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Information technology — Digitally recorded media for information interchange and storage — 120 mm Triple Layer (100,0 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 triple couche (100,0 Go par disque)

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Foreword

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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 ISO documents 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 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 is in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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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 30193:2016), which has been technically revised. It also incorporates the Amendment ISO 30193:2016/DAM1.

The main changes compared to the previous edition are as follows:

— additional requirements for 4x reading velocity have been added;

— additional requirements for physical access control and reserved area of BD application have been added.

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.

This corrected version of ISO 30193:2020 incorporates the following corrections:

— minor editorial corrections in symbols (italicization, bolding);

— in 15.8.3.2, reinstatement of "These two bytes shall be set to 44 49h, representing the characters “DI”." in Bytes 0 to 1 and deletion from Byte 3.

Introduction

In March 2002, nine companies known as the Blu-ray Disc Founders, or BDF, came together to create optical-disk formats with large capacity and high-speed transfer rates that would be needed for recording and reproducing high-definition video content. This joint effort turned out to be fruitful and the first version of its Blu-ray Disc™ Rewritable Format Part 1 version 1.0 in June 2002.

Then, in October 2004, more than 100 companies joined and BDF became an open forum called the Blu-ray Disc Association (BDA). The BDA issued version 2.1 of the Blu-ray Disc™ Rewritable Format Part 1 in October 2005 and version 3.0 in June 2010. By the end of 2010, over a hundred million Blu-ray Disc™ had been shipped and Blu-ray™ devices such as players, recorders, game consoles and PC drives were in use all over the world.

The BDA also conducts verification activities for both disks and devices and has established more than 10 testing centers in Asia, Europe and the USA.

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 chairs of ISO/IEC JTC 1/SC 23 and JIIMA (Japan Image and information Management Association) formally requested the BDA 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 the test methods for the estimation of lifetime of optical storage media for long-term data storage. In October 2011, the President of the BDA responded that his organization had decided to pursue international standardization for the basic physical formats for the recordable and rewritable Blu-ray™ Formats.

In December 2011, the BDA sent project proposals for international standardization of four formats to ISO/IEC JTC 1/SC 23 via the Japanese national body. They are 120 mm single layer (25,0 Gbytes per disk) and dual layer (50,0 Gbytes per disk) BD recordable 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.

This document specifies the mechanical, physical and optical characteristics of a 120 mm rewritable optical disk with a capacity of 100,0 Gbytes.

A few additional specifications are required in order to write and read video-recording applications, such as BDAV format which had been specified by the BDA for use on BD rewritable disks. These specifications, which are related to the BD application, the file system or the content-protection system, are required for the disk, the generating system and the receiving system. For more information about the BD application, the content-protection system and the additional requirements for the Blu-ray™ Format specifications, see http://www.blu-raydisc.info.

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.

Information technology — Digitally recorded media for information interchange and storage — 120 mm Triple Layer (100,0 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 100,0 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:

— the one disk type;

— the conditions for conformance;

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

— the mechanical and physical characteristics of the disk, so as to provide mechanical interchange between data processing systems;

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

— the error-correcting codes and the coding method used;

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

This document provides for interchange of disks between disk 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 9352, *Plastics — Determination of resistance to wear by abrasive wheels*

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

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

IEC 60068-2-30, *Environmental 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 following terms and definitions 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/

3.1
BD
disk having a *cover layer* (3.4) around 0,1 mm thick and a *substrate* (3.43) around 1,1 mm thick on which data is read or recorded by an optical pick-up unit (OPU) using 405 nm laser diode and numerical aperture, NA = 0,85 lens

Note 1 to entry: User data recorded on a disk is formatted using 17PP modulation and an LDC+BIS Code.

3.2
BD application
BDAP
contents standard specified for a *BD* (3.1), for instance a video application, which requires area for a content-protection system and for its own defect-management system on the disk

3.3
channel bit
element by which the binary value ZERO or ONE is represented by *pits* (3.27)/*marks* (3.19) and *spaces* (3.42) on a disk

3.4
cover layer
transparent layer with precisely controlled optical properties that covers the *recording layer* (3.33) closest to the entrance surface of a disk

3.5
data zone *n*
area between the inner zone and the outer zone on *layer Ln* (3.17)

3.6
defective cluster
cluster in a *user-data area* (3.47) that has been registered in a defect list as unreliable or uncorrectable one

3.7
digital-sum value
DSV
arithmetic sum obtained from a bit stream by assigning the decimal value +1 to *channel bits* (3.3) set to ONE and the decimal value −1 to channel bits set to ZERO

3.8
disk reference plane
plane defined by the perfect flat annular surface of an ideal spindle, onto which the clamping zone of a disk is clamped, that is normal to the axis of rotation

3.9
embossed HFM area
area on a disk where information has been stored by means of an *HFM groove* (3.13) during manufacturing of the disk

3.10
entrance surface
surface of a disk onto which the optical beam first impinges

3.11
erased groove
blank *groove* (3.12) on a disk that has been erased by irradiating the *track* (3.44) using only erase power level, P_{EO}, as determined by the OPC algorithm

3.12
groove
trench-like feature of a disk connected to a *recording layer* (3.33)

Note 1 to entry: In case of triple-layer disk, one groove can be carried by the *substrate* (3.43) and other grooves can be carried by the *spacer layer* (3.41) or the *cover layer* (3.4) (see Figure 1) grooves are used to define the *track* (3.44) locations.

In the BD rewritable system, there are 3 types of grooves:

— *wobbled groove* (3.49) in rewritable area containing address information;

— *HFM groove* (3.13) in embossed HFM area containing permanent information and control data;

— straight groove without any modulation in the BCA zone.

3.13
high-frequency modulated groove
HFM groove
groove (3.12) modulated in the radial direction with a rather high bandwidth signal

Note 1 to entry: HFM groove creates a data channel with sufficient capacity and data rate for replicated information.

3.14
information area
area on a disk in which information can be recorded

3.15
information zone
recorded part of the *information area* (3.14)

3.16
land
surface of a *recording layer* (3.33) between successive windings of a *groove* (3.12)

3.17
layer L*n*
one *recording layer* (3.33) of a disk identified by *n*

Note 1 to entry: layer L(*n*+1) is closer to the *entrance surface* (3.10) of a disk than layer L*n*.

3.18
layer type
identification of a disk using number of layer(s)

Note 1 to entry: In case of triple-layer disk, the layer type is TL (see Clause 7).

3.19
mark
feature of a *recording layer* (3.33), which can take the form of an amorphous domain in the crystalline recording stack due to recording, that can be sensed by an optical read-out system

Note 1 to entry: The pattern of marks and *spaces* (3.42) represents the data on a disk.

3.20
mark polarity
polarity of reflectivity change when *marks* (3.19) are recorded

3.21
measurement velocity
linear velocity at which a disk is measured during reading

Note 1 to entry: The *n*x measurement velocity means the measurement velocity of *n* times the *reference velocity* (3.36).

3.22
modulation bit
alternative form representing the data, that is more suited to be transmitted via a communication channel or to be stored on a storage system

3.23
NRZI conversion
method of converting modulation-bit stream into a physical signal

3.24
on-groove
geometry where *grooves* (3.12) are nearer to the *entrance surface* (3.10) of a disk than the *lands* (3.16)

3.25
padding
process in a drive to fill up the missing sectors in a 64K cluster, which consists of 32 *sectors* (3.40), with all 00h data when the host supplies less than the 32 sectors and needs to fill up the cluster

3.26
phase change
physical effect by which an area of a *recording layer* (3.33) is irradiated by a laser beam and heated so as to change from a crystalline state to an amorphous state and vice versa

3.27
pit
feature of a *recording layer* (3.33), which can take the form of a depression in or elevation on the *land* (3.16) surface, that can be sensed by the optical read-out system

Note 1 to entry: The pattern of pits and *spaces* (3.42) represents the data on a disk.

3.28
polarization
direction of the electric field vector of an optical beam

Note 1 to entry: The plane of polarization is the plane containing the electric field vector and the direction of propagation of the beam.

3.29
pre-recorded area
area on a disk where information has been recorded by the manufacturer/supplier of the disk by applying standard recording techniques after finishing of the replication process

3.30
protective coating
optional additional layer on top of the *cover layer* (3.4) provided for extra protection against scratches and other types of damage

3.31
reading velocity
linear velocity at which a disk is actually read

Note 1 to entry: The *n*x reading velocity means the reading velocity of *n* times the *reference velocity* (3.36).

3.32
read-modify-write
process in a drive to read full content of a 64K cluster, which consists of 32 *sectors* (3.40), replace the sector(s) concerned and write back the full cluster to a disk when one or more, but less than 32, sector(s) in a cluster is(are) rewritten

3.33
recording layer
part of a disk consisting of a stack of films of specific materials on or in which data is written during manufacture and/or use

3.34
reference servo
servomechanism of a reference drive with parameters defined for measuring disks

3.35
recording velocity
linear velocity at which a disk is recorded

Note 1 to entry: The *n*x recording velocity means the recording velocity of *n* times the *reference velocity* (3.36).

3.36
reference velocity
linear velocity that results in the nominal channel-bit rate of 66 000 Mbit/s

3.37
reserved
<value> value(s) not used in this document

3.38
reserved
<field> field(s) not specified in use, to be ignored in interchange and to be set to ZERO as value

3.39
rewritable area
area on a disk where information can be recorded by means of *marks* (3.19) and *spaces* (3.42) using the phase-change effect and during the manufacture and/or use of the disk

3.40
sector
minimum-size addressable data part of a *track* (3.44) in the *information zone* (3.15)

3.41
spacer layer
transparent layer with precisely-controlled optical properties separating two *recording layers* (3.33)

3.42
space
area separating *pits* (3.27) or *marks* (3.19) in the tangential direction in the context of HF signals

Note 1 to entry: The pattern of *pits* (3.27)/*marks* (3.19) and spaces represents the data on a disk.

3.43
substrate
layer, which can be transparent or not, provided for the mechanical support of a *recording layer* (3.33)

3.44
track
360° turn of a continuous spiral, formed by a *groove* (3.12)

3.45
track pitch
distance between centrelines of a *groove* (3.12), in adjacent *tracks* (3.44), measured in the radial direction

3.46
transmission stack
set of all layers between the *entrance surface* (3.10) of a disk and the *recording layer* (3.33) concerned

Note 1 to entry: In other words, the transmission stack of a specific recording layer consists of all layers that are passed through by the light beam, when accessing that recording layer.

3.47
user-data area
collection of all data zone(s) on a disk, consisting only of the clusters in which user data can be recorded

3.48
virgin groove
blank *groove* (3.12) on a disk which has never been recorded nor erased

3.49
wobbled groove
groove (3.12) that has a periodic sinusoidal deviation from its average centreline

Note 1 to entry: By modulating the sinusoidal deviation, the wobble provides address information and general information about a disk.

3.50
zone
annular area of a disk

4 Symbols 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
DCZ	drive-calibration zone
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*)	*n*th overwrite
DOW(0)	initial recording
DSV	digital-sum value
DWP	disk write protect
EB	emergency brake
ECC	error-correction code
EDC	error-detection code
EQ	equalizer
FAA	first ADIP address (of data zone)
FS	frame sync
FWHM	full width at half maximum
HF	high frequency
HFM	high-frequency modulated
HMW	harmonic-modulated wave
HPF	high-pass filter
HTL	high-to-low
LAA	last ADIP address (of data zone)
LDC	long-distance code
LPF	low-pass filter
LSB	least-significant byte
lsb	least-significant bit
LSN	logical-sector number
MM	MSK mark
MSB	most-significant byte
msb	most-significant bit

MSK	minimum-shift keying
MW	monotone wobble
NA	numerical aperture
NHWS	normalized HFM-wobble signal
NRD	non-reallocatable defect
NRZ	non-return-to-zero
NRZI	non-return-to-zero inverting
NWL	nominal wobble length
NWS	normalized wobble signal
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
RH	relative humidity
RMTR	repeated minimum-transition run-length
R-M-W	read-modify-write
RS	Reed-Solomon (code)
RT	relative thickness
RUB	recording-unit block
SER	symbol error rate
SHD	second-harmonic distortion
SHL	second-harmonic level
S/N	signal-to-noise ratio
SPS	start-position shift

STW	saw-tooth wobble
Sync	synchronization
TL	triple layer
TP	track pitch
TS	transmission stack
V_{ref}	reference velocity
wbs	wobbles
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 the 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 the type of optical disk 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

Data is often collected into groups where these groups of data can be collected into higher level groups. For the clarity of the grouping hierarchy, in this document the following levels of hierarchy are 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 $1{,}235 \le x_{measured} < 1{,}275$ fulfils this specification.

— The specification is: $x \le 0{,}3$:

  — a measured value $x_{measured} < 0{,}35$ fulfils 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 $x_{measured} = 0{,}299$ fulfils 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 be outside of 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 fulfils 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 fulfils this specification;

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

Numbers in decimal notations 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 notations 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 sequences 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 8n 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 *x* and *y* are included in the range.

A list of integers is indicated as *i* .. *j*. The list contains all numbers between *i* and *j*, including *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*, including *m* and *n* (e.g. byte 16 .. 31, bit 7 .. 4, Add_0 .. Add_{255}).

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*).

For 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 description 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 consists of several layers. The three recording layers are separated by two transparent spacer layers whose thicknesses are about 25,0 µm and 18,0 µm, respectively, in this order from the substrate. On top of these recording layer, a transparent cover layer of about 57,0 µm is applied with accurately defined optical characteristics (see Figure 1).

This document provides for one type of such disk, type TL, whose capacity is 100,0 Gbytes. To improve the scratch resistance, the cover layer optionally can be protected with an additional hard coating.

Data can be written onto the disk as amorphous marks in the crystalline recording layer(s) and can be overwritten with a high-power focused optical beam using the phase-change effect between amorphous and crystalline states of the recording material.

The data can be read with a low power focused optical beam, using the difference in the reflectivity of the amorphous and the crystalline states.

Depending on which recording layer is to be accessed, the optical beam passes through the transparent cover layer or through the transparent cover layer, the semi-transparent recording layer(s) and the transparent spacer layer(s).

For reference purposes, all layers together, passed through by the light beam when accessing a certain recording layer, are called the transmission stack of that specific recording layer.

Data is recorded on the grooves. The wobble of the grooves modulated with addresses serve as a system for positioning and speed control during recording.

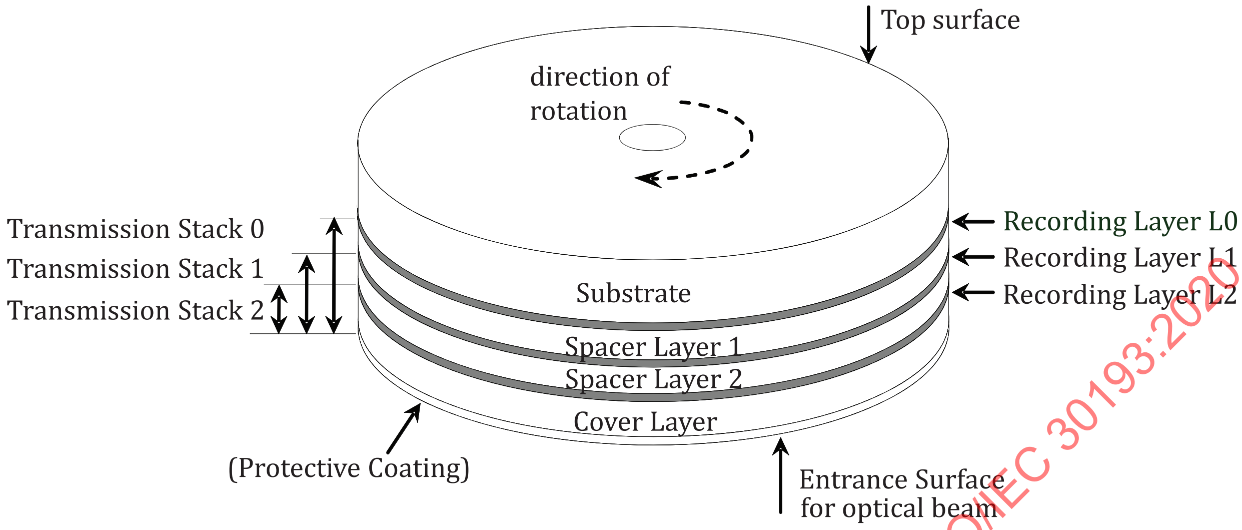


Figure 1 — Outline of triple layer BD rewritable disk

Figure 2 shows the recording velocity requirements.

Disk Type	Disk Type parameters			Recording Velocity	
	Mark polarity	Push-Pull Polarity (see 26.1)	Layer Type	1x	2x
Type TL	HTL	On-Groove[a]	TL	—	m

m Mandatory.
— Not allowed in this document.
[a] Groove geometry is On-Groove for all Layer L0, Layer L1 and Layer L2 (see 15.2).

Figure 2 — 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 the conformance of the 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 the following properties:

— temperature, T: (23 ± 2) °C;

— relative humidity, RH: 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 sufficient time.

8.1.1.2 Test conditions for sudden change in operating environment

Some parameters can be rather sensitive for 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.

Apply a sudden change in relative humidity, while keeping the temperature at a constant level:
RH = 90 %, T = 25 °C → RH = 45 %, T = 25 °C (see Figure 3).

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

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, RH: 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 hours before use.

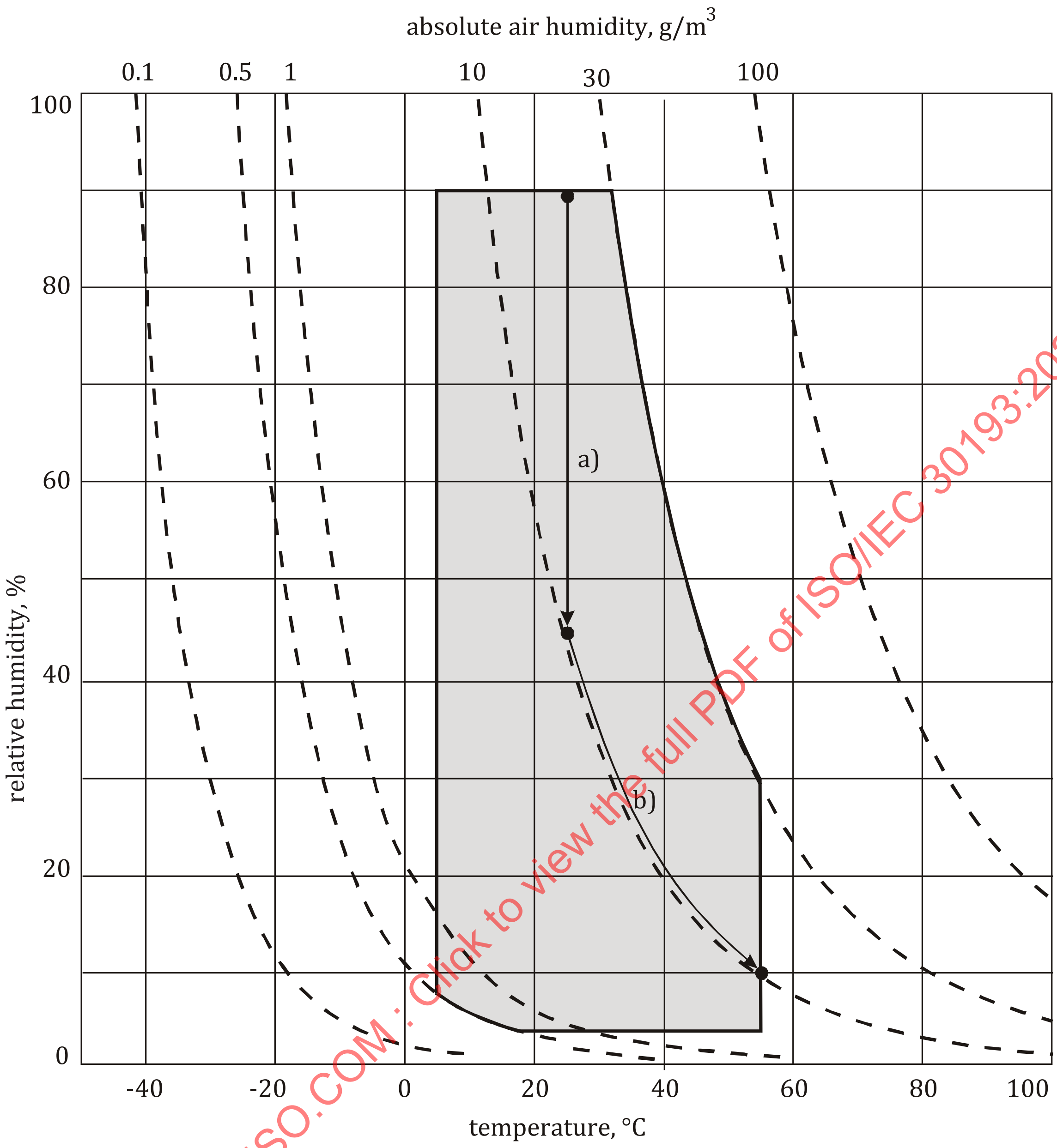


Figure 3 — Operating environment

8.1.3 Storage environment

8.1.3.1 General

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

— temperature, T: –10 °C to 55 °C;

— relative humidity, RH: 5 %to 90 %;

— absolute humidity: 1 g/m^3 to 30 g/m^3;

— atmospheric pressure: 60 kPa to 106 kPa;

— temperature variation max.: 15 °C/h;

— relative humidity variation max.: 10 %/h.

8.1.3.2 Climatic storage tests

To check the 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, RH = 50 %, 96 h;

— damp heat cycle test according to IEC 60068-2-30 Db:
T_{high} = 40 °C, T_{low} = 25 °C, RH = 95 %, cycle time = (12 + 12) h, 6 cycles.

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

8.1.4 Transportation

8.1.4.1 General

As transportation occurs under a wide range of temperatures and humidities, 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. In the absence of such an agreement, the form of packaging is the responsibility of the sender. The following hazards should be taken into account.

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 meet 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 for conformance with the requirements of this document. The critical components of this device have the characteristics specified in Clause 9.

9.2 Measurement 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 4. Different components and locations of components are permitted, provided that the performance remains the same as that of the set-up in Figure 4.

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.

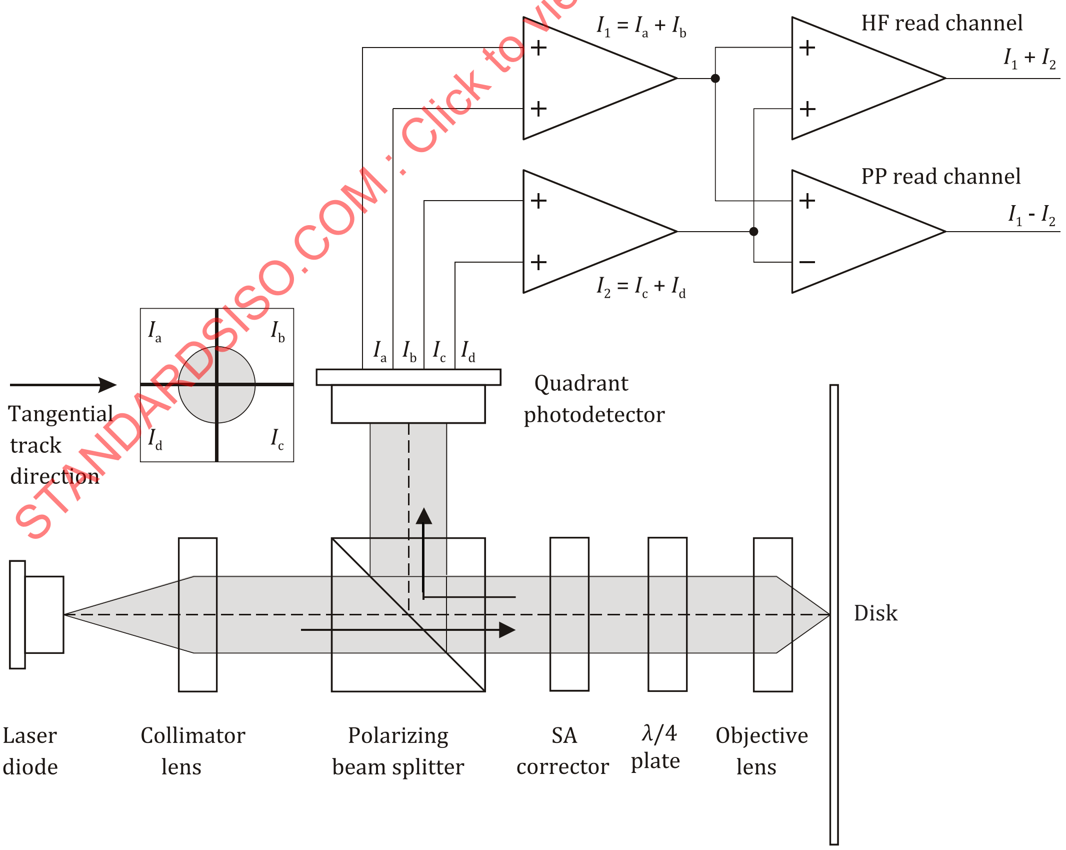


Figure 4 — Optical system of reference drive

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 multi-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. For a type TL disk, however, the effect cannot be neglected even if the length and width of photodetector are smaller than $M \times 5$ µm. Therefore, observed reflectivity shall be compensated using the procedure shown in B.4.

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 × λ rms;

  (after correction of tilt and spherical aberrations)

— maximum relative-intensity noise of the laser diode:

$$\left[10 \times \log\left(\frac{P_{\mathrm{m}}}{P_{\mathrm{dc}}}\right)\right]$$

  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 4-quadrant photodetector;

— read power for disk testing (average):

— layer L0 and layer L1: (1,44 ± 0,10) mW;

— layer L2: (1,00 ± 0,10) mW;

— write power and pulse shape: see 29.4.2 and Annex F.

9.5 HF read channel

The HF read channel is provided to supply a signal from which the user data can be retrieved. The signal is generated by summing all 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 44 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 1,5 ns pp. in the frequency range from 6 MHz to 44 MHz.

For measurement of i-MLSE, the characteristics of the signal processing, the Viterbi decoder and the PLL, etc., are specified in Annex H.

9.6 Radial PP read channel

The radial PP read channel provides a 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 16 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 5).

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, 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 5).

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

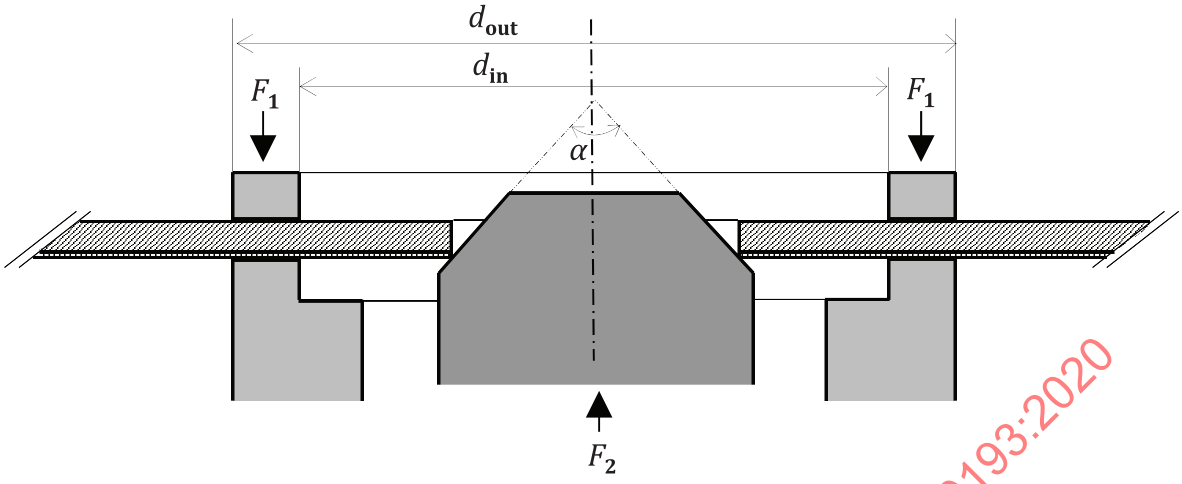


Figure 5 — Clamping conditions for measurement

9.8 Rotation of 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 2 times the reference velocity, unless otherwise specified. This corresponds to a constant linear velocity of 7,375 m/s.

9.9 Normalized servo transfer function

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

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

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:

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

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

The term $\left(1 + \dfrac{\omega_{int}}{\mathrm{i}\omega} \right)$ in Formula (1) 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 velocities and reference servos for axial tracking

9.10.1 General

The applicable reference servo and conditions for measuring residual axial errors depend on the measurement velocities under testing: measurement velocities for axial residual errors shall be a half of the recording velocities, a reference servo for 1x measurement velocity refers to 9.10.2. Only if the disk supports reading at 4x reference velocity, measurement velocities for axial residual errors shall be a half of the reading velocities, a reference servo for 2x measurement velocity refers to 9.10.3. The servo for all conditions has the same basics, however with a modified integrator.

9.10.2 Reference servo for axial tracking for 1x measurement velocity

Regarding the open-loop transfer function $H(f)$ of the reference servo for axial tracking, $|1 + H(f)|$ is limited as shown schematically by the shaded area in Figure 6.

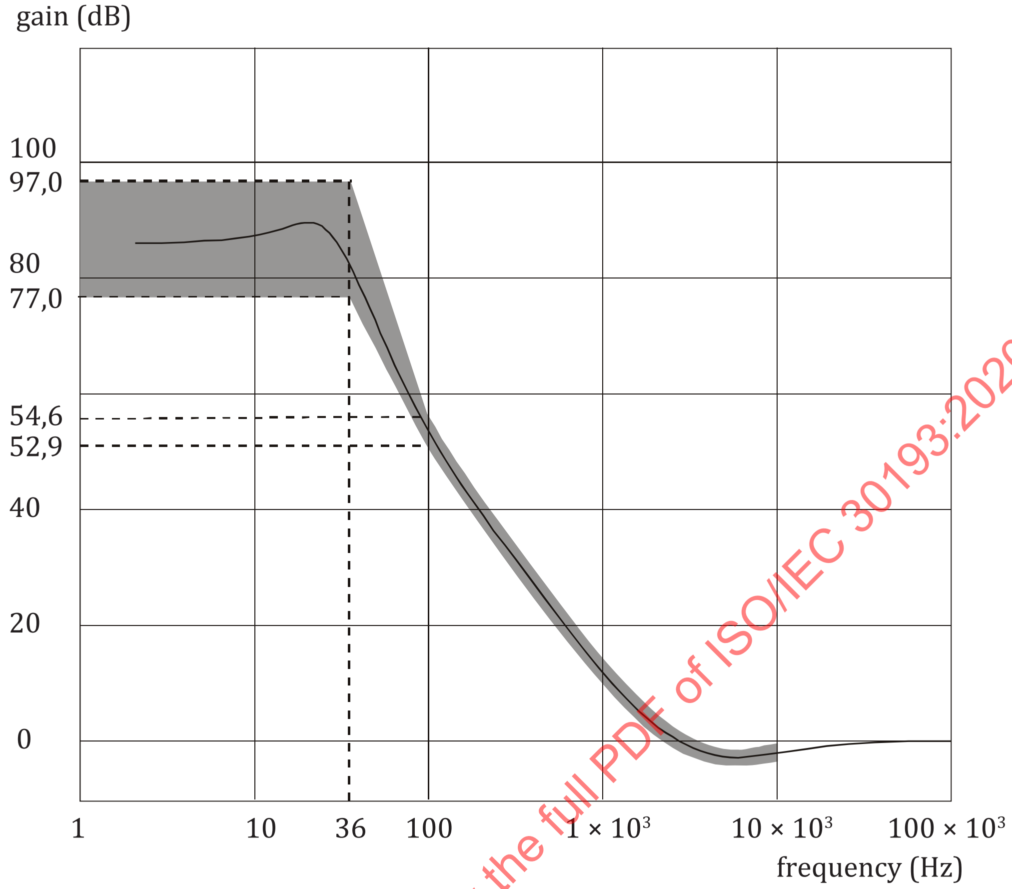


Figure 6 — Servo characteristic for axial tracking for 1x measurement velocity

The crossover frequency, f_0, of $H_N(f)$, in kHz (see 9.9), used to define the limits of $|1 + H(f)|$, is specified by 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:

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

The integrator shall be first order (K = 1) with a crossover frequency of f_{int} = 100 Hz [see Formulae (4) to (6)].

In the frequency range 100 Hz to 10 kHz:

$$0,9\times|1+H_N(f)|\leq|1+H(f)|\leq1,1\times|1+H_N(f)| \quad (4)$$

In the frequency range 36 Hz to 100 Hz:

$$0,9\times|1+H_N(f)|\leq|1+H(f)|\leq1,1\times|1+H_N(f_{int})|\times\left(\frac{f_{int}}{f}\right)^{4,78} \quad (5)$$

In the frequency range up to 36 Hz (in dB):

$$77,0\leq|1+H(f)|\leq97,0 \quad (6)$$

The frequency, f_x, in kHz, has the value determined by Formula (7):

$$f_x=\frac{1}{2\pi}\sqrt{\frac{\alpha_{max}}{e_{max}}}=\frac{1}{2\pi}\sqrt{\frac{6,0}{55\times10^{-9}}}\approx1,6 \quad (7)$$

9.10.3 reference servo for axial tracking for 2x measurement velocity

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

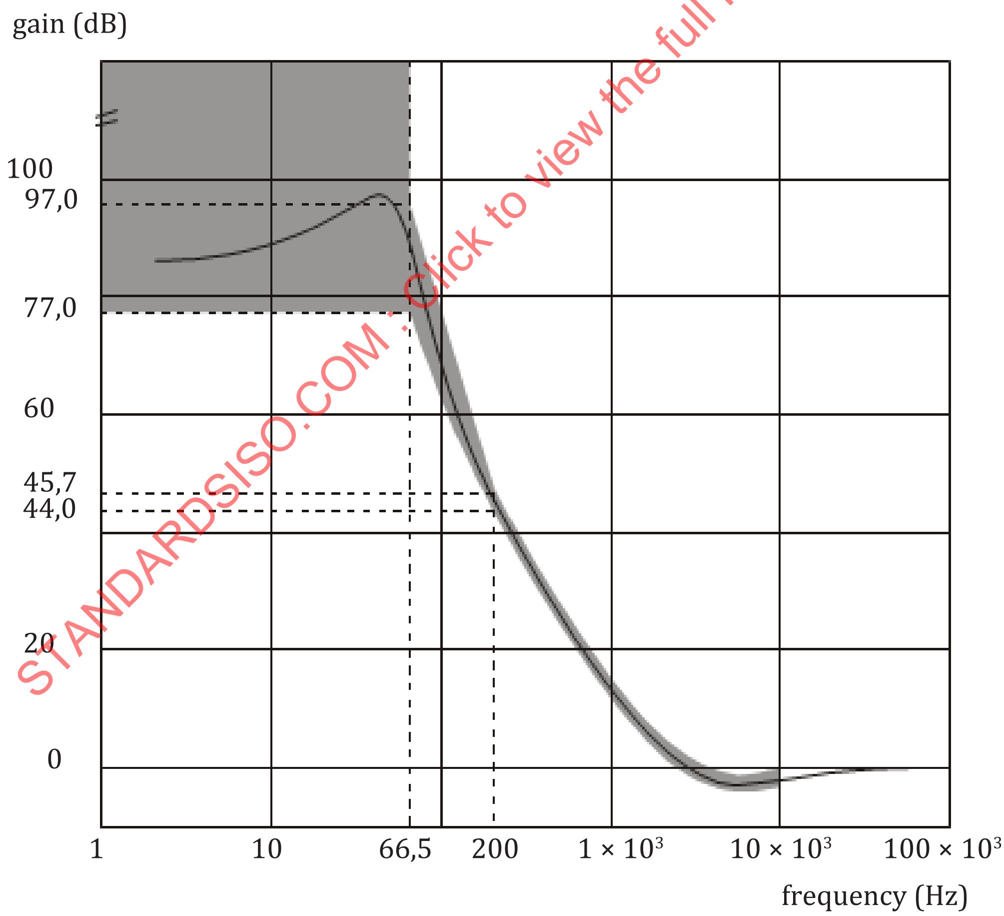


Figure 7 — Servo characteristic for axial tracking for 2x measurement velocity

The 0 dB crossover frequency, f_0, shall be 3,2 kHz, the same as the 1x measurement condition. For the maximum residual tracking error of 80 nm (see 11.4.2), this corresponds to an acceleration, α_{max} in m/s^2, as per Formula (8):

$$\alpha_{max} = \frac{(2\pi \times f_0)^2}{3} \times e_{max} = \frac{(2\pi \times 3{,}2 \times 10^3)^2}{3} \times 80 \times 10^{-9} = 10{,}8 \quad (8)$$

For the maximum residual tracking error of 110 nm (see 11.4.3), this corresponds to an acceleration, α_{max} in m/s^2, as per Formula (9):

$$\alpha_{max} = \frac{(2\pi \times f_0)^2}{3} \times e_{max} = \frac{(2\pi \times 3{,}2 \times 10^3)^2}{3} \times 110 \times 10^{-9} = 14{,}8 \quad (9)$$

The integrator shall be second order (K = 2) with the crossover frequency f_{int} = 200 Hz [see Formulae (10) to (12)].

Frequency range 200 Hz to 10 kHz:

$$0{,}9 \times |1 + H_N(f)| \leq |1 + H(f)| \leq 1{,}1 \times |1 + H_N(f)| \quad (10)$$

Frequency range 66,5 Hz to 200 Hz:

$$0{,}9 \times |1 + H_N(f)| \leq |1 + H(f)| \leq 1{,}1 \times |1 + H_N(f_{int})| \times \left(\frac{f_{int}}{f}\right)^{5{,}36} \quad (11)$$

Frequency range up to 66,5 Hz (in dB):

$$|1 + H(f)| \geq 77{,}0 \quad (12)$$

9.11 Measurement velocities and reference servos for radial tracking

9.11.1 General

The applicable reference servo and conditions for measuring residual radial errors depend on the measurement velocities: measurement velocities for radial residual errors shall be a half of the recording velocities, a reference servo for 1x measurement velocity refers to 9.11.2. Only if the disk supports reading at 4x reference velocity, measurement velocities for radial residual errors shall be a half of the reading velocities, a reference servo for 2x measurement velocity refers to 9.11.3. The servo for all conditions has the same basics, however with a modified integrator.

9.11.2 Reference servo for radial tracking for 1x measurement velocity

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

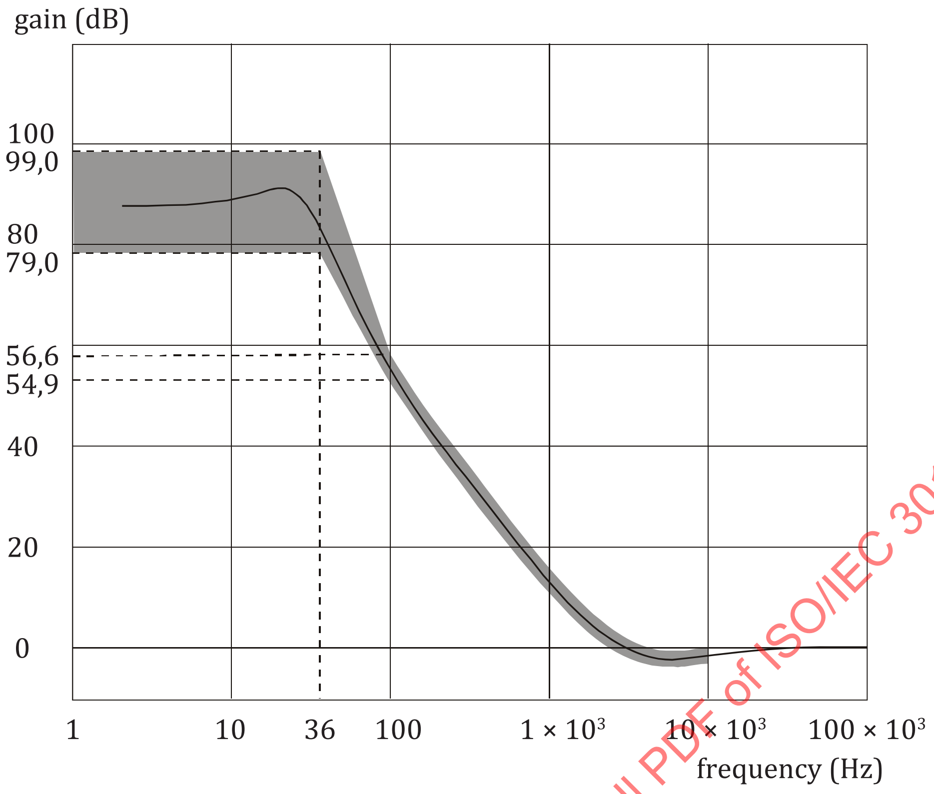


Figure 8 — Servo characteristic for radial tracking for 1x measurement velocity

The crossover frequency, f_0, of $H_N(f)$, in kHz (see 9.9), used to define the limits of $|1 + H(f)|$, is specified by Formula (13), where α_{max} = 2,2 m/s² 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 follows:

$$f_0 = \frac{1}{2\pi}\sqrt{\frac{3 \times m \times \alpha_{max}}{e_{max}}} = \frac{1}{2\pi}\sqrt{\frac{3 \times 1{,}25 \times 2{,}2}{16 \times 10^{-9}}} = 3{,}6 \tag{13}$$

The integrator shall be first order with crossover frequency f_{int} = 100 Hz [see Formulae (14) to (16)].

In the frequency range 100 Hz to 10 kHz:

$$0{,}9 \times |1 + H_N(f)| \le |1 + H(f)| \le 1{,}1 \times |1 + H_N(f)| \tag{14}$$

In the frequency range 36 Hz to 100 Hz:

$$0{,}9 \times |1 + H_N(f)| \le |1 + H(f)| \le 1{,}1 \times |1 + H_N(f_{int})| \times \left(\frac{f_{int}}{f}\right)^{4{,}78} \tag{15}$$

In the frequency range up to 36 Hz (in dB):

$$79{,}0 \le |1 + H(f)| \le 99{,}0 \tag{16}$$

The frequency, f_x, in kHz, has the value by Formula (17):

$$f_x = \frac{1}{2\pi}\sqrt{\frac{\alpha_{max}}{e_{max}}} = \frac{1}{2\pi}\sqrt{\frac{2{,}2}{16 \times 10^{-9}}} \approx 1{,}8 \tag{17}$$

9.11.3 Reference servo for radial tracking for 2x measurement velocity

For the open-loop transfer function $H(f)$ of the reference servo for radial tracking, $|1+ H(f)|$ is limited as schematically shown by the shaded area of the Figure 9.

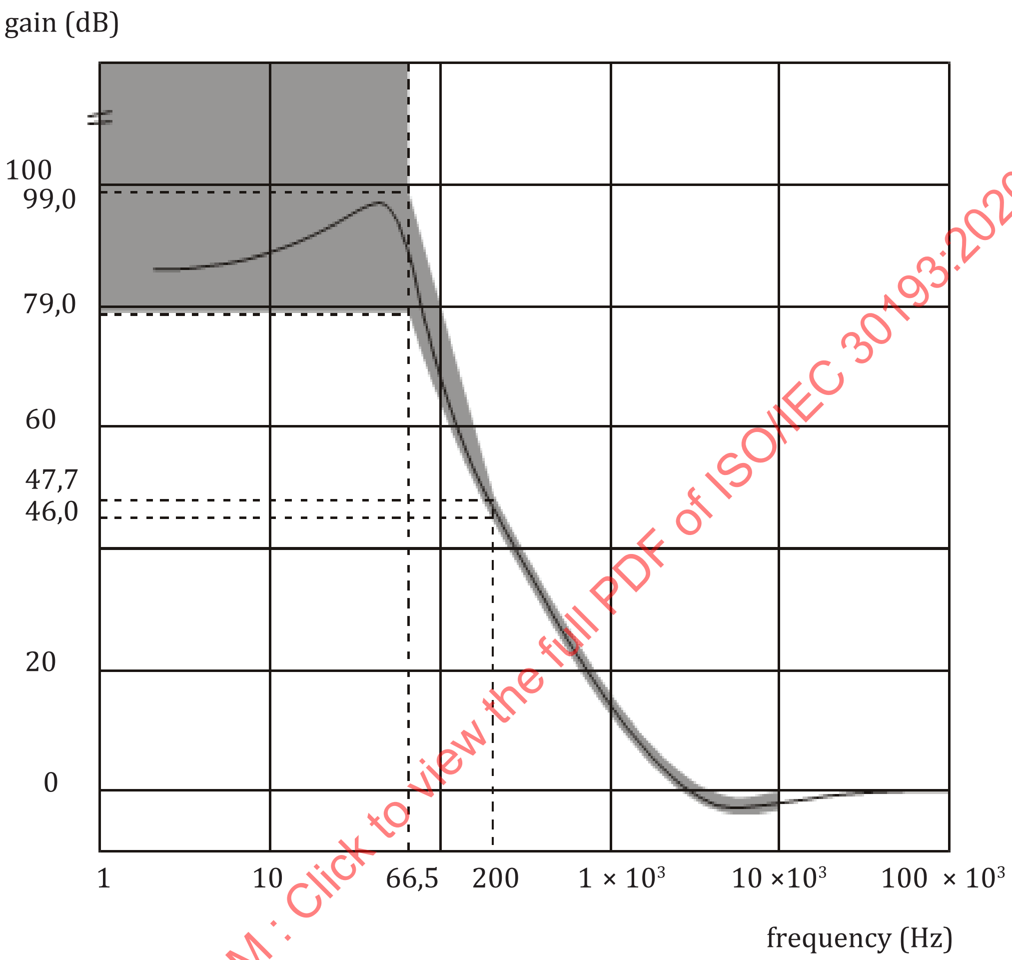


Figure 9 — Servo characteristic for radial tracking for 2x measurement velocity

The 0 dB crossover frequency f_0 shall be 3,6 kHz, the same as the 1x measurement condition. For the maximum residual tracking error of 20 nm (see 11.5.3), this corresponds to an acceleration, α_{max} in m/s^2, as per Formula (18):

$$\alpha_{max} = \frac{(2\pi \times f_0)^2}{3} \times e_{max} = \frac{(2\pi \times 3{,}6 \times 10^3)^2}{3} \times 20 \times 10^{-9} = 3{,}4 \qquad (18)$$

The integrator shall be second order ($K = 2$) with the crossover frequency f_{int} = 200 Hz [see Formulae (19) to (21)].

Frequency range 200 Hz to 10 kHz:

$$0,9 \times |1 + H_N(f)| \leq |1 + H(f)| \leq 1,1 \times |1 + H_N(f)| \quad (19)$$

Frequency range 66,5 Hz to 200 Hz:

$$0,9 \times |1 + H_N(f)| \leq |1 + H(f)| \leq 1,1 \times |1 + H_N(f_{int})| \times \left(\frac{f_{int}}{f} \right)^{5,36} \quad (20)$$

Frequency range up to 66,5 Hz (in dB):

$$|1 + H(f)| \geq 79,0 \quad (21)$$

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. The enclosed drawing, Figure 10, shows the dimensional requirements in summarized form. The different parts of the disk are described from the centre hole to the outside rim.

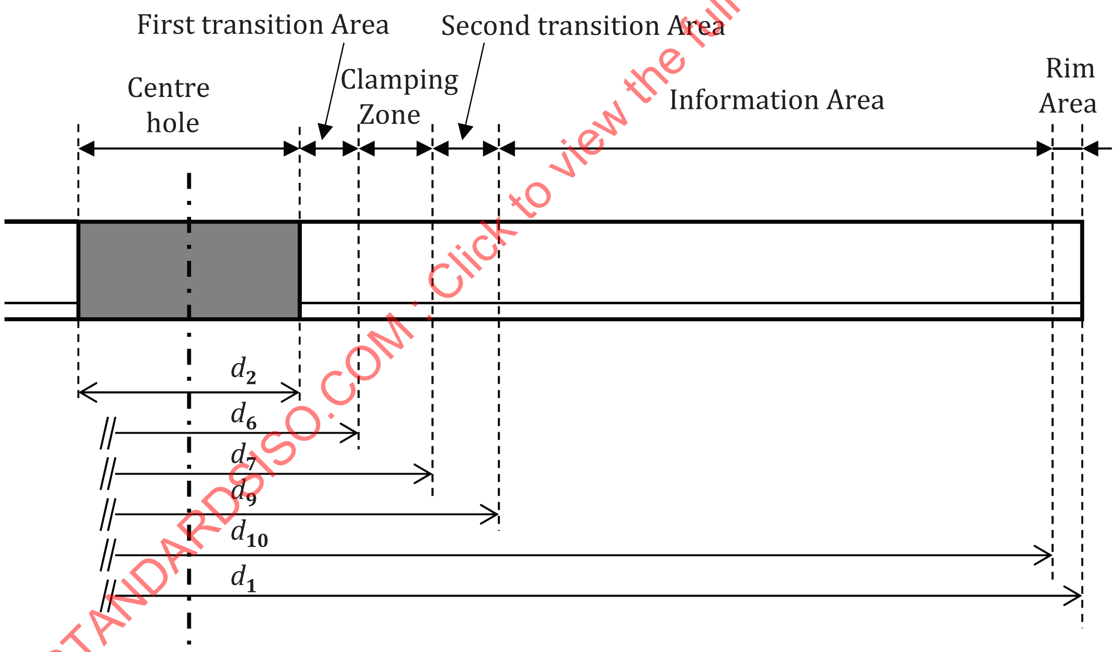


Figure 10 — Overview of disk dimensions

10.2 Disk reference planes and reference axis

(For the disk reference planes see also Figure 11 and Figure 12).

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 11 and Figure 12).

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

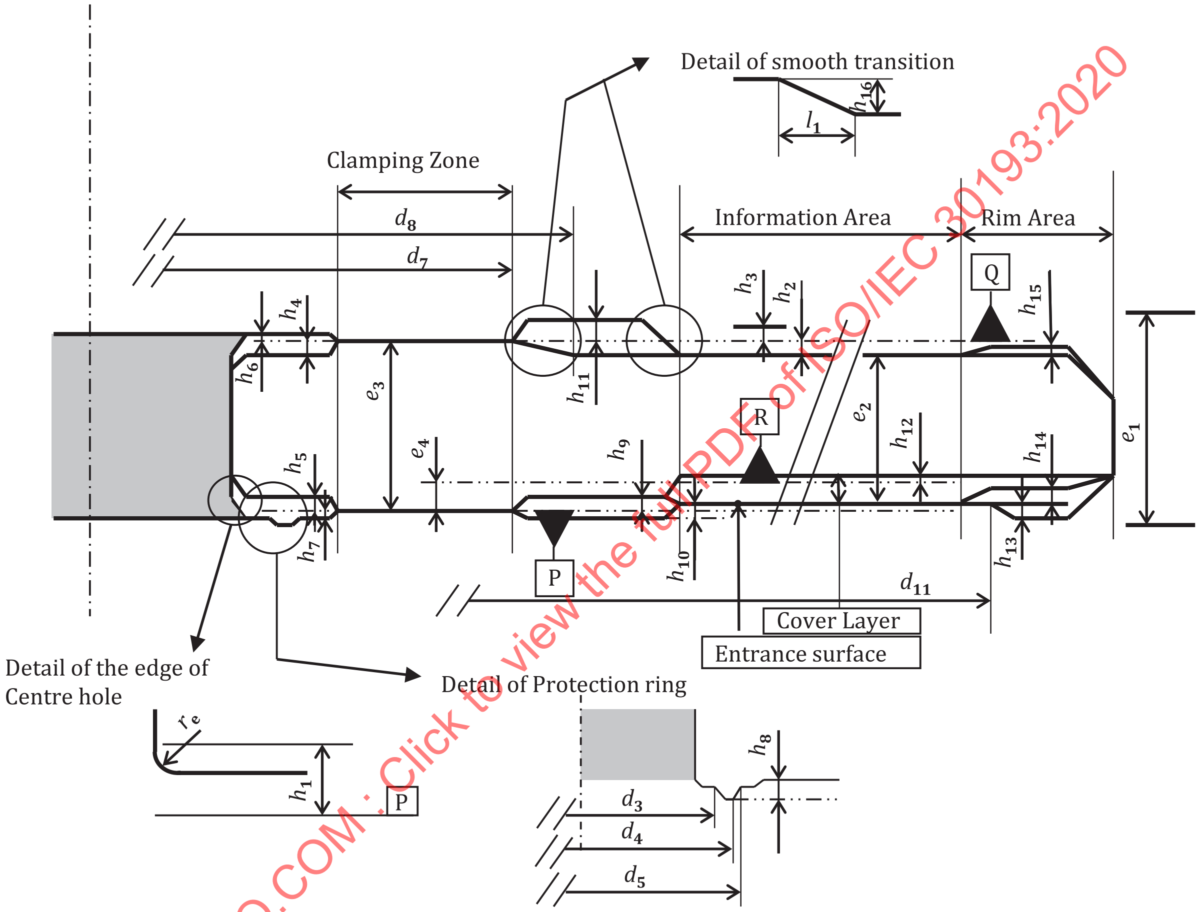


Figure 11 — Details of disk dimensions

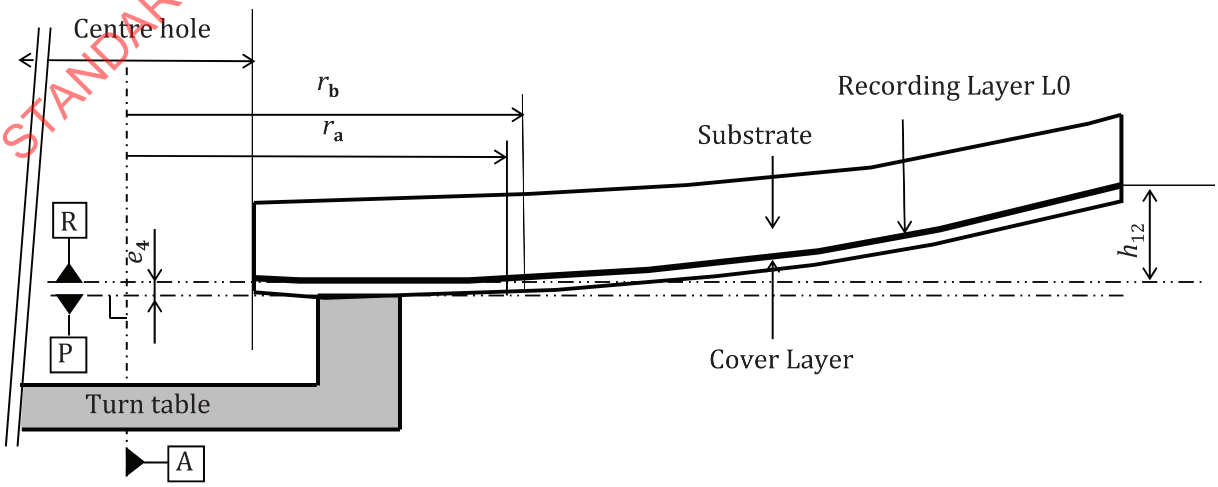


Figure 12 — Details of disk reference planes P and R and recording layer L0

10.3 Overall dimensions

The overall outer diameter of the disk shall be d_1 = (120,0 ± 0,3) mm (see Figure 10).

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

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 the 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 (for the details see Figure 11).

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.

The 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 11).

The 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 11).

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 have burrs up to maximum h_7 = 0,05 mm and maximum h_6 = 0,05 mm, respectively, outside the disk reference planes P and Q (see Figure 10 and Figure 11).

10.5 Protection ring

An optional ring-shaped protrusion in the inner area of the disk 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 damages 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 h_8 = 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 11).

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 10).

The thickness of the disk within the clamping zone shall be $e_3 = 1,20^{+0,10}_{-0,05}$ mm (see Figure 11).

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 the area between the clamping zone and the information area: $d_7 < d < d_9$ (see Figure 10).

In the area, the surface at the read-out side of the disk may be inside the disk 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 11).

In the 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 diameter of the step is I_1. If h_{16} > 0,2 mm, then the slope down to the top surface of the information area shall be smooth and I_1 shall be greater than1,8 mm as indicated in Figure 11. 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 11 and Figure 13).

On each recording layer, the data zone shall be located between the inner diameter, d_{DZIn}, and the 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 L*n* shall be $d_{DZIn} = 48{,}0^{\;0{,}0}_{-0{,}2}$ mm and the outer diameter, d_{DZO}, on recording layer L*n* shall be $d_{DZOn} \leq 116{,}2$ 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 13).

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

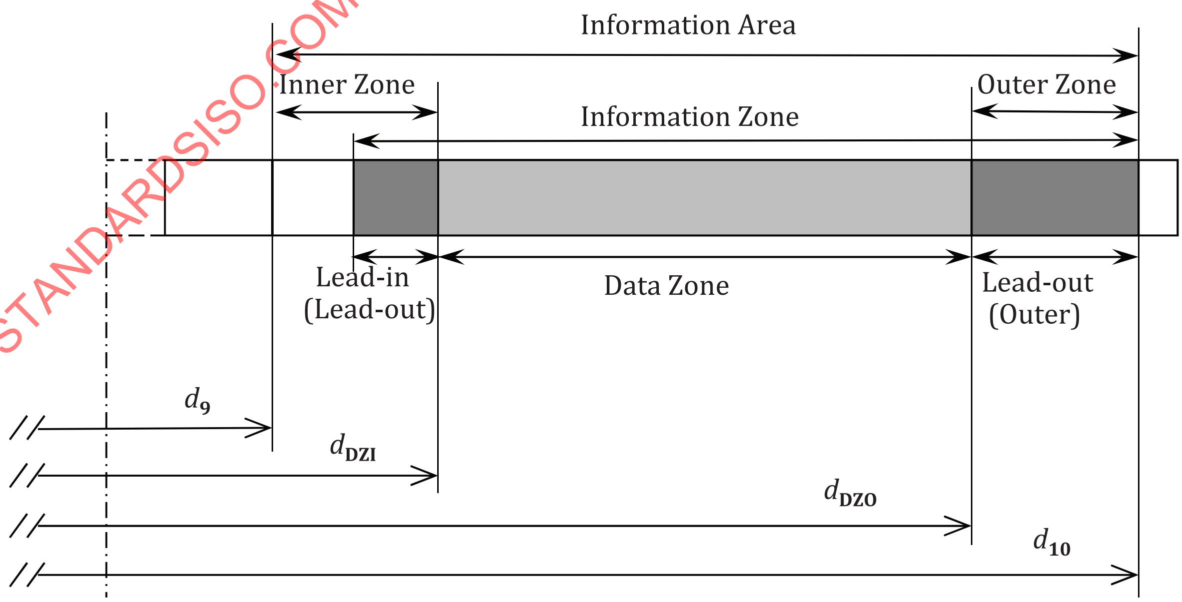


Figure 13 — Division of information area

10.8.2 Subdivision of information zone on TL disk

The information area is used to record the information zone and is divided over the three recording layers. The information zone is subdivided into the following main parts (see Figure 14):

On recording layer L0:

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

— data zone 0;

— outer zone 0.

On recording layer L1:

— outer zone1;

— data zone1;

— inner zone 1.

On recording layer L2:

— inner zone 2;

— data zone 2;

Lead-out zone (outer zone 2).

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.

On layer L2, the spiral groove shall run from the inner side of the disk towards the outer side of the disk.

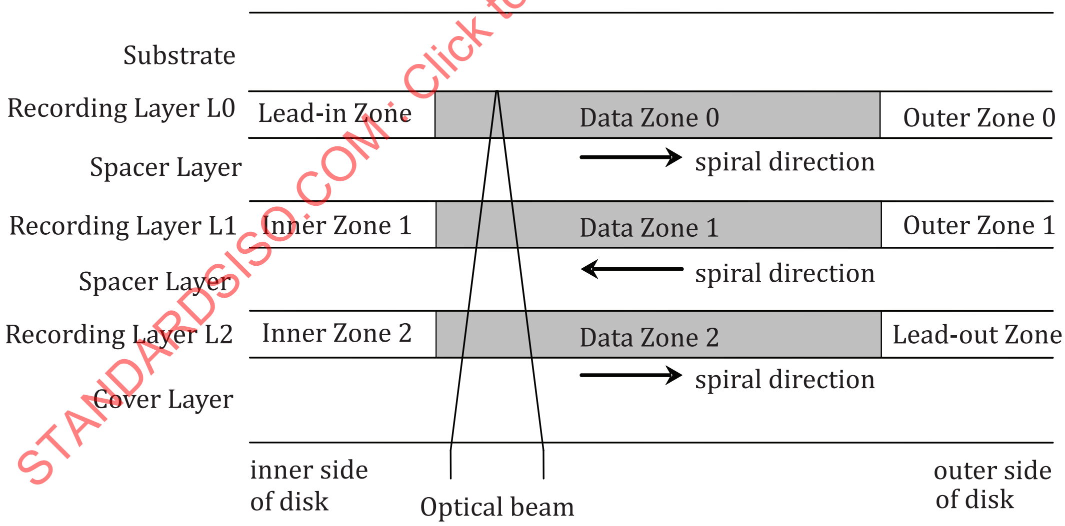


Figure 14 — Subdivision of information zone

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

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

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

Inner zone 1 shall start at the end of the data zone 1 d_{DZI1} and shall end at the beginning of data zone 1 at diameter d_{DZO1}.

Inner zone 2 starts in the area extending from diameter 44,0 mm to diameter 44,4 mm and shall end at the beginning of the data zone 2 at diameter d_{DZI2}.

Lead-out zone shall start at the end of the data zone 2 at diameter d_{DZO2} and shall end at diameter minimum 117 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 10).

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.

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 11).

In the rim area, the top surface of the disk shall not extend outside the top surface in the information area by maximum h_{15} = 0,05 mm (see Figure 11).

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 the disk rotating at a half of the recording velocity, the distance between each recording layer and the disk reference plane R (see Figure 11 and Figure 12) 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.

Due to the integrator function in the reference servo (see 9.10.2 and 9.10.3), this component is suppressed sufficiently such that the residual tracking errors as defined in 11.4.2 and 11.4.3 are mainly due to local disturbances.

11.4.2 Residual axial tracking error for 1x measurement velocity

The residual axial tracking error of each recording layer for frequencies below 1,6 kHz (= f_x, see 9.10.2), measured using the reference servo for axial tracking as specified in 9.10.2, shall be maximum 45 nm, (displacement of the objective lens needed to move the focal point of the optical beam onto the recording layer) with the disk rotating at 1x reference velocity, 3,688 m/s, and with the read power at (0,70 ± 0,10) mW for any layers of a TL disk. It is recommended to measure the residual axial tracking-error signal in a short period to avoid the deterioration of the read stability at 1x reference velocity.

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 $f_{-3\ \mathrm{dB}}$ = 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 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 maximum 32 nm. The measuring filter shall be a Butterworth BPF from $f_{-3\ \mathrm{dB}}$ = 1,6 kHz with slope = +60 dB/decade to $f_{-3\ \mathrm{dB}}$ = 10 kHz with slope = −60 dB/decade.

11.4.3 Residual axial tracking error for 2x measurement velocity

The residual axial tracking error of each recording layer for frequencies below 3,2 kHz, measured using the reference servo for axial tracking as specified in 9.10.3, shall be maximum 110 nm (displacement of the objective lens needed to move the focal point of the optical beam onto the recording layer) with the disk rotating at 2x reference velocity, 7,375 m/s, and with the read power refers to 9.4.

Spikes in the residual axial tracking-error signal due to local defects, like for instance dust and scratches, shall be excluded. For 2x measurement velocity, local defects that cause large axial tracking errors shall be taken into account as described in I.10.

The measuring filter shall be a Butterworth LPF, with $f_{-3\ \mathrm{dB}}$ = 3,2 kHz and slope = −60 dB/decade.

This means that for frequencies <3,2 kHz the maximum local acceleration of the recording layer in the direction of the reference axis A does not exceed 10,8 m/s^2 (see 9.10.3). However, due to the additional reduction of low-frequency components by the second order integrator function, the maximum acceleration at frequencies below about 400 Hz can reach values up to 45 m/s^2. The rms noise value of the residual error signal in the frequency band from 3,2 kHz to 20 kHz, measured with an integration time of 10 ms, using the reference servo for axial tracking, shall be maximum 32 nm. The measuring filter shall be a Butterworth BPF, from $f_{-3\ \mathrm{dB}}$ = 3,2 kHz with slope = +60 dB/decade, to $f_{-3\ \mathrm{dB}}$ = 20 kHz with slope = −60 dB/decade.

NOTE Residual axial tracking error for 2x measurement velocity defined in 11.4.3 is applied, only if the disk supports reading at 4x reference velocity.

11.5 Radial runout

11.5.1 General

The runout of the outer edge of the disk shall be maximum 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 half of the recording velocity.

The radial runout shall be maximum 75 µm pp.

Due to the integrator function in the reference servo (see 9.11.2 and 9.11.3), 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 4.

11.5.2 Residual radial tracking error for 1x measurement velocity

The residual radial tracking error for frequencies below 1,8 kHz (= f_x, see 9.11.2), measured using the reference servo for radial tracking as specified in 9.11.2, shall be maximum 13 nm with the disk rotating at 1x reference velocity, 3,688 m/s, and with the read power at (0,70 ± 0,10) mW for any layer of a TL disk. It is recommended to measure the residual radial tracking-error signal in a short period to avoid deterioration of the read stability at 1x reference velocity.

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 $f_{-3\ dB}$ = 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 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 maximum 9,2 nm. The measuring filter shall be a Butterworth BPF from $f_{-3\ dB}$ = 1,8 kHz with slope = +60 dB/decade to $f_{-3\ dB}$ = 10 kHz with slope = −60 dB/decade.

11.5.3 Residual radial tracking error for 2x measurement velocity

The residual radial tracking error in each recording layer for frequencies below 3,6 kHz, measured using the reference servo at for radial tracking as specified in 9.11.3, shall be maximum 20 nm with the disk rotating at 2x reference velocity, 7,375 m/s, and with the read power as in 9.4.

Spikes in the residual radial tracking-error signal due to local defects, like for instance dust and scratches, shall be excluded.

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

This means that for frequencies <3,6 kHz, the maximum local acceleration in the radial direction does not exceed 3,4 m/s^2, see 9.11.3. However, due to the additional reduction of low-frequency components by the second order integrator function the maximum acceleration at frequencies below about 400 Hz can reach values up to 15 m/s^2. The rms noise value of the residual error signal in the frequency band from 3,6 kHz to 20 kHz, measured with an integration time of 10 ms, using the reference servo for radial tracking, shall be maximum 9,2 nm. The measuring filter shall be a Butterworth BPF, from $f_{-3\ dB}$ = 3,6 kHz with slope = +60 dB/decade, to $f_{-3\ dB}$ = 20 kHz with slope = −60 dB/decade.

NOTE Residual axial tracking error for 2x measurement velocity defined in 11.5.3 is applied, only if the disk supports reading at 4x reference velocity.

11.6 Durability of cover layer

11.6.1 Impact resistance of cover layer

To prevent excessive disk damage in case an object lens hits the entrance surface at the read-out side of the disk, the surface of the disk should have a minimum impact resistance. This 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 a 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 should 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 layers and all the semi-transparent recording stack of layer L*n* 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 (22):

$$1{,}45 \le n \le 1{,}70 \tag{22}$$

12.3 Thickness of transmission stacks (TS)

The average thickness between radius r_a and radius r_b is called the reference thickness of the related transmission stack (TS0, TS1 or TS2) on the disk (see 10.2 and Figure 12).

The thicknesses of TS0, TS1 and TS2, measured over the whole disk, shall fulfil the following eight requirements:

In Figure 15, for reference to requirements a) to c), the curves show the thickness ranges with equivalent spherical aberration. The ratio of a thickness with arbitrary refractive index n to that with refractive index 1,60 is expressed by an approximate function of $g(n)$ [see Formula (23)]:

$$g(n) = -1{,}111\,1 \times n^3 + 5{,}814\,3 \times n^2 - 9{,}880\,8 \times n + 6{,}476\,0 \tag{23}$$

Figure 16 shows a coefficient function for converting the actual thickness to an effective thickness for requirements f). The actual thickness means physical value. The effective thickness means imaginary value when refractive index is assumed to be 1,60.

The actual thickness of arbitrary refractive index n is converted to an effective thickness of standard refractive index of 1,60. Defocus values of the actual and effective thickness are the same. In this subclause, defocus is defined as the focus position movement of the light going through the transparent medium with each thickness and each refractive index.

The coefficient function of $f(n)$ equals $\tan(\theta_r) / \tan(\theta_o)$, where θ_o and θ_r are the converging angles in the transmission stack with refractive indexes of 1,60 and the arbitrary value of n, respectively. The function $f(n)$ is expressed approximately by Formula (24):

$$f(n) = -1{,}088\,0 \times n^3 + 6{,}102\,7 \times n^2 - 12{,}042 \times n + 9{,}100\,7 \quad (24)$$

a) The thickness of TS0 (all layers on top of layer L0) depends on the refractive index and shall be within the uppermost shaded area in Figure 15 (In case of a refractive index of n, the thickness shall be between 94,0 × $g(n)$ µm and 106,0 × $g(n)$ µm, and the dashed curve 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 middle shaded area in Figure 15 (In case of a refractive index of n, the thickness shall be between 69,0 × $g(n)$ µm and 81,0 × $g(n)$ µm, and the dashed curve indicates the nominal thickness as a function of the refractive index).

c) The thickness of TS2 (all layers on top of layer L2), as determined by its refractive index, shall be within the undermost shaded area in Figure 15 (In case of a refractive index of n, the thickness shall be between 52,0 × $g(n)$ µm and 62,0 × $g(n)$ µm, and the dashed curve indicates the nominal thickness as a function of the refractive index).

d) The thickness of spacer layer1 ($S1$), sandwiched by layer L0 and layer L1, shall be between 20,0 µm and 30,0 µm.

e) The thickness of spacer layer2 ($S2$), sandwiched by layer L1 and layer L2, shall be between 13,0 µm and 23,0 µm.

f) The thickness differences shall meet the requirement $C - (S1 + S2) \geq 1{,}0$ µm and $S1 - S2 \geq 1{,}0$ µm [C, $S1$, $S2$ shall be converted from their actual thickness to their effective thickness by being multiplied by $f(n)$ shown in Figure 16, where thickness of TS2 equals the cover-layer thickness (C) and n is refractive index].

g) The maximum deviation, ΔD, of the thickness of TS0 and TS1 from their respective reference thickness shall meet the requirement $|\Delta D| \leq 2{,}5$ µm.

h) The maximum deviation, ΔD, of the thickness of TS2 from its reference thickness shall meet the requirement $|\Delta D| \leq 2{,}0$ µm.

12.4 Example of target thickness of spacer layers for TL disks

In mass production, simple target values of thicknesses are useful.

It is recommended that when the following three requirements are fulfilled, then requirements a) to f) of 12.3 are always fulfilled for a refractive index of 1,60.

a) The thickness of the spacer layer1 ($S1$) should be 25,0 µm ± 2,0 µm.

b) The thickness of the spacer layer2 ($S2$) should be 18,0 µm ± 2,0 µm.

c) The thickness of TS2 (= C) should be 57,0 µm ± 2,0 µm.

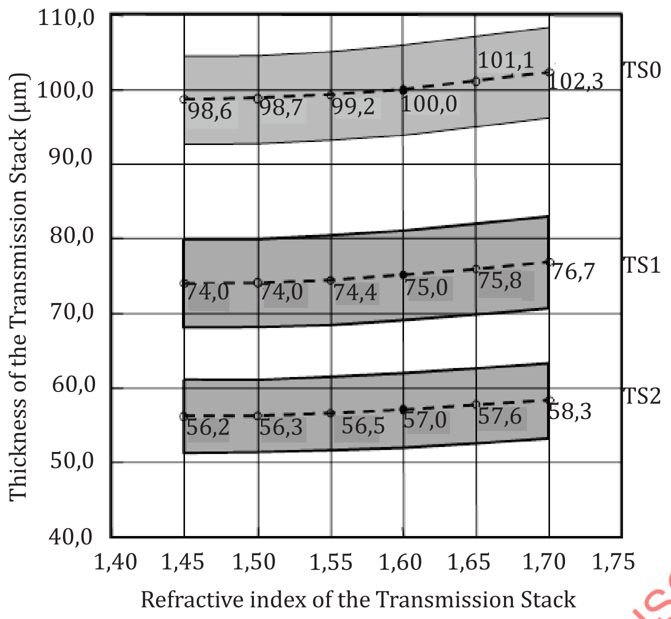


Figure 15 — Thickness of transmission stacks as function of reflective index

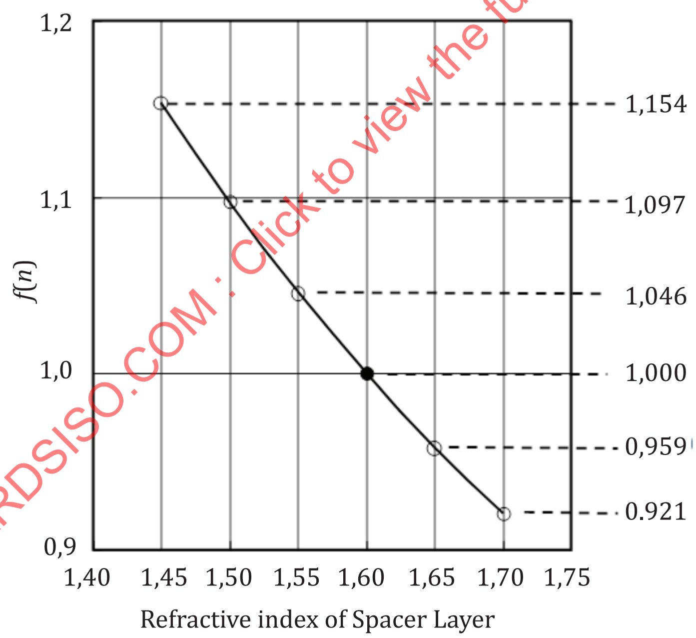


Figure 16 — Ratio of effective thickness with refractive index 1,60 and that with arbitral refractive index, *n*

12.5 Reflectivity of recording layers

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

— in unrecorded virgin grooves:

  — of layer L0 and layer L1: $R_{g\text{-}v}$ = 1,5 %to 4,0 %;

  — and of layer L2: $R_{g\text{-}v}$ = 2,2 %to 4,0 %;

— in unrecorded erased grooves:

  — of layer L0 and layer L1: $R_{g\text{-}e}$ = 1,4 %to 4,0 %;

  — and of layer L2: $R_{g\text{-}e}$ = 2,0 %to 4,0 %;

  — at each location on the disk: $0{,}75 \times R_{g\text{-}v} < R_{g\text{-}e} < 1{,}25 \times R_{g\text{-}v}$;

— in recorded grooves for the first 10 DOW cycles:

  — of layer L0 and layer L1: R_{8H} = 1,4 %to 4,0 %;

  — and of layer L2: R_{8H} = 2,0 %to 4,0 %;

  — at each location on the disk: $0{,}75 \times R_{g\text{-}v} < R_{8H} < 1{,}25 \times R_{g\text{-}v}$.

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

12.6 Birefringence

The in-plane birefringence of the transmission stacks shall be (see Annex J) as per Formula (25):

$$\Delta n_{//} \le 1{,}5 \times 10^{-4} \quad (25)$$

The perpendicular birefringence of the transmission stacks shall be (see Annex J) as per Formula (26):

$$\Delta n_{\perp} \le 1{,}2 \times 10^{-3} \quad (26)$$

12.7 Angular deviation

The angular deviation is the angle α 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 α includes deflections of the entrance surface and to lack of parallelism of the cover layer and/or spacer layer (see Figure 17).

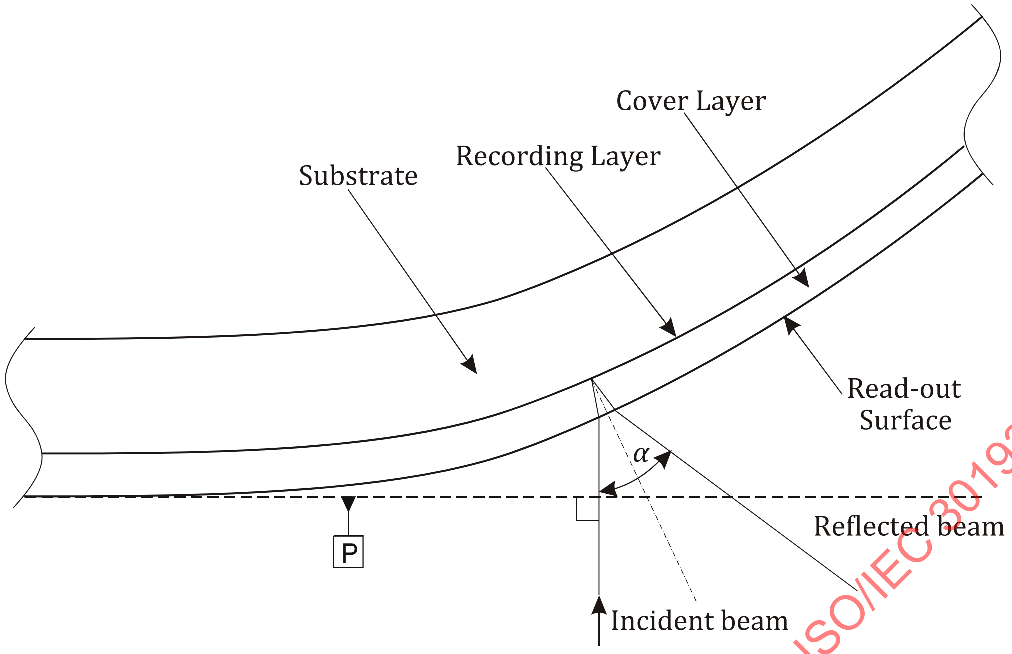


Figure 17 — Definition of angular deviation

The requirements for the angle α are as follows:

— in the radial direction:

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

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

— in the tangential direction:

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

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 18).

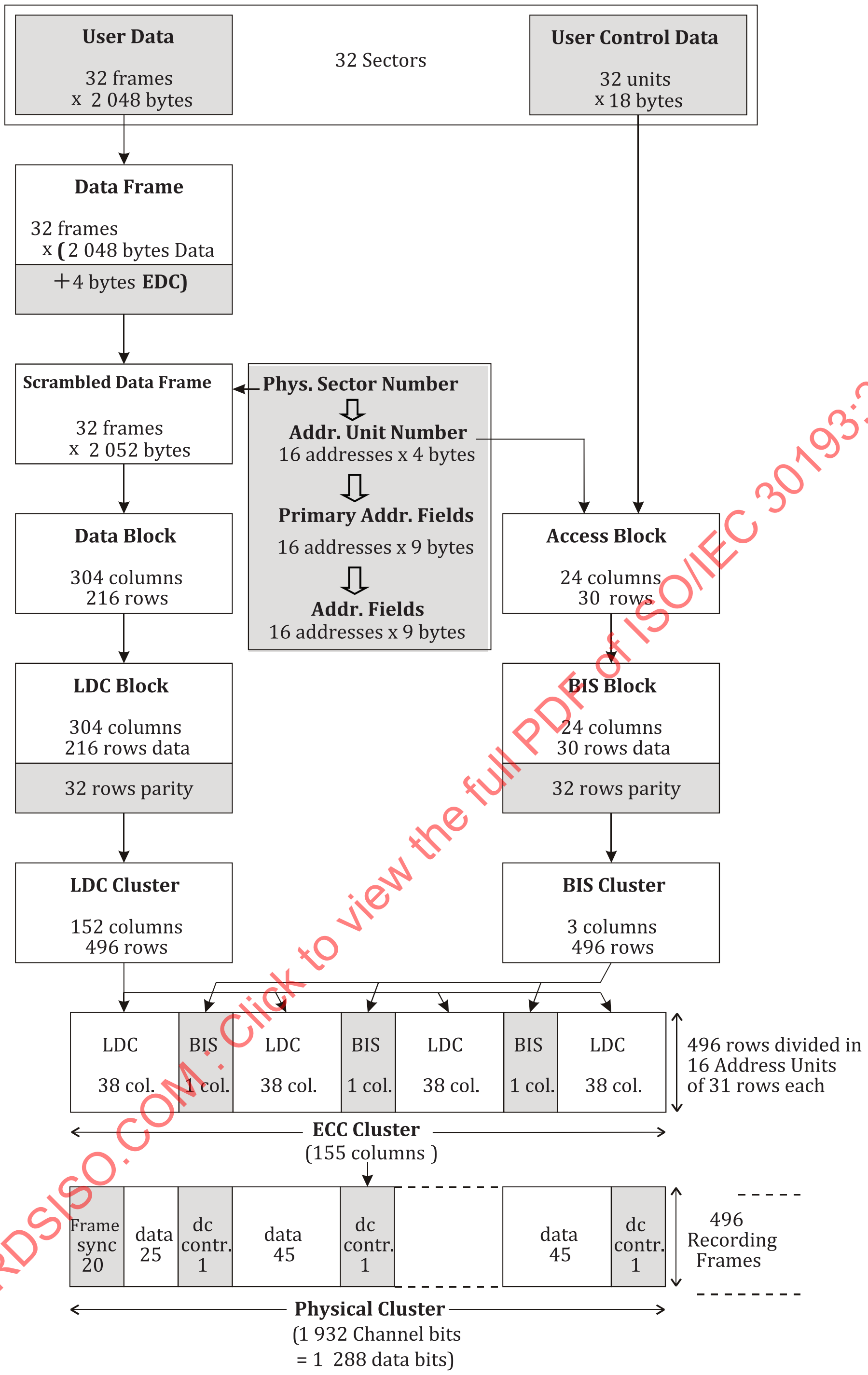


Figure 18 — Schematic representation of encoding process

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:

— an ECC cluster, subdivided into 16 address units; and

— 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 2 error correction mechanisms as follows.

— First the data is protected by a long-distance error-correction code (LDC), 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.

— Secondly, the data is multiplexed with a powerful burst indicator 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 19).

All the data is arranged in an array as indicated in Figure 19. This array is read in the horizontal direction, row after row, and recorded on the disk after insertion of additional d.c. 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.

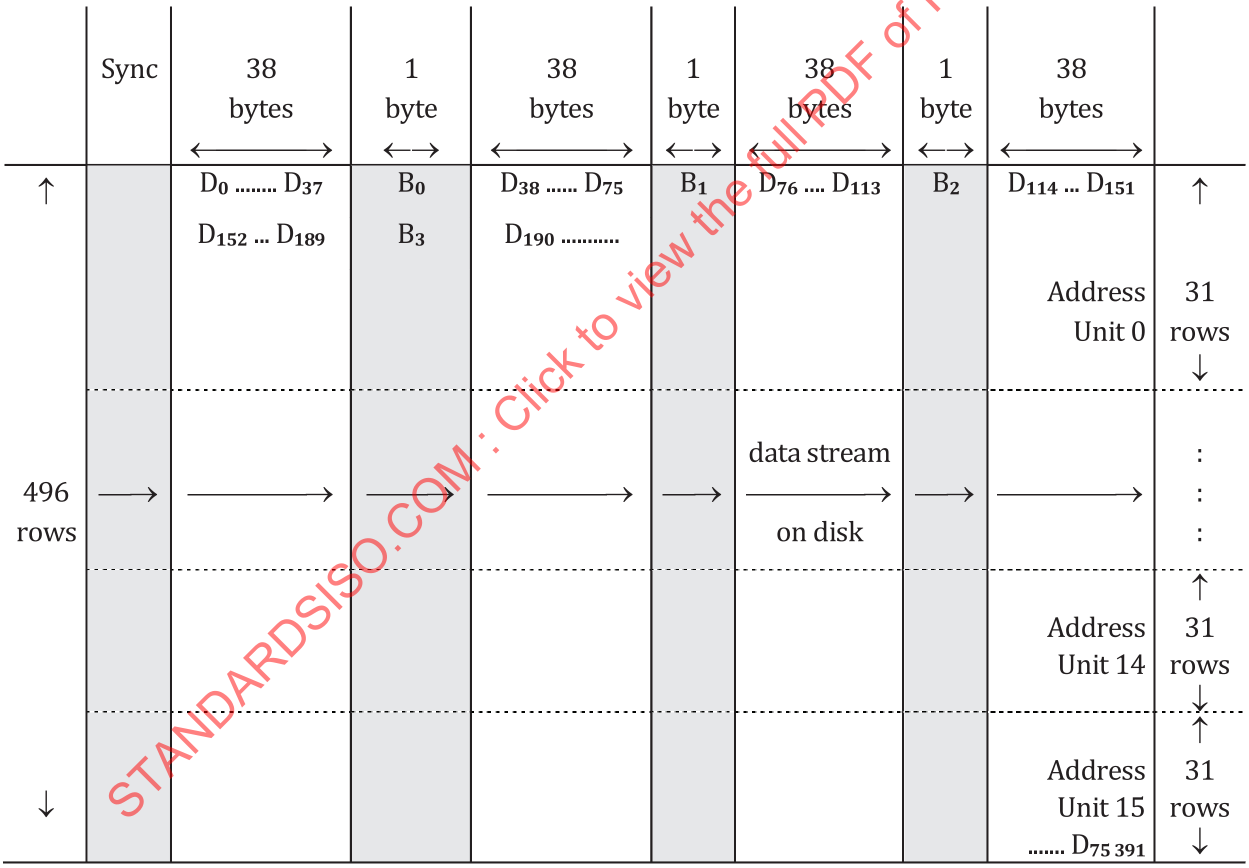


Figure 19 — Schematic representation of physical cluster on disk

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 for 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 frame

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 20).

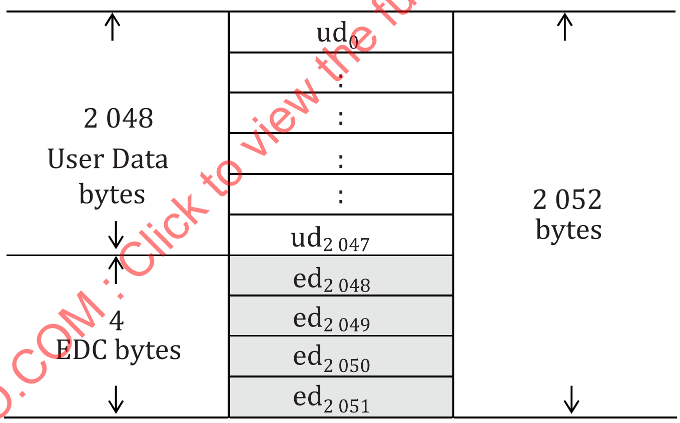


Figure 20 — data frame

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 Formula (27) for i = 0 to 31:

$$EDC(x) = \sum_{i=31}^{0} b_i x^i = I(x) \bmod G(x) \tag{27}$$

where

$$I(x)=\sum_{i=16\,415}^{32} b_i x^i \text{ and } G(x)=x^{32}+x^{31}+x^4+1.$$

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 21 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 (28):

$$\Phi(x)=x^{16}+x^{15}+x^{13}+x^4+1 \quad (28)$$

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 21).

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

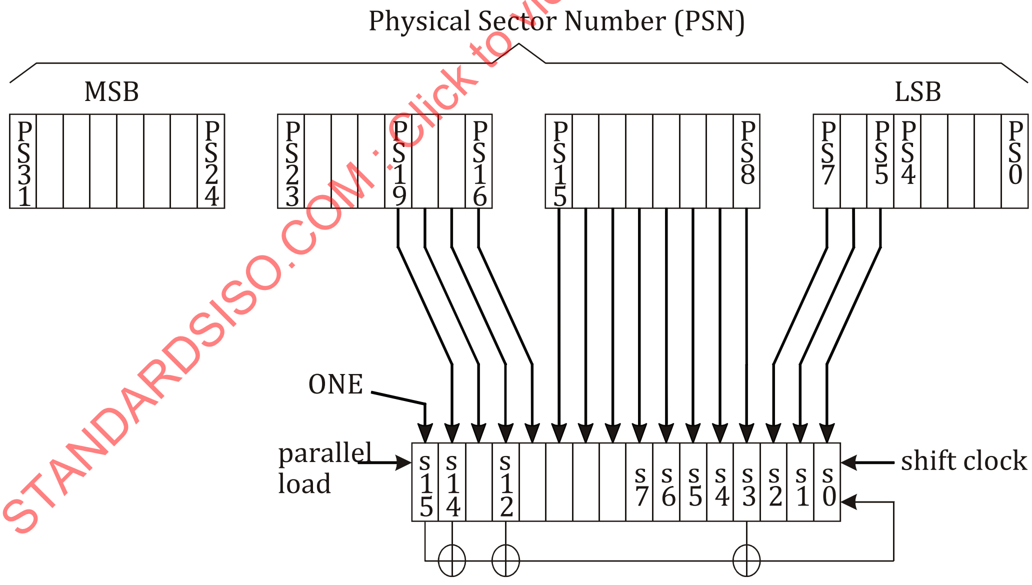


Figure 21 — Scrambler circuit

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 (see Figure 22).

32 Frames

2 052 bytes	0	1	:	F	:	31
	$d_{0,0}$	$d_{0,1}$	:	$d_{0,F}$	:	$d_{0,31}$
	$d_{1,0}$	$d_{1,1}$	:	$d_{1,F}$	:	$d_{1,31}$
	:		:	:	:	:
	:		:	:	:	:
	$d_{2\,050,0}$	$d_{2\,050,1}$	:	$d_{2\,050,F}$	:	$d_{2\,050,31}$
	$d_{2\,051,0}$	$d_{2\,051,1}$	:	$d_{2\,051,F}$	:	$d_{2\,051,31}$

Figure 22 — 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 23. 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

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

Figure 23 — 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 24 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
↑	↑	$e_{0,0}$	$e_{0,1}$	:	$e_{0,L}$	:	$e_{0,302}$	$e_{0,303}$
	216	$e_{1,0}$	$e_{1,1}$	:	$e_{1,L}$	:	$e_{1,302}$	$e_{1,303}$
	rows	$e_{2,0}$	:	:	:	:	:	:
	with	:	:	:	:	:	:	:
1 LDC	data	:	:	:	:	:	:	:
code-word	↓	$e_{215,0}$	$e_{215,1}$	:	$e_{215,L}$	:	$e_{215,302}$	$e_{215,303}$
= 248	↑	$p_{216,0}$	$p_{216,1}$	:	$p_{216,L}$	:	$p_{216,302}$	$p_{216,303}$
bytes	32	:	:	:	:	:	:	:
	rows	:	:	:	:	:	:	:
	with	:	:	:	:	:	:	:
	parity	:	:	:	:	:	:	:
↓	↓	$p_{247,0}$	$p_{247,1}$	:	$p_{247,L}$	:	$p_{247,302}$	$p_{247,303}$

Figure 24 — 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 (29):

$$p(x)=x^8+x^4+x^3+x^2+1 \quad (29)$$

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 (30):

$$g(x)=\prod_{i=0}^{31}(x-\alpha^i) \quad (30)$$

The LDC is systematic: the 216 information bytes appear unaltered in the highest-degree positions of each code word. The parity-check matrix H_{LDC} of code l_{dc} is such that $H_{LDC} \times l_{dc}^T = 0$ for all LDC code-words l_{dc}.

The second row $h_{LDC\,2}$ 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 (31):

$$h_{LDC\,2} = (\alpha^{247}, \alpha^{246} .. \alpha^2, \alpha, 1) \quad (31)$$

13.8 LDC cluster

13.8.1 General

After generating the LDC code-words, the LDC block is interleaved in a 2-step process, resulting in the LDC cluster.

13.8.2 First interleaving 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 25.

	← 152 columns →					
	0	1			151	
↑	$e_{0,0}$	$e_{0,2}$	:	:	$e_{0,302}$	↑
	$e_{0,1}$	$e_{0,3}$	:	:	$e_{0,303}$	
432 rows with data	$e_{1,0}$	$e_{1,2}$	:	:	$e_{1,302}$	
	$e_{1,1}$	$e_{1,3}$	:	:	$e_{1,303}$	
	:	:	:	:	:	
	:	:	:	:	:	
	$e_{215,0}$	$e_{215,2}$	:	:	$e_{215,302}$	
↓	$e_{215,1}$	$e_{215,3}$	:	:	$e_{215,303}$	496 rows
↑	$p_{216,0}$	$p_{216,2}$	:	:	$p_{216,302}$	
	$p_{216,1}$	$p_{216,3}$	:	:	$p_{216,303}$	
64 rows with parity	$p_{217,0}$	$p_{217,2}$	:	:	$p_{217,302}$	
	$p_{217,1}$	$p_{217,3}$	:	:	$p_{217,303}$	
	:	:	:	:	:	
	:	:	:	:	:	
	$p_{247,0}$	$p_{247,2}$	:	:	$p_{247,302}$	
↓	$p_{247,1}$	$p_{247,3}$	:	:	$p_{247,303}$	↓

Figure 25 — 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 26).

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 19.

	←								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 26 — 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 are 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 27).

Each address field consists of 9 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
↑	Partially modified and inverted 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	$AF_{4,0}$	$AF_{4,1}$	:	$AF_{4,S}$	:	$AF_{4,15}$
	Partially inverted 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 27 — 16 address fields

13.9.2.2 Byte assignment for address fields

Before describing address fields, primary address fields, which consists of address-unit number, flag bits and parity bytes, are defined as follows:

$PAF_{0,S}$ = MSB of the address-unit number with modified bit order as {AU31, AU30, AU29, AU28, *AU24*, AU27, AU26, AU25};

$PAF_{1,S}$ = 2nd SB of the address-unit number;

$PAF_{2,S}$ = 3rd SB of the address-unit number;

$PAF_{3,S}$ = LSB of the address-unit number;

$PAF_{4,S}$ = 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 for instance an address. The basic format for assigning some of these flag bits is specified in 13.9.2.3. Flag bits not used shall be set to ZERO.

$PAF_{5,S}$ .. $PAF_{8,S}$ = 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 (32):

$$p(x)=x^8+x^4+x^3+x^2+1 \tag{32}$$

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 primary address-field code-word, represented by the vector $pafc$ = ($PAF_{0,S}$ ..$PAF_{i,S}$ .. $PAF_{8,S}$), is a Reed-Solomon code over GF(2^8) having 4 parity bytes and 5 information bytes. Such a code word can be represented by a polynomial $pafc(x)$ of degree 8 (possibly having some coefficients equal to zero), where the highest degrees correspond to the information part of the vector ($PAF_{0,S}$ .. , etc.) and the lowest degrees correspond to the parity part of the vector ($PAF_{5,S}$ .., etc.).

$pafc(x)$ is a multiple of the generator polynomial $g(x)$ of the primary address-field code-word. The generator polynomial is as per Formula (33):

$$g(x)=\prod_{i=0}^{3}\left(x-\alpha^i\right) \tag{33}$$

The primary address-field code is systematic: the 5 information bytes appear unaltered in the highest-degree positions of each code word. The parity-check matrix H_{PAFC} of code $pafc$ is such that $H_{PAFC} \times pafc^T = 0$ for all primary address-field code-words $pafc$.

The second row $h_{PAFC\,2}$ of the parity-check matrix H_{PAFC} 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 $h_{PAFC\,2}$ of the parity-check matrix H_{PAFC} is given by Formula (34):

$$h_{PAFC\,2} = (\alpha^8, \alpha^7 .. \alpha^2, \alpha, 1) \tag{34}$$

Address fields are defined as the following by partially inverting primary address fields:

$AF_{0,S} = PAF_{0,S}$;

$AF_{1,S} = PAF_{1,S}$;

$AF_{2,S}$ = all bits inversion in $PAF_{2,S}$;

$AF_{3,S}$ = all bits inversion in $PAF_{3,S}$;

$AF_{4,S} = PAF_{4,S}$;

$AF_{5,S}$ = all bits inversion in $PAF_{5,S}$;

$AF_{6,S}$ = all bits inversion in $PAF_{6,S}$;

$AF_{7,S} = PAF_{7,S}$;

$AF_{8,S} = PAF_{8,S}$.

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 PSN as defined in Figure 28. The address-unit numbers increase by 2 for each successive address unit, for reasons of synchronization with the PSN (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 the data zone 0 is 00 10 00 00h (1 048 576 decimal).

The last address-unit number in data zone 1 is 03 EF FF FEh (66 060 286 decimal)

The first address-unit number in data zone 2 is 04 10 00 00h (68 157 440 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.

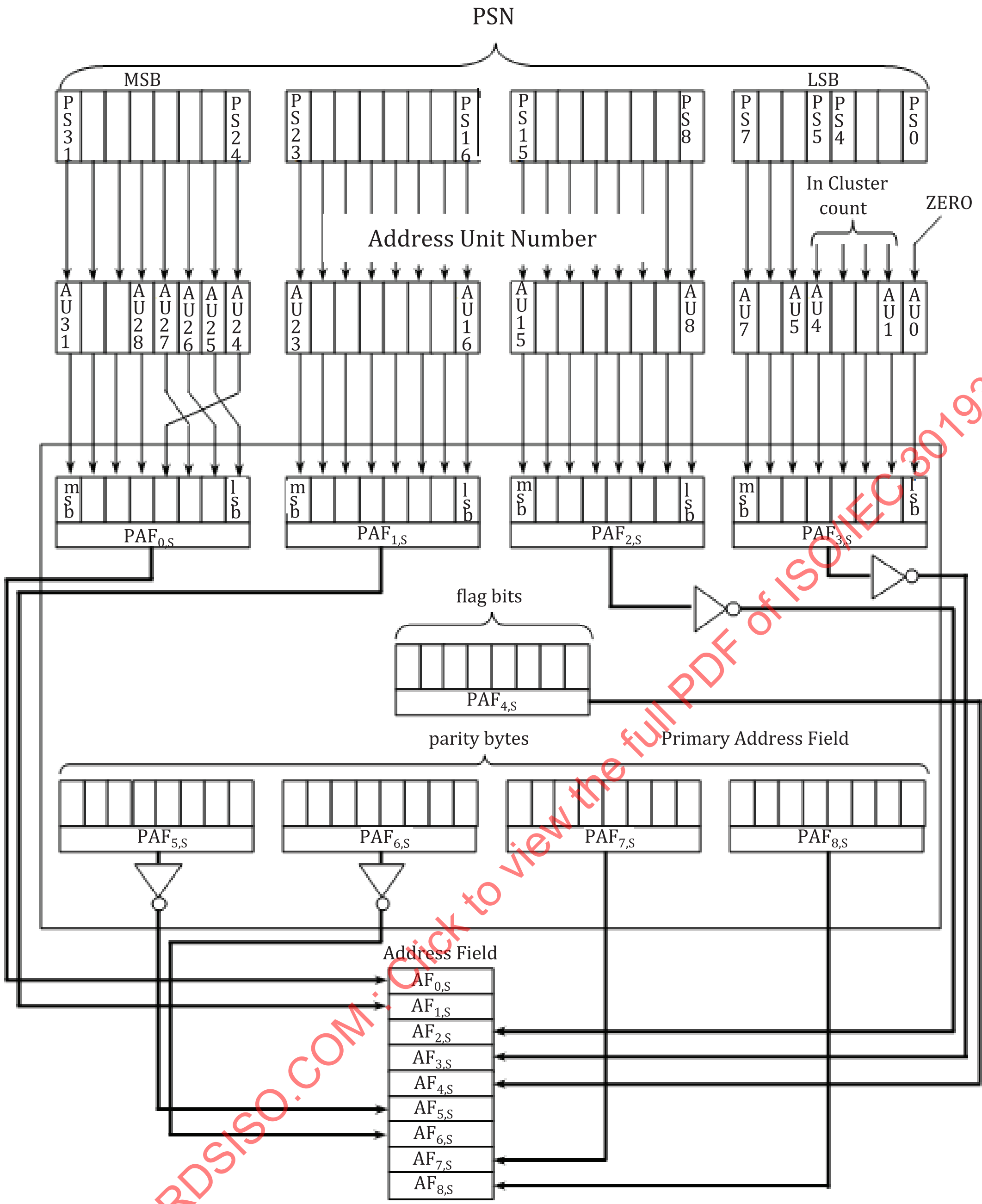


Figure 28 — Composition of AUNs, primary address field and address field from PSNs

13.9.2.4 Assignments for the flag bits

Byte $AF_{4,S}$ \ Bit	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 29 — 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 address unit shall hold the flag bits for 2 data frames (see Figure 29).

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

Bits b_3 and b_0 of all flag bytes $AF_{4,S}$ shall be reserved unless otherwise specified by the BDAP.

RID_tag bits IdT_i: Bits b_3 of the 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 29).

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

Recording data bits Rd_i: Bits b_2 of the 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 29):

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;

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

Other: reserved unless otherwise specified by the BDAP.

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 the user data, special control data can be added to each user-data frame. These additional bytes can carry the 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 30).

	← 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 30 — 32 user-control data units

13.9.4 Byte/Bit assignment for user-control data

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

← 24 columns →

↑ 6 rows with Physical Addresses ↓	$AF_{0,0}$	$AF_{1,0}$	$AF_{2,0}$	$AF_{0,7}$	$AF_{1,7}$	$AF_{2,7}$	$AF_{0,6}$	$AF_{1,6}$	$AF_{2,6}$	$AF_{0,5}$	:	:	$AF_{0,1}$	$AF_{1,1}$	$AF_{2,1}$	↑ 30 rows ↓
	$AF_{0,8}$	$AF_{1,8}$	$AF_{2,8}$	$AF_{0,15}$	:	:	$AF_{0,14}$	:	:	$AF_{0,13}$	:	:	$AF_{0,9}$	$AF_{1,9}$	$AF_{2,9}$	
	$AF_{4,1}$	$AF_{5,1}$	$AF_{3,1}$	$AF_{4,0}$	$AF_{5,0}$	$AF_{3,0}$	$AF_{4,7}$	$AF_{5,7}$	$AF_{3,7}$	$AF_{4,6}$	:	:	$AF_{4,2}$	$AF_{5,2}$	$AF_{3,2}$	
	$AF_{4,9}$	:	:	$AF_{4,8}$	$AF_{5,8}$	$AF_{3,8}$	$AF_{4,15}$	:	:	$AF_{4,14}$	:	:	$AF_{4,10}$	$AF_{5,10}$	$AF_{3,10}$	
	$AF_{8,2}$	$AF_{6,2}$	$AF_{7,2}$	$AF_{8,1}$	$AF_{6,1}$	$AF_{7,1}$	$AF_{8,0}$	$AF_{6,0}$	$AF_{7,0}$	$AF_{8,7}$	:	:	$AF_{8,3}$	$AF_{6,3}$	$AF_{7,3}$	
	$AF_{8,10}$	:	:	$AF_{8,9}$	:	:	$AF_{8,8}$	$AF_{6,8}$	$AF_{7,8}$	$AF_{8,15}$	:	:	$AF_{8,11}$	$AF_{6,11}$	$AF_{7,11}$	
↑ 24 rows with User Control Data ↓	$UC_{0,0}$	$UC_{6,1}$	$UC_{12,2}$	$UC_{0,4}$	:	:	:	:	:	:	:	:	:	:	$UC_{12,30}$	
	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	
	:	:	$UC_{17,2}$	:	:	:	:	:	:	:	:	:	:	:	$UC_{17,30}$	
	:	:	$UC_{0,3}$	:	:	:	:	:	:	:	:	:	:	:	$UC_{0,31}$	
	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	
	:	$UC_{17,1}$	:	:	:	:	:	:	:	:	:	:	:	:	:	
	:	$UC_{0,2}$	:	:	:	:	:	:	:	:	:	:	:	$UC_{0,30}$	:	
	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	
	$UC_{17,0}$	:	:	$UC_{17,4}$	:	:	:	:	:	:	:	:	:	:	:	
	$UC_{0,1}$	:	:	$UC_{0,5}$	:	:	:	:	:	:	:	:	:	:	:	
	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	
	$UC_{5,1}$	$UC_{11,2}$	$UC_{17,3}$	:	:	:	:	:	:	:	:	:	:	$UC_{11,30}$	$UC_{17,31}$	

Figure 31 — Composition of access block (from 16 address fields and 32 user-control data units)

13.10 Access block

The data for the address fields and user control 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 is mapped in a special pre-interleaved way.

The 9 bytes of each of the 16 addresses (see Figure 31) are grouped into 3 groups of 3 bytes.

The 3 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 3 positions to the left (see Figure 31).

The 3 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 3 positions to the left.

Within each group of bytes in the third and fourth rows, the bytes are shifted cyclically to the left over one-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 (35):

byte $AF_{x,y}$ shall be allocated in:

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

$$\text{column } c = 3 \times \text{mod}\{[\text{div}(x,3) + 16 - y],8\} + \text{mod}\{[x - \text{div}(x,3)],3\} \quad (35)$$

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 31).

13.11 BIS block

The bytes in each column of an access block are renumbered as shown in Figure 32 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
One BIS code-word = 62 bytes ↑	↑ 30 Information bytes ↓	$b_{0,0}$	$b_{0,1}$	:	$b_{0,C}$	:	:	$b_{0,23}$
		$b_{1,0}$	$b_{1,1}$	:	$b_{1,C}$	:	:	$b_{1,23}$
		:	:	:	:	:	:	:
		:	:	:	$b_{N,C}$	:	:	:
		:	:	:	:	:	:	:
		$b_{29,0}$	$b_{29,1}$	:	$b_{29,C}$	:	:	$b_{29,23}$
	↑ 32 Parity bytes ↓	$pb_{30,0}$	$pb_{30,1}$	:	$pb_{30,C}$	:	:	$pb_{30,23}$
		:	:	:	:	:	:	:
		:	:	:	:	:	:	:
		:	:	:	:	:	:	:
↓		$pb_{61,0}$	$pb_{61,1}$	:	$pb_{61,C}$	:	:	$pb_{61,23}$

Figure 32 — 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 (36):

$$p(x)=x^8+x^4+x^3+x^2+1 \tag{36}$$

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 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 (37):

$$g(x)=\prod_{i=0}^{31}\left(x-\alpha^i\right) \tag{37}$$

The BIS code is systematic: the 30 information bytes appear unaltered in the highest-degree positions of each code word. The parity-check matrix H_{BIS} of code bis is such that $H_{BIS} \times bis^T = 0$ for all BIS code-words bis.

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 $h_{BIS\ 2}$ of the parity-check matrix H_{BIS} is given by Formula (38):

$$h_{BIS\ 2} = (\alpha^{61}, \alpha^{60} .. \alpha^{2}, \alpha, 1) \quad (38)$$

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 19. 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 33).

The essentials of the BIS interleaving scheme are the following (see Figure 32 and Figure 33 and the examples in Figure 34 and Figure 35):

— each row of the 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 as follows:

  — 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;

  — etc., 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.

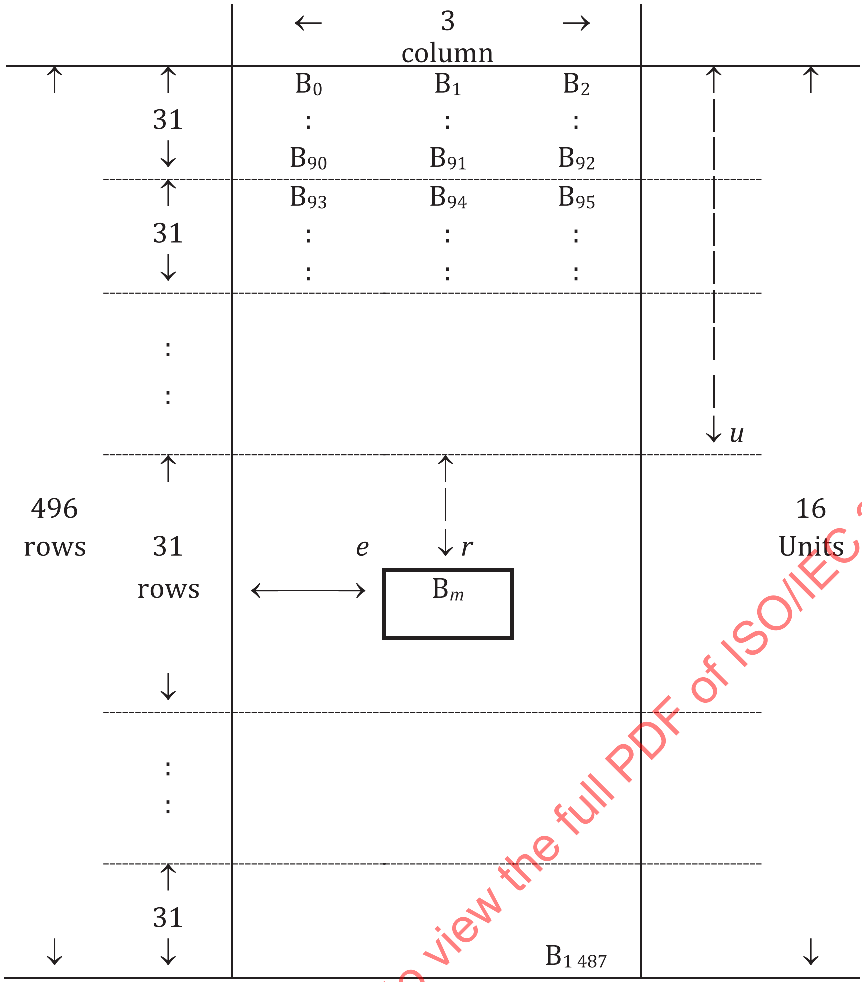


Figure 33 — BIS cluster

Mathematically, the mapping of the bytes from a BIS block into a BIS cluster can be represented by Formulae (39) to (41):

Byte $b_{N,C}$ or $pb_{N,C}$ (see Figure 32) is placed as follows:

— in unit $u = \mathrm{mod}\{[\mathrm{div}(N,2) + 8 - \mathrm{div}(C,3)],8\} + 8 \times \mathrm{mod}(N,2)$ (39)

— on row $r = \mathrm{div}(N,2)$ (40)

— in column $e = \mathrm{mod}\{[C + \mathrm{div}(N,2)],3\}$ (41)

The byte number m, giving the sequence number B_m as the physical cluster is written to the disk (see Figure 19), is as per Formula (42):

$$m = (u \times 31 + r) \times 3 + e \qquad (42)$$

		Byte number *N,C* from BIS Block			Shift right (= mod(*r*,3))	Filling in upward direction
			column *e*			
Unit *u*	row *r*	0	1	2		
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 34 — 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 35 — Example of mapping (partial) of BIS bytes into last 8 units

Some conclusions:

— All information bytes of the BIS block are found in the first 15 rows of each address unit.

— All parity bytes of the BIS block are found in the last 16 rows of each address unit.

— Each address field is found in the first 3 rows of each address unit (see Figure 36).

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 3 columns from the BIS cluster are inserted one by one. After multiplexing the BIS cluster with the LDC cluster, the ECC cluster of Figure 36 is reached.

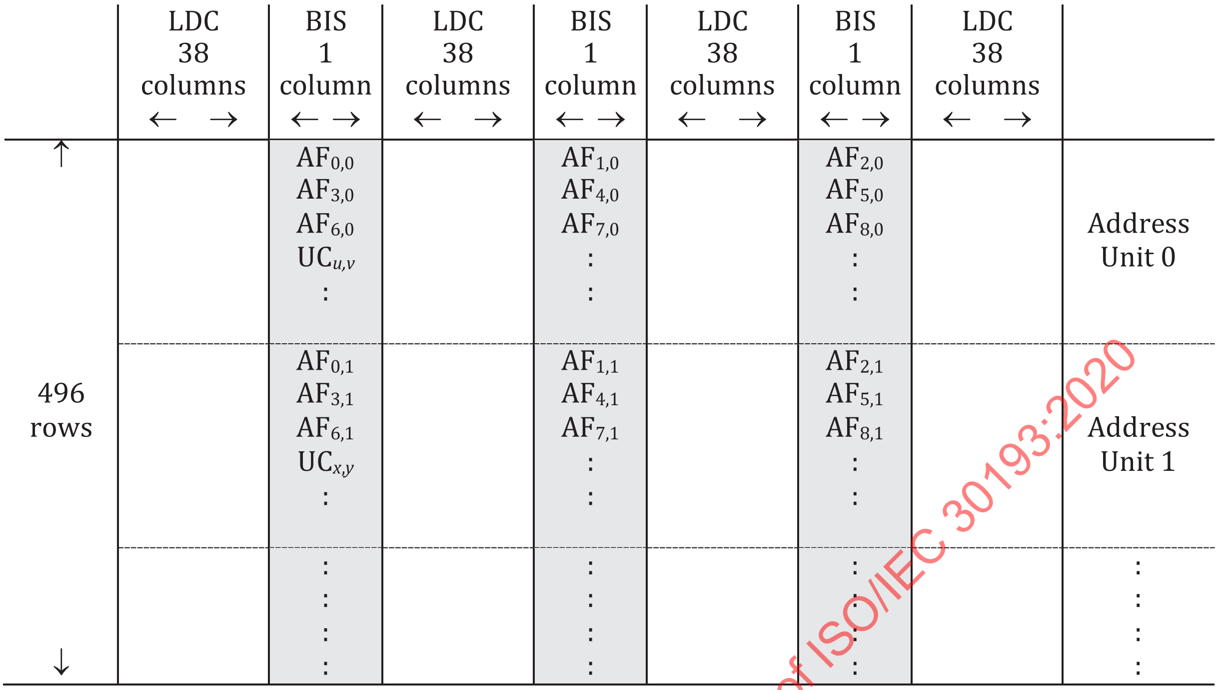


Figure 36 — ECC cluster after multiplexing of BIS cluster with LDC cluster

13.15 Recording frames

Each row of an ECC cluster is transformed into a recording frame by adding locations for the 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 1 group of 25 data bits and 27 groups of 45 data bits (see Figure 37), 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 1 additional bit position to form a dc-control block.

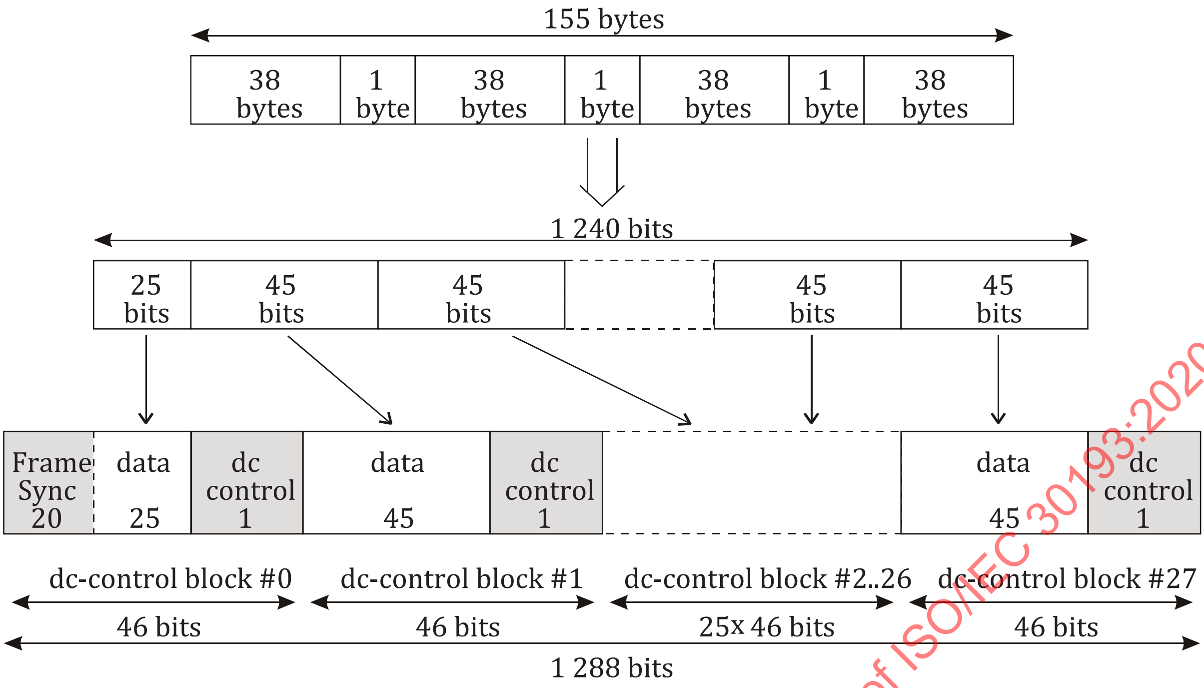


Figure 37 — Composition of recording frame

13.16 Physical cluster

The 496 rows from an ECC cluster, transformed into recording frames, form what is 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 ≥2T and ≤8T with and 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 13.17.3).

— 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

The table in Figure 38 defines the conversion rules from data bits to modulation bits. The data bits shall be processed from the left to the right (msb's first, see Figure 37). 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 38 — 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 37).

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 37).

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 (2 times run-length 9T).

The last 6 bits define a signature that identifies 1 of 7 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 38), then the first modulation bit of the frame sync # = ONE, else # = ZERO (see Figure 39).

The frame sync patterns are defined in terms of modulation bits. A ONE 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 39 — 30-bit frame-sync codes

Because 7 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 40).

Rec.Frame *n*-4	Rec.Frame *n*-3	Rec.Frame *n*-2	Rec.Frame *n*-1	Rec.Frame *n*
Recording Frame *n* can be identified from the Frame Sync ID of 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				

Figure 40 — 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 41.

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 41 — 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 following process (see Figure 42).

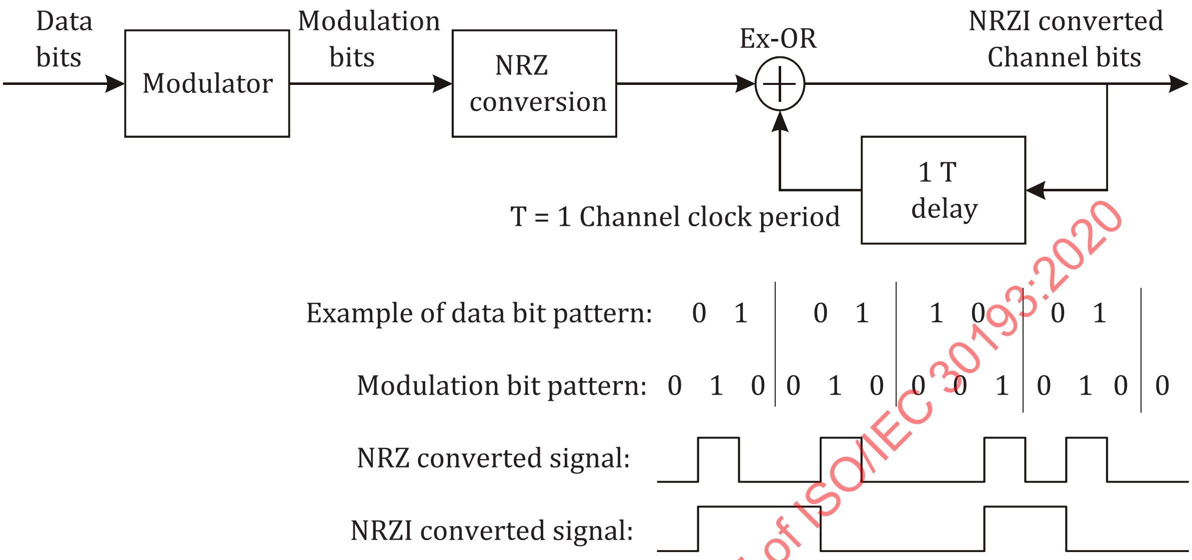


Figure 42 — Modulation and NRZI conversion

14 Physical data allocating 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 as 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) (see Figure 43).

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

Figure 43 — 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 occur between any 2 RUBs shown as Figure 44.

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 44 — Layout of continuously written sequence of recording-unit blocks

With the above choices, an SPS (see 14.3.2) of about maximum ±2 wobbles 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:

— Guard_1: 1 080 channel bits; and

— PrA (pre-amble): 1 680 channel bits.

The PrA field is meant as a run-in for the 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 (see Figure 45).

Guard_1 1 080 cbs		PrA 1 680 cbs
optional APC ≈ 5 wobbles	repeated bit pattern ≈ 11 wobbles	nominal ≈ 24 wobbles

Figure 45 — Layout of data run-in

14.2.2.2 Content of Guard_1 fields

The Guard_1 field has a length of 1 080 channel bits.

The content represented in modulation bits is: 36 times repeated 01[0^4]1[0^4]1[0^2]1[0^2]1[0^6]1[0^5]

These patterns result in a repeated 5T/5T/3T/3T/7T/7T sequence, which is well-suited to re-settle the electronic circuits.

14.2.2.3 Automatic power control (APC)

The first 5 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 fields

The PrA field has a length of 1 680 channel bits.

The content of the PrA field shall be shown as Figure 46.

52 times repeated 01[0^4]1[0^4]1[0^2]1[0^2]1[0^6]1[0^5]	Sync_1	01[0^4]1[0^4]1[0^2]1[0^2] 1[0^6]1[0^6] 1[0^4] 1[0^3]	Sync_2	01[0^2]1[0^2]1 [0^6]1[0^5]
←—— 1 560 cbs ——→	←30 cbs→	←—— 40 cbs ——→	←30 cbs→	←—— 20 cbs ——→

Figure 46 — 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 is allowed to be used for dc-control (# = ZERO or ONE, see Figure 39).

14.2.3 Data run-out

14.2.3.1 General

The data run-out consists of the following parts as shown in Figure 47:

— PoA (post-amble): 564 channel bits; and

— Guard_2: 540 channel bits.

The PoA field is meant as a run-out for the 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
nominal ≈ 8 wobbles	nominal ≈ 8 wobbles

Figure 47 — Layout of data run-out

14.2.3.2 Content of PoA fields

The PoA field has a length of 564 channel bits.

The content of the PoA field shall be as shown in Figure 48.

Sync_3	01[0^8]1[0^8]1[0^8]1[0^8]1[0^8]1[0^7]	16 times repeated 01[0^4]1[0^4]11[0^2]11[0^2]1[0^6]1[0^5]
← 30 cbs →	←—— 54 cbs ——→	←—— 480 cbs ——→

Figure 48 — 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 fields

The Guard_2 field has a length of 540 channel bits.

The content represented in modulation bits is: 18 times repeated $01[0^4]1[0^4]1[0^2]1[0^2]\ 1[0^6]1[0^5]$.

14.2.4 Guard_3 field

14.2.4.1 General

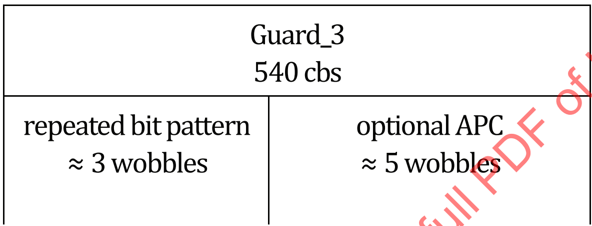


Figure 49 — Layout of Guard_3 field

The Guard_3 field has a length of 540 channel bits (see Figure 49).

The content represented in modulation bits is: 18 times repeated $01[0^4]1[0^4]1[0^2]1[0^2]\ 1[0^6]1[0^5]$.

14.2.4.2 Automatic power control (APC)

The last 5 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.

14.3 Locating data relative to wobble addresses

14.3.1 General

The nominal start positions for recordings (as well single RUBs 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).

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 ≤ *SPS* ≤ +127 cbs) (see Figure 50).

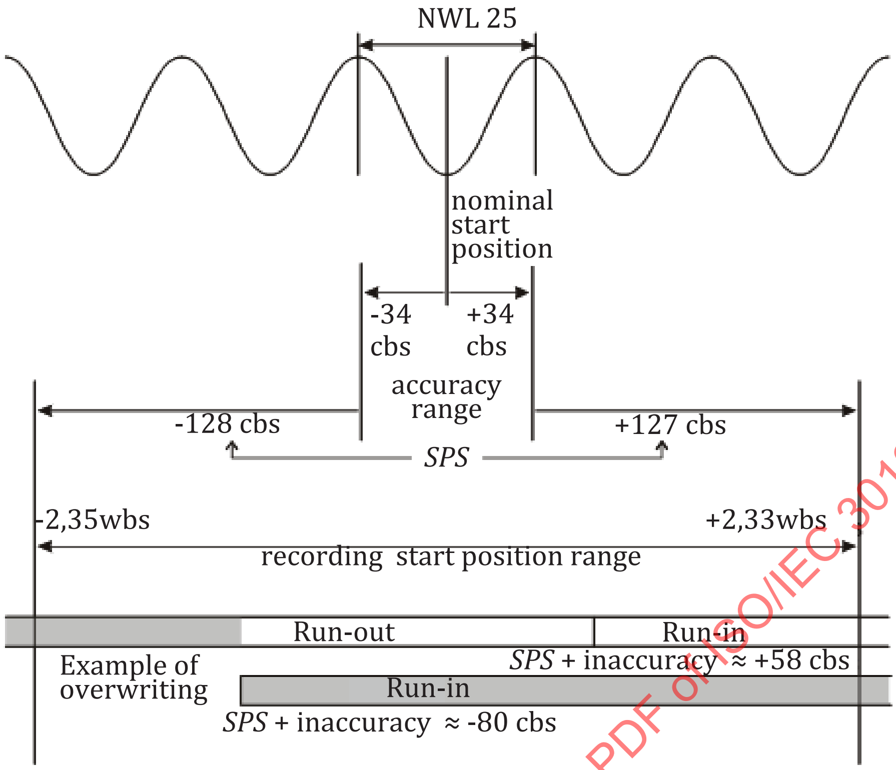


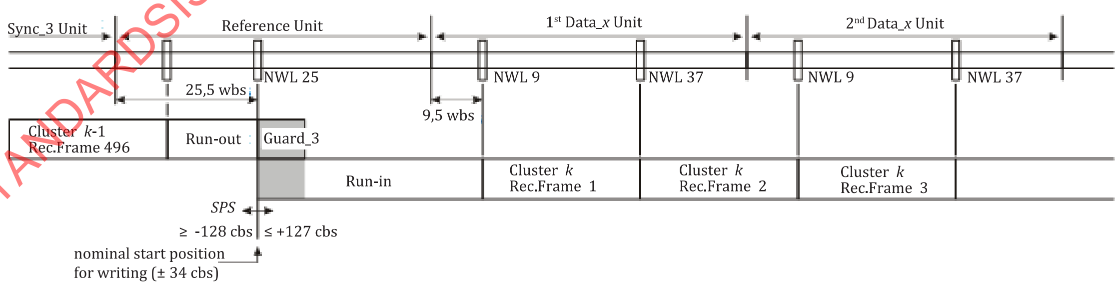
Figure 50 — Nominal start position for data recording

Figure 51, Figure 52 and Figure 53 show examples how newly written RUB's overlap with previously written RUB's.

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).

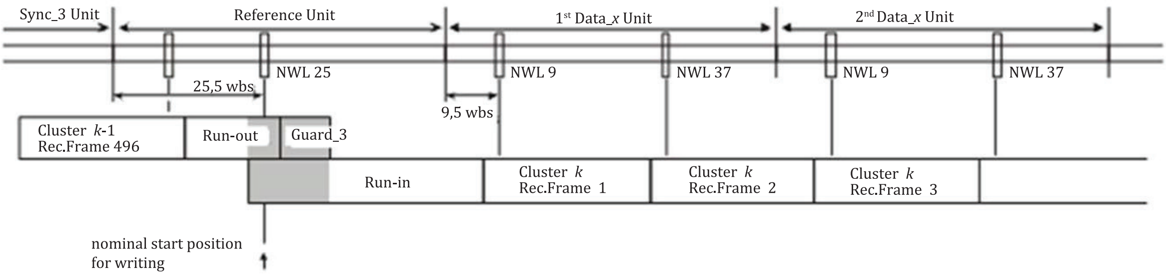
At the end of the newly written RUB, the run-out/Guard_3 of the newly written RUB overwrites a part of the run-in of the following RUB (if this had been written already before).

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



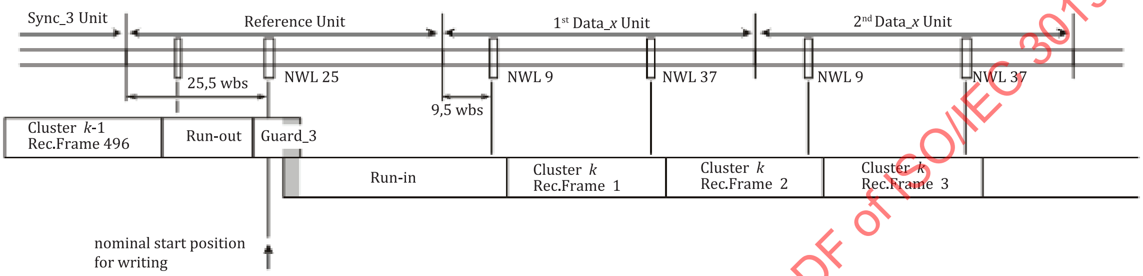
NOTE *SPS* + inaccuracy of previous recording = 0 and *SPS* + inaccuracy of new recording = 0.

Figure 51 — Example of nominal start position for data recording



NOTE *SPS* + inaccuracy of previous recording = +161 and *SPS* + inaccuracy of new recording = −162.

Figure 52 — Example of data recording with maximum overlap



NOTE *SPS* + inaccuracy of previous recording = −162 and *SPS* + inaccuracy of new recording = +161.

Figure 53 — 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 54).

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 whose inner edge shall be at the radius $21{,}0_{-0{,}1}^{\;0{,}0}$ mm.

On layer L0, a transition from a straight groove to an HFM groove between the BCA zone and the embossed HFM area shall occur between radius r_2 = 22,0 mm and radius r_3 (see Figure 54).

At the transition, the spiral groove shall be uninterrupted.

The tracks in the BCA zone shall be straight groove (without any modulation) between radius r_1 and the inner edge of the HFM groove on layer L0 or the inner edge of the wobbled groove on other layers (see Clause 18).

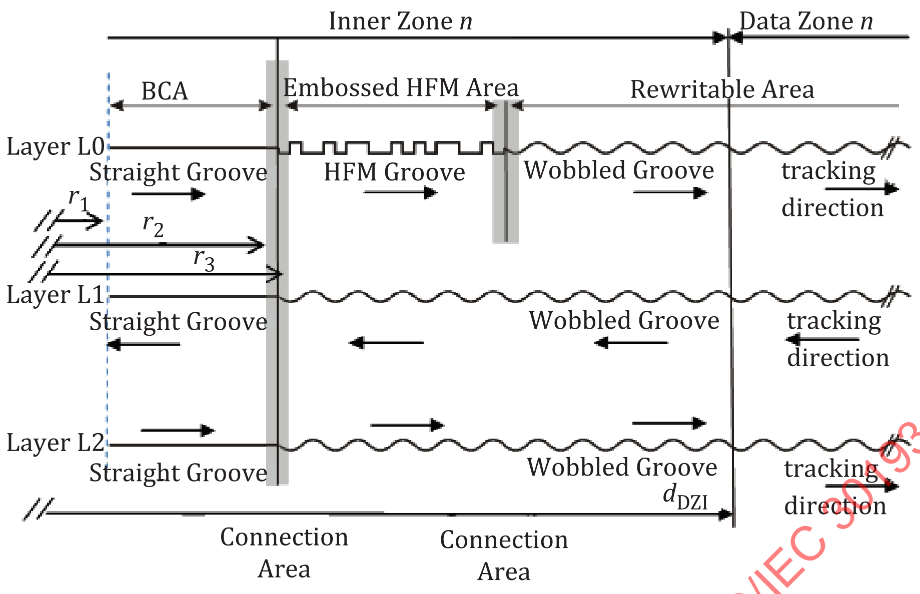


Figure 54 — Connection areas between different groove types

In the embossed HFM area of layer L0 (see Clause 17), the tracks are formed by a single spiral groove continuing uninterruptedly from the end of the straight groove in the BCA zone.

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

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 from the end of the straight-groove area on layer L2. On layer L1, they end at the beginning of the straight-groove area. These groove tracks in the rewritable areas deviate mainly sinusoidally and monotonically in the radial direction from their nominal centrelines and are called wobbled grooves. The sinusoidal deviation is modulated by replacing some of its cycles with different signal patterns at certain locations.

The wobble can be used for speed control of the disk and synchronization of the write clock of the drive and the modulated parts represent addressing information called address in pregroove or ADIP (see 15.7). The shape of each track is determined by the requirements specified in Clause 27.

NOTE Although the term "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.

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

Groove geometry

On each layer, only “on-groove recording” is allowed.

For “on-groove recording”, a geometry is used where the grooves are nearer to the entrance surface of the disk than the lands. The outline of the groove geometry is presented in Figure 55.

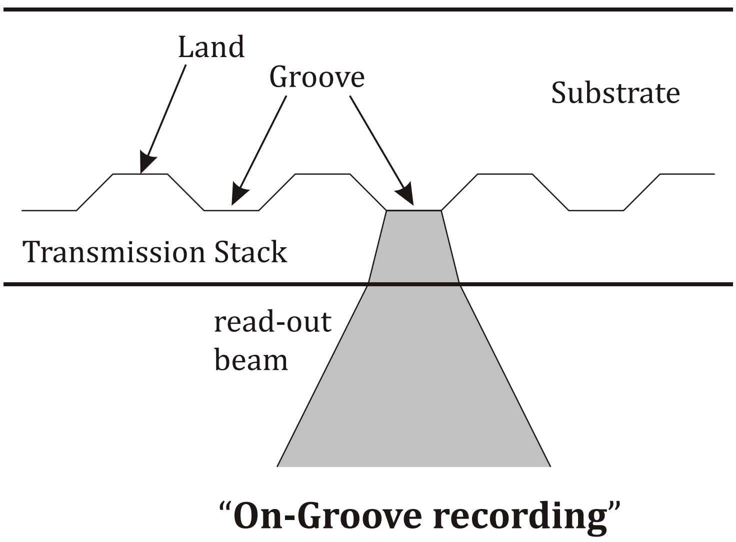


Figure 55 — Outline of groove geometry (radial cross-section of disk)

15.3 Track path

On layers with even layer number, 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(s) with odd layer number, 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.

The tracks on layers with even layer number *n* shall start at the beginning of inner zone *n* and terminate at the end of the outer zone *n* and shall be continuous in the information zone. The tracks on the layer with odd layer(s) number *n* shall start at the beginning of the outer zone *n* and terminate at the end of the inner zone *n* and be continuous in the information zone (see 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 radial direction.

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

In the area between r_2 and r_3, the track pitch shall change over from 2,0 µm to match 0,35 µm in the embossed HFM area on layer L0 or to 0,32 µm in the wobbled groove area on other layers.

15.4.2 Track pitch in embossed HFM areas

The track pitch in embossed HFM area is the distance between the average centrelines of an HFM groove in adjacent tracks, measured in 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 in rewritable area is the distance between the average centrelines of a wobbled groove in adjacent tracks, measured in 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) shall be realized within maximally 100 tracks (revolutions), which tracks shall be located completely in protection-zone 2 (see Figure 87).

15.5 Track layout of HFM grooves

15.5.1 General

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

The data in HFM grooves is recorded in 4K partitions, called PIC clusters. Each such PIC cluster contains 2 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 56.

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

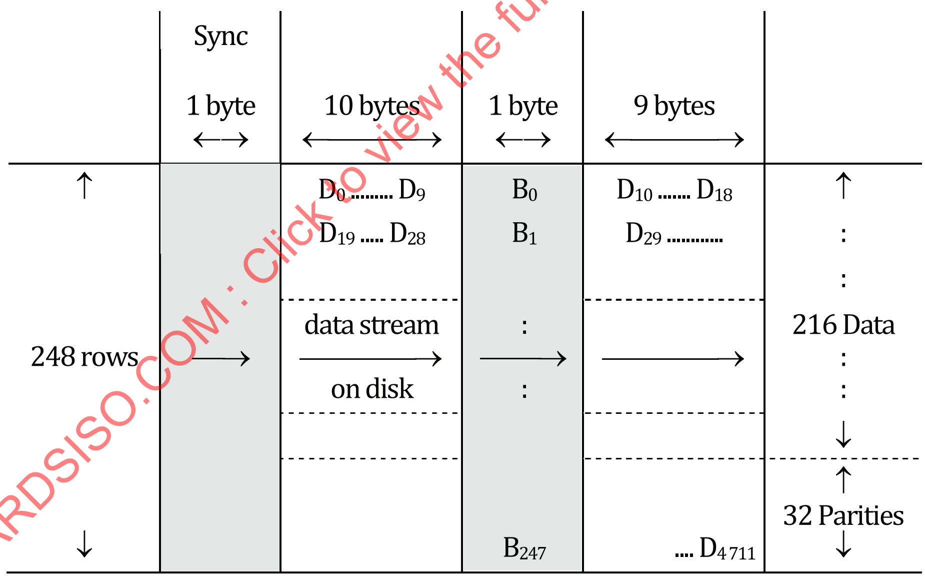


Figure 56 — Schematic representation of 4K PIC cluster on disk

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 15.5.3.2 and 13.9.2.2) shall be used instead of PS_{19} .. PS_5.

15.5.2.3 Data block

Each 2 scrambled data frames are mapped into an array of 216 rows × 19 columns as described in 13.5 and indicated in Figure 23 (only columns 0..18).

15.5.2.4 LDC block

The 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 57).

	←			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 57 — 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 56.

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 9 bytes each in 18 rows and 2 user-control data units of 24 bytes each in 12 rows (see Figure 58).

		← 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 Addresses
	9	$AF_{4,4}$	:	:	:	
	10	$AF_{5,1}$	***$AF_{5,0}$***	:	:	
	11	$AF_{5,5}$	:	:	:	
1 BIS code-word = 62 bytes	12	$AF_{6,2}$	$AF_{6,1}$	***$AF_{6,0}$***	:	
	13	$AF_{6,6}$	:	:	:	
	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 Data
	:	:	:	:	:	
	28	$UC_{10,0}$	$UC_{22,0}$	$UC_{10,1}$	$UC_{22,1}$	
	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 58 — PIC BIS block

15.5.3.2 Address fields

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 2 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: The address fields are derived through the primary address fields (see 13.9) as follows:

$AF_{0,S} = PAF_{0,S}$ (all the same for S = 0 .. 7);

$AF_{1,S} = PAF_{1,S}$ (all the same for S = 0 .. 7);

$AF_{2,S}$ = all bits inversion in $PAF_{2,S}$ (all the same for S = 0 .. 7);

$AF_{3,S}$ = all bits inversion in $PAF_{3,S}$ (all the same for S = 0 .. 7);

$AF_{4,S} = PAF_{4,S}$;

flag bits:

Bits b_7 to b_3 shall be reserved;

Bits b_2 to b_0 shall be set to the binary value of *S*.

$AF_{5,S}$ = all bits inversion in $PAF_{5,S}$;

$AF_{6,S}$ = all bits inversion in $PAF_{6,S}$;

$AF_{7,S} = PAF_{7,S}$;

$AF_{8,S} = PAF_{8,S}$;

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

The parity bytes of $PAF_{5,S}$ .. $PAF_{8,S}$ in the primary address fields shall be calculated according to the descriptions given in 13.9.2.

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 1 more position to the left (see Figure 58).

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 shifted cyclically 1more position to the left.

Mathematically, this mapping of the address bytes into the PIC BIS cluster can be represented by Formula (43):

byte $AF_{x,y}$ shall be allocated in:

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

column $c = \mathrm{mod}[(x + 8 - y),4]$ (43)

15.5.3.3 User-control data

There are 2 units of user-control data, each consisting of 24 bytes. Bytes 0 to 11 of the first 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 unit shall be placed in column 2 and bytes 12 to 23 in column 3 (see Figure 58). 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 58) according to the procedure described in 13.11 and 13.12, with the difference that there are only 4 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 56.

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 59).

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 (44) to (46):

Let byte $b_{r,c}$ be the byte in row r and column c of the BIS block,
and byte B_i is the ith byte in the column of the BIS cluster,

then $$r = \mathrm{mod}(2 \times i, 62) + \mathrm{div}(i, 124); \quad (44)$$

$$c = \mathrm{mod}(i, 4); \quad (45)$$

and vice versa $$i = 124 \times \mathrm{mod}(r, 2) + \mathrm{div}(r, 2) + 31 \times \mathrm{mod}\{[4 - c + \mathrm{div}(r, 2)], 4\}. \quad (46)$$

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 9 address bytes, 6 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

i	*c* = 0	1	2	3
r = 0	***0***	***93***	***62***	***31***
1	124	217	186	155
2	***32***	***1***	***94***	***63***
3	156	125	218	187
4		***33***	***2***	***95***
5		157	126	219
6			***34***	***3***
7			158	127
8	***4***			***35***
9	128			159
10		***5***		
11		129		
12			***6***	
13			130	
:	:	:	:	:
53				243
54	***120***			***27***
55	244			
56	***28***	***121***		
57	152	245		
58	***60***	***29***	***122***	
59	184	153	246	
60	***92***	***61***	***30***	***123***
61	216	185	154	247

BIS Cluster

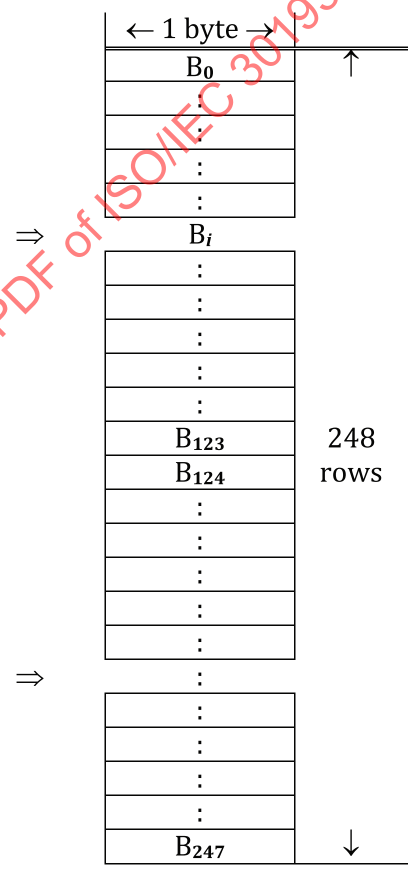


Figure 59 — Reading order for constructing PIC BIS cluster

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 56.

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 transitions 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 60). The modulated bits are recorded on the disk by a deviation of the groove from its average centrelines as indicated in Figure 60. The length of each bit cell shall be 36T, where T corresponds to the length of a channel bit in the rewritable areas.

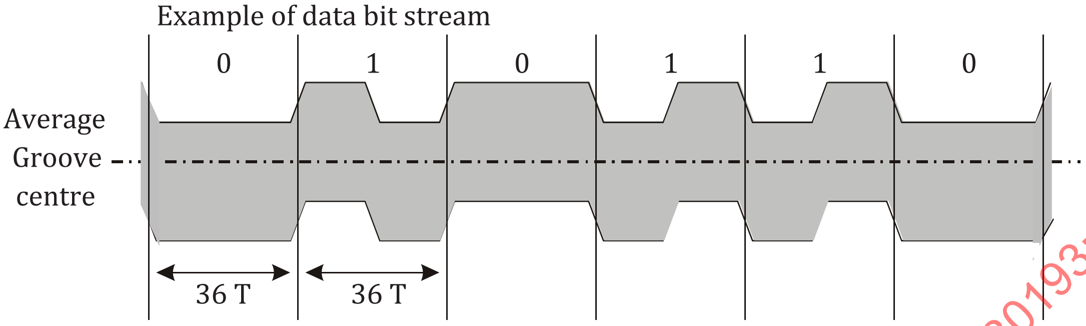


Figure 60 — Biphase modulated HFM groove

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 61: two possible patterns depending on the initial phase).

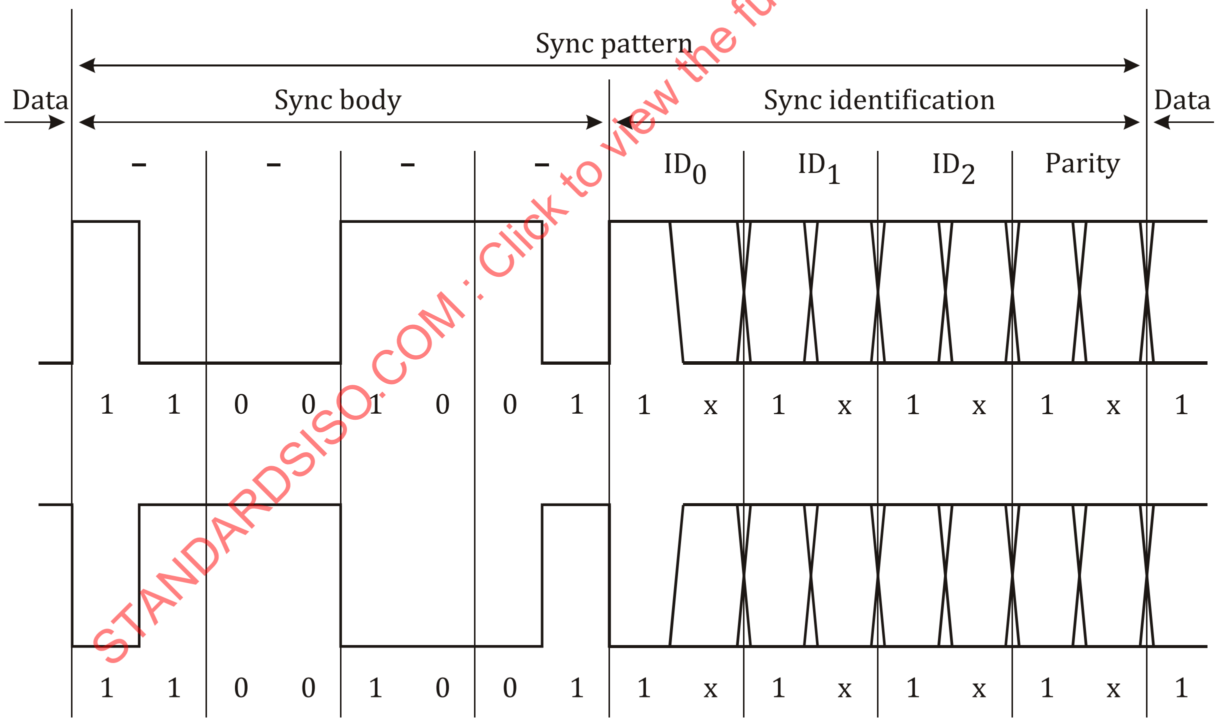


Figure 61 — Biphase synchronization pattern

Seven different sync patterns are identified by the last 4 bits: ID_0 .. ID_2 and a parity bit (see Figure 62).

Sync number	ID0	ID1	ID2	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 62 — Sync identification

By means of the PIC BIS column, the 248 rows of a PIC cluster can be divided into eight groups of 31 recording frames, where each group of recording frames carries an address in its first 9 rows (see 15.5.3.5).

The 31 successive recording frames of each such group are identified by a special sequence of the

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 63.

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 63 — Mapping of sync patterns on PIC recording frames

15.6 Track layout of wobbled grooves

15.6.1 General

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

The nominal wobble length (NWL) (equivalent to 69 channel bits) shall be 3,855 3 µm ± 0,005 µm for a disk with a user data capacity of 33,4 GB per layer, averaged over the rewritable areas.

This corresponds to a fundamental frequency f_{wob} = 1 913,043 kHz at the 2 times reference velocity.

15.6.2 Modulation of wobbles

15.6.2.1 General

The basic shape of the wobbles is a cosine wave: $\cos(2\pi \times f_{wob} \times t)$. wobbles with this basic shape are called monotone wobbles (MW).

Some wobbles are modulated, and 2 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 17 and 20.10), 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 three nominal wobble lengths (NWL) with the following wobble patterns as indicated in Figure 64:

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

— 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 = $1{,}5 \times f_{wob}$.

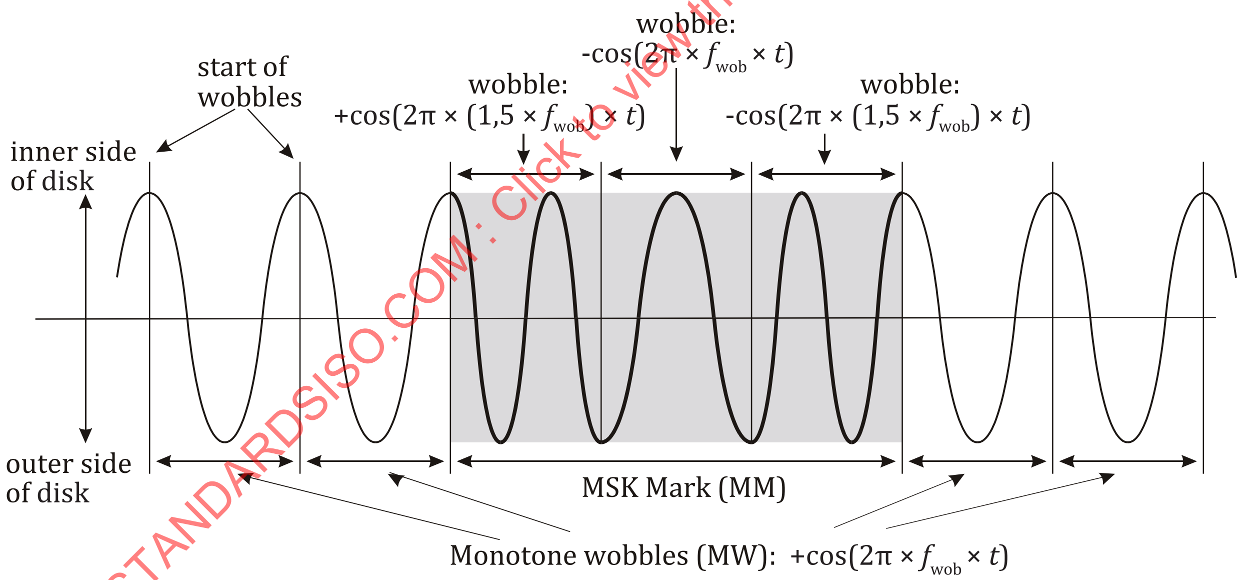


Figure 64 — Definition of MSK mark (on groove)

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 the doubled frequency as per Formula (47):

$$\cos(2\pi \times f_{wob} \times t) \pm a \times \sin[2\pi \times (2 \times f_{wob}) \times t] \tag{47}$$

where $a = 0{,}25$.

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 a bit value ONE and the “–” sign is used to represent a bit value ZERO (see Figure 65).

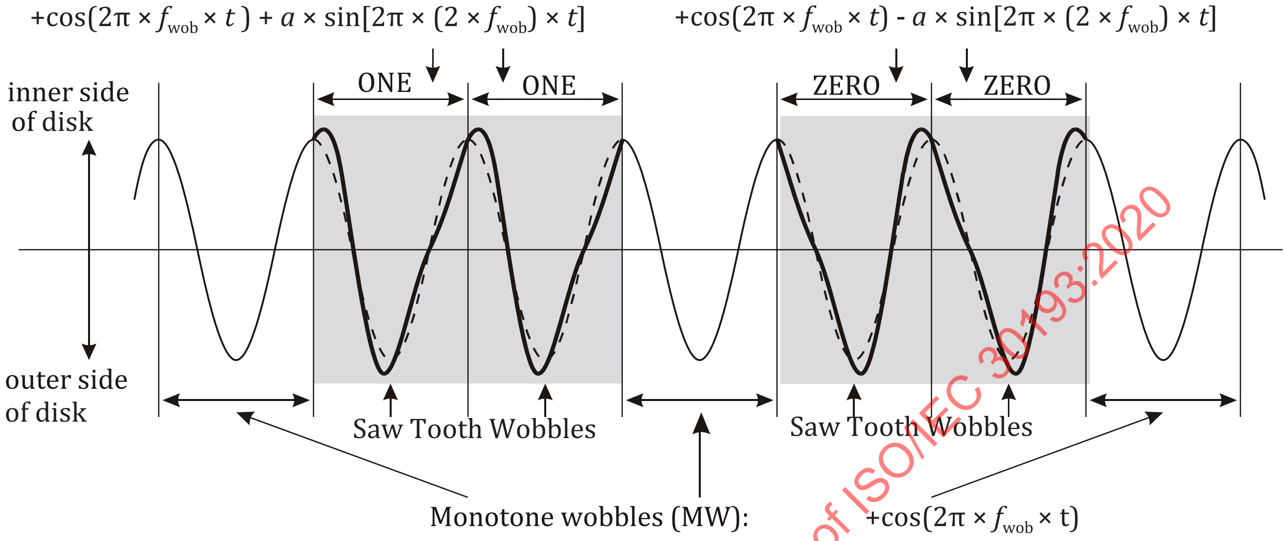


Figure 65 — Definition of saw-tooth wobbles (on groove)

15.6.3 Wobble polarity

When push–pull polarity (see 26.1) is negative, then the wobble groove shall start its first wobble deviation towards the outer side of the disk.

When push–pull polarity (see 26.1) is positive, then the wobble groove shall start its first wobble deviation towards inner side of the disk.

15.7 ADIP information

15.7.1 General

The data to be recorded onto the disk shall be aligned with the ADIP addresses. The ADIP address is derived from ADIP symbols modulated in the wobble (see Figure 70). Therefore, 56 NWLs shall correspond to 2 recording frames (see 13.15). Each group of such 56 NWLs is called an ADIP unit (see Figure 66).

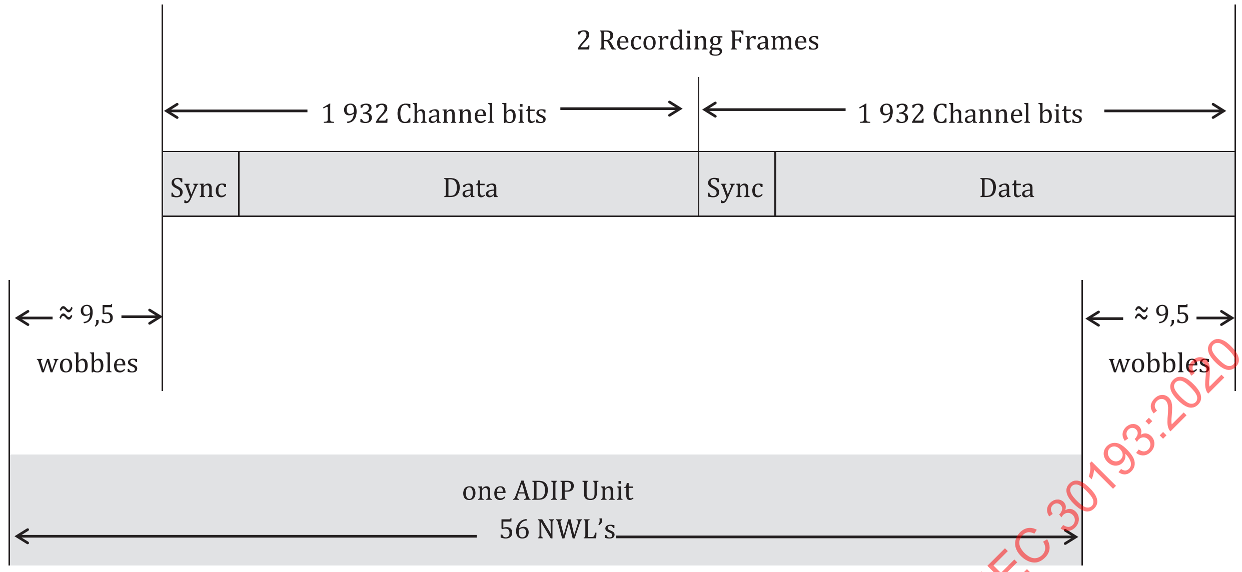


Figure 66 — General ADIP structure

15.7.2 ADIP-unit types

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

The ADIP units representing a data bit are additionally modulated with STWs.

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 67):

— 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 1 or 0:

  — Data_1 unit: consisting of one MM followed by 9 MWs, one MM, 3 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, the Data_1 unit is used to represent a bit value ONE and the Data_0 unit is used to represent a bit value ZERO.

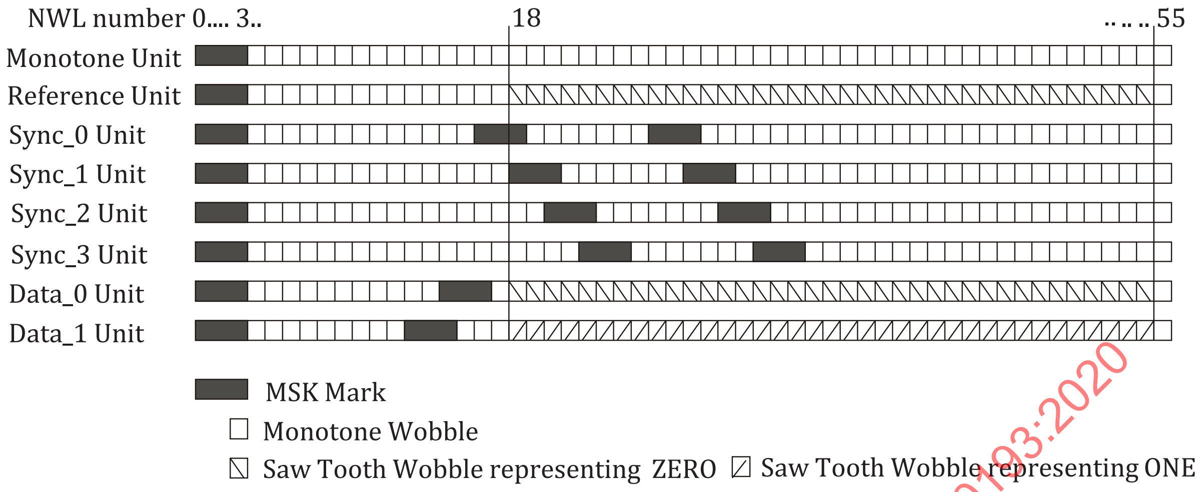


Figure 67 — ADIP-unit types

15.7.3 ADIP word structure

83 ADIP units are grouped into one ADIP word each. This means that 3 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 68.

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 68 — 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 69.

Nibble	b_3	b_2	b_1	b_0		
n_0	AS23	AS22	AS21	AS20	↑ 6 nibbles ↓	ADIP symbol
n_1	AS19	AS18	:	:		
:	:	:	:	:		
n_5	AS3	:	:	AS0		
n_6	AX11	:	:	:	↑ 3 nibbles ↓	AUX data
:	:	:	:	:		
n_8	AX3	:	:	AX0		

Figure 69 — ADIP-information structure

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

— AS23..AS0: These 24 bits shall contain the physical ADIP symbol (PAS). AS23 shall be the msb and AS0 shall be the lsb. These symbols are converted from the physical ADIP address (PAA) as follows (see Figure 70 and Figure 71).

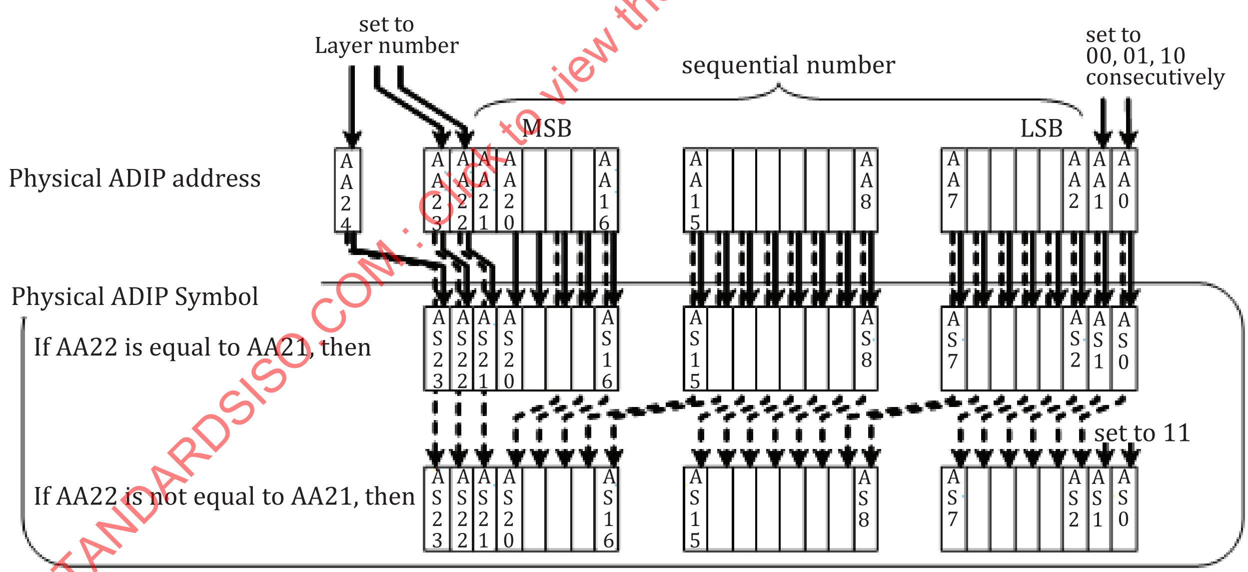


Figure 70 — Relation between PAA and PAS

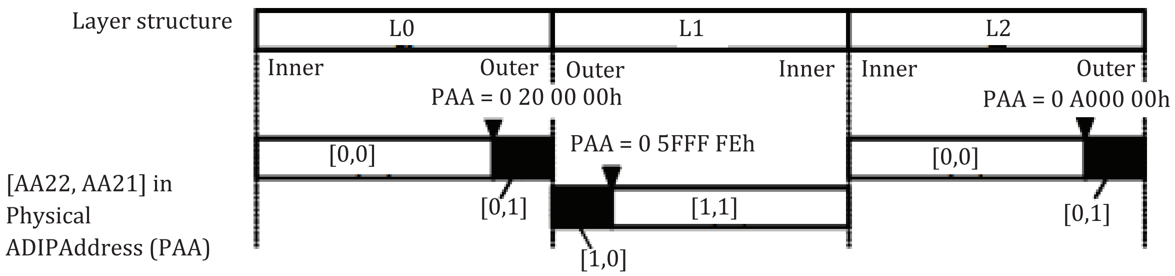


Figure 71 — Combination of AA22 and AA21

— AA24..AA0**:** These 25 bits shall contain the physical ADIP address (PAA). AA24 shall be the msb and AA0 shall be the lsb. This address shall consist of three parts:

  — AA24..AA22: These 3 bits shall indicate the layer number and shall be set to: 000, 001 and 010 on layer L0, layer L1 and layer L2, respectively. All other settings shall be reserved;

  — AA21..AA2: These 20 bits shall contain a sequential number, which number shall increase by one after each 3 consecutive ADIP words (synchronized to the RUBs, see 14.2);

  — AA1,AA0: These 2 bits shall be set to 00, 01 and 10 consecutively in each 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 0 02 00 00h, is located at radius $24{,}0_{-0{,}1}^{\;0{,}0}$ 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 (0 7D FF FEh) shall be located at a radius $24{,}0_{-0{,}1}^{\;0{,}0}$ mm.

The first address of the data zone on layer L2 (0 82 00 00h) shall be located at a radius $24{,}0_{-0{,}1}^{\;0{,}0}$ mm.

The last address of the data zone on layer L2 (LAA + 0 80 00 00h) shall be located at a radius <58,1 mm.

— AX11..AX0: These 12 bits contain auxiliary information about the disk;

  — In the data zone(s) and 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:

    — AX11..AX0 from 96 consecutive ADIP words (equivalent to 32 RUB's) 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 which is a multiple of 128 (PAA = x xxxx xxxx xxxx xxxx x000 0000);

    — The content of the 144 bytes are defined in 15.7.

15.7.4.3 Relation between physical ADIP addresses on layers from layer L0 to layer L2

There shall be a fixed relation between the PAAs on layers from layer L0 to layer L2. The PAAs on layer L0 (or layer L2) and layer L1 that are located at the same radius (having the same distance in number of ADIP words from their respective inner zone) shall have inverted bits AA21 to AA2. The PAAs on layer L0 and layer L2 that are located at the same radius shall have the same bits AA21 to AA2 (see Figure 72).

In this way, the PAAs on layer L1 increase from the outside towards the inside of the disk, which is in the tracking direction. Simultaneously, the inverted address bits AA21.AA2 of PAA_1 have the same relation with the radius as the equivalent non-inverted bits on layer L0 (or layer L2).

	Layer number	Sequence number	Intra-RUB number
PAA_0 on Layer L0	AA24 .. AA22 = 000	AA21 .. AA2	AA1,AA0 = 00,01,10 from inner to outer
PAA_1 on Layer L1	AA24 .. AA22 = 001	$\overline{\text{AA21}}$ ... $\overline{\text{AA2}}$	AA1,AA0 = 00,01,10 from outer to inner
PAA_2 on Layer L2	AA24 .. AA22 = 010	AA21 .. AA2	AA1,AA0 = 00,01,10 from inner to outer

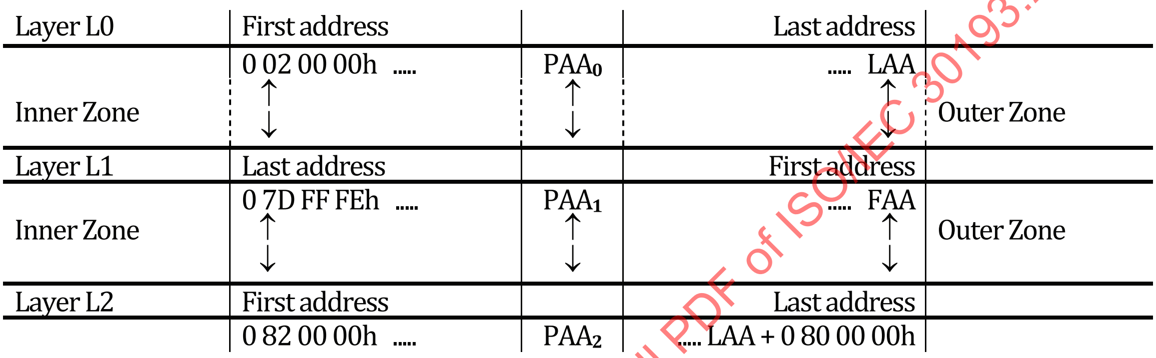


Figure 72 — Illustration of PAA relation among layer L0, layer L1 and layer L2

Mathematically, this can be expressed in the following way.

After adding 1 80 00 01h to PAA_0, all 25 bits are inverted, resulting directly in the full corresponding address PAA_1 on layer L1 [see Formula (48)].

$$PAA_1 = \overline{PAA_0 + 1\,80\,00\,01\text{h}} \qquad (48)$$

(The addition of 1 corrects for the order of the intra-RUB numbers, while the addition of 1 80 00 00h takes care of the correct layer number.)

In this way, the last address of data zone 1 can be derived as Formula (49):

$$0\,7\text{D FF FEh} = \overline{0\,02\,00\,00\text{h} + 1\,80\,00\,01\text{h}} \qquad (49)$$

and the first address of data zone 1 is as per Formula (50):

$$FAA = \overline{LAA + 1\,80\,00\,01\text{h}} \qquad (50)$$

The corresponding address PAA_2 are obtained by adding 0 80 00 00h to PAA_0.

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 9 information nibbles and the minimum distance of this code is 7.

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 (51):

$$p(x)=x^4+x+1 \tag{51}$$

The symbols of GF(2^4) are represented by nibbles (groups of 4 bits), using the polynomial-base representation, with (α^3, α^2, α, 1) as a basis. The root α is thus represented as α = 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 (52):

$$C(x)=\sum_{i=0}^{14} c_i \times x^{14-i} = \sum_{i=0}^{7} n_i \times g^{(i)}(x)+n_8 \times g_p(x) \tag{52}$$

where

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

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

$g^{(i)}(x)$ 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 (53):

$$z_i = \alpha^{i+6} \tag{53}$$

The generator polynomials are then calculated as per Formula (54):

$$g^{(i)}(x)=\frac{\tilde{g}^{(i)}(x)}{\beta_i} \tag{54}$$

where

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

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

Before recording them on the disk, all bits of the nibbles c_0, c_1, c_2, c_3, c_7 and c_{12} shall be inverted.

Remark 1

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 per Formula (55):

$$n_i=S_{i+6}=C\left(\alpha^{i+6}\right)=\sum_{j=0}^{14} c_{14-j} \times \alpha^{(i+6)\times j} \tag{55}$$

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

Remark 2

Each information symbol n_i corresponds to a zero in the parent generator polynomial $g_p(x)$. Figure 73 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 73 — 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 74. 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 74 — 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 75). 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.

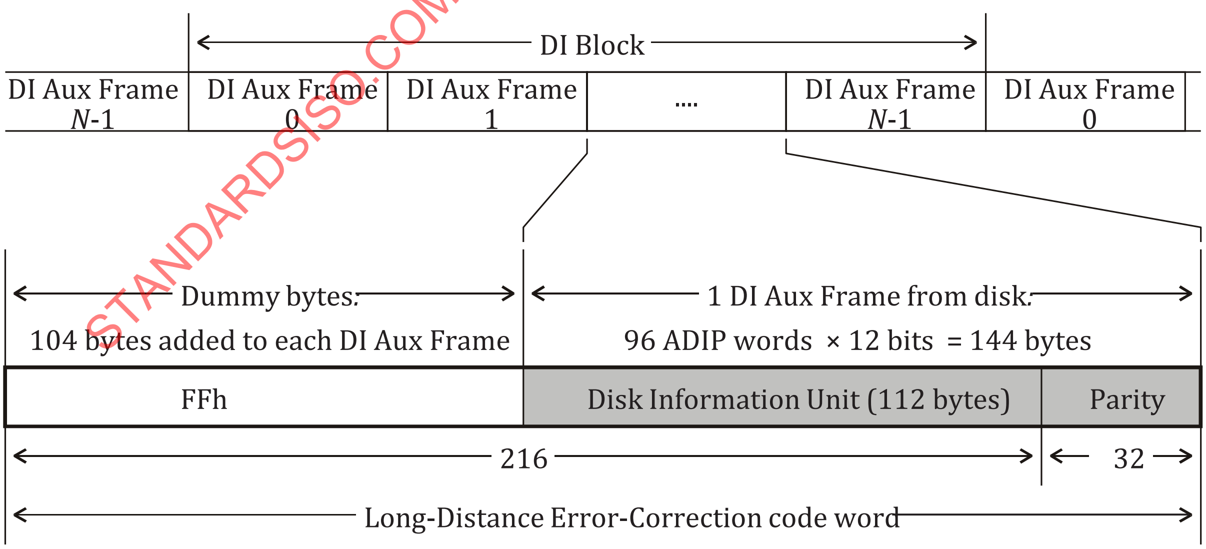


Figure 75 — Disk information structure and error correction format

15.8.3 Disk-Information data structure

15.8.3.1 General

A DI block can consist of multiple 144-byte aux DI frames (see Figure 75). 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, from PAA 0 7E 00 00h on layer L1, and from PAA 0 81 B8 00h on layer L2.

From the starting PAA of protection-zone 2 to PAA 0 01 B7 FEh of layer L0 (see Figure 87), from PAA 0 7E 48 00h to the last PAA of protection-zone 1 of layer L1 (see Figure 88), and from the starting PAA of protection-zone 1 to PAA 0 81 B7 FEh of layer L2 (see Figure 89), 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 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 6 indicates that the next DI unit in the sequence is a continuation of the actual one.

An example usage of DI units for write a strategy is given in 15.8.3.8. Whenever new DI aux frames are added, the existing ones can still be used if appropriate and, this 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 28 and 29), only use the ones that it is supporting (see also 15.8.3).

15.8.3.2 General definitions for DI units

Each DI unit shall consist of a header, a body and a footer as depicted in Figure 76.

	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	Reserved	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 76 — 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 kept by conforming 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 kept), but which new specifications result in a write-compatibility break. Although such a BD layer carries a higher version number, it can still 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 (e.g. recording speed, 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 the version number as described above, backwards compatibility of future disks can be maximized, while 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 of the write strategy type, which is specified in the DI unit.

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: **Reserved**
This byte shall be set to 00h.

Byte 5: **DI-unit sequence number in DI block**
This byte specifies 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 77) first according to increasing nominal recording velocity (byte 28 and 29), then, within each sequence of DI units with the same nominal recording velocity, according to increasing reading velocity, according to ascending layer number (byte 3) and last according to the preference of the write strategy (identified by the DI-format number, but need not to be in sequence of DI-format numbers).

Sequence number	Recording Velocity	Reading Velocity	Layer number	Write strategy
0	v_1	v_{r1}(=v1)	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		$v_{r2} > v_{r1}$	0	preferred WS
				alternative WS
			1	preferred WS
				alternative WS
			:	preferred WS
				alternative WS
			k-1	preferred WS
4k-1				alternative WS
4k	$v_2 > v_1$	$v_{r3}(=v_2)$	0	most preferred WS
⋮			:	:
:			k–1	least preferred WS
:		$v_{r4} > v_{r3}$	0	most preferred WS
			:	:
8k-1			k–1	least preferred WS
:	$v_3 > v_2$		0	:
:	:		:	:
N–1	etc.		etc.	:

Figure 77 — 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; and

ONE if the parameter set in this DI unit is continued in the next DI unit (see Figure 78).

Bits b_6 to b_0: These 7 bits 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 79).

	:	
	Byte 2 = .. Byte 3 = N/L0 Byte 5 = n-1 Byte 6, bit b_7 = 0	end of preceding parameter set
Parameter set for Layer L1 spans 3 DI Units	Byte 2 = x Byte 3 = N/L1 Byte 5 = n **Byte 6, bit b_7 = 1**	start of actual parameter set : : :
	Byte 2 = x Byte 3 = N/L1 Byte 5 = n+1 **Byte 6, bit b_7 = 1**	: continuation of actual parameter set :
	Byte 2 = x Byte 3 = N/L1 Byte 5 = n+2 **Byte 6, bit b_7 = 0**	: : : end of actual parameter set
	Byte 2 = .. Byte 3 = N/L2 Byte 5 = n+3 Byte 6, bit b_7= ..	start of next parameter set
	:	

Figure 78 — Example of DI-unit extension

Byte 7: **Reserved**
This byte shall be set to 00h.

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 4 (Extended N-1 write strategy)

The content of the body of DI units according to format 4 shall be as depicted in Figure 79.

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	Push-Pull polarity flag bits	1
15	Recorded Mark polarity flag bits	1
16	BCA descriptor	1
17 to 18	Reserved	2
19 to 26	Data-Zone allocation	8
27	Reserved	1
28 to 29	Recording Velocities	2
30	Maximum dc read power	1
31	Maximum HF-modulated read power	1
32	Reserved	1
33 to 41	Write-power settings	9
42	T_{MP} write multi-pulse duration	1
43 to 47	dT_{top} first-write-pulse start time	5
48 to 52	T_{top} first-write-pulse duration	5
53 to 55	dT_{LP} last write pulse start time	3
56 to 58	T_{LP} last pulse duration	3
59 to 63	dT_E start time of the erase level	5
64	Reserved	1
65 to 72 and 73 (msb 4bits)	ΔdT_{top} first write-pulse start time offset	8,5
73 (lsb 4bits) and 74 to 80	ΔT_{top} first write-pulse duration offset	7,5
81 to 84 and 85 (msb 4bits)	ΔdT_{LP} last-pulse start time offset	4,5
85 (lsb 4bits) and 86 to 89	ΔT_{LP} last-pulse duration offset	4,5
90 to 97 and 98 (msb 4bits)	ΔdT_E start time offset of the erase level	8,5
98 (lsb 4bits)	Reserved	0,5
99	Reserved	1
	DI Unit footer	12

Figure 79 — Content of disk information for DI format 4

Bytes 0 to 1: **Disk-information identifier**
See 15.8.3.2.

Byte 2: **DI-format number**
This byte shall be set to 04h for disks with BCA code.

This byte shall be set to 84h for the disks without BCA code.

Byte 3: **Number of DI aux frames in each DI block/Number of the layer to which this DI unit applies**
See 15.8.3.2.

Byte 4: **Reserved**
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 indicating 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 2 bits specify the disk size. They shall be set to 00, indicating a 120 mm disk.

Bits b_5 to b_4: These 2 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 01.

Drives 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 0011, indicating 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 in the disk.

These bits shall be set to 0011, indicating 3 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, indicating 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:

0000: reserved,

0101: indicating a channel-bit length of 55,87 nm (33,4 GB per layer), and

Other settings: reserved.

Byte 14: **Push-pull polarity flag bits**

Bit b_i : Each bit b_i shall specify the polarity of the push–pull signal on recorded layer L*i* see 26.1). They shall be set to as follows:
ZERO, indicating that the push–pull polarity on layer L*i* is positive;

ONE, indicating that the push–pull polarity on layer L*i* is negative;

For recording layers that are not present, bit b_i shall be set to ZERO;

For this document, this byte shall be set to 00h.

Byte 15: **Recorded-mark polarity flag bits**

Bit b_i : Each bit b_i shall specify the polarity of the recorded marks on recording layer L*i*.

They shall be set to ZERO, indicating a layer type on which recorded marks have a lower reflectivity than the unrecorded layer (HTL disks),

ONE, indicating a layer type on which recorded marks have a higher reflectivity than the unrecorded layer.

For recording layers that are not present, bit b_i shall be set to ZERO.

For this document, this byte shall be set to 00h.

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 indicate the presence of a BCA code on this disk:

They shall be set to as follows:

0000: indicating no BCA code;

0001: indicating BCA code is present;

Other settings: reserved.

Bytes 17 to 18: **Reserved**
These bytes shall be set to all 00h.

Bytes 19 to 26 **Data-zone allocation**

Bytes 19 to 22: These bytes shall 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 indicating PAA 131 072 as the first PAA of the data zone 0.

In each DI unit relating to layer L1, these bytes shall be set to a value FAA, which shall be 00 5E EC 80h for a disk with a user data capacity of 33,4 GB per layer, indicating PAA 6 220 928 for 33,4 GB per layer as the first PAA of data zone 1.

In each DI unit relating to layer L2, these bytes shall be set to 00 82 00 00h indicating PAA 8 519 680 as the first PAA of the data zone 2.

Bytes 23 to 26: These bytes shall 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 21 13 7Eh for a disk with a user data capacity of 33,4 GB per layer, indicating PAA 2 167 678 for 33,4 GB per layer as the last PAA of the data zone 0.

In each DI unit relating to layer L1, these bytes shall be set to 00 7D FF FEh indicating PAA 8 257 534 as the last PAA of the data zone 1.

In each DI unit relating to layer L2, these bytes shall be set to the value LAA + 00 80 00 00h, which shall be 00 A1 13 7E h for a disk with a user data capacity of 33,4 GB per layer, indicating PAA 10 556 286 for 33,4 GB per layer as the last PAA of the data zone 2.

Byte 27: **Reserved**

This byte shall be set to 00h.

Bytes 28 to 29: **Recording velocity**

These bytes shall specify the nominal recording velocity, to be used with the parameters as defined in this DI unit, as a 2-byte binary number (byte 28 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 02 E2h to indicate a nominal recording velocity of 7,38 m/s.

Byte 30: **Maximum dc read power at the nominal recording velocity**

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 30.7). Maximum read powers in this clause shall be greater than or equal to the read powers defined in 30.7. By default, the powers defined in 30.7 shall be used.

This byte shall specify the dc read power $P_{r.}$ at a readout velocity equal to the nominal recording velocity defined in byte 28 and 29 of this DI unit. The decimal expression of this byte is as follows:

$n = 100 \times P_r$, where P_r is expressed in milliwatt.

NOTE For reading at lower speeds than the nominal velocity specified in this DI unit, a reduction of the read power can be necessary to guarantee the stability of recordings on the disk.

Byte 31: **Maximum HF-modulated read powers at the nominal recording velocity**

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 recorded signals (see 30.7). Maximum read powers in this clause shall be greater than or equal to the read powers defined in 30.7. By default, the powers defined in 30.7 shall be used.

This byte shall specify the maximum HF-modulated read power, $P_{r.}$ at the same readout velocity as the nominal recording velocity defined in byte 28 and 29 of this DI unit. The decimal expression of this byte is as follows:

$n = 100 \times P_r$, where the unit of $P_{r.}$ is milliwatt.

NOTE For reading at lower speeds than the nominal velocity specified in this DI unit, a reduction of the read power can be necessary to guarantee the stability of the recordings on the disk.

Byte 32: **Reserved**

This byte shall be set to 00h.

Bytes 33 to 41: **Write-power settings**

Bytes 33 to 34: ***P_{IND}***: P_{IND} can be used as a starting value for the determination of P_{target} in the OPC procedure (see Annex G).

These bytes shall specify the indicative value P_{IND} of P_{target} in milliwatts as a number n such that:

$n = 20 \times P_{IND}$.

bit b_7 of Byte 33 is msb and bit b0 of Byte 34 is lsb.

Byte 35: ***m_{IND}***: m_{IND} can be used as a starting value for the determination of P_{target} in the OPC procedure (see Annex G).

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 36: ***ρ***: This byte shall specify the write-power multiplication factor ρ used in the OPC algorithm (see Annex G) as a number n such that:

$n = 100 \times \rho$.

Byte 37: ***ε_{BW}***: This byte shall specify the write-bias/write-peak power ratio ε_{BW} used in the OPC algorithm (see Annex G) as a number n such that:

$n = 200 \times \varepsilon_{BW}$.

Byte 38: ***ε_C***: This byte shall specify the cooling/write-peak power ratio ε_C used in the OPC algorithm (see Annex G) as a number n such that:

$n = 200 \times \varepsilon_C$.

Byte 39: ***ε_E***: This byte shall specify the erase/write-peak power ratio ε_E used in the OPC algorithm (see Annex G) as a number n such that:

$n = 200 \times \varepsilon_E$.

Byte 40: ***κ***: This byte shall specify the target value for κ used in the OPC procedure (see Annex G) as a number n such that $n = 20 \times \kappa$.

Byte 41: This byte shall be reserved.

Byte 42: **T_{MP} write multi-pulse duration**

This byte specifies the duration of the second and higher pulses of the multi-pulse train, in the extended N-1 write strategy, for recording marks (see Annex F).

The first 5 bits (bits b_7 to b_3) of this byte shall specify the fraction of the actual channel-bit clock period, as an unsigned binary number p, such that:

$$p = 32 \times \frac{T_{MP}}{T_W} \quad (0 \le p \le 30).$$

The last 3 bits (bits b_2 to b_0) of this byte shall be reserved.

Bytes 43 to 63: In these bytes, Anchor position or duration time is defined for $dT_{top,}$ $T_{top,}$ $dT_{LP,}$ $T_{LP,}$ and dT_E.

Anchor position means the leading-edge position of each write pulse (see Figure F.1).

Regarding the duration time, anchor is specified in a similar way.

Bytes 43 to 47: **dT_{top} first-write-pulse start time**

The first 6 bits (bits b_7 to b_2) of these bytes specify the start time of the first pulse of the multi-pulse train, in the extended N-1 write strategy, for recording marks with run-lengths 2T, 3T, 4T and ≥5T with a preceding ≥5T space (positive values are leading, negative values are lagging; see Annex F).

The first pulse start time dT_{top} shall specify a fraction of the actual channel-bit clock period, as a signed two's-complement binary number a, such that:

$$a = 32 \times \frac{dT_{top}}{T_W} \qquad (-28 \le a \le 30).$$

The last 2 bits (bits b_1 to b_0) of these bytes shall be reserved.

Byte 43: This byte shall specify the start time of the pulse for recording marks of run-length 2T with a succeeding 2T space, relative to the trailing edge of the first channel bit of the data pulse (positive values are leading, negative values are lagging; see Annex F).

Byte 44: This byte shall specify the start time of the pulse for recording marks of run-length 2T with a succeeding ≥3T space, relative to the trailing edge of the first channel bit of the data pulse (positive values are leading, negative values are lagging; see Annex F).

Byte 45: This byte shall specify the start time of the first pulse of the multi-pulse train for recording marks of run-length 3T, relative to the trailing edge of the first channel bit of the data pulse (positive values are leading, negative values are lagging; see Annex F).

Byte 46: This byte shall specify the start time of the first pulse of the multi-pulse train for recording marks of run-length 4T, relative to the trailing edge of the first channel bit of the data pulse (positive values are leading, negative values are lagging; see Annex F).

Byte 47: This byte shall specify the start time of the first pulse of the multi-pulse train for recording marks of run-lengths ≥5T, relative to the trailing edge of the first channel bit of the data pulse (positive values are leading, negative values are lagging; see Annex F).

Bytes 48 to 52: **T_{top} first write-pulse duration**

The first 6 bits (bits b_7 to b_2) of these bytes specify the duration of the first pulse of the multi-pulse train, in the extended N-1 write strategy, for recording marks with run-lengths 2T, 3T, 4T, and ≥5T with a preceding ≥5T space (see Annex F).

These bytes shall specify a fraction of the actual channel-bit clock period, as an unsigned binary number b, such that:

$$b = 32 \times \frac{T_{top}}{T_W} \qquad (0 \le b \le 60).$$

The last 2 bits (bits b_1 to b_0) of these bytes shall be reserved.

Byte 48: This byte shall specify the duration of the pulse for recording marks of run-length 2T with a succeeding 2T space (see Annex F).

Byte 49: This byte shall specify the duration of the pulse for recording marks of run-length 2T with a succeeding ≥3T space (see Annex F).

Byte 50: This byte shall specify the duration of the first pulse, of the multi-pulse train, for recording marks of run-length 3T (see Annex F).

Byte 51: This byte shall specify the duration of the first pulse, of the multi-pulse train, for recording of marks of run-length 4T (see Annex F).

Byte 52: This byte shall specify the duration of the first pulse, of the multi-pulse train, for recording marks of run-lengths ≥5T (see Annex F).

Bytes 53 to 55: ***dT_{LP}* last write-pulse start time**

The first 6 bits (bits b_7 to b_2) of these bytes specify the start time of the last pulse of the multi-pulse train, in the extended N-1 write strategy, for recording marks with run-lengths 3T, 4T, and ≥5T with a succeeding ≥5T space (positive values are leading, negative values are lagging; see Annex F).

The last-pulse start time dT_{LP} is expressed as a fraction of the actual channel-bit clock period, as a signed two's-complement binary number *c,* such that:

$$c = 32 \times \frac{dT_{LP}}{T_W} \qquad (-30 \le c \le 30).$$

The last 2 bits (bits b_1 to b_0) of these bytes shall be reserved.

Byte 53: This byte shall specify the start time of the last pulse of the multi-pulse train for recording marks of run-length 3T relative to the leading edge of the last channel bit of the data pulse (positive values are leading, negative values are lagging; see Annex F).

Byte 54: This byte shall specify the start time of the first pulse, of the multi-pulse train, for recording marks of run-length 4T relative to the leading edge of the last channel bit of the data pulse (positive values are leading, negative values are lagging; see Annex F).

Byte 55: This byte shall specify the start time of the first pulse of the multi-pulse train for recording marks of run-lengths ≥5T relative to the leading edge of the last channel bit of the data pulse (positive values are leading, negative values are lagging; see Annex F).

Bytes 56 to 58: ***T_{LP}* last-pulse duration**

The first 5 bits (bits b_7 to b_3) of these bytes specify the last pulse length of the multi-pulse train, in the extended N-1 write strategy, for recording marks with run-lengths 3T, 4T and ≥5T with a succeeding ≥5T space (see Annex F).

These bytes shall specify a fraction of the actual channel-bit clock period as an unsigned binary number *d* such that:

$$d = 32 \times \frac{T_{LP}}{T_W} \qquad (0 \le d \le 30).$$

The last 3 bits (bits b_2 to b_0) of these bytes shall be reserved.

Byte 56: This byte shall specify the duration of the last pulse, of the multi-pulse train, for recording marks of run-length 3T (see Annex F).

Byte 57: This byte shall specify the duration of the last pulse, of the multi-pulse train, for recording marks of run-length 4T (see Annex F).

Byte 58: This byte shall specify the duration of the last pulse, of the multi-pulse train, for recording marks of run-lengths ≥5T (see Annex F).

Bytes 59 to 63: dT_E start time of the erase level

The first 7 bits (bits b_7 to b_1) of these bytes specify the start time of the erase level of the extended N-1 write strategy for the recording marks with run-lengths 2T, 3T, 4T, and ≥5T with a succeeding ≥5T space (positive values are leading, negative values are lagging; see Annex F).

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 *e,* such that:

$$e = 32 \times \frac{dT_E}{T_W} \quad (-48 \le e \le 30).$$

The last bit (bit b_0) of these bytes shall be reserved.

Byte 59: This byte shall specify the start time of the erase level for recording marks of run-length 2T with a preceding 2T space.

Byte 60: This byte shall specify the start time of the erase level for recording marks of run-length 2T with a preceding ≥3T space.

Byte 61: This byte shall specify the start time of the erase level of the multi-pulse train for recording marks of run-length 3T.

Byte 62: This byte shall specify the start time of the erase level of the multi-pulse train for recording marks of run-length 4T.

Byte 63: This byte shall specify the start time of the erase level of the multi-pulse train for recording marks of run-lengths ≥5T.

Byte 64: Reserved

This byte shall be set to 00h.

Bytes 65 to 98: In these bytes, Δ is defined as the offset from the anchor position or duration time which is specified from bytes 43 to 63.

Offset means the time difference from the anchor position. Regarding the duration time, offset is specified in a similar way (see Figure F.1).

Bytes 65 to 72 and 73 (msb 4 bits): ΔdT_{top} first write-pulse start time offset

These bytes specify the leading edge offset of the first pulse of the multi-pulse train, in the extended N-1 write strategy, for recording marks with run-lengths 2T, 3T, 4T and ≥5T with a preceding 2T, 3T, or 4T space (see Annex F).

The first-pulse start time offset ΔdT_{top} is expressed as a fraction of the actual channel bit clock period, as a signed two's-complement binary number *f,* such that:

$$f = 32 \times \frac{\Delta dT_{top}}{T_W} \quad (-28 \le f \le 30). \text{ for Byte 65 and 66;}$$

$$f = 32 \times \frac{\Delta dT_{top}}{T_W} \quad (-8 \le f \le 7). \text{ for Byte 67 to 72 and 73 (MSB 4 bits).}$$

Table 1 — Dependence of the dT_{top} value for each mark

Mark	2M		3M	4M	≥5M
Succeeding space	2S	≥3S			
Preceding space					
2S	*f*				
3S					
4S					
≥5S	*a*				

Table 1 shows the dependence of the dT_{top} value for each mark that is going to be written, on the preceding and succeeding spaces. The area denoted by "*a*" accommodates the anchor values and the area denoted by "*f*" includes the offset value as follows:

f The area with this pattern includes the offset values, which are represented by "*f*".

a The area with this pattern includes the anchor values, which are represented by "*a*". The value "$i = f + a$" shall satisfy $-28 \leq i \leq 30$.

See F.2.

Byte 65: The first 6 bits (bits b_7 to b_2) of this byte shall specify the start time offset of the pulse for recording marks of run-length 2T with a preceding 2T space and a succeeding 2T space. In case this byte applies, the anchor position is specified in byte 43 (dT_{top} for a 2T mark with a preceding ≥5T space and a succeeding 2T space).

The last 2 bits (bits b_1 to b_0) of this byte shall be reserved.

Byte 66: The first 6 bits (bits b_7 to b_2) of this byte shall specify the start time offset of the pulse for recording marks of run-length 2T with a preceding 2T space and a succeeding ≥3T space. In case this byte applies, the anchor position is specified in byte 44 (dT_{top} for a 2T mark with a preceding ≥5T space and a succeeding ≥3T space).

The last 2 bits (bits b_1 to b_0) of this byte shall be reserved.

Byte 67: The first 4 bits (bits b_7 to b_4) of this byte shall specify the start time offset of the first pulse of the multi-pulse train for recording marks of run-length 3T with a preceding 2T space. In case these bits (bits b_7 to b_4) apply, the anchor position is specified in byte 45 (dT_{top} for a 3T mark with a preceding ≥5T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the start time offset of the first pulse of the multi-pulse train for recording marks of run-length 4T with a preceding 2T space. In case these bits (bits b_3 to b_0) apply, the anchor position is specified in byte 46 (dT_{top} for a 4T mark with a preceding ≥5T space).

Byte 68: The first 4 bits (bits b_7 to b_4) of this byte shall specify the start time offset of the first pulse of the multi-pulse train for recording marks of run-lengths ≥5T with a preceding 2T space. In case these bits (bits b_7 to b_4) apply, the anchor position is specified in byte 47 (dT_{top} for ≥5T mark with a preceding ≥5T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the start time offset of the pulse for recording marks of run-length 2T with a preceding 3T space and a succeeding a 2T space. In case these bits (bits b_3 to b_0) apply, the anchor position is specified in byte 43 (dT_{top} for a 2T mark with a preceding ≥5T space and a succeeding 2T space).

Byte 69: The first 4 bits (bits b_7 to b_4) of this byte shall specify the start time offset of the pulse for recording marks of run-length 2T with a preceding 3T space and a succeeding ≥3T space. In case of these bits (bits b_7 to b_4) the anchor position is specified in byte 44 (dT_{top} for 2T mark with a preceding ≥5T space and a succeeding ≥3T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the start time offset of the first pulse of the multi-pulse train for recording marks of run-length 3T with a preceding 3T space. In case of these bits (bits b_3 to b_0), the anchor position is specified in byte 45 (dT_{top} for 3T mark with a preceding ≥5T space).

Byte 70: The first 4 bits (bits b_7 to b_4) of this byte shall specify the start time offset of the first pulse of the multi-pulse train for recording marks of run-length 4T with a preceding 3T space. In case these bits (bits b_7 to b_4) apply, the anchor position is specified in byte 46 (dT_{top} for a 4T mark with a preceding ≥5T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the start time offset of the first pulse of the multi-pulse train for recording marks of run-lengths ≥5T with a preceding 3T space. In case these bits (bits b_3 to b_0) apply, the anchor position is specified in byte 47 (dT_{top} for a ≥5T mark with a preceding ≥5T space).

Byte 71: The first 4 bits (bits b_7 to b_4) of this byte shall specify the start time offset of the pulse for recording marks of run-length 2T with a preceding 4T space and a succeeding 2T space. In case these bits (bits b_7 to b_4) apply, the anchor position is specified in byte 43 (dT_{top} for 2T mark with a preceding ≥5T space and a succeeding 2T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the start time offset of the pulse for recording marks of run-length 2T with a preceding 4T space and a succeeding ≥3T space. In case these bits (bits b_3 to b_0) apply, the anchor position is specified in byte 44 (dT_{top} for a 2T mark with a preceding ≥5T space and a succeeding ≥3T space).

Byte 72: The first 4 bits (bits b_7 to b_4) of this byte shall specify the start time offset of the first pulse of the multi-pulse train for recording marks of run-length 3T with a preceding 4T space. In case these bits (bits b_7 to b_4) apply, the anchor position is specified in byte 45 (dT_{top} for a 3T mark with a preceding ≥5T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the start-time offset of the first pulse of the multi-pulse train for recording marks of run-length 4T with a preceding 4T space. In case these bits (bits b_3 to b_0) apply, the anchor position is specified in byte 46 (dT_{top} for a 4T mark with a preceding ≥5T space).

Byte 73 (msb 4 bits):

The first 4 bits (bits b_7 to b_4) of this byte shall specify the start-time offset of the first pulse of the multi-pulse train for recording marks of run-lengths ≥5T with a preceding 4T. In case these bits (bits b_7 to b_4) apply, the anchor position is specified in byte 47 (dT_{top} for a ≥5T mark with a preceding ≥5T space).

Bytes 73 (lsb 4 bits) and 74 to 80: ΔT_{top} first write-pulse duration offset

These bytes specify the duration offset of the first pulse of the multi-pulse train, in the extended N-1 write strategy, for recording marks with run-lengths 2T, 3T, 4T, and ≥5T with a preceding 2T, 3T, or 4T space (see Annex F).

These bytes shall specify a fraction of the actual channel-bit clock period, as a signed two's-complement binary number *g*, such that:

$$g = 32 \times \frac{\Delta T_{top}}{T_W} \qquad (-8 \le g \le 7).$$

Table 2 — Dependence of the T_{top} value for each mark

Mark	2M		3M	4M	≥5M
Succeeding space	2S	≥3S			
Preceding space					
2S	*g*				
3S					
4S					
≥5S	*b*				

Table 2 shows the dependence of the T_{top} value for each mark that is going to be written, on the preceding and succeeding spaces. The area denoted by "*b*" accommodates the anchor values and the area denoted by "*g*" includes the offset values as follows:

g The area with this pattern includes the offset values, which are represented by "*g*".

b The area with this pattern includes the anchor values, which are represented by "*b*". The value "$j = g + b$" shall satisfy $0 \le j \le 60$.

See F.2.

Byte 73: (lsb 4 bits):

The last 4 bits (bits b_3 to b_0) of this byte shall specify the duration offset of the pulse for recording marks of run-length 2T with a preceding 2T space and a succeeding 2T space (see Annex F). In case these bits (bits b_3 to b_0) apply, the anchor duration time is specified in byte 48 (T_{top} for a 2T mark with a preceding ≥5T space and a succeeding 2T space).

Byte 74: The first 4 bits (bits b_7 to b_4) of this byte shall specify the duration offset of the pulse for recording marks of run-length 2T with a preceding 2T space and a succeeding ≥3T space (see Annex F). In case these bits (bits b_7 to b_4) apply, the anchor duration time is specified in byte 49 (T_{top} for a 2T mark with a preceding ≥5T space and a succeeding ≥3T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the duration offset of the first pulse of the multi-pulse train for recording marks of run-length 3T with a preceding 2T space (see Annex F). In case these bits (bits b_3 to b_0) apply, the anchor duration time is specified in byte 50 (T_{top} for a 3T mark with a preceding ≥5T space).

Byte 75: The first 4 bits (bits b_7 to b_4) of this byte shall specify the duration offset of the first pulse of the multi-pulse train for recording marks of run-length 4T with a preceding 2T space (see Annex F). In case these bits (bits b_7 to b_4) apply, the anchor duration time is specified in byte 51 (T_{top} for a 4T mark with a preceding ≥5T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the duration offset of the first pulse of the multi-pulse train for recording marks of run-lengths ≥5T with a preceding 2T space (see Annex F). In case these bits (bits b_3 to b_0) apply, the anchor duration time is specified in byte 52 (T_{top} for a ≥5T mark with a preceding ≥5T space).

Byte 76: The first 4 bits (bits b_7 to b_4) of this byte shall specify the duration offset of the pulse for recording marks of run-length 2T with a preceding 3T space and a succeeding 2T space (see Annex F). In case these bits (bits b_7 to b_4) apply, the anchor duration time is specified in byte 48 (T_{top} for 2T mark with a preceding ≥5T space and a succeeding 2T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the duration offset of the pulse for recording marks of run-length 2T with a preceding 3T space and a succeeding ≥3T space (see Annex F). In case these bits (bits b_3 to b_0) apply, the anchor duration time is specified in byte 49 (T_{top} for a 2T mark with a preceding ≥5T space and a succeeding ≥3T space).

Byte 77: The first 4 bits (bits b_7 to b_4) of this byte shall specify the duration offset of the first pulse of the multi-pulse train for recording of marks of run-length 3T with a preceding 3T space (see Annex F). In case these bits (bits b_7 to b_4) apply, the anchor duration time is specified in byte 50 (T_{top} for 3T mark with a preceding ≥5T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the duration offset of the first pulse of the multi-pulse train for recording marks of run-length 4T with a preceding 3T space (see Annex F). In case these bits (bits b_3 to b_0) apply, the anchor duration time is specified in byte 51 (T_{top} for a 4T mark with a preceding ≥5T space).

Byte 78: The first 4 bits (bits b_7 to b_4) of this byte shall specify the duration offset of the first pulse of the multi-pulse train for recording marks of run-lengths ≥5T with a preceding 3T space (see Annex F). In case these bits (bits b_7 to b_4) apply, the anchor duration time is specified in byte 52 (T_{top} for a ≥5T mark with a preceding ≥5T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the duration offset of the pulse for recording marks of run-length 2T with a preceding 4T space and a succeeding 2T space (see Annex F). In case these bits (bits b_3 to b_0) apply, the anchor duration time is specified in byte 48 (T_{top} for a 2T mark with a preceding ≥5T space and a succeeding 2T space).

Byte 79: The first 4 bits (bits b_7 to b_4) of this byte shall specify the duration offset of the pulse for recording marks of run-length 2T with a preceding 4T space and a succeeding ≥3T space (see Annex F). In case these bits (bits b_7 to b_4) apply, the anchor duration time is specified in byte 49 (T_{top} for a 2T mark with a preceding ≥5T space and a succeeding ≥3T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the duration offset of the first pulse of the multi-pulse train for recording marks of run-length 3T with a preceding 4T space (see Annex F). In case these bits (bits b_3 to b_0) apply, the anchor duration time is specified in byte 50 (T_{top} for a 3T mark with a preceding ≥5T space).

Byte 80: The first 4 bits (bits b_7 to b_4) of this byte shall specify the duration offset of the first pulse of the multi-pulse train for recording marks of run-length 4T with a preceding 4T space (see Annex F). In case these bits (bits b_7 to b_4) apply, the anchor duration time is specified in byte 51 (T_{top} for 4T mark with a preceding ≥5T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the duration offset of the first pulse of the multi-pulse train for recording marks of run-lengths ≥5T with a preceding 4T space.(see Annex F). In case these bits (bits b_3 to b_0) apply, the anchor duration time is specified in byte 52 (T_{top} for a ≥5T mark with a preceding ≥5T space).

Bytes 81 to 84 and 85 (msb 4 bits): ΔdT_{LP} last-pulse start time offset

These bytes specify the start time offset of the last pulse of the multi-pulse train, in the extended N-1 write strategy, for recording marks with run-lengths 3T, 4T, and ≥5T with a succeeding 2T, 3T, or 4T space (see Annex F).

The last-pulse start time offset ΔdT_{LP} is expressed as a fraction of the actual channel-bit clock period, as a signed two's-complement binary number h, such that:

$$h = 32 \times \frac{\Delta dT_{LP}}{T_W} \qquad (-8 \le h \le 7).$$

Table 3 — Dependence of the dT_{LP} value for each mark

Mark / Succeeding space	3M	4M	≥5M
2S			
3S		*h*	
4S			
≥5S		*c*	

Table 3 shows the dependence of the dT_{LP} value for each mark that is going to be written, on the preceding and succeeding spaces. The area denoted by "*c*" accommodates the anchor values and the area denoted by "*h*" includes the offset values as follows:

h The area with this pattern includes the offset values, which are represented by "*h*".

c The area with this pattern includes the anchor values, which are represented by "*c*". The value "$r = h + c$" shall satisfy $-30 \le r \le 30$.

See F.2.

Byte 81: The first 4 bits (bits b_7 to b_4) of this byte shall specify the start time offset of the last pulse of the multi-pulse train for recording marks of run-length 3T with a succeeding 2T space. In case these bits (bits b_7 to b_4) apply, the anchor position is specified in byte 53 (dT_{LP} for a 3T mark with a succeeding ≥5T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the start time offset of the last pulse of the multi-pulse train for recording marks of a run-length 4T with a succeeding 2T space. In case these bits (bits b_3 to b_0) apply, the anchor position is specified in byte 54 (dT_{LP} for a 4T mark with a succeeding ≥5T space).

Byte 82: The first 4 bits (bits b_7 to b_4) of this byte shall specify the start time offset of the last pulse of the multi-pulse train for recording marks of run-lengths ≥5T with a succeeding 2T space. In case these bits (bits b_7 to b_4) apply, the anchor position is specified in byte 55 (dT_{LP} for a ≥5T mark with a succeeding ≥5T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the start time offset of the last pulse of the multi-pulse train for recording marks of run-length 3T with a succeeding 3T space. In case these bits (bits b_3 to b_0) apply, the anchor position is specified in byte 53 (dT_{LP} for a 3T mark with a succeeding ≥5T space).

Byte 83: The first 4 bits (bits b_7 to b_4) of this byte shall specify the start time offset of the last pulse of the multi-pulse train for recording marks of run-length 4T with a succeeding 3T space. In case these bits (bits b_7 to b_4) apply, the anchor position is specified in byte 54 (dT_{LP} for 4T mark with a succeeding ≥5T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the start time offset of the last pulse of the multi-pulse train for recording marks of run-lengths ≥5T with a succeeding 3T space. In case these bits (bits b_3 to b_0) apply, the anchor position is specified in byte 55 (dT_{LP} for a ≥5T mark with a succeeding ≥5T space).

Byte 84: The first 4 bits (bits b_7 to b_4) of this byte shall specify the start time offset of the last pulse of the multi-pulse train for recording marks of run-length 3T with a succeeding 4T space. In case these bits (bits b_7 to b_4) apply, the anchor position is specified in byte 53 (dT_{LP} for a 3T mark with a succeeding ≥5T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the start time offset of the last pulse of the multi-pulse train for recording of marks of run-length 4T with a succeeding 4T space. In case these bits (bits b_3 to b_0) apply, the anchor position is specified in byte 54 (dT_{LP} for 4T mark with a succeeding ≥5T space).

Byte 85 (msb 4 bits):

The first 4 bits (bits b_7 to b_4) of this byte shall specify the start time offset of the last pulse of the multi-pulse train for recording marks of run-lengths ≥5T with a succeeding 4T space. In case these bits (bits b_7 to b_4) apply, the anchor position is specified in byte 55 (dT_{LP} for ≥ a 5T mark with a succeeding ≥5T space).

Bytes 85 (lsb 4 bits) and 86 to 89: ΔT_{LP} last-pulse duration offset

These bytes specify the duration offset for the last pulse length of the multi-pulse train, in the extended N-1 write strategy, for recording marks with run-lengths 3T, 4T, and ≥5T with a succeeding 2T, 3T, or 4T space (see Annex F).

This byte shall specify a fraction of the actual channel-bit clock period, as a signed two's-complement binary number *v*, such that:

$$v = 32 \times \frac{\Delta T_{LP}}{T_W} \qquad (-8 \leq v \leq 7).$$

Table 4 — Dependence of the T_{LP} value for each mark

<table>
<tr><th>Mark</th><th rowspan="2">3M</th><th rowspan="2">4M</th><th rowspan="2">≥5M</th></tr>
<tr><th>Succeeding space</th></tr>
<tr><td>2S</td><td colspan="3" rowspan="3">v</td></tr>
<tr><td>3S</td></tr>
<tr><td>4S</td></tr>
<tr><td>≥5S</td><td colspan="3">d</td></tr>
</table>

Table 4 shows the dependence of the T_{LP} value for each mark that is going to be written, on the preceding and succeeding spaces. The area denoted by "*d*" accommodates the anchor values and the area denoted by "*v*" includes the offset values as follows:

v The area with this pattern includes the offset values, which are represented by "*v*".

d The area with this pattern includes the anchor values, which are represented by "*d*". The value "$s = v + d$" shall satisfy $0 \le s \le 30$.

See F.2.

Byte 85 (lsb 4 bits):

The last 4 bits (bits b_3 to b_0) of this byte shall specify the duration offset of the last pulse of the multi-pulse train for recording marks of run-length 3T with a succeeding 2T space (see Annex F). In case these bits (bits b_3 to b_0) apply, the anchor duration time is specified in byte 56 (T_{LP} for a 3T mark with a succeeding ≥5T space).

Byte 86: The first 4 bits (bits b_7 to b_4) of this byte shall specify the duration offset of the last pulse of the multi-pulse train for recording marks of run-length 4T with a succeeding 2T space (see Annex F). In case these bits (bits b_7 to b_4) apply, the anchor duration time is specified in byte 57 (T_{LP} for a 4T mark with a succeeding ≥5T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the duration offset of the last pulse of the multi-pulse train for recording marks of run-lengths ≥5T with a succeeding 2T space (see Annex F). In case these bits (bits b_3 to b_0) apply, the anchor duration time is specified in byte 58 (T_{LP} for ≥5T mark with a succeeding ≥5T space).

Byte 87: The first 4 bits (bits b_7 to b_4) of this byte shall specify the duration offset of the last pulse of the multi-pulse train for recording marks of run-length 3T with a succeeding 3T space (see Annex F). In case these bits (bits b_7 to b_4) apply, the anchor duration time is specified in byte 56 (T_{LP} for a 3T mark with a succeeding ≥5T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the duration offset of the last pulse of the multi-pulse train for recording marks of run-length 4T that with a succeeding 3T space (see Annex F). In case these bits (bits b_3 to b_0) apply, the anchor duration time is specified in byte 57 (T_{LP} for a 4T mark with a succeeding ≥5T space).

Byte 88: The first 4 bits (bits b_7 to b_4) of this byte shall specify the duration offset of the last pulse of the multi-pulse train for recording marks of run-lengths ≥5T with a succeeding 3T space (see Annex F). In case these bits (bits b_7 to b_4) apply, the anchor duration time is specified in byte 58 (T_{LP} for a ≥5T mark with a succeeding ≥5T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the duration offset of the last pulse of the multi-pulse train for recording marks of run-length 3T with a succeeding 4T space (see Annex F). In case these bits (bits b_3 to b_0) apply, the anchor duration time is specified in byte 56 (T_{LP} for a 3T mark with a succeeding ≥5T space).

Byte 89: The first 4 bits (bits b_7 to b_4) of this byte shall specify the duration offset of the last pulse of the multi-pulse train for recording marks of run-length 4T with a succeeding 4T space (see Annex F). In case these bits (bits b_7 to b_4) apply, the anchor duration time is specified in byte 57 (T_{LP} for a 4T mark with a succeeding ≥5T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the duration offset of the last pulse of the multi-pulse train for recording marks of run-lengths ≥5T with a succeeding 4T space (see Annex F). In case these bits (bits b_3 to b_0) apply, the anchor duration time is specified in byte 58 (T_{LP} for a ≥5T mark with a succeeding ≥5T space).

Bytes 90 to 97 and 98 (msb 4 bits): ΔdT_E start time offset of the erase level

These bytes specify the start time offset of the erase level, in the extended N-1 write strategy, for recording marks with run-lengths 2T, 3T, 4T, and ≥5T with a succeeding 2T, 3T, or ≥ 4T space (positive values are leading, negative values are lagging; see Annex F).

The start time offset of the erase level ΔdT_E is expressed as a fraction of the actual channel-bit clock period, as a signed two's-complement binary number *w*, such that:

$$w = 32 \times \frac{\Delta dT_E}{T_W} \quad (-24 \le w \le 15). \text{ for Byte 90 and 91;}$$

$$w = 32 \times \frac{\Delta dT_{top}}{T_W} \quad (-8 \le w \le 7) \text{ for Byte 92 to 97 and 98 (MSB 4 bits).}$$

Table 5 — Dependence of the dT_E value for each mark

<table>
<tr><td>Mark</td><td colspan="2">2M</td><td rowspan="3">3M</td><td rowspan="3">4M</td><td rowspan="3">≥5M</td></tr>
<tr><td>Preceding space</td><td rowspan="2">2S</td><td rowspan="2">≥3S</td></tr>
<tr><td>Succeeding space</td></tr>
<tr><td>2S</td><td colspan="5" rowspan="3">w</td></tr>
<tr><td>3S</td></tr>
<tr><td>4S</td></tr>
<tr><td>≥5S</td><td colspan="5">e</td></tr>
</table>

Table 5 shows the dependence of the dT_E value for each mark that is going to be written, on the preceding and succeeding spaces. The area denoted by "*e*" accommodates the anchor values and the area denoted by "*w*" includes the offset values as follows:

w The area with this pattern includes the offset values, which are represented by "*w*".

e The area with this pattern includes the anchor values, which are represented by "*e*". The value "$u = w + e$" shall satisfy $-48 \le u \le 30$.

See F.2.

Byte 90: The first 6 bits (bits b_7 to b_2) of this byte shall specify the start time offset of the erase level for recording marks of run-length 2T with a succeeding 2T space and a preceding 2T space. In case this byte applies, the anchor position is specified in byte 59 (dT_E for a 2T mark with a preceding 2T space and a succeeding ≥5T space).

The last 2 bits (bits b_1 to b_0) of this byte shall be reserved.

Byte 91: The first 6 bits (bits b_7 to b_2) of this byte shall specify the start time offset of the erase level for recording marks of run-length 2T with a succeeding 2T space and a preceding ≥3T space. In case this byte applies, the anchor position is specified in byte 60 (dT_E for a 2T mark with a preceding ≥3T space and a succeeding ≥5T space).

The last 2 bits (bits b_1 to b_0) of this byte shall be reserved.

Byte 92: The first 4 bits (bits b_7 to b_4) of this byte shall specify the start time offset of the erase level of the multi-pulse train for recording marks of run-length 3T with a succeeding 2T space. In case these bits (bits b_7 to b_4) apply, the anchor position is specified in byte 61 (dT_E for a 3T mark with a succeeding ≥5T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the start time offset of the succeeding erase level of the multi-pulse train for recording marks of run-length 4T with a 2T space. In case these bits (bits b_3 to b_0) apply, the anchor position is specified in byte 62 (dT_E for a 4T mark with a succeeding ≥5T space).

Byte 93: The first 4 bits (bits b_7 to b_4) of this byte shall specify the start time offset of the erase level of the multi-pulse train for recording marks of run-lengths ≥5T with a succeeding 2T space. In case these bits (bits b_7 to b_4) apply, the anchor position is specified in byte 63 (dT_E for a ≥5T mark with a succeeding ≥5T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the start time offset of the erase level for recording marks of run-length 2T with a succeeding 3T space and a preceding 2T space. In case these bits (bits b_3 to b_0) apply, the anchor position is specified in byte 59 (dT_E for a 2T mark with a preceding 2T space and a succeeding ≥5T space).

Byte 94: The first 4 bits (bits b_7 to b_4) of this byte shall specify the start time offset of the erase level for recording of marks of run-length 2T with a succeeding 3T space and a preceding ≥3T space. In case these bits (bits b_7 to b_4) apply, the anchor position is specified in byte 60 (dT_E for 2T mark with a succeeding ≥5T space and a preceding ≥3T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the start time offset of the erase level of the multi-pulse train for recording marks of run-length 3T with a succeeding 3T space. In case these bits (bits b_3 to b_0) apply, the anchor position is specified in byte 61 (dT_E for a 3T mark with a succeeding ≥5T space).

Byte 95: The first 4 bits (bits b_7 to b_4) of this byte shall specify the start time offset of the erase level of the multi-pulse train for recording marks of run-length 4T with a succeeding 3T space. In case these bits (bits b_7 to b_4) apply, the anchor position is specified in byte 62 (dT_E for a 4T mark with a succeeding ≥5T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the start time offset of the erase level of the multi-pulse train for recording marks of run-lengths ≥5T with a succeeding 3T space. In case these bits (bits b_3 to b_0) apply, the anchor position is specified in byte 63 (dT_E for ≥ a 5T mark with a succeeding ≥5T space).

Byte 96: The first 4 bits (bits b_7 to b_4) of this byte shall specify the start time offset of the erase level for recording marks of run-length 2T with a succeeding 4T space and a preceding 2T space. In case these bits (bits b_7 to b_4) apply, the anchor position is specified in byte 59 (dT_E for a 2T mark with a succeeding ≥5T space and a preceding 2T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the start time offset of the erase level for recording marks of run-length 2T with a succeeding 4T and a preceding ≥3T space. In case these bits (bits b_3 to b_0) apply, the anchor position is specified in byte 60 (dT_E for a 2T mark with a preceding ≥3T space and a succeeding ≥5T space).

Byte 97: The first 4 bits (bits b_7 to b_4) of this byte shall specify the start time offset of the erase level of the multi-pulse train for recording marks of run-length 3T with a succeeding 4T space. In case these bits (bits b_7 to b_4) apply, the anchor position is specified in byte 61 (dT_E for a 3T mark with a succeeding ≥5T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the start time offset of the erase level of the multi-pulse train for recording marks of run-length 4T with a succeeding 4T space. In case these bits (bits b_3 to b_0) apply, the anchor position is specified in byte 62 (dT_E for a 4T mark with a succeeding ≥5T space).

Byte 98 (msb 4 bits):

The first 4 bits (bits b_7 to b_4) of this byte shall specify the start time offset of the erase level of the multi-pulse train for recording marks of run-lengths ≥5T with a succeeding 4T space. In case these bits (bits b_7 to b_4) apply, the anchor position is specified in byte 63 (dT_E for a ≥5T mark with a succeeding ≥5T space).

Byte 98: (lsb 4 bits):

Reserved

These bits shall be set to 0000.

Byte 99: **Reserved**

This byte shall be set to 00h.

Bytes 100 to 111: DI unit footer

See 15.8.3.2.

15.8.3.4 Definitions for DI format 5 (Extended N/2 write strategy)

The content of the body of DI units according to format 5 shall be as depicted in Figure 80.

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	Push-Pullpolarity flag bits	1
15	Recorded mark polarity flag bits	1
16	BCA descriptor	1
17 to 18	Reserved	2
19 to 26	Data-Zone allocation	8
27	Reserved	1
28 to 29	Recording Velocity	2
30	Maximum dc read powers	1
31	Maximum HF-modulated read powers	1
32	Reserved	1
33 to 41	Write-power settings	9
42	T_{MP} write multi-pulse duration	1
43 to 47	dT_{top} first write-pulse start time	5
48 to 52	T_{top} first write-pulse duration	5
53 to 54	dT_{LP} last-write pulse start time	2
55 to 56	T_{LP} last-pulse duration	2
57 to 61	dT_E start time of the erase level	5
62	Reserved	1
63 to 70 and 71 (msb 4 bits)	ΔdT_{top} first write-pulse start time offset	8,5
71 (lsb 4 bits) and 72 to 78	ΔT_{top} first write-pulse duration offset	7,5
79 to 81	ΔdT_{LP} last-pulse start time offset	3
82 to 84	ΔT_{LP} last-pulse duration offset	3
85 to 92 and 93 (msb 4 bits)	ΔdT_E start time offset of the erase level	8,5
93 (lsb 4 bits)	Reserved	0,5
94 to 99	Reserved	6
100 to 111	DI Unit footer	12

Figure 80 — Content of disk information for DI format 5

Bytes 0 to 1: **Disk-information identifier**
See 15.8.3.2.

Byte 2: **DI-format number**
This byte shall be set to 05h for the disks with BCA code.

This byte shall be set to 85h for the disks without BCA code.

Byte 3: **Number of DI aux frames in each DI block/Number of the layer to which this DI unit applies**
See 15.8.3.2.

Byte 4: **Reserved**
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 5Eh indicating that the first 94 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 2 bits specify the disk size. They shall be set to 00, indicating a 120 mm disk.

Bits b_5 to b_4: These 2 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 01.

Drives 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 0011, indicating 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. These bits shall be set to 0011, indicating 3 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, indicating 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:

0000, reserved;

0101, indicating a channel-bit length of 55,87 nm (33,4 GB per layer);

Others: reserved.

Byte 14: **Push–pull polarity flag bits**

Bit b_i : Each bit b_i shall specify the polarity of the push–pull signal on recording layer L*i* (see 26.1). They shall be set to as follows:

ZERO, indicating that the push–pull polarity on layer L*i* is positive;

ONE, indicating that the push–pull polarity on layer L*i* is negative.

For recording layers that are not present, bit b_i shall be set to ZERO;

For this document, this byte shall be set to 00h.

Byte 15: **Recorded mark polarity flag bits**

Bit b_i : Each bit b_i shall specify the polarity of recorded marks on recording layer L*i*.

They shall be set to as follows:

ZERO, indicating a layer type on which recorded marks have a lower reflectivity than the unrecorded layer (HTL disks);

ONE, indicating a layer type on which recorded marks have a higher reflectivity than the unrecorded layer;

For recording layers that are not present, bit b_i shall be set to ZERO;

For this document, this byte shall be set to 00h.

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 indicate the presence of a BCA code on this disk:

They shall be set to as follows:

0000: indicating no BCA code;

0001: indicating BCA code is present;

Others: reserved.

Bytes 17 to 18: **Reserved**
These bytes shall be set to all 00h.

Bytes 19 to 26: **Data-zne allocation**

Bytes 19 to 22: These bytes shall 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 indicating 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 5E EC 80h for a disk with a user-data capacity of 33,4 GB per layer, indicating PAA 6 220 928 for 33,4 GB per layer as the first PAA of the data zone 1.

In each DI unit relating to layer L2, these bytes shall be set to 00 82 00 00h indicating PAA 8 519 680 as the first PAA of the data zone 2.

Bytes 23 to 26: These bytes shall 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 21 13 7Eh for a disk with a user-data capacity of 33,4 GB per layer, indicating PAA 2 167 678 for 33,4 GB per layer as the last PAA of the data zone 0.

In each DI unit relating to layer L1, these bytes shall be set to 00 7D FF FEh indicating PAA 8 257 534 as the last PAA of the data zone 1.

In each DI unit relating to layer L2, these bytes shall be set to the value LAA + 00 80 00 00h, which shall be 00 A1 13 7E h for a disk with a user data capacity of 33,4 GB per layer, indicating PAA 10 556 286 for 33,4 GB per layer as the last PAA of the data zone 2.

Byte 27: **Reserved**

This byte shall be set to 00h.

Bytes 28 to 29: **Recording velocity**

Bytes 28 to 29: These bytes shall specify the nominal recording velocity, to be used with the parameters as defined in this DI unit, as a 2-byte binary number (byte 28 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 02 E2h to indicate a nominal recording velocity of 7,38 m/s.

Byte 30: **Maximum dc read power at the nominal recording velocity**

The maximum read power is defined as the maximum optical power to which this DI unit applies on the entrance surface of the disk, at which at least 10^6 successive reads can be applied without degrading the recorded signals (see 30.7). Maximum read powers in this clause shall be greater than or equal to the read powers defined in 30.7. By default, the powers defined in 30.7 shall be used.

This byte shall specify the dc read power P_r at a readout velocity equal to the nominal recording velocity defined in bytes 28 and 29 of this DI unit. The decimal expression of this byte is as follows:

$n = 100 \times P_r$, where P_r is expressed in milliwatts.

NOTE For reading at lower speeds than the nominal velocity specified in this DI unit, a reduction of the read power can be necessary to guarantee the stability of recordings on the disk.

Byte 31: **Maximum HF-modulated read powers at the nominal recording velocity**

The maximum read power is defined as the maximum optical power to which this DI unit applies on the entrance surface of the disk, at which at least 10^6 successive reads can be applied without degrading the recorded signals (see 30.7). Maximum read powers in this clause shall be greater than or equal to the read powers defined in 30.7. By default, the powers defined in 30.7 shall be used.

This byte shall specify the maximum HF-modulated read power P_r. at a readout velocity equal to the nominal recording velocity defined in byte 28 and 29 of this DI unit. The decimal expression of this byte is as follows:

$n = 100 \times P_r$, where P_r is expressed in milliwatts.

NOTE For reading at lower speeds than the nominal velocity specified in this DI unit, a reduction of the read power can be necessary to guarantee the stability of recordings on the disk.

Byte 32: **Reserved**

This byte shall be set to 00h.

Bytes 33 to 41: **Write-power settings**

Bytes 33 to 34: $\boldsymbol{P_{IND}}$: P_{IND} can be used as a starting value for the determination of P_{target} in the OPC procedure (see Annex G).

These bytes shall specify the indicative value P_{IND} of P_{target} in milliwatts, as a number n such that:

$n = 20 \times P_{IND}$.

where bit b_7 of byte 33 is the MSB and bit b_0 of byte 34 is the LSB.

Byte 35: $\boldsymbol{m_{IND}}$: m_{IND} can be used as a starting value for the determination of P_{target} in the OPC procedure (see Annex G).

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 36: $\boldsymbol{\rho}$: This byte shall specify the write-power multiplication factor ρ used in the OPC algorithm (see Annex G) as a number n such that:

$n = 100 \times \rho$.

Byte 37: $\boldsymbol{\varepsilon_{BW}}$: This byte shall specify the write-bias/write-peak power ratio ε_{BW} used in the OPC algorithm (see Annex G) as a number n such that:

$n = 200 \times \varepsilon_{BW}$.

Byte 38: $\boldsymbol{\varepsilon_{C}}$: This byte shall specify the cooling/write-peak power ratio ε_C used in the OPC algorithm (see Annex G) as a number n such that:

$n = 200 \times \varepsilon_C$.

Byte 39: $\boldsymbol{\varepsilon_{E}}$: This byte shall specify the erase/write-peak power ratio ε_E used in the OPC algorithm (see Annex G) as a number n such that:

$n = 200 \times \varepsilon_E$.

Byte 40: $\boldsymbol{\kappa}$: This byte shall specify the target value for κ used in the OPC procedure (see Annex G) as a number n such that:

$n = 20 \times \kappa$.

Byte 41: This byte shall be reserved.

Byte 42: $\boldsymbol{T_{MP}}$ **write multi-pulse duration**

This byte specifies the duration of the second and subsequent pulses of the multi-pulse train, in the extended N/2 write strategy, for recording marks (see Annex F).

The first 6 bits (bits b_7 to b_2) of this byte shall specify the fraction of the actual channel-bit clock period, as an unsigned binary number p, such that:

$$p = 32 \times \frac{T_{MP}}{T_W} \quad (0 \le p \le 62).$$

The last 2 bits (bits b_1 to b_0) of this byte shall be reserved.

Bytes 43 to 61 **In these bytes, anchor position or duration time is defined for dT_{top}, T_{top}, dT_{LP}, T_{LP}, and dT_E**

Anchor position means the leading edge position of each write pulse (see Figure F.3). Regarding the duration time, anchor is specified in a similar way.

Bytes 43 to 47: ***dT*$_{top}$ first write-pulse start time**

The first 6 bits (bits b_7 to b_2) of these bytes specify the start time of the first pulse, of the multi-pulse train, in the extended N/2 write strategy, for recording of marks with run-lengths 2T, 3T, [4T,6T,8T], and [5T,7T,9T] with a preceding ≥5T space (positive values are leading, negative values are lagging; see Annex F).

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 *a*, such that:

$$a = 32 \times \frac{dT_{top}}{T_W} \qquad (-32 \le a \le 30).$$

The last 2 bits (bits b_1 to b_0) of these bytes shall be reserved.

Byte 43: This byte shall specify the start time of the pulse for recording marks of run-length 2T with a succeeding 2T space, relative to the trailing edge of the first channel bit of the data pulse (positive values are leading, negative values are lagging; see Annex F).

Byte 44: This byte shall specify the start time of the pulse for recording marks of run-length 2T with a succeeding ≥3T space, relative to the trailing edge of the first channel bit of the data pulse (positive values are leading, negative values are lagging; see Annex F).

Byte 45: This byte shall specify the start time of the first pulse, of the multi-pulse train, for recording marks of run-length 3T, relative to the trailing edge of the first channel bit of the data pulse (positive values are leading, negative values are lagging; see Annex F).

Byte 46: This byte shall specify the start time of the first pulse, of the multi-pulse train, for recording marks of run-lengths [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 Annex F).

Byte 47: This byte shall specify the start time of the first pulse of the multi-pulse train for recording marks of run-lengths [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 Annex F).

Bytes 48 to 52: ***T*$_{top}$ first write-pulse duration**

The first 7 bits (bits b_7 to b_1) of these bytes specify the duration of the first pulse of the multi-pulse train, in the extended N/2 write strategy, for recording marks with run-lengths 2T, 3T, [4T, 6T, 8T], and [5T, 7T, 9T] with a preceding ≥ T space (see Annex F).

These bytes shall specify a fraction of the actual channel-bit clock period, as an unsigned binary number *b,* such that:

$$b = 32 \times \frac{T_{top}}{T_W} \qquad (0 \le b \le 92).$$

The last bit (bit b_0) of these bytes shall be reserved.

Byte 48: This byte shall specify the duration of the pulse for recording marks of run-length 2T with a succeeding 2T space (see Annex F).

Byte 49: This byte shall specify the duration of the pulse for recording marks of run-length 2T with a succeeding ≥3T space (see Annex F).

Byte 50: This byte shall specify the duration of the first pulse, of the multi-pulse train, for recording marks of run-length 3T (see Annex F).

Byte 51: This byte shall specify the duration of the first pulse, of the multi-pulse train, for recording marks of run-lengths [4T, 6T, 8T] (see Annex F).

Byte 52: This byte shall specify the duration of the first pulse, of the multi-pulse train, for recording marks of run-lengths [5T, 7T, 9T] (see Annex F).

Bytes 53 to 54: **dT_{LP} last write-pulse start time**

The first 6 bits (bits b_7 to b_2) of these bytes specify the start time of the last pulse of the multi-pulse train, in the extended N/2 write strategy, for recording marks with run-lengths [4T, 6T, 8T] and [5T, 7T, 9T] with a succeeding ≥5T space (positive values are leading, negative values are lagging; see Annex F).

The last-pulse start time dT_{LP} is expressed as a fraction of the actual channel-bit clock period, as a signed two's-complement binary number *c,* such that:

$$c = 32 \times \frac{dT_{LP}}{T_W} \qquad (-30 \le c \le 30).$$

The last 2 bits (bits b_1 to b_0) of these bytes shall be reserved.

Byte 53: This byte shall specify the start time of the last pulse of the multi-pulse train for recording marks of run-lengths [4T, 6T, 8T] relative to the leading edge of the last channel bit of the data pulse (positive values are leading, negative values are lagging; see Annex F).

Byte 54: This byte shall specify the start time of the last pulse of the multi-pulse train for recording marks of run-lengths [5T, 7T, 9T] relative to the leading edge of the last channel bit of the data pulse (positive values are leading, negative values are lagging; see Annex F).

Bytes 55 to 56: **T_{LP} last-pulse duration**

The first 6 bits (bits b_7 to b_2) of these bytes specify the last-pulse length, of the multi-pulse train, in the extended N/2 write strategy, for recording marks with run-lengths [4T,6T,8T] and [5T,7T,9T] with a succeeding ≥5T space (see Annex F).

These bytes shall specify a fraction of the actual channel-bit clock period, as an unsigned binary number *d,* such that:

$$d = 32 \times \frac{T_{LP}}{T_W} \qquad (0 \le d \le 62).$$

The last 2 bits (bits b_1 to b_0) of these bytes shall be reserved.

Byte 55: This byte shall specify the duration of the last pulse, of the multi-pulse train, for recording marks of run-lengths [4T, 6T, 8T] (see Annex F).

Byte 56: This byte shall specify the duration of the last pulse, of the multi-pulse train, for recording marks of run-lengths [5T, 7T, 9T] (see Annex F).

Bytes 57 to 61: ***dT_E* start time of the erase level**

The first 7 bits (bits b_7 to b_1) of these bytes specify the start time of the erase level, in the extended N/2 write strategy, for recording marks with run-lengths 2T, 3T, [4T, 6T, 8T], and [5T, 7T, 9T] with a succeeding ≥5T space (positive values are leading, negative values are lagging; see Annex F).

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 *e*, such that:

$$e = 32 \times \frac{dT_E}{T_W} \quad (-62 \leq e \leq 30).$$

The last bit (bit b_0) of these bytes shall be reserved.

Byte 57: This byte shall specify the start time of the erase level for recording marks of run-length 2T with a preceding 2T space, relative to the trailing edge of the last channel bit of the data pulse (positive values are leading, negative values are lagging; see Annex F).

Byte 58: This byte shall specify the start time of the erase level for recording marks of run-length 2T with a preceding ≥3T space, relative to the trailing edge of the last channel bit of the data pulse (positive values are leading, negative values are lagging; see Annex F).

Byte 59: This byte shall specify the start time of the erase level, of the multi-pulse train, for recording marks of run-length 3T, relative to the trailing edge of the last channel bit of the data pulse (positive values are leading, negative values are lagging; see Annex F).

Byte 60: This byte shall specify the start time of the erase level, of the multi-pulse train, for recording marks of run-lengths [4T, 6T, 8T], relative to the trailing edge of the last channel bit of the data pulse (positive values are leading, negative values are lagging; see Annex F).

Byte 61: This byte shall specify the start time of the erase level, of the multi-pulse train, for recording marks of run-lengths [5T, 7T, 9T], relative to the trailing edge of the last channel bit of the data pulse (positive values are leading, negative values are lagging; see Annex F).

Byte 62: **Reserved**

This byte shall be set to 00h.

Bytes 63 to 93 In these bytes, Δ is defined as the offset from the anchor position or duration time which is specified from bytes 43 to 61.

Offset means the time difference from the Anchor position. Regarding the duration time, Offset is specified in a similar way (see Figure F.3).

Bytes 63 to 70 and 71 (msb 4 bits): ΔdT_{top} first write-pulse start time offset

These bytes specify the leading edge offset of the first pulse of the multi-pulse train, in the extended N/2 write strategy, for recording marks with run-lengths 2T, 3T, [4T, 6T, 8T], and [5T, 7T, 9T] with a preceding 2T, 3T, or 4T space (see Annex F).

The first-pulse start time offset ΔdT_{top} is expressed as a fraction of the actual channel bit clock period, as a signed two's-complement binary number f, such that:

$$f = 32 \times \frac{\Delta dT_{top}}{T_W} \quad (-32 \le f \le 30)\text{. for byte 63 and 64;}$$

$$f = 32 \times \frac{\Delta dT_{top}}{T_W} \quad (-8 \le f \le 7)\text{. for byte 65 to 70 and 71 (msb 4 bits).}$$

Table 6 — Dependence of the dT_{top} value for each mark

Mark	2M		3M	4,6,8M	5,7,9M
Succeeding space	2S	≥3S			
Preceding space					
2S	*f*				
3S					
4S					
≥5S	*a*				

Table 6 shows the dependence of the dT_{top} value for each mark that is going to be written, on the preceding and succeeding spaces. The area denoted by "*a*" accommodates the anchor values and the area denoted by "*f*" includes the offset values as follows:

f The area with this pattern includes the offset values, which are represented by "*f*".

a The area with this pattern includes the anchor values, which are represented by "*a*". The value "$i = f + a$" shall satisfy $-28 \le i \le 30$.

See F.3.

Byte 63: The first 6 bits (bits b_7 to b_2) of this byte shall specify the start time offset of the pulse for recording marks of run-length 2T with a preceding 2T space and a succeeding 2T space. In case this byte applies, the anchor position is specified in byte 43 (dT_{top} for a 2T mark with a preceding ≥5T space and a succeeding 2T space).

The last 2 bits (bits b_1 to b_0) of this byte shall be reserved.

Byte 64: The first 6 bits (bits b_7 to b_2) of this byte shall specify the start-time offset of the pulse for recording marks of run-length 2T with a preceding 2T space and a succeeding ≥3T space. In case this byte applies, the anchor position is specified in byte 44 (dT_{top} for a 2T mark with a preceding ≥5T space and a succeeding ≥3T space).

The last 2 bits (bits b_1 to b_0) of this byte shall be reserved.

Byte 65: The first 4 bits (bits b_7 to b_4) of this byte shall specify the start time offset of the first pulse of the multi-pulse train for recording marks of run-length 3T with a preceding 2T space. In case these bits (bits b_7 to b_4) apply, the anchor position is specified in byte 45 (dT_{top} for a 3T mark with a preceding ≥5T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the start time offset of the first pulse, of the multi-pulse train, for recording marks of run-lengths [4T, 6T, 8T] with a preceding 2T space. In case these bits (bits b_3 to b_0) apply, the anchor position is specified in byte 46 (dT_{top} for a [4T, 6T, 8T] mark with a preceding ≥5T space).

Byte 66: The first 4 bits (bits b_7 to b_4) of this byte shall specify the start-time offset of the first pulse of the multi-pulse train for recording marks of run-lengths [5T, 7T, 9T] with a preceding 2T space. In case these bits (bits b_7 to b_4) apply, the anchor position is specified in byte 47 (dT_{top} for a [5T, 7T, 9T] mark with a preceding ≥5T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the start-time offset of the pulse for recording marks of run-length 2T with a preceding 3T space and a succeeding a 2T space. In case these bits (bits b_3 to b_0) apply, the anchor position is specified in byte 43 (dT_{top} for a 2T mark with a preceding ≥5T space and a succeeding 2T space).

Byte 67: The first 4 bits (bits b_7 to b_4) of this byte shall specify the start-time offset of the pulse for recording marks of run-length 2T with a preceding 3T space and a succeeding ≥3T space. In case these bits (bits b_7 to b_4) apply, the anchor position is specified in byte 44 (dT_{top} for a 2T mark with a preceding ≥5T space and a succeeding ≥3T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the start-time offset of the first pulse, of the multi-pulse train, for recording marks of run-length 3T with a preceding 3T space. In case these bits (bits b_3 to b_0) apply, the anchor position is specified in byte 45 (dT_{top} for a 3T mark with a preceding ≥5T space).

Byte 68: The first 4 bits (bits b_7 to b_4) of this byte shall specify the start-time offset of the first pulse, of the multi-pulse train, for recording marks of run-lengths [4T, 6T, 8T] with a preceding 3T space. In case these bits (bits b_7 to b_4) apply, the anchor position is specified in byte 46 (dT_{top} for a [4T, 6T, 8T] mark with a preceding ≥5T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the start-time offset of the first pulse, of the multi-pulse train, for recording marks of run-length [5T, 7T, 9T] with a preceding 3T space. In case these bits (bits b_3 to b_0) apply, the anchor position is specified in byte 47 (dT_{top} for a [5T, 7T, 9T] mark with a preceding ≥5T space).

Byte 69: The first 4 bits (bits b_7 to b_4) of this byte shall specify the start-time offset of the pulse for recording marks of run-length 2T with a preceding 4T space and a succeeding 2T space. In case these bits (bits b_7 to b_4) apply, the anchor position is specified in byte 43 (dT_{top} for a 2T mark with a preceding ≥5T space and a succeeding 2T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the start-time offset of the pulse for recording marks of run-length 2T with a preceding 4T space and a succeeding ≥3T space. In case these bits (bits b_3 to b_0) apply, the anchor position is specified in byte 44 (dT_{top} for a 2T mark with a preceding ≥5T space and a succeeding ≥3T space).

Byte 70: The first 4 bits (bits b_7 to b_4) of this byte shall specify the start-time offset of the first pulse, of the multi-pulse train, for recording marks of run-length 3T with a preceding 4T space. In case these bits (bits b_7 to b_4) apply, the anchor position is specified in byte 45 (dT_{top} for a 3T mark with a preceding ≥5T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the start-time offset of the first pulse, of the multi-pulse train, for recording marks of run-lengths [4T, 6T, 8T] with a preceding 4T space. In case of these bits (bits b_3 to b_0), the anchor position is specified in byte 46 (dT_{top} for a [4T, 6T, 8T] mark with a preceding ≥5T space).

Byte 71 (msb 4 bits):

The first 4 bits (bits b_7 to b_4) of this byte shall specify the start time offset of the first pulse, of the multi-pulse train, for recording marks of run-lengths [5T, 7T, 9T] with a preceding 4T space. In case these bits (bits b_7 to b_4) apply, the anchor position is specified in byte 47 (dT_{top} for a [5T, 7T, 9T] mark with a preceding ≥5T space).

Bytes 71 (lsb 4 bits) and 72 to 78: ΔT_{top} first write-pulse duration offset

These bytes specify the duration offset of the first pulse, of the multi-pulse train, in the extended N/2 write strategy, for recording marks with run-lengths 2T, 3T, [4T, 6T, 8T], and [5T, 7T, 9T] with a preceding 2T, 3T, or 4T space (see Annex F).

These bytes shall specify a fraction of the actual channel-bit clock period, as a signed two's-complement binary number *g*, such that:

$$g = 32 \times \frac{\Delta T_{top}}{T_W} \quad (-8 \le g \le 7).$$

Table 7 — Dependence of the T_{top} value for each mark

<table>
<tr><th>Mark</th><th colspan="2">2M</th><th rowspan="3">3M</th><th rowspan="3">4,6,8M</th><th rowspan="3">5,7,9M</th></tr>
<tr><th>Succeeding space</th><td rowspan="2">2S</td><td rowspan="2">≥3S</td></tr>
<tr><th>Preceding space</th></tr>
<tr><td>2S</td><td colspan="5" rowspan="3">g</td></tr>
<tr><td>3S</td></tr>
<tr><td>4S</td></tr>
<tr><td>≥5S</td><td colspan="5">b</td></tr>
</table>

Table 7 shows the dependence of the T_{top} value for each mark that is going to be written, on the preceding and succeeding spaces. The area denoted by "*b*" accommodates the anchor values and the area denoted by "*g*" includes the offset values as follows:

g The area with this pattern includes the offset values, which are represented by "*g*".

b The area with this pattern includes the anchor values, which are represented by "*b*". The value "$j = g + b$" shall satisfy $0 \le j \le 92$.

See F.3.

Byte 71 (lsb 4 bits):

The last 4 bits (bits b_3 to b_0) of this byte shall specify the duration offset of the pulse for recording marks of run-length 2T with a preceding 2T space and a succeeding 2T space (see Annex F). In case these bits (bits b_3 to b_0) apply, the anchor duration time is specified in byte 48 (T_{top} for a 2T mark with a preceding ≥5T space and a succeeding 2T space).

Byte 72:

The first 4 bits (bits b_7 to b_4) of this byte shall specify the duration offset of the pulse for recording marks of run-length 2T with a preceding 2T space and a succeeding ≥3T space (see Annex F). In case these bits (bits b_7 to b_4) apply, the anchor duration time is specified in byte 49 (T_{top} for a 2T mark with a preceding ≥5T space and a succeeding ≥3T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the duration offset of the first pulse, of the multi-pulse train, for recording marks of run-length 3T with a preceding 2T space (see Annex F). In case these bits (bits b_3 to b_0) apply, the anchor duration time is specified in byte 50 (T_{top} for a 3T mark with a preceding ≥5T space).

Byte 73:

The first 4 bits (bits b_7 to b_4) of this byte shall specify the duration offset of the first pulse, of the multi-pulse train, for recording marks of run-lengths [4T, 6T, 8T] with a preceding 2T space (see Annex F). In case these bits (bits b_7 to b_4) apply, the anchor duration time is specified in byte 51 (T_{top} for a [4T, 6T, 8T] mark with a preceding ≥5T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the duration offset of the first pulse, of the multi-pulse train, for recording of marks of run-lengths [5T, 7T, 9T] with a preceding 2T space (see Annex F). In case these bits (bits b_3 to b_0) apply, the anchor duration time is specified in byte 52 (T_{top} for [5T, 7T, 9T] mark with a preceding ≥5T space).

Byte 74:

The first 4 bits (bits b_7 to b_4) of this byte shall specify the duration offset of the pulse for recording marks of run-length 2T with a preceding 3T space and a succeeding 2T space (see Annex F). In case these bits (bits b_7 to b_4) apply, the anchor duration time is specified in byte 48 (T_{top} for a 2T mark with a preceding ≥5T space and a succeeding 2T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the duration offset of the pulse for recording marks of run-length 2T with a preceding 3T space and a succeeding ≥3T space (see Annex F). In case these bits (bits b_3 to b_0) apply, the anchor duration time is specified in byte 49 (T_{top} for a 2T mark with a preceding ≥5T space and a succeeding ≥3T space).

Byte 75:

The first 4 bits (bits b_7 to b_4) of this byte shall specify the duration offset of the first pulse, of the multi-pulse train, for recording marks of run-length 3T with a preceding 3T space (see Annex F). In case these bits (bits b_7 to b_4) apply, the anchor duration time is specified in byte 50 (T_{top} for a 3T mark with a preceding ≥5T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the duration offset of the first pulse of the multi-pulse train for recording marks of run-lengths [4T, 6T, 8T] with a preceding 3T space (see Annex F). In case these bits (bits b_3 to b_0) apply, the anchor duration time is specified in byte 51 (T_{top} for a [4T, 6T, 8T] mark with a preceding ≥5T space).

Byte 76: The first 4 bits (bits b_7 to b_4) of this byte shall specify the duration offset of the first pulse, of the multi-pulse train, for recording marks of run-lengths [5T, 7T, 9T] with a preceding 3T space (see Annex F). In case of these bits (bits b_7 to b_4), the anchor duration time is specified in byte 52 (T_{top} for [5T, 7T, 9T] mark with a preceding ≥5T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the duration offset of the pulse for recording marks of run-length 2T with a preceding 4T space and a succeeding 2T space (see Annex F). In case these bits (bits b_3 to b_0) apply, the anchor duration time is specified in byte 48 (T_{top} for a 2T mark with a preceding ≥5T space and a succeeding 2T space).

Byte 77: The first 4 bits (bits b_7 to b_4) of this byte shall specify the duration offset of the pulse for recording marks of run-length 2T with a preceding 4T space and a succeeding ≥3T space (see Annex F). In case these bits (bits b_7 to b_4) apply, the anchor duration time is specified in byte 49 (T_{top} for a 2T mark with a preceding ≥5T space and a succeeding ≥3T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the duration offset of the first pulse, of the multi-pulse train, for recording marks of run-length 3T with a preceding 4T space (see Annex F). In case these bits (bits b_3 to b_0) apply, the anchor duration time is specified in byte 50 (T_{top} for a 3T mark with a preceding ≥5T space).

Byte 78: The first 4 bits (bits b_7 to b_4) of this byte shall specify the duration offset of the first pulse, of the multi-pulse train, for recording marks of run-lengths [4T, 6T, 8T] with a preceding 4T space (see Annex F). In case these bits (bits b_7 to b_4) apply, the anchor duration time is specified in byte 51 (T_{top} for a [4T, 6T, 8T] mark with a preceding ≥5T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the duration offset of the first pulse of the multi-pulse train for recording marks of run-lengths [5T, 7T, 9T] with a preceding 4T space (see Annex F). In case these bits (bits b_3 to b_0) apply, the anchor duration time is specified in byte 52 (T_{top} for a [5T, 7T, 9T] mark with a preceding ≥5T space).

Bytes 79 to 81: ΔdT_{LP} last pulse start time offset

These bytes specify the start-time offset of the last pulse of the multi-pulse train, in the N/2 write strategy, for recording marks with run-lengths [4T, 6T, 8T] and [5T, 7T, 9T] with a succeeding 2T, 3T, or 4T space (see Annex F).

The last pulse start time offset ΔdT_{LP} is expressed as a fraction of the actual channel-bit clock period, as a signed two's-complement binary number h, such that:

$$h = 32 \times \frac{\Delta dT_{LP}}{T_W} \quad (-8 \le h \le 7).$$

Table 8 — Dependence of the dT_{LP} value for each mark

Mark / Succeeding space	4,6,8M	5,7,9M
2S	*h*	
3S		
4S		
≥5S	*c*	

Table 8 shows the dependence of the dT_{LP} value for each mark that is going to be written, on the preceding and succeeding spaces. The area denoted by "*c*" accommodates the anchor values and the area denoted by "*h*" includes the offset values as follows.

h	The area with this pattern includes the offset values, which are represented by "*h*".
c	The area with this pattern includes the anchor values, which are represented by "*c*". The value "$r = h + c$" shall satisfy $-30 \le r \le 30$.

See F.3.

Byte 79: The first 4 bits (bits b_7 to b_4) of this byte specify the start-time offset of the last pulse, of the multi-pulse train, for recording marks of run-lengths [4T, 6T, 8T] with a succeeding 2T space. In case these bits (bits b_7 to b_4) apply, the anchor position is specified in byte 53 (dT_{LP} for a [4T, 6T, 8T] mark with a succeeding ≥5T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the start-time offset of the last pulse, of the multi-pulse train, for recording marks of run-lengths [5T, 7T, 9T] with a succeeding 2T space. In case these bits (bits b_3 to b_0) apply, the anchor position is specified in byte 54 (dT_{LP} for a [5T, 7T, 9T] mark with a succeeding ≥5T space).

Byte 80: The first 4 bits (bits b_7 to b_4) of this byte shall specify the start-time offset of the last pulse, of the multi-pulse train, for recording marks of run-lengths [4T, 6T, 8T] with a succeeding 3T space. In case these bits (bits b_7 to b_4) apply, the anchor position is specified in byte 53 (dT_{LP} for a [4T, 6T, 8T] mark with a succeeding ≥5T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the start-time offset of the last pulse, of the multi-pulse train, for recording marks of run-lengths [5T, 7T, 9T] with a succeeding 3T space. In case these bits (bits b_3 to b_0) apply, the anchor position is specified in byte 54 (dT_{LP} for a [5T, 7T, 9T] mark with a succeeding ≥5T space).

Byte 81: The first 4 bits (bits b_7 to b_4) of this byte shall specify the start-time offset of the last pulse of the multi-pulse train for recording marks of run-lengths [4T, 6T, 8T] with a succeeding 4T space. In case these bits (bits b_7 to b_4) apply, the anchor position is specified in byte 53 (dT_{LP} for a [4T, 6T, 8T] mark with a succeeding ≥5T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the start-time offset of the last pulse, of the multi-pulse train, for recording marks of run-lengths [5T, 7T, 9T] with a succeeding 4T space. In case these bits (bits b_3 to b_0) apply, the anchor position is specified in byte 54 (dT_{LP} for a [5T, 7T, 9T] mark with a succeeding ≥5T space).

Bytes 82 to 84: ΔT_{LP} last-pulse duration offset

These bytes specify the duration offset for the last pulse length of the multi-pulse train, in the extended N/2 write strategy, for recording marks with run-lengths [4T, 6T, 8T] and [5T, 7T, 9T] with a succeeding 2T, 3T, or 4T space (see Annex F).

These bytes shall specify a fraction of the actual channel-bit clock period, as a signed two's-complement binary number v, such that:

$$v = 32 \times \frac{\Delta T_{LP}}{T_W} \quad (-8 \le v \le 7).$$

Table 9 — Dependence of the T_{LP} value for each mark

<table>
<tr><th>Mark</th><th rowspan="2">4,6,8M</th><th rowspan="2">5,7,9M</th></tr>
<tr><th>Succeeding space</th></tr>
<tr><td>2S</td><td colspan="2" rowspan="3">v</td></tr>
<tr><td>3S</td></tr>
<tr><td>4S</td></tr>
<tr><td>≥5S</td><td colspan="2">d</td></tr>
</table>

This table shows the dependence of the T_{LP} value for each mark that is going to be written, on the preceding and succeeding spaces. The area denoted by "d" accommodates the anchor values and the area denoted by "v" includes the offset values as follows:

- v The area with this pattern includes the offset values, which are represented by "v".
- d The area with this pattern includes the anchor values, which are represented by "d". The value "$s = v + d$" shall satisfy $0 \leq s \leq 62$.

See F.3.

Byte 82: The first 4 bits (bits b_7 to b_4) of this byte shall specify the duration offset of the last pulse, of the multi-pulse train, for recording marks of run-lengths [4T,6T,8T] with a succeeding 2T space (see Annex F). In case these bits (bits b_7 to b_4) apply, the anchor duration time is specified in byte 55 (T_{LP} for a [4T, 6T, 8T] mark with a succeeding ≥5T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the duration offset of the last pulse, of the multi-pulse train, for recording marks of run-lengths [5T, 7T, 9T] with a succeeding 2T space (see Annex F). In case these bits (bits b_3 to b_0) apply, the anchor duration time is specified in byte 56 (T_{LP} for a [5T, 7T, 9T] mark with a succeeding ≥5T space).

Byte 83: The first 4 bits (bits b_7 to b_4) of this byte shall specify the duration offset of the last pulse of the multi-pulse train for recording marks of run-lengths [4T, 6T, 8T] with a succeeding 3T space (see Annex F). In case these bits (bits b_7 to b_4) apply, the anchor duration time is specified in byte 55 (T_{LP} for a [4T, 6T, 8T] mark with a succeeding ≥5T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the duration offset of the last pulse of the multi-pulse train for recording marks of run-lengths [5T, 7T, 9T] with a succeeding 3T space (see Annex F). In case these bits (bits b_3 to b_0) apply, the anchor duration time is specified in byte 56 (T_{LP} for a [5T, 7T, 9T] mark with a succeeding ≥5T space).

Byte 84: The first 4 bits (bits b_7 to b_4) of this byte shall specify the duration offset of the last pulse, of the multi-pulse train, for recording marks of run-lengths [4T, 6T, 8T] with a succeeding 4T space (see Annex F). In case these bits (bits b_7 to b_4) apply, the anchor duration time is specified in byte 55 (T_{LP} for a [4T, 6T, 8T] mark with a succeeding ≥5T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the duration offset of the last pulse, of the multi-pulse train, for recording marks of run-lengths [5T, 7T, 9T] with a succeeding 4T space (see Annex F). In case these bits (bits b_3 to b_0) apply, the anchor duration time is specified in byte 56 (T_{LP} for a [5T, 7T, 9T] mark with a succeeding ≥5T space).

Bytes 85 to 92 and 93 (msb, 4 bits): ΔdT_E start time offset of the erase level

These bytes specify the start-time offset of the erase level, in the extended N/2 write strategy for recording marks with run-lengths 2T, 3T, 4T, and ≥5T with a succeeding 2T, 3T, or 4T space (positive values are leading, negative values are lagging; see Annex F).

The start time offset of the erase level ΔdT_E is expressed as a fraction of the actual channel-bit clock period, as a signed two's-complement binary number w, such that:

$$w = 32 \times \frac{\Delta dT_E}{T_w} \quad (-24 \le w \le 15) \text{ forByte 85 and 86;}$$

$$w = 32 \times \frac{\Delta dT_E}{T_w} \quad (-8 \le w \le 7) \text{ forByte 87 to 92 and 93 (msb 4 bits).}$$

Table 10 — Dependence of the dT_E value for each mark

Mark	2M		3M	4,6,8M	5,7,9M
Preceding space	2S	≥3S			
Succeeding space					
2S	*w*				
3S					
4S					
≥5S	*e*				

Table 10 shows the dependence of the dT_E value for each mark that is going to be written on the preceding and succeeding spaces. The area denoted by "*e*" accommodates the anchor values and the area denoted by "*w*" includes the offset values as follows:

w The area with this pattern includes the offset values, which are represented by "*w*".

e The area with this pattern includes the anchor values, which are represented by "*e*". The value "$u = w + e$" shall satisfy $-62 \le u \le 30$.

See F.3.

Byte 85: The first 6 bits (bits b_7 to b_2) of this byte shall specify the start-time offset of the erase level for recording marks of run-length 2T with a succeeding 2T space and a preceding 2T space. In case this byte applies, the anchor position is specified in byte 57 (dT_E for a 2T mark with a preceding 2T space and a succeeding ≥5T space).

The last 2 bits (bits b_1 to b_0) of this byte shall be reserved.

Byte 86: The first 6 bits (bits b_7 to b_2) of this byte shall specify the start-time offset of the erase level for recording marks of run-length 2T with a succeeding 2T space and a preceding ≥3T space. In case this byte applies, the anchor position is specified in byte 58 (dT_E for a 2T mark with a preceding ≥3T space and a succeeding ≥5T space).

The last 2 bits (bits b_1 to b_0) of this byte shall be reserved.

Byte 87: The first 4 bits (bits b_7 to b_4) of this byte shall specify the start-time offset of the erase level of the multi-pulse train for recording of marks of run-length 3T with a succeeding 2T space. In case of these bits (bits b_7 to b_4), the anchor position is specified in byte 59 (dT_E for 3T mark with a succeeding ≥5T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the start-time offset of the erase level of the multi-pulse train for recording marks of run-lengths [4T, 6T, 8T] with a succeeding 2T space. In case these bits (bits b_3 to b_0) apply, the anchor position is specified in byte 60 (dT_E for a [4T, 6T, 8T] mark with a succeeding ≥5T space).

Byte 88: The first 4 bits (bits b_7 to b_4) of this byte shall specify the start-time offset of the erase level of the multi-pulse train for recording marks of run-length [5T, 7T, 9T] with a succeeding 2T space. In case these bits (bits b_7 to b_4) apply, the anchor position is specified in byte 61 (dT_E for a [5T, 7T, 9T] mark with a succeeding ≥5T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the start-time offset of the erase level for recording marks of run-length 2T with a succeeding 3T space and a preceding 2T space. In case these bits (bits b_3 to b_0) apply, the anchor position is specified in byte 57 (dT_E for a 2T mark with a preceding 2T space and a succeeding ≥5T space).

Byte 89: The first 4 bits (bits b_7 to b_4) of this byte shall specify the start-time offset of the erase level for recording marks of run-length 2T with a succeeding 3T space and a preceding ≥3T space. In case these bits (bits b_7 to b_4) apply, the anchor position is specified in byte 58 (dT_E for a 2T mark with a succeeding ≥5T space and a preceding ≥3T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the start-time offset of the erase level, of the multi-pulse train, for recording marks of run-length 3T with a succeeding 3T space. In case these bits (bits b_3 to b_0) apply, the anchor position is specified in byte 59 (dT_E for a 3T mark with a succeeding ≥5T space).

Byte 90: The first 4 bits (bits b_7 to b_4) of this byte shall specify the start-time offset of the erase level, of the multi-pulse train, for recording marks of run-lengths [4T, 6T, 8T] with a succeeding 3T space. In case these bits (bits b_7 to b_4) apply, the anchor position is specified in byte 60 (dT_E for a [4T, 6T, 8T] mark with a succeeding ≥5T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the start-time offset of the erase level, of the multi-pulse train, for recording marks of run-lengths [5T, 7T, 9T] with a succeeding 3T space. In case of these bits (bits b_3 to b_0) the anchor position is specified in byte 61 (dT_E for a [5T, 7T, 9T] mark with a succeeding ≥5T space).

Byte 91: The first 4 bits (bits b_7 to b_4) of this byte shall specify the start-time offset of the erase level for recording marks of run-length 2T with a succeeding 4T space and a preceding 2T space. In case these bits (bits b_7 to b_4) apply, the anchor position is specified in byte 57 (dT_E for a 2T mark with a succeeding ≥5T space and a preceding 2T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the start-time offset of the erase level for recording of marks of run-length 2T with a succeeding 4T and a preceding ≥3T space. In case these bits (bits b_3 to b_0) apply, the anchor position is specified in byte 58 (dT_E for a 2T mark with a preceding ≥3T space and a succeeding ≥5T space).

Byte 92: The first 4 bits (bits b_7 to b_4) of this byte shall specify the start-time offset of the erase level of the multi-pulse train for recording marks of run-length 3T with a succeeding 4T space. In case these bits (bits b_7 to b_4) apply, the anchor position is specified in byte 59 (dT_E for a 3T mark with a succeeding ≥5T space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the start-time offset of the erase level of the multi-pulse train for recording marks of run-lengths [4T, 6T, 8T] with a succeeding 4T space. In case these bits (bits b_3 to b_0) apply, the anchor position is specified in byte 60 (dT_E for a [4T, 6T, 8T] mark with a succeeding ≥5T space).

Byte 93 (msb, 4 bits):

The first 4 bits (bits b_7 to b_4) of this byte shall specify the start-time offset of the erase level of the multi-pulse train for recording marks of run-lengths [5T, 7T, 9T] with a succeeding 4T space. In case these bits (bits b_7 to b_4) apply, the anchor position is specified in byte 61 (dT_E for a [5T, 7T, 9T] mark with a succeeding ≥5T space).

Byte 93 (lsb, 4 bits): Reserved
These bits shall be set to 0000.

Bytes 94 to 99: Reserved
These bytes shall be set to 00h.

Bytes 100 to 111: DI unit footer
See 15.8.3.2.

15.8.3.5 Definitions for DI format 6 (Extended N-1 write strategy and higher reading velocity)

DI format 6 shall be used only with DI format 4. The content of the body of DI units according to DI format 6 shall be as depicted in Figure 81.

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	Push-pull polarity flag bits	1
15	Recorded mark polarity flag bits	1
16	BCA descriptor	1
17	Read transfer rate corresponding to higher reading velocity	1
18	Reserved	1
19 to 26	Data-zone allocation	8
27	Reserved	1
28 to 29	Recording velocities	2
30	Maximum dc read power at the read transfer rate corresponding to higher reading velocity	1
31	Maximum HF-modulated read power at the read transfer rate corresponding to higher reading velocity	1
32	Reserved	1
33 to 41	Write-power settings	9
42	T_{MP} write multi-pulse duration	1
43 to 47	dT_{top} first write-pulse start time	5
48 to 52	T_{top} first write-pulse duration	5
53 to 55	dT_{LP} last write-pulse start time	3
56 to 58	T_{LP} last-pulse duration	3
59 to 63	dT_{E} start time of the erase level	5
64	Reserved	1
65 to 72 and 73 (msb 4bits)	ΔdT_{top} first write-pulse start time offset	8,5
73 (lsb 4bits) and 74 to 80	ΔT_{top} first write-pulse duration offset	7,5
81 to 84 and 85 (msb 4bits)	ΔdT_{LP} last-pulse start time offset	4,5
85 (lsb 4bits) and 86 to 89	ΔT_{LP} last-pulse duration offset	4,5
90 to 97 and 98 (msb 4bits)	ΔdT_{E} start time offset of the erase level	8,5
98 (lsb 4bits)	Reserved	0,5
99	Reserved	1
100 to 111	DI unit footer	12

Figure 81 — Content of disk information for DI format 6

Bytes 0 to 1, 3 to 16, 18 to 29, 32 to 111: Each of these bytes shall be set to the same value as that of DI format 4 of this document.

Byte 2: **DI format number**

This byte shall be set to 06h, identifying a DI unit according to the description in this 15.8.3.5.

Byte 17: **Read transfer rate corresponding to higher reading velocity**

This byte specifies the data transfer rate to define higher velocity for reading than the nominal recording velocity, as a number n such that

n = data transfer rate in M bit/s ($n \le 255$: M = 10^6);

In this document, n shall be set to 90h and referred as 4x reference velocity in read stability (see 30.7).

Byte 30: **Maximum dc read power at the read transfer rate corresponding to higher reading velocity**

The maximum read power is defined as the maximum optical power to which this DI unit applies on the entrance surface of the disk, at which at least 10^6 successive reads can be applied without degrading the recorded signals (see 30.7). Maximum read powers in this clause shall be greater than or equal to the read powers defined in 30.7. By default, the powers defined in 30.7 shall be used. This byte shall specify the maximum dc read power P_r at the read transfer rate corresponding to higher reading velocity. The decimal expression of this byte is:

$n = 100 \times P_r$, where P_r is expressed in milliwatts.

NOTE For reading at lower velocities than the reading velocity specified in this DI unit, a reduction of the read power can be necessary to guarantee stability of the recordings on the disk. Read power at intermediate velocity can be obtained with linear interpolation.

Byte 31: **Maximum HF modulated read powers at the read transfer rate corresponding to higher reading velocity**

The maximum read power is defined as the maximum optical power to which this DI unit applies on the entrance surface of the disk, at which at least 10^6 successive reads can be applied without degrading the recorded signals (see 30.7). Maximum read powers in this clause shall be greater than or equal to the read powers defined in 30.7. By default, the powers defined in 30.7 shall be used. This byte shall specify the maximum HF modulated read power P_r at the read transfer rate corresponding to higher reading velocity.

The decimal expression of this byte is:

$n = 100 \times P_r$, where P_r is expressed in milliwatts.

NOTE For reading at lower velocities than the reading velocity specified in this DI unit, a reduction of the read power can be necessary to guarantee stability of the recordings on the disk. Read power at intermediate velocity can be obtained with linear interpolation.

15.8.3.6 Definitions for DI format 7 (Extended N/2 write strategy and higher reading velocity)

DI format 7 shall be used only with DI format 5. The contents of the body of DI units according to DI format 7 shall be as depicted in Figure 82.

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	Push-Pull polarity flag bits	1
15	Recorded mark polarity flag bits	1
16	BCA descriptor	1
17	Read transfer rate corresponding to higher Reading Velocity	1
18	Reserved	1
19 to 26	Data-Zone allocation	8
27	Reserved	1
28 to 29	Recording Velocity	2
30	Maximum dc read power at the read transfer rate corresponding to higher Reading Velocity	1
31	Maximum HF-modulated read power at the read transfer rate corresponding to higher Reading Velocity	1
32	Reserved	1
33 to 41	Write-power settings	9
42	T_{MP} write multi-pulse duration	1
43 to 47	dT_{top} first write-pulse start time	5
48 to 52	T_{top} first write-pulse duration	5
53 to 54	dT_{LP} last write-pulse start time	2
55 to 56	T_{LP} last-pulse duration	2
57 to 61	dT_E start time of erase level	5
62	Reserved	1
63 to 70 and 71 (msb 4 bits)	ΔdT_{top} first write-pulse start time offset	8,5
71 (lsb 4 bits) and 72 to 78	ΔT_{top} first write-pulse duration offset	7,5
79 to 81	ΔdT_{LP} last-pulse start time offset	3
82 to 84	ΔT_{LP} last-pulse duration offset	3
85 to 92 and 93 (msb 4 bits)	ΔdT_E start time offset of the erase level	8,5
93 (lsb 4 bits)	Reserved	0,5
94 to 99	Reserved	6
100 to 111	DI Unit footer	12

Figure 82 — Content of disk information for DI format 7

Bytes 0 to 1, 3 to 16, 18 to 29, 32 to 111: Each of these bytes shall be set to the same value as that of DI format 5 of this document.

Byte 2: **DI format number**

This byte shall be set to 07h, identifying a DI unit according to the description in this 15.8.3.6.

Byte 17: **Read transfer rate corresponding to higher reading velocity**

This byte specifies the data transfer rate to define higher velocity for reading than the nominal recording velocity, as a number n such that:

n = data transfer rate in M bit/s ($n \leq 255$: M = 10^6).

In this document, n shall be set to 90h and referred as 4x reference velocity in read stability (see 30.7).

Byte 30: **Maximum dc read power at the read transfer rate corresponding to higher reading velocity**

The maximum read power is defined as the maximum optical power to which this DI unit applies on the entrance surface of the disk, at which at least 10^6 successive reads can be applied without degrading the recorded signals (see 30.7). Maximum read powers in this clause shall be greater than or equal to the read powers defined in 30.7. By default, the powers defined in 30.7 shall be used. This byte shall specify the maximum dc read power P_r at the read transfer rate corresponding to higher reading velocity. The decimal expression of this byte is:

$n = 100 \times P_r$, where P_r is expressed in milliwatts.

NOTE For reading at lower velocities than the reading velocity specified in this DI unit, a reduction of the read power can be necessary to guarantee stability of the recordings on the disk. Read power at intermediate velocity can be obtained with linear interpolation.

Byte 31: **Maximum HF modulated read powers at the read transfer rate corresponding to higher reading velocity**

The maximum read power is defined as the maximum optical power to which this DI unit applies on the entrance surface of the disk, at which at least 10^6 successive reads can be applied without degrading the recorded signals (see 30.7). Maximum read powers in this clause shall be greater than or equal to the read powers defined in 30.7. By default, the powers defined in 30.7 shall be used. This byte shall specify the maximum HF modulated read power P_r at the read transfer rate corresponding to higher reading velocity.

The decimal expression of this byte is:

$n = 100 \times P_r$, where P_r is expressed in milliwatts.

NOTE For reading at lower velocities than the reading velocity specified in this DI unit, a reduction of the read power can be necessary to guarantee stability of the recordings on the disk. Read power at intermediate velocity can be obtained with linear interpolation.

15.8.3.7 Write-strategy requirements

Disks according to this document shall contain at least one DI unit of DI format 4 or DI format 5 for each recording layer as depicted in Figure 83. Additional DI units, containing alternative write strategy parameter sets, may be added in order of preference. See Figure 77.

	DI Unit according to 15.8.3.3 (DI Format 4, Extended N-1 write strategy)	DI Unit according to 15.8.3.4 (DI Format 5, Extended N/2 write strategy)
for 2x Recording Velocity	Optional[a]	Optional[a]
[a] At least one of these two shall be present.		

Figure 83 — Write-strategy type (DI format 4 and 5) requirements

Furthermore, DI units of DI format 6 and DI format 7 containing read power parameters for higher reading velocity, may be added (see Figure 84) in order of preference. See Figure 77.

	DI Unit according to 15.8.3.5 (DI Format 6, Extended N-1 write strategy and higher Reading Velocity)	DI Unit according to 15.8.3.6 (DI Format 7, Extended N/2 write strategy and higher Reading Velocity)
for 4x Reading Velocity	Optional[a]	Optional[b]
[a] Applicable only when DI format 4 is present [b] Applicable only when DI format 5 is present		

Figure 84 — Write-strategy type (DI format 6 and 7) requirements

15.8.3.8 Usage of DI units

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 for different recording velocities and with three 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 a different set of values for the write strategy parameters.

Byte 3 shall be set according to the specifications in 15.8.3.2.

Byte 5 shall be used according to the description in 15.8.3.2.

In this document, bytes 28 and 29 in all DI units are set to 02 E2h to indicate a nominal recording velocity of 7,38 m/s (33,4 GB per layer) for defining various parameters for 2x recording velocity, and byte 17 in DI units of DI format 6 and DI format 7 is set to 90 h to indicate a data transfer rate of 143,860 Mbit/s for defining the read power parameters for 4x reading velocity.

An example of those assignments is shown in Figure 85.

2x disk (TL) with 2x EX N-1& N/2 write strategy

byte 2: DI-Format Number	4
byte 3: # of DI's/L#	6/0
byte 4: ---	00h
byte 5: sequence #	0
msb of byte 6:	0
byte 28 to 29: Velocity	2x
byte 42 to 98:WS	EX_N-1

byte 2: DI-Format Number	5
byte 3: # of DI's/L#	6/0
byte 4: ---	00h
byte 5: sequence #	1
msb of byte 6:	0
byte 28 to 29: Velocity	2x
byte 42 to 93:WS	EX_N/2

byte 2: DI-Format Number	4
byte 3: # of DI's/L#	6/1
byte 4: ---	00h
byte 5: sequence #	2
msb of byte 6:	0
byte 28 to 29: Velocity	2x
byte 42 to 98:WS	EX_N-1

byte 2: DI-Format Number	5
byte 3: # of DI's/L#	6/1
byte 4: ---	00h
byte 5: sequence #	3
msb of byte 6:	0
byte 28 to 29: Velocity	2x
byte 42 to 93:WS	EX_N/2

byte 2: DI-Format Number	4
byte 3: # of DI's/L#	6/2
byte 4: ---	00h
byte 5: sequence #	4
msb of byte 6:	0
byte 28 to 29: Velocity	2x
byte 42 to 98:WS	EX_N-1

byte 2: DI-Format Number	5
byte 3: # of DI's/L#	6/2
byte 4: ---	00h
byte 5: sequence #	5
msb of byte 6:	0
byte 28 to 29: Velocity	2x
byte 42 to 93:WS	EX_N/2

Repeat

Figure 85 — Example of DI sequence for 2x disk (TL) with 6 DI units of DI format 4 and 5

byte 2: DI-Format Number	4
byte 3: # of DI's/L#	12/0
byte 4: ---	00h
byte 5: sequence #	0
msb of byte 6:	0
byte 28 to 29: Velocity	2x
byte 42 to 98:WS	EX_N-1

byte 2: DI-Format Number	5
byte 3: # of DI's/L#	12/0
byte 4: ---	00h
byte 5: sequence #	1
msb of byte 6:	0
byte 28 to 29: Velocity	2x
byte 42 to 93:WS	EX_N/2

byte 2: DI-Format Number	4
byte 3: # of DI's/L#	12/1
byte 4: ---	00h
byte 5: sequence #	2
msb of byte 6:	0
byte 28 to 29: Velocity	2x
byte 42 to 98:WS	EX_N-1

byte 2: DI-Format Number	5
byte 3: # of DI's/L#	12/1
byte 4: ---	00h
byte 5: sequence #	3
msb of byte 6:	0
byte 28 to 29: Velocity	2x
byte 42 to 93:WS	EX_N/2

byte 2: DI-Format Number	4
byte 3: # of DI's/L#	12/2
byte 4: ---	00h
byte 5: sequence #	4
msb of byte 6:	0
byte 28 to 29: Velocity	2x
byte 42 to 98:WS	EX_N-1

Figure 86 — Example of DI sequence for 2x disk (TL) with 12 DI units of DI format 4,5,6 and 7 (1 of 3)

byte 2: DI-Format Number	5
byte 3: # of DI's/L#	12/2
byte 4: ---	00h
byte 5: sequence #	5
msb of byte 6:	0
byte 28 to 29: Velocity	2x
byte 42 to 93:WS	EX_N/2

byte 2: DI-Format Number	6
byte 3: # of DI's/L#	12/0
byte 4: ---	00h
byte 5: sequence #	6
msb of byte 6:	0
byte 17: Read transfer rate (Reading Velocity)	4x
byte 28 to 29: Recording Velocity	2x
byte 30 to 31: Maximum read power	Maximum read power @byte 17
byte 42 to 98:WS	EX_N-1

byte 2: DI-Format Number	7
byte 3: # of DI's/L#	12/0
byte 4: ---	00h
byte 5: sequence #	7
msb of byte 6:	0
byte 17: Read transfer rate (Reading Velocity)	4x
byte 28 to 29: Recording Velocity	2x
byte 30 to 31: Maximum read power	Maximum read power @byte 17
byte 42 to 93:WS	EX_N/2

byte 2: DI-Format Number	6
byte 3: # of DI's/L#	12/1
byte 4: ---	00h
byte 5: sequence #	8
msb of byte 6:	0
byte 17: Read transfer rate (Reading Velocity)	4x
byte 28 to 29: Recording Velocity	2x
byte 30 to 31: Maximum read power	Maximum read power @byte 17
byte 42 to 98:WS	EX_N-1

Figure 86 — Example of DI sequence for 2x disk (TL) with 12 DI units of DI format 4,5,6 and 7 (2 of 3)

byte 2: DI-Format Number	7
byte 3: # of DI's/L#	12/1
byte 4: ---	00h
byte 5: sequence #	9
msb of byte 6:	0
byte 17: Read transfer rate (Reading Velocity)	4x
byte 28 to 29: Recording Velocity	2x
byte 30 to 31: Maximum read power	Maximum read power @byte 17
byte 42 to 93:WS	EX_N/2

byte 2: DI-Format Number	6
byte 3: # of DI's/L#	12/2
byte 4: ---	00h
byte 5: sequence #	10
msb of byte 6:	0
byte 17: Read transfer rate (Reading Velocity)	4x
byte 28 to 29: Recording Velocity	2x
byte 30 to 31: Maximum read power	Maximum read power @byte 17
byte 42 to 98:WS	EX_N-1

byte 2: DI-Format Number	7
byte 3: # of DI's/L#	12/2
byte 4: ---	00h
byte 5: sequence #	11
msb of byte 6:	0
byte 17: Read transfer rate (Reading Velocity)	4x
byte 28 to 29: Velocity	2x
byte 30 to 31: Maximum read power	Maximum read power @byte 17
byte 42 to 93:WS	EX_N/2

Repeat

Figure 86 — Example of DI sequence for 2x disk (TL) with 12 DI units of DI format 4,5,6 and 7 (3 of 3)

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 13).

The inner part of inner zone 0 (protection-zone 1 + PIC) shall contain HFM grooves which can hold replicated information about the disk. The outer part of the inner zone 0, the other inner zones, data zones and outer zones constitute the rewritable areas in which the information is recorded on the wobbled grooves using the phase-change effect.

16.2 Format of information zone

The information zone is divided into nine parts: a Lead-in zone (part of inner zone 0), data zone 0 and outer zone 0 on layer L0, outer zone 1, data zone 1 and inner zone 1 on layer L1, and inner zone 2, data zone 2 and a lead-out zone on layer L2 (see Figure 87, Figure 88 and Figure 89).

Data zone 0, data zone 1 and data zone 2 are intended for recording user data. The lead-in zone contains replicated and rewritable control information and an area for disk and drive testing. The inner part of inner zone 0, inner zone 1, inner zone 2, outer zone 0, outer zone 1 and outer zone 2 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 part of the inner zones, the data zones and the outer zones. The start radii for the zones indicated in Figure 87, Figure 88 and Figure 89 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 number of physical clusters (RUBs) that can be recorded per zone are indicated.

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** (HFM Groove)		Protection-Zone 1	22,2	---	---
				PIC	22,510	(First AUN = 00 0C 04 80h : Last AUN = 00 0C 19 BEh)	2 720 (×4KB)
		Rewritable (Wobbled Groove)	**Lead-in Zone (part of Inner Zone 0)**	Protection - Zone 2	23,068	0 01 83 38h : 0 01 87 E6h	300
				Buffer	23,107	0 01 87 E8h : 0 01 B7 FEh	3 078
				INFO 2	23,468	0 01 B8 00h : 0 01 BB FEh	256
				OPC 0	23,498	0 01 BC 00h : 0 01 DB FEh	2 048
				Reserved	23,736	0 01 DC 00h : 0 01 FB FEh	2 048
				INFO 1	23,971	0 01 FC 00h : 0 01 FF FEh	256
			Data Zone 0		24,000	0 02 00 00h : : LAA	509 152
			Outer Zone 0	INFO 3/4	58,000	LAA + 2h : LAA + 4 98h	294
				DCZ 0	58,014	LAA + 4 9Ah : LAA + 10 78h	760
				Protection-Zone 3	58,050	LAA + 10 7Ah :	---
	ending radius 58,5 mm						
Rim Area	starting radius 58,5 mm						

Figure 87 — Layout of information zone on layer L0

Layer L1				Description	Nominal ending radius (mm)	Last PAA of Zone : First PAA of Zone	Number of Phys. Clusters
Information Area	ending radius 21,0 mm	"wide pitch" Groove					
	tracking direction ↑ Information Zone ↑	Wobbled Groove		Protection - Zone 1	22,2	: 0 7E C5 B8h	---
		Rewritable (Wobbled Groove)	**Inner Zone 1**	Buffer	22,510	0 7E C5 B6h : 0 7E 85 98h	4 104
				OPC 1	23,004	0 7E 85 96h : 0 7E 65 98h	2 048
				Reserved	23,246	0 7E 65 96h : 0 7E 48 00h	1 894
				INFO 2	23,468	0 7E 47 FEh : 0 7E 44 00h	256
				Reserved	23,498	0 7E 43 FEh : 0 7E 04 00h	4 096
				INFO 1	23,971	0 7E 03 FEh : 0 7E 00 00h	256
			Data Zone 1		24,000	0 7D FF FEh : : FAA[a]	509 152
			Outer Zone 1	INFO 3/4	58,000	FAA – 2h : FAA – 4 98h	294
				DCZ 1	58,014	FAA – 4 9Ah : FAA – 10 78h	760
				Protection - Zone 3	58,050	FAA – 10 7Ah :	---
	starting radius 58,5 mm						

[a] FAA = $\overline{\text{LAA + 1 80 00 01h}}$ (see 15.7.4.3).

Figure 88 — Layout of information zone on layer L1

Layer L2				Description	Nominal starting radius (mm)	First PAA of Zone : Last PAA of Zone	Number of Phys. Clusters
Information Area	starting radius 21,0 mm	“wide pitch” Groove					
	Information Zone, tracking direction ↓	Wobbled Groove		Protection - Zone 1	22,2	---	---
		Rewritable (Wobbled Groove)	**Inner Zone 2**	Buffer	22,510	0 81 3A 48h : 0 81 3D 66h	200
				OPC 2	22,535	0 81 3D 68h : 0 81 5D 66h	2 048
				Reserved	22,782	0 81 5D 68h : 0 81 76 66h	1 600
				INFO 2	22,973	0 81 76 68h : 0 81 7A 66h	256
				Reserved	23,004	0 81 7A 68h : 0 81 9A 66h	2 048
				Buffer	23,246	0 81 9A 68h : 0 81 FB FEh	6 246
				INFO 1	23,971	0 81 FC 00h : 0 81 FF FEh	256
			Data Zone 2		24,000	0 82 00 00h : : LAA2[a]	509 152
			Lead-out Zone (Outer Zone 2)	INFO 3/4	58,000	LAA2 + 2h : LAA2 + 4 98h	294
				DCZ 2	58,014	LAA2 + 4 9Ah : LAA2 + 10 78h	760
				Protection - Zone 3	58,050	LAA2 + 10 7Ah :	---
	ending radius 58,5 mm						
Rim Area		starting radius 58,5 mm					

[a] LAA2 = LAA + 0 80 00 0h (see 15.7.4.3).

Figure 89 — Layout of information zone on layer L2

Physical-sector numbering

Each cluster contains 32 physical sectors, and each physical sector contains 2K data bytes. Although these numbers are not included in the data recorded on the disk, each physical sector is associated with a (virtual) physical-sector number (PSN).

The PSN 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_{28} of the PSN shall be reserved.

Bits PS_{27} to PS_{25} 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

01 08 9B FFh.

The first PSN in the data zone 1 is 8 × FAA, which is

02 F7 64 00h.

The last PSN in the data zone 1 is 03 EF FF FFh.

The first PSN in the data zone 2 is 04 10 00 00h.

The last PSN in the data zone 2 is 8 × LAA2 + 15, which is

05 08 9B FFh.

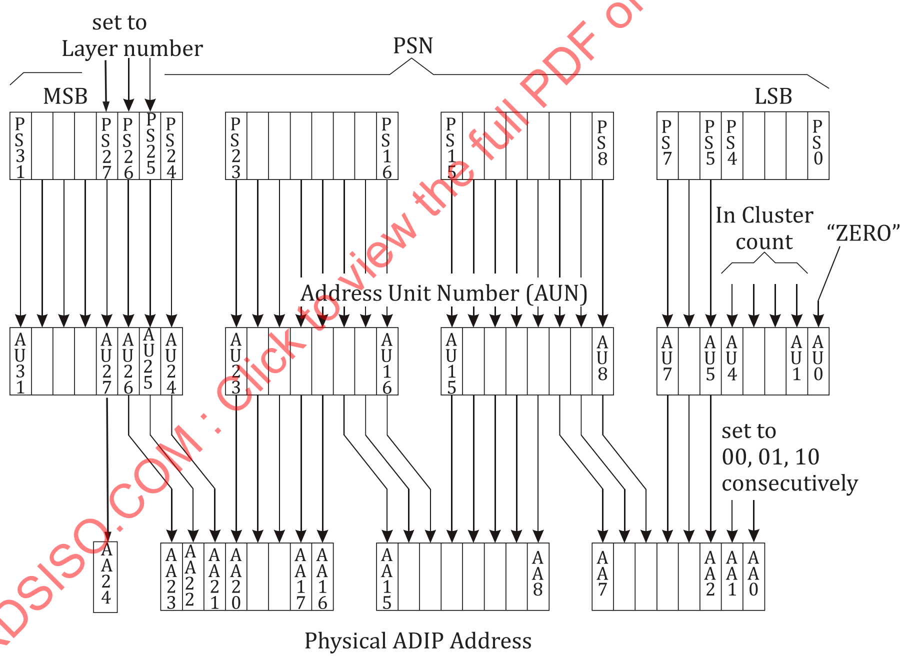


Figure 90 — Physical ADIP addresses derived from PSNs

These PSNs are converted to address-unit numbers, which shall be recorded in the BIS columns of the ECC clusters (see 13.9.2.3).

Finally, a physical ADIP address is derived from the PSN/AUN as defined in Figure 90. 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 (part of inner zone 0). On layer L1 and layer L2, they are called inner zone 1 and inner zone 2.

Inner zone 0 (in its lead-in zone part) contains an embossed HFM area and a rewritable area inner zone 1 and inner zone 2 (in its lead-out zone part) contain embossed wobbled parts and rewritable areas (see Figure 91, Figure 92 and Figure 93).

In the embossed HFM area on layer L0, all grooves shall be encoded according to the format as defined in 15.5 and with its other subclauses.

On layer L0, this encoding shall start at a radius $22,2^{0,0}_{-0,1}$ mm, such that the first AUN of the first cluster shall be 00 0B F8 E2h.

The addresses shall be continuously increasing as described in 15.5.3.2 and shall end with AUN = 00 0C 19 BEh in the last 4K cluster at the outermost radius of the PIC zone.

In protection-zone 1 of inner zone 0, the content of the data frames can be set to all 00h or they can be equal to the content in the PIC zone.

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, general information about the disk and various other information can be stored in the embossed HFM groove.

In the rewritable area and the wobbled grooved area (protection-zone 1 on layer L1 and layer L2), all grooves shall be wobbled as defined in 15.6.

The rewritable areas of each inner zone are 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.

Lead-in zone		Description	First PAA of zone	Number of Phys.clusters	Purpose
Embossed HFM		Protection-zone 1	---	---	---
		PIC	---	---	Permanent information & control data zone
↓ Rewritable ↓ tracking direction	---	Protection-zone 2	0 01 83 38h	300	---
	Buffer	---	0 01 87 E8h	3 078	---
	INFO 2	Reserved 8	0 01 B8 00h	32	future extension
		Reserved 7	0 01 B8 80h	32	future extension
		Reserved 6	0 01 B9 00h	32	future extension
		Reserved 5	0 01 B9 80h	32	future extension
		PAC 2	0 01 BA 00h	32	Physical-access control
		DMA 2	0 01 BA 80h	32	Disk management
		Control data 2	0 01 BB 00h	32	data information
		Buffer 2	0 01 BB 80h	32	---
	OPC 0	Test Zone	0 01 BC 00h	2 048	OPC testing
	Reserved	---	0 01 DC 00h	2 048	future extension
	INFO 1	Buffer 1	0 01 FC 00h	32	---
		Drive area	0 01 FC 80h	32	Drive-specific
		Reserved 3	0 01 FD 00h	32	future extension
		Reserved 2	0 01 FD 80h	32	future extension
		Reserved 1	0 01 FE 00h	32	future extension
		DMA 1	0 01 FE 80h	32	Disk management
		Control data 1	0 01 FF 00h	32	data information
		PAC 1	0 01 FF 80h	32	Physical-access control
		(Data zone 0)	0 02 00 00h		

Figure 91 — 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	0 7E 00 00h	32	Physical-access control
		Control data 1	0 7E 00 80h	32	data information
		DMA 1	0 7E 01 00h	32	Disk management
		Reserved 1	0 7E 01 80h	32	future extension
		Reserved 2	0 7E 02 00h	32	future extension
		Reserved 3	0 7E 02 80h	32	future extension
		Drive area	0 7E 03 00h	32	Drive-specific information
		Buffer 1	0 7E 03 80h	32	---
	Reserved	---	0 7E 04 00h	4 096	future extension
	INFO 2	Buffer 2	0 7E 44 00h	32	---
		Control data 2	0 7E 44 80h	32	data information
		DMA 2	0 7E 45 00h	32	Disk management
		PAC 2	0 7E 45 80h	32	Physical-access control
		Reserved 5	0 7E 46 00h	32	future extension
		Reserved 6	0 7E 46 80h	32	future extension
		Reserved 7	0 7E 47 00h	32	future extension
		Reserved 8	0 7E 47 80h	32	future extension
	Reserved	---	0 7E 48 00h	1 894	future extension
	OPC 1	Test zone	0 7E 65 98h	2 048	OPC testing
	Buffer	---	0 7E 85 98h	4 104	---
Wobbled grooves		Protection-zone 1	0 7E C5 B8h	---	---

Figure 92 — Inner zone 1

Inner zone 2		Description	First PAA of zone	Number of Phys. clusters	Purpose
Wobbled grooves		Protection-zone 1	---	---	---
	Buffer	---	0 81 3A 48h	200	---
	OPC 2	Test Zone	0 81 3D 68h	2 048	OPC testing
	Reserved	---	0 81 5D 68h	1 600	future extension
	INFO 2	Reserved 8	0 81 76 68h	32	future extension
		Reserved 7	0 81 76 E8h	32	future extension
		Reserved 6	0 81 77 68h	32	future extension
		Reserved 5	0 81 77 E8h	32	future extension
		Reserved	0 81 78 68h	32	future extension
		DMA 2	0 81 78 E8h	32	Disk management
		Control data 2	0 81 79 68h	32	data information
		Buffer 2	0 81 79 E8h	32	---
↓ Rewritable ↓ tracking direction	Reserved	---	0 81 7A 68h	2 048	future extension
	Buffer	---	0 81 9A 68h	6 246	---
	INFO 1	Buffer 1	0 81 FC 00h	32	---
		Drive area	0 81 FC 80h	32	Drive-specific information
		Reserved 3	0 81 FD 00h	32	future extension
		Reserved 2	0 81 FD 80h	32	future extension
		Reserved 1	0 81 FE 00h	32	future extension
		DMA 1	0 81 FE 80h	32	Disk management
		Control data 1	0 81 FF 00h	32	data information
		Reserved	0 81 FF 80h	32	future extension
		(Data zone 2)	0 82 00 00h		

Figure 93 — Inner zone 2

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.

18.2.2 Content of PIC zone

The PIC zone shall consist of 5 repetitions of a PIC-info fragment, where each PIC-info fragment consists of 544 PIC clusters (for a total of 2 720, see Figure 94). The PIC clusters shall be formatted as described in 15.5.

The PIC-info fragments shall start on layer L0 at AUNs: 00 0C 04 80h, 00 0C 08 C0h, 00 0C 0D 00h, 00 0C 11 40h and 00 0C 15 80h.

PIC-Info Fragment number	PIC-Cluster number	AUN on Layer L0
IF 0	0	00 0C 04 80h
	1	00 0C 04 82h
	2	00 0C 04 84h
	:	:
	543	00 0C 08 BEh
IF 1	0	00 0C 08 C0h
	:	:
	543	00 0C 0C FEh
IF 2	0	00 0C 0D 00h
	:	:
	543	00 0C 11 3Eh
IF 3	0	00 0C 11 40h
	:	:
	543	00 0C 15 7Eh
IF 4	0	00 0C 15 80h
	:	:
	543	00 0C 19 BEh

Figure 94 — 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 95). 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 95.

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 95 — First PIC cluster of each info fragment

All other PIC clusters shall be reserved, unless otherwise specified by the BDAP.

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.

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 96.

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
: :	: :	: :	: :
$(3\,584 + i \times 8)$ to $(3\,584 + i \times 8) + 1$	EB Data field i $(1 \le i \le N)$	Drive-Manufacturer ID	2
$(3\,584 + i \times 8) + 2$ to $(3\,584 + i \times 8) + 3$		Drive Model	2
$(3\,584 + i \times 8) + 4$ to $(3\,584 + i \times 8) + 5$		Firmware Version	2
$(3\,584 + i \times 8) + 6$ to $(3\,584 + i \times 8) + 7$		Drive Actions	2
: :	: :	: :	: :
$(3\,584 + N \times 8)$ to $(3\,584 + N \times 8) + 1$	EB Data Field N $(N \le 62)$	Drive-Manufacturer ID	2
$(3\,584 + N \times 8) + 2$ to $(3\,584 + N \times 8) + 3$		Drive Model	2
$(3\,584 + N \times 8) + 4$ to $(3\,584 + N \times 8) + 5$		Firmware Version	2
$(3\,584 + N \times 8) + 6$ to $(3\,584 + N \times 8) + 7$		Drive Actions	2
$[3\,584 + (N+1) \times 8]$ to $[3\,584 + (N+1) \times 8] + 7$	EB Footer	Terminator	8
$[3\,584 + (N+2) \times 8]$ to 4 095	---	Reserved	$512 - (N+2) \times 8$

Figure 96 — 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 300 physical clusters starts at PAA 0 01 83 38h on layer L0 and 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 Buffer

This zone has 3 078 physical clusters starting at PAA 0 01 87 E8h on layer L0, 4 104 physical cluster starting at PAA 0 7E 85 98h on layer L1, and 200 physical clusters starting at PAA 0 81 3A 48h plus 6 246 physical clusters starting at PAA 0 81 9A 68h on layer L2 and shall be left unrecorded.

18.3.3 INFO 2/Reserved 8

This zone of 32 physical clusters starting at PAA 0 01 B8 00h on layer L0, at PAA 0 7E 47 80h on layer L1 and at PAA 0 81 76 68h on layer L2 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.

18.3.4 INFO 2/Reserved 7

This zone has the size of 32 physical clusters starting at PAA 0 01 B8 80h on layer L0, at PAA 0 7E 47 00h on layer L1 and at PAA 0 81 76 E8h on layer L2 and shall be left unrecorded.

18.3.5 INFO 2/Reserved 6

This zone has the size of 32 physical clusters starting at PAA 0 01 B9 00h on layer L0, at PAA 0 7E 46 80h on layer L1 and at PAA 0 81 77 68h on layer L2 and 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.

18.3.6 INFO 2/Reserved 5

This zone has the size of 32 physical clusters starting at PAA 0 01 B9 80h on layer L0, at PAA 0 7E 46 00h on layer L1 and at PAA 0 81 77 E8h on layer L2 and 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.

18.3.7 INFO 2/PAC 2

This zone of 32 physical clusters starts at PAA 0 01 BA 00h on layer L0 and at PAA 0 7E 45 80h on layer L1 and 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.

18.3.8 INFO 2/Reserved

This zone has the size of 32 physical clusters starting at PAA 0 81 78 68h on layer L2 unrecorded.

18.3.9 INFO 2/DMA 2

This zone of 32 physical clusters starts at PAA 0 01 BA 80h on layer L0, at PAA 0 7E 45 00h on layer L1 and at PAA 0 81 78 E8h on layer L2 and is intended for use by the disk management system (see 22.2). Unused clusters in this zone shall contain all 00h or left unrecorded.

18.3.10 INFO 2/Control data 2

This zone of 32 physical clusters starts at PAA 0 01 BB 00h on layer L0, at PAA 0 7E 44 80h on layer L1 and at PAA 0 81 79 68h on layer L2 and is intended to store control information. Unused clusters in this zone shall contain all 00h.

18.3.11 INFO 2/Buffer 2

This zone with the size of 32 physical clusters starts at PAA 0 01 BB 80h on layer L0, at PAA 0 7E 44 00h on layer L1 and at PAA 0 81 79 E8h on layer L2 and shall be left unrecorded.

18.3.12 OPC/Test zone

The test zone of 2 048 physical clusters starts at PAA 0 01 BC 00h on layer L0, at PAA 0 7E 65 98h on layer L1 and at PAA 0 81 3D 68h on layer L2 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.

18.3.13 Reserved

This zone has 2 048 physical clusters starting at PAA 0 01 DC 00h on layer L0, 4 096 physical clusters starting at PAA 0 7E 04 00h plus 1 894 physical clusters starting at PAA 0 7E 48 00h on layer L1 and 1 600 physical clusters starting at PAA 0 81 5D 68h plus 2 048 physical clusters starting at PAA 0 81 7A 68h on layer L2 shall be left unrecorded.

18.3.14 INFO 1/Buffer 1

This zone of 32 physical clusters, which starts at PAA 0 01 FC 00h on layer L0, at PAA 0 7E 03 80h on layer L1 and at PAA 0 81 FC 00h on layer L2 shall be left unrecorded.

18.3.15 INFO 1/Drive area (optional)

18.3.15.1 General

The use of this zone of 32 physical clusters starting at PAA 0 01 FC 80h on layer L0, at PAA 0 7E 03 00h on layer L1 and at PAA 0 81 FC 80h on layer L2 is optional. This zone can be used by drives to store drive-specific information, only by the drive that has created the information. To guarantee that drives can allocate their own information, the following format shall be used. These clusters in this zone shall be ignored in interchange.

18.3.15.2 Format of drive-specific information

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 manufacturer's name, represented by characters from the ISO/IEC 646 character set;

— 48 bytes of additional identification, represented by characters from the ISO/IEC 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 each drive designer.

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 97).

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 0 01 FC 80h and 0 01 FC 84h shall be used to store 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.

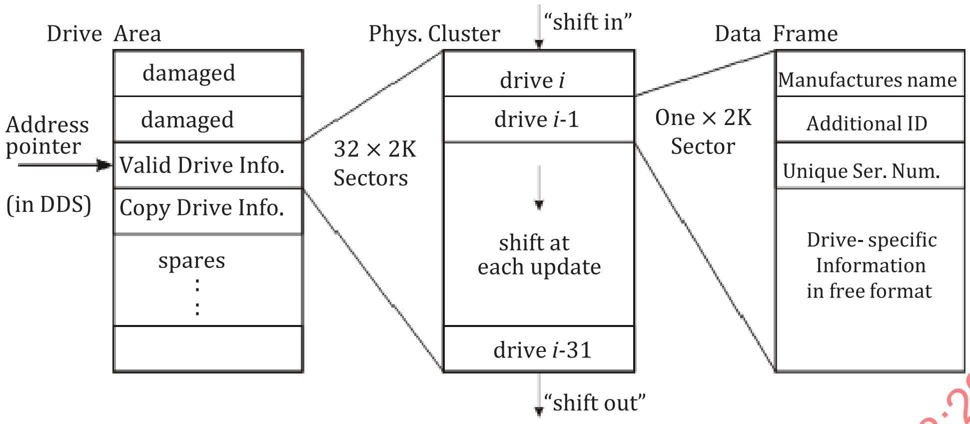


Figure 97 — Format of drive area (example)

18.3.16 INFO 1/Reserved 3

This zone of 32 physical clusters starting at PAA 0 01 FD 00h on layer L0, at PAA 0 7E 02 80h on layer L1 and at PAA 0 81 FD 00h on layer L2 shall be left unrecorded.

18.3.17 INFO 1/Reserved 2

This zone of 32 physical clusters starting at PAA 0 01 FD 80h on layer L0, at PAA 0 7E 02 00h on layer L1 and at PAA 0 81 FD 80h on layer L2 shall be left unrecorded.

18.3.18 INFO 1/Reserved 1

This zone has the size of 32 physical clusters starting at PAA 0 01 FE 00h on layer L0, at PAA 0 7E 01 80h on layer L1 and at PAA 0 81 FE 00h on layer L2 shall be left unrecorded.

18.3.19 INFO 1/DMA 1

This zone of 32 physical clusters, which starts at PAA 0 01 FE 80h on layer L0, at PAA 0 7E 01 00h on layer L1 and at PAA 0 81 FE 80h on layer L2, is intended for use by the disk management system (see 22.2). Unused clusters in this zone shall contain all 00h or can be left unrecorded.

18.3.20 INFO 1/Control Data 1

This zone of 32 physical clusters, which starts at PAA 0 01 FF 00h on layer L0, at PAA 0 7E 00 80h on layer L1 and at PAA 0 81 FF 00h on layer L2, is intended to store control information.

Unused clusters in this zone shall contain all 00h.

18.3.21 INFO 1/PAC 1

This zone of 32 physical clusters, which starts at PAA 0 01 FF 80h on layer L0 and PAA 0 7E 00 00h 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 can be left unrecorded.

18.3.22 INFO 1/Reserved

This zone of 32 physical clusters, starting at PAA 0 81 FF 80h on layer L2, shall be left unrecorded.

19 Data zone

The data zone can contain a total of 1 527 456 clusters of user data.

20 Outer zone(s)

20.1 General

Outer zone 0 and outer zone 1 function together as a transition area between the data zones on layer L0 and layer L1. outer zone 2 functions as a lead-out zone (see Figure 98 and Figure 99).

Outer Zone 0/2		Description	First PAA of Zone	Number of Phys. Clusters	Purpose
↓ Rewritable ↓ tracking direction	INFO 3	Buffer 3	LAA*n* + 2h	32	---
		DMA 3	LAA*n* + 82h	32	Disk Management
		Control Data 3	LAA*n* + 1 02h	32	data information
	---	Angular buffer	LAA*n* + 1 82h	102	---
	INFO 4	DMA 4	LAA*n* + 3 1Ah	32	Disk Management
		Control Data 4	LAA*n* + 3 9Ah	32	data information
		Buffer 4	LAA*n* + 4 1Ah	32	---
	DCZ 0/2	Test Zone	LAA*n* + 4 9Ah	760	Drive calibration
	---	Protection-Zone 3	LAA*n* +10 7Ah	---	---
LAA*n* is LAA in Outer Zone 0 and LAA2 in Outer Zone 2.					

Figure 98 — Outer zone 0/2 (Lead-out zone)

Outer Zone 1		Description	First PAA of Zone	Number of Phys. Clusters	Purpose
	---	Protection-Zone 3	---	---	---
↓ Rewritable ↓ tracking direction	DCZ 1	Test Zone	FAA – 10 78h	760	Drive calibration
	INFO 4	Buffer 4	FAA – 4 98h	32	---
		Control Data 4	FAA – 4 18h	32	data information
		DMA 4	FAA – 3 98h	32	Disk Management
	---	Angular buffer	FAA – 3 18h	102	---
	INFO 3	Control Data 3	FAA – 1 80h	32	data information
		DMA 3	FAA – 1 00h	32	Disk Management
		Buffer 3	FAA - 80h	32	---

Figure 99 — Outer zone 1

20.2 INFO 3/Buffer 3

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 22.2). Unused clusters in this zone shall contain all 00h or can be left unrecorded.

20.4 INFO 3/Control data 3

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 of 102 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 22.2). Unused clusters in this zone shall contain all 00h or can 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 4

This zone of 32 physical clusters shall be left unrecorded.

20.9 DCZ 0/Test zone, DCZ 1/Test zone and DCZ 2/Test zone

These test zones of 760 physical clusters are reserved for drive calibrations.

20.10 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 INFO 1/PAC 1 zone and backup copies shall be recorded in the INFO 2/PAC 2 zone. All PAC clusters shall have the same format for the 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 of 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 of 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.

NOTE To preserve compatibility:

— from the point of view of zone layout, PAC 1 and PAC 2 are allocated only on layer L0 and layer L1, and the corresponding zone on layer L2 is reserved; and

— from the point of view of PAC content, there are no additional unknown-PAC rules for this reserved zone and this reserved zone is out of PAC control.

21.2 Layout of PAC zones

The INFO 1/PAC 1 zones on layer L0 and layer L1 form one area of 64 clusters available for the storage of PAC and the INFO 2/PAC 2 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 INFO 1/PAC 1 and INFO 2/PAC 2, so there are always 2 copies of each PAC cluster recorded. A PAC shall always be updated first in the INFO 1/PAC 1 zone and then be copied to the INFO 2/PAC 2 zone, which eases the handling of possible power-down failures. The PAC-update count of the PAC cluster recorded in the INFO 2/PAC 2 zone shall be the same as the PAC-update count of the PAC cluster recorded in the INFO 1/PAC 1 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 100). A replacement PAC should be recorded in the next available cluster.

The status of all locations in both the INFO 1/PAC 1 and INFO 2/PAC 2 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, although overwriting is allowed (independent on the setting of bit b_0 and b_1 of the Unknown-PAC Rules).	

Figure 100 — Status of PAC locations

21.3 General structure of PAC clusters

The user data of the PAC clusters shall be formatted according to Figure 101. 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 101 — 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 INFO 1/PAC 1 zone or INFO 2/PAC 2 zone shall be set to 00 00 00h or those subsequent cluster locations shall be left 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 INFO 1/PAC 1 zone or INFO 2/PAC 2 zone shall be recorded at the first available cluster in these zones (indicated by status 00 or 01 in the DDS, see Figure 100).

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 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 102). The actions described for the user-data area shall be taken only within the specified segments if segments have been defined. Otherwise, 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&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 102 — 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-formatting.

— 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 specifies unknown-PAC rules that cover the entire disk as follows:

— 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 ($0 \leq N \leq 32$) 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 (56).

$$\sum_{i=0}^{N} n_{S_i} \leq 32 \qquad (56)$$

where n_{S_i} is the 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) ($N \leq 32$).

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 $i \geq N$, shall be set to all 00h.

— the first four bytes of the Segment_*i* field, if used, shall contain the first PSN of the first cluster belonging to the segment, and

— the last four 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 as follows:

— 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 103.

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 to14	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 896	Recorder ID for RID_Tag 03h	128
:	:	:	:
0	1 920 to 2047	:	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 103 — 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, indicating this is a primary PAC version 0.

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 104.

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 chapter 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&2	PAC cluster	b_1	write	ZERO
		b_0	read	ZERO

Figure 104 — Bit assignments for unknown-PAC rules for primary PAC

The unknown-PAC entire_disk_flags byte shall be set to 00h indicating 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 all be set to all 00h.

The known-PAC entire_disk_flags byte shall be set to 00h indicating 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 (2 digits BCD) and the date (2 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 (re-) formatted 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 according to the following format (see 18.3.15.2):

— 48 bytes for the manufacturer's name, represented by characters from the ISO/IEC 646 character set;

— 48 bytes of additional identification, represented by characters from the ISO/IEC 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 103) assigned to each specific recorder. After all available recorder ID fields have been used, recorders whose recorder ID cannot 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 byte, else they shall follow the unknown-PAC rules. The layout of the DWP PAC cluster shall be formatted as depicted in Figure 105.

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 to14	Reserved	2
0	15	number of Segments	1
0	16 to23	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 105 — Layout of the 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, indicating this is a DWP PAC version 0.

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 Figure 106:

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 chapter 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&2	PAC cluster	b_1	write	ONE
		b_0	read	ONE

Figure 106 — 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 indicating 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 indicating 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 107) 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 the table of Figure 107, 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 the table of Figure 107, 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 the table of Figure 107;
  - 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 the table of Figure 107.

The WP password can consist of up to 32 characters from the ISO/IEC 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			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
1	0	1	with PWD/virtual/WP on	allowed after confirmation of the password supplied by	allowed after confirmation of the password supplied by
1	1	0	with PWD/physical/WP off	allowed	allowed after confirmation of the password supplied by
1	1	1	with PWD/physical/WP on	allowed after confirmation of the password supplied by the host and changing to	allowed after confirmation of the password supplied by the host

Figure 107 — 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 an unrecorded disk. When BCA code is not recorded on an unrecorded disk, IS1/IS2 PAC structures shall be recorded in INFO 1/PAC 1 and INFO 2/PAC 2 before shipping as pre-recorded area. When BCA code is recorded on an unrecorded disk, IS1/IS2 PAC structures shall not recorded.

The layout of the IS1 PAC and IS2 PAC cluster shall be formatted as depicted in Figure 108.

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 108 — 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, indicating this is version 0.

The PAC-update count shall be set to 00 00 00 00h for both PACs.

The unknown-PAC rules shall be set 00 AA 2A 00h for an IS1 PAC and shall be set 00 AA 2A CBh for an 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 methods of recording data on the disk including defect management. Defect management is used to solve problems related to areas on the disk that can have become defective or unreliable through damages 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.

The data originally intended to be recorded at a defective location is recorded at an alternative location that is, determined by the file system.

In the defect list, according to this document, 2 types of defects can be distinguished (see 22.2.3.3) as follows:

— defects that are indicated as non-reallocatable defect (NRD); and

— unreliable areas on the disk, called possibly bad area (PBA). 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 which shall be repeated 4 times, for robustness reasons, and the defect list consists of 8 consecutive clusters.

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 the 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 22.2.3.1, byte 4 of data frame 0/cluster 0 and 22.2.3.2, defect-list terminator) shall be the same.

DMS

The DMA zones consist of 96 consecutive clusters divided over the 3 recording layers as indicated in Figure 109.

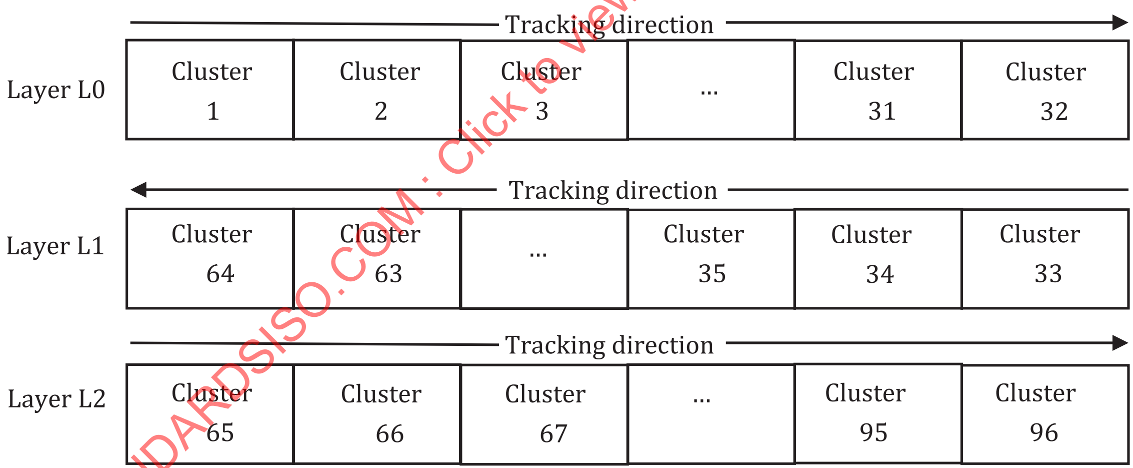


Figure 109 — Clusters of DMA zones

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 110). The position of the valid DFL is indicated in the DDS.

Cluster 1 to 4	DDS (4 repetitions)	
Cluster 5 to 8	Reserved	
Cluster 9 to16	1st position of DFL	damaged DFL
Cluster 17 to 24	2nd position of DFL	valid DFL
Cluster 25 to 32	3rd position of DFL	empty
:	:	:
Cluster 89 to 96	11th position of DFL	empty

Figure 110 — Example of DMA zone

22.2.2 Disk-definition structure (DDS)

The DDS specifies the format and status of the disk with relation to the disk management. The format of the DDS is defined in Figure 111.

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 43	Reserved unless otherwise specified by the BDAP	4
0	44 to 47	Reserved unless otherwise specified by the BDAP	4
0	48 to 51	Reserved unless otherwise specified by the BDAP	4
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
0	80 to 87	Status bits of INFO 1/PAC 1 locations on layer L1	8
0	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 111 — 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 and 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 02 E9 D3 FFh unless otherwise specified by the BDAP.

The 8-bit flag A field specifies the status of the TL disk. Bits b_7 and b_6 shall be reserved. Bits b_5, b_4, b_3, b_2, b_1, and b_0 shall be set to ONE 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 112). The bit pairs shall be set as defined in 21.2.

Byte position	Bits	INFO 1/PAC 1 location PAA
64	b_7 b_6	0 01 FF 80h
64	b_5 b_4	0 01 FF 84h
64	b_3 b_2	0 01 FF 88h
64	b_1 b_0	0 01 FF 8Ch
65	b_7 b_6	0 01 FF 90h
:	:	:
:	:	:
70	b_1 b_0	0 01 FF ECh
71	b_7 b_6	0 01 FF F0h
71	b_5 b_4	0 01 FF F4h
71	b_3 b_2	0 01 FF F8h
71	b_1 b_0	0 01 FF FCh

Figure 112 — 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 113). The bit pairs shall be set as defined in 21.2.

Byte position	Bits	INFO 2/PAC 2 location PAA
72	b_7 b_6	0 01 BA 00h
72	b_5 b_4	0 01 BA 04h
72	b_3 b_2	0 01 BA 08h
72	b_1 b_0	0 01 BA 0Ch
73	b_7 b_6	0 01 BA 10h
:	:	:
:	:	:
78	b_1 b_0	0 01 BA 6Ch
79	b_7 b_6	0 01 BA 70h
79	b_5 b_4	0 01 BA 74h
79	b_3 b_2	0 01 BA 78h
79	b_1 b_0	0 01 BA 7Ch

Figure 113 — 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 114). The bit pairs shall be set as defined in 21.2.

Byte position	Bits	INFO 1/PAC 1 location PAA
80	b_7 b_6	0 7E 00 00h
80	b_5 b_4	0 7E 00 04h
80	b_3 b_2	0 7E 00 08h
80	b_1 b_0	0 7E 00 0Ch
81	b_7 b_6	0 7E 00 10h
:	:	:
:	:	:
86	b_1 b_0	0 7E 00 6Ch
87	b_7 b_6	0 7E 00 70h
87	b_5 b_4	0 7E 00 74h
87	b_3 b_2	0 7E 00 78h
87	b_1 b_0	0 7E 00 7Ch

Figure 114 — 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 115). The bit pairs shall be set as defined in 21.2.

Byte position	Bits	INFO 2/PAC 2 location PAA
88	b_7 b_6	0 7E 45 80h
88	b_5 b_4	0 7E 45 84h
88	b_3 b_2	0 7E 45 88h
88	b_1 b_0	0 7E 45 8Ch
89	b_7 b_6	0 7E 45 90h
:	:	:
:	:	:
94	b_1 b_0	0 7E 45 ECh
95	b_7 b_6	0 7E 45 F0h
95	b_5 b_4	0 7E 45 F4h
95	b_3 b_2	0 7E 45 F8h
95	b_1 b_0	0 7E 45 FCh

Figure 115 — Status bits and related INFO 2/PAC 2 address locations on layer L1

22.2.3 Defect list (DFL)

The first data frame of the 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 116.

Cluster number/ Data Frame	Start byte position in Data Frame	Content	Number of bytes
0/0	0	Defect-List Header	128
0/0 : 0/31	128 :	List of Defects	65 408
1/0 : 1/31	0 :	List of Defects	65 536
:			
K/0 : :	0	List of Defects	n×8
:	n×8	Defect-List Terminator	8
: : *K*/31	(n + 1) ×8	set 00h	..
K = 7.			

Figure 116 — Format of DFL

The defect-list header (DLH) identifies the defect list and contains information about the composition of the list of defects (see 22.2.3.1).

The list of defects contains a list of clusters determined to be defective during use of the disk (see 22.2.3.2).

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 8 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.

22.2.3.1 Defect-list header (DLH)

The format of the DLH is defined in Figure 117.

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 shall indicate the total number of entries in the DFL and shall be as follows:

N_DFL = No. of NRD + No. of PBA unless otherwise specified by the BDAP;

$N\_DFL \leq 65\,519$.

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
0/0	64 to 67	Reserved unless otherwise specified by the BDAP	4
0/0	68 to 71	Reserved unless otherwise specified by the BDAP	4
0/0	72 to 75	Reserved unless otherwise specified by the BDAP	4
0/0	76 to 79	Reserved unless otherwise specified by the BDAP	4
0/0	80 to 83	Reserved unless otherwise specified by the BDAP	4
0/0	84 to 87	Reserved unless otherwise specified by the BDAP	4
0/0	88 to 127	Reserved	40

Figure 117 — 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 change 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 change during the use of the disk.

22.2.3.2 List of defects

The format of the list of defects is shown in Figure 118.

The DFL shall be updated after formatting and each time an entry is added, removed or changed (change in status or address).

The DFL entries shall be formatted as specified in 22.2.3.3. DFL entries consist of 8 bytes and these entries shall be recorded contiguously, even across the borders of data frames and clusters.

The defect-list terminator shall be composed of two 4-byte parts as follows:

— 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	128	DFL entry 0	8
0/0	136	DFL entry 1	8
:	:	...	..
0/0	$i \times 8 + 128$	DFL entry i	8
:	:	...	..
0/0	2 032	DFL entry 238	8
0/0	2 040	DFL entry 239	8
0/1	0	DFL entry 240	8
0/1	8	DFL entry 241	8
:	:	...	..
0/1	2 040	DFL entry 495	8
:	:	...	..
0/n	0	DFL entry $n \times 256 - 16$	8
:	:	...	..
:	:	...	..
0/31	2 040	DFL entry 8 175	8
:			
m/0	0	DFL entry $m \times 8\,192 - 16$	8
:	:	...	..
m/0	$j \times 8$	DFL entry $m \times 8\,192 - 16 + j$	8
:	:	...	..
m/0	2 040	DFL entry $m \times 8\,192 - 16 + 255$	8
m/1	0	DFL entry $m \times 8\,192 - 16 + 256$	8
:	:	...	..
m/1	2 040	DFL entry $m \times 8\,192 - 16 + 511$	8
:	:	...	..
m/n	0	DFL entry $m \times 8\,192 + n \times 256 - 16$	8
:	:	...	..
:	:	...	..
m/31	2 040	DFL entry $m \times 8\,192 + 8\,191 - 16$	8
:			
:	:	...	..
K/n ($K \geq m$)	$[(N\_DFL - 1) \times 8 + 128 - n \times 2\,048 - K \times 65\,536]$	DFL entry ($N\_DFL - 1$)	8
K/n	$(N\_DFL \times 8 + 128 - n \times 2\,048 - K \times 65\,536)$	DFL terminator	8
K/n	$[(N\_DFL + 1) \times 8 + 128 - n \times 2\,048 - K \times 65\,536]$	set to 00h	..
K/(n+1) to K/31	0	set to 00h	2 048
$K = 7$			

Figure 118 — Format of list of defects

22.2.3.3 DFL entries

Each DFL entry shall be formatted as shown in Figure 119. 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 0), which means: 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 & byte 1 to 3 of DFL entry *i*	Byte 4/bit 7..4 of DFL entry *i*	Byte 4/bit 3..0 & 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 119 — 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 120). 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 120.

Status 1	Status 2	Type	Definition
0001	0000	NRD	The entry identifies a defective location.
0100	0000 or 0100	PBA	The entry identifies an area on the disk that might be defective and has to 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		Reserved unless otherwise specified by the BDAP	---

Figure 120 — DFL-entry status 1 definition

The status 2 field shall indicate the status of the entry as shown in Figure 121.

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.) Then 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 might contain valid User Data, the Status 2 of such a PBA shall be set to 0000.
Other	Reserved unless otherwise specified by the BDAP.

Figure 121 — DFL-entry status 2 definition

23 Assignment of logical-sector numbers (LSNs)

Logical-sector numbers shall be assigned contiguously over all clusters available for storage of user data, so starting from LSN 0 and increasing by one for each successive user-data frame (see Figure 122). LSN 0 is assigned to the first user-data frame in the first cluster after lead-in zone (at PSN = 00 10 00 00h).

The last LSN on layer L0 is equal to 8 × LAA + 15 − 00 10 00 00h and is assigned to the last user-data frame in the last cluster before the 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 = $\overline{X + FC\,00\,00\,00h}$).

The last LSN on layer L1 is equal to 16 × LAA + 31 − 00 20 00 00h and is assigned to the last user-data frame in the last cluster before the inner zone 1 (at PSN = 03 EF FF FFh).

The first LSN on layer L2 shall be one higher than the last LSN on layer L1 and is assigned to the first user-data frame in the first cluster after the inner zone 2 (at PSN = 04 10 00 00 h).

The last LSN on layer L2 = 24 × LAA + 47 − 00 30 00 00h and is assigned to the last user-data frame in the last cluster before the lead-out zone (at PSN = 04 00 00 00h + 8 × LAA + 15 = *X* + 04 00 00 00h).

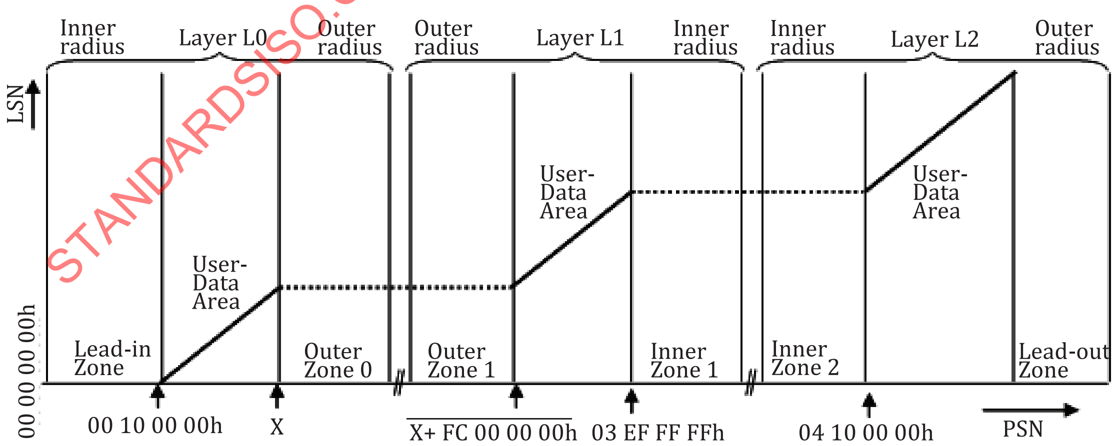


Figure 122 — Assignment of logical-sector numbers

24 Characteristics of grooved areas

In this document, two types of signals are distinguished as follows:

— signals generated by the groove structures on the disk; and

— signals generated by user-written marks.

In Clauses 25 to 27, 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 27 shall be fulfilled in all layers independent of the recording status of other recording layers (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

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, erroneous ADIP information or uncorrectable data (see Clause 33).

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 (1,44 ± 0,10) mW for layer L0 and layer L1 and (1,00 ± 0,10) mW for layer L2 except when measuring push–pull signals. For measurement of push–pull signals, the read power shall be (0,70 ± 0,10) mW.

25.3.3 Read channels

The drive shall have 2 read channels as defined in 9.5 and 9.6. The HF signal from the HF read channel shall not be equalized.

For measurement of the push–pull signals, the read channels shall be filtered by a first order LPF with $f_{-3\ dB}$ = 30 kHz.

For measurement of the wobble signals, the read channels shall be filtered by a first order LPF with $f_{-3\ dB}$ = 16 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.

Local defects that cause large axial tracking errors shall be taken into account as described in Annex I.

25.3.5 Scanning velocities

The actual rotation speed of the disk shall be such that it results in an average channel-bit rate of 132,000 Mbit/s or an average wobble frequency of 1 913,043 kHz except when measuring push–pull signals. For the measurement of push–pull signals, 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 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.

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 (57):

$$I_G = (I_1 + I_2)_{groove} \tag{57}$$

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 4), when the focus of the optical beam converges on the tracks. The push–pull signal can be used by the drive for radial tracking (see Figure 123).

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 is defined as per Formula (58):

$$PP_{norm} = \left[\frac{I_1(t) - I_2(t)}{I_1(t) + I_2(t)}\right]_{peak\text{-}peak} \equiv \frac{(I_1 - I_2)_{at\ t_2}}{(I_1 + I_2)_{at\ t_2}} - \frac{(I_1 - I_2)_{at\ t_1}}{(I_1 + I_2)_{at\ t_1}} \tag{58}$$

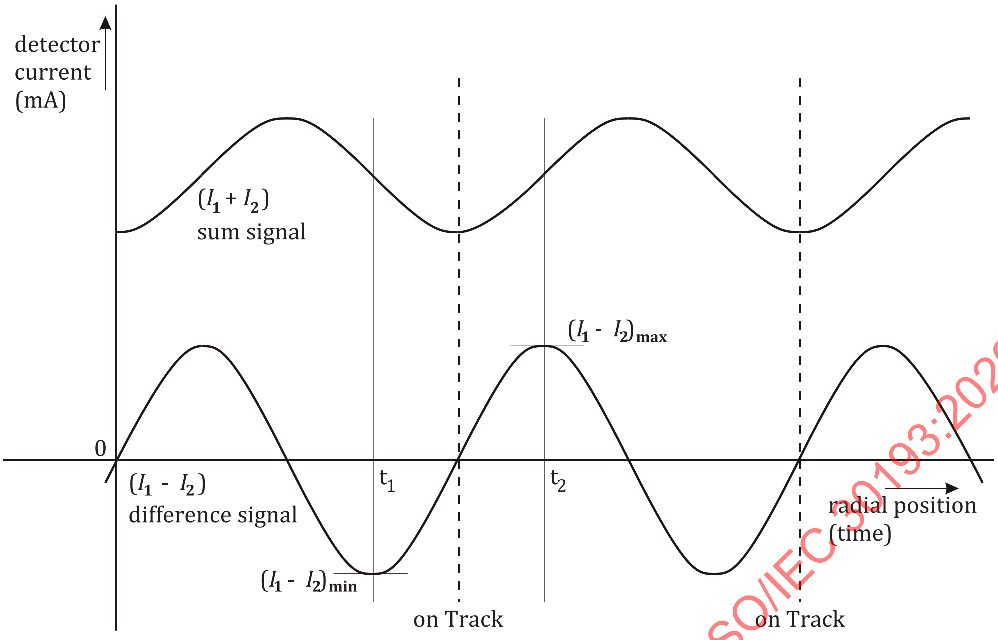


Figure 123 — Definition of push–pull signals

The real-time normalized push–pull signal, PP_{norm}, shall be converted for the photodetector size of 25 µm^2 (see I.9).

Wobble signal:

The wobble signal I_{Wpp} is the peak-to-peak value of the band-pass filtered sinusoidal difference signal ($I_1 - I_2$) in the radial PP read channel (see Figure 4), when the focus of the optical beam follows the tracks according to 25.3.4. See also Annex E and Annex M for a measurement method.

The signal shall be normalized by the peak-to-peak value of the push–pull signal $(I_1 - I_2)_{pp}$ as per Formula (59):

$$NWS = \frac{I_{Wpp}}{(I_1 - I_2)_{pp}} \tag{59}$$

26 Signals from HFM grooves

26.1 Push–pull polarity

The polarity of the push–pull signal is said to be positive if the signal has the same polarity as the push–pull signal detected from the following pit/groove geometry:

— “on-groove recording” (see 15.2);

— the single pass phase depth of the grooves is less than 90°.

If the polarity is opposite to the polarity of the specified case, it is said to be negative.

The polarity of the push–pull signal on each recorded layer of the disk shall be indicated in the disk information (see 15.8.3).

26.2 Push–pull signal

The peak-to-peak value of the real-time normalized push–pull signal, $(PP_{norm,HFM})_{conv}$, in the embossed HFM areas shall be as $0{,}26 \leq (PP_{norm,HFM})_{conv} \leq 0{,}52$.

26.3 Wobble signal

The normalized HFM-wobble signal (NHWS) is a measure of the deviation of the groove track from its average centrelines. 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 NHWS shall be as per Formula (60):

$$0{,}30 \le \mathrm{NHWS}_{\mathrm{min}} \le 0{,}60 \quad (60)$$

At locations where the HFM wobble signal shows maximum amplitudes due to the wobble beat, the NHWS shall be as Formula (61):

$$NHWS_{\mathrm{max}} \le 3 \times \mathrm{NHWS}_{\mathrm{min}} \quad (61)$$

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.

26.4 Jitter of HFM signal

The binarized 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, $f_{-3\ \mathrm{dB}} = 20$ kHz;

— no equalization; and

— normalized by 18T clock period (see 15.5.4.2).

27 Signals from wobbled grooves

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 $(\mathrm{PP}_{\mathrm{norm}})_{\mathrm{conv}}$ shall meet the following requirements in each layer:

— in unrecorded areas (all neighbouring tracks unrecorded):

$$0{,}21 \le (\mathrm{PP}_{\mathrm{norm,unrec,}})_{\mathrm{conv.}} \le 0{,}45$$

— maximum variation of push–pull signal within 150 tracks in unrecorded areas:

$$\frac{(\mathrm{PP}_{\mathrm{norm,unrec.}})_{\mathrm{max}} - (\mathrm{PP}_{\mathrm{norm,unrec.}})_{\mathrm{min}}}{(\mathrm{PP}_{\mathrm{norm,unrec.}})_{\mathrm{max}} + (\mathrm{PP}_{\mathrm{norm,unrec.}})_{\mathrm{min}}} \le 0{,}18$$

— maximum variation of push–pull signal within one layer in unrecorded areas:

$$\frac{\left(PP_{norm,unrec.}\right)_{max} - \left(PP_{norm,unrec.}\right)_{min}}{\left(PP_{norm,unrec.}\right)_{max} + \left(PP_{norm,unrec.}\right)_{min}} \leq 0{,}25$$

— in recorded areas (all neighbouring tracks recorded):

$$0{,}21 \leq (PP_{norm,rec.})_{conv} \leq 0{,}45$$

— ratio of average push–pull signals in recorded and unrecorded areas within

$$0{,}75 \leq \frac{PP_{norm,rec.}}{PP_{norm,unrec.}} \leq 1{,}25$$

27.3 Wobble signal

27.3.1 General

The NWS is a measure of the deviation of the groove track from its average centrelines. The distance that the actual centre of the wobbled groove track deviates from the average track centre line can be calculated according to Annex M.

27.3.2 Measurement of 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 is described in Annex E.

At locations where the wobble signal shows minimum amplitudes (excluding the effects of MSK marks), NWS shall be $0{,}20 \leq NWS_{min} \leq 0{,}55$.

At locations where the wobble signal shows maximum amplitudes due to the wobble beat, NWS shall be $NWS_{max} \leq 3 \times NWS_{min}$.

27.3.3 Measurement of the wobble CNR

The narrow band *S*/*N* (or CNR) of the wobble signal after recording at nominal recording velocity of the disk as defined in 15.8.3, shall be greater than 29 dB at the locations where the wobble signal shows minimum amplitudes.

The carrier shall be measured at 1 913,043 kHz, and the noise level shall be measured at 1 MHz (see Annex E).

27.3.4 Measurement of harmonic distortion of wobble

To guarantee a minimum quality of the HMW modulation, the second-harmonic distortion of the wobble signal shall be sufficiently low compared with the second-harmonic level originating from the HMW modulation.

The second-harmonic level (SHL) and the second-harmonic distortion (SHD) shall be determined by measuring the fundamental wobble frequency level and the second harmonic frequency level at two locations of the disk. Booth levels shall be measured in the data zone and in protection-zone 3.

The ratio of the SHD and SHL, normalized to the local fundamental wobble frequency level, shall meet one of the following requirements:

— SHD/SHL < −12 dB with zero radial tilt;

— SHD/SHL < −6 dB within ± 0,70° of radial tilt.

The measurements shall be made using a spectrum analyzer (see Annex E).

28 Characteristics of recording layer

In this document, two types of signals are distinguished as follows:

— 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 phase change 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 layers (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).

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 with the disk in the 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 (1,44 ± 0,10) mW for layer L0 and layer L1 and (1,00 ± 0,1) mW for layer L2.

29.3.3 Read channels

The drive shall have 2 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 i-MLSE (see Annex H).

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 maximum 55 nm at 2x reference velocity, or maximum 110 nm at

4x reference velocity. The radial tracking error between the focus of the optical beam and the centre of the track shall be maximum 16 nm at 2x reference velocity, or maximum 20 nm at 4x reference velocity.

Local defects that cause large axial tracking errors shall be taken into account as described in Annex I.

29.3.5 Scanning velocities

All write tests shall be carried out at the speeds 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 132,000 Mbit/s or an average wobble frequency of 1 913,043 kHz. Only for the read stability test (see 30.7) at 4x reference velocity with the disk contains a DI unit of DI format 6 or DI format 7, the actual rotation speed of the disk shall be such, that it results in an average channel bit rate of 264,000 Mbit/s or an average wobble frequency of 3 826,086 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 and erase pulses.

The write/erase power has four levels as follows:

— the write peak power, P_W;

— the bias write power, P_{BW};

— the cooling power, P_C;

— the erase power, P_E;

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.

The values of P_W, P_{BW}, P_C and P_E shall be optimized according to Annex G.

The actual powers P_W, P_{BW}, P_C, and P_E for testing shall be within ±5% of their optimum values, where P_{BW}, P_C and P_E shall be proportional to P_W according to the ratios ε as specified in the disk information (see 15.8.3.3 and 15.8.3.4).

29.4.2 Write powers

The optimized write powers P_{WO}, P_{BWO}, P_{CO}, and P_{EO} shall meet the conditions as shown in Figure 124.

Velocity	Disk Type	TL	
	Power (mW)	Min.	Max.
2x	P_{WO} (mW)	8,0	28,0
	P_{BWO} (mW)	0,10	16,8
	P_{EO} (mW)	0,60	16,8
	P_{CO} (mW)	0,10	16,8

Figure 124 — Write power requirements for triple-layer disk

In addition to the conditions shown in Figure 124, the write powers shall be such that

— $P_{WO} > P_{EO} \geq P_{CO}$; and

— $P_{WO} \geq P_{BWO}$.

29.4.3 Average power

The average write power, P_{AVE}, shall be equal or less than 14,0 mW.

29.4.4 Write conditions for i-MLSE measurement

The test for i-MLSE (integrated-maximum likelihood sequence error estimation) 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 i-MLSE after *n* overwrites [i-MLSE @ DOW(*n*)], all five tracks are overwritten *n* times with random data with a write power $P_W = P_{WO}$.

29.4.5 Write conditions for cross-erase measurements

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 10 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).

29.5 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.

i-MLSE:

i-MLSE is a quality indicator of the signal in PR(1, 2, 2, 2, 1) ML reproduction system with 17PP modulation code. It is defined by standard deviation, σ, that correlate with the error probability of specific patterns in PR(1, 2, 2, 2, 1) ML reproduction signals (see Annex H).

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 125).

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_{3pp} is the peak-to-peak value of the HF signal generated by the second 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 do occur. However, the recurrence of these 9Ts is very low and therefore their influence on the HF peak-to-peak signal is negligible.

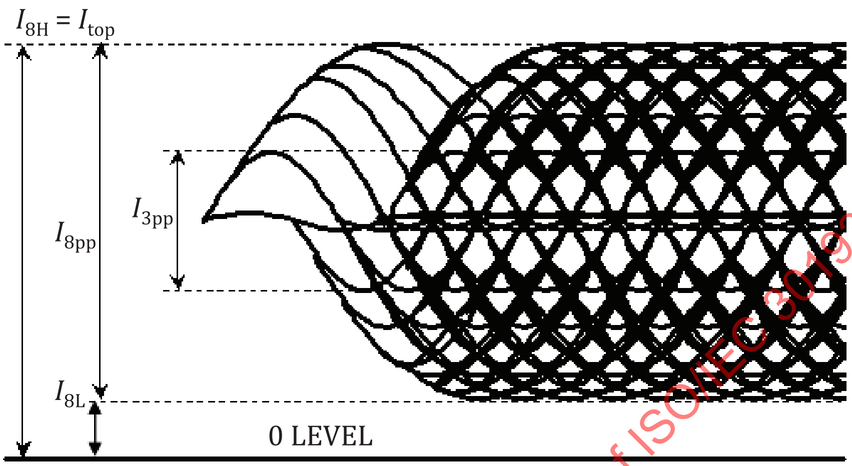


Figure 125 — Schematic representation of HF signal from marks and spaces

Because the I_{3pp} is a relatively small signal, its amplitude cannot be determined reliably from a random HF signal. Therefore, it is recommended, for observation of $I_{3pp}/I_{8pp,}$ to record an area with consecutive 3T 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 signal I_{8pp}/I_{8H} shall be converted by the photodetector size of 25 µm^2 (see I.6).

The modulation signals shall meet the following requirements:

— $I_{8pp}/I_{8H} \geq 0{,}40$;

— $I_{3pp}/I_{8pp} \geq 0{,}040$.

The variations of the modulation signals shall be as follows:

— $(I_{8Hmax} - I_{8Hmin})/I_{8Hmax} \leq 0{,}33$ within one layer at DOW(0)(continuously recorded);

— $(I_{8Hmax} - I_{8Hmin})/I_{8Hmax} \leq 0{,}15$ within one revolution at DOW(0)(continuously recorded).

The ratio between the actual modulation signals (I_{8Ha}) on each layer shall be as per Formula (62):

$$-0{,}25 \leq (I_{8Ha,Lj} - I_{8Ha,Lk})/(I_{8Ha,Lj} + I_{8Ha,Lk}) \leq +\,0{,}25 \text{ at DOW(0) (continuously recorded)} \quad (62)$$

where

$I_{8Ha,Lj}$ and $I_{8Ha,Lk}$ are measured at the same position, both in radial and in tangential direction;

$j = 1, 2$ $k = 0, 1$ $j > k$.

The ratio between the reflectivity on each layer shall be as per Formula (63):

$$-0{,}33 \leq (R_{8H,Lj} - R_{8H,Lk})/(R_{8H,Lj} + R_{8H,Lk}) \leq +\,0{,}33 \text{ at DOW(0) (continuously recorded)} \quad (63)$$

where

$R_{8H,Lj}$ and $R_{8H,Lk}$ are measured at the same position, both in radial and in tangential direction;

$I_{8Ha} = R_{8H} \times$ read power;

$j = 1, 2 \;\; k = 0, 1 \;\; j > k.$

30.3 Reflectivity-modulation product

The reflectivity of the disk multiplied by the I_8 modulation (= normalized I_{8pp} modulated amplitude) shall be (see Annex B) as follows:

$$R \times M = R_{8H} \times \left(\frac{I_{8pp}}{I_{8H}} \right)_{conv}$$

with 0,006 4 ≤ $R \times M$ ≤ 0,019 for layer L0 and layer L1;

0,009 1 ≤ $R \times M$ ≤ 0,027 for layer L2.

The reflectivity of the disk multiplied by the I_3 modulation (= normalized I_{3pp} modulated amplitude) shall be as follows:

$$R \times I_3 = R_{8H} \times \left(\frac{I_{3pp}}{I_{8H}} \right)_{conv}$$

with $R \times I_3$ ≥ 0,000 48 for layer L0 and layer L1;

$R \times I_3$ ≥ 0,000 68 for layer L2.

30.4 Asymmetry

The HF signal asymmetry shall be measured by averaged levels using combination of decoded signal and HF signal without any equalization (see I.7)

The HF signal asymmetry, A_s, shall be -0,10 ≤ A_s ≤ +0,15.

30.5 i-MLSE@DOW(*n*)

The tracks on which the i-MLSE is to be measured shall be recorded as specified in 29.4.4.

The i-MLSE shall be measured on the centre track *m* of the five recorded tracks at 2 times reference velocity.

After *n* overwrites (0 ≤ *n* ≤ 10) track *m*, the i-MLSE in track *m* shall fulfil the following requirements:

— On layer L0: ≤11,0 % when measured using the circuit specified in Annex H;

— On layer L1: ≤11,5 % when measured using the circuit specified in Annex H;

— On layer L2: ≤12,0 % when measured using the circuit specified in Annex H.

30.6 Cross-erase @ DOW(*n*)$_{XE}$

The tracks on which the cross-erase is to be measured shall be recorded as specified in 29.4.5. After *n* overwrites (0 ≤ *n* ≤ 100) tracks (*m*–1) and (*m*+1), the modulation and i-MLSE in track *m* shall fulfil the requirement of Formula (64):

$$\left[\frac{\left(I_{8pp} / I_{8H} \right)_{\text{at DOW}(n)_{XE}}}{\left(I_{8pp} / I_{8H} \right)_{\text{at DOW}(0)_{XE}}} \right] \geq 0,90 \qquad (64)$$

After *n* overwrites, the i-MLSE shall fulfil the following requirements:

— On layer L0: ≤11,5 % when measured using the circuit specified in Annex H;

— On layer L1: ≤12,0 % when measured using the circuit specified in Annex H;

— On layer L2: ≤12,5 % when measured using the circuit specified in Annex H.

30.7 Read stability

Up to 10^6 successive reads from a single track with a dc read power and an HF-modulated read power as follows:

— 1,44 mW for layer L0 and layer L1 at 2x reference velocity reading; and

— 1,00 mW for layer L2 at 2x reference velocity reading.

Only if the disk contains a DI unit of DI format 6 or DI format 7 to support reading at 4x reference velocity as follows:

— 2,00 mW for layer L0 and layer L1 at 4x reference velocity reading; and

— 1,15 mW for layer L2 at 4x reference velocity reading.

The disk shall remain within all specifications in the operating environment.

Higher dc read powers and higher HF-modulated read powers shall be applied when specified in DI bytes 30 to 31 (see 15.8.3.3, 15.8.3.4, 15.8.3.5 and 15.8.3.6).

The modulation should fulfil the following (see Figure 126):

— modulation frequency (= $1/T_{\text{HF-laser}}$) (400 ± 40) MHz;

— ratio of peak power and average power 2,0 ± 0,2.

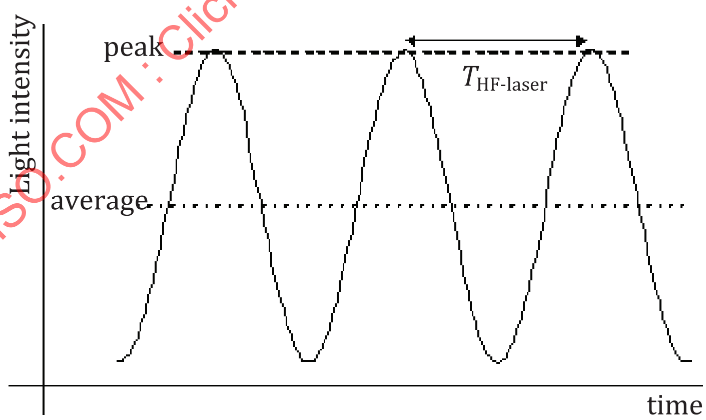


Figure 126 — Schematic representation of light pulses from laser diode

Additionally, the SER (see 34.2) shall be < 4,2 × 10^{-3} in any LDC block.

[Equivalent to <317 counts (= 4,2 × 10^{-3} × 75 392 bytes)].

In order to prevent the recorded signals from degrading, it is strongly recommended that dc read powers and HF-modulated read powers of drives should not exceed the powers provided in DI bytes 30 to 31 at 2 times reference velocity.

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 diameter of such defects shall be as follows:

— air bubbles: <100 µm;

— black dots with birefringence: <150 µm;

— black dots without birefringence: <150 µm.

32 Characteristics of user data

Clauses 32 to 34 describe a series of measurements to test conformance of user data on the disk with this document. 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 with the disk in the 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 (1,44 ± 0,10) mW for layer L0 and layer L1 and (1,00 ± 0,10) mW for layer L2.

33.3.3 Read channels

The drive shall have 2 read channels as defined in 9.5 and 9.6.

The HF signal from the HF read channel shall not be equalized and filtered before processing. For measurement of the disk quality, the characteristics of the HF signal pre-processing shall be the same as specified in Annex H for the i-MLSE 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 132,000 Mbit/s or an average wobble frequency of 1 913,043 kHz.

33.4 Definition of 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 127).

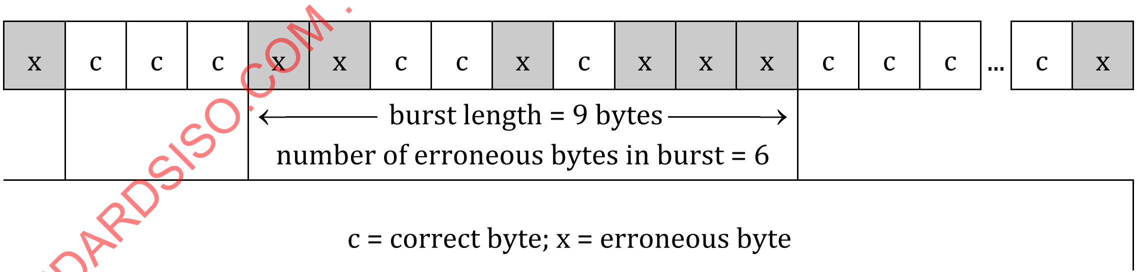


Figure 127 — Example of burst error

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 (65):

$$\frac{\sum_{i=1}^{N} E_{a_i}}{N \times 75\,392} \qquad (65)$$

where

E_{a_i} is the number of all erroneous bytes in LDC block i;

N is the number of LDC block.

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 (66):

$$\frac{\sum_{i=1}^{N}\left(E_{a_i}-E_{b_i}\right)}{N\times 75\,392-\sum_{i=1}^{N}E_{b_i}} \qquad (66)$$

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 block.

34 Minimum quality of recorded information

34.1 General

When checking the quality of the disk, the area selected for determining SER and burst errors shall be overwritten 10 times with arbitrary user data.

34.2 Random symbol error rate

Random SER after 10 times overwrites shall be $<2{,}0 \times 10^{-4}$ averaged over any 10 000 consecutive LDC blocks.

34.3 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.

34.4 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 Burst-cutting area (BCA)

The zone between r_1 and r_3 is reserved for use as a burst-cutting area (BCA) (see 15.2 and Figure 54).

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 initialize 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 128).

The BCA code shall be located between radius $21{,}3_{-0{,}3}^{\ 0{,}0}$ mm and radius $22{,}0_{\ 0{,}0}^{+0{,}2}$ mm on layer L0. (The BCA code is allowed to overlap the protection-zone 1 partially.)

The BCA code shall be written on the layer L0, but some effect of writing the BCA code on layer L0 can be visible on the other layers.

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 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.

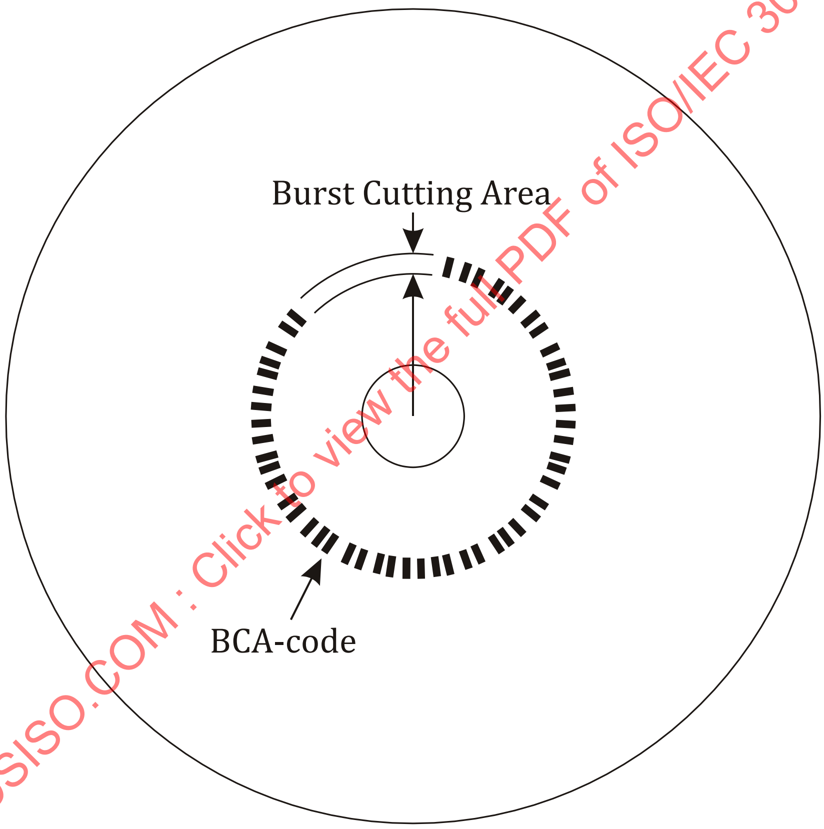


Figure 128 — Schematic representation of BCA

Annex A
(normative)

Thickness of transmission stacks in case of multiple layers

A.1 General

In case the total transmission stack consist of k layers, the following procedure shall be applied in determining the thickness of the individual layers as follows:

— 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;

— for a TL disk, the curves show the thickness of equivalent spherical aberration.

$D(n)$ can be expressed as Formula (A.1), using Formula (23):

$$D(n) = D(1{,}6) \times g(n) \quad \text{(A.1)}$$

Then the thickness d_k of layer k should be as per Formula (A.2):

$$d_k = D(n_k) \times \left(1 - \sum_{i=1}^{k-1} \frac{d_i}{D(n_i)}\right) \quad \text{(A.2)}$$

A.2 Refractive index n_i of all layers in cover and spacer layers

The refractive index n_i of each layer in the cover and spacer shall be $1{,}45 \le n_i \le 1{,}70$.

A.3 Thickness variation of transmission stack

The relative thickness of the transmission stack j is defined as per Formula (A.3):

$$RT_j = \sum_{i=1}^{k} \frac{d_i}{D(n_i)} \quad \text{(A.3)}$$

The relative thickness, RT, of the transmission stacks, measured over the whole disk, shall fulfil the following requirements.

a) Relative thickness, RT_0, of the transmission stack TS0: $94{,}0 \le 100{,}0 \times RT_0 \le 106{,}0$.

b) Relative thickness, RT_1, of the transmission stack TS1: $69{,}0 \le 75{,}0 \times RT_1 \le 81{,}0$.

c) Relative thickness, RT_2, of the transmission stack TS2: $52{,}0 \le 57{,}0 \times RT_2 \le 62{,}0$.

NOTE The thickness of recording layer is very thin and negligible in the calculation of the thickness.

A.4 Thickness variations of spacer layers

The effective thickness of the spacer layer j is defined as per Formula (A.4):

$$ES_j = \sum_{i=1}^{k} d_i \times f(n_i) \tag{A.4}$$

ES_1: Effective thickness of the spacer layer 1.

ES_2: Effective thickness of the spacer layer 2.

ES_c: Effective thickness of TS2 or cover layer.

Function $f(n)$ is defined in Clause 12 and shown in Figure 16. The effective thickness means imaginary value when refractive index is assumed to be 1,60.

The actual thickness (that can be measured by the method described in Annex K) under arbitral refractive index is converted to the effective thickness under standard refractive index of 1,60. Defocus values of both the actual and effective thickness are the same. In this Annex, defocus is defined as focus position movement of the light going through the transparent medium with each thickness and each refractive index.

The effective thicknesses shall meet the requirement as per Formulae (A.5) and (A.6):

$$ES_c - (ES_1 + ES_2) \geq 1{,}0\ \mu m \tag{A.5}$$

$$ES_1 - ES_2 \geq 1{,}0\ \mu m \tag{A.6}$$

A.5 Example of thickness calculation

Assume a cover sheet with refractive index n_1 = 1,52 and a nominal thickness of 55,0 µm is attached to the Substrate which has layer L2 by a gluing sheet with a refractive index n_2 = 1,58. In this case, the nominal thickness of cover layer at index n_1 = 1,52 and 1,58, in µm, are calculated as per Formulae (A.7) and (A.8):

$$D(1{,}52) = D(1{,}6) \times g(1{,}52) = 56{,}35 \tag{A.7}$$

$$D(1{,}58) = D(1{,}6) \times g(1{,}58) = 56{,}81 \tag{A.8}$$

where

$D(1{,}6)$ = 57,0 µm;

$g(1{,}52)$ = 0,988 6;

$g(1{,}58)$ = 0,996 6 (see 12.3).

Then the nominal thickness of the gluing sheet, in µm, is calculated as per Formula (A.9):

$$d_2 = 56{,}81 \times \left(1 - \frac{55}{56{,}35}\right) = 1{,}36 \tag{A.9}$$

and the effective thickness of cover layer (ES_c: cover sheet + gluing sheet), in µm, is calculated as per Formula (A.10):

$$ES_C = 55 \times 1{,}075\,7 + 1{,}36 \times 1{,}017\,7 = 60{,}55 \tag{A.10}$$

where

$f(1{,}52)$ = 1,075 7;

$f(1{,}58)$ = 1,017 7(see Clause 12).

The result shows that effective thickness ES_c is larger when refractive index n is smaller. Then, it is better that that refractive index of cover layer (n_c) be smaller than those of spacer layers (n_{S1}, n_{S2}, n_{S3}) from the the view point of the requirement of $ES_c - (ES_1 + ES_2) \geq 1{,}0$ µm. Also, $n_{S2} > n_{S1} > n_c$ is a preferable condition from the view point of the requirement of $ES_1 - ES_2 \geq 1{,}0$ µm.

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 the following:

— parallel method; and

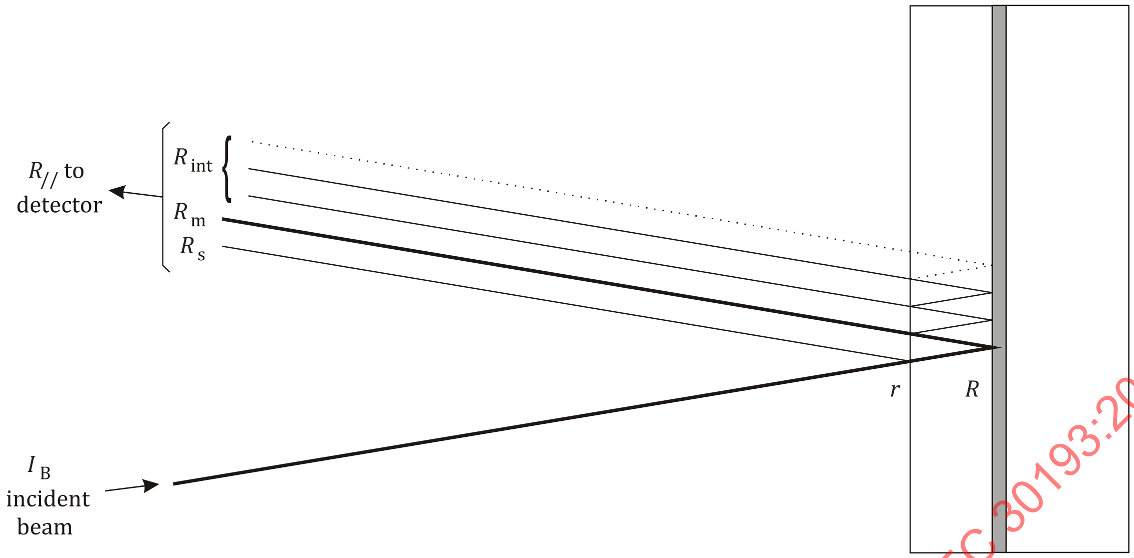
— focused method.

The reflectivity of the disk is measured by the focused method with the help of a reference disk with known reflectivity, while the reflectivity 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):

$$r=\left(\frac{n-1}{n+1}\right)^2 \qquad \text{(B.1)}$$

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):

$$R_{ref}=\frac{R_m}{I_B}=\left[\frac{(1-r)^2\times\left(\frac{R_{//}}{I_B}-r\right)}{1-r\times\left(2-\frac{R_{//}}{I_B}\right)}\right] \qquad \text{(B.2)}$$

The reference disk shall be measured on a reference drive. The total detector current (the sum of all 4 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

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, $R_{g\text{-}v}$, in the groove tracks of the rewritable area as per Formula (B.3):

$$R_{g\text{-}v} = \frac{(I_1 + I_2)_G}{(I_1 + I_2)_{ref}} \times R_{ref} \quad \text{(B.3)}$$

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).

c) Calculate the unrecorded erased disk reflectivity, $R_{g\text{-}e}$, in the groove tracks of the rewritable area as per Formula (B.4):

$$R_{g\text{-}e} = \frac{(I_1 + I_2)_G}{(I_1 + I_2)_{ref}} \times R_{ref} \quad \text{(B.4)}$$

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).

c) Calculate the recorded disk reflectivity, R_{8H}, in the groove tracks of the rewritable area as per Formula (B.5):

$$R_{8H} = \frac{I_{8H}}{(I_1 + I_2)_{ref}} \times R_{ref} \quad \text{(B.5)}$$

NOTE When measuring the reflectivity on a recording layer, make sure that the corresponding portions of all other layers are unrecorded.

B.4 Procedure for compensating stray light effect from observed reflectivity

The reflectivity obtained by applying the measuring method described in B.3 is influenced by the stray lights which are caused by the reflection from other layers (see Figure B.2). Therefore, the observed reflectivity shall be compensated to decrease the influence. Hereafter, the reflectivity obtained by applying the measuring method described in B.3 shall be referred as the observed reflectivity and the reflectivity compensated using the procedure below shall be referred as the compensated reflectivity.

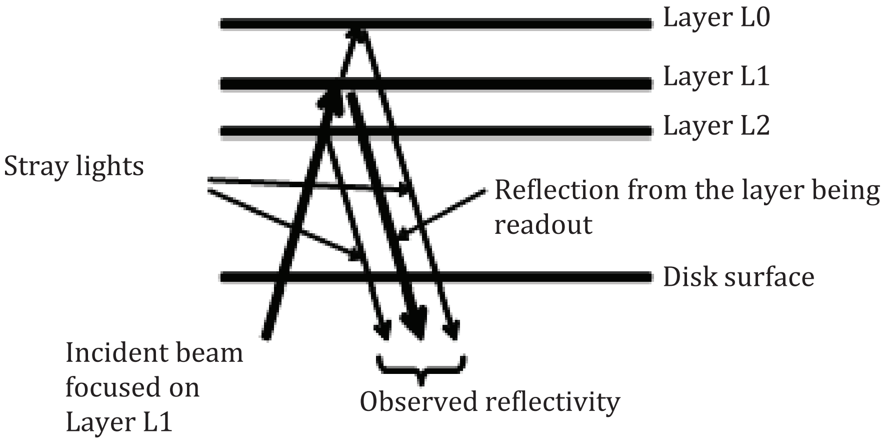


Figure B.2 — Influence of stray lights from other layers

The observed reflectivity of the reproduction layer can be compensated by the procedure below.

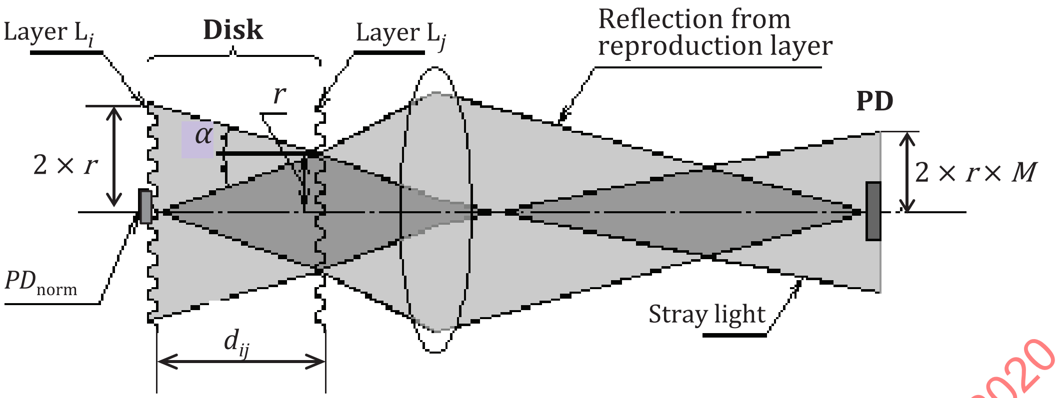
Following conditions are assumed.

a) Multiple reflection can be ignored.

b) Observed light is the sum of reflection from reproduction layer and all stray lights from all other layers.

c) Effects of coherent optical interference on the detector surface is ignored.

d) The intensity of the stray light spot projected on the detector is uniform. Thus, the detector output of the single stray light is proportional to the ratio of area of the stray light spot and photodetector.



Key

i	layer index of reproduction layer
j	layer index of other layers
n	refractive index of the transmission stack
α	angle of incidence beam at interior of the disk, $\sin\alpha$ = NA/n
d_{ij}	physical distance between layer Li and layer Lj
r	spot radius on the other layer: $r = d_{ij}\tan\alpha$
PD_{norm}	size of detector projected on the reproduction layer (see 9.4)
M	transversal optical magnification of the optical system

Figure B.3 — Ray trace of stray light

In geometrical optics view, the radius of the stray light spot projected on the reproduction layer Li is $2 \times r$ as shown in Figure B.3.

The areal ratio of the stray light spot from layer Li and the detector, both projected on the reproduction layer, is then derived as per Formula (B.6):

$$A_{ij} = \frac{PD_{norm}}{\pi(2r)^2} = \frac{PD_{norm}}{\pi\left(2d_{ij}\tan\alpha\right)^2} \qquad \text{(B.6)}$$

The observed light is the sum of reflection from the reproduction layer and all stray lights from all other layers. Thus, the observed reflectivity of the reproduction layer Li is then expressed with Formula (B.7):

$$S_i = R_i + \sum_{\substack{j=0 \\ [j \neq i]}}^{N} R_j A_{ij} \ (N = 2, 3) \qquad \text{(B.7)}$$

where

S_i is the observed reflectivity ($\boldsymbol{R}_{\text{m,g-v}}$, $\boldsymbol{R}_{\text{m,g-e}}$, $\boldsymbol{R}_{\text{m,8H}}$) of layer L$i$ (including influence of stray light);

R_i is the compensated reflectivity ($\boldsymbol{R}_{\text{g-v}}$, $\boldsymbol{R}_{\text{g-e}}$, $\boldsymbol{R}_{\text{8H}}$) of layer L$i$;

N is the number of recording layers of disk (2 for a TL disk).

For $\boldsymbol{R}_{\text{g-v}}$, Formula (B.7) can be rewritten as $\boldsymbol{S}_{\text{g-v}} = \boldsymbol{A} \bullet \boldsymbol{R}_{\text{g-v}}$ using the vector and matrix representation, where $\boldsymbol{S}_{\text{g-v}}$ is the observed reflectivity vector in the unrecorded virgin layer, $\boldsymbol{R}_{\text{g-v}}$ is the compensated reflectivity vector in the unrecorded virgin layer, and A is the areal ratio matrix.

Thus, the compensated reflectivity vector $\boldsymbol{R}_{\text{g-v}}$ can be derived as Formula (B.8):

$$\boldsymbol{R}_{\text{g-v}} = \boldsymbol{A}^{-1} \cdot \boldsymbol{S}_{\text{g-v}} \tag{B.8}$$

For $\boldsymbol{R}_{\text{g-e}}$, the compensated reflectivity in the unrecorded erased layer ($R_{\text{g-e},i}$) can be expressed as Formula (B.9):

$$R_{\text{g-e},i} = S_{\text{g-e},i} - \sum_{\substack{j=0 \\ [j \neq i]}}^{N} R_{\text{g-v},j} A_{ij} \ (N=2,3) \tag{B.9}$$

where $S_{\text{g-e},i}$ is the observed reflectivity of the unrecorded erased layer Li.

For $\boldsymbol{R}_{\text{8H}}$, the compensated reflectivity in the recorded layer ($R_{\text{8H},i}$) can be expressed as Formula (B.10):

$$R_{\text{8H},i} = S_{\text{8H},i} - \sum_{\substack{j=0 \\ [j \neq i]}}^{N} R_{\text{g-v},j} A_{ij} \ (N=2,3) \tag{B.10}$$

where $S_{\text{8H},i}$ is the observed reflectivity of the recorded layer Li.

Annex C
(normative)

Measurement of scratch resistance of cover layer

C.1 General

The entrance surface of the disk has sufficient scratch resistance, which may be improved by a protective coating.

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).

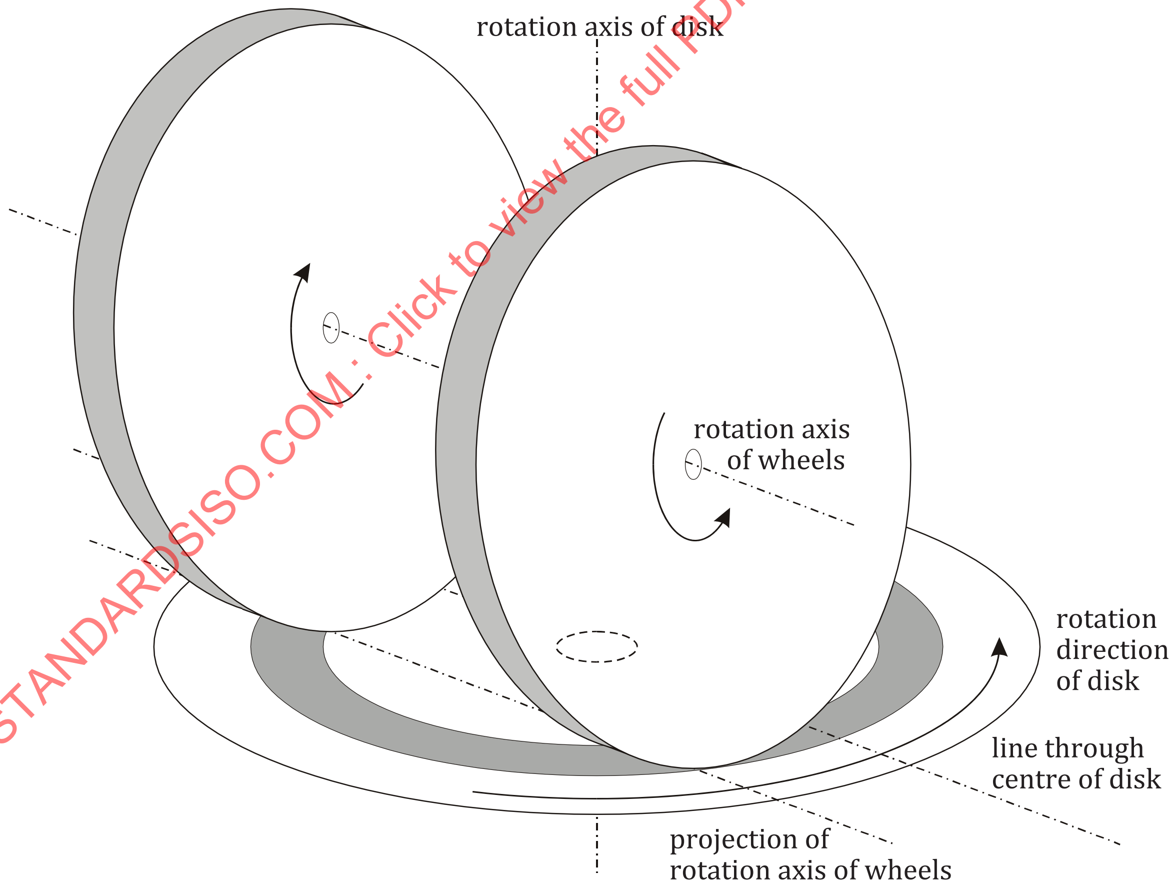


Figure C.1 — Typical abrasive test setup

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 i-MLSE as specified in Annex H, when measured on layer L0, shall be ≤14 %.

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

This annex describes a method of applying an artificial finger print (AFP) to the disk for the purpose of determining the disk's sensitivity to fingerprints. Figure D.1 shows the basic procedure.

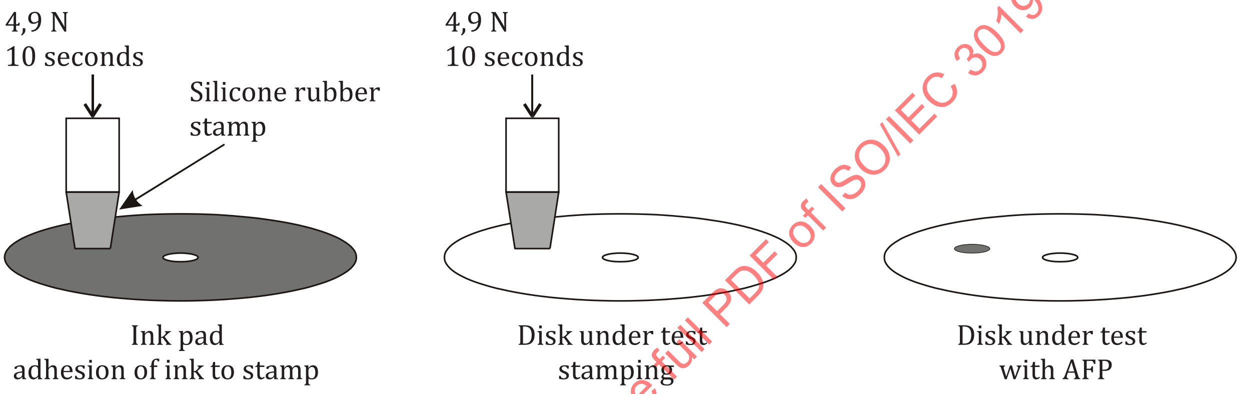


Figure D.1 — Applying AFP to disk

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 $<4.2 \times 10^{-3}$ 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 (see Figure D.2):

— dimensions: stamp shape Φ16 mm × Φ12 mm × 20 mm height; and

— shore hardness is A60.

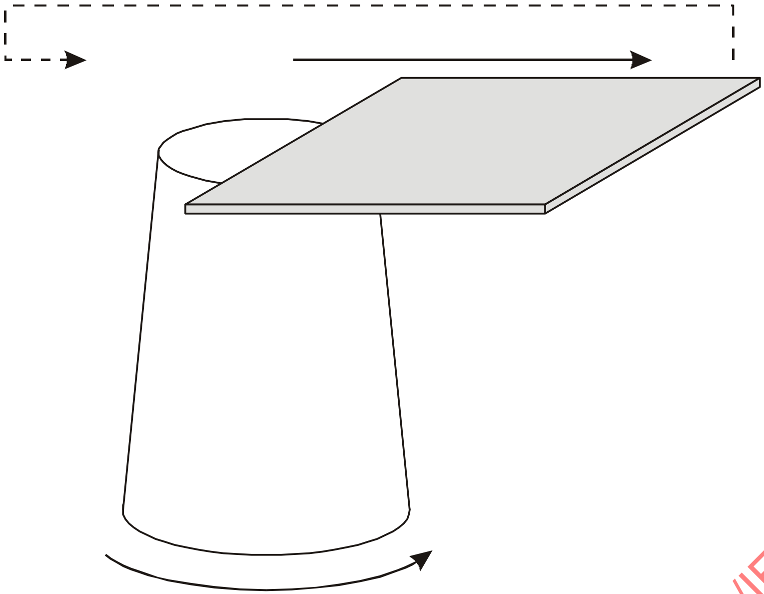


Figure D.2 — Stamp shape and preparation

To provide the stamp with random scratches, it shall be abraded with sandpaper #240.

The sandpaper is moved slowly in one direction between 10 times and 20 times. The force on the sandpaper shall be between 4,9 N and 9,8 N.

Then the stamp is rotated over an arbitrary angle and the previous process is repeated.

Rotating and abrading shall be repeated at least 30 times.

D.3 Preparation of ink

The ink to print the AFP shall be composed of the following components:

— M: Methoxy Propanol (1-Methoxy-2-Propanol);

— T: Triolein (purity of at least 60 %);

— D: Standard Dust (according to specifications defined in JIS Z 8 901, selected grade: class 11 KANTO loam).[1)]

The components M, T and D shall be mixed in the mass ratio 240:20:8. The mixture shall be stirred rapidly using a plastic stick for at least 15 s by hand. Every time mixing the solution, the stirring stick shall be cleaned by ethyl alcohol.

D.4 Preparation of ink pad

To guarantee a fixed amount of ink taken up by the stamp, the ink is spin coated onto the ink pad, which pad shall be an injection-molded polycarbonate Substrate without any pit or groove pattern. Just before applying the ink on the disk, it shall be stirred very well, e.g. by ultrasonic vibration for at least 30 s.

While rotating the Substrate on a spinner at 60 revolutions per minute, within 10 s, at least 2 ml of the ink solution is applied on it at a radius of about 12 mm (see Figure D.3).

1) For further information, contact the Association of Powder Process Industry and Engineering, Japan (http://www.appie.or.jp/english/).

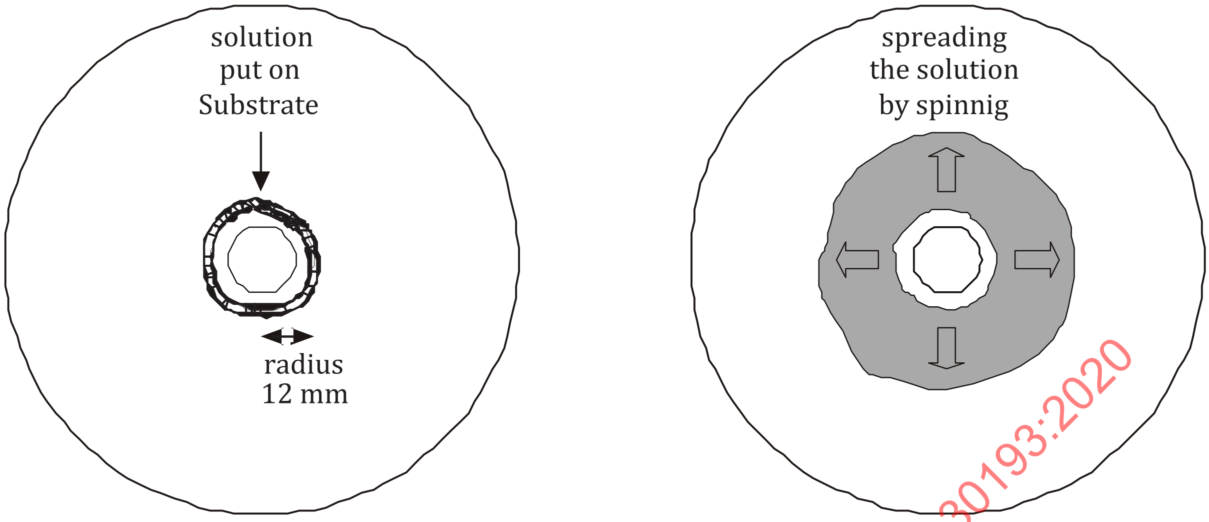


Figure D.3 — Spin coating ink pad

After applying the ink on the disk, the rotational speed shall be 100 revolutions per minute for one second, then the speed shall be increased linearly to 5 000 revolutions per minute in 5 s, which speed shall be held for 1 s (see Figure D.4). The spin-down time is not critical.

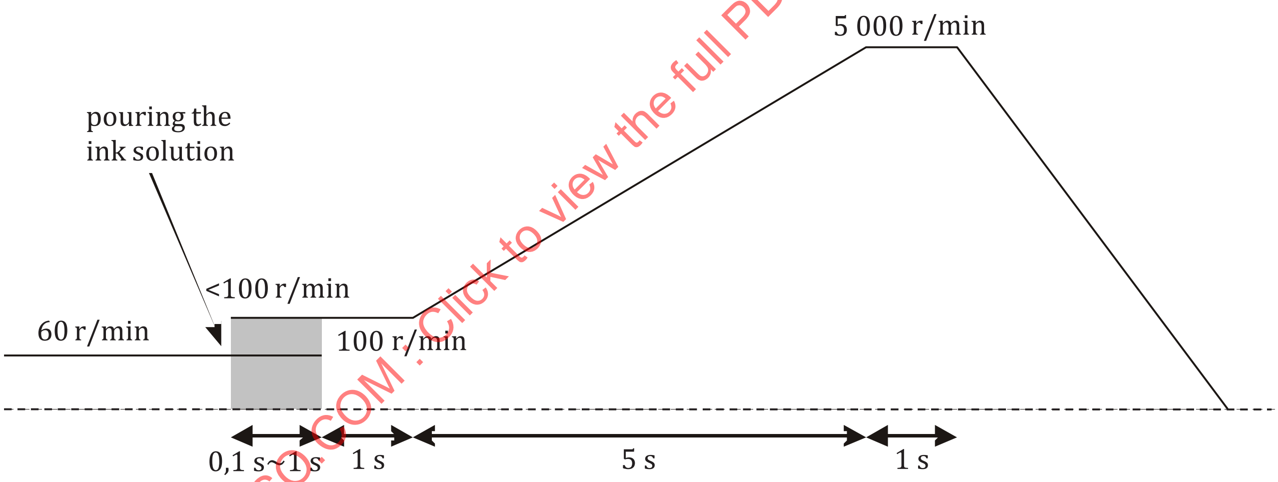


Figure D.4 — Speed profile for spin coating ink pad

D.5 Using ink pad and stamp

The recommended location for applying ink to the stamp is around radius 30 mm.

The stamp can be cleaned with lint-free tissues, such as BEMCOT.

The stamp can be cleaned first with a tissue wetted with ethyl alcohol, after which it can be wiped off with a dry tissue.

Annex E
(normative)

Measurement of wobble amplitude

E.1 Measurement methods

The wobble signal and the push–pull signal shall be filtered before measurement. The wobble signal shall be filtered through a 16 MHz low-pass filter, the push–pull signal through a 30 kHz low-pass filter.

Because of the wobble beat and the modulation of the grooves, it is very difficult to determine the wobble signals sufficiently accurately by normal oscilloscope measurement. Therefore, it is prescribed to measure the wobble signals by means of a spectrum analyzer according to the following procedures (while continuously tracking the spiral groove):

Step 1) Measurement of non-NWS

Under the tracking requirements of 25.3.4, the push–pull signal shall be measured by a spectrum analyzer with the following settings:

— centre frequency: 1 913,043 kHz;

— span: zero span;

— resolution bandwidth: 30 kHz;

— video bandwidth: 100 Hz;

— sweep time: set it such that several beats in the wobble signal can be observed.

Under these conditions, the spectrum analyzer shows the RMS value of the input signal as a function of time (see Figure E.1).

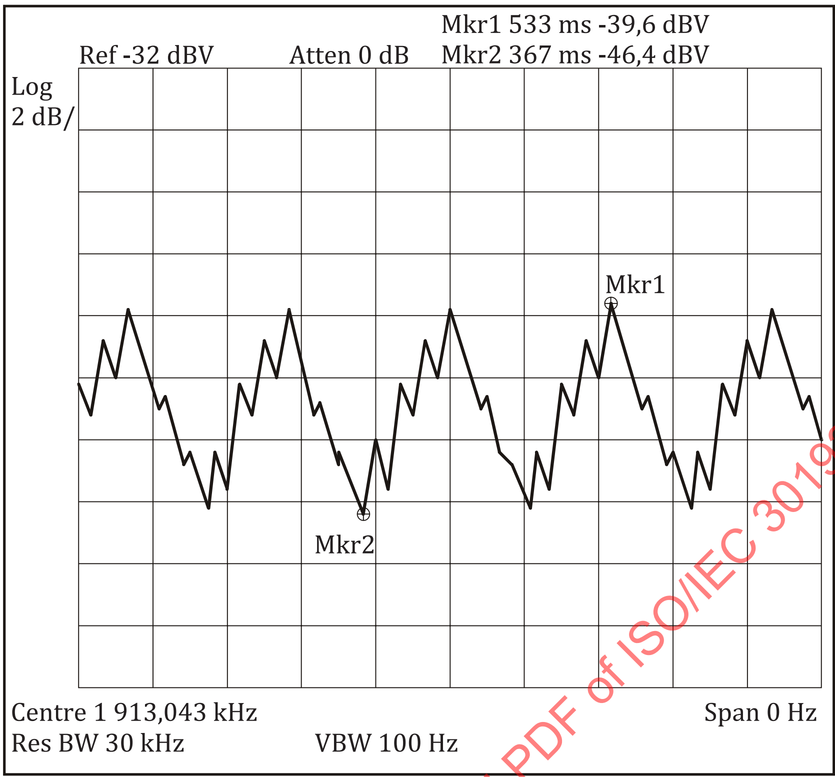


Figure E.1 — Example of spectrum analyzer showing wobble signal

The signal level at marker Mkr2 represents the minimum wobble signal WS_{min} in dBV. Because the spectrum analyzer measures RMS values, a multiplication factor of 2 × √2 shall be added to translate the measured value into volts peak-to-peak (−46,4 dBV in the example corresponds to 13,5 mVpp).

Step 2) Measurement of the non-normalized push–pull signal

Next the open-loop push–pull signal $(I_1 - I_2)_{pp}$ is measured (see 25.4):

Suppose for this example the value is 30 mVpp.

Step 3) Calculate the NWS

$$\mathrm{NWS}_{min} = \frac{\mathrm{WS}_{min}}{(I_1 - I_2)_{pp}} = \frac{13{,}5}{30} = 0{,}45$$

Step 4) Determine the wobble beat

The signal level at marker Mkr1 represents the maximum wobble signal WS_{max} in dBV.

The wobble beat is as per Formula (E.1):

$$\mathrm{WS}_{max} - \mathrm{WS}_{min} = 6{,}8 \text{ dB or } \mathrm{NWS}_{max} = 2{,}2 \times \mathrm{NWS}_{min} \quad \text{(E.1)}$$

Step 5) Measurement of the CNR of the wobble signal

Under the tracking requirements of 25.3.4, the push–pull signal shall be measured by a spectrum analyzer with the following settings:

— centre frequency: 1 MHz;

— span: zero span;

— resolution bandwidth: 30 kHz;

— video bandwidth: 10 Hz;

— sweep time: set it such that several beats in the wobble signal can be observed.

Under these conditions, the spectrum analyzer shows the RMS value of the noise signal in the band around 1 MHz as a function of time (see Figure E.2).

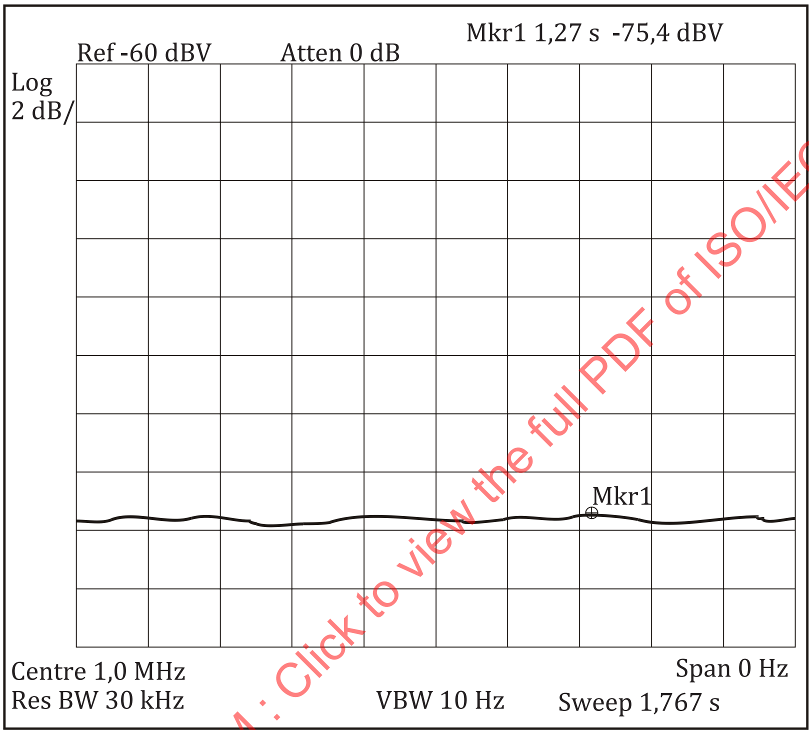


Figure E.2 — Example of spectrum analyzer showing noise signal

The signal level at marker Mkr1 represents the level of the noise signal in dBV.

The wobble CNR, in dB, can now easily be calculated to be as per Formula (E.2):

$$WS_{min} - NoiseLevel = -46,4 + 75,4 = 29 \text{ (according to the example values)} \quad (E.2)$$

Step 6) Measurement of the SHD/SHL

This measurement shall be performed as indicated in 27.3.4.

Under the tracking requirements of 25.3.4, the push–pull signal shall be measured by a spectrum analyzer with the following settings:

For fundamental frequency level measurements:

— centre frequency: 1 913,043 kHz;

— span: zero span;

— resolution bandwidth: 10 kHz;

— video bandwidth: 1 Hz;

— sweep time: about 5 seconds.

For second-harmonic level measurements:

— centre frequency: 3 826,0 kHz;

— span: zero span;

— resolution bandwidth: 10 kHz;

— video bandwidth: 1 Hz;

— sweep time: about 5 seconds.

Under these conditions, the spectrum analyzer shows the RMS value of the fundamental frequency levels in the data zone and protection-zone 3 as functions of time, see Figure E.3.

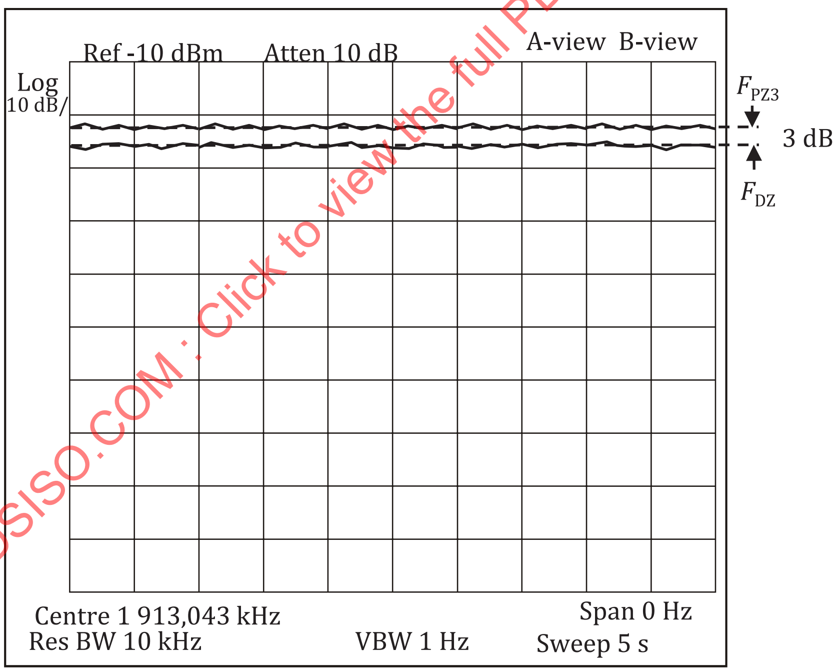


Figure E.3 — Example of fundamental wobble frequency level measurement

In Figure E.3, the lower trace represents the fundamental-frequency level measurement in any rewritable area of the data zone, indicated as F_{DZ}.

In Figure E.3, the upper trace represents the fundamental-frequency level measurement in protection zone 3, indicated as F_{PZ3}.

F_{DZ} and F_{PZ3} values are determined at the average levels of the F_{DZ} and F_{PZ3} traces.

Likewise, the spectrum analyzer shows the RMS value of the second-harmonic levels in the data zone and protection-zone 3 as functions of time, see Figure E.4.