MP,fix}$$

The first 4 bits (bit b_7 to b_4) of this byte shall specify the variable part as a fraction of the actual channel bit clock period as an unsigned binary number p such that:

$$p = 16 \times \frac{T_{MP,\ var}}{T_W}$$

The last 4 bits (bit b_3 to b_0) of this byte shall specify the fixed part expressed in ns as an unsigned binary number q such that:

$$q = T_{MP,fix}$$

Bytes 73 to 75: T_{top} first write pulse duration

Byte 73: This byte shall specify the duration of the first pulse of the multi-pulse train for recording marks with run lengths ≥4T (see F.2 for detailed definition).

The first pulse duration $T_{top,4T}$ consists of two contributions: a variable part and a fixed part as follows:

$$T_{top,4T} = T_{top,var} + T_{top,fix}$$

The first 4 bits (bit b_7 to b_4) of this byte shall specify the variable part as a fraction of the actual channel bit clock period as an unsigned binary number j such that:

$$j = 16 \times \frac{T_{top,var}}{T_W}$$

The last 4 bits (bit b_3 to b_0) of this byte shall specify the fixed part expressed in ns as an unsigned binary number k such that:

$$k = T_{top,fix}$$

Byte 74: This byte shall specify the duration of the first pulse of the multi-pulse train for recording marks with a run length of 3T (see F.2 for detailed definition).

The first pulse duration $T_{top,3T}$ consists of two contributions: a variable part and a fixed part as follows:

$$T_{top,3T} = T_{top,var} + T_{top,fix}$$

The first 4 bits (bit b_7 to b_4) of this byte shall specify the variable part, as a fraction of the actual channel bit clock period, as an unsigned binary number *j* such that:

$$j = 16 \times \frac{T_{top,var}}{T_W}$$

The last 4 bits (bit b_3 to b_0) of this byte shall specify the fixed part, expressed in ns, as an unsigned binary number *k* such that:

$$k = T_{top,fix}$$

Byte 75: This byte shall specify the duration of the first pulse of the multi-pulse train for recording marks with a run length of 2T (see F.2 for detailed definition).

The first pulse duration $T_{top,2T}$ consists of two contributions: a variable part and a fixed part as follows:

$$T_{top,2T} = T_{top,var} + T_{top,fix}$$

The first 4 bits (bit b_7 to b_4) of this byte shall specify the variable part, as a fraction of the actual channel bit clock period, as an unsigned binary number *j* such that:

$$j = 16 \times \frac{T_{top,var}}{T_W}$$

The last 4 bits (bit b_3 to b_0) of this byte shall specify the fixed part, expressed in ns, as an unsigned binary number *k* such that:

$$k = T_{top,fix}$$

Bytes 76 to 84: dT_{top} first write pulse start time

For each of the byte fields *f* to (*f* + 2), with *f* = 76, 79 and 82, the following values are defined at the following three different recording velocities.

Byte *f*: The first five bits (bit b_7 to b_3) of this byte shall specify the start time of the first pulse of the multi-pulse train for recording marks with run lengths ≥4T, relative to the trailing edge of the first channel-bit of the data pulse (positive values are leading, negative values are lagging; see F.2 for detailed definition).

The first pulse start time $dT_{top,4T}$ is expressed as a fraction of the actual channel bit clock period as a signed two's-complement binary number *i* such that:

$$i = 16 \times \frac{dT_{top}}{T_W}$$

The last three bits (bit b_2 to b_0) of this byte shall be reserved.

Byte (*f* + 1): The first five bits (bit b_7 to b_3) of this byte shall specify the start time of the first pulse of the multi-pulse train for recording marks with a run length of 3T, relative to the trailing edge of the first channel bit of the data pulse (positive values are leading, negative values are lagging; see F.2 for detailed definition).

The first pulse start time $dT_{top,3T}$ is expressed as a fraction of the actual channel bit clock period as a signed two's-complement binary number *i* such that:

$$i = 16 \times \frac{dT_{top}}{T_W}$$

The last three bits (bit b_2 to b_0) of this byte shall be reserved.

Byte (*f* + 2): The first fivr bits (bit b_7 to b_3) of this byte shall specify the start time of the first pulse of the multi-pulse train for recording marks with a run length of 2T, relative to the trailing edge of the first channel bit of the data pulse (positive values are leading, negative values are lagging; F.2 for detailed definition).

The first pulse start time $dT_{top,2T}$ is expressed as a fraction of the actual channel bit clock period as a signed two's-complement binary number *i* such that:

$$i = 16 \times \frac{dT_{top}}{T_W}$$

The last three bits (bit b_2 to b_0) of this byte shall be reserved.

Bytes 76 to 78: **dT_{top} first write pulse start time at nominal recording velocity**

Byte 76: dT_{top} at nominal recording velocity for recording marks with run lengths ≥4T.

Byte 77: dT_{top} at nominal recording velocity for recording marks with a run length of 3T.

Byte 78: dT_{top} at nominal recording velocity for recording marks with a run length of 2T.

Bytes 79 to 81: **dT_{top} first write pulse start time at maximum recording velocity**

Byte 79: dT_{top} at maximum recording velocity for recording marks with run lengths ≥4T.

Byte 80: dT_{top} at maximum recording velocity for recording marks with a run length of 3T.

Byte 81: dT_{top} at maximum recording velocity for recording marks with a run length of 2T.

Bytes 82 to 84: **dT_{top} first write pulse start time at minimum recording velocity**

Byte 82: dT_{top} at minimum recording velocity for recording marks with run lengths ≥4T.

Byte 83: dT_{top} at minimum recording velocity for recording marks with a run length of 3T.

Byte 84: dT_{top} at minimum recording velocity for recording marks with a run length of 2T.

Bytes 85 to 87: **Reserved**

Byte 88: **T_E erase multi-pulse duration**

This byte shall specify the basic duration of the pulses of the multi-pulse train for recording of spaces (see F.2 for detailed definition).

The multi-pulse duration T_E consists of two contributions: a variable part and a fixed part as follows:

$$T_E = T_{E,var} + T_{E,fix}$$

The first 4 bits (bit b_7 to b_4) of this byte shall specify the variable part, as a fraction of the actual channel bit clock period, as an unsigned binary number v such that:

$$v = 16 \times \frac{T_{E,var}}{T_W}$$

The last 4 bits (bit b_3 to b_0) of this byte shall specify the fixed part, expressed in ns, as an unsigned binary number w such that:

$$w = T_{E,fix}$$

Bytes 89 to 97: dT_E first erase pulse start time

For each of the byte fields f to $(f + 2)$, with $f = 89$, 92 and 95, the following values are defined at three different recording velocities:

Byte f: The first five bits (bit b_7 to b_3) of this byte shall specify the start time of the first erase pulse following the recording of marks with run lengths ≥4T, relative to the trailing edge of the last channel bit of the data pulse (positive values are leading, negative values are lagging; see F.2 for detailed definition).

The first erase pulse start time $dT_{E,4T}$ is expressed, as a fraction of the actual channel bit clock period, as a signed two's-complement binary number u such that:

$$u = 16 \times \frac{dT_E}{T_W}$$

The last three bits (bit b_2 to b_0) of this byte shall be reserved.

Byte $(f + 1)$: The first five bits (bit b_7 to b_3) of this byte shall specify the start time of the first erase pulse following the recording of marks with a run length of 3T, relative to the trailing edge of the first channel bit of the data pulse (positive values are leading, negative values are lagging; see F.2 for detailed definition).

The first erase pulse start time $dT_{E,3T}$ is expressed, as a fraction of the actual channel bit clock period, as a signed two's-complement binary number u such that:

$$u = 16 \times \frac{dT_E}{T_W}$$

The last three bits (bit b_2 to b_0) of this byte shall be reserved.

Byte $(f + 2)$: The first five bits (bit b_7 to b_3) of this byte shall specify the start time of the first erase pulse following the recording of marks with a run length of 2T, relative to the trailing edge of the first channel bit of the data pulse (positive values are leading, negative values are lagging; see F.2 for detailed definition).

The first erase pulse start time $dT_{E,2T}$ is expressed, as a fraction of the actual channel bit clock period, as a signed two's-complement binary number u such that:

$$u = 16 \times \frac{dT_E}{T_W}$$

The last three bits (bit b_2 to b_0) of this byte shall be reserved.

Bytes 89 to 91: dT_E first erase pulse start time at nominal recording velocity

Byte 89: dT_E at nominal recording velocity when the preceding mark has a run length ≥4T.

Byte 90: dT_E at nominal recording velocity when the preceding mark has a run length of 3T.

Byte 91: dT_E at nominal recording velocity when the preceding mark has a run length of 2T.

Bytes 92 to 94: dT_E first erase pulse start time at maximum recording velocity

Byte 92: dT_E at maximum recording velocity when the preceding mark has a run length ≥4T.

Byte 93: dT_E at maximum recording velocity when the preceding mark has a run length of 3T.

Byte 94: dT_E at maximum recording velocity when the preceding mark has a run length of 2T.

Bytes 95 to 97: dT_E first erase pulse start time at minimum recording velocity

Byte 95: dT_E at minimum recording velocity when the preceding mark has a run length of 4T.

Byte 96: dT_E at minimum recording velocity when the preceding mark has a run length of 3T.

Byte 97: dT_E at minimum recording velocity when the preceding mark has a run length of 2T.

Byte 98:

Bits b_7 to b_6: Reserved

Bit b_5: if set to ZERO, P_{EF} shall be equal to P_{E1} at the minimum recording velocity.
if set to ONE, P_{EF} shall be equal to P_{E2} at the minimum recording velocity.

Bit b_4: if set to ZERO, P_{EL} shall be equal to P_{E1} at the minimum recording velocity.
if set to ONE, P_{EL} shall be equal to P_{E2} at the minimum recording velocity.

Bit b_3: if set to ZERO, P_{EF} shall be equal to P_{E1} at the maximum recording velocity.
if set to ONE, P_{EF} shall be equal to P_{E2} at the maximum recording velocity.

Bit b_2: if set to ZERO, P_{EL} shall be equal to P_{E1} at the maximum recording velocity.
if set to ONE, P_{EL} shall be equal to P_{E2} at the maximum recording velocity.

Bit b_1: if set to ZERO, P_{EF} shall be equal to P_{E1} at the nominal recording velocity.
if set to ONE, P_{EF} shall be equal to P_{E2} at the nominal recording velocity.

Bit b_0: if set to ZERO, P_{EL} shall be equal to P_{E1} at the nominal recording velocity.
if set to ONE, P_{EL} shall be equal to P_{E2} at the nominal recording velocity.

Byte 99: Reserved

Bytes 100 to 111: DI unit footer

See 15.8.3.2.

15.8.3.4 Definitions for DI format 2 (N-1 write strategy B)

The content of the body of DI units according to DI format 2 shall be as depicted in Figure 77.

Byte number	Content	Number of bytes
0 to 7	DI-unit header	8
8 to 10	BD layer type identifier	3
11	Disk size / Class / Version	1
12	BD structure	1
13	Channel bit length	1
14 to 15	Reserved	2
16	BCA descriptor	1
17	Maximum transfer rate of application	1
18 to 23	Reserved	6
24 to 31	Data zone allocation	8
32 to 35	Recording velocities	4
36 to 39	Maximum dc read powers	4
40 to 43	Maximum HF-modulated read powers	4
44 to 47	Reserved	4
48 to 55	Write power settings	8
56	T_{MP} write multi-pulse duration	1
57 to 68	dT_{top} first write pulse start time	12
69 to 92	T_{top} first write pulse duration	12 × 2
93 to 94	T_{LP} last-pulse duration	2
95 to 97	dT_{E} erase level start time	3
98 to 99	Unused = all 00h	2
100 to 111	DI-unit footer	12

Figure 77 — Content of disk information for DI format 2

Bytes 0 to 31: Same as specifications in 15.8.3.3, except for the following bytes:

Byte 2: **DI format number**

This byte shall be set to 02h for disks with BCA code.

This byte shall be set to 82h for disks without BCA code.

Byte 6: **Continuation flag/Number of DI bytes in use in this DI unit**

This byte shall be set to 62h to indicate that the first 98 bytes of the DI unit are used and that there is no continuation in the next DI unit. All remaining bytes of the DI unit body (excluding the bytes in the DI unit footer) are unused and shall be set to 00h.

Bytes 32 to 35: **Recording velocities**

Byte 32 to 33: These bytes specify the nominal recording velocity to be used with the parameters as defined in this DI unit as a 2-byte binary number (byte 32 is MSB).

It shall specify the nominal recording velocity as a number n such that:

$$n = 100 \times V_{nom}$$

n shall be equal to:

01 ECh to indicate a nominal recording velocity of 4,92 m/s; or

03 D7h to indicate a nominal recording velocity of 9,83 m/s.

Byte 34 This byte specifies the maximum recording velocity to be used with the parameters as defined in this DI unit.

It shall specify the maximum recording velocity as a number n such that:

$n = 100 \times V_{max}/V_{nom}$ $(n \geq 100)$

Here, n shall be equal to 64h to indicate a maximum recording velocity equal to the nominal recording velocity.

Byte 35: This byte specifies the minimum recording velocity to be used with the parameters as defined in this DI unit.

It shall specify the minimum recording velocity as a number n such that:

$n = 100 \times V_{min}/V_{nom}$ $(n \leq 100)$

Here, n shall be equal to 64h to indicate a minimum recording velocity equal to the nominal recording velocity.

Bytes 36 to 39: Maximum dc read powers

The maximum read power is defined as the maximum optical power on the entrance surface of the disk, at which at least 10^6 successive reads can be applied without degrading the recorded signals (see 30.8).

Byte 36 This byte shall specify the maximum dc read power P_r, at the reference velocity, in milliwatts, as a number n such that:

$n = 100 \times P_r$

Byte 37 This byte shall specify the maximum dc read power P_r, at the nominal recording velocity as defined in bytes 32 and 33 of this DI unit, in milliwatts, as a number n such that:

$n = 100 \times P_r$

Byte 38 This byte shall specify the maximum dc read power P_r, at the maximum recording velocity as defined by byte 34 of this DI unit, in milliwatts, as a number n such that:

$n = 100 \times P_r$

Byte 39 This byte shall specify the maximum dc read power P_r, at the minimum recording velocity as defined by byte 35 of this DI unit, in milliwatts, as a number n such that:

$n = 100 \times P_r$

NOTE 1 For reading at lower velocities than the lowest specified velocity, a reduction of the read power can be necessary to guarantee stability of the recordings on the disk.

Bytes 40 to 43: Maximum HF-modulated read powers

The maximum read power is defined as the maximum optical power, on the entrance surface of the disk, at which at least 10^6 successive reads can be applied without degrading the recorded signals (see 30.8).

Byte 40 This byte shall specify the maximum HF-modulated read power P_r, at the reference velocity, in milliwatts, as a number n such that:

$n = 100 \times P_r$

Byte 41 This byte shall specify the maximum HF-modulated read power P_r, at the nominal recording velocity as defined in bytes 32 and 33 of this DI unit, in milliwatts, as a number n such that:

$$n = 100 \times P_r$$

Byte 42 This byte shall specify the maximum HF-modulated read power P_r, at the maximum recording velocity as defined by byte 34 of this DI unit, in milliwatts, as a number n such that:

$$n = 100 \times P_r$$

Byte 43 This byte shall specify the maximum HF-modulated read power P_r, at the minimum recording velocity as defined by byte 35 of this DI unit, in milliwatts, as a number n such that:

$$n = 100 \times P_r$$

NOTE 2 For reading at lower velocities than the lowest specified velocity, a reduction of the read power can be necessary to guarantee stability of the recordings on the disk.

Bytes 44 to 47: **Reserved**

Bytes 48 to 55: **Write power settings**

Byte 48: $\boldsymbol{P_{IND}}$: P_{IND} can be used as a starting value for the determination of P_{target} in the OPC procedure (see Annex G for detailed procedure).

This byte shall specify the indicative value P_{IND} of P_{target}, in milliwatts, as a number n such that:

$$n = 20 \times P_{IND}$$

Byte 49: $\boldsymbol{m_{IND}}$: m_{IND} can be used as a starting value for the determination of P_{target} in the OPC procedure (see Annex G for detailed procedure).

This byte shall specify the modulation at P_{IND} as determined by the media manufacturer, as a number n such that:

$$n = 200 \times m_{IND}$$

Byte 50: $\boldsymbol{\rho}$: This byte shall specify the write power multiplication factor ρ, used in the OPC algorithm (see Annex G for detailed procedure), as a number n such that:

$$n = 100 \times \rho$$

Byte 51: $\boldsymbol{\varepsilon_{BW}}$: This byte shall specify the write bias/write peak power ratio ε_{BW}, used in the OPC algorithm (see Annex G for detailed procedure), as a number n such that:

$$n = 200 \times \varepsilon_{BW}$$

Byte 52: $\boldsymbol{\varepsilon_C}$: This byte shall specify the cooling/write peak power ratio ε_C, used in the OPC algorithm (see Annex G for detailed procedure), as a number n such that:

$$n = 200 \times \varepsilon_C$$

Byte 53: $\boldsymbol{\varepsilon_E}$: This byte shall specify the erase/write peak power ratio ε_E, used in the OPC algorithm (see Annex G for detailed procedure), as a number n such that:

$$n = 200 \times \varepsilon_E$$

Byte 54: $\boldsymbol{\kappa}$: This byte shall specify the target value for κ, used in the OPC procedure (see Annex G for detailed procedure), as a number n such that:

$$n = 20 \times \kappa$$

Byte 55: Reserved

Byte 56: **T_{MP} write multi-pulse duration**

This byte shall specify the duration of the second and higher pulses of the multi-pulse train for recording marks (see F.3 for detailed definition).

The multi-pulse duration T_{MP} consists of two contributions: a variable part and a fixed part as follows:

$$T_{MP} = T_{MP,var} + T_{MP,fix}$$

The first 4 bits (bit b_7 to b_4) of this byte shall specify the variable part, as a fraction of the actual channel bit clock period, as an unsigned binary number p such that:

$$p=16\times\frac{T_{MP,var}}{T_W}$$

The last 4 bits (bit b_3 to b_0) of this byte shall specify the fixed part, as a fraction of the time period T_X, where T_X = 15,15 ns at 1x recording velocity or T_X = 7,58 ns at 2× recording velocity. The value is expressed as an unsigned binary number q such that:

$$q=16\times\frac{T_{MP,fix}}{T_X}$$

Bytes 57 to 68: **dT_{top} first write pulse start time**

The first five bits (bit b_7 to b_3) of these bytes specify the start time of the first pulse of the multi-pulse train for recording marks with run lengths of 2T, 3T and ≥4T that succeed a 2T, 3T, 4T or ≥5T space (see F.3 for detailed definition).

The first pulse start time dT_{top} is expressed, as a fraction of the actual channel bit clock period, as a signed two's-complement binary number i such that:

$$i=16\times\frac{dT_{top}}{T_W}$$

The last three bits (bit b_2 to b_0) of these bytes shall be reserved.

Bytes 57 to 60: These bytes specify the start time of the first pulse of the multi-pulse train for recording marks of run lengths ≥4T that succeed a space with run lengths of 2T, 3T, 4T or ≥5T, relative to the trailing edge of the first channel bit of the data pulse (positive values are leading, negative values are lagging; see F.3 for detailed definition).

Byte 57: This byte shall specify the start time of the first pulse for recording marks with run lengths ≥4T that succeed a space with a run length ≥5T.

Byte 58: This byte shall specify the start time of the first pulse for recording marks with run lengths ≥4T that succeed a space with a run length of 4T.

Byte 59: This byte shall specify the start time of the first pulse for recording marks with run lengths ≥4T that succeed a space with a run length of 3T.

Byte 60: This byte shall specify the start time of the first pulse for recording marks with run lengths ≥4T that succeed a space with a run length of 2T.

Bytes 61 to 64: These bytes specify the start time of the first pulse of the multi-pulse train for recording marks of a run length 3T that succeed a space with a run length 2T, 3T, 4T or ≥5T, relative to the trailing edge of the first channel bit of the data pulse (positive values are leading, negative values are lagging; see F.3 for detailed definition).

Byte 61: This byte shall specify the start time of the first pulse for recording marks with a run length of 3T that succeed a space with a run length ≥5T.

Byte 62: This byte shall specify the start time of the first pulse for recording marks with a run length of 3T that succeed a space with a run length of 4T.

Byte 63: This byte shall specify the start time of the first pulse for recording marks with a run length of 3T that succeed a space with a run length of 3T.

Byte 64: This byte shall specify the start time of the first pulse for recording marks with a run length of 3T that succeed a space with a run length of 2T.

Bytes 65 to 68: These bytes specify the start time of the first pulse of the multi-pulse train for recording marks of a run length of 2T that succeed a space with a run length of 2T, 3T, 4T or ≥5T, relative to the trailing edge of the first channel bit of the data pulse (positive values are leading, negative values are lagging; see F.3 for detailed definition).

Byte 65: This byte shall specify the start time of the first pulse for recording marks with a run length of 2T that succeed a space with a run length of ≥5T.

Byte 66: This byte shall specify the start time of the first pulse for recording marks with a run length of 2T that succeed a space with a run length of 4T.

Byte 67: This byte shall specify the start time of the first pulse for recording marks with a run length of 2T that succeed a space with a run length of 3T.

Byte 68: This byte shall specify the start time of the first pulse for recording marks with a run length of 2T that succeed a space with a run length of 2T.

Bytes 69 to 92: T_{top} first write pulse duration

These bytes specify the duration of the first pulse of the multi-pulse train for recording marks with run lengths of 2T, 3T, and ≥4T that succeed a space with a run length of 2T, 3T, 4T or ≥5T (see F.3 for detailed definition).

The first pulse duration T_{top} consists of two contributions: a variable part and a fixed part as follows:

$$T_{\text{top}} = T_{\text{top,var}} + T_{\text{top,fix}}$$

For each of the byte fields *f* to (*f* + 1), with *f* = 69, 71, .. 91 the following values are defined:

Byte *f*: The first five bits (bit b_7 to b_3) of this byte shall specify the variable part, as a fraction of the actual channel-bit clock period, as an unsigned binary number *j* such that:

$$j = 16 \times \frac{T_{\text{top,var}}}{T_W}$$

The last three bits (bit b_2 to b_0) of this byte shall be reserved.

Byte (f + 1): The first five bits (bit b_7 to b_3) of this byte shall specify the fixed part as a fraction of the time period T_X where T_X = 15,15 ns at 1x recording velocity or T_X = 7,58 ns at 2x recording velocity. The value is expressed as an unsigned binary number k such that:

$$k = 16 \times \frac{T_{top,fix}}{T_X}$$

The last three bits (bit b_2 to b_0) of this byte shal be reserved.

Bytes 69 to 76: These bytes specify the duration of the first pulse of the multi-pulse train for recording marks with run lengths ≥4T that succeed a space with a run length of 2T, 3T, 4T or ≥5T (see F.3 for detailed definition).

Bytes 69 and 70: These bytes specify the duration of the first pulse for recording marks with run lengths ≥4T that succeed a space with a run length **≥** 5T.

Bytes 71 and 72: These bytes specify the duration of the first pulse for recording marks with run lengths ≥4T that succeed a space with a run length of 4T.

Bytes 73 and 74: These bytes specify the duration of the first pulse for recording marks with run lengths ≥4T that succeed a space with a run length of 3T.

Bytes 75 and 76: These bytes specify the duration of the first pulse for recording marks with run lengths ≥4T that succeed a space with a run length of 2T.

Bytes 77 to 84: These bytes specify the duration of the first pulse of the multi-pulse train for recording marks with a run length of 3T that succeed a space with a run length of 2T, 3T, 4T or ≥5T (see F.3 for detailed definition).

Bytes 77 and 78: These bytes specify the duration of first pulse for recording marks with a run length of 3T that succeed a space with a run length **≥**5T.

Bytes 79 and 80: These bytes specify the duration of the first pulse for recording marks with a run length of 3T that succeed a space with a run length of 4T.

Bytes 81 and 82: These bytes specify the duration of the first pulse for recording marks with a run length of 3T that succeed a space with a run length of 3T.

Bytes 83 and 84: These bytes specify the duration of the first pulse for recording marks with a run length of 3T that succeed a space with a run length of 2T.

Bytes 85 to 92: These bytes specify the duration of the first pulse of the multi-pulse train for recording marks with a run length of 2T that succeed a space with a run length of 2T, 3T, 4T or ≥5T (see F.3 for detailed definition).

Bytes 85 and 86: These bytes specify the duration of the first pulse for recording marks with a run length of 2T that succeed a space with a run length **≥**5T**.**

Bytes 87 and 88: These bytes specify the duration of the first pulse for recording marks with a run length of 2T that succeed a space with a run length of 4T.

Bytes 89 and 90: These bytes specify the duration of the first pulse for recording marks with a run length of 2T that succeed a space with a run length of 3T.

Bytes 91 and 92: These bytes specify the duration of the first pulse for recording marks with a run length of 2T that succeed a space with a run length of 2T.

Bytes 93 to 94: T_{LP} **last pulse duration**

These bytes specify the duration of the last pulse of the multi-pulse train for recording marks with run lengths of 3T and ≥4T (see F.3 for detailed definition). The last pulse duration T_{LP} consists of two contributions: a variable part and a fixed part

$$T_{LP} = T_{LP,var} + T_{LP,fix}$$

The first 4 bits (bit b_7 to b_4) of each byte shall specify the variable part, as a fraction of the actual channel-bit clock period, as an unsigned binary number s such that:

$$s = 16 \times \frac{T_{LP,var}}{T_W}$$

The last 4 bits (bit b_3 to b_0) of each byte shall specify the fixed part as a fraction of the time period T_X where T_X = 15,15 ns at 1x recording velocity or T_X = 7,58 ns at 2x recording velocity. The value is expressed as an unsigned binary number t such that:

$$t = 16 \times \frac{T_{LP,fix}}{T_X}$$

Byte 93: This byte shall specify the duration of the last pulse of the multi-pulse train for recording marks of run lengths ≥4T (see F.3 for detailed definition).

Byte 94: This byte shall specify the duration of the last pulse of the multipulse train for recording marks of a run length of 3T (see F.3 for detailed definition).

Bytes 95 to 97: ***dT*$_E$ erase level start time**

The first six bits (bit b_7 to b_2) of these bytes specify the start time of the erase level, succeeding the recording of marks with run lengths of 2T, 3T and ≥4T (positive values are leading, negative values are lagging; see F.3 for detailed definition).

The start time of the erase level dT_E is expressed as a fraction of the actual channel-bit clock period as a signed two's-complement binary number u such that:

$$u = 16 \times \frac{dT_E}{T_W}$$

The last two bits (bit b_1 to b_0) of these bytes shall be reserved.

Byte 95: This byte shall specify the start time of the erase level succeeding the recording of marks with run lengths ≥4T.

Byte 96: This byte shall specify the start time of the erase level succeeding the recording of marks with a run length of 3T.

Byte 97: This byte shall specify the start time of the erase level succeeding the recording of marks with a run length of 2T.

Bytes 98 to 99: **Reserved.**

Bytes 100 to 111: **DI unit footer**

See 15.8.3.2.

15.8.3.5 Definitions for DI format 3 (N/2 write strategy)

The content of the body of DI units according to DI format 3 shall be as depicted in Figure 78.

Byte number	Content	Number of bytes
0 to 7	DI-unit header	8
8 to 10	BD layer type identifier	3
11	Disk size / Class / Version	1
12	BD structure	1
13	Channel bit length	1
14 to 15	Reserved	2
16	BCA descriptor	1
17	Maximum transfer rate of application	1
18 to 23	Reserved	6
24 to 31	Data-zone allocation	8
32 to 35	Recording velocities	4
36 to 39	Maximum dc read powers	4
40 to 43	Maximum HF-modulated read powers	4
44 to 47	Reserved	4
48 to 55	Write power settings	8
56 to 57	T_{MP} write multi-pulse duration	2
58 to 61	dT_{top} first write pulse start time	4
62 to 69	T_{top} first write pulse duration	4 × 2
70 to 73	T_{LP} last pulse duration	2 × 2
74 to 77	dT_E erase level start time	4
78 to 99	Unused = all 00h	22
100 to 111	DI-unit footer	12

Figure 78 — Content of disk information for DI format 3

Bytes 0 to 31: Same as specifications in 15.8.3.3, except for the following bytes:

Byte 2: **DI format number**

This byte shall be set to 03h for the disks with BCA code.

This byte shall be set to 83h for the disks without BCA code.

Byte 6: **Continuation flag/Number of DI bytes in use in this DI unit**

This byte shall be set to 4Eh to indicate that the first 78 bytes of the DI unit are used and that there is no continuation in the next DI unit. All remaining bytes of the DI unit body (excluding the bytes in the DI unit footer) are unused and shall be set to 00h.

Bytes 32 to 35: **Recording velocities**

Bytes 32 to 33: These bytes specify the nominal recording velocity, to be used with the parameters as defined in this DI unit, as a 2-byte binary number (byte 32 is MSB).

It shall specify the nominal recording velocity as a number n such that:

$n = 100 \times V_{nom}$

Here, n shall be equal to

01 ECh to indicate a nominal recording velocity of 4,92 m/s, or

03 D7h to indicate a nominal recording velocity of 9,83 m/s.

Byte 34: This byte shall specify the maximum recording velocity to be used with the parameters as defined in this DI unit.

It shall specify the maximum recording velocity as a number n such that:

$n = 100 \times V_{max}/V_{nom}$ ($n \geq 100$)

Here, n shall be equal to 64h to indicate a maximum recording velocity equal to the nominal recording velocity.

Byte 35: This byte shall specify the minimum recording velocity to be used with the parameters as defined in this DI unit.

It shall specify the minimum recording velocity as a number n such that:

$n = 100 \times V_{min}/V_{nom}$ ($n \leq 100$)

Here, n shall be equal to 64h to indicate a minimum recording velocity equal to the nominal recording velocity.

Bytes 36 to 39: Maximum dc read powers

The maximum read power is defined as the maximum optical power, on the entrance s urface of the disk, at which at least 10^6 successive reads can be applied without degrading recorded signals (see 30.8).

Byte 36 This byte shall specify the maximum dc read power P_r, at the reference velocity, in milliwatts, as a number n such that:

$n = 100 \times P_r$

Byte 37 This byte shall specify the maximum dc read power P_r, at the nominal recording velocity, as defined in bytes 32 and 33 of this DI unit, in milliwatts, as a number n such that:

$n = 100 \times P_r$

Byte 38 This byte shall specify the maximum dc read power P_r, at the maximum recording velocity, as defined by byte 34 of this DI unit, in milliwatts, as a number n such that:

$n = 100 \times P_r$

Byte 39 This byte shall specify the maximum dc read power P_r, at the minimum recording velocity, as defined by byte 35 of this DI unit, in milliwatts, as a number n such that:

$n = 100 \times P_r$

NOTE 1 For reading at lower velocities than the lowest specified velocity, a reduction of the read power can be necessary to guarantee the stability of the recordings on the disk.

Bytes 40 to 43: **Maximum HF-modulated read powers**

The maximum read power is defined as the maximum optical power, on the entrance surface of the disk, at which at least 10^6 successive reads can applied without degrading the recorded signals (see 30.8).

Byte 40 This byte shall specify the maximum HF-modulated read power P_r, at the reference velocity, in milliwatts, as a number n such that:

$$n = 100 \times P_r$$

Byte 41 This byte shall specify the maximum HF-modulated read power P_r, at the nominal recording velocity as defined in bytes 32 and 33 of this DI unit, in milliwatts, as a number n such that:

$$n = 100 \times P_r$$

Byte 42 This byte shall specify the maximum HF-modulated read power P_r, at the maximum recording velocity as defined by byte 34 of this DI unit, in milliwatts, as a number n such that:

$$n = 100 \times P_r$$

Byte 43 This byte shall specify the maximum HF-modulated read power P_r, at the minimum recording velocity as defined by byte 35 of this DI unit, in milliwatts, as a number n such that:

$$n = 100 \times P_r$$

NOTE 2 For reading at lower velocities than the lowest specified velocity, a reduction of the read power can be necessary to guarantee the stability of the recordings on the disk.

Bytes 44 to 47: **Reserved**

Bytes 48 to 55: **Write power settings**

Byte 48: $\boldsymbol{P}_{\mathrm{IND}}$: P_{IND} can be used as a starting value for the determination of P_{target} in the OPC procedure (see Annex G for detailed procedure).

This byte shall specify the indicative value P_{IND} of P_{target}, in milliwatts, as a number n such that:

$$n = 20 \times P_{\mathrm{IND}}$$

Byte 49: $\boldsymbol{m}_{\mathrm{IND}}$: m_{IND} can be used as a starting value for the determination of P_{target} in the OPC procedure (see Annex G for detailed procedure).

This byte shall specify the modulation at P_{IND}, as determined by the media manufacturer, as a number n such that:

$$n = 200 \times m_{\mathrm{IND}}$$

Byte 50 $\boldsymbol{\rho}$: This byte shall specify the write power multiplication factor ρ, used in the OPC algorithm (see Annex G for detailed procedure), as a number n such that:

$$n = 100 \times \rho$$

Byte 51: $\boldsymbol{\varepsilon}_{\mathrm{BW}}$: This byte shall specify the write bias/write peak power ratio $\varepsilon_{\mathrm{BW}}$, used in the OPC algorithm (see Annex G for detailed procedure), as a number n such that:

$$n = 200 \times \varepsilon_{\mathrm{BW}}$$

Byte 52: **ε_C:** This byte shall specify the cooling/write peak power ratio ε_C, used in the OPC algorithm (see Annex G for detailed procedure), as a number n such that:

$$n = 200 \times \varepsilon_C$$

Byte 53: **ε_E:** This byte shall specify the erase/write peak power ratio ε_E, used in the OPC algorithm (see Annex G for detailed procedure), as a number n such that:

$$n = 200 \times \varepsilon_E$$

Byte 54: **κ:** This byte shall specify the target value for κ, used in the OPC procedure (see Annex G for detailed procedure), as a number n such that:

$$n = 20 \times \kappa$$

Byte 55: Reserved

Bytes 56 to 57: T_{MP} write multi-pulse duration

These bytes shall specify the duration of the second and higher pulses of the multi-pulse train for recording marks (see F.4 for detailed definition).

The multi-pulse duration T_{MP} consists of two contributions: a variable part and a fixed part as follows:

$$T_{MP} = T_{MP,var} + T_{MP,fix}$$

Byte 56: The first five bits (bit b_7 to b_3) of this byte shall specify the variable part, as a fraction of the actual channel-bit clock period, as an unsigned binary number p such that:

$$p = 16 \times \frac{T_{MP,var}}{T_W}$$

The last three bits (bit b_2 to b_0) of this byte shall be reserved.

Byte 57: The first five bits (bit b_7 to b_3) of this byte shall specify the fixed part as a fraction of the time period T_X where T_X = 15,15 ns at 1x recording velocity or T_X = 7,58 ns at 2x recording velocity. The value is expressed as an unsigned binary number q such that:

$$q = 16 \times \frac{T_{MP,fix}}{T_X}$$

The last three bits (bit b_2 to b_0) of this byte shall be reserved.

Bytes 58 to 61: dT_{top} first write pulse start time

The first five bits (bit b_7 to b_3) of these bytes specify the start time of the first pulse of the multi-pulse train for recording marks with run lengths of 2T, 3T, [4T,6T,8T], and [5T,7T,9T] (positive values are leading, negative values are lagging; see F.4 for detailed definition).

The first pulse start time dT_{top} is expressed, as a fraction of the actual channel bit clock period, as a signed two's complement binary number i such that:

$$i = 16 \times \frac{dT_{top}}{T_W}$$

The last three bits (bit b_2 to b_0) of these bytes shall be reserved.

Byte 58: This byte shall specify the start time of the first pulse of the multi-pulse train for recording marks with run lengths of [5T,7T,9T], relative to the trailing edge of the first channel bit of the data pulse (positive values are leading, negative values are lagging; see F.4 for detailed definition).

Byte 59: This byte shall specify the start time of the first pulse of the multi-pulse train for recording marks with run lengths of [4T,6T,8T], relative to the trailing edge of the first channel bit of the data pulse (positive values are leading, negative values are lagging; see F.4 for detailed definition).

Byte 60: This byte shall specify the start time of the first pulse of the multi-pulse train for recording marks with a run length of 3T, relative to the trailing edge of the first channel bit of the data pulse (positive values are leading, negative values are lagging; see F.4 for detailed definition).

Byte 61: This byte shall specify the start time of the first pulse of the multi-pulse train for recording marks with a run length of 2T, relative to the trailing edge of the first channel bit of the data pulse (positive values are leading, negative values are lagging; see F.4 for detailed definition).

Bytes 62 to 69: **T_{top} first write-pulse duration**

These bytes specify the duration of the first pulse of the multi-pulse train for recording marks with run lengths of 2T, 3T, [4T,6T,8T] and [5T,7T,9T] (see F.4).

The first pulse duration T_{top} consists of two contributions: a variable part and a fixed part as follows:

$$T_{top} = T_{top,var} + T_{top,fix}$$

For each of the byte fields f to $f + 1$, with $f = 62, 64, 66$ and 68, the following values are defined.

Byte f: The first six bits (bit b_7 to b_2) of this byte shall specify the variable part, as a fraction of the actual channel bit clock period, as an unsigned binary number j such that:

$$j = 16 \times \frac{T_{top,\,var}}{T_W}$$

The last two bits (bit b_1 to b_0) of this byte shall be reserved.

Byte ($f + 1$): The first six bits (bit b_7 to b_2) of this byte shall specify the fixed part as a fraction of the time period T_X where T_X = 15,15 ns at 1x recording velocity or T_X = 7,58 ns at 2x recording velocity. The value is expressed as an unsigned binary number k such that:

$$k = 16 \times \frac{T_{top,\,fix}}{T_X}$$

The last two bits (bit b_1 to b_0) of this byte shall be reserved.

Bytes 62 to 63: These bytes specify the duration of the first pulse of the multi-pulse train for recording marks with run lengths of [5T,7T,9T] (see F.4 for detailed definition).

Bytes 64 to 65: These bytes specify the duration of the first pulse of the multi-pulse train for recording marks with run lengths of [4T,6T,8T] (see F.4 for detailed definition).

Bytes 66 to 67: These bytes specify the duration of the first pulse of the multi-pulse train for recording marks with a run length of 3T (see F.4 for detailed definition).

Bytes 68 to 69: These bytes specify the duration of the first pulse of the multi-pulse train for recording marks with a run length of 2T (see F.4 for detailed definition).

Bytes 70 to 73: **T_{LP} last pulse duration**

These bytes specify the duration of the last pulse of the multi-pulse train for recording marks with run lengths of [4T,6T,8T], and [5T,7T,9T] (see F.4 for detailed definition).

The last pulse duration T_{LP} consists of two contributions: a variable part and a fixed part as follows:

$$T_{LP} = T_{LP,var} + T_{LP,fix}$$

For each of the byte fields *f* to *f* + 1, with *f* = 70 and 72, the following values are defined:

Byte *f*: The first five bits (bit b_7 to b_3) of this byte shall specify the variable part, as a fraction of the actual channel-bit clock period, as an unsigned binary number *s* such that:

$$s = 16 \times \frac{T_{LP,\,var}}{T_W}$$

The last three bits (bit b_2 to b_0) of this byte shall be reserved.

Byte (*f* + 1): The first five bits (bit b_7 to b_3) of this byte shall specify the fixed part as a fraction of the time period T_X where T_X = 15,15 ns at 1x recording velocity or T_X = 7,58 ns at 2x recording velocity. The value is expressed as an unsigned binary number *t* such that:

$$t = 16 \times \frac{T_{LP,\,fix}}{T_X}$$

The last three bits (bit b_2 to b_0) of this byte shall be reserved.

Bytes 70 to 71: These bytes specify the duration of the last pulse of the multi-pulse train for recording marks with run lengths of [5T,7T,9T] (see F.4 for detailed definition).

Bytes 72 to 73: These bytes specify the duration of the last pulse of the multi-pulse train for recording marks with run lengths of [4T,6T,8T] (see F.4 for detailed definition).

Bytes 74 to 77: **dT_E erase level start time**

The first six bits (bit b_7 to b_2) of these bytes specify the start time of an Erase level succeeding the recording of marks with run lengths of 2T, 3T, [4T,6T,8T] and [5T,7T,9T] (positive values are leading, negative values are lagging, see F.4 for detailed definition).

The start time of the erase level dT_E is expressed, as a fraction of the actual channel bit clock period, as a signed two's-complement binary number *u* such that:

$$u = 16 \times \frac{dT_E}{T_W}$$

The last two bits (bit b_1 to b_0) of these bytes shall be reserved.

Byte 74: This byte shall specify the start of the Erase level for recording marks with run lengths of [5T,7T,9T].

Byte 75: This byte shall specify the start of the Erase level for recording marks with run lengths of [4T,6T,8T].

Byte 76: This byte shall specify the start of the Erase level for recording marks with a run length of 3T.

Byte 77: This byte shall specify the start of the Erase level for recording marks with a run length of 2T.

Bytes 78 to 99: Reserved

15.8.3.6 Write strategy requirements

The write strategy requirements for disks are depicted in Figure 79.

Recording velocity	Write strategy		
	N-1 A	N-1 B	N/2
1x	Mandatory	Optional	Optional
2x	—	Optional[a]	Optional[a]
[a] At least one of these two write strategies shall be present.			

Figure 79 — Write strategy type requirements

15.8.3.7 Usage of DI units for write strategies

By using the concept of multiple DI units, identified by their DI format number (byte 2), the BD system facilitates the (future) use of disks with different recording velocities and with one, two or more recording layers, while keeping backwards compatibility in the best possible way.

Generally, each different recording velocity can need a different write strategy (different set of parameters), which write strategy furthermore can depend on the applied technology. Additionally, each recording layer can need a different set of values for the write strategy parameters.

Disks shall contain at least two DI units for each recording layer, as depicted in Figure 79; at least one containing parameters for 1x recording velocity and at least one containing parameters for 2x recording velocity. Additional DI units, containing alternative write strategy parameter sets, may be added in order of preference (see Figure 74).

For 1x recording velocity, the N-1 write strategy A described by DI format 1 shall always be placed in the DI block sequence as the most-preferred write strategy.

Byte 3 is set according to the specifications in 15.8.3.2.

Byte 4 is set to 01h for SL disks;

02h for DL disk.

Byte 5 is used according to the description in 15.8.3.2.

In all DI units defining 1x recording parameters, bytes 32 to 35 shall be set to the following.

Bytes 32 to 33: These bytes are set to 01 ECh to indicate a nominal recording velocity of 4,92 m/s.

Byte 34: This byte is set to 64h to indicate a maximum recording velocity equal to the nominal recording velocity.

Byte 35: This byte is set to 64h to indicate a minimum recording velocity equal to the nominal recording velocity.

In all DI units defining parameters for 2x recording velocity, bytes 32 to 35 are set to as follows.

Bytes 32 to 33: These bytes are set to 03 D7h to indicate a nominal recording velocity of 9,83 m/s.

Byte 34: This byte is set to 64h to indicate a maximum recording velocity equal to the nominal recording velocity.

Byte 35: This byte is set to 64h to indicate a minimum recording velocity equal to the nominal recording velocity.

An example of those assignments is shown in Figure 80.

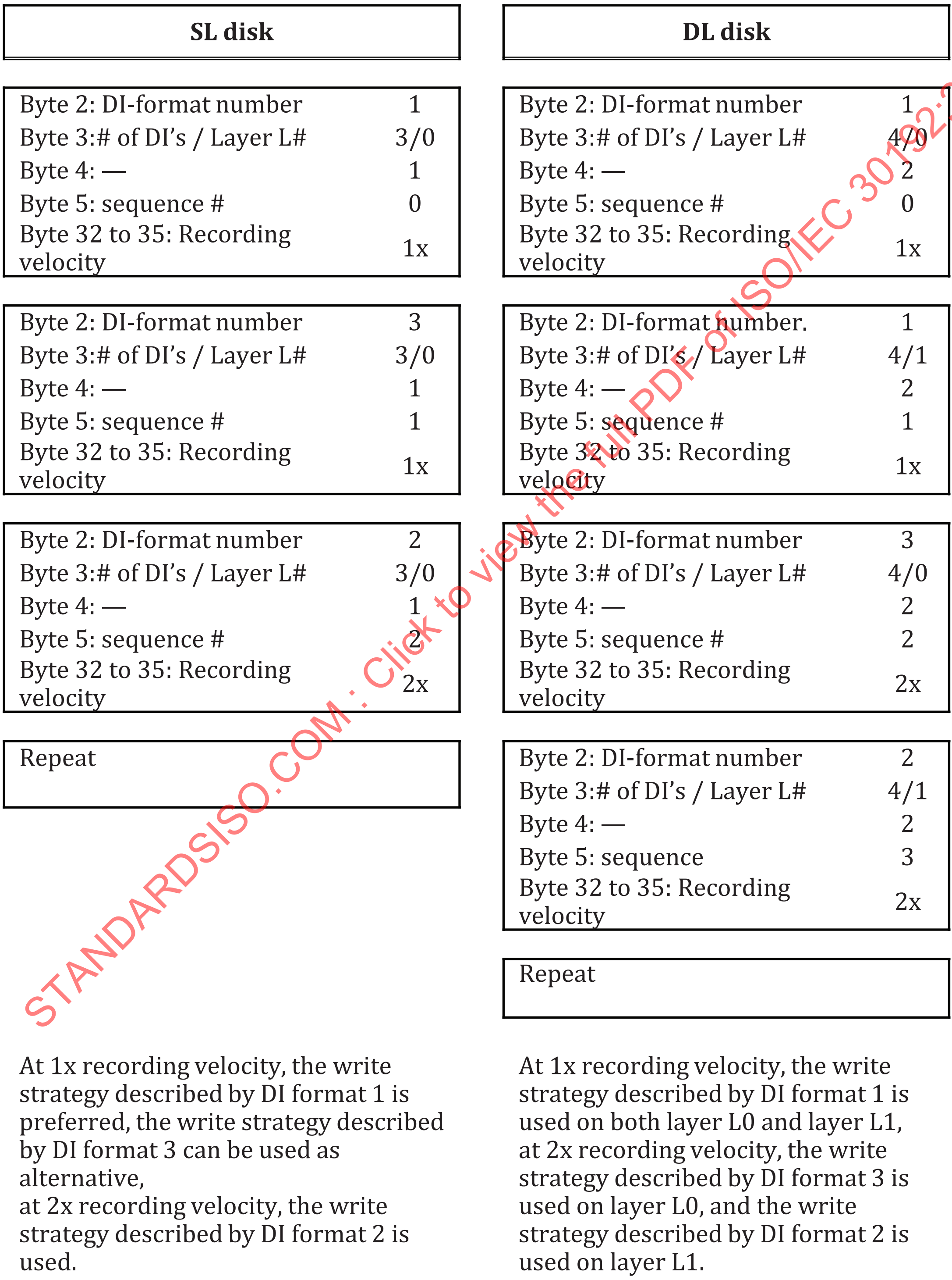


Figure 80 — Example of DI sequence

16 General description of information zone

16.1 General

The information zone, which contains all information on the disk that is relevant for data interchange, is located in the information area extending from d_9 to d_{10}. (see 10.8.1 and Figure 17).

The inner part of inner zone(s) (protection zone 1 + PIC) shall contain HFM groove which can hold replicated information about the disk. The other parts of the inner zone(s), data zone(s) and outer zone(s) constitute the rewritable area(s), in which the information can be recorded on wobbled groove using the Phase-change effect.

16.2 Format of information zone on single-layer disk

For consistency reasons, the sole recording layer on an SL disk is also called layer L0.

The information zone is divided in three parts: a lead-in zone (part of the inner zone 0), a data zone and a lead-out zone (outer zone 0) (see Figure 81).

The data zone is intended for recording user data. The lead-in zone contains replicated and rewritable control information and an area for disk and drive testing. The lead-out zone allows for a smooth runout and also contains control information.

16.3 Format of information zone on dual-layer disk

The information zone is divided in six parts: a lead-in zone (part of the inner zone 0), data zone 0 and outer zone 0 on layer L0, outer zone 1, data zone 1 and a lead-out zone (part of the inner zone 1) on layer L1 (see Figure 81 and Figure 82).

Data zone 0 and data zone 1 are intended for recording user data. The lead-in zone and the lead-out zone contain replicated and rewritable control information and an area for disk and drive testing. Outer zone 0 and outer zone 1 allow for a smooth run-in/run-out for their respective layers and also contain control information.

17 Layout of rewritable area of information zone

The rewritable area of the information zone is constituted from parts of the inner zone(s), the data zone(s) and the outer zone(s). The starting radii for the zones indicated in Figure 81 and Figure 82 are the nominal values of the centre of the first/last groove track of that zone.

The physical ADIP addresses (PAA) listed are the first/last address in the groove tracks of each zone. Also, the numbers of physical clusters (RUBs) that can be recorded per zone are indicated.

The values given in Figure 81 are for a disk capacity of 25,0 Gbytes or 50,0 Gbytes.

Layer L0				Description	Nominal starting radius (mm)	First PAA of zone : Last PAA of zone	Number of phys. clusters
First transition area	Ending radius 11,5 mm						
Clamping zone	Starting radius 11,5 mm Ending radius 16,5 mm						
Second transition area	Starting radius 16,5 mm Ending radius 21,0 mm						
Information area	Starting radius 21,0 mm	"Wide pitch" grooves	BCA				
	Information zone ↓ Tracking direction	Embossed HFM Area (HFM groove)		Protection zone 1	22,2	—	---
				PIC	22,512	(First AUN = 00 0D 8E C0h : Last AUN = 00 0D A3 FEh)	2 720 (× 4KB)
		Rewitable (wobbled groove)	Lead-in zone (part of Inner zone 0)	Protection zone 2	23,252	01 B4 80h : 01 B7 FEh	224
				INFO 2	23,289	01 B8 00h : 01 BB FEh	256
				OPC	23,329	01 BC 00h : 01 DB FEh	2 048
				Reserved	23,647	01 DC 00h : 01 FB FEh	2 048
				INFO 1	23,961	01 FC 00h : 01 FF FEh	256
			Data zone 0		24,000	02 00 00h : : LAA	381 856
			Lead-out zone / Outer zone 0	INFO 3/4	58,000	LAA + 2h : : LAA + 4 30h	268
				Protection zone 3	58,017	LAA + 4 32h :	—
	Ending radius 58,5 mm						
Rim area	Starting radius 58,5 mm						

Figure 81 — Layout of information zone on layer L0

The values given in Figure 82 are for a disk capacity of 50,0 Gbytes.

Layer L1				Description	Nominal ending radius (mm)	Last PAA of zone : First PAA of zone	Number of phys. clusters
	Ending radius 21,0 mm	"Wide pitch" grooves					
Information area	Tracking direction ↑ Information zone ↓	**Embossed HFM area** (HFM groove)		Protection zone 1	22,2	—	—
				PIC	22,512	(Last AUN = 01 F2 71 3Eh : First AUN = 01 F2 5C 00h)	2 720 (× 4KB)
		Rewritable (wobbled groove)	**Lead-out zone (Inner zone 1)**	Protection zone 2	23,252	3E 4B 7Eh : 3E 48 00h	224
				INFO 2	23,289	3E 47 FEh : 3E 44 00h	256
				Reserved	23,329	3E 43 FEh : 3E 24 00h	2 048
				OPC	23,647	3E 23 FEh : 3E 04 00h	2 048
				INFO 1	23,961	3E 03 FEh : 3E 00 00h	256
			Data zone 1		24,000	3D FF FEh : : FAA [a]	381 856
			Outer zone 1	INFO 3/4	58,000	FAA – 2h : FAA – 4 30h	268
				Protection zone 3	58,017	FAA – 4 32h :	—
	Starting radius 58,5 mm						

[a] FAA = $\overline{\text{LAA + C0 00 01h}}$ (see 15.7.4.3).

Figure 82 — Layout of information zone on layer L1

Physical sector numbering

A cluster contains 32 physical sectors and each physical sector contains 2K data bytes. Although their numbers are not included in the data recorded on the disk, each physical sector is associated with a (virtual) physical sector number (PSN).

The PSNs increase by one for each successive physical sector in the tracking direction of the related recording layer.

The PSN of the first physical sector of each physical cluster is a multiple of 32.

Bits PS_{31} to PS_{27} of the PSN shall be reserved.

Bits PS_{26} to PS_{24} of the PSN shall be set to the layer number.

The first PSN in the data zone 0 is 00 10 00 00h.

The last PSN in the data zone 0 is 8 × LAA + 15, which is 00 CA 73 FFh on a 25,0 GB and 50,0 GB disk.

The first PSN in the data zone 1 is 8 × FAA, which is 01 35 8C 00h on a 50,0 GB disk.

The last PSN in the data zone 1 is 01 EF FF FFh.

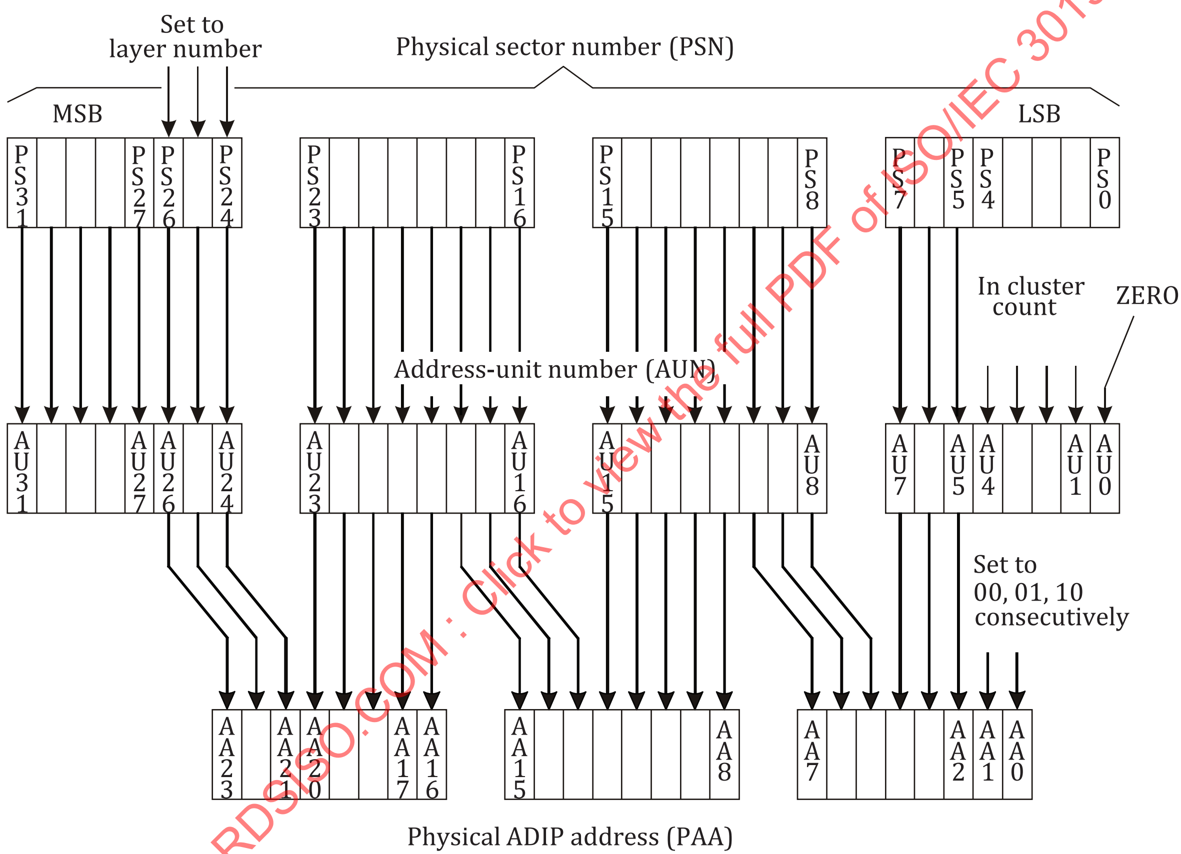


Figure 83 — Physical ADIP addresses derived from PSNs

These PSNs are converted to address unit numbers, which shall be recorded in the BIS columns of the ECC clusters (see 13.9.2).

Finally, a physical ADIP address is derived from the PSN/AUN as defined in Figure 83. This PAA identifies the location on the disk where the data shall be recorded.

18 Inner zone

18.1 General

On layer L0, the innermost zone of the information zone is called the lead-in zone. On layer L1, the innermost zone of the information zone is called the lead-out zone.

Both inner zone 0 (lead-in zone part) and inner zone 1 (lead-out zone part) contain an embossed HFM area and a rewritable area (see Figure 84 and Figure 85).

In the embossed HFM area on layer L0, groove shall be encoded according to the format defined in 15.5 and its subclauses.

On layer L0, this encoding shall start at radius $22{,}2^{0{,}0}_{-0{,}1}$ mm, such that the AUN of the first cluster shall be 00 0D 85 F4h.

The addresses shall be continuously increasing as described in 15.5.3.2 and shall end with AUN = 00 0D A3 FEh in the last 4K cluster at the outermost radius of the PIC zone.

On layer L1, this encoding shall end at radius $22{,}2^{0{,}0}_{-0{,}1}$ mm, such that the AUN of the last cluster shall be 01 F2 7A 0Ah.

The addresses shall be continuously increasing as described in 15.5.3.2 and shall start with AUN = 01 F2 5C 00h in the first 4K cluster at the outermost radius of the PIC zone.

In the protection zone 1 of both inner zones, the contents of the data frames can be set to all 00h or they can be equal to the content in the PIC zone.

The protection zone 1 is intended to be a protection area against overwriting of the PIC zone by the BCA code.

In the permanent information and control data (PIC) zone(s), general information about the disk and various other information can be stored in the embossed HFM groove.

In the rewritable area, groove(s) shall be wobbled as defined in 15.6.

The rewritable area of the inner zone(s) is used to execute OPC (optimum power control) procedures and to store specific information about the disk, such as disk management information and control information. Also, a zone has been reserved where drives can store their own specific information.

<table>
<tr><th>Inner zone 0</th><th></th><th>Description</th><th>First PAA of zone</th><th>Number of phys. clusters</th><th>Purpose</th></tr>
<tr><td rowspan="2">Embossed HFM</td><td></td><td>Protection zone 1</td><td>—</td><td>—</td><td>—</td></tr>
<tr><td></td><td>PIC</td><td>—</td><td>—</td><td>Permanent information and control data zone</td></tr>
<tr><td rowspan="20">↓
Rewritable
↓
Tracking direction</td><td>—</td><td>Protection zone 2</td><td>01 B4 80h</td><td>224</td><td>—</td></tr>
<tr><td rowspan="8">INFO 2</td><td>Reserved 8</td><td>01 B8 00h</td><td>32</td><td rowspan="4">Future extension</td></tr>
<tr><td>Reserved 7</td><td>01 B8 80h</td><td>32</td></tr>
<tr><td>Reserved 6</td><td>01 B9 00h</td><td>32</td></tr>
<tr><td>Reserved 5</td><td>01 B9 80h</td><td>32</td></tr>
<tr><td>PAC 2</td><td>01 BA 00h</td><td>32</td><td>Physical-access control</td></tr>
<tr><td>DMA 2</td><td>01 BA 80h</td><td>32</td><td>Disk management</td></tr>
<tr><td>Control data 2</td><td>01 BB 00h</td><td>32</td><td>Data information</td></tr>
<tr><td>Buffer 2</td><td>01 BB 80h</td><td>32</td><td>—</td></tr>
<tr><td>OPC</td><td>Test zone</td><td>01 BC 00h</td><td>2 048</td><td>OPC testing</td></tr>
<tr><td>Reserved</td><td>—</td><td>01 DC 00h</td><td>2 048</td><td>Future extension</td></tr>
<tr><td rowspan="9">INFO 1</td><td>Buffer 1</td><td>01 FC 00h</td><td>32</td><td>—</td></tr>
<tr><td>Drive area</td><td>01 FC 80h</td><td>32</td><td>Drive-specific information</td></tr>
<tr><td>Reserved 3</td><td>01 FD 00h</td><td>32</td><td rowspan="3">Future extension</td></tr>
<tr><td>Reserved 2</td><td>01 FD 80h</td><td>32</td></tr>
<tr><td>Reserved 1</td><td>01 FE 00h</td><td>32</td></tr>
<tr><td>DMA 1</td><td>01 FE 80h</td><td>32</td><td>Disk management</td></tr>
<tr><td>Control data 1</td><td>01 FF 00h</td><td>32</td><td>Data information</td></tr>
<tr><td>PAC 1</td><td>01 FF 80h</td><td>32</td><td>Physical-access control</td></tr>
<tr><td></td><td>(Data zone 0)</td><td>02 00 00h</td><td></td><td></td></tr>
</table>

Figure 84 — Inner zone 0 (lead-in zone)

Inner zone 1		Description	First PAA of zone	Number of phys. clusters	Purpose
↓ Rewritable ↓ Tracking direction		(Data zone 1)			
	INFO 1	PAC 1	3E 00 00h	32	Physical-access control
		Control data 1	3E 00 80h	32	Data information
		DMA 1	3E 01 00h	32	Disk management
		Reserved 1	3E 01 80h	32	Future extension
		Reserved 2	3E 02 00h	32	
		Reserved 3	3E 02 80h	32	
		Drive area	3E 03 00h	32	Drive-specific information
		Buffer 1	3E 03 80h	32	—
	OPC	Test zone	3E 04 00h	2 048	OPC testing
	Reserved	—	3E 24 00h	2 048	Future extension
	INFO 2	Buffer 2	3E 44 00h	32	—
		Control data 2	3E 44 80h	32	Data information
		DMA 2	3E 45 00h	32	Disk management
		PAC 2	3E 45 80h	32	Physical-access control
		Reserved 5	3E 46 00h	32	Future extension
		Reserved 6	3E 46 80h	32	
		Reserved 7	3E 47 00h	32	
		Reserved 8	3E 47 80h	32	
	—	Protection zone 2	3E 48 00h	224	—
Embossed HFM		PIC	—	—	Permanent information and control data zone
		Protection zone 1	—	—	—

Figure 85 — Inner zone 1 (lead-out zone)

18.2 Permanent information and control data (PIC) zone

18.2.1 General

The permanent information and control data (PIC) zone is an embossed HFM area with data for various purposes, such as disk information. If no specific PIC data is supplied, all user data bytes (before scrambling) shall be set to 00h. Both layers shall contain the same PIC data.

18.2.2 Content of PIC zone

The PIC zone shall consist of five repetitions of a PIC-info fragment, where each PIC-info fragment consists of 544 PIC clusters (for a total of 2 720, see Figure 86). The PIC clusters shall be formatted as described in 15.5.

The PIC-info fragments shall start on layer L0 at AUNs: 00 0D 8E C0h, 00 0D 93 00h, 00 0D 97 40h, 00 0D 9B 80h and 00 0D 9F C0h, and on layer L1 at AUNs: 01 F2 5C 00h, 01 F2 60 40h, 01 F2 64 80h, 01 F2 68 C0h and 01 F2 6D 00h.

PIC-info fragment number	PIC cluster number	AUN on layer L0	AUN on layer L1
IF 0	0	00 0D 8E C0h	01 F2 5C 00h
	1	00 0D 8E C2h	01 F2 5C 02h
	2	00 0D 8E C4h	01 F2 5C 04h
	:	:	
	543	00 0D 92 FEh	01 F2 60 3Eh
IF 1	0	00 0D 93 00h	01 F2 60 40h
	:	:	
	543	00 0D 97 3Eh	01 F2 64 7Eh
IF 2	0	00 0D 97 40h	01 F2 64 80h
	:	:	
	543	00 0D 9B 7Eh	01 F2 68 BEh
IF 3	0	00 0D 9B 80h	01 F2 68 C0h
	:	:	
	543	00 0D 9F BEh	01 F2 6C FEh
IF 4	0	00 0D 9F C0h	01 F2 6D 00h
	:	:	
	543	00 0D A3 FEh	01 F2 71 3Eh

Figure 86 — PIC zone

The first PIC cluster of each info fragment shall contain a copy of the disk information block as contained in the ADIP aux frames (see 15.8.3 and Figure 87). Only the first 112 bytes of each disk information aux frame shall be included (excluding the 32 parity bytes). If less than 32 DI units are present, then the remaining bytes up to byte 3 584 shall be set to 00h.

The last 512 bytes of the first PIC cluster of each info fragment shall contain the emergency brake data set (see 18.2.3 and Figure 87).

Byte position in PIC cluster	Content	Number of bytes
0 to 111	DI unit 0	112
112 to 223	DI unit 1	112
:	:	112 × 28
3 360 to 3 471	DI unit 30	112
3 472 to 3 583	Reserved	112
3 584 to 4 095	EB data set	512

Figure 87 — First PIC cluster of each info fragment

All other PIC clusters shall be reserved unless specified otherwise (e.g. in other BDAPs).

18.2.3 Emergency brake

As a protective measure, a data set is defined that can be used by specific drive models to recognize disks that need special handling to prevent destructive malfunction.

This data is called emergency brake (EB) data.

The EB data is specified in bytes 3 584 to 4 095 of the first PIC cluster of each info fragment. It consists of an EB header, EB data field(s) and an EB footer. EB data fields shall be included only after mutual agreement between the disk manufacturer and the drive manufacturer involved, when specific drives require special actions when handling such disks, e.g. to prevent damage to the disk or the drive. Up to a maximum of 62 EB data fields may be applied.

The emergency brake data shall be implemented as depicted in Figure 88.

Byte number	Function	Definition	Number of bytes
3 584 to 3 585	EB header	Identifier	2
3 586		Version	1
3 587		Reserved	1
3 588		List length	1
3 589 to 3 591		Reserved	3
3 592 to 3 593	EB data field 1	Drive-manufacturer ID	2
3 594 to 3 595		Drive model	2
3 596 to 3 597		Firmware version	2
3 598 to 3 599		Drive actions	2
: :	: :	: :	: :
(3 584 + i × 8) to (3 584 + i × 8) + 1	EB data field i ($1 \le i \le N$)	Drive-manufacturer ID	2
(3 584 + i × 8) + 2 to (3 584 + i × 8) + 3		Drive model	2
(3 584 + i × 8) + 4 to (3 584 +i × 8) + 5		Firmware version	2
(3 584 + i × 8) + 6 to (3 584+ i × 8) + 7		Drive actions	2
: :	: :	: :	: :
(3 584 + N × 8) to (3 584 + N × 8) + 1	EB data Field N ($N \le 62$)	Drive-manufacturer ID	2
(3 584 + N × 8) + 2 to (3 584 + N × 8) + 3		Drive model	2
(3 584 + N × 8) + 4 to (3 584 + N × 8) + 5		Firmware version	2
(3 584 + N × 8) + 6 to (3 584 + N × 8) + 7		Drive actions	2
[3 584 + (N + 1) × 8] to [3 584 + (N + 1) × 8] + 7	EB footer	Terminator	8
[3 584 + (N + 2) × 8] to 4 095	Unused	Reserved	512 – (N + 2) × 8

Figure 88 — Definition of emergency brake data

Bytes 3 584 to 3 585: EB identifier

These bytes shall be set to 45 42h, representing the characters “EB”.

Byte 3 586: EB version

This byte shall be set to 01h, representing version 1 of the emergency brake format.

Byte 3 587: reserved

This byte shall be set to 00h.

Byte 3 588: EB list length *N*

This byte shall represent the number of EB data fields.

This byte shall be set to 00h when no EB data fields are present.

Bytes 3 589 to 3 591: reserved

These bytes shall be set to 00 00 00h.

Bytes (3 584 + *i* × 8) to (3 584 + *i* × 8) + 1 (1 ≤ *i* ≤ *N*): drive manufacturer ID

The format and the content of these 2 bytes require agreement between the interchange parties, else these bytes shall be set to all 00h.

Bytes (3 584 + *i* × 8) + 2 to (3 584 + *i* × 8) + 3 (1 ≤ *i* ≤ *N*): drive model number

These two bytes represent the drive model number and shall be defined by the drive manufacturer. This document does not specify the format and the content of these bytes. It shall be ignored in interchange.

Bytes (3 584 + *i* × 8) + 4 to (3 584 + *i* × 8) + 5 (1 ≤ *i* ≤ *N*): drive firmware version

These two bytes represent the drive firmware version and shall be defined by the drive manufacturer. This document does not specify the format and the content of these bytes. It shall be ignored in interchange.

Bytes (3 584 + *i* × 8) + 6 to (3 584 + *i* × 8) + 7 (1 ≤ *i* ≤ *N*): drive manufacturer actions

These two bytes represent the actions to be performed by the drive model to handle this disk. These bytes shall be defined by the drive manufacturer. This document does not specify the format and the content of these bytes. It shall be ignored in interchange.

Bytes [3 584 + (*N*+1) × 8] to [3 584 + (*N*+1) × 8] + 7 (0 ≤ *N* ≤ 62): EB terminator

These bytes shall be set to FF FF FF FF FF FF FF FFh to indicate the end of the EB data.

Bytes [3 584 + (*N*+2) × 8] to 4 095 (0 ≤ *N* ≤ 62): reserved

These bytes are reserved.

18.3 Rewritable area of inner zone(s)

18.3.1 Protection zone 2

This zone of 224 physical clusters, starting at PAA 01 B4 80h on layer L0 and at PAA 3E 48 00h on layer L1, is intended to be a buffer zone for the transition from the embossed HFM area to the rewritable area (see 15.4.4).

18.3.2 INFO 2/Reserved 8

This zone of 32 physical clusters, starting at PAA 01 B8 00h on layer L0 and at PAA 3E 47 80h on layer L1, is BDAP-dependent.

For the disks with BCA code, if this setting is not specified by the BDAP, these bytes shall be left unrecorded.

For the disks without BCA code, this zone shall be recorded all 00h before shipping.

18.3.3 INFO 2/Reserved 7

This zone of 32 physical clusters, starting at PAA 01 B8 80h on layer L0 and at PAA 3E 47 00h on layer L1, shall be unrecorded.

18.3.4 INFO 2/Reserved 6

This zone has the size of 32 physical clusters starting at PAA 01 B9 00h on layer L0 and at PAA 3E 46 80h on layer L1, is BDAP-dependent.

For the disks with BCA code, this zone shall be left unrecorded unless otherwise specified by the BDAP.

For the disks without BCA code, this zone shall be recorded all 00h before shipping.

18.3.5 INFO 2/Reserved 5

The use of this zone of 32 physical clusters, starting at PAA 01 B9 80h on layer L0 and at PAA 3E 46 00h on layer L1, is BDAP-dependent.

For the disks with BCA code, this zone shall be left unrecorded unless otherwise specified by the BDAP.

For the disks without BCA code, this zone shall be recorded all 00h before shipping.

18.3.6 INFO 2/PAC 2

This zone of 32 physical clusters, which starts at PAA 01 BA 00h on layer L0 and at PAA 3E 45 80h on layer L1, is intended to be used for storing physical access control (PAC) clusters (see 21.2). Unused clusters in this zone shall contain all 00h or left unrecorded.

18.3.7 INFO 2/DMA 2

This zone of 32 physical clusters starts at PAA 01 BA 80h on layer L0 and at PAA 3E 45 00h on layer L1 and is intended for use by the disk management system (see Clause 22). Unused clusters in this zone shall contain all 00h or left unrecorded.

18.3.8 INFO 2/Control data 2

This zone of 32 physical clusters starts at PAA 01 BB 00h on layer L0 and at PAA 3E 44 80h on layer L1 and is intended to store control information.

Unused clusters in this zone shall contain all 00h.

18.3.9 INFO 2/Buffer 2

This zone of 32 physical clusters starts at PAA 01 BB 80h on layer L0 and at PAA 3E 44 00h on layer L1 and shall be unrecorded.

18.3.10 OPC/Test zone

The test zone of 2 048 physical clusters starts at PAA 01 BC 00h on layer L0 and at PAA 3E 04 00h on layer L1 and is reserved for testing and/or OPC procedures.

After using any part of this area, the used tracks shall either be erased by irradiating these tracks using only the optimum erase powers or be overwritten with clusters containing arbitrary user data using the optimum write powers.

18.3.11 Reserved

This zone of 2 048 physical clusters starts at PAA 01 DC 00h on layer L0 and at PAA 3E 24 00h on layer L1 and shall be unrecorded.

18.3.12 INFO1/Buffer 1

This zone of 32 physical clusters starts at PAA 01 FC 00h on layer L0 and at PAA 3E 03 80h on layer L1 and shall be unrecorded.

18.3.13 INFO 1/Drive area (optional)

18.3.13.1 General

The use of this zone of 32 physical clusters starting at PAA 01 FC 80h on layer L0 and at PAA 3E 03 00h on layer L1 is optional. It can be used by drives to store drive-specific information, restricted to be used only by the drive that has created the information. To guarantee that drives can allocate their own information, the following format shall be used. The clusters in this zone shall be ignored in interchange.

18.3.13.2 Format of drive-specific information

Each drive-specific information shall be contained in one 2K data frame. The first 128 bytes of such a data frame shall contain a signature of the drive that has created the related data frame, according to the following format:

— 48 bytes for the manufacturers name, represented by characters from the ISO 646 character-set;

— 48 bytes of additional identification, represented by characters from the ISO 646 character-set;

— 32 bytes for a unique serial number of the drive.

The format of the remaining 1 920 bytes of the data frame is not defined and can be chosen freely by the drive designer.

The drive-specific information of the last 32 drives that have used this option, shall be stored in one physical cluster. Each time a new drive is going to write its drive-specific information, the oldest drive-specific information located in data frame 31 of the physical cluster is removed from the physical cluster, the content of data frames 0 to 30 are moved into data frames 1 to 31 and the new information is written in data frame 0 (see Figure 89).

For robustness reasons, the physical cluster containing the drive-specific information frames is written on the disk twice.

Initially, the two physical clusters starting at PAA 01 FC 80h and 01 FC 84h shall be used to store the drive-specific information. When both physical clusters become unreliable, the next two physical clusters of the drive area can be used to store the drive-specific information. For a fast and efficient access to the drive area, the DDS in the DMA zones contain an address pointer to the first valid physical cluster in the drive area.

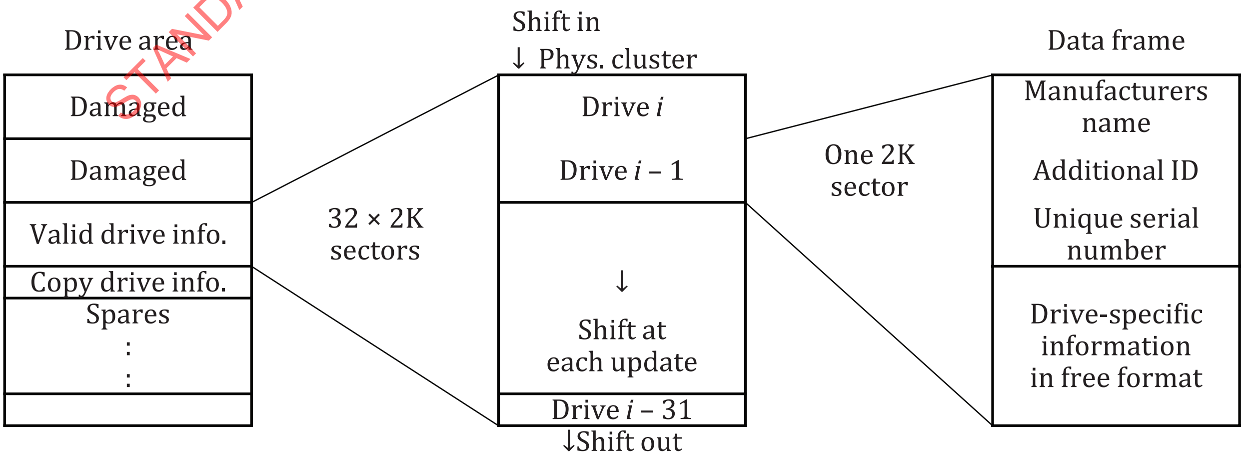


Figure 89 — Format of drive area (example)

18.3.14 INFO 1/Reserved 3

This zone of 32 physical clusters, starting at PAA 01 FD 00h on layer L0 and at PAA 3E 02 80h on layer L1, shall be left unrecorded.

18.3.15 INFO 1/Reserved 2

This zone of 32 physical clusters, starting at PAA 01 FD 80h on layer L0 and at PAA 3E 02 00h on layer L1, shall be left unrecorded.

18.3.16 INFO 1/Reserved 1

This zone of 32 physical clusters, starting at PAA 01 FE 00h on layer L0 and at PAA 3E 01 80h on layer r L1, shall be left unrecorded.

18.3.17 INFO 1/DMA 1

This zone of 32 physical clusters, starting at PAA 01 FE 80h on layer L0 and at PAA 3E 01 00h on layer L1, is intended for use by the disk management system (see Clause 22). Unused clusters in this zone shall contain all 00h or be left unrecorded.

18.3.18 INFO1/Controle data 1

This zone of 32 physical clusters, starting at PAA 01 FF 00h on layer L0 and at PAA 3E 00 80h on layer L1, is intended to store control information. Unused clusters in this zone shall contain all 00h.

18.3.19 INFO1/PAC 1

This zone of 32 physical clusters, starting at PAA 01 FF 80h on layer L0 and at PAA 3E 00 00h on layer L1, is intended to be used for storing physical access control (PAC) clusters (see Clause 21). Unused clusters in this zone shall contain all 00h or be left unrecorded.

19 Data zone

On an SL disk, the data zone can contain a total of 381 856 clusters of user data on a 25,0 GB disk.

On a DL disk, the data zones can contain a total of 763 712 clusters of user data on a 50,0 GB disk.

20 Outer zone(s)

20.1 General

On an SL disk, the outermost zone of the information zone functions as a lead-out zone (see Figure 90).

On a DL disk, the outer zone 0 and outer zone 1 function as a transition area between the data zones on layer L0 and layer L1 (see Figure 91).

Outer zone 0		Description	First PAA of zone	Number of phys. clusters	Purpose
↓ Rewritable ↓ Tracking direction		(Data zone 0)			
	INFO 3	Buffer 3	LAA + 2h	32	—
	INFO 3	DMA 3	LAA + 82h	32	Disk management
	INFO 3	Control data 3	LAA + 1 02h	32	Data information
	—	Angular buffer	LAA + 1 82h	76	—
	INFO 4	DMA 4	LAA + 2 B2h	32	Disk management
	INFO 4	Control data 4	LAA + 3 32h	32	Data information
	INFO 4	Buffer 4	LAA + 3 B2h	32	—
	—	Protection zone 3	LAA + 4 32h	—	—

Figure 90 — Outer zone 0/lead-out zone

Outer zone 1		Description	First PAA of zone	Number of phys. clusters	Purpose
	—	Protection zone 3		—	—
↓ Rewritable ↓ Tracking direction	INFO 4	Buffer 4	FAA – 4 30h	32	—
	INFO 4	Control data 4	FAA – 3 B0h	32	Data information
	INFO 4	DMA 4	FAA – 3 30h	32	Disk management
	—	Angular buffer	FAA – 2 B0h	76	—
	INFO 3	Control data 3	FAA – 1 80h	32	Data information
	INFO 3	DMA 3	FAA – 100h	32	Disk management
	INFO 3	Buffer 3	FAA – 80h	32	—
		(Data zone 1)	FAA		

Figure 91 — Outer zone 1

20.2 INFO 3/Buffer 4

This zone of 32 physical clusters shall be left unrecorded.

20.3 INFO 3/DMA 3

This zone of 32 physical clusters is intended for use by the disk management system (see Clause 22).

Unused clusters in this zone shall contain all 00h or be left unrecorded.

20.4 INFO 3/Control data 4

This zone of 32 physical clusters is intended to store control information.

Unused clusters in this zone shall contain all 00h.

20.5 Angular buffer

This zone with the size of 76 physical clusters shall be left unrecorded.

20.6 INFO 4/DMA 4

This zone of 32 physical clusters is intended for use by the disk management system (see Clause 22).

Unused clusters in this zone shall contain all 00h or be left unrecorded.

20.7 INFO 4/Control data 4

This zone of 32 physical clusters is intended to store control information.

Unused clusters in this zone shall contain all 00h.

20.8 INFO 4 / Buffer 6

This zone of 32 physical clusters shall be unrecorded.

20.9 Protection zone 3

This zone contains an unrecorded groove.

All ADIP units in the grooves in this zone shall be modulated by MSK-cos only and not by HMW (see 15.6.2).

21 Physical access control clusters

21.1 General

Physical access control (PAC) clusters provide a structure on the disk for the exchange of additional information between interchange parties. PAC clusters shall be recorded in the INFO1/PAC1 zone and backup copies shall be recorded in the INFO2/PAC2 zone. All PAC clusters shall have the same format for their first 384 data bytes, which constitute the PAC header.

In the future, new PACs can be defined for specific applications/functions.

Drives designed before the introduction date a new PAC are, in general, not able to interpret it and therefore shall treat such a PAC as a so-called “unknown PAC”. By obeying standard “unknown PAC rules”, defined in the header of the PACs, compatibility problems and unwanted destruction of data for specific applications can be avoided as much as possible.

Drives designed after the introduction date of a new PAC can be assumed to be familiar with the specific application/function connected to the new PAC. Such drives can therefore ignore the “unknown PAC rules” and apply the rules defined in the “PAC-specific information” fields of the PAC. For such “known PACs”, there are no physical access restrictions unless specified otherwise in the “PAC-specific information” fields.

21.2 Layout of PAC zones

On SL disks, the INFO1/PAC1 and INFO2/PAC2 zones each form one area of 32 clusters available for the storage of PAC.

On DL disks, the INFO1/PAC1 zones on layer L0 and layer L1 form one area of 64 clusters available for the storage of PAC, and the INFO2/PAC2 zones on layer L0 and layer L1 form another area of 64 clusters available for the storage of PAC.

Each PAC cluster shall be recorded in both zones, INFO1/PAC1 and INFO2/PAC2, so there are always two copies of each PAC cluster recorded. A PAC shall always be updated first in the INFO1/PAC1 zone and then be copied to the INFO2/PAC2 zone, which eases the handling of possible power-down failures. The PAC-update count of the PAC cluster recorded in the INFO2/PAC2 zone shall be the same as the PAC-update count of the PAC cluster recorded in the INFO1/PAC1 zone.

If a PAC cluster is found to be defective during recording, the defective cluster shall be skipped and indicated as invalid in the DDS (see Figure 92). Such a PAC should be recorded in the next available cluster.

The status of all locations in both the INFO1/PAC1 and INFO2/PAC2 zones shall be indicated in the DDS (see 22.2.2) by a 2-bit pattern as follows:

$b_{(n+1)}$, b_n	Content in PAC location
00	Unrecorded (also to be used if layer not present)
01	Available for re-use[a]
10	Contains an invalid PAC[a]
11	Contains a valid PAC

[a] PAC clusters with status 01 or 10, as indicated in the DDS, shall not be transferred outside the drive, though overwriting is allowed (independent on the setting of bit b_0 and b_1 of the unknown-PAC rules).

Figure 92 — Status of PAC locations

21.3 General structure of PAC clusters

The user data of PAC clusters shall be formatted according to Figure 93. The first 384 bytes constitute the PAC header.

Data frame	Byte position in data frame	Content	Number of bytes
0	0 to 2	PAC_ID	3
0	3	PAC format	1
0	4 to 7	PAC-update count	4
0	8 to 11	Unknown-PAC rules	4
0	12	Unknown-PAC entire_disk_flags	1
0	13 to 14	Reserved	2
0	15	Number of segments	1
0	16 to 23	Segment_0	8
0	24 to 31	Segment_1	8
0	32 to 263	:	29 × 8
0	264 to 271	Segment_31	8
0	272 to 383	Reserved	112
0	384	Known-PAC entire_disk_flags	1
0	385 to 387	Reserved	3
0	388 to 2 047	PAC-specific information	1 660
1	0 to 2 047	PAC-specific information	2 048
:	:	:	:
30	0 to 2 047	PAC-specific information	2 048
31	0 to 2 047	Reserved	2 048

Figure 93 — General layout of PAC clusters

The PAC_ID shall identify the specific type of PAC cluster as follows:

— if set to 00 00 00h, the PAC cluster is unused. The PAC_ID of all subsequent PAC clusters in the INFO1/PAC1 zone or INFO2/PAC2 zone shall be set to 00 00 00h or those subsequent cluster locations shall be unrecorded;

— if set to 50 52 4Dh, the PAC cluster is the primary PAC as defined in 21.4;

— if set to 44 57 50h, the PAC cluster is the DWP PAC as defined in 21.5;

— if set to 49 53 31h, the PAC cluster is the IS1 PAC as defined in 21.6;

— if set to 49 53 32h, the PAC cluster is the IS2 PAC as defined in 21.6;

— if set to FF FF FFh, the PAC cluster is unused. The PAC was previously used and is now available for re-use.

Other values for the PAC_ID are reserved.

Each new PAC added to the INFO1/PAC1 zone or INFO2/PAC2 zone shall be recorded in the first available cluster in these zones (indicated by status 00 or 01 in the DDS, see Figure 92)

The PAC-format field shall indicate the version number of the specific PAC.

The PAC-update count shall specify the total number of update operations of the current PAC. This field shall be set to 00 00 00 00h during the first format operation only and it shall be incremented by one each time the current PAC is re-written.

The unknown PAC rules shall specify the required actions when the content and use of the PAC are unknown (i.e. the PAC_ID is not set to a known value). These bytes form a field consisting of 32 individual bits (bit b_{31} shall be the msb of byte 8 and bit b_0 shall be the lsb of byte 11). The actions described below shall be taken (when the PAC is unknown) for any cluster contained within the related area (see Figure 94). The actions described for the user data area shall be taken only within the specified segments, if segments have been defined; else these actions shall be taken for any cluster contained within the full user data area.

If a drive encounters multiple unknown PACs on one disk, it shall use the OR-function of the unknown PAC rules (in other words, if one of the PACs excludes an action, the same rule of the other PACs is irrelevant).

Area		Bits	Control type	Mandatory setting
		b_{31} to b_{24}	Reserved	0000 0000
INFO 2	Reserved 8	b_{23}	Write	-
		b_{22}	Read	-
	Reserved 7	b_{21}	Write	ONE
		b_{20}	Read	-
	Reserved 6	b_{19}	Write	-
		b_{18}	Read	-
	Reserved 5	b_{17}	Write	-
		b_{16}	Read	-
INFO 1	Drive area	b_{15}	Write	ZERO
		b_{14}	Read	ZERO
INFO 1	Reserved 3	b_{13}	Write	ONE
		b_{12}	Read	-
	Reserved 2	b_{11}	Write	ONE
		b_{10}	Read	-
	Reserved 1	b_9	Write	ONE
		b_8	Read	-
INFO 1,2,3,4	DMA zones (not including the DDS; see 22.2)	b_7	Write	-
		b_6	Reserved unless otherwise specified by the BDAP	
INFO 1,2,3,4	Control data zones	b_5	Write	-
		b_4	Read	-
Data zones	User-data area / Segments	b_3	Write	-
		b_2	Read	-
INFO 1 and 2	PAC cluster	b_1	Write	-
		b_0	Read	-

"-": No mandatory setting specified, as well ZERO as ONE can be allowed depending on specific PAC

Figure 94 — General bit assignments for unknown PAC rules

For all zones/areas, except the PAC cluster, the bits have the following meaning:

— Control type = write:

— if set to ZERO: indicating that writing in the related zone/area is allowed; and

— if set to ONE: indicating that writing in the related zone/area shall not be allowed.

— Control type = read:

— if set to ZERO: indicating that reading in the related zone/area is allowed; and

— if set to ONE: indicating that reading in the related zone/area shall not be allowed.

The meaning of “reading shall not be allowed” in this context is: the data content of the clusters in the related area(s) are not allowed to be transferred outside the drive or presented to the user.

For the PAC cluster, the bits have the following meaning:

— Control type = write:

  — if set to ZERO: indicating that overwriting the current PAC cluster or changing its status bits in the DDS is allowed; and

  — if set to ONE: indicating that overwriting the current PAC cluster and changing its status bits in the DDS shall not be allowed, except during re-initialization.

— Control type = read:

  — if set to ZERO: indicating that reading and transferring the content of the current cluster outside the drive is allowed; and

  — if set to ONE: indicating that the content of the current PAC cluster, except for the first 384 bytes of the first data frame, shall not be transferred outside the drive, to be enforced by setting all bytes not belonging to the PAC header to 00h before passing the content of the cluster.

The unknown PAC entire_disk_flags byte shall specify unknown PAC rules that cover the entire disk:

— Bits b_7 to b_1: These bits shall be reserved.

— Bit b_0: Re-initialization:

  — if set to ZERO: indicating that re-initialization is allowed, if not blocked by any other write protect mechanism for the entire disk; and

  — if set to ONE: indicating that re-initialization shall not be allowed if the PAC is unknown to the drive.

The number of segments shall specify the total number N ($0 \le N \le 32$) of segments specified in the current PAC.

Moreover, the total number of segments defined for all PACs on a disk shall not exceed 32 as per Formula (52):

$$\sum_{i=0}^{N} n_{S,i} \le 32 \qquad (52)$$

where $n_{S,i}$ is number of segments in PAC_i.

The Segment_*i* field shall specify the starting and ending address of a contiguous range of clusters, called a segment. Segments shall be assigned, starting from Segment_0 to Segment (N – 1) ($N \le 32$).

Segments specified within one PAC shall not overlap and shall be sorted in ascending order according to their addresses. Segments shall only start and end at cluster boundaries. All Segment_*i* fields, where $i \ge N$, shall be set to all 00h:

— the first 4 bytes of the Segment_*i* field, if used, shall contain the first PSN of the first cluster belonging to the segment;

— the last 4 bytes shall contain the last PSN of the last cluster belonging to the segment.

These segments shall only be applied to the unknown PAC rules. If overlapping segments in different PAC clusters are encountered, the drive shall apply the OR-function to the related unknown PAC rules in the overlap areas.

The known-PAC entire_disk_flags byte specifies rules for the entire disk in case the drive is able to interpret the PAC:

— Bits b_7 to b_1: These bits shall be reserved.

— Bit b_0: Re-initialization:

 — if set to ZERO: indicating that re-initialization is allowed, if not blocked by any other write-protect mechanism for the entire disk; and

 — if set to ONE: indicating that re-initialization shall not be allowed.

The PAC-specific information fields contain information that is specific to the current PAC.

21.4 Primary PAC cluster (mandatory)

The primary PAC cluster shall be included on each disk to provide information about the date when the disk was initially recorded and to identify each recorder that has recorded individual clusters on the disk. The layout of the primary PAC cluster shall be formatted as depicted in Figure 95.

Data frame	Byte position in data frame	Content	Number of bytes
0	0 to 2	PAC_ID	3
0	3	PAC format	1
0	4 to 7	PAC-update count	4
0	8 to 11	Unknown-PAC rules	4
0	12	Unknown-PAC entire_disk_flags	1
0	13 to 14	Reserved	2
0	15	Number of segments	1
0	16 to 23	Segment_0	8
0	24 to 31	Segment_1	8
0	32 to 263	:	29 × 8
0	264 to 271	Segment_31	8
0	272 to 383	Reserved	112
0	384	Known-PAC entire_disk_flags	1
0	385 to 387	Reserved	3
0	388 to 389	Number of recorder ID entries	2
0	390 to 393	Year/Month/Date of initial recording	4
0	394	Re-initialization RID_tag #	1
0	395 to 511	Reserved	117
0	512 to 639	Recorder ID for RID_tag 01h	128
0	640 to 767	Recorder ID for RID_tag 02h	128
0	768 to 895	Recorder ID for RID_tag 03h	128
:	:	:	:
0	1 920 to 2 047	:	128
1	0 to 127	Recorder ID for RID_tag xxh	128
:	:	:	:
15	1 920 to 2 047	Recorder ID for RID_tag FCh	128
16	0 to 2 047	Reserved	2 048
:	:	:	:
31	0 to 2 047	Reserved	2 048

Figure 95 — Layout of primary PAC cluster

The PAC_ID shall be set to 50 52 4Dh, representing the characters “PRM”.

The PAC-format field shall be set to 00h, to indicate this is a primary PAC version zero.

The PAC-update count shall specify the total number of update operations of the current PAC. This field shall be set to 00 00 00 00h during the first format operation only and shall be incremented by one each time the current PAC is re-written.

The unknown PAC rules shall be set as shown in Figure 96.

Area		Bits	Control type	Mandatory setting
		b_{31} to b_{24}	Reserved	0000 0000
INFO 2	Reserved 8	b_{23}	Write	ZERO
		b_{22}	Read	ZERO
	Reserved 7	b_{21}	Write	ONE
		b_{20}	Read	ZERO
	Reserved 6	b_{19}	Write	ONE
		b_{18}	Read	ZERO
	Reserved 5	b_{17}	Write	ZERO
		b_{16}	Read	ZERO
INFO 1	Drive area	b_{15}	Write	ZERO
		b_{14}	Read	ZERO
INFO 1	Reserved 3	b_{13}	Write	ONE
		b_{12}	Read	ZERO
	Reserved 2	b_{11}	Write	ONE
		b_{10}	Read	ZERO
	Reserved 1	b_9	Write	ONE
		b_8	Read	ZERO
INFO 1,2,3,4	DMA zones (not including the DDS; see 22.2)	b_7	Write	ZERO
		b_6	Reserved unless otherwise specified by the BDAP	
INFO 1,2,3,4	Control-data zones	b_5	Write	ZERO
		b_4	Read	ZERO
Data zones	User-data area / Segments	b_3	Write	ZERO
		b_2	Read	ZERO
INFO 1 and 2	PAC cluster	b_1	Write	ZERO
		b_0	Read	ZERO

Figure 96 — Bit assignments for unknown PAC rules for primary PAC

The unknown PAC entire_disk_flags byte shall be set to 00h to indicate re-initialization of the disk is allowed if this PAC is unknown to the drive and there are no other mechanisms blocking re-initialization.

The number of segments shall be set to 00h.

The Segment_*i* fields shall be set to all 00h.

The known-PAC entire_disk_flags byte shall be set to 00h to indicate re-initialization of the disk is allowed in case the drive is able to interpret this PAC and there are no other mechanisms blocking re-initialization.

The number of recorder ID entries field shall specify the number (≤252) of 128-byte recorder IDs contained in bytes 512 to 2 047 of data frame 0 and bytes 0 to 2 047 of data frames 1 to 15. The maximum number of available locations is 252 (see also description at recorder ID for RID_tag xxh).

The year/month/date of initial recording fields shall indicate the year (4 digits BCD), the month (two digits BCD) and the date (two digits BCD) when the very first recording on this disk was made. If a drive is not able to correctly set this field, these bytes shall be set to 00h.

The re-initialization RID_tag # shall specify the recorder-ID tag number of the recorder that last initialized/re-initialized the disk.

The recorder ID for RID_tag xxh fields shall contain the 128-byte drive signatures of all recorders (up to a maximum of 252) that have made any recordings on this disk. Such drive signatures shall be entered according to the following format (see 18.3.13.2):

— 48 bytes for the manufacturers name, represented by characters from the ISO 646 character-set;

— 48 bytes of additional identification, represented by characters from the ISO 646 character-set;

— 32 bytes for a unique serial number of the drive.

The first time a recorder writes data to a disk, it shall add its recorder ID to this list. There shall be no duplicate entries and new entries shall only be appended to the end of the list. This list shall not be sorted or changed in any other way, since the relative location of each entry determines the RID_tag value (see Figure 95) assigned to each specific recorder. After all available recorder ID fields have been used, recorders whose recorder ID can not be registered in the PAC anymore, shall use the RID_tag value FFh.

The RID_tag value assigned to a specific recorder shall be recorded in the address units as defined in 13.9.2.3 to indicate that the cluster has been recorded by that recorder.

21.5 Disk write-protect PAC cluster (optional)

The disk write-protect (DWP) PAC cluster is optional and can be used to protect a disk against unintended write actions or write actions by unauthorized persons. For the latter purpose, a password can be included. If a valid DWP PAC cluster exists on the disk, products that understand the PAC shall follow the rules indicated by the WP control bits, else they shall follow the unknown PAC rules. The layout of the DWP PAC cluster shall be formatted as depicted in Figure 97.

Data frame	Byte position in data frame	Content	Number of bytes
0	0 to 2	PAC_ID	3
0	3	PAC format	1
0	4 to 7	PAC-update count	4
0	8 to 11	Unknown-PAC rules	4
0	12	Unknown-PAC entire disk flags	1
0	13 to 14	Reserved	2
0	15	Number of segments	1
0	16 to 23	Segment_0	8
0	24 to 31	Segment_1	8
0	32 to 263	:	29 × 8
0	264 to 271	Segment_31	8
0	272 to 383	Reserved	112
0	384	Known-PAC entire_disk_flags	1
0	385 to 387	Reserved	3
0	388	WP control byte	1
0	389 to 395	Reserved	7
0	396 to 427	WP password	32
0	428 to 2 047	Reserved	1 620
1	0 to 2 047	Reserved	2 048
:	:	:	:
31	0 to 2 047	Reserved	2 048

Figure 97 — Layout of DWP PAC cluster

The PAC_ID shall be set to 44 57 50h, representing the characters “DWP”.

The PAC-format field shall be set to 00h, to indicate this is a DWP PAC version zero.

The PAC-update count shall specify the total number of update operations of the current PAC. This field shall be set to 00 00 00 00h during the first format operation only and shall be incremented by one each time the current PAC is re-written.

The unknown PAC rules shall be set as shown in Figure 98.

Area		Bits	Control type	Mandatory setting
		b_{31} to b_{24}	Reserved	0000 0000
INFO 2	Reserved 8	b_{23}	Write	ZERO
		b_{22}	Read	ZERO
	Reserved 7	b_{21}	Write	ONE
		b_{20}	Read	ZERO
	Reserved 6	b_{19}	Write	ONE
		b_{18}	Read	ZERO
	Reserved 5	b_{17}	Write	ZERO
		b_{16}	Read	ZERO
INFO 1	Drive area	b_{15}	Write	ZERO
		b_{14}	Read	ZERO
INFO 1	Reserved 3	b_{13}	Write	ONE
		b_{12}	Read	ZERO
	Reserved 2	b_{11}	Write	ONE
		b_{10}	Read	ZERO
	Reserved 1	b_9	Write	ONE
		b_8	Read	ZERO
INFO 1,2,3,4	DMA zones (not including the DDS; see 22.2)	b_7	Write	ZERO/ONE
		b_6	Reserved unless otherwise specified by the BDAP	
INFO 1,2,3,4	Control data zones	b_5	Write	ZERO/ONE
		b_4	Read	ZERO
Data zones	User-data area/Segments	b_3	Write	ZERO/ONE
		b_2	Read	ZERO
INFO 1 and 2	PAC cluster	b_1	Write	ONE
		b_0	Read	ONE

Figure 98 — Bit assignments for unknown PAC rules for DWP PAC

Bits b_7, b_6, b_5 and b_3 shall be set to ZERO if bit b_0 of the WP control byte is set to ZERO (WP off) and bits b_7, b_6, b_5 and b_3 shall be set to ONE if bit b_0 of the WP control byte is set to ONE (WP on).

The unknown PAC entire_disk_flags byte shall be set to 01h to indicate re-initialization of the disk is not allowed if this PAC is unknown to the drive.

The number of segments shall be set to 00h.

The Segment_*i* fields shall all be set to all 00h.

The known-PAC entire_disk_flags byte shall be set to 00h to indicate re-initialization of the disk is allowed in case the drive is able to interpret this PAC and there are no other mechanisms blocking re-initialization.

The WP control byte shall specify the allowed and required actions (see Figure 99) as follows:

— Bits b_7 to b_3: These 5 bits shall be reserved.

— Bit b_2: This bit indicates WP with/without password (PWD):

  — if it is set to ZERO, no checking of the password is needed;

  — if it is set to ONE, in case bit b_0 is set to ONE, the write protection is switched on, only host-initiated write actions shall be allowed if the password supplied by the host matches the password contained on the disk.

— Bit b_1: This bit indicates the method of write protection:

  — if set to ZERO, this bit indicates virtual WP. After executing the required actions as specified in Figure 99, host-initiated write actions shall be executed without changing the write protection settings on the disk;

  — if set to ONE, this bit indicates the physical WP. After executing the required actions as specified in Figure 99, host-initiated write actions shall only be executed after setting bit b_0 to ZERO, indicating that the write protection is switched off.

— Bit b_0: This bit indicates write protect on/off:

  — if set to ZERO, it indicates that write protection is switched off (WP off) and the host-initiated write actions is allowed without any restrictions;

  — if set to ONE, it indicates that write protection is switched on (WP on), meaning that all write actions initiated by the host shall be blocked by the drive and the host-initiated write actions are only allowed after executing the required actions as specified in Figure 99;

  — if the write protection is switched on, re-initializing the disk shall not be allowed.

The WP control byte shall only be changed after executing the required actions as specified in Figure 99.

The WP password can consist of up to 32 characters from the ISO 646 character-set. Trailing bytes not used shall be set to 00h. The WP password shall never be transferred outside the drive.

If all bytes of the WP password field are set to 00h, then the WP password feature is inactive and bit b_2 of the WP control byte shall be set to ZERO.

If the WP password field is set to all FFh, then the disk is permanently write-protected and further host-initiated write actions on the disk shall not be allowed. Bits b_2, b_1 and b_0 of the WP control byte shall be set to 111.

WP control			Status	Actions	
b_2	b_1	b_0		For writing data	For changing WP control bits or the password
0	0	0	No PWD/virtual/WP off	Allowed	Allowed
0	0	1	No PWD/virtual/WP on	Allowed after confirmation by the host	Allowed after confirmation by the host
0	1	0	No PWD/physical/WP off	Allowed	Allowed
0	1	1	No PWD/physical/WP on	Allowed after confirmation by the host and changing to WP off	Allowed after confirmation by the host
1	0	0	With PWD/virtual/WP off	Allowed	Allowed after confirmation of the password supplied by the host
1	0	1	With PWD/virtual/WP on	Allowed after confirmation of the password supplied by the host	Allowed after confirmation of the password supplied by the host
1	1	0	With PWD/physical/WP off	Allowed	Allowed after confirmation of the password supplied by the host
1	1	1	With PWD/physical/WP on	Allowed after confirmation of the password supplied by the host and changing to WP off	Allowed after confirmation of the password supplied by the host

Figure 99 — Status and allowed actions defined by write-control bits

21.6 IS1 and IS2 PAC clusters

The IS1 PAC and IS2 PAC may be recorded on a disk. When BCA code is not recorded on a disk, IS1/IS2 PAC structures shall be recorded in INFO1/PAC1 and INFO2/PAC2 before being shipped. When BCA code is recorded on a disk, IS1/IS2 PAC structures shall not be recorded.

The layout of the IS1 PAC and IS2 PAC cluster shall be formatted as depicted in Figure 100.

Data frame	Byte position in data frame	Content	Number of bytes
0	0 to 2	PAC_ID	3
0	3	PAC format	1
0	4 to 7	PAC-update count	4
0	8 to 11	Unknown-PAC rules	4
0	12	Unknown-PAC entire_disk_flags	1
0	13 to 14	Reserved	2
0	15	Number of segments	1
0	16 to 23	Segment_0	8
0	24 to 31	Segment_1	8
0	32 to 263	:	29 × 8
0	264 to 271	Segment_31	8
0	272 to 383	Reserved	112
0	384	Known-PAC entire_disk_flags	1
0	385 to 2 047	Reserved	1 663
1	0 to 2 047	Reserved	2 048
:	:	:	:
31	0 to 2 047	Reserved	2 048

Figure 100 — General layout of IS1 and IS2 PAC clusters

The PAC_ID shall be set to 49 53 31h, representing the characters “IS1” for IS1 PAC. The PAC_ID shall be set to 49 53 32h, representing the characters “IS2” for IS2 PAC.

The PAC-format field shall be set to 00h for both PACs, to indicate this is version zero.

The PAC-update count shall be set to 00 00 00 00h for both PACs.

The unknown PAC rules shall be set to 00 AA 2A 00h for IS1 PAC and shall be set to 00 AA 2A CBh for IS2 PAC.

The unknown PAC entire_disk_flags byte shall be set to 01h for IS1 PAC and shall be set to 00h for IS2 PAC.

The number of segments shall be set to 00h for both PACs.

The Segment_*i* fields shall be set to all 00h for both PACs.

The known-PAC entire_disk_flags byte shall be set to 01h for both PACs

22 Disk management

22.1 General

Disk management defines and controls method of recording data on the disk including defect management data. defect management is used to solve problems related to areas on the disk that can have become defective or unreliable through damage or contamination.

Depending on the BDAP and/or the applied file system, defect management can be handled by the drive or by the file system.

In the defect list, the following two types of defects can be distinguished:

— defects called NRD which stands for non-re-allocatable defect;

— unreliable areas on the disk, called PBA which stands for possibly bad area. Before using such a PBA for the allocation of data, the reliability of the area should be checked.

22.2 Disk management structure (DMS)

22.2.1 General

A disk management structure is made up of a disk definition structure (DDS) and a defect list (DFL). The disk definition structure consists of one cluster that shall be repeated 4 times for robustness reasons. The defect list consists of 4 consecutive clusters on an SL disk and 8 consecutive clusters on a DL disk.

Whenever a disk leaves a recorder, all DMS shall correctly reflect the current status of the disk.

All 4 occurrences of the DMS, recorded in the DMA zones in the inner and outer zone(s), shall contain the same information, except for the first PSN of defect list (see 22.2.2, byte 24 of data frame 0). The DMA zones shall be updated in the order DMA 1, DMA 2, DMA 3, DMA 4 for ease of handling possible power-down failures. After such an update, all DDS update counts (see 22.2.2, byte 4 of data frame 0) shall be the same and all DFL-update counts (see 22.2.4, byte 4 of data frame 0/cluster 0 and 22.2.5, defect list terminator) shall be the same.

DMS on an SL disk

On an SL disk, the DMA zones consist of 32 consecutive clusters as indicated in Figure 101.

Tracking direction →

Layer L0	Cluster 1	Cluster 2	Cluster 3	...	Cluster 31	Cluster 32

Figure 101 — Clusters of DMA zones on SL disk

The DDS shall always be recorded in the first 4 clusters of each DMA zones.

The DFL is recorded initially in clusters 5 to 8 of each DMA zone. Whenever any of the 4 clusters of the DFL in a DMA zone starts to become unreliable, the complete DFL is moved to the next 4 clusters of the DMA zone concerned (see Figure 102). The position of the valid DFL is indicated in the DDS.

Cluster 1 to 4	DDS (four repetitions)	
Cluster 5 to 8	First position of DFL	Damaged DFL
Cluster 9 to 12	Second position of DFL	Valid DFL
Cluster 13 to 16	Third position of DFL	Empty
:	:	:
Cluster 29 to 32	Seventh position of DFL	Empty

Figure 102 — Example of DMA zone on SL disk

DMS on a DL disk

On a DL disk, the DMA zones consist of 64 clusters divided over the two recording layers as indicated in Figure 103.

Tracking direction →

Layer L0	Cluster 1	Cluster 2	Cluster 3	...	Cluster 31	Cluster 32
Layer L1	Cluster 64	Cluster 63	...	Cluster 35	Cluster 34	Cluster 33

← Tracking direction

Figure 103 — Clusters of DMA zones on DL disk

The DDS shall always be recorded in the first 4 clusters of each DMA zone. The next 4 clusters are reserved.

The DFL is recorded initially in clusters 9 to 16 of each DMA zone. Whenever any of the 8 clusters of the DFL in a DMA zone starts to become unreliable, the complete DFL is moved into the next 8 clusters of the DMA zone concerned (see Figure 104). The position of the valid DFL is indicated in the DDS.

Cluster 1 to 4	DDS (four repetitions)	
Cluster 5 to 8	Reserved	
Cluster 9 to 16	First position of DFL	Damaged DFL
Cluster 17 to 24	Second position of DFL	Valid DFL
Cluster 25 to 32	Third position of DFL	Empty
:	:	:
Cluster 57 to 64	Seventh position of DFL	Empty

Figure 104 — Example of DMA zone on DL disk

22.2.2 Disk definition structure (DDS)

The DDS specifies the format and status of the disk with respect to the disk management. The format of the DDS is defined in Figure 105.

Data frame	Byte position in data frame	Content	Number of bytes
0	0 to 1	DDS identifier	2
0	2	DDS format	1
0	3	Reserved	1
0	4 to 7	DDS-update count	4
0	8 to 15	Reserved	8
0	16 to 19	First PSN of drive area	4
0	20 to 23	Reserved	4
0	24 to 27	First PSN of defect list	4
0	28 to 31	Reserved	4
0	32 to 35	Location of LSN 0 of user-data area	4
0	36 to 39	Last LSN of user-data area	4
0	40 to 51	Reserved unless otherwise specified by the BDAP	12
0	52	Flag A	1
0	53	Reserved	1
0	54	Reserved unless otherwise specified by the BDAP	1
0	55	Reserved	1
0	56 to 59	Reserved unless otherwise specified by the BDAP	4
0	60 to 63	Reserved	4
0	64 to 71	Status bits of INFO 1/PAC 1 locations on layer L0	8
0	72 to 79	Status bits of INFO 2/PAC 2 locations on layer L0	8
	80 to 87	Status bits of INFO 1/PAC 1 locations on layer L1	8
	88 to 95	Status bits of INFO 2/PAC 2 locations on layer L1	8
0	96 to 2 047	Reserved	1 952
1	0 to 2 047	Reserved	2 048
:	:	:	:
31	0 to 2 047	Reserved	2 048

Figure 105 — Format of DDS

The DDS identifier shall be set to 44 53h, representing the characters “DS”.

The DDS format field shall be set to 00h, identifying a DDS.

The DDS update count shall specify the total number of update operations of the DDS. This field shall be set to 00 00 00 00h during the first format operation only and shall be incremented by one each time the DDS is re-written.

The first PSN of drive area field shall specify the first PSN of the first cluster of the pair of clusters that contains the drive-specific information frames.

If the drive area is unrecorded, this field shall be set to 00 00 00 00h.

The first PSN of defect list field shall specify the first PSN of the defect list in the DMA zone containing this particular DDS.

The location of LSN 0 of user data area field shall specify the PSN of the first user data frame in the first cluster after the Lead-in zone. This field shall be set to 00 10 00 00h unless otherwise specified by the BDAP.

The last LSN of user data area field shall specify the logical sector number (LSN; see Clause 23) of the last sector available for the storage of user data and shall be set to 00 BA 73 FFh for SL disks and 01 74 E7 FFh for DL disks unless otherwise specified by the BDAP.

The 8-bit flag A field specifies the status of an SL disk or a DL disk. This byte shall be set to 03h on SL disks and 0Fh on DL disks unless otherwise specified by the BDAP.

The status bits of INFO 1/PAC 1 locations on layer L0 field shall specify the recording status of all 32 clusters in the INFO 1/PAC 1 zone on layer L0 (see Figure 106). The bit pairs shall be set as defined in 21.3.

Byte position	Bits	INFO 1/PAC 1 location PAA
64	b_7 b_6	01 FF 80h
64	b_5 b_4	01 FF 84h
64	b_3 b_2	01 FF 88h
64	b_1 b_0	01 FF 8Ch
65	b_7 b_6	01 FF 90h
:	:	:
:	:	:
70	b_1 b_0	01 FF ECh
71	b_7 b_6	01 FF F0h
71	b_5 b_4	01 FF F4h
71	b_3 b_2	01 FF F8h
71	b_1 b_0	01 FF FCh

Figure 106 — Status bits and related INFO 1/PAC 1 address locations on layer L0

The status bits of INFO 2/PAC 2 locations on layer L0 field shall specify the recording status of all 32 clusters in the INFO 2/PAC 2 zone on layer L0 (see Figure 107). The bit pairs shall be set as defined in 21.3.

Byte position	Bits	INFO 2/PAC 2 location PAA
72	b_7 b_6	01 BA 00h
72	b_5 b_4	01 BA 04h
72	b_3 b_2	01 BA 08h
72	b_1 b_0	01 BA 0Ch
73	b_7 b_6	01 BA 10h
:	:	:
:	:	:
78	b_1 b_0	01 BA 6Ch
79	b_7 b_6	01 BA 70h
79	b_5 b_4	01 BA 74h
79	b_3 b_2	01 BA 78h
79	b_1 b_0	01 BA 7Ch

Figure 107 — Status bits and related INFO 2/PAC 2 address locations on layer L0

The status bits of INFO 1/PAC 1 locations on layer L1 field shall specify the recording status of all 32 clusters in the INFO 1/PAC 1 zone on layer L1 (see Figure 108). The bit pairs shall be set as defined in 21.3.

Byte position	Bits	INFO 1/PAC 1 location PAA
80	b_7 b_6	3E 00 00h
80	b_5 b_4	3E 00 04h
80	b_3 b_2	3E 00 08h
80	b_1 b_0	3E 00 0Ch
81	b_7 b_6	3E 00 10h
:	:	:
:	:	:
86	b_1 b_0	3E 00 6Ch
87	b_7 b_6	3E 00 70h
87	b_5 b_4	3E 00 74h
87	b_3 b_2	3E 00 78h
87	b_1 b_0	3E 00 7Ch

Figure 108 — Status bits and related INFO 1/PAC 1 address locations on layer L1

The status bits of INFO 2/PAC 2 locations on layer L1 field shall specify the recording status of all 32 clusters in the INFO 2/PAC 2 zone on layer L1 (see Figure 109). The bit pairs shall be set as defined in 21.3.

Byte position	Bits	INFO 2/PAC 2 location PAA
88	b_7 b_6	3E 45 80h
88	b_5 b_4	3E 45 84h
88	b_3 b_2	3E 45 88h
88	b_1 b_0	3E 45 8Ch
89	b_7 b_6	3E 45 90h
:	:	:
:	:	:
94	b_1 b_0	3E 45 ECh
95	b_7 b_6	3E 45 F0h
95	b_5 b_4	3E 45 F4h
95	b_3 b_2	3E 45 F8h
95	b_1 b_0	3E 45 FCh

Figure 109 — Status bits and related INFO 2/PAC 2 address locations on layer L1

22.2.3 Defect list (DFL)

The first of the 4 or 8 clusters constituting the DFL contains a defect list header followed by a list of defects. The list of defects shall be terminated by a defect list terminator.

The DFL shall be composed as shown in Figure 110.

Cluster number/ data frame	Start byte position in data frame	Content	Number of bytes
0/0	0	Defect-list header	64
0/0 : 0/31	64	List of defects	65 472
1/0 : 1/31	0	List of defects	65 536
:			
K/0 : :	0	List of defects	$n \times 8$
:	$n \times 8$	Defect-list terminator	8
: : *K*/31	$(n + 1) \times 8$	set 00h	..
K = 3 on an SL disk and *K* = 7 on a DL disk			

Figure 110 — Format of DFL

The defect list header (DLH) identifies the defect list and contains information about the composition of the list of defects (see 22.2.4).

The list of defects contains a list of clusters determined to be defective during use of the media (see 22.2.5).

The defect list terminator closes the list of defects and shall be written immediately following the actual last entry in the list of defects. The defect list terminator can be located in any of the 4 (SL disk) or 8 (DL disk) clusters constituting the DFL, depending on the number of entries in the list of defects. All remaining bytes following the defect list terminator shall be set to 00h.

22.2.4 Defect list header (DLH)

The format of the DLH is defined in Figure 111.

The DFL identifier shall be set to 44 4Ch, representing the characters “DL”.

The DFL format field shall be set to 00h, identifying a DFL.

The DFL-update count shall specify the total number of update operations of the defect list. This field shall be set to 00 00 00 00h during the first format operation only and shall be incremented by one each time the DFL is re-written.

The number of DFL entries, N_{DFL}, shall indicate the total number of entries in the DFL and N_{DFL} shall be sum of numbers of NRD and PBA unless otherwise specified by the BDAP:

— For an SL disk: $N_{DFL} \leq 32\ 759$;

— For a DL disk: $N_{DFL} \leq 65\ 527$.

Cluster number/ data frame	Byte position in data frame	Content	Number of bytes
0/0	0 to 1	DFL identifier	2
0/0	2	DFL format	1
0/0	3	Reserved	1
0/0	4 to 7	DFL-update count	4
0/0	8 to 11	Reserved	4
0/0	12 to 15	Number of DFL entries (N_{DFL})	4
0/0	16 to 19	Reserved unless otherwise specified by the BDAP	4
0/0	20 to 23	Number of NRD entries	4
0/0	24 to 27	Reserved unless otherwise specified by the BDAP	4
0/0	28 to 31	Number of PBA entries	4
0/0	32 to 35	Reserved unless otherwise specified by the BDAP	4
0/0	36 to 63	Reserved	28

Figure 111 — Format of DLH

The number of NRD entries shall specify the total number of NRD entries in the DFL.

The number of NRD entries is a variable number that can be changed during the use of the disk.

The number of PBA entries shall specify the total number of PBA entries in the DFL.

The number of PBA entries is a variable number that can be changed during the use of the disk.

22.2.5 List of defects

The format of the list of defects is shown in Figure 112.

The DFL entries shall be formatted as specified in 22.2.6. DFL entries consist of 8 bytes and are recorded contiguously, even across the borders of data frames and clusters.

The defect list terminator (DFL terminator) shall be composed of the following two 4-byte parts:

— the first 4 bytes shall be set FF FF FF FFh;

— the second 4 bytes shall be equal to the DFL-update count in the header of the DFL (can be used to check the validity of the defect list at power-down failures).

Cluster number/ data frame	Start byte position in data frame	Content	Number of bytes
0/0	64	DFL entry 0	8
0/0	72	DFL entry 1	8
:	:	...	..
0/0	$i \times 8 + 64$	DFL entry i	8
:	:	...	..
0/0	2 032	DFL entry 246	8
0/0	2 040	DFL entry 247	8
0/1	0	DFL entry 248	8
0/1	8	DFL entry 249	8
:	:	...	..
0/1	2 040	DFL entry 503	8
:	:	...	..
0/n	0	DFL entry $n \times 256 - 8$	8
:	:	...	..
:	:	...	..
0/31	2 040	DFL entry 8 183	8
:			
m/0	0	DFL entry $m \times 8\,192 - 8$	8
:	:	...	..
m/0	$j \times 8$	DFL entry $m \times 8\,192 - 8 + j$	8
:	:	...	..
m/0	2 040	DFL entry $m \times 8\,192 - 8 + 255$	8
m/1	0	DFL entry $m \times 8\,192 - 8 + 256$	8
:	:	...	..
m/1	2 040	DFL entry $m \times 8\,192 - 8 + 511$	8
:	:	...	..
m/n	0	DFL entry $m \times 8\,192 + n \times 256 - 8$	8
:	:	...	..
:	:	...	..
m/31	2 040	DFL entry $m \times 8\,192 + 8\,191 - 8$	8
:			
:	:	...	..
K/n (K⊠m)	$[(N_{DFL} - 1) \times 8 + 64 - n \times 2\,048 - K \times 65\,536]$	DFL entry $(N_{DFL} - 1)$	8
K/n	$[N_{DFL} \times 8 + 64 - n \times 2\,048 - K \times 65\,536]$	DFL terminator	8
K/n	$[(N_{DFL} + 1) \times 8 + 64 - n \times 2\,048 - K \times 65\,536]$	Set to 00h	..
K/(n + 1) to K/31	0	Set to 00h	2 048

K = 3 on an SL disk and K = 7 on a DL disk

Figure 112 — Format of list of defects

22.2.6 DFL entries

Each DFL entry shall be formatted as shown in Figure 113. The bytes of the DFL entry are converted into a 64-bit sequence with the msb's first.

The list of defects shall be sorted in ascending order as if each entry were a single 64-bit unsigned integer of which the msb is ignored (always supposed to be ZERO), which means that first sorted by status 1, and within status 1 by defective cluster first PSN, and within defective cluster first PSN by status 2, and within status 2 by number of successive clusters.

byte 0/bit 7..4 of DFL entry *i*	byte 0/bit 3..0 and byte 1 to 3 of DFL entry *i*	byte 4/bit 7..4 of DFL entry *i*	byte 4/bit 3..0 and byte 5 to 7 of DFL entry *i*
b_{63} .. b_{60}	b_{59} .. b_{32}	b_{31} .. b_{28}	b_{27} .. b_0
Status 1	Defective cluster first PSN	Status 2	Number of successive clusters

Figure 113 — DFL entry format

The defective cluster first PSN shall identify the PSN of the first physical sector of the cluster to be indicated. Only the 28 least significant bits of the PSN shall be stored in bits b_{59} .. b_{32} (the 4 most significant bits are discarded). Each defective cluster shall appear only once in the list of defects.

The number of successive clusters field shall indicate the number of successive clusters covered by the possibly bad area (the value 0 00 00 00h indicates that the number of unreliable clusters is unknown) when status 1 field is set to 0100 (see Figure 114). When status 1 field is not set to 0100, this field is reserved unless otherwise specified by the BDAP.

The status 1 field shall indicate the status of the entry as shown in Figure 114.

Status 1	Type	Definition
0001	NRD	The entry identifies a defective location.
0100	PBA	The entry identifies an area on the disk that can be defective and shall be checked. The defective cluster first PSN shall identify the PSN of the first physical sector of the first cluster related to an error event. PBAs shall not include any NRD locations.
Other settings	Reserved unless otherwise specified by the BDAP.	

Figure 114 — DFL entry status 1 definition

The status 2 field shall indicate the status of the entry as shown in Figure 115.

Status 2	Definition
0000	This (default) setting shall be used if none of the following settings is valid.
0100	(Only allowed in combination with status 1 = 0100 unless otherwise specified by the BDAP.) The clusters do not contain any relevant user data. During read-modify-write actions the content of such clusters can be discarded (related status bits $Sa_{i,1}/Sa_{i,0}$ at new location can be set to 11). If the clusters covered by a PBA can contain valid user data, the status 2 of such a PBA shall be set to 0000.
Other settings	Reserved unless otherwise specified by the BDAP.

Figure 115 — DFL entry status 2 definition

23 Assignment of logical sector numbers (LSNs)

Logical sector numbers shall be assigned contiguously over all clusters available for the storage of user data starting from LSN 0 and increasing by one for each successive user data frame (see Figure 116).

Unless otherwise specified by the BDAP, LSN 0 is assigned to the first user data frame in the first cluster after the lead-in zone (at PSN = 1 048 576).

The last LSN on layer L0 is equal to 8 × LAA + 15 – 1 048 576 and is assigned to the last user data frame in the last cluster before the lead-out zone/outer zone 0 (at PSN = 8 × LAA + 15 = *X*).

The first LSN on layer L1 shall be one higher than the last LSN on layer L0 and is assigned to the first user data frame in the first cluster after the outer zone 1 (at PSN = 8 × FAA = $\overline{X + \text{FE 00 00 00h}}$).

The last LSN on layer L1 is equal to 16 × LAA + 31 – 2 097 152 and is assigned to the last user data frame in the last cluster before the lead-out zone (at PSN = 01 EF FF FFh).

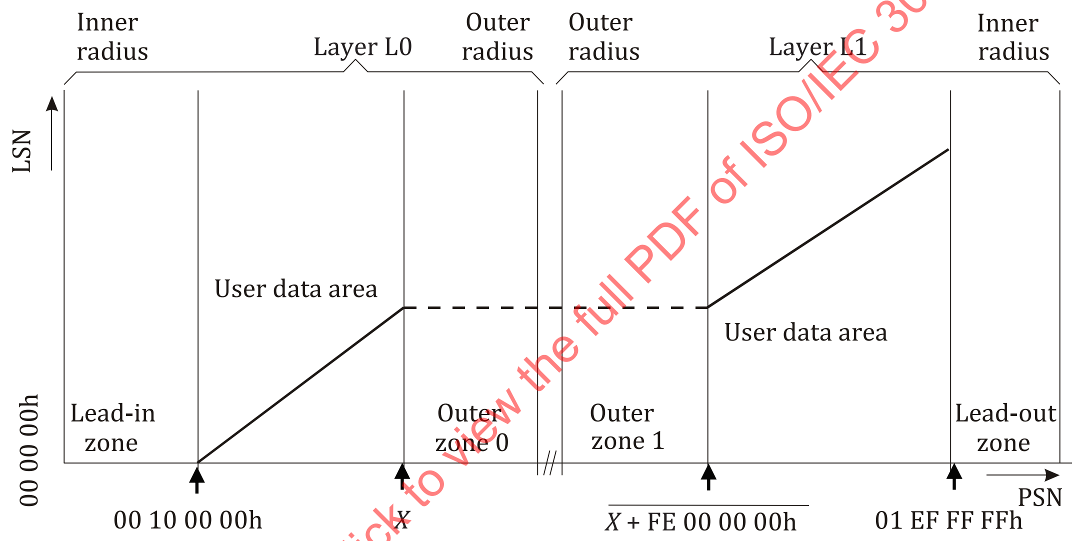


Figure 116 — Assignment of logical sector numbers

24 Characteristics of grooved areas

The signal values specified in Clauses 24 to 28 are valid for all disk capacities, unless specified otherwise.

In this document, the following two types of signals are distinguished:

— signals generated by the groove structures on the disk;

— signals generated by user-written marks.

In Clauses 25 to 28, the signals generated by the groove structures are defined and specified (the format of the grooves has been defined in Clause 15).

All requirements in Clauses 25 to 28 shall be fulfilled in all layers independent of the recording status of other recording layer (whether unrecorded, recorded or partially recorded) from the inner radius of the embossed HFM area(s) (start/end of the PIC zone) at nominal radius 22,4 mm up to the inner radius of the outer zone(s) + 20 µm (d_{DZO}/2 + 20 µm). It is recommended that the requirements are also fulfilled in the remainder of the outer zone(s).

25 Method of testing for grooved area

25.1 General

When measuring the signals, the influence of local defects, such as dust and scratches, are excluded. Local defects can cause tracking errors, erroneous ADIP information or uncorrectable data (see Clause 34).

Measurement for Clause 25 to 27 shall follow the procedure in Annex I.

25.2 Environment

All signals shall be within their specified ranges if the disk is in its range of allowed environmental conditions as defined in 8.1.1.

25.3 Reference drive

25.3.1 General

All signals shall be measured in the appropriate channels of a reference drive as specified in Clause 9 and in Annex H.

25.3.2 Read power

The read power is the optical power incident on the entrance surface of the disk. The read power shall be (0,35 ± 0,1) mW for an SL disk and (0,70 ± 0,1) mW for a DL disk.

25.3.3 Read channels

The drive shall have two read channels as defined in 9.5 and 9.6.

The HF signal from the HF read channel shall not be equalized, except when measuring jitter (see Annex H for detailed specifications).

For measurement of the push-pull signals, the radial PP read channels shall be filtered by a first order LPF with f_{-3dB} = 30 kHz.

For measurement of the wobble signals, the radial PP read channels shall be filtered by a first order LPF with f_{-3dB} = 8 MHz.

25.3.4 Tracking requirements

During measurement of the signals, the axial tracking error between the focus of the optical beam and the recording layer shall be maximum 55 nm, and the radial tracking error between the focus of the optical beam and the centre of the track shall be maximum 16 nm.

25.3.5 Scanning velocity

The actual rotation speed of the disk shall be such that it results in an average channel-bit rate of 66,000 Mbit/s or an average wobble frequency of 956,522 kHz.

25.4 Signals

The amplitudes of all signals are linearly related to currents through a photodetector and therefore linearly related to the optical power falling on the detector.

Some signals are normalized relative to the total detector current in an unrecorded, grooved area.

This total detector current is referred to as per Formula (53):

$$I_G = (I_1 + I_2)_{groove} \tag{53}$$

Push-pull signal

The push-pull signal is the low-pass filtered sinusoidal difference signal ($I_1 - I_2$) in the radial PP read channel (see Figure 8), when the focus of the optical beam crosses the tracks. The push-pull signal can be used by the drive for radial tracking (see Figure 117).

In general, the difference signal ($I_1 - I_2$) is normalized relative to the low-pass filtered total detector current ($I_1 + I_2$). The peak-to-peak value of this real-time normalized push-pull signal, V_{PPnorm}, is defined as per Formula (54):

$$V_{PPnorm} = \left[\frac{I_1(t) - I_2(t)}{I_1(t) + I_2(t)}\right]_{peak-peak} \equiv \frac{(I_1 - I_2)_{at\ t_2}}{(I_1 + I_2)_{at\ t_2}} - \frac{(I_1 - I_2)_{at\ t_1}}{(I_1 + I_2)_{at\ t_1}} \tag{54}$$

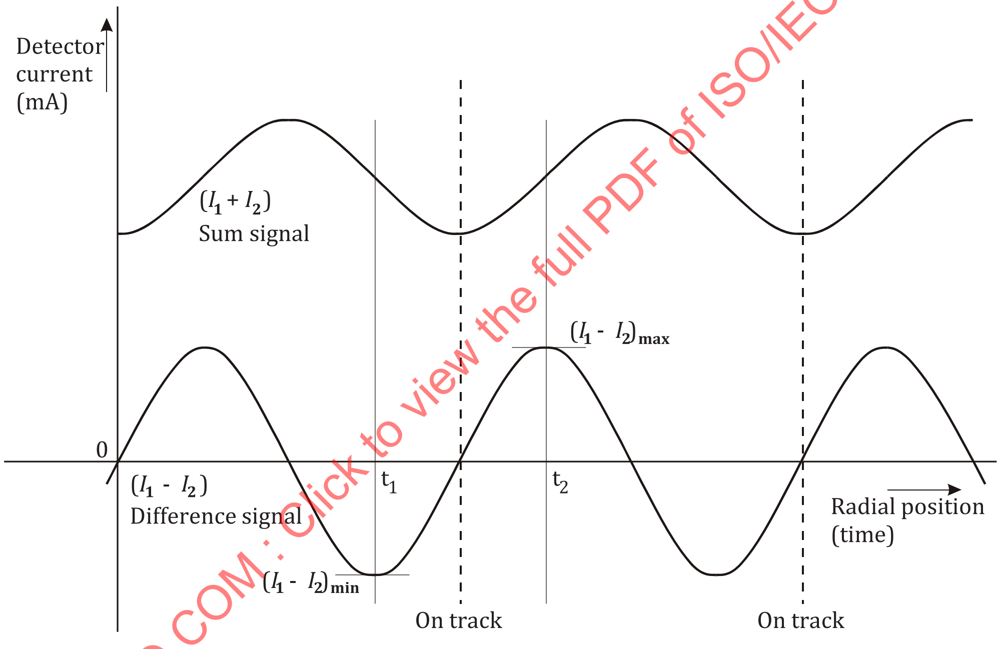


Figure 117 — Definition of push-pull signals

Wobble signal

The wobble signal I_{Wpp} is the peak-to-peak value of the sinusoidal difference signal ($I_1 - I_2$) in the radial PP read channel (see Figure 8), when the focus of the optical beam follows the tracks according to 25.3.4. See also Annex M and Annex E for a measurement method.

The signal shall be normalized by the peak-to-peak value of the push-pull signal $(I_1 - I_2)_{pp}$ to be, I_{NWS}, as per Formula (55):

$$I_{NWS} = \frac{I_{Wpp}}{(I_1 - I_2)_{pp}} \tag{55}$$

26 Signals from HFM grooves

26.1 Push-pull signal

The peak-to-peak value of the real-time normalized push-pull signal, $V_{PPnorm,HFM}$, in the embossed HFM areas shall be as per Formula (56):

$$0,26 \leq V_{PPnorm,HFM} \leq 0,52 \tag{56}$$

26.2 HFM wobble signal

The normalized HFM-wobble signal is a measure of the deviation of the groove track from its average centreline. Due to interference with the wobbles of adjacent tracks, the amplitude of the HFM wobble signal shows a variation (called "wobble beat").

At locations where the HFM wobble signal shows minimum amplitudes due to the wobble beat, the normalized HFM-wobble signal amplitude, I_{NHWS}, shall be as per Formula (57):

$$0,30 \leq I_{NHWS,min} \leq 0,60 \tag{57}$$

At locations where the HFM wobble signal shows maximum amplitudes due to the wobble beat, the normalized HFM-wobble signal shall be as per Formula (58):

$$I_{NHWS,max} \leq 3 \times I_{NHWS,min} \tag{58}$$

NOTE Because the shape of the HFM-wobble signal detected in the embossed HFM areas differs significantly from the wobble signal in the rewritable areas, the measurement procedure as described in Annex E is not suitable for measuring these HFM-wobble signals.

26.3 Jitter of HFM signal

The binarized HFM wobble signal from the HFM grooves represents the embossed HFM information in the PIC zone. The jitter of the leading edges and the jitter of the trailing edges of this binarized signal shall be measured separately relative to a PLL clock.

Both the leading-edge jitter and the trailing-edge jitter shall be ≤4,5 %.

The jitter shall be measured under the following conditions:

— ac coupling (High-Pass Filter): first order, f_{-3dB} = 10 kHz;

— no equalization;

— normalized by 18T clock period (see 15.5.4.2).

27 Signals from wobbled groove(s)

27.1 Phase depth

The single-pass phase depth of the groove shall not exceed 90°.

27.2 Push-pull signal

The peak-to-peak value of the real-time normalized push-pull signal, V_{PPnorm}, shall meet the requirements of Formulae (59) to (64) in each layer:

— in unrecorded areas (all neighboring tracks unrecorded):

$$0{,}21 \leq V_{\text{PPnorm,unrec.}} \leq 0{,}45 \tag{59}$$

— maximum variation of push-pull signal within 150 tracks in unrecorded areas:

— for SL disks;

$$\frac{(V_{\text{PPnorm,unrec.}})_{\max} - (V_{\text{PPnorm,unrec.}})_{\min}}{(V_{\text{PPnorm,unrec.}})_{\max} + (V_{\text{PPnorm,unrec.}})_{\min}} \leq 0{,}15 \tag{60}$$

— for DL disks;

$$\frac{(V_{\text{PPnorm,unrec.}})_{\max} - (V_{\text{PPnorm,unrec.}})_{\min}}{(V_{\text{PPnorm,unrec.}})_{\max} + (V_{\text{PPnorm,unrec.}})_{\min}} \leq 0{,}18 \tag{61}$$

— maximum variation of push-pull signal within one layer in unrecorded areas:

$$\frac{(V_{\text{PPnorm,unrec.}})_{\max} - (V_{\text{PPnorm,unrec.}})_{\min}}{(V_{\text{PPnorm,unrec.}})_{\max} + (V_{\text{PPnorm,unrec.}})_{\min}} \leq 0{,}25 \tag{62}$$

— in recorded areas (all neighboring tracks recorded):

$$0{,}21 \leq V_{\text{PPnorm,rec.}} \leq 0{,}45 \tag{63}$$

— ratio of average push-pull signals in recorded and unrecorded areas within one layer:

$$0{,}75 \leq \frac{V_{\text{PPnorm,rec.}}}{V_{\text{PPnorm,unrec.}}} \leq 1{,}25 \tag{64}$$

27.3 Wobble signal

27.3.1 General

The normalized wobble signal is a measure of the deviation of the groove track from its average centreline. The distance that the actual centre of the wobbled groove track deviates from the average track centre line can be calculated according to information in Annex M.

27.3.2 Measurement of I_{NWS}

Due to interference with the wobbles of adjacent tracks, the amplitude of the wobble signal shows a variation (called “wobble beat”). The wobble signals shall be measured in an unrecorded area while continuously tracking the spiral groove. A measurement procedure shall follow Annex E.

At locations where the wobble signal shows minimum amplitudes (excluding the effects of MSK marks), the normalized wobble signal shall be as per Formula (65):

$$0{,}20 \leq I_{\text{NWS,min}} \leq 0{,}55 \tag{65}$$

At locations where the wobble signal shows maximum amplitudes due to the wobble beat, the

normalized wobble signal shall be as per Formula (66):

$$I_{\text{NWS,max}} \leq 3 \times I_{\text{NWS,min}} \tag{66}$$

27.3.3 Measurement of wobble CNR

The narrow band S/N (or CNR) of the wobble signal after recording shall be greater than 26 dB at the locations where the wobble signal shows minimum amplitudes.

The carrier shall be measured at 956,5 kHz and while the noise level shall be measured at 500 kHz (see Annex E for detailed specifications).

27.3.4 Measurement of harmonic distortion requirements

To guarantee a minimum quality of the HMW modulation, the second harmonic distortion of the wobble signal shall be sufficiently low compared to the second harmonic level originating from the HMW modulation.

The second harmonic level, L_{SHL}, and the second harmonic distortion level, L_{SHD}, shall be determined by measuring the fundamental wobble frequency level and the second harmonic frequency level at two locations of the disk. Both levels shall be measured in the data zone and in protection zone 3.

The ratio of the L_{SHD} and L_{SHL}, normalized to the local fundamental wobble frequency level, shall meet one of the following requirements:

— L_{SHD}/L_{SHL} < –12 dB with zero radial tilt;

— L_{SHD}/L_{SHL} < –6 dB within ±0,70° of radial tilt.

The measurements shall be made using a spectrum analyzer (see Annex E for detailed specifications).

28 Characteristics of recording layer

The signal values specified in Clauses 28 to 31 are valid for all disk capacities, unless specified otherwise.

In this document, the following two types of signals are distinguished:

— signals generated by groove structures on the disk;

— signals generated by user-written marks.

Clauses 28 to 31 specify a series of tests to assess the recording properties of the recording layer, as used for writing data.

All requirements in Clauses 28 to 31 shall be fulfilled in all layers independent of the recording status of other recording layer (whether unrecorded, recorded or partially recorded) from the inner radius of the rewritable area (start/end of the INFO/OPC zone) at nominal radius 23,2 mm up to the inner radius of the outer zone(s) + 20 µm (d_{DZO}/2 + 20 µm). It is recommended that the requirements are also fulfilled in the remainder of the outer zone(s).

Measurement for Clause 28 to 31 shall follow the procedure in Annex I.

29 Method of testing for recording layer

29.1 General

The tests shall be performed in the rewritable areas. The write and read operations necessary for the tests shall be made on the same reference drive.

When measuring the signals, the influence of local defects, such as dust and scratches, are excluded. Local defects can cause tracking errors or uncorrectable data (see Clause 33).

29.2 Environment

All signals shall be within their specified ranges when the disk is in its range of allowed environmental conditions as defined in 8.1.1.

29.3 Reference drive

29.3.1 General

All signals shall be measured in the appropriate channels of a reference drive as specified in Clause 9 and in Annex H.

29.3.2 Read power

The read power is the optical power, incident on the entrance surface of the disk and only used for reading the information. The read power shall be (0,35 ± 0,1) mW for an SL disk and (0,70 ± 0,1) mW for a DL disk.

29.3.3 Read channels

The drive shall have two read channels as defined in 9.5 and 9.6. The HF signal from the HF read channel shall not be equalized, except when measuring jitter (see Annex H for detailed specifications).

29.3.4 Tracking requirements

During the writing and reading of the signals, the axial tracking error between the focus of the optical beam and the recording layer shall be a maximum of 55 nm, and the radial tracking error between the focus of the optical beam and the centre of the track shall be maximum 16 nm.

29.3.5 Scanning velocities

Write tests shall be carried out at all velocities defined in each of the DI units that are present on the disk (see 15.8.3).

During reading, the actual rotation speed of the disk shall be such, that it results in an average channel-bit rate of 66,000 Mbit/s or an average wobble frequency of 956,522 kHz.

29.4 Write conditions

29.4.1 Write-pulse waveform

Marks and spaces are written on the disk by pulsing a laser. The laser power is modulated according to one of the write-pulse waveforms given in Annex F. A 2T to 9T NRZI run length is written by applying a multi-pulse train of write pulses.

The laser power during recording has the following four levels:

— the write peak power P_W;

— the bias write power P_{BW};

— the cooling power P_C;

— the erase power P_E (or P_{E1} and P_{E2} in case of the N-1 write strategy A, see Annex F for detailed definition).

which are the optical powers incident on the entrance surface of the disk.

Marks are created by the write peak power P_W, spaces are created by the erase power P_E (or P_{E1} and P_{E2}).

The values of P_W, P_{BW}, P_C, P_E or P_{E1} and P_{E2} shall be optimized according to Annex G for detailed procedure.

The actual powers P_W, P_{BW}, P_C, P_E or P_{E1} and P_{E2} for testing shall be within ±5% of their optimum values, where P_{BW}, P_C, P_E or P_{E1} and P_{E2} shall be proportional to P_W according to the ratios ε as specified in the disk information (see 15.8.3).

29.4.2 Write powers

The optimized write powers P_{WO}, P_{BWO}, P_{CO}, P_{EO} or P_{E1O} and P_{E2O} shall meet the conditions as shown in Figure 118 (values in mW).

	Single-layer disk				Dual-layer disk			
	1x recording velocity		2x recording velocity		1x recording velocity		2x recording velocity	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
P_{WO}	3,0	6,0	3,0	7,0	6,0	12,0	6,0	14,0
P_{BWO}	0,1	4,0	0,1	7,0	0,1	8,0	0,1	14,0
P_{CO}	0,1	4,0	0,1	7,0	0,1	8,0	0,1	14,0
P_{EO} / P_{EO1}	0,3	4,6	0,3	5,4	0,6	9,2	0,6	10,8
P_{E2O}	0,3	4,6	0,3	5,4	0,6	9,2	0,6	10,8

Figure 118 — Write power values for single and dual-layer disks at 1x and 2x recording velocity

29.4.3 Write conditions for jitter measurement

The test for jitter shall be carried out on any group of five adjacent tracks, designated (m – 2), (m – 1), m, (m + 1), (m + 2) in the rewritable areas of the disk.

The five tracks are recorded consecutively with random data with a write power $P_W = P_{WO}$ as specified in 29.4.1. To measure the jitter after n overwrites [jitter @ DOW(n)], all five tracks are overwritten n times with random data with a write power $P_W = P_{WO}$.

29.4.4 Write conditions for cross-erase measurement

The test for cross-erase shall be carried out on any group of five adjacent tracks, designated (m – 2), (m – 1), m, (m + 1), (m + 2), in the rewritable areas of the disk.

To initialize the measurement, the five tracks are recorded ten times repeatedly with random data with a write power $P_W = P_{WO}$ as specified in 29.4.1. After that, the initial values of the needed parameters are measured. This initial condition is defined as the $DOW(0)_{XE}$ condition.

To measure the cross-erase after n overwrites [cross-erase @ $DOW(n)_{XE}$], the tracks (m – 1) and (m + 1), are overwritten n times with $P_W = 1{,}1 \times P_{WO}$ (all power levels shall be proportional to P_W, see 29.4.1).

29.4.5 Write conditions for inter-velocity overwrite measurements

The test for inter-velocity overwrite shall be carried out on any group of five adjacent tracks, designated (m – 2), (m – 1), m, (m + 1), (m + 2), in the rewritable areas of the disk.

To initialize the measurement, the five tracks are recorded at one of the specified recording velocities ten times repeatedly with random data with a write power $P_W = P_{WO}$ as specified in 29.4.1. After that, the five tracks shall be overwritten once at another recording velocity.

29.5 Definition of signals

The amplitudes of all signals are linearly related to currents through a photodetector and therefore linearly related to the optical power falling on the detector.

Jitter

Jitter is the standard deviation σ of the time variations of the transitions in the binary read signal. This binary read signal is obtained by feeding the HF signal from the HF read channel through an equalizer, a LPF and a slicer (see Annex H for detailed specifications). The jitter of the leading edges and the jitter of the trailing edges is measured separately relative to a PLL clock and normalized by the channel-bit clock period.

30 Signals from recorded areas

30.1 HF signals

The HF signal is obtained by summing the currents of the four elements of the photodetector. These currents get modulated by the different reflectivity of the marks and spaces representing the information on the recording layer (see Figure 119).

30.2 Modulated amplitude

The modulated amplitude I_{8pp} is the peak-to-peak value of the HF signal generated by the largest mark and space lengths. The peak value I_{8H} is the peak value of the HF signal before ac coupling.

The modulated amplitude I_{2pp} is the peak-to-peak value of the HF signal generated by the smallest mark and space lengths. The 0 level is the signal level obtained from the measuring device when no disk is inserted.

NOTE In the sync patterns, run lengths of 9T occur. However, the recurrence of these 9Ts is very low and therefore their influence on the HF peak-to-peak signal is negligible.

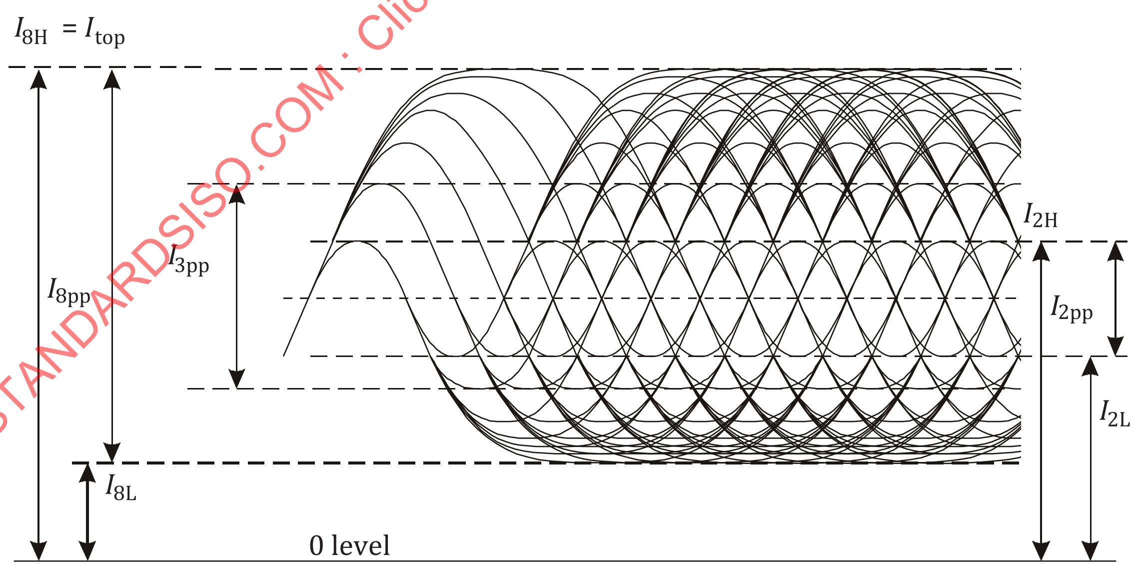


Figure 119 — Schematic representation of HF signal from marks and spaces

Because the I_{2pp} is a relatively small signal, its amplitude can not be determined reliably from a random HF signal. Therefore, it is recommended to record an area with consecutive 2T marks and spaces only and to record an area with consecutive 8T marks and spaces only. The signals can now be measured accurately with appropriate measuring equipment.

The modulation signals shall meet the requirements of Formulae (67) to (69):

$$I_{8pp} / I_{8H} \geq 0{,}40 \tag{67}$$

$$I_{3pp} / I_{8pp} \geq 0{,}25 \tag{68}$$

$$I_{2pp} / I_{8pp} \geq 0{,}050 \text{ for disks with a capacity of 25,0 GB and 50,0 GB} \tag{69}$$

The variations of the modulation signals shall be as per Formulae (70) and (71):

— within one layer at DOW(0) (continuously recorded):

$$(I_{8Hmax} - I_{8Hmin}) / I_{8Hmax} \leq 0{,}33 \tag{70}$$

— within one revolution at DOW(0) (continuously recorded):

$$(I_{8Hmax} - I_{8Hmin}) / I_{8Hmax} \leq 0{,}15 \tag{71}$$

For DL disks, the ratio between the modulation signals on layer L0 and layer L1, at DOW(0) (continuously recorded), shall be as per Formula (72):

$$-0{,}25 \leq (I_{8H,L0} - I_{8H,L1}) / (I_{8H,L0} + I_{8H,L1}) \leq +0{,}25 \tag{72}$$

where $I_{8H,L0}$ and $I_{8H,L1}$ are measured at the same position, both in radial and in tangential direction.

30.3 Reflectivity modulation product

The reflectivity of the disk multiplied by the modulation (= normalized I_{8pp} modulated amplitude) shall be as per Formulae (73) and (74) (see Annex B for detailed specifications):

— for SL disks:

$$R \times M = R_{8H} \times \left(\frac{I_{8pp}}{I_{8H}}\right), \text{ with } 0{,}050 \leq R \times M \leq 0{,}15 \tag{73}$$

— for DL disks:

$$R \times M = R_{8H} \times \left(\frac{I_{8pp}}{I_{8H}}\right), \text{ with } 0{,}016 \leq R \times M \leq 0{,}048 \tag{74}$$

The reflectivity of the disk multiplied by the I_2 resolution (= normalized I_{2pp} modulated amplitude) shall be as per Formulae (75) and (76):

— for SL disks with capacity of 25,0 GB:

$$R \times I_2 = R_{8H} \times \left(\frac{I_{2pp}}{I_{8H}}\right), \quad R \times I_2 \geq 0{,}005\,0 \tag{75}$$

— for DL disks with capacity of 50,0 GB:

$$R \times I_2 = R_{8H} \times \left(\frac{I_{2pp}}{I_{8H}}\right), \quad R \times I_2 \geq 0{,}001\,2 \tag{76}$$

30.4 Asymmetry

The HF signal asymmetry shall meet the requirement of Formula (77):

$$-0,10 \le \left(\frac{\frac{I_{8H}+I_{8L}}{2} - \frac{I_{2H}+I_{2L}}{2}}{I_{8pp}} \right) \le +0,15 \quad (77)$$

30.5 Jitter

The tracks on which the jitter is to be measured, shall be recorded as specified in 29.4.3.

The jitter shall be measured on the centre track m of the five recorded tracks, at the reference velocity.

After n overwrites ($0 \le n \le 10$) of track m, both the leading-edge jitter and the trailing-edge jitter in track m (measured separately) shall fulfil the following requirements:

On an SL disk and on layer L0 of a DL disk for all disks, independent on capacity:

— ≤7,0 % when measured using the circuit specified in Annex H and this circuit set to limit-equalizer mode, and

— ≤6,5 % when measured using the circuit specified in Annex H and this circuit set to limit-equalizer mode and the edges that are adjacent to a 2T mark or a 2T space are not included in the jitter measurement.

On layer L1 of a DL disk for all disks, independent on capacity:

— ≤8,5 % when measured using the circuit specified in Annex H and this circuit set to limit-equalizer mode, and

— ≤6,5 % when measured using the circuit specified in Annex H and this circuit set to limit-equalizer mode and the edges that are adjacent to a 2T mark or a 2T space are not included in the jitter measurement.

NOTE Not including edges that are adjacent to a 2T mark or a 2T space means that in the jitter measurement only those edges are taken into account that are in between an nT mark/space and an mT space/mark, with both $n \ge 3$ and $m \ge 3$.

30.6 Cross-erase

The tracks on which the cross-erase is to be measured, shall be recorded as specified in 29.4.4. After n overwrites ($0 \le n \le 10$) of tracks (m − 1) and (m + 1), the modulation and jitter in track m shall fulfil the requirement of Formula (78):

$$\left(\frac{\left(I_{8pp}/I_{8H}\right) \text{at DOW}(n)_{XE}}{\left(I_{8pp}/I_{8H}\right) \text{at DOW}(0)_{XE}} \right) \ge 0,90 \quad (78)$$

After n overwrites, both the leading-edge jitter and the trailing edge jitter (measured separately) shall fulfil the following requirements:

— on an SL disk and on layer L0 of a DL disk for all disks, independent on capacity, ≤7,0 % when measured using the circuit specified in Annex H and this circuit set to limit equalizer mode;

— on layer L1 of a DL disk for all disks, independent on capacity:

  — ≤9,0 % when measured using the circuit specified in Annex H and this circuit set to limit equalizer mode; and

  — ≤ 7,0 % when measured using the circuit specified in Annex H and this circuit set to limit equalizer mode and the edges that are adjacent to a 2T mark or a 2T space are not included in the jitter measurement.

NOTE Not including edges that are adjacent to a 2T mark or a 2T space means that in the jitter measurement only those edges are taken into account that are in between an *n*T mark/space and an *m*T space/mark, with both $n \geq 3$ and $m \geq 3$.

30.7 Inter-velocity overwrite

The tracks on which the inter-velocity overwrite is to be measured and shall be recorded as specified in 29.4.5 for all combinations of all specified recording velocities.

The jitter shall be measured on the centre track *m* of the five recorded tracks, at the reference velocity and shall fulfil the following requirements:

— on an SL disk and on layer L0 of a DL disk for all disks, independent on capacity:

  — ≤7,0 % when measured using the circuit specified in Annex H and this circuit set to limit equalizer mode; and

  — ≤6,5 % when measured using the circuit specified in Annex H and this circuit set to limit equalizer mode and the edges that are adjacent to a 2T mark or a 2T space are not included in the jitter measurement;

— on layer L1 of a DL disk for all disks, independent on capacity:

  — ≤8,5 % when measured using the circuit specified in Annex H and this circuit set to limit equalizer mode, and

  — ≤6,5 % when measured using the circuit specified in Annex H and this circuit set to limit equalizer mode and the edges that are adjacent to a 2T mark or a 2T space are not included in the jitter measurement.

NOTE Not including edges that are adjacent to a 2T mark or a 2T space means that, in the jitter measurement, only those edges are taken into account which are between an *n*T mark/space and an *m*T space/mark, with both $n \geq 3$ and $m \geq 3$.

30.8 Read stability

Up to 10^6 successive reads from a single track with a DC read power of:

— 0,40 mW for SL disks at 1x speed reading;

— 0,44 mW for SL disks at 2x speed reading;

— 0,70 mW for DL disks at 1x speed reading; and

— 0,80 mW for DL disks at 2x speed reading.

The disk shall remain within all specifications in the operating environment.

Up to 10^6 successive reads from a single track with an HF-modulated read power (averaged) of:

— 0,30 mW for SL disks at 1x speed reading;

— 0,33 mW for SL disks at 2x speed reading;

— 0,60 mW for DL disks at 1x speed reading; and

— 0,70 mW for DL disks at 2x speed reading.

The disk shall remain within all specifications in the operating environment.

The modulation should fulfil the following (see Figure 120):

—	modulation frequency (= $1/T_{\text{HF-laser}}$)	(400 ± 40) MHz;
—	pulse width	(300 ± 30) ps;
—	ratio of peak power and average power	7,0 ± 0,7;
—	bottom level between peaks	flat

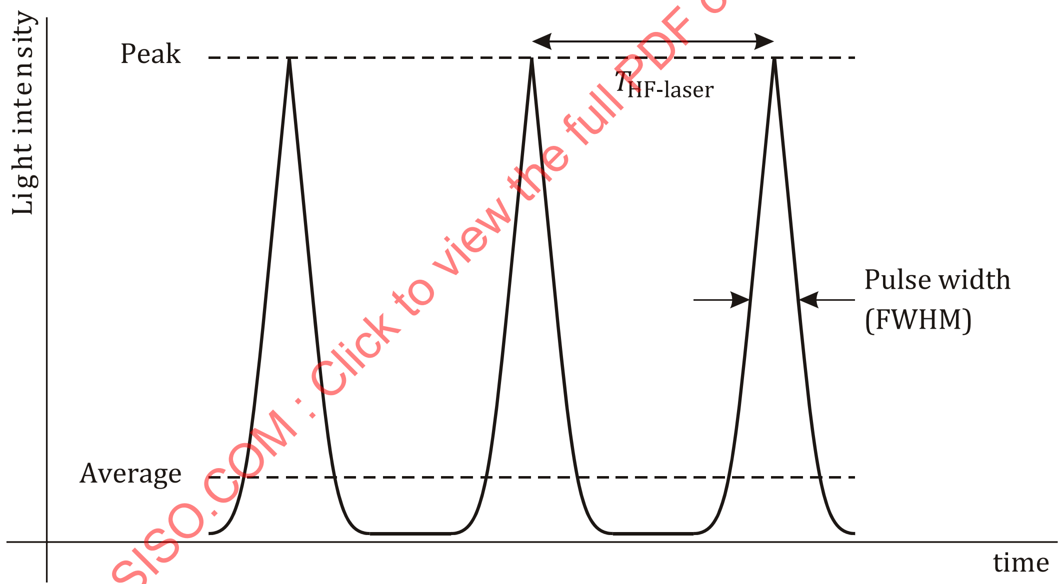


Figure 120 — Schematic representation of light pulses from laser diode

Additionally, the SER (see 34.1) shall be <4,2 × 10^{-3} in any LDC block.

Equivalent to <317 counts (= 4,2 × 10^{-3} × 75 392 bytes).

31 Local defects

Defects on the recording layer or in the transmission stack, such as “air bubbles” or “black dots” (such as dust enclosures in the transmission stack or pin holes in the reflective layer) shall not cause any unintended track jumping or uncorrectable errors (see also 33.4 and Clause 34).

The size of such defects shall be as follows:

— air bubbles: <100 µm;

— black dots with birefringence: <150 µm; and

— black dots without birefringence: <150 µm.

32 Characteristics of user data

Clauses 32 to 34 describes a series of measurements to test conformance of user data on the disk. They check the legibility of user-written data. The data is assumed to be arbitrary.

User-written data may have been written by any drive at any speed in any operating environment.

33 Method of testing for user data

33.1 General

The read tests described in Clauses 32 to 34 shall be performed on the reference drive.

Whereas Clauses 24 to 30 disregard local defects, Clauses 32 to 34 include them as unavoidable deterioration of the read signals. The gravity of a defect is determined by the correctability of the ensuing errors by the error detection and correction circuit in the read channel defined below. The requirements in Clauses 32 to 34 define a minimum quality of the data, necessary for data interchange.

33.2 Environment

All signals shall be within their specified ranges when the disk is in its range of allowed environmental conditions as defined in 8.1.1.

33.3 Reference drive

33.3.1 General

All signals shall be measured in the appropriate channels of a reference drive as specified in Clause 9.

33.3.2 Read power

The read power is the optical power incident on the entrance surface of the disk. The read power shall be (0,35 ± 0,1) mW for an SL disk and (0,70 ± 0,1) mW for a DL disk.

33.3.3 Read channels

The drive shall have two read channels as defined in 9.5 and 9.6.

The HF signal from the HF read channel shall be equalized and filtered before processing. The threshold level for converting an HF signal into a binary read signal shall be controlled to minimize the effects of mark and space size changes, due to parameter variations during writing. For measurement of disk quality, the characteristics of the equalizer, filter and slicer, as well as the characteristics of the PLL shall be the same as specified in Annex H (limit equalizer) for the jitter measurement.

33.3.4 Error correction

Correction of errors in the data bytes shall be carried out by an error detection and correction system based on the definitions in Clause 13.

33.3.5 Tracking requirements

During measurements of the signals, the axial tracking error between the focus of the optical beam and the recording layer shall be maximum 55 nm and the radial tracking error between the focus of the optical beam and the centre of the track shall be maximum 16 nm.

33.3.6 Scanning velocities

The actual rotation speed of the disk shall be such that it results in an average channel-bit rate of 66,000 Mbit/s or an average wobble frequency of 956,522 kHz.

33.4 Error signals

Byte error

A byte error occurs when one or more bits in a byte have a wrong value, as detected by the related error detection and/or correction circuits.

Burst error

A burst error is defined to be a sequence of bytes where there are not more than two correct bytes between any two erroneous bytes. For determining burst errors, the bytes shall be ordered in the same sequence as they were recorded on the disk (see 13.1 and 13.8).

The length of a burst error is defined as the total number of bytes counting from the first erroneous byte that is separated by at least three correct bytes from the last preceding erroneous byte until the last erroneous byte that is separated by at least three correct bytes from the first succeeding erroneous byte.

The number of erroneous bytes in a burst is defined as the actual number of bytes in that burst that are not correct.

See example in Figure 121.

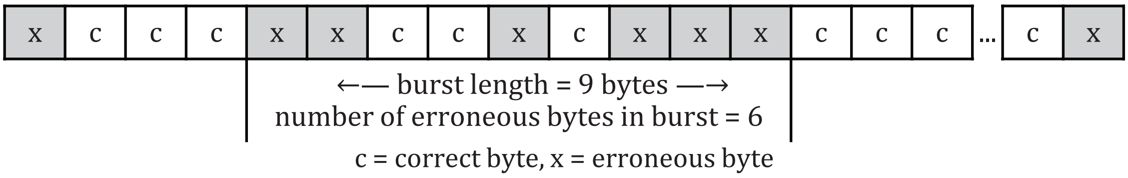


Figure 121 — Example of burst error

Symbol error rate

The symbol error rate (SER) averaged over N LDC blocks is defined as the total number of all erroneous bytes in the selected LDC blocks divided by the total number of bytes in those LDC blocks as per Formula (79):

$$\frac{\sum_{i=1}^{N} E_{a,i}}{N \times 75\,392} \tag{79}$$

where

$E_{a,i}$ is the number of all erroneous bytes in LDC block i;

N is the number of LDC blocks.

Random symbol error rate

The random symbol error rate is defined as the symbol error rate where all erroneous bytes contained in burst errors of length ≥40 bytes are counted neither in the numerator nor in the denominator of the SER calculation as per Formula (80):

$$\frac{\sum_{i=1}^{N} \left(E_{a,i} - E_{b,i}\right)}{N \times 75\,392 - \sum_{i=1}^{N} E_{b,i}} \tag{80}$$

where

$E_{a,i}$ is the number of all erroneous bytes in LDC block i;

$E_{b,i}$ is the number of all erroneous bytes in burst errors ≥40 bytes in LDC block i;

N is the number of LDC blocks.

34 Minimum quality of recorded information

34.1 Random symbol error rate

When checking the quality of the disk, the area selected for determining SER and burst errors shall be overwritten ten times with arbitrary user data.

Random SER after ten overwrites, averaged over any 10 000 consecutive LDC blocks shall be $<2{,}0 \times 10^{-4}$.

34.2 Maximum burst errors

In each recording unit, block the number of burst errors with length ≥40 bytes shall be less than 8 and the sum of the lengths of these burst errors shall be ≤600 bytes.

34.3 User-written data

User-written data in a recording unit block (RUB) as read in the HF read channel shall not contain any byte errors that cannot be corrected by the error correction system defined in Clause 13.

35 BCA

The zone between r_1 and r_3 is reserved for use as a burst-cutting area (BCA) (see 15.2 and Figure 53).

The BCA shall be used to add information to the disk after completion of the manufacturing process.

The BCA code can be written by a high-power laser system or by the initializer in the case of rewritable disks.

All information in the BCA code shall be written in CAV mode, where every revolution has exactly the same content, which content shall be radial aligned (see Figure 122).

The BCA code shall be located between radius $21{,}3^{0{,}0}_{-0{,}3}$ mm and radius $22{,}0^{+0{,}2}_{0{,}0}$ mm on layer L0. (the BCA code is allowed to overlap the protection zone 1 partially).

No BCA code shall be written on layer L1, but some effect of writing the BCA code on layer L0 can be visible on layer L1.

The BCA code shall be written as a series of low-reflectance stripes arranged in circumferential direction. Each of the stripes shall extend fully across the BCA in the radial direction.

The information in the BCA code can be read by a drive at any radius between radius 21,3 mm and radius 22,0 mm on layer L0.

The decision to record the BCA code is BDAP-dependent. BCA code shall not be recorded in the BCA unless otherwise specified by the BDAP. The format and content of the BCA code is defined by agreement between the interchange parties.

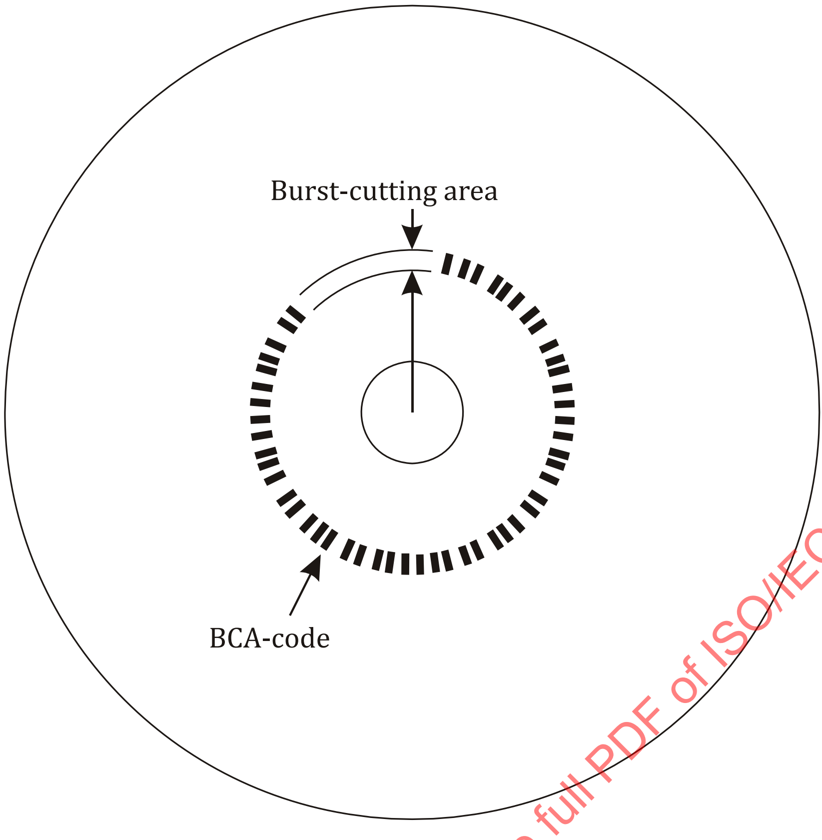


Figure 122 — Schematic representation of BCA

Annex A
(normative)

Thickness of transmission stacks in case of multiple layers

A.1 General

In case the total transmission stack consists of k layers, the following procedure shall be applied in determining the thickness of the individual layers:

— the values d_1 .. d_k represent the thicknesses of layers 1 .. k;

— the values n_1 .. n_k represent the refractive indices of layers 1 .. k.

Let $D(n)$ be the nominal thickness at refractive index n according to Figure 15.

Then, the thickness d_k of layer k should be as per Formula (A.1):

$$d_k = D(n_k) \times \left(1 - \sum_{i=1}^{k-1} \frac{d_i}{D(n_i)}\right) \quad \text{(A.1)}$$

A.2 Refractive index n_i of all layers in cover layer and spacer layer

The refractive index n_i of each layer in the cover and spacer layers shall be as per Formula (A.2):

$$1{,}45 \le n_i \le 1{,}70 \quad \text{(A.2)}$$

A.3 Thickness variation of the transmission stack

The relative thickness of the transmission stack j, $R_{\mathrm{T,j}}$, is defined as per Formula (A.3):

$$R_{\mathrm{T},j} = \sum_{i=1}^{k} \frac{d_i}{D(n_i)} \quad \text{(A.3)}$$

The relative thickness, R_{T}, of the transmission stacks, measured over the whole disk, shall fulfil the following requirements.

a) The relative thickness, $R_{\mathrm{T},0}$, of the transmission stack TS0 shall be as per Formula (A.4):

$$95 \le 100 \times R_{\mathrm{T},0} \le 105 \quad \text{(A.4)}$$

b) The relative thickness, $R_{\mathrm{T},1}$, of the transmission stack TS1 shall be as per Formula (A.5):

$$70 \le 75 \times R_{\mathrm{T},1} \le 80 \quad \text{(A.5)}$$

NOTE The thickness of the recording layer is very thin and negligible in the calculation of the thickness in case of type DL disk.

A.4 Example of thickness calculation for SL

Assume a cover sheet with refractive index n_1 = 1,70 and a nominal thickness of 75 µm is attached to the substrate by a gluing sheet with a refractive index n_2 = 1,45.

From Figure 15, $D(n_1)$ = 102,4 and $D(n_2)$ = 98,5.

From Formulae (A.1) and (A.2), d_2, in µm, can be calculated as per Formula (A.6):

$$d_2 = 98{,}5 \times \left(1 - \frac{75}{102{,}4}\right) = 26{,}356 \quad \text{(A.6)}$$

Annex B
(normative)

Measurement of reflectivity

B.1 General

The reflectivity of a disk can be measured in several ways. The two most common methods are as follows:

— parallel method; and

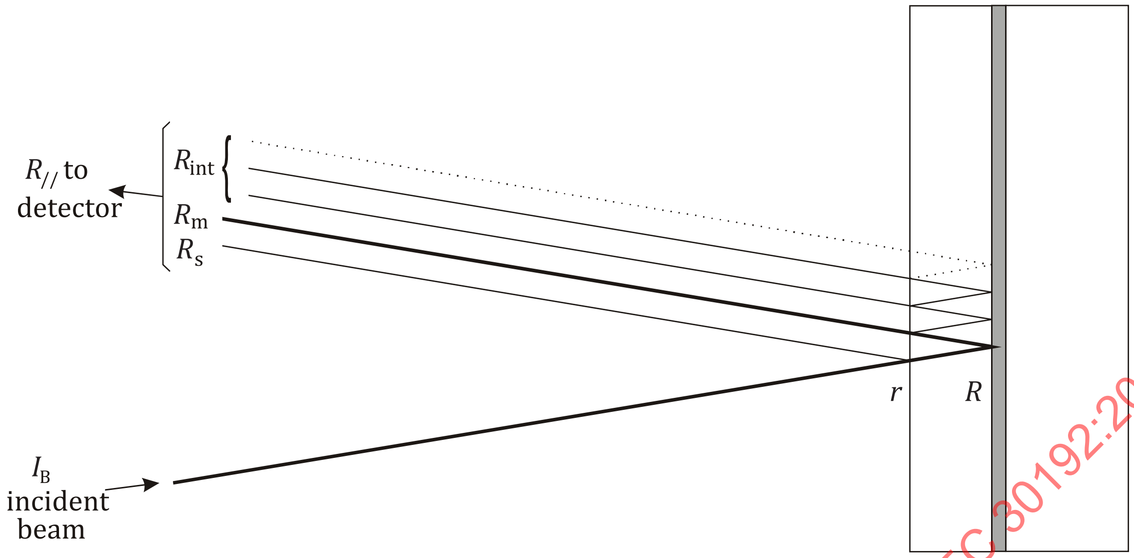
— focused method.

The reflectivity of the disk is measured by the focused method with the help of a reference disk with known reflectivity, while the reflectivity of the reference disk is calibrated by the parallel method.

When measuring the reflectivity in the focused way, only the light returned by the reflective layer of the disk, R_m, falls onto the photodetector. The reflected light coming from the front surface of the disk and the light coming from the parasitic reflectance's inside the disk mainly falls outside the photodetector. Because in the parallel method only the "total" reflectance, $R_{//}$, can be measured, a calculation is needed to determine the "main" reflectance from the reflective layer.

B.2 Calibration method

A good reference disk free of birefringence shall be chosen, for instance with a 0,1 mm glass cover layer with a golden reflective mirror. This reference disk shall be measured by a parallel beam as shown in Figure B.1.



Key

R reflectivity of the recording layer (including the double pass transmission stack transmission);

r reflectivity of the entrance surface;

R_{ref} reflectivity as measured by the focussed beam (is by definition = R_m / I_B);

I_B incident beam;

R_s reflectance caused by the reflectivity of the entrance surface;

R_m main reflectance caused by the reflectivity of the recording layer;

R_{int} reflectance caused by the internal reflectance's between the entrance surface and the recording layer;

$R_{//}$ measured value (R_s + R_m + R_{int}).

Figure B.1 — Reflectivity calibration

The reflectivity of the entrance surface is defined by Formula (B.1):

$$r = \left(\frac{n-1}{n+1} \right)^2 \tag{B.1}$$

where n is the index of refraction of the cover layer.

The main reflectance $R_m = R_{//} - R_s - R_{int}$ which leads to Formula (B.2):

$$R_{ref} = \frac{R_m}{I_B} = \left[\frac{(1-r)^2 \times \left(\frac{R_{//}}{I_B} - r \right)}{1 - r \times \left(2 - \frac{R_{//}}{I_B} \right)} \right] \tag{B.2}$$

The reference disk shall be measured on a reference drive. The total detector current (the sum of all four quadrants = I_{total}) obtained from the reference disk and measured by the focused beam is equated to R_m as determined above.

Now the arrangement is calibrated, and the focused reflectivity is a linear function of the reflectivity of the recording layer and the double pass transmission stack transmission, independently from the reflectivity of the entrance surface.

B.3 Measuring method

B.3.1 Reflectivity in unrecorded, virgin rewritable areas

A method of measuring the reflectivity using the reference drive.

a) Measure the total detector current $(I_1 + I_2)_{ref}$ from the reference disk with calibrated reflectivity R_{ref}.

b) Measure the total detector current $(I_1 + I_2)_G$ from a groove track in an area of the disk under investigation where the groove track and the two adjacent tracks on each side of the groove track never have been recorded nor erased.

c) Calculate the unrecorded virgin disk reflectivity R_{g-v} in the groove tracks of the rewritable area as per Formula (B.3):

$$R_{\text{g-v}} = \frac{(I_1 + I_2)_G}{(I_1 + I_2)_{ref}} \times R_{ref} \quad \text{(B.3)}$$

B.3.2 Reflectivity in unrecorded, erased rewritable areas

A method of measuring the reflectivity using the reference drive.

a) Measure the total detector current $(I_1 + I_2)_{ref}$ from the reference disk with calibrated reflectivity R_{ref}.

b) Measure the total detector current $(I_1 + I_2)_G$ from a groove track in an area of the disk under investigation where the groove track and the two adjacent tracks on each side of the groove track to be measured have been erased. Erasure of these tracks shall be done by irradiating the tracks using only the P_E power as determined from the OPC algorithm (see Annex G for detailed procedure).

c) Calculate the unrecorded erased disk reflectivity R_{g-e} in the groove tracks of the rewritable area as per Formula (B.4):

$$R_{\text{g-e}} = \frac{(I_1 + I_2)_G}{(I_1 + I_2)_{ref}} \times R_{ref} \quad \text{(B.4)}$$

B.3.3 Reflectivity in recorded rewritable areas

A method of measuring the reflectivity using the reference drive.

a) Measure the total detector current $(I_1 + I_2)_{ref}$ from the reference disk with calibrated reflectivity R_{ref}.

b) Measure I_{8H} from a recorded groove track in an area of the disk under investigation where at least the two adjacent tracks on each side of the groove track also have been recorded. Recording of the tracks shall be done using the optimum powers as determined from the OPC algorithm (see Annex G for detailed procedure).

c) Calculate the recorded disk reflectivity R_{8H} in the groove tracks of the rewritable area as per Formula (B.5):

$$R_{8H} = \frac{I_{8H}}{(I_1 + I_2)_{ref}} \times R_{ref} \quad \text{(B.5)}$$

Annex C
(normative)

Measurement of scratch resistance of cover layer

C.1 General

The entrance surface of the disk has sufficient scratch resistance, which can be improved by a protective coating (see 11.6.2).

C.2 Taber abrasion test

The following so-called taber abrasion test verifies whether the scratch resistance of the entrance surface of the disk is sufficient.

Two wheels covered with abrasive material are applied to the disk under test with a specified load (see Figure C.1).

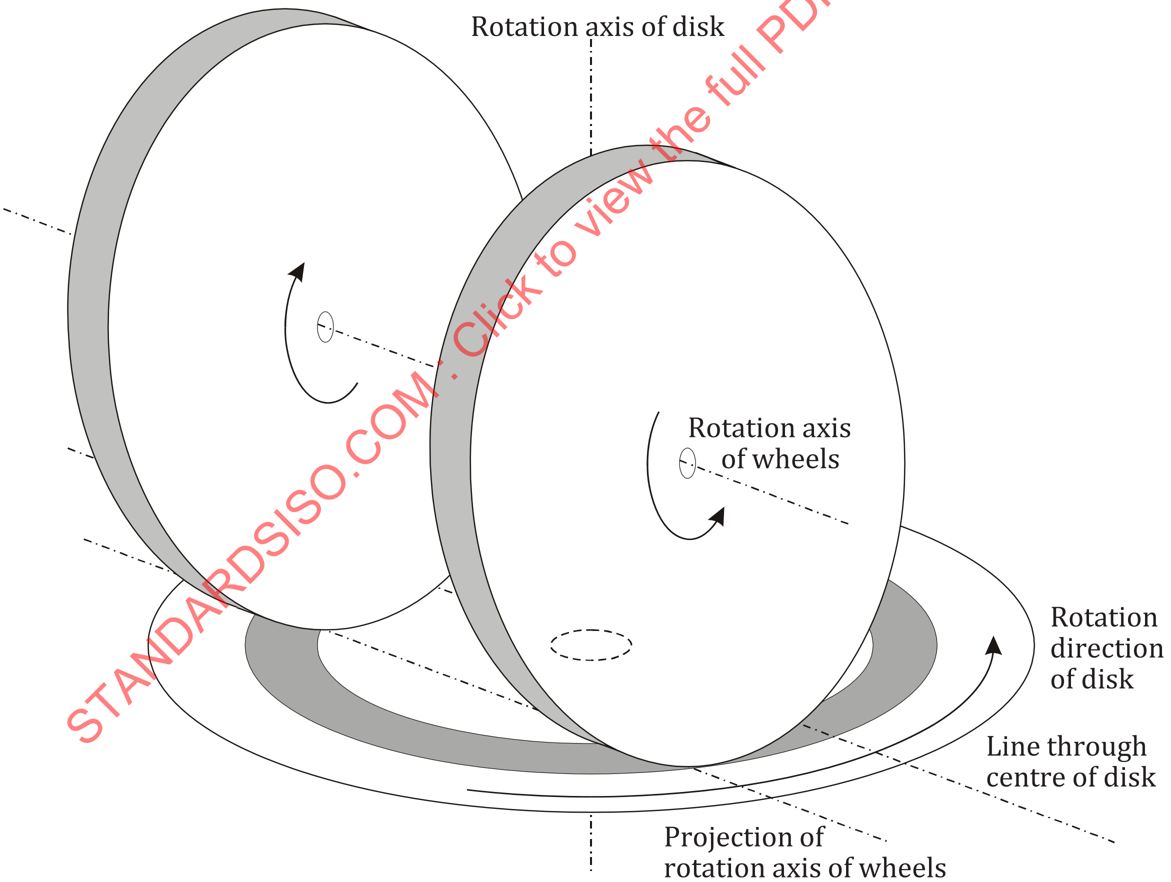


Figure C.1 — Typical abrasive test setup

Conditions for the test:

The test setup shall be according to ISO 9352 with the following details:

- type of wheels: CS10F;
- load applied to each wheel: 2,5 N;
- number of revolutions: 5.

The abrasion test shall be applied before the necessary recordings are made.

Results after test:

The jitter measured on layer L0 after equalization as specified in Annex H, with the circuit set to limit-equalizer mode, shall be ≤10 %.

Treatment of the abrasive wheels

Treatment of the abrasive wheels should be based on ASTM D1044.[1]

Before performing a taber abrasion test, each time both abrasive wheels should be refaced by an ST-11 refacing stone as follows:

- new wheels shall be refaced for 100 cycles; and
- wheels that have been used before shall be refaced for 25 cycles.

Annex D
(normative)

Measurement of repulsion of grime by cover layer

D.1 General

Annex D describes a method of applying an artificial fingerprint (AFP) to the disk for the purpose of determining the disk's sensitivity to fingerprints. Figure D.1 shows the basic procedure.

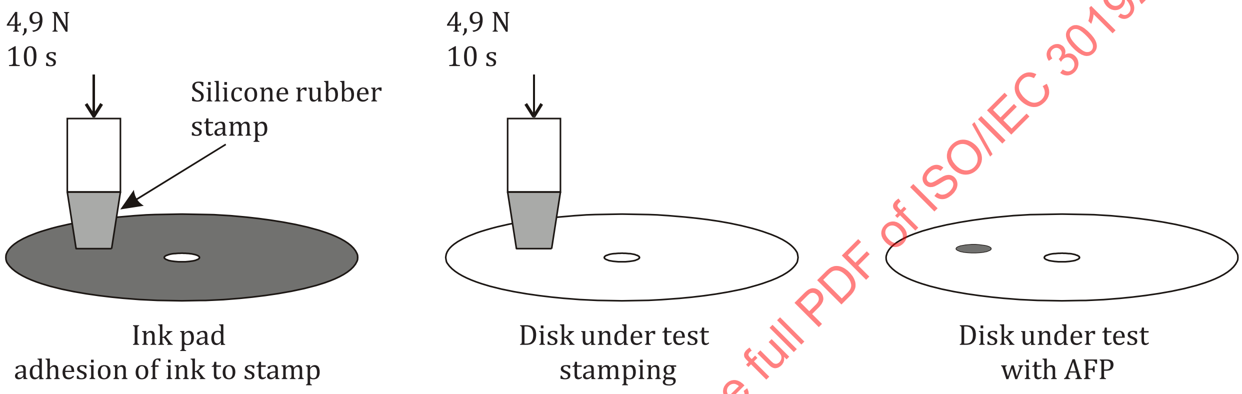


Figure D.1 — Applying AFP to disk

After applying the AFP, the random SER (see 33.4) in each physical cluster in the AFP-printed area, when measured on layer L0, shall be <4,2 × 10^{-3} when recording and reading through the AFP. In each physical cluster, the number of burst errors with length ≥40 bytes shall be less than 8 and the sum of the lengths of these burst errors shall be ≤800 bytes.

D.2 Specifications of stamp

The silicone rubber stamp shall have the following specifications:

— dimensions: stamp shape Φ16 mm × Φ12 mm × 20 mm height;

— shore hardness is A60.