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Information technology — Digitally recorded media for information interchange and storage — 120 mm Triple Layer (100,0 Gbytes single sided disk and 200,0 Gbytes double sided disk) and Quadruple Layer (128,0 Gbytes single sided disk) BD Recordable disk

Technologies de l'information — Supports enregistrés numériquement pour échange et stockage d'information — 120 mm de couche triple (100,0 Go disque unique face et 200,0 Go disque double face) et quadruple couche (128,0 Go disque unique face) sur disque enregistrable BD

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Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work. In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1.

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

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

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

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/IEC JTC 1, *Information technology*, SC 23, *Digitally recorded media for information interchange and storage.*

This second edition cancels and replaces (ISO/IEC 30191: 2013), of which it constitutes a minor revision.

Introduction

In March 2002, 9 companies started BDF (Blu-ray Disc Founders) aiming for the creation of the Formats with large capacity and high speed transfer rate, that enable the recording and reproducing of the high definition video contents. In October 2004, more than 100 companies joined and BDF was changed to an open forum named BDA (Blu-ray Disc Association). In October 2005, BDA issued the first version of the Blu-ray Disc™ Recordable Format Part1 and in April 2008 Version 1.3 of Blu-ray Disc™ Recordable Format Part1 was issued, which enabled the Recording Velocity up to 6x. In June 2010, BDA issued Blu-ray Disc™ Recordable Format Part1 Version 2.0, which specifies the TL and QL of BD Recordable disk.

By the end of 2010, over 100 million Blu-ray Disc™ had already 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 February and January of 2011, the chairs of ISO/IEC JTC 1/SC 23 and JIIMA (Japan Image & 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 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 Standard of the basic physical formats for the Recordable and Rewritable Blu-ray™ Formats.

In December of 2011, the BDA sent project proposals for the International standardization of four formats to ISO/IEC JTC 1/SC 23 via the Japan national body. In July of 2013, ISO/IEC published the four International standards. They are ISO/IEC 30190 - 120 mm Single Layer (25,0 Gbytes per disk) and Dual Layer (50,0 Gbytes per disk) BD Recordable disk, ISO/IEC 30192 - 120 mm Single Layer (25,0 Gbytes per disk) and Dual Layer (50,0 Gbytes per disk) BD Rewritable disk, ISO/IEC 30191 - 120 mm Triple Layer (100,0 Gbytes per disk) and Quadruple Layer (128,0 Gbytes per disk) BD Recordable disk and ISO/IEC 30193 - 120 mm Triple Layer (100,0 Gbytes per disk) BD Rewritable disk.

In July of 2014, the BDA developed a double sided Triple Layer BD Recordable disk of 200,0 Gbytes and revised Blu-ray Disc™ Recordable Format Part1 Version 2.0 to Version 2.1. In the same month, the BDA sent a project proposal to revise ISO/IEC 30191 to include the double sided Triple Layer BD Recordable disk to ISO/IEC JTC 1/SC 23 via the Japan national body. The revised edition of ISO/IEC 30191 includes the 120 mm Triple Layer (100,0 Gbytes single sided disk and 200,0 Gbytes double sided disk) and Quadruple Layer (128,0 Gbytes single sided disk) BD Recordable disk.

This International Standard specifies the mechanical, physical and optical characteristics of a 120 mm recordable optical disk with a capacity of 100,0 Gbytes, 128,0 Gbytes or 200,0 Gbytes.

A few additional specifications are required in order to write and read video-recording applications, such as the BDMV and BDAV formats, which have been specified by the BDA for use on BD Recordable disks. These specifications, which are related to the Application, the file system or the Content-protection system, are required for the disk, the generating system and the receiving system. For more information of the 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 patents.

ISO and IEC take no position concerning the evidence, validity and scope of these patent rights.

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ISO (http://www.iso.org/patents) and IEC (http://patents.iec.ch) maintain on-line databases of patents relevant to their standards. Users are encouraged to consult the databases for the most up to data information concerning patents.

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

Information technology — Digitally recorded media for Information interchange and storage — 120 mm Triple Layer (100,0 Gbytes single sided disk and 200,0 Gbytes double sided disk) and Quadruple Layer (128,0 Gbytes single sided disk) BD Recordable disk

1 Scope

This International Standard specifies the mechanical, physical and optical characteristics of a 120 mm recordable optical disk with a capacity of 100,0 Gbytes, 128,0 Gbytes or 200,0 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 once and read many times using a non-reversible method. This disk is identified as BD Recordable disk.

This International Standard specifies

— three related but different Types of this disk,

— 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 the data from the disk.

This International Standard 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 Conformance

2.1 Optical disk

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

2.2 Generating system

A generating system shall be in conformance with this International Standard if the optical disk it generates is in accordance with 2.1.

2.3 Receiving system

A receiving system shall be in conformance with this International Standard if it is able to handle both a Type TL disk and a Type QL disk according to 2.1. Handling of a Type TL/D disk is optional for a receiving system. See Clause 7 for the Types of disk.

2.4 Compatibility statement

A claim of conformance by a Generating or Receiving system with this International Standard 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.

3 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

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

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*

4 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

4.1
Application
application specified for a BD, for instance a video application, which requires some areas for a Content-protection system and for its own Defect-Management system on the disk

4.2
BD
disk having a thin Cover Layer of around 0,1 mm thick and a Substrate around 1,1 mm thick on which data is read or recorded by an OPU using - 405 nm laser diode and NA = 0,85 lens

Note1 to entry User Data recorded on the disk is formatted using the 17PP modulation and an LDC+BIS Code.

4.3
Case
housing for an optical disk, that protects the disk and facilitates disk interchange

4.4
Channel bit
element by which the binary value ZERO or ONE is represented by Marks and Spaces on the disk

4.5
Cover Layer
transparent layer with precisely-controlled optical properties that covers the Recording Layer closest to the Entrance surface of the disk

4.6
Data Zone *n*
area between the Inner Zone and the Outer Zone on Layer L*n*

4.7
Defective Cluster
Cluster in a User-Data Area that has been registered in a Defect List as unreliable or uncorrectable

4.8
Digital-Sum Value (DSV)
arithmetic sum obtained from a bit stream by assigning the decimal value +1 to Channel bits set to ONE and the decimal value −1 to Channel bits set to ZERO

4.9
Disk reference plane
plane defined by the perfect flat annular surface of an ideal spindle, onto which the Clamping Zone of the disk is clamped, that is normal to the axis of rotation

4.10
Embossed HFM Area
area on the disk where information has been stored by means of an HFM Groove during the manufacture of the disk

4.11
Entrance surface
surface of the disk onto which the optical beam first impinges

4.12
Groove
trench-like feature of the disk, connected to a Recording Layer

Note1 to entry One Groove can be carried by the Substrate and the other Groove by the Spacer Layer or the Cover Layer, (see Figure 1, Figure 2 and Figure O.1). Grooves are used to define Track location. The Groove corresponds to the area that has been exposed to the mastering spot. In general the Groove can be a depression in the carrier, or elevation on the carrier. If the Groove is nearer to the Entrance surface than the Land (see Figure 55), the recording method is called “On-Groove recording”. In the BD Recordable system there are three types of Grooves:

— Wobbled Groove in Recordable Areas containing address information, and
— HFM Groove in Embossed HFM Areas containing Permanent Information and Control data, and
— Straight Groove without any modulation in the BCA Zone.

4.13
HFM (High-Frequency Modulated) Groove
Groove modulated in the radial direction with a rather high bandwidth signal

Note1 to entry HFM Groove creates a data channel with sufficient capacity and data rate for replicated information.

4.14
Information Area
area on the disk in which information can be recorded

4.15
Information Zone
actually recorded part of the Information Area

4.16
Land
surface of the Recording Layer between successive windings of a Groove

4.17
Layer L*n*
one Recording Layer of the disk identified by *n*

Note1 to entry Layer L(*n*+1) is closer to the Entrance surface of the disk than Layer L*n*.

4.18
Marks
feature of the Recording Layer which may take the form of lower/higher reflectivity domains in the Unrecorded Recording Layer, that can be sensed by the optical read-out system

Note1 to entry The pattern of Marks and Spaces represents the data on the disk.

4.19
Measurement Velocity
linear velocity at which the disk is measured during reading

Note1 to entry *n*x Measurement Velocity means the Measurement Velocity of *n* times the Reference Velocity.

4.20
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

4.21
NRZ/NRZI conversion
method of converting a Modulation-bit stream into a physical signal

4.22
Padding
process in a drive to fill up the missing Sectors in a 64K Cluster, which is consisting of 32 Sectors, with all 00h data when the host supplies less than the 32 Sectors and need to fill up the Cluster

4.23
Pits
features of the Recording Layer which may take the form of depressions in or elevations on the Land surface, that can be sensed by the optical read-out system

Note1 to entry The pattern of Pits and Spaces represents the data on the disk.

4.24
Polarization
direction of the electric field vector of an optical beam

Note1 to entry The plane of Polarization is the plane containing the electric field vector and the direction of propagation of the beam.

4.25
Pre-recorded Area
area on the disk where information has been recorded by the manufacturer/supplier of the disk by applying standard recording techniques after finishing of the replication process

4.26
Protective Coating
optional additional layer on top of the Cover Layer provided for extra protection against scratches and other types of damage

4.27
Recordable Area
area on the disk where information is recorded by means of Marks and Spaces according to the data format as defined in Clause 13, either by the manufacturer/supplier of the disk or by the end user of the disk

Note1 to entry The Recording Layer material in the Area is composed such that once the layer has been recorded, any attempt to change the information will result in Unreadable Data.

4.28
Recording Layer
part of the disk consisting of a stack of films of specific materials on or in which data is written during manufacture and/or use

4.29
Recording Velocity
linear velocity at which the disk is actually recorded

Note1 to entry *n*x Recording Velocity means the Recording Velocity of *n* times the Reference Velocity.

4.30
Reference Velocity
linear velocity that results in the nominal Channel-bit rate of 66,000 Mbit/s

Note1 to entry *n*x Reference Velocity means *n* times the Reference Velocity.

4.31
Reserved
<value> not used in this International Standard

Note1 to entry In future standards, the value can be released.

4.32
Reserved
<field>not specified in use, to be ignored in interchange and to be set to ZERO as value

Note1 to entry In future standards, the use of a field can be defined and value(s) can be assigned.

4.33
Sector
minimum-size addressable data part of a Track in the Information Zone

4.34
Spacer Layer
transparent layer with precisely-controlled optical properties separating two Recording Layers

4.35
Spaces
areas separating Pits or Marks in the tangential direction in the context of HF signals

Note1 to entry The pattern of Pits/Marks and Spaces represents the data on the disk.

4.36
Substrate
layer which may be transparent or not, provided for the mechanical support of the Recording Layer(s)

4.37
Track
360° turn of a continuous spiral, formed by a Groove

4.38
Track Pitch
distance between centrelines of a Groove in adjacent Tracks, measured in the radial direction

4.39
Transmission Stack
all layers together between the Entrance surface of the disk and the Recording Layer concerned

Note1 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.

4.40
User-Data Area
collection of all Data Zone(s) on the disk and consists only of the Clusters in which User Data can be recorded

4.41
Virgin Groove
blank Groove on the disk which has never been recorded

4.42
Wobbled Groove
Groove that has a periodic sinusoidal deviation from its average centreline

Note1 to entry By modulating the sinusoidal deviation, the wobble provides address information and general information about the disk.

4.43
Zone
annular area of the disk

5 Conventions and notations

5.1 Terminology

5.1.1 Meaning of words

In this International Standard the following words have a special meaning:

May: indicates an action or feature that is optional.
Optional: describes a feature that may or may not be implemented. If implemented, the feature shall be implemented as described.
Shall: indicates an action or feature that is mandatory and must be implemented to claim compliance to this specification.
Should: indicates an action or feature that is optional, but its implementation is strongly recommended.

5.1.2 Levels of grouping

Many times data is 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 will be 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 will be allocated to a (fixed) number of consecutive Clusters.

5.2 Representation of numbers

A measured value $x_{\mathbf{measured}}$ 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 $1{,}235 \le x_{\mathbf{measured}} < 1{,}275$ fulfills this specification.

— The specification is: $x \le 0{,}3$:
  — A measured value $x_{\mathbf{measured}} < 0{,}35$ fulfills this specification (rounding off is applied for $0{,}30 < x_{\mathbf{measured}} < 0{,}35$: $x_{\mathbf{rounded}} = 0{,}3$).

— The specification is: $x < 0{,}3$:
  — A measured value $x_{\mathbf{measured}} = 0{,}299$ fulfills this specification (no rounding off needs to be applied).
  — A measured value $x_{\mathbf{measured}} = 0{,}3$ exactly does not fulfill this specification.

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

EXAMPLEs:

— The specification is maximum 0,3 mm :
  — A measured value of 0,300 mm fulfills this specification.
  — A measured value of 0,301 mm does not fulfill this specification.

— The specification is minimum 3 dB :

- A measured value of 3,00 dB fulfills this specification.
- A measured value of 2,99 dB does not fulfill this specification.

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

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

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

The setting of bits is denoted by ZERO and ONE.

In data fields composed of bytes, the data is recorded so that the Most-Significant Byte (MSB), identified as Byte 0, shall be recorded first and the Least-Significant Byte (LSB) last.

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

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

In a field of 4n 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 1, 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).

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

5.3 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

floor(x) represents the largest integer number ≤ x

For example: floor(+3,7) = +3 floor(–3,7) = –4

5.4 Names

The names of specific entities, e.g. particular tracks, fields, etc., are given with an initial capital. Other terms having explicitly-defined meanings for the purposes of this document are also capitalized.

6 List of acronyms

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
BP	Byte Position
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
DSV	Digital-Sum Value
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
LRA	Last-Recorded Address
LSB	Least-Significant Byte
lsb	least-significant bit
LSN	Logical-Sector Number
MM	MSK Mark
MSB	Most-Significant Byte
ms	millisecond
msb	most-significant bit
MSK	Minimum-Shift Keying
MW	Monotone Wobble
NA	Numerical Aperture
NHWS	Normalized HFM-Wobble Signal
NRZ	Non-Return-to-Zero
NRZI	Non-Return-to-Zero Inverting
ns	nanosecond
NWA	Next-Writable Address
NWL	Nominal Wobble Length
NWS	Normalized Wobble Signal
OPU	Optical Pick-up Unit
PAA	Physical ADIP Address
PIC	Permanent Information & Control data
PLL	Phase-Lock Loop

PoA	Post-amble
PP	Push-Pull
pp	peak-to-peak
PrA	Pre-amble
ps	picosecond
PSN	Physical-Sector Number
QL	Quadruple Layer
RH	Relative Humidity
RIN	Relative-Intensity Noise
RMTR	Repeated Minimum-Transition Run-length
RS	Reed-Solomon (code)
RT	Relative Thickness
RUB	Recording-Unit Block
RxIn	Reflectivity × In Resolution
RxM	Reflectivity × Modulation
SER	Symbol Error Rate
SHD	Second-Harmonic Distortion
SHL	Second-Harmonic Level
SL	Single Layer
SNR	Signal-to-Noise Ratio
SRM	Sequential-Recording Mode
SRR	Sequential-Recording Range
SRRI	Sequential-Recording Range Information
STW	Saw-Tooth Wobble
Sync	Synchronization
TDDS	Temporary Disk-Definition Structure
TDFL	Temporary Defect List
TDMA	Temporary Disk-Management Area
TDMS	Temporary Disk-Management Structure
TL	Triple Layer
TL/D	Triple Layer Double-sided
TP	Track Pitch
TS	Transmission Stack
V_{ref}	Reference Velocity
wbs	wobbles

7 General description of disk

This International Standard provides for three Types of disks.

Type TL disk: The 120 mm optical disk consists of a Substrate of about 1,1 mm nominal thickness. The Substrate is covered with three Recording Layers. The Recording Layers consist 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 Layers, a transparent Cover Layer of about 57,0 µm is applied with accurately defined optical characteristics (see Figure 1).

Type QL disk: The 120 mm optical disk consists of a Substrate of about 1,1 mm nominal thickness. The Substrate is covered with four Recording Layers. The four Recording Layers are separated by three transparent Spacer Layers whose thickness are about 15,5 µm, 19,5 µm and 11,5 µm, respectively in this order from the Substrate, and on top of these Recording Layers, a transparent Cover Layer of about 53,5 µm is applied (see Figure 2).

Type TL/D disk: The 120 mm optical disk consists of a Substrate of about 1,0 mm nominal thickness. The Substrate is covered with three Recording Layers on each side. The Recording Layers of each side have the same characteristics and structure as a Type TL disk (see Figure O.1). The three Recording Layers on each side of a disk can be accessed from the side only. Requirements specific for a Type TL/D disk are defined in Annex O. All requirements for a Type TL disk shall be applied to a Type TL/D disk unless otherwise described including Annex O.

The first (Layer L2) and second (Layer L1) Recording Layers of a Type TL disk and a Type TL/D disk and the first (Layer L3), second (Layer L2) and third (Layer L1) Recording Layers of a Type QL disk seen from the read-out side of the disks shall be semi-transparent.

To improve the scratch resistance, the Cover Layer optionally can be protected with an additional hard coating.

Clamping is performed in the Clamping Zone.

Data can be written onto the disk with a high power focused optical beam. The data can be read with a low power focused optical beam, using the difference in the reflectivity of the Marks and the Spaces.

The Recording Layer(s) contain Wobbled Groove (s) with addresses, which serve as a speed control and navigation system for the data to be written to the Recording Layer concerned.

Recording and read-out of the data is accomplished through the Cover Layer or through the total stack of Cover Layer, Recording Layers and Spacer Layers, depending on which Recording Layer is involved.

Depending on which Recording Layer is to be accessed, the optical beam passes through the transparent Cover Layer (reading/writing Layer L2 on a Type TL disk or a Type TL/D disk, or Layer L3 on a Type QL disk) or through the transparent Cover Layer, the semi-transparent Recording Layer(s) and the transparent Spacer Layer(s) (reading/writing Layer L0 and Layer L1 on a Type TL disk or a Type TL/D disk, or Layer L0, Layer L1 and Layer L2 on a Type QL disk).

A TL disk and a QL disk also denote a Type TL disk and a Type QL disk respectively in this International Standard.

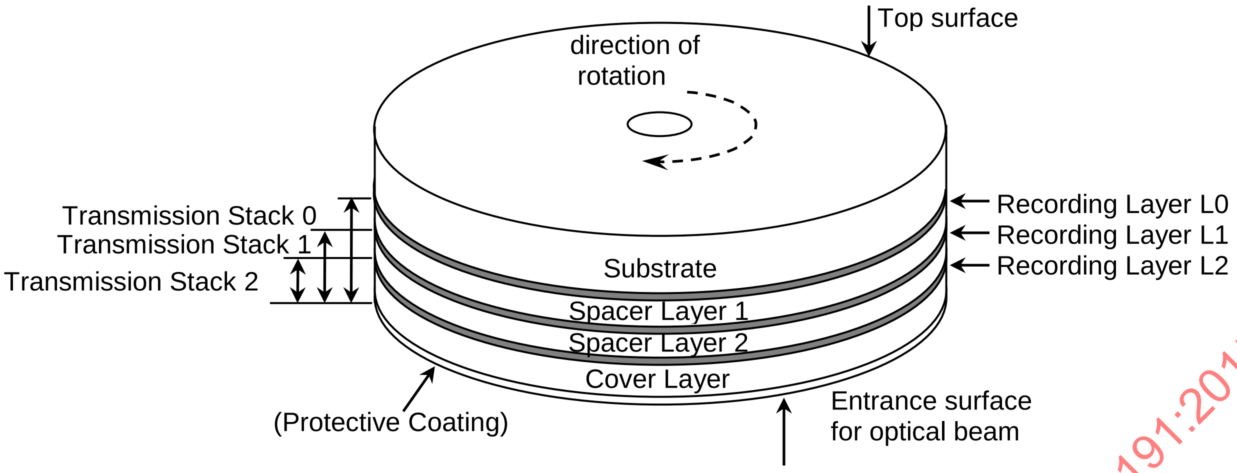


Figure 1 — Outline of Type TL disk

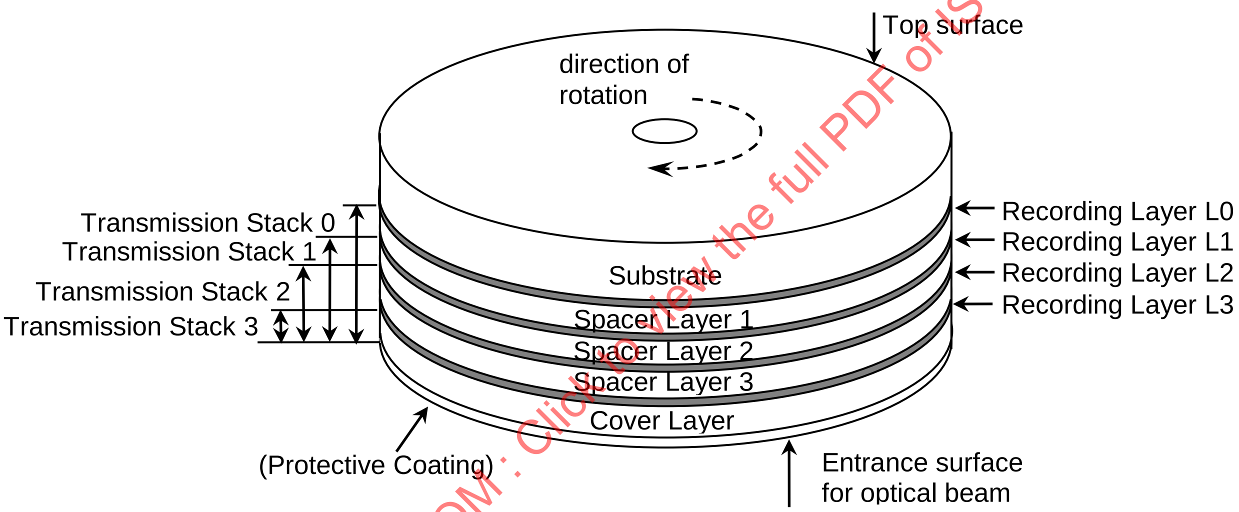


Figure 2 — Outline of Type QL disk

This International Standard specifies two kinds of Recording Velocity 2x, 4x.

Figure 3 shows the Recording Velocity requirements for each Disk Type.

Disk Type	Push-Pull polarity	Layer Type	Recording Velocity	
			2x	4x
Type TL Type TL/D	On-Groove [a]	TL	m	m
Type QL	On-Groove [a]	QL	m	m

m Mandatory
o Optional
[a] Groove polarity shall be On-Groove for both Layer L0 and Layer L1

Figure 3 — Recording Velocity requirements for Disk Type

8 General requirements

8.1 Environments

8.1.1 Test environment

8.1.1.1 General

During measurements for testing 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 :	(23 ± 2) °C
— relative humidity :	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.

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

b) apply a sudden change in temperature, while keeping the absolute humidity at a constant level (about 10,4 g/m³): temperature = 25 °C, relative humidity = 45 % ⇒ temperature = 55 °C, relative humidity = 10 % (see Figure 4).

8.1.2 Operating environment

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

— temperature :	5 °C to 55 °C
— relative humidity :	3 % to 90 %
— absolute humidity :	0,5 g/m³ to 30 g/m³
— 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.

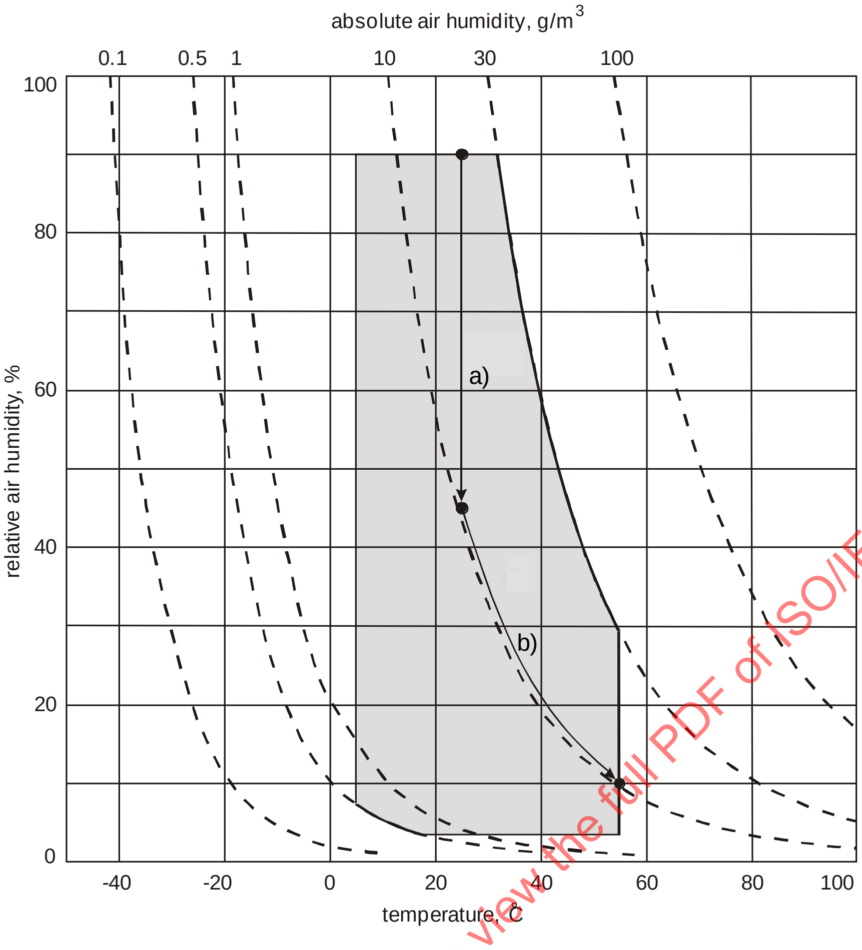


Figure 4 — Operating environment

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 : –10 °C to 55 °C
- relative humidity : 5 % to 90 %
- absolute humidity : 1 g/m³ to 30 g/m³
- 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 hours.

- 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) hours, 6 cycles.

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

8.1.4 Transportation

8.1.4.1 General

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

8.1.4.2 Packaging

8.1.4.2.1 General

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

8.1.4.2.2 Temperature and humidity

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

8.1.4.2.3 Impact loads and vibrations

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

b) Avoid dropping the disk.

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

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

8.2 Safety requirements

The disk shall satisfy the requirement of Standard 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 Standard 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 write and read parameters is shown in Figure 5. Different components and locations of components are permitted, provided that the performance remains the same as that of the set-up in Figure 5.

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

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

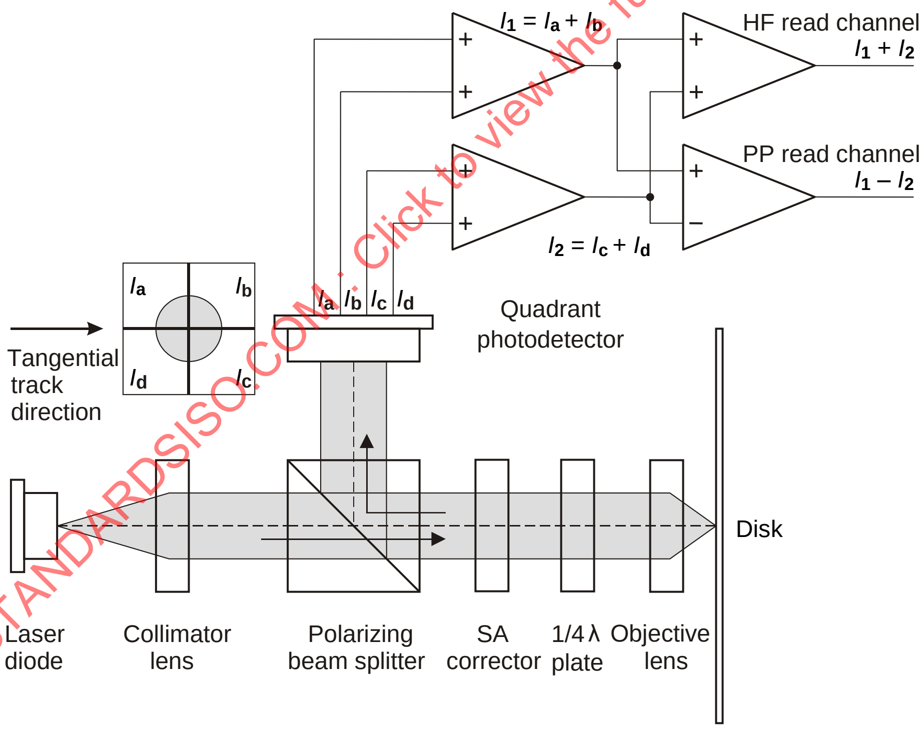


Figure 5 — Optical system of Reference drive

A combination of 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 layers can influence the measurements on the layer under investigation. To cope with these effects, the photodetector shall have defined 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 TL disk or a QL disk, however, the effect cannot be neglected even if length and width of the photodetector is 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 listed below:

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

— Polarization: circular

— Numerical aperture: 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: –125 dB/Hz

$$\left[10 \times \log\left(\frac{\text{ac light power density / Hz}}{\text{dc light power}}\right)\right]$$

— Normalized detector size: $S / M^2 \leq 25$ µm²
(where S is the total surface of the quadrant photodetector)

— Read power for disk testing (average)
  - — Layer L0 and Layer L1 for a TL disk: (1,20 ± 0,10) mW
  - — Layer L2 for a TL disk: (1,10 ± 0,10) mW
  - — Layer L0, Layer L1 and Layer L2 for a QL disk: (1,20 ± 0,10) mW
  - — Layer L3 for a QL disk: (1,10 ± 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 User Data can be retrieved. This signal is generated by summing the currents from all four elements of the photodetector ($I_a+I_b+I_c+I_d$). These currents are modulated by the user-written information, due to the difference in reflectivity of the Marks and Spaces.

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 and the PLL, etc. are specified in Annex H.

9.6 Radial PP read channel

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

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

The read amplifiers including the photodetectors in the radial PP read channel shall have a flat amplitude response within ± 1,0 dB relative to their dc gain from dc to 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 6).

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

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

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

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

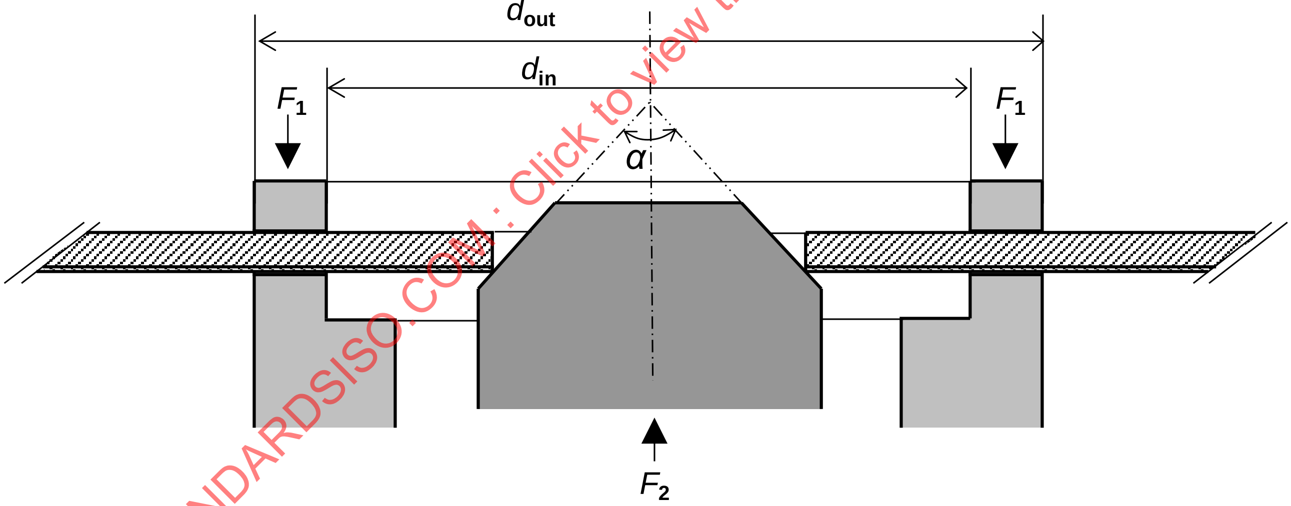


Figure 6 — Clamping conditions for measurement

9.8 Rotation of 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 2x Reference Velocity unless otherwise specified. This corresponds to a Constant Linear Velocity of

7,375 m/s for a TL disk with a User Data capacity of 33,368 GB per layer,

7,690 m/s for a QL disk with a User Data capacity of 32,000 GB per layer.

9.9 Normalized servo transfer function

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

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

where:

$\omega = 2\pi \times f$
$\omega_0 = 2\pi \times f_0$
$\omega_{int} = 2\pi \times f_{int}$
$i^2 = -1$
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 $\left(1 + \frac{\omega_{int}}{i\omega}\right)$ in the formula above represents an integrator function. Such an integrator or equivalent function is used to further reduce of low-frequency components, especially those due to deviations with frequencies equal to the rotational frequency of the disk or its harmonics.

Also, f_{int} is the 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 as follows:

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

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 disks Measurement Velocity refers to 9.10.2 and
- a Reference servo for 2x disks Measurement Velocity refers to 9.10.3.

The servo for all these conditions has the same basic characteristics with, however a modified integrator.

9.10.2 Reference servo for axial tracking at 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 7:

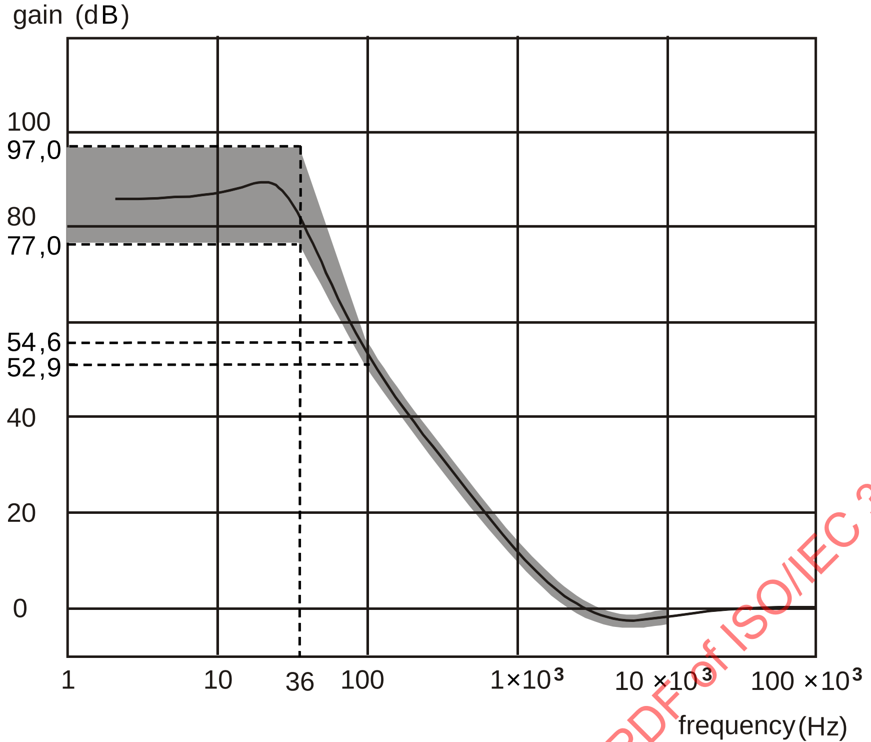


Figure 7 — Servo characteristic for axial tracking at 1x Measurement Velocity

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

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

The integrator shall be first order (K=1) with a crossover frequency of f_{int} = 100 Hz

In the frequency range 100 Hz to 10 kHz:

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

In the frequency range 36 Hz to 100 Hz:

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

In the frequency range up to 36 Hz:

$$77{,}0 \text{ dB} \leq |1+H(f)| \leq 97{,}0 \text{ dB}$$

The frequency f_x has the following value: $f_x = \frac{1}{2\pi}\sqrt{\frac{\alpha_{max}}{e_{max}}} = \frac{1}{2\pi}\sqrt{\frac{6{,}0}{55 \times 10^{-9}}} \approx 1{,}6 \text{ kHz}$

9.10.3 Reference servo for axial tracking at 2x 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 of the Figure 8:

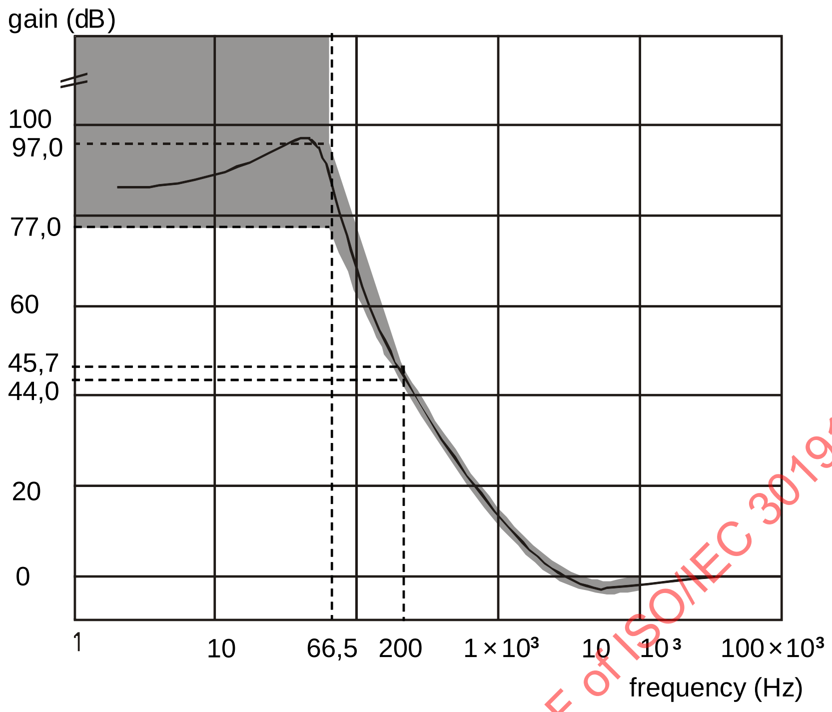


Figure 8 — Servo characteristic for axial tracking at 2x Measurement Velocity

The 0-dB crossover frequency f_0 shall be 3,2 kHz, the same as the measurement condition for the 1x Measurement Velocity.

For the maximum residual tracking error of 80 nm (see 11.4.3), this corresponds to an acceleration of

$$\alpha_{max} = \frac{(2\pi \times f_0)^2}{3} \times e_{max} = \frac{(2\pi \times 3{,}2 \times 10^3)^2}{3} \times 80 \times 10^{-9} = 10{,}8\,\text{m/s}^2 .$$

For the maximum residual tracking error of 110 nm (see 11.4.3), this corresponds to an acceleration of

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

The integrator shall be second order (K = 2) with the crossover frequency f_{int} = 200 Hz.

In the frequency range 200 Hz to 10 kHz:

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

In the frequency range 66,5 Hz to 200 Hz:

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

In the frequency range up to 66,5 Hz:

$|1 + H(f)| \geq 77$ dB

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 disks Measurement Velocity refers to 9.11.2, and
— a Reference servo for 2x disks Measurement Velocity refers to 9.11.3.

The servo for all conditions has the same basic characteristics, however with a modified integrator.

9.11.2 Reference servo for radial tracking at 1x Measurement Velocity

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

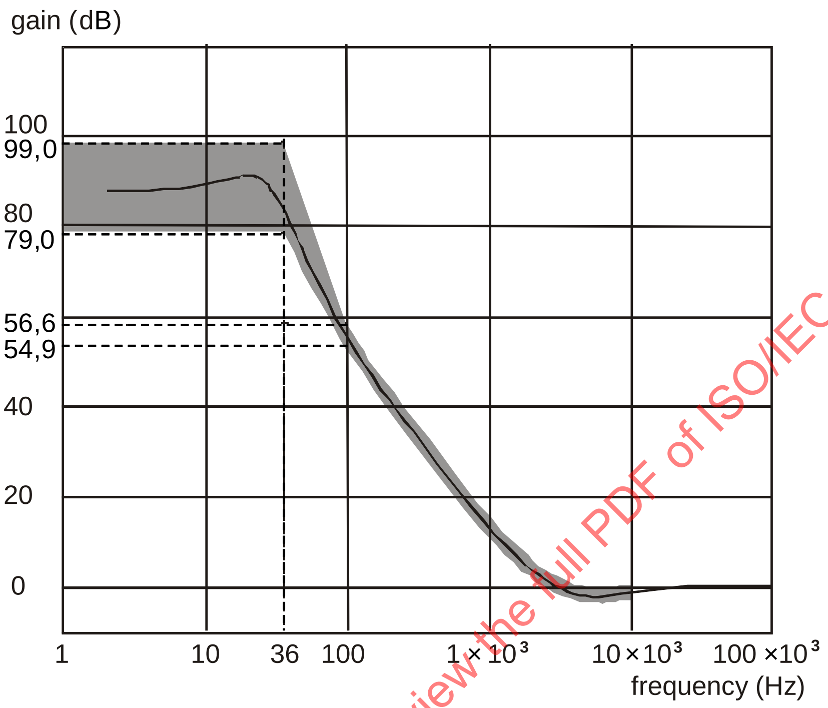


Figure 9 — Servo characteristic for radial tracking at 1x Measurement Velocity

The crossover frequency f_0 of $H_N(f)$ (see 9.9), which is used to define the limits of $|1+H(f)|$, is specified by the following formula. Here α_{max} = 2,2 m/s² is the worst-case maximum expected radial acceleration due to local disturbances. Here 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:

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

The integrator shall be first order with crossover frequency at f_{int} = 100 Hz

In the frequency range 100 Hz to 10 kHz:
$0{,}9 \times |1+H_N(f)| \leq |1+H(f)| \leq 1{,}1 \times |1+H_N(f)|$

In the frequency range 36 Hz to 100 Hz:

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

In the frequency range up to 36 Hz:
$79{,}0\ \mathrm{dB} \leq |1+H(f)| \leq 99{,}0\ \mathrm{dB}$

The frequency f_X has the following value: $f_X = \frac{1}{2\pi}\sqrt{\frac{\alpha_{max}}{e_{max}}} = \frac{1}{2\pi}\sqrt{\frac{2{,}2}{16 x 10^{-9}}} \approx 1{,}8\ \mathrm{kHz}$

9.11.3 Reference servo for radial tracking at 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 10:

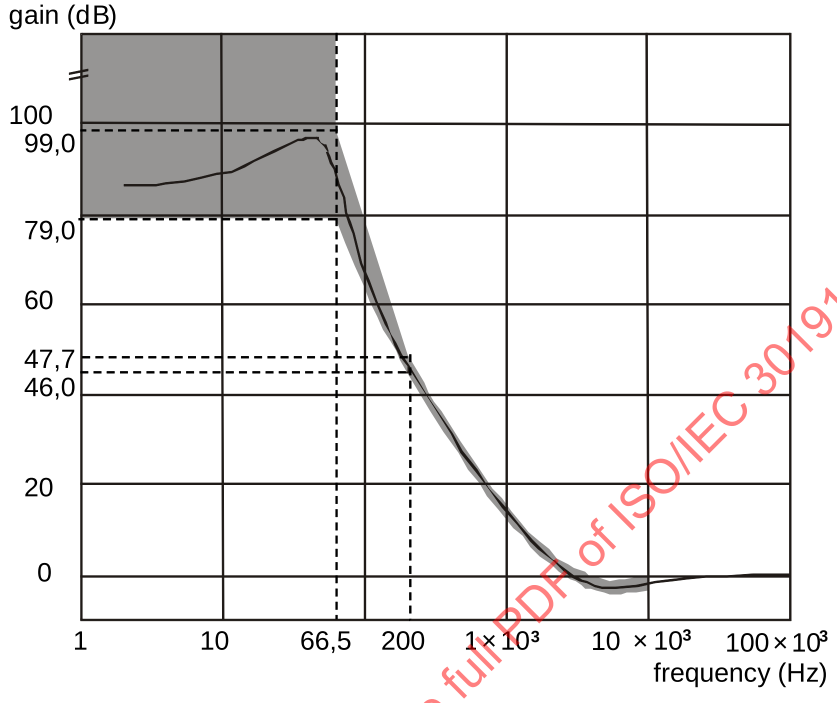


Figure 10 — Servo characteristic for radial tracking at 2x Measurement Velocity

The 0-dB crossover frequency f_0 shall be 3,6 kHz, the same as the measurement condition for the 1x Measurement Velocity. For the maximum residual tracking error of 20 nm (see 11.5.3), this corresponds to an acceleration of $\alpha_{max} = \frac{(2\pi \times f_0)^2}{3} \times e_{max} = \frac{(2\pi \times 3,6 \times 10^3)^2}{3} \times 20 \times 10^{-9} = 3,4\,\mathrm{m/s^2}$.

The integrator shall be second order (K = 2) with the crossover frequency at f_{int} = 200 Hz.

In the frequency range 200 Hz to 10 kHz:
$0,9 \times |1+H_N(f)| \leq |1+H(f)| \leq 1,1 \times |1+H_N(f)|$

In the frequency range 66,5 Hz to 200 Hz:

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

In the frequency range up to 66,5 Hz:
$|1+H_N(f)| \geq 79$ dB

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 11 shows the dimensional requirements in summarized form. The different parts of the disk are described from the centre hole to the outside Rim.

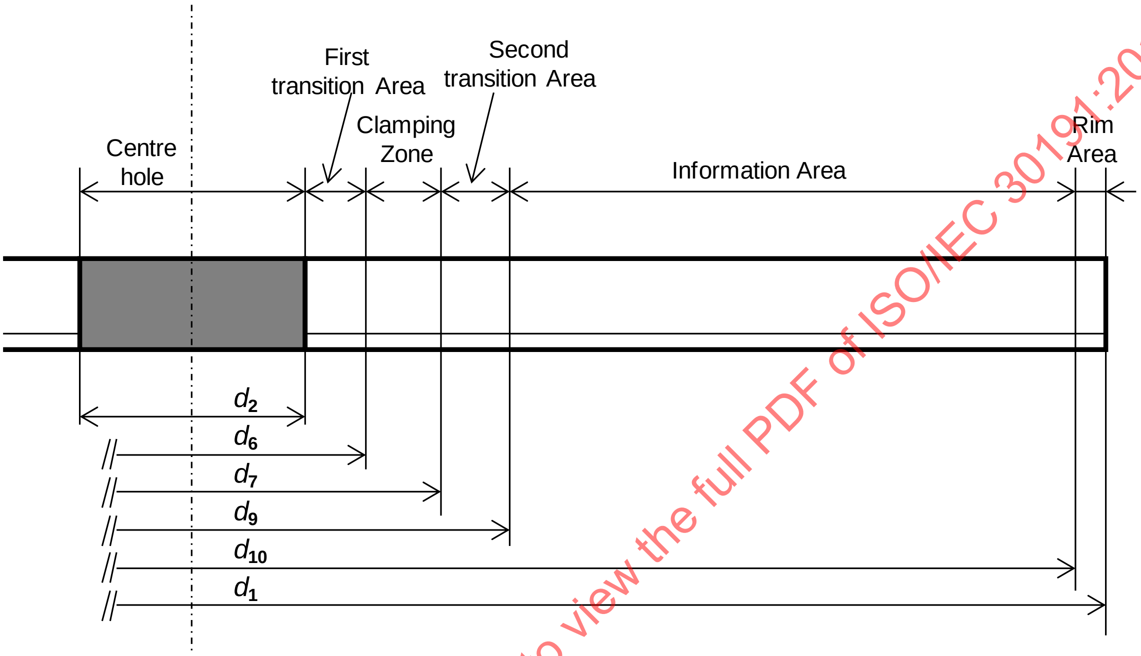


Figure 11 — Overview of disk dimensions

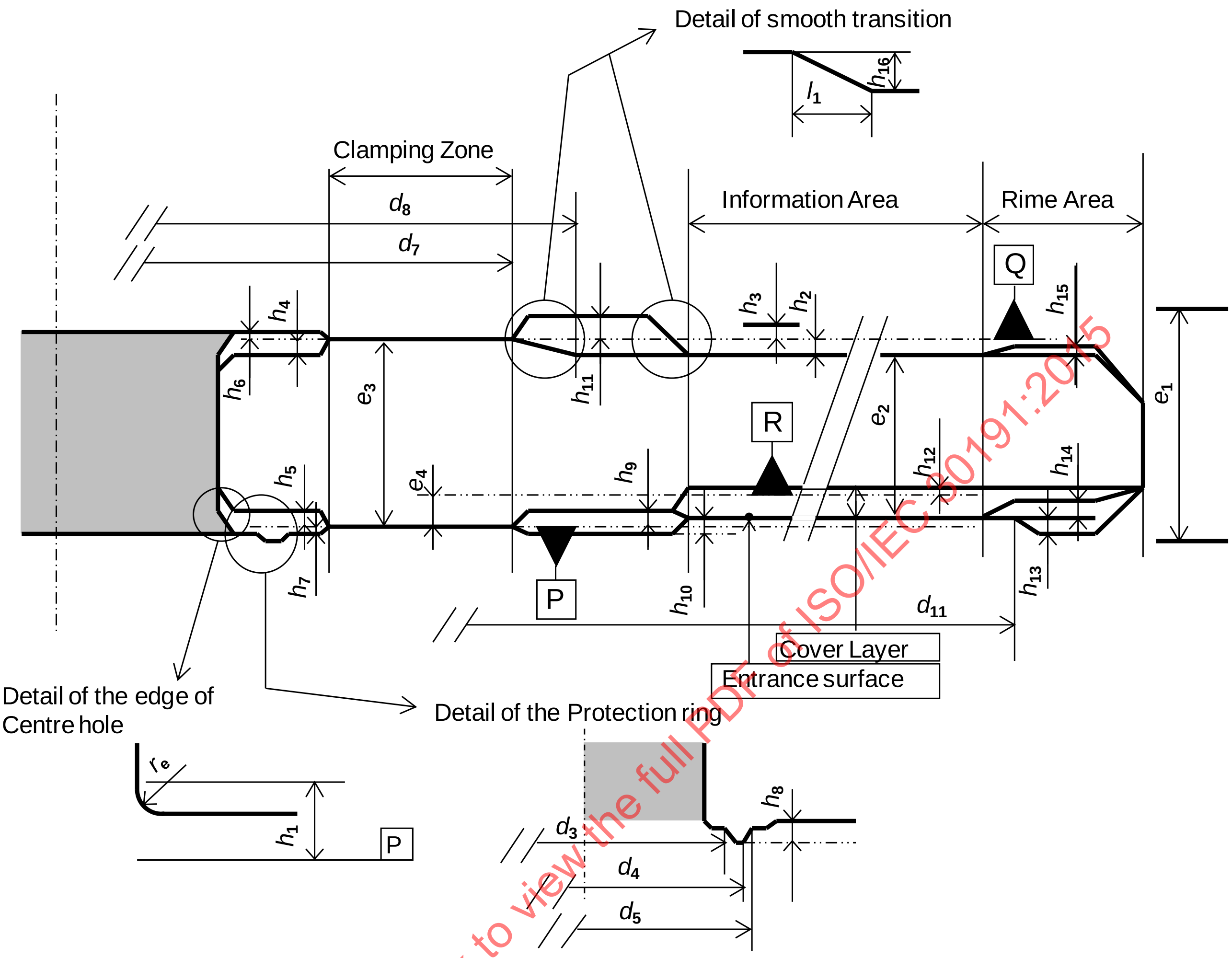


Figure 12 — Details of disk dimensions for Type TL disk and Type QL disk

10.2 Disk reference planes and reference axis

(For Disk reference planes see also Figure 12, Figure O.2 and Figure 13).

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 12, Figure O.2 and Figure 13).

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 and a QL disk).

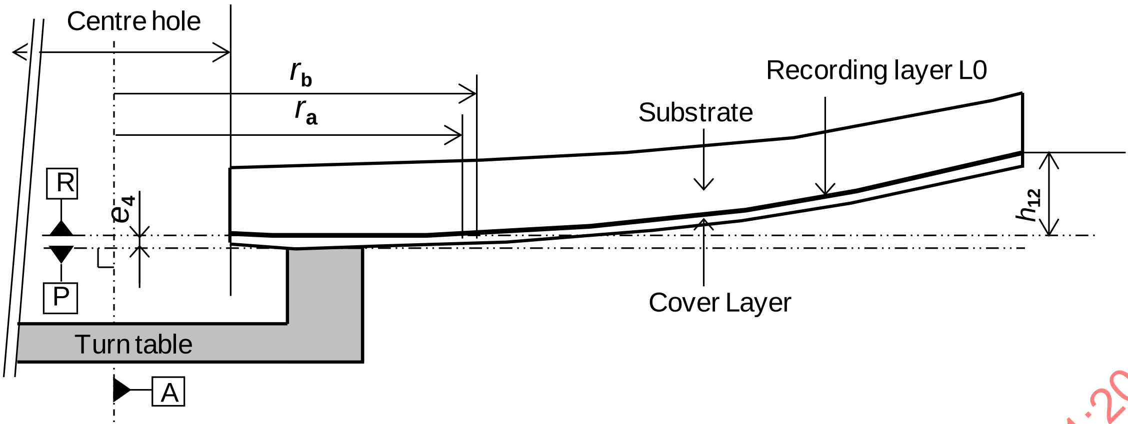


Figure 13 — Details of Disk reference planes P and R and Recording Layer L0

10.3 Overall dimensions

The overall outer diameter of the disk shall be d_1 = (120,0 ± 0,3) mm (see Figure 11).

The diameter of the centre hole shall be $d_2 = 15{,}00^{+0{,}10}_{\ 0{,}00}$ mm (see Figure 11).

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 (see detail in Figure 12 and Figure O.2).
The maximum thickness of the disk is defined as the distance in the direction of the reference axis A between the highest structure protruding from the Entrance surface of the disk and the highest structure protruding from the top surface of the disk.

Maximum thickness of the disk, including Cover Layer, Protective Coating and Label printing, at any radius shall be e_1 = 1,40 mm for a Type TL disk and a Type QL disk (see Figure 12). See Annex O for a Type TL/D disk.

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 12).

The parameters h_2 and h_3 are only for a Type TL disk and a Type QL disk.

10.4 First transition Area

In the Inner Area inside the Clamping Zone ($d < d_6$) the surfaces may be inside the Disk reference planes P and Q by maximum h_5 = 0,20 mm and maximum h_4 = 0,12 mm, respectively. These surfaces may be uneven or may have burrs up to maximum h_7 = 0,05 mm and maximum h_6 = 0,05 mm outside the Disk reference planes P and Q, respectively (see Figure 11, Figure 12 and Figure O.2).

The parameters h_4 and h_6 are only for a Type TL disk and a Type QL disk.

10.5 Protection ring

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

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

10.6 Clamping Zone

The inner diameter of the disk Clamping Zone shall be $d_6 \leq 23{,}0$ mm (see Figure 11).
The outer diameter of the disk Clamping Zone shall be $d_7 \geq 33{,}0$ mm (see Figure 11, Figure 12 and Figure O.2).

The thickness of the disk within the Clamping Zone shall be $e_3 = 1{,}20^{+0{,}10}_{-0{,}05}$ mm (see Figure 12 and Figure O.2).

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

10.7 Second transition Area

The Second transition Area is an area between the Clamping Zone and the Information Area: $d_7 < d < d_9$ (see Figure 11).

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 12 and Figure O.2).

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 diameters of the step is l_1. If h_{16} > 0,2 mm, then the slope down to the top surface of the Information Area shall be smooth and l_1 shall be > 1,8 mm as indicated in Figure 12. If the top surface in the Information Area is stepped down from the top surface in the area, then the step shall end within diameters d_8 = 40,0 mm.

The parameters h_{11}, h_{16}, l_1 and d_8 are only for a Type TL disk and a Type QL disk.

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 14).

On each Recording Layer the Data Zone shall be located between inner diameter d_{DZI} and outer diameter d_{DZO}. The Data Zones on all Recording Layers shall have the same storage capacity.

The inner diameter d_{DZI} on Recording Layer n shall be $d_{DZIn} = 48{,}0^{\,0{,}0}_{-0{,}2}$ mm and the outer diameter d_{DZO} on Recording Layer 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 14).

The total thickness of the disk in the Information Area is as specified in 10.3.

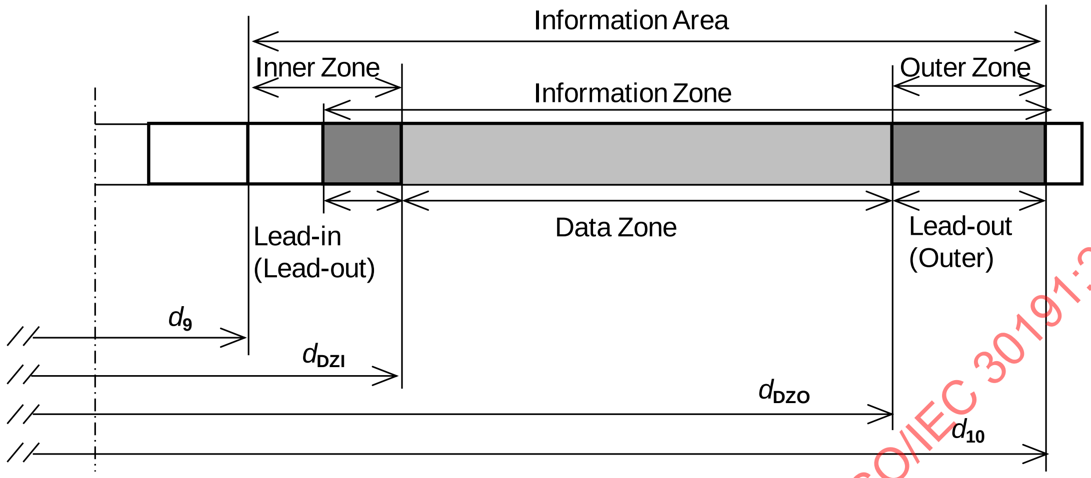


Figure 14 — Division of Information Area

10.8.2 Subdivision of Information Zone on TL disk

The Information Area is used to record the Information Zone, divided over the three Recording Layers.

The Information Zone is subdivided in the following main parts (see Figure 15):

On Recording Layer L0:
— a Lead-in Zone (part of the Inner Zone 0)
— a Data Zone 0
— a Outer Zone 0

On Recording Layer L1:
— a Outer Zone 1
— a Data Zone 1
— a Inner Zone 1

On Recording Layer L2:
— a Inner Zone 2
— a Data Zone 2
— a Lead-out Zone (Outer Zone 2)

On Layer L0 and Layer L2 the spiral Grooves shall run from the inner side of the disk towards the outer side of the disk.
On Layer L1 the spiral Groove shall run from the outer side of the disk towards the inner side of the disk.

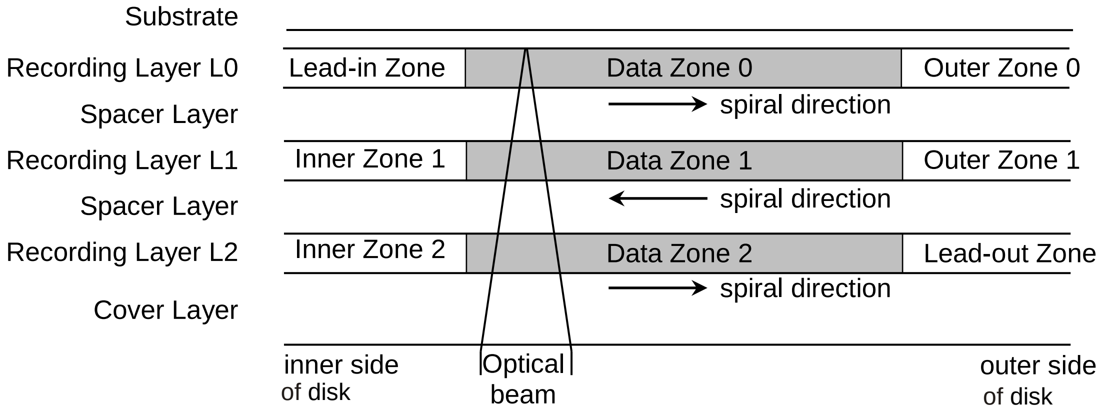


Figure 15 — Use of Information Area on TL disk

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 the Data Zone 0 at diameter d_{DZI0}.

The Outer Zone 0 shall start at the end of the Data Zone 0 at diameter d_{DZO0} and shall end at diameter minimum 117 mm.

The Outer Zone 1 shall start at diameter minimum 117 mm and shall end at the beginning of Data Zone 1 at diameter d_{DZO1}.

The Inner Zone 1 shall start at the end of the Data Zone 1 d_{DZI1} and shall end at the diameter maximum 44,4 mm.

The Inner Zone 2 shall start at the diameter maximum 44,4 mm and shall end at the beginning of the Data Zone 2 at diameter d_{DZI2}.

The 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.

10.8.3 Subdivision of Information Zone on QL disk

The Information Area is used to record the Information Zone, divided over the four Recording Layers.

The Information Zone is subdivided into the following main parts (see Figure 16):

On Recording Layer L0:
— a Lead-in Zone (part of the Inner Zone 0)
— a Data Zone 0
— a Outer Zone 0

On Recording Layer L1:
— a Outer Zone 1
— a Data Zone 1
— a Inner Zone 1

On Recording Layer L2:
— a Inner Zone 2
— a Data Zone 2
— a Outer Zone 2

On Recording Layer L3:
— a Outer Zone 3
— a Data Zone 3
— a Lead-out Zone (part of the Inner Zone 3)

On Layer L0 and Layer L2, the spiral Grooves shall run from the inner side of the disk towards the outer side of the disk.

On Layer L1 and Layer L3, the spiral Grooves shall run from the outer side of the disk towards the inner side of the disk.

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 the Data Zone 0 at diameter d_{DZI0}.

The Outer Zone 0 shall start at the end of the Data Zone 0 at diameter d_{DZO0} and shall end at diameter minimum 117 mm.

The Outer Zone 1 shall start at diameter minimum 117 mm and shall end at the beginning of Data Zone 1 at diameter d_{DZO1}.

The Inner Zone 1 shall start at the end of the Data Zone 1 at diameter d_{DZI1} and shall end at the diameter maximum 44,4 mm.

The Inner Zone 2 shall start at the diameter maximum 44,4 mm and shall end at the beginning of the Data Zone 2 at diameter d_{DZI2}.

The Outer Zone 2 shall start at the end of the Data Zone 2 at diameter d_{DZO2} and shall end at diameter minimum 117 mm.

The Outer Zone 3 shall start at diameter minimum 117 mm and shall end at the beginning of Data Zone 3 at diameter d_{DZO3}.

The Lead-out Zone shall start at the end of the Data Zone 3 at diameter d_{DZI3} and shall end in the area extending from diameter 44,0 mm to diameter 44,4 mm.

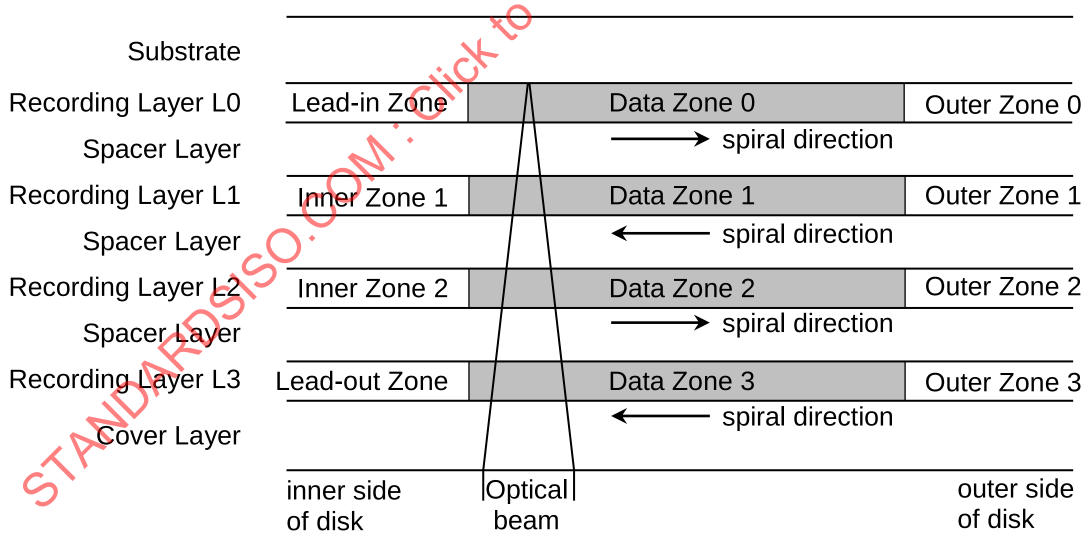


Figure 16 — Use of Information Area on QL disk

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 11).

In the first 0,5 mm of the Rim Area the surface at the read-out side of the disk shall not be outside the Entrance surface in the Information Area.

In the remainder of the Rim Area the surface at the read-out side of the disk shall not be outside the Entrance surface in the Information Area by maximum h_{13} = 0,05 mm (see Figure 12 and Figure O.2).

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 12 and Figure O.2).

In the Rim Area the top surface of the disk shall not be outside the top surface in the Information Area by maximum h_{15} = 0,05 mm (see Figure 12).

The parameter h_{15} is only for a Type TL disk and a Type QL disk.

11 Mechanical characteristics

11.1 Mass

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

11.2 Moment of inertia

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

11.3 Dynamic imbalance

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

11.4 Axial runout

11.4.1 General

When measured by an optical system using the Reference servo for axial tracking, and with the disk rotating at a half of the Recording Velocity, the distance between each Recording Layer and the Disk reference plane R (see Figure 12, Figure O.2 and Figure 13) 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), this component will be 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 for a TL disk and 3,845 m/s for a QL disk respectively, and with the read power at (0,70 ± 0,10) mW for any layers for a TL and a QL 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_{-3dB} = 1,6 kHz and slope = –60 dB/decade.

This means that for frequencies < 1,6 kHz the maximum local acceleration of the Recording Layer in the direction of the reference axis A will 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_{-3dB} = 1,6 kHz with slope = +60 dB/decade, to f_{-3dB} = 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 80 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 for a TL disk and 7,690 m/s for a QL disk respectively, and with the read power (see 9.4).

Spikes in the residual axial tracking-error signal due to local defects, such as dust and scratches, shall be excluded. For 4x 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_{-3dB} = 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 will 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, and using the Reference servo for axial tracking, shall be maximum 32 nm. The measuring filter shall be a Butterworth BPF, from f_{-3dB} = 3,2 kHz with slope = +60 dB/decade, to f_{-3dB} = 20 kHz with slope = –60 dB/decade.

11.5 Radial runout

11.5.1 General

The runout of the outer edge of the disk shall be maximum 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), this component will be suppressed sufficiently such that the residual tracking errors as defined in 11.5.2 and 11.5.3 are mainly due to local disturbances.

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

11.5.2 Residual radial tracking error on 1x Measurement Velocity

The residual radial tracking error in each Recording Layer 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 for a TL disk and 3,845 m/s for a QL disk respectively, and with the read power at (0,70 ± 0,10) mW for any layers of a TL and a QL disk. It is recommended to measure the residual radial tracking-error signal in a short period to avoid the 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_{-3dB} = 1,8 kHz and slope = –60 dB/decade.

This means that for frequencies < 1,8 kHz the maximum acceleration of the Tracks in the radial direction will not exceed 2,2 m/s².

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, using the Reference servo for radial tracking, shall be maximum 9,2 nm. The measuring filter shall be a Butterworth BPF, from f_{-3dB} = 1,8 kHz with slope = +60 dB/decade, to f_{-3dB} = 10 kHz with slope = –60 dB/decade.

11.5.3 Residual radial tracking error on 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 for a TL disk and 7,690 m/s for a QL disk, respectively, and with the read power refers to 9.4.

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

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

This means that for frequencies < 3,6 kHz the maximum local acceleration in the radial direction will not exceed 3,4 m/s² (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/s².

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, and using the Reference servo for radial tracking, shall be maximum 9,2 nm. The measuring filter shall be a Butterworth BPF, from f_{-3dB} = 3,6 kHz with slope = +60 dB/decade, to f_{-3dB} = 20 kHz with slope = –60 dB/decade.

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 a 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 Layer of Layer L*n* in case of TS0, the Cover Layer and possibly a Protective Coating).

12.2 Refractive index of the 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: $1{,}45 \le n \le 1{,}70$

12.3 Thickness of Transmission Stacks (TS)

12.3.1 Thickness of Transmission Stack of TL disks

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.

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

In Figure 17 for reference to requirements a) to c), the curves show the thickness of equivalent spherical aberration. The ratio of the thickness with arbitrary refractive index n to that with refractive index 1,60 is expressed by the approximately by the function of $g(n)$

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

Figure 18 shows a coefficient function for converting the actual thickness to an effective thickness for requirements f). The actual thickness means its physical value. The effective thickness means imaginary value where the refractive index is assumed to be 1,60.

The actual thickness of arbitrary refractive index is converted to an effective thickness of standard refractive index of 1,60. The defocus values of both the actual and effective thickness are the same. In this section, 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 (θ_r) / tan (θ_o), where θ_o and θ_r are the converging angles in the Transmission Stack with each refractive indexes of 1,60 and arbitrary n, respectively. The function $f(n)$ is expressed by approximately as,

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

a) The thickness of the TS0 (all layers on top of Layer L0) as determined by its refractive index shall be within the uppermost shaded area in Figure 17 (In case of a refractive index of n, the thickness shall be between 94,0×$g(n)$ µm and 106,0×$g(n)$ µm, the dashed curve indicates the nominal thickness as a function of the refractive index),

b) The thickness of the TS1 (all layers on top of Layer L1) as determined by its refractive index shall be within the middle shaded area in Figure 17 (In case of a refractive index of n, the thickness shall be between 69,0×$g(n)$ µm and 81,0×$g(n)$ µm, the dashed curve indicates the nominal thickness as a function of the refractive index),

c) The thickness of the TS2 (all layers on top of Layer L2) as determined by its refractive index shall be within the lowest shaded area in Figure 17 (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 the Spacer Layer1 ($S1$) sandwiched by Layer L0 and Layer L1 shall be between 20,0 µm and 30,0 µm,

e) The thickness of the 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 thicknesses to effective thicknesses by being multiplied by coefficient $f(n)$ shown in Figure 18, where the thickness of TS2 equals the Cover Layer thickness (C) and n is the refractive index),

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

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

12.3.2 Example of target thickness of Spacer Layers for TL disks

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

It is recommended that following three requirements are fulfilled, then the requirements a) to f) of 12.3.1 are always fulfilled for a refractive index of 1,60.

a) The thickness of the Spacer Layer1 ($S1$) should be (25,0 ± 2,0) µm.

b) The thickness of the Spacer Layer2 ($S2$) should be (18,0 ± 2,0) µm.

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

12.3.3 Thickness of Transmission Stacks of QL disks

The average thickness between radius 23 mm and 24 mm is called the Reference Thickness of the related Transmission Stack (TS0 , TS1 , TS2 or TS3) on the disk.

The thicknesses of TS0, TS1, TS2 and TS3, measured over the whole disk, shall fulfill the following ten requirements:

In Figure 19 for reference to requirements a) to d), the curves show the thicknesses having equivalent spherical aberration. The ratio of thickness with arbitrary refractive index n to that with refractive index 1,60 is expressed by approximately the function of $g(n)$.

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

Figure 18 shows a conversion coefficient for converting the actual thickness to an effective thickness for requirements h). The actual thickness means its physical value. The effective thickness means an imaginary value when refractive index is assumed to be 1,60.

The actual thickness under arbitrary refractive index is converted to an effective thickness with standard refractive index of 1,60. The defocus values of both the actual and effective thicknesses are the same. In this section, 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 converging angle in disk Substrate with each refractive index of 1,60 and arbitrary n, respectively. The function $f(n)$ is expressed by approximately as,

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

a) The thickness of the TS0 (all layers on top of Layer L0) as determined by its refractive index shall be within the uppermost shaded area in Figure 19 (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 the TS1 (all layers on top of Layer L1) as determined by its refractive index shall be within the second-uppermost shaded area in Figure 19 (In case of a refractive index of n, the thickness shall be between 78,5×$g(n)$ µm and 90,5×$g(n)$ µm, and the dashed curve indicates the nominal thickness as a function of the refractive index).

c) The thickness of the TS2 (all layers on top of Layer L2) as determined by its refractive index shall be within the second-lowest shaded area in Figure 19 (In case of a refractive index of n, the thickness shall be between 60,5×$g(n)$ µm and 69,5×$g(n)$ µm, and the dashed curve indicates the nominal thickness as a function of the refractive index).

d) The thickness of the TS3 (all layers on top of Layer L3) as determined by its refractive index shall be within the undermost shaded area in Figure 19 (In case of a refractive index of n, the thickness shall be between 50,5×$g(n)$ µm and 56,5×$g(n)$ µm, and the dashed curve indicates the nominal thickness as a function of the refractive index).

e) The thickness of the Spacer Layer1 ($S1$) sandwiched by Layer L0 and Layer L1 shall be between 11,0 µm and 20,5 µm.

f) The thickness of the Spacer Layer2 ($S2$) sandwiched by Layer L1 and Layer L2 shall be between 14,5 µm and 24,5 µm.

g) The thickness of the Spacer Layer3 ($S3$) sandwiched by Layer L2 and Layer L3 shall be between 10,0 µm and 16,5 µm.

h) The thickness differences shall meet the requirement $C - (S1 + S2 + S3) \geq 1{,}0$ µm, $S1 - S3 \geq 1{,}0$ µm , $S2 - S1 \geq 1{,}0$ µm and $S3 \geq 10{,}0$ µm (C, $S1$, $S2$, $S3$ shall be converted from actual thickness to effective thickness by being multiplied by coefficient $f(n)$ shown in Figure 18, where the thickness of TS3 equals the Cover Layer thickness (C), and n is refractive index).

i) The maximum deviation ΔD of the thickness of the TS0, TS1 and the TS2 from their respective Reference Thickness shall meet the requirement $|\Delta D| \leq 2{,}5$ µm, and

j) The maximum deviation ΔD of the thickness of the TS3 from its Reference Thickness shall meet the requirement $|\Delta D| \leq 2{,}0$ µm.

12.3.4 Example of target thickness of Spacer Layers for QL disks

In mass production, simple target values for the thicknesses are useful.

It is recommended that when the following four requirements be fulfilled, then the requirements a) to h) of 12.3.3 are always fulfilled for a refractive index of 1,60,

a) The thickness of the Spacer Layer1 ($S1$) should be (15,5 ± 1,5) µm,

b) The thickness of the Spacer Layer2 ($S2$) should be (19,5 ± 1,5) µm,

c) The thickness of the Spacer Layer3 ($S3$) should be (11,5 ± 1,5) µm,

d) The thickness of TS3 (=C) should be (53,5 ± 1,5) µm.

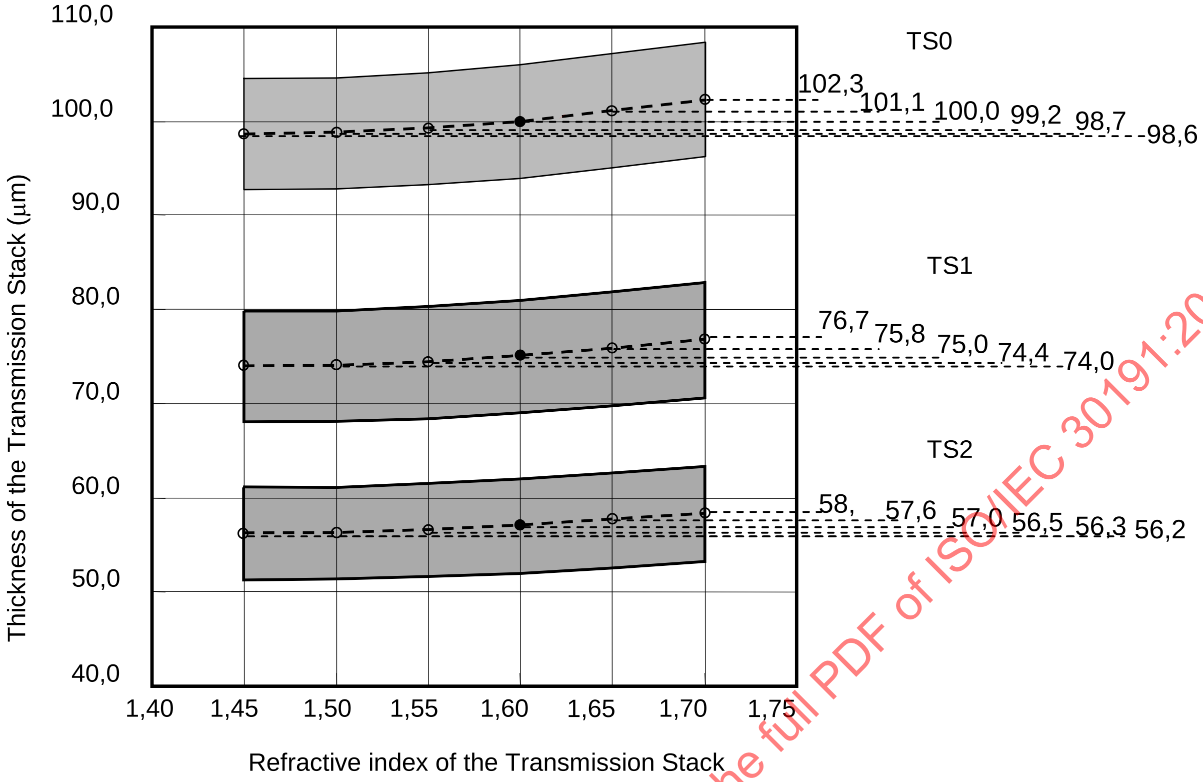


Figure 17 — Thickness of the Transmission Stacks as a function of the refractive index

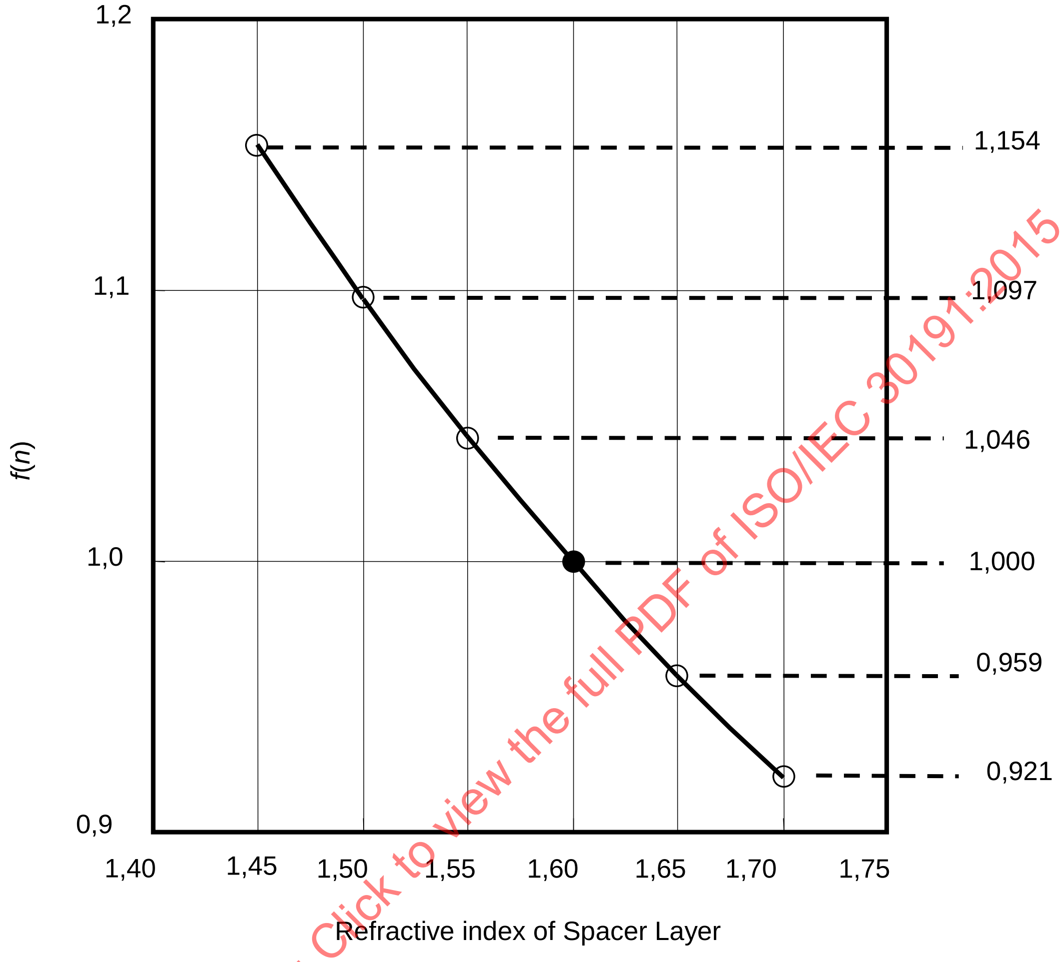


Figure 18 — Ratio of effective thickness with refractive index 1,60 and that with arbitrary refractive index *n*

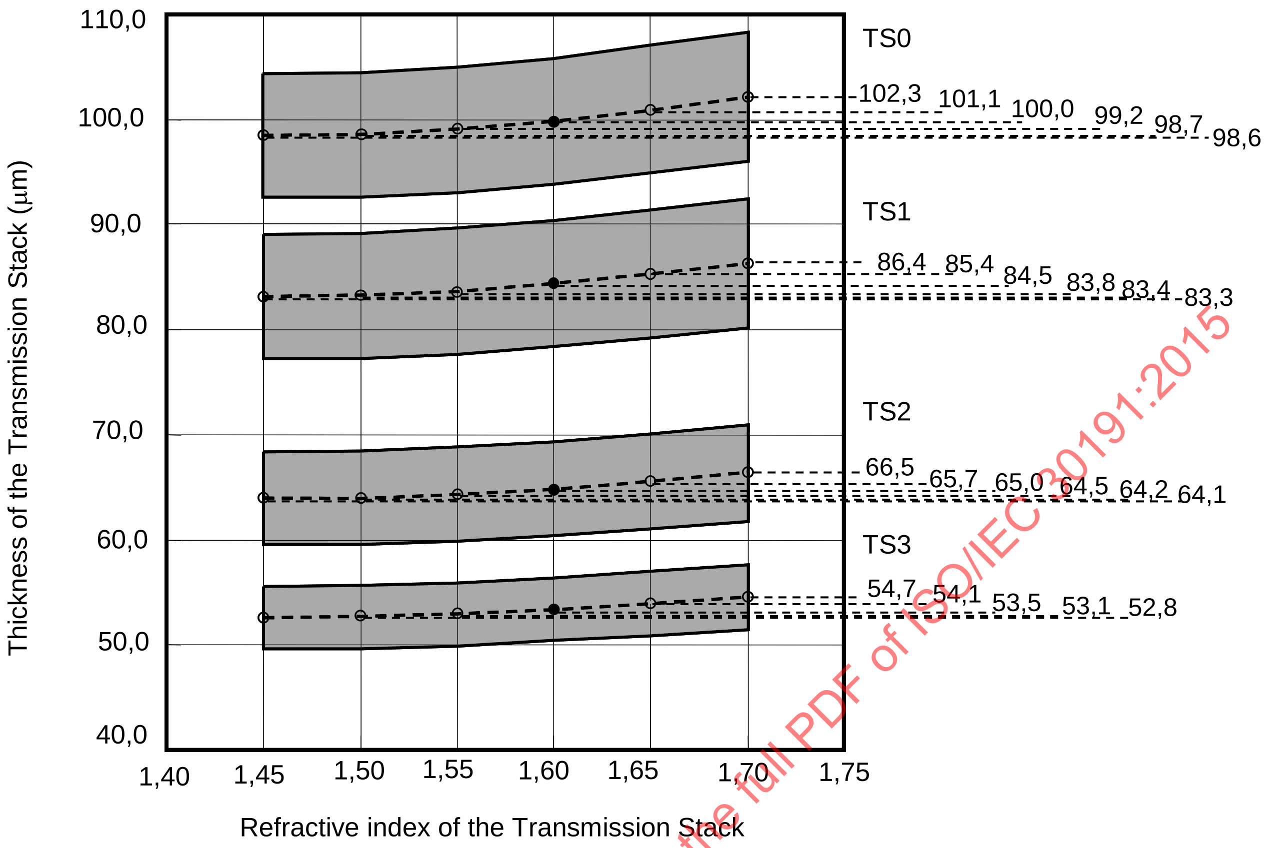


Figure 19 — Thickness of the Transmission Stacks as a function of the refractive index

12.4 Reflectivity of Recording Layers

The reflectivity of each Recording Layer in the Information Zone, including the transmission through the Cover Layer, shall fulfil the following requirements under the measurement conditions of Annex B:

— in Unrecorded Virgin Groove:

— of Layer L0 and Layer L1 of a TL disk / Layer L0, Layer L1 and Layer L2 of a QL disk: $R_{g\text{-}v}$ = 1,8 to 4,0 %

— of Layer L2 of a TL disk / Layer L3 of a QL disk: $R_{g\text{-}v}$ = 2,0 to 4,0 %

— in Recorded Groove:

— of Layer L0 and Layer L1 of a TL disk / Layer L0, Layer L1 and Layer L2 of a QL disk: R_{8H} = 1,6 to 4,0 %

— of Layer L2 of a TL disk / Layer L3 of QL disk: R_{8H} = 1,8 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.

12.5 Birefringence

The in-plane birefringence of the Transmission Stacks shall be (see Annex J): $\Delta n_{//} \leq 1{,}5 \times 10^{-4}$

The perpendicular birefringence of the Transmission Stacks shall be (see Annex J): $\Delta n_{\perp} \leq 1{,}2 \times 10^{-3}$

12.6 Angular deviations

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 Layers (see Figure 20).

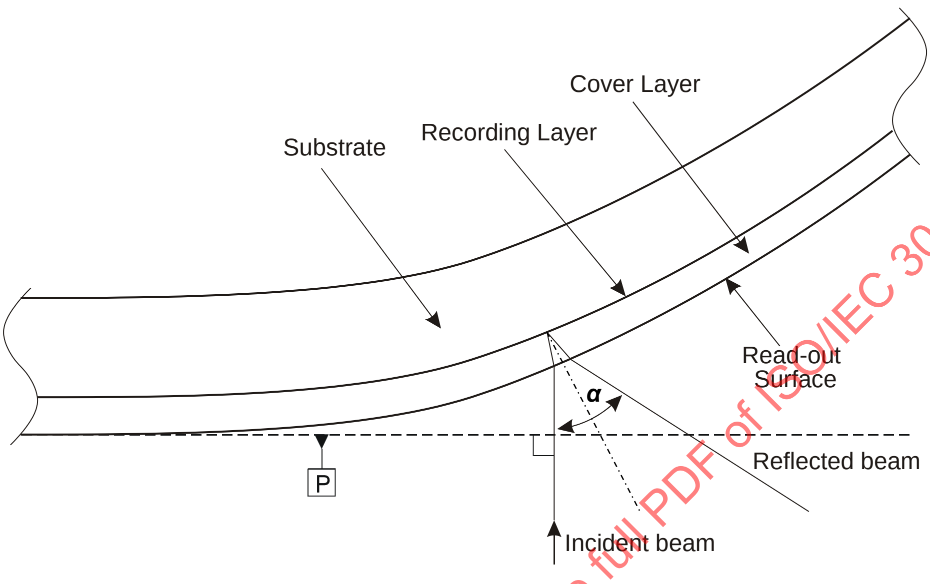


Figure 20 — Definition of angular deviation

The requirements for the angle *α* are:

— In the radial direction
  — under the normal test conditions specified in 8.1.1: |*α*|max. = 0,60°.
  — under the “sudden change” test conditions specified in 8.1.1: |*α*|max. = 0,70°.

— In the tangential direction
  — under the normal test conditions specified in 8.1.1: |*α*|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 21).

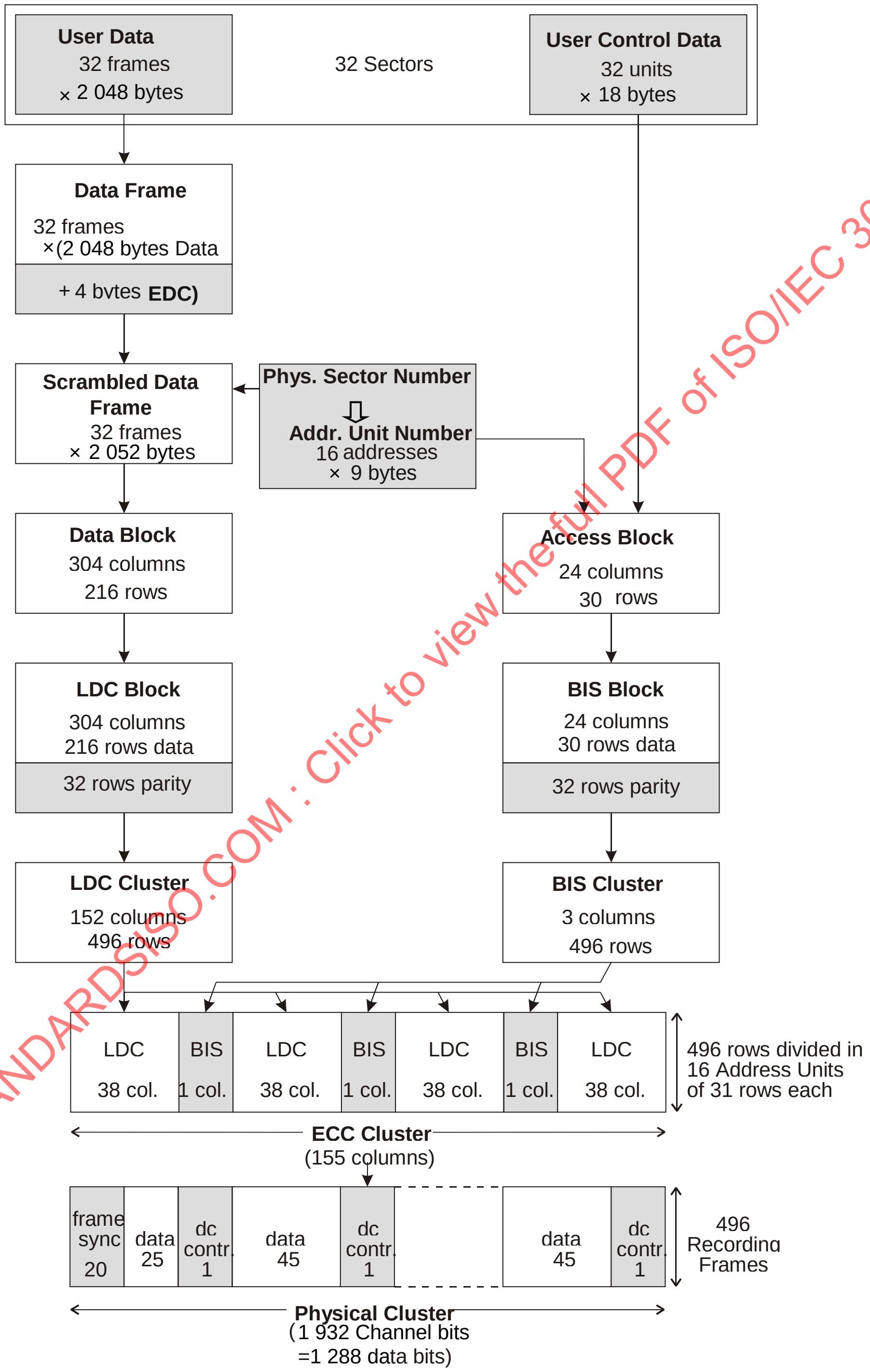


Figure 21 — Schematic representation of encoding process

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 Recordable 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 Recordable disks is recorded in 64K partitions, called Clusters, containing 32 Data Frames with 2 048 bytes of User Data. These Clusters are protected by two error correction mechanisms:

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

— 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 22).

All the data is arranged in an array as indicated in Figure 22. 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.

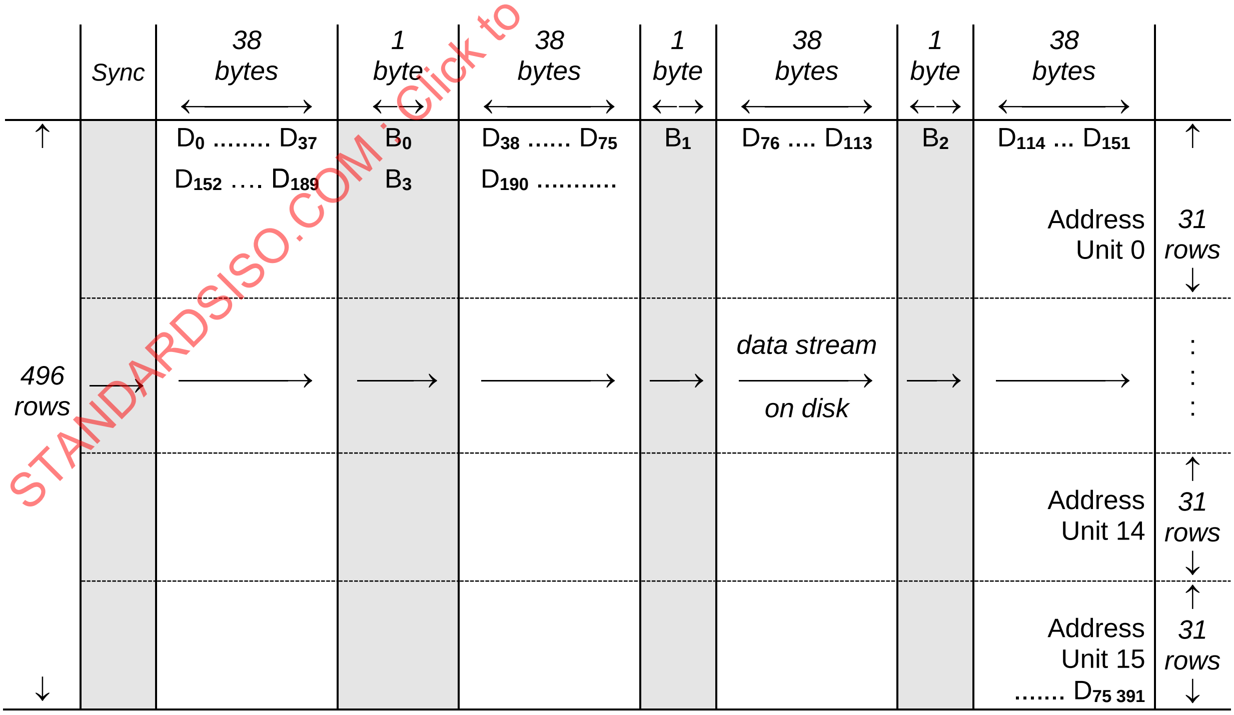


Figure 22 — Schematic representation of Physical Cluster on disk

Address Units, Physical Sectors and Logical Sectors

Address Units:
For the purpose of allocating the optical pick-up to a certain position on the disk, the Physical Cluster is subdivided into 16 Address Units, each consisting of 31 consecutive rows. The Address-Unit Numbers (AUN) provide a fast addressing mechanism embedded in the written data.

Physical Sectors:
A Data Frame accompanied by its Control Data is called a Sector. All Sectors in all Physical Clusters all over the disk (including the Inner and Outer Zones) are called Physical Sectors. All Physical Sectors have a virtual number assigned, called the Physical-Sector Number (PSN). These PSN's are not recorded onto the disk; however they are synchronized with the AUN's.

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 23).

↑ *2 048 User Data bytes* ↓	ud_0	↑ *2 052 bytes* ↓
	:	
	:	
	:	
	:	
	$ud_{2\,047}$	
↑ *4 EDC bytes* ↓	$ed_{2\,048}$	
	$ed_{2\,049}$	
	$ed_{2\,050}$	
	$ed_{2\,051}$	

Figure 23 — 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 will be $b_{16\,415}$ and the lsb will be b_0.

Each bit b*i* of the EDC is shown as follows for *i* = 0 to 31:

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

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

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 24, 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

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

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) Physical-Sector Number (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 24).

The same preset value shall be used for all 32 Data Frames within the same Cluster.

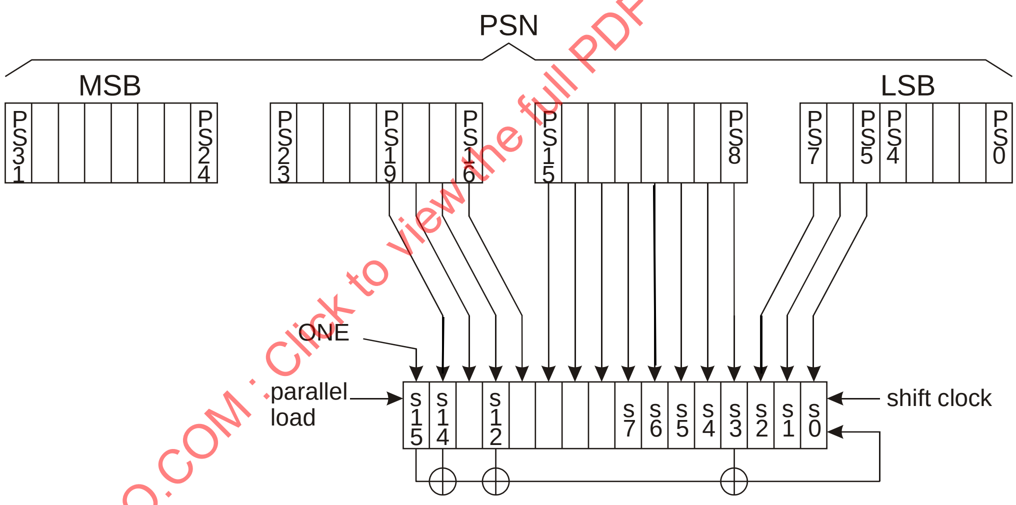


Figure 24 — Scrambler circuit

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:

$$d_k = ud/ed_k \oplus S_k \quad \text{for } k = 0 \text{ to } 2\,051; \qquad \oplus \text{ stands for Exclusive-Or.}$$

13.5 Data Block

In the next step, 32 Scrambled Data Frames (F = 0..31) are combined into one block of data (see Figure 25).

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

Figure 25 — 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 26. 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 a column.

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

Figure 26 — 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 27 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 rows with data	$e_{1,0}$	$e_{1,1}$	:	$e_{1,L}$	:	$e_{1,302}$	$e_{1,303}$
		$e_{2,0}$	:	:	:	:	:	:
1 LDC code-word = 248 bytes		:	:	:	:	:	:	:
		:	:	:	:	:	:	:
	↓	$e_{215,0}$	$e_{215,1}$	:	$e_{215,L}$	:	$e_{215,302}$	$e_{215,303}$
	↑	$p_{216,0}$	$p_{216,1}$	:	$P_{216,L}$	:	$p_{216,302}$	$p_{216,303}$
	32 rows with parity	:	:	:	:	:	:	:
		:	:	:	:	:	:	:
		:	:	:	:	:	:	:
		:	:	:	:	:	:	:
↓	↓	$p_{247,0}$	$p_{247,1}$	:	$p_{247,L}$	:	$p_{247,302}$	$p_{247,303}$

Figure 27 — 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 $p(x)$:

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

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:

$$\alpha = 00000010$$

Each LDC code-word, represented by the vector I_{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 $I_{dc}(x)$ 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.).

$I_{dc}(x)$ is a multiple of the generator polynomial $g(x)$ of the LDC code-word. The generator polynomial equals:

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

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 I_{dc} is such that:

$$H_{LDC} \times I_{dc}^{T} = 0 \text{ for all LDC code-words } I_{dc}$$

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 $h_{LDC\,2}$ of the parity-check matrix H_{LDC} is given by:

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

13.8 LDC Cluster

13.8.1 General

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

13.8.2 First 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 28.

	← *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 28 — 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 ($k \times 3$, 152) bytes to the left, where k = div (row_number,2), $0 \leq$ row_number ≤ 495. The bytes that shift out at the left side are re-entered in the array from the right side (see Figure 29).

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 22.

	←								152 bytes								→
← shift	$e_{0,0}$	$e_{0,2}$		…						…						$e_{0,300}$	$e_{0,302}$
0	$e_{0,1}$	$e_{0,3}$		…						…						$e_{0,301}$	$e_{0,303}$
← shift	$e_{1,6}$	$e_{1,8}$		…						…			$e_{1,300}$	$e_{1,302}$	$e_{1,0}$	$e_{1,2}$	$e_{1,4}$
3	$e_{1,7}$	$e_{1,9}$		…						…			$e_{1,301}$	$e_{1,303}$	$e_{1,1}$	$e_{1,3}$	$e_{1,5}$
← shift	$e_{2,12}$	$e_{2,14}$		…						…	$e_{2,302}$	$e_{2,0}$	$e_{2,2}$	$e_{2,4}$	$e_{2,6}$	$e_{2,8}$	$e_{2,10}$
6	$e_{2,13}$	$e_{2,15}$		…						…	$e_{2,303}$	$e_{2,1}$	$e_{2,3}$	$e_{2,5}$	$e_{2,7}$	$e_{2,9}$	$e_{2,11}$
	…	…		…						…							
	…	…		…						…							
← shift	$e_{50,300}$	$e_{50,302}$	$e_{50,0}$	…						…							$e_{50,298}$
150	$e_{50,301}$	$e_{50,303}$	$e_{50,1}$	…						…							$e_{50,299}$
← shift	$e_{51,2}$	$e_{51,4}$		…						…					$e_{51,300}$	$e_{51,302}$	$e_{51,0}$
1	$e_{51,3}$	$e_{51,5}$		…						…					$e_{51,301}$	$e_{51,303}$	$e_{51,1}$
	…	…		…						…							
	…	…		…						…							
← 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 29 — LDC Cluster

13.9 Addressing and Control Data

13.9.1 General

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

13.9.2 Address Units

13.9.2.1 General

For positioning the optical head onto the desired Track, a fast addressing mechanism is implemented by subdividing the 64K Physical Clusters into 16 Address Units. Each Address Unit contains an address, which is placed in such a way into the BIS code-words (see 13.11) that it can be accessed quickly (see Figure 30).

Each Address Field consists of 9 bytes:

— 4 bytes partially for, modified and inverted, Address-Unit Number (see 13.9.2.2)
— 1 byte for flag bits
— 4 bytes for error correction

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

Figure 30 — 16 Address Fields

13.9.2.2 Byte assignments for Address Fields

Before describing Address Fields, Primary Address Fields, which consists of Address-Unit Number, flag bits and parity bytes, are defined as following (see Figure 31).

$PAF_{0,S}$ =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 status of individual Data Frames in a Cluster or can be used to hold other information, such as an address. The basic format for assigning some of these flag bits is specified in 13.9.2.4. Flag bits not used shall be set to ZERO.
$PAF_{5,S}$ .. $PAF_{8,S}$ = parity bytes for forming an (9,5,5) RS code over the Primary Address Fields.

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 $p(x)$:

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

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 (PAFC), 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 equals:

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

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:

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

Address Fields are defined as 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-byte Address-Unit Number (AUN).

The Address-Unit Numbers shall be derived from the Physical-Sector Numbers (PSN) as defined in Figure 31.

The Address-Unit Numbers increase by two for each successive Address Unit, for reasons of synchronization with the PSNs (see Clause 17).

The Address-Unit Number of the first Address Unit of each Physical Cluster is a multiple of 32.

The first Address-Unit Number in Data Zone 0 will be 00 10 00 00h (1 048 576 decimal).

The last Address-Unit Number in Data Zone 1 will be 03 EF FF FEh (66 060 286 decimal).

The first Address-Unit Number in Data Zone 2 will be 04 10 00 00h (68 157 440 decimal).

If a QL disk is considered, the last Address-Unit Number in Data Zone 3 will be 07 EF FF FEh (133 169 150 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.

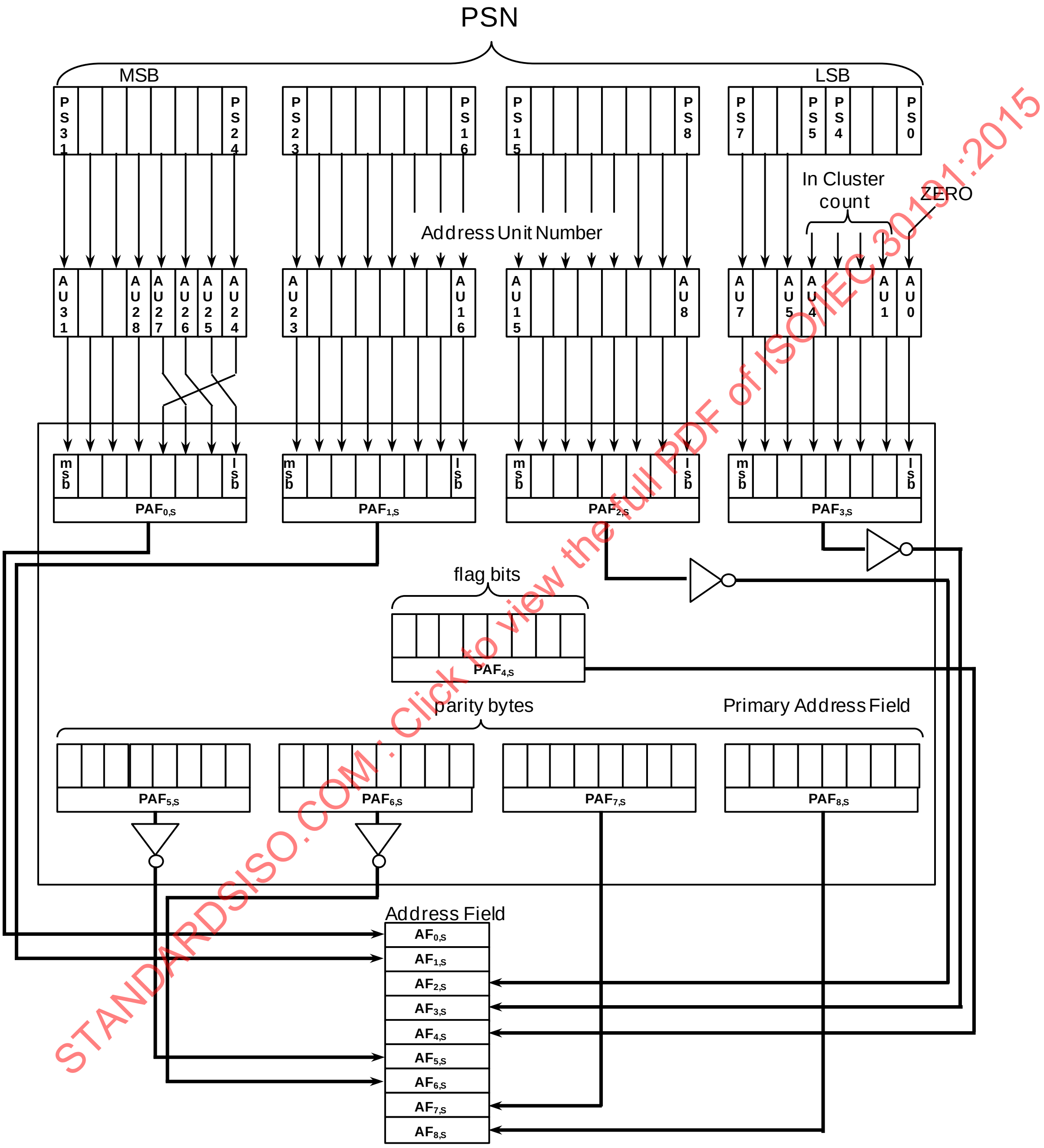


Figure 31 — Composition of AUN's, Primary Address Field and Address Field from PSN's

13.9.2.4 Assignments for flag bits

Bit / Byte $AF_{4,s}$	b_7	b_6	b_5	b_4	b_3	b_2	b_1	b_0
$AF_{4,0}$	$Sa_{0,1}$	$Sa_{1,1}$	$Sa_{0,0}$	$Sa_{1,0}$	Rsv	Rsv	Rsv	Rsv
$AF_{4,1}$	$Sa_{2,1}$	$Sa_{3,1}$	$Sa_{2,0}$	$Sa_{3,0}$	Rsv	Rsv	Rsv	Rsv
$AF_{4,2}$	$Sa_{4,1}$	$Sa_{5,1}$	$Sa_{4,0}$	$Sa_{5,0}$	Rsv	Rsv	Rsv	Rsv
$AF_{4,3}$	$Sa_{6,1}$	$Sa_{7,1}$	$Sa_{6,0}$	$Sa_{7,0}$	Rsv	Rsv	Rsv	Rsv
$AF_{4,4}$	$Sa_{8,1}$	$Sa_{9,1}$	$Sa_{8,0}$	$Sa_{9,0}$	Rsv	Rsv	Rsv	Rsv
$AF_{4,5}$	$Sa_{10,1}$	$Sa_{11,1}$	$Sa_{10,0}$	$Sa_{11,0}$	Rsv	Rsv	Rsv	Rsv
$AF_{4,6}$	$Sa_{12,1}$	$Sa_{13,1}$	$Sa_{12,0}$	$Sa_{13,0}$	Rsv	Rsv	Rsv	Rsv
$AF_{4,7}$	$Sa_{14,1}$	$Sa_{15,1}$	$Sa_{14,0}$	$Sa_{15,0}$	Rsv	Rsv	Rsv	Rsv
$AF_{4,8}$	$Sa_{16,1}$	$Sa_{17,1}$	$Sa_{16,0}$	$Sa_{17,0}$	Rsv	Rsv	Rsv	Rsv
$AF_{4,9}$	$Sa_{18,1}$	$Sa_{19,1}$	$Sa_{18,0}$	$Sa_{19,0}$	Rsv	Rsv	Rsv	Rsv
$AF_{4,10}$	$Sa_{20,1}$	$Sa_{21,1}$	$Sa_{20,0}$	$Sa_{21,0}$	Rsv	Rsv	Rsv	Rsv
$AF_{4,11}$	$Sa_{22,1}$	$Sa_{23,1}$	$Sa_{22,0}$	$Sa_{23,0}$	Rsv	Rsv	Rsv	Rsv
$AF_{4,12}$	$Sa_{24,1}$	$Sa_{25,1}$	$Sa_{24,0}$	$Sa_{25,0}$	Rsv	Rsv	Rsv	Rsv
$AF_{4,13}$	$Sa_{26,1}$	$Sa_{27,1}$	$Sa_{26,0}$	$Sa_{27,0}$	Rsv	Rsv	Rsv	Rsv
$AF_{4,14}$	$Sa_{28,1}$	$Sa_{29,1}$	$Sa_{28,0}$	$Sa_{29,0}$	Rsv	Rsv	Rsv	Rsv
$AF_{4,15}$	$Sa_{30,1}$	$Sa_{31,1}$	$Sa_{30,0}$	$Sa_{31,0}$	Rsv	Rsv	Rsv	Rsv

Rsv: Reserved unless otherwise specified by the Application.

Figure 32 — Flag bits from 16 Address Fields

Status bits $Sa_{i,j}$ ($0 \leq i \leq 31$, $0 \leq j \leq 1$): Because each Cluster contains 32 Data Frames and there are only 16 Address Units, each such Address Unit has to hold the flag bits for 2 Data Frames (see Figure 32).

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

Bit b_3 to bit b_0 of all flag bytes $AF_{4,S}$ are Reserved unless otherwise specified by the Application.

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: the Data Frame contains general User Data,
$Sa_{i,1}/Sa_{i,0}$ = 11: the 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 Application.

In the User-Data Area, 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 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.

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 Application 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 33).

	← *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 33 — 32 User-Control-Data Units

13.9.4 Byte/Bit assignments for User Control Data

The User Control Data bytes are Application dependent. If this setting is not specified by the Application these bytes shall be set to 00h**.**

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

Figure 34 — 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-Data Units is mapped into an array of 30 rows × 24 columns, that is called an Access Block.

Because of the need for a fast access of the Address Fields, the data for these Address Fields is mapped in a special pre-interleaved way.

The 9 bytes of each of the 16 addresses (see Figure 34) are grouped into three groups of 3 bytes.

The three groups of bytes of each of the addresses 0 to 7 are placed in the Access Block in a diagonal direction in the first, third and fifth row, starting with address 0 and each successive address shifted cyclically three positions to the left (see Figure 34).

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

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

Within each group of bytes in the fifth and sixth rows, the bytes are shifted cyclically to the left over 2 byte positions.

Mathematically, this mapping of the address bytes into the Access Block can be represented by the following formulae:

byte $AF_{x,y}$ shall be allocated in: row $r = 2 \times \text{div}(x,3) + \text{div}(y,8)$
and column $c = 3 \times \text{mod}\{[\text{div}(x,3) + 16 - y],8\} + \text{mod}\{[x - \text{div}(x,3)],3\}$

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 34).

13.11 BIS Block

The bytes in each column of an Access Block are renumbered as shown in Figure 35 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
↑ 1 BIS code-word = 62 bytes	↑ *30 Information bytes* ↓	$b_{0,0}$ $b_{1,0}$: : : $b_{29,0}$	$b_{0,1}$ $b_{1,1}$: : : $b_{29,1}$	: : : : : :	$b_{0,C}$ $b_{1,C}$: $b_{N,C}$: $b_{29,C}$	: : : : : :	: : : : : :	$b_{0,23}$ $b_{1,23}$: : : $b_{29,23}$
↓	↑ *32 Parity bytes* ↓	$pb_{30,0}$: : $pb_{61,0}$	$pb_{30,1}$: : $pb_{61,1}$	: : : :	$pb_{30,C}$: : $pb_{61,C}$	: : : :	: : : :	$pb_{30,23}$: : $pb_{61,23}$

Figure 35 — 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 $p(x)$:

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

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:

$$\alpha = 00000010$$

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 equals:

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

The BIS code is systematic: the 30 information bytes appear unaltered in the highest-degree positions of each code word. The parity-check matrix $H_{\mathbf{BIS}}$ of code bis is such that:

$$H_{\mathbf{BIS}} \times bis^{\mathrm{T}} = 0 \quad \text{for all BIS code-words } bis$$

The second row $h_{\mathbf{BIS\,2}}$ of the parity-check matrix $H_{\mathbf{BIS}}$ 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 $h_{\mathbf{BIS\,2}}$ of the parity-check matrix $H_{\mathbf{BIS}}$ is given by:

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

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 22. 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 36).

The essentials of the BIS interleaving scheme are the following (see Figure 35, Figure 36 and the examples in Figure 37 and Figure 38):

— Each row of a BIS Block is split into eight groups of 3 bytes. These 3-byte groups are each placed in one row of the BIS Cluster.

— The even rows of the BIS Block are mapped into Units 0 to 7, the odd rows of the BIS Block are mapped into Units 8 to 15.

— The 3-byte groups from an even row of the BIS Block are placed each in the same row of Units 0 to 7, whereby the Units are used in reverse order (according to their numbering).

— The first 3-byte group of each successive row of the BIS Block shall be placed in a Unit with a number which is one higher than the start Unit used for the previous row:

  — row *N* = 0 of the BIS Block is placed on rows *r* = 0 of Units: 0, 7, 6, 5, .. , 2, 1

  — row *N* = 2 of the BIS Block is placed on rows *r* = 1 of Units: 1, 0, 7, 6, .. , 3, 2

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

  — 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 the BIS Block the same kind of procedure is followed, but then using the Units 8 to 15.

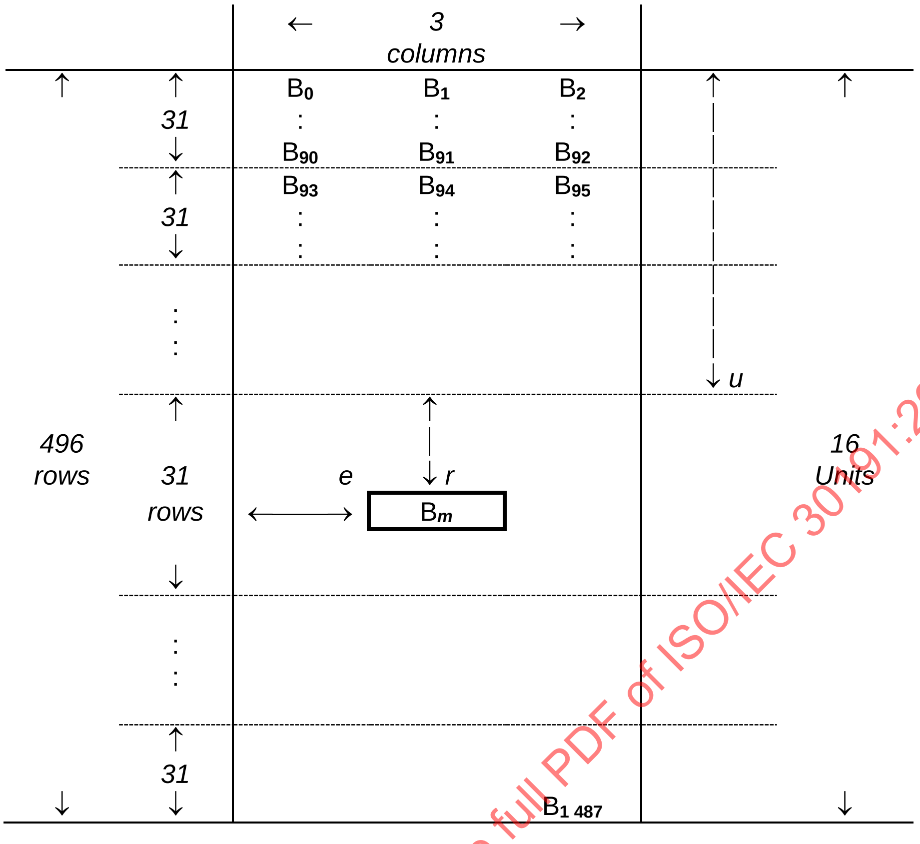


Figure 36 — BIS Cluster

Mathematically, the mapping of the bytes from a BIS Block into a BIS Cluster can be represented by the following formulae:

Byte $b_{N,C}$ or pb $_{N,C}$ (see Figure 35) is placed

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

— on row $r = \mathrm{div}(N,2)$

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

The byte number m, giving the sequence number B_m as the Physical Cluster is written to the disk (see Figure 22), is

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

Unit *u*	row *r*	byte number N,C from BIS Block — column *e* 0	1	2	shift right (= mod(*r*,3))	filling in upward direction
0	0	0,0	0,1	0,2	0	start of Block row *N* = 0
	1	2,5	2,3	2,4	1	↑ continuation of Block row *N* = 2
	2	4,7	4,8	4,6	2	
	3	6,9	6,10	6,11	0	
	:					
	7	14,23	14,21	14,22	1	
	8	16,1	16,2	16,0	2	start of Block row *N* = 16
	:					
	30	60,18	60,19	60,20	0	
1	0	0,21	0,22	0,23	0	end of Block row *N* = 0
	1	2,2	2,0	2,1	1	start of Block row *N* = 2
	2	4,4	4,5	4,3	2	
	3	6,6	6,7	6,8	0	
	:					
2	0	0,18	0,19	0,20	0	
	1	2,23	2,21	2,22	1	end of Block row *N* = 2
	2	4,1	4,2	4,0	2	start of Block row *N* = 4
	3	6,3	6,4	6,5	0	
	:					
3	0	0,15	0,16	0,17	0	
	1	2,20	2,18	2,19	1	
	2	4,22	4,23	4,21	2	
	3	6,0	6,1	6,2	0	start of Block row *N* = 6
	:					
4	0	0,12	0,13	0,14	0	
	1	2,17	2,15	2,16	1	
	2					
	:					
5	0	0,9	0,10	0,11	0	
	1	2,14	2,12	2,13	1	
	2					
	:					
6	0	0,6	0,7	0,8	0	
	1	2,11	2,9	2,10	1	
	2	4,13	4,14	4,12	2	
	:					
7	0	0,3	0,4	0,5	0	↑ continuation of Block row *N* = 0
	1	2,8	2,6	2,7	1	↑ continuation of Block row *N* = 2
	2	4,10	4,11	4,9	2	
	:					
	7	14,2	14,0	14,1	1	start of Block row *N* = 14
	:					
	30	60,21	60,22	60,23	0	end of Block row *N* = 60

Figure 37 — Example of mapping (partial) of BIS bytes into first 8 units

Unit *u*	row *r*	byte number N,C from BIS Block 0	column *e* 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 38 — Example of mapping (partial) of BIS bytes into last 8 units

Some conclusions:

— All information bytes of a BIS Block are found in the first 15 rows of each Address Unit.
— All parity bytes of a BIS Block are found in the last 16 rows of each Address Unit.
— Each Address Field is found in the first 3 rows of each Address Unit (see Figure 39).

13.14 ECC Cluster

After constructing the LDC Cluster and the BIS Cluster, the LDC Cluster is split into four groups of 38 columns each. In between these four 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 39 is reached.

	LDC *38* *columns* ← →	*BIS* *1* *column* ← →	*LDC* *38* *columns* ← →	*BIS* *1* *column* ← →	*LDC* *38* *columns* ← →	*BIS* *1* *column* ← →	*LDC* *38* *columns* ← →	
↑		$AF_{0,0}$ $AF_{3,0}$ $AF_{6,0}$ $UC_{u,v}$:		$AF_{1,0}$ $AF_{4,0}$ $AF_{7,0}$: :		$AF_{2,0}$ $AF_{5,0}$ $AF_{8,0}$: :		Address Unit 0
496 rows		$AF_{0,1}$ $AF_{3,1}$ $AF_{6,1}$ $UC_{x,y}$:		$AF_{1,1}$ $AF_{4,1}$ $AF_{7,1}$: :		$AF_{2,1}$ $AF_{5,1}$ $AF_{8,1}$: :		Address Unit 1
↓		: : : :		: : : :		: : : :		: : : :

Figure 39 — ECC Cluster after multiplexing of BIS Cluster with LDC Cluster

13.15 Recording Frames

Each row of the ECC Cluster is transformed into a Recording Frame by adding locations for Frame-Sync bits and for dc-control bits.

For this purpose a stream of 1 240 data bits which is formed by the 155 bytes of each row of the ECC Cluster is divided into one group of 25 data bits and 27 groups of 45 data bits (see Figure 40), 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.

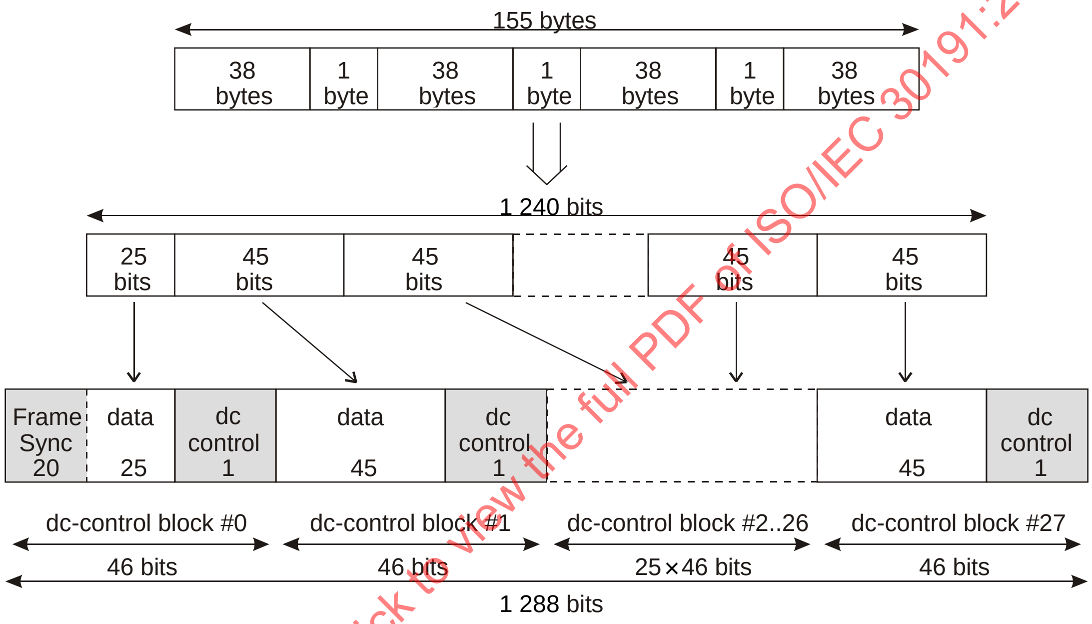


Figure 40 — Composition of Recording Frame

Next, each group of 45 data bits is completed with 1 additional bit position to form a dc-control Block.

13.16 Physical Cluster

The 496 rows from an ECC Cluster, transformed into Recording Frames are called a Physical Cluster.

13.17 17PP Modulation for Recordable data

13.17.1 General

All the bits of Recording Frames, except the Frame Sync, are converted to Modulation bits according to the 17PP modulation code. This is an RLL(1,7) code with run-lengths ≥ 2T and ≤ 8T and with some special properties. PP means: Parity preserve / Prohibit RMTR:

— 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 41 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 40). 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 41 — 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 ONE s 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 40).

13.17.4 Frame Sync

The Physical Clusters consist of 16 Address Units, where each Address Unit contains 31 Recording Frames (see Figure 22 and Figure 40).

A modulated Recording Frame starts with a Frame Sync consisting of 30 Channel bits.

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

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

If the last data bits preceding the Frame Sync have been coded according to the termination table (see Figure 41), then the first modulation bit of the Frame Sync # =ONE, else # =ZERO (see Figure 42).

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 42 — 30-bit Frame-Sync codes

Because seven different Frame Syncs are insufficient to identify 31 Recording Frames, each Frame is identified by the combination of its own Frame Sync and the Frame Sync of one of the preceding Recording Frames. The mapping of these combinations can be made such that, even with missing Frame Syncs in 1, 2 or 3 preceding Frames, a Recording Frame can still be identified by its own Frame Sync and the last present Frame Sync (see Figure 43).

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 IDs 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 43 — 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 44.

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 44 — 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, which in turn are converted to NRZI Channel bits according to the following process (see Figure 45):

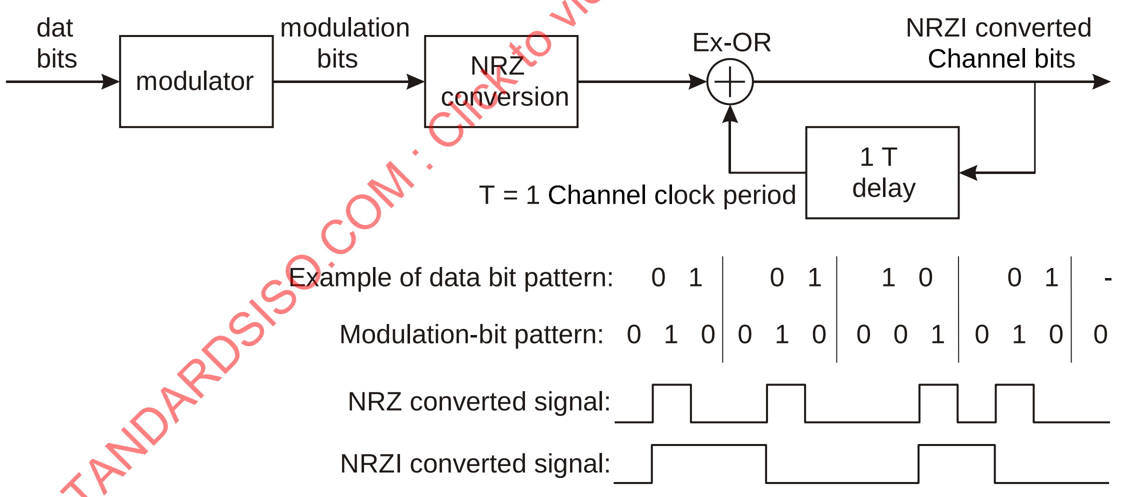


Figure 45 — Modulation and NRZI conversion

14 Physical Data Allocation and Linking

14.1 General

The unit of recording is a Recording-Unit Block (RUB), consisting of a Physical Cluster preceded by a Data Run-in and followed by a Data Run-out.

Recording-Unit Blocks can be written one by one or in a continuous sequence of several RUB's (write_streaming).

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

14.2 Recording-Unit Block (RUB)

14.2.1 General

Each RUB consists of a Data Run-in of 2 760 cbs (nominally 40 wobble periods), a Physical Cluster of 496 × 1 932 cbs (nominally 496 × 28 wobble periods) and a Data Run-out of 1 104 cbs (nominally 16 wobble periods).

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

Figure 46 — Layout of single written Recording-Unit Block

Each single written RUB or each continuously written sequence of RUB's shall be terminated by a Guard_3 field, ensuring that no gaps (Unrecorded Areas) will ever occur between any 2 RUB's.

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 47 — Layout of continuously written sequence of Recording-Unit Blocks

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,

— PrA (Pre-amble): 1 680 Channel bits.

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

The Guard_1 field is meant to cope with the overlaps due to inaccuracies in determining the start location of recording sequences (see Figure 48).

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

Figure 48 — 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 as shown in Figure 49:

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 49 — 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 42).

14.2.3 Data Run-out

14.2.3.1 General

The Data Run-out consists of the following parts:

— PoA (Post-amble): 564 Channel bits,

— Guard_2: 540 Channel bits.

The PoA field is meant as a run-out for signal processing.

The Guard_2 field is meant to cope with inaccuracies in determining the start location of recording sequences (see Figure 50).

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

Figure 50 — 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 51:

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

Figure 51 — 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

Guard_3 540 cbs	
repeated bit pattern ≈ 3 wobbles	optional APC ≈ 5 wobbles

Figure 52 — Layout of Guard_3 field

The Guard_3 field has a length of 540 Channel bits.

The content represented in Modulation bits is: 18 times repeated $01[0^4]1[0^4]1[0^2]1[0^2]1[0^6]1[0^5]$ (see Figure 52)

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 14.2.4.1.

14.2.4.3 Linking requirements

The Guard_1 and Guard_3 fields shall be used for linking separately written Recording-Unit Block sequences. The Guard_3 area of the previous Recording-Unit Block sequence shall be overwritten by the Guard_1 field of the actual written Recording-Unit Block sequence. The SER requirement for linked sequences is specified in 34.1.

A linking example of 3 separately-written single Recording-Unit Blocks is given in Figure 53

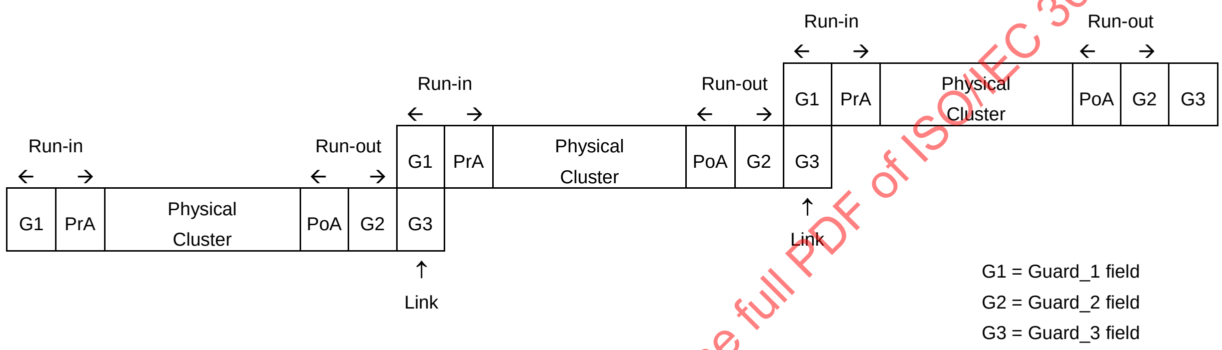


Figure 53 — Linking of 3 separately written single Recording-Unit Blocks

14.3 Locating data relative to wobble addresses

The nominal start positions for recordings (and single RUB's), as continuous sequences of several RUB's, 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.

As a consequence, the length of the Overwritten Area shall be between 7 and 9 wobble lengths.

15 Track Format

15.1 General

A Track is formed by a 360 ° turn of the continuous spiral Groove.

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 = $21{,}0^{\,0{,}0}_{-0{,}1}$ mm.

On Layer L0, the 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 this transition, the spiral Groove shall be uninterrupted.

The Groove Tracks in the BCA Zone shall be Straight Grooves (without any modulation) between a radius of 21 mm and the inner edge of the HFM Groove on Layer L0 or the inner edge of the Wobbled Grooves on the other Layers (see Clause 18).

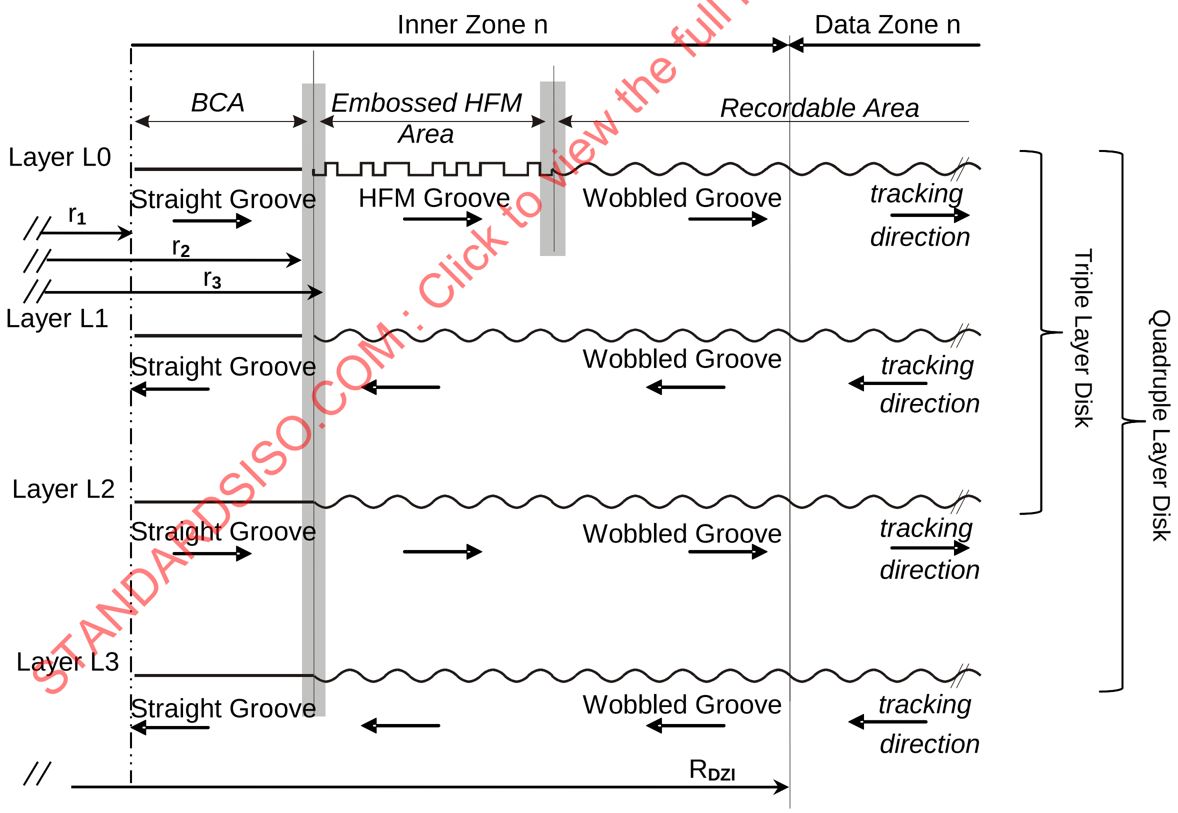


Figure 54 — Connection Areas between different Groove types

In the Embossed HFM Area on Layer L0 (see Clause 16) the Tracks are formed by a single spiral Groove, continuing uninterruptedly from the end of the Groove in the BCA Zone.

These Tracks in the Embossed HFM Areas deviate with a rather high frequency in the radial direction from their nominal Track centre, thereby providing a high bit rate / high capacity data channel for the storage of replicated information (HFM Groove).

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

In the Recordable Areas (see Clause 16) the Tracks are formed by a single spiral Groove. They start from the end of the Embossed HFM Area on Layer L0 or from the end of the Straight Groove Area on Layer L2. On Layers with odd Layer number, they end at the beginning of the Straight-Groove Area. Tracks in the Recordable Areas deviate mainly sinusoidally and monotonically in the radial direction from their nominal centrelines of the Wobbled Grooves. This 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 Pre-Groove or ADIP (see 15.7). The shape of each Track is determined by the requirements specified in Clause 27.

NOTE Although the term of "Pre-Groove" is not defined in this International Standard, "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 International Standards.

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 is allowed to form a Groove-only part (without any modulation) for maximum 1 mm length in the tangential direction along the Track.

Groove geometry
On each layer, only On-Groove recording is allowed in this International Standard (see Clause 7).

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.

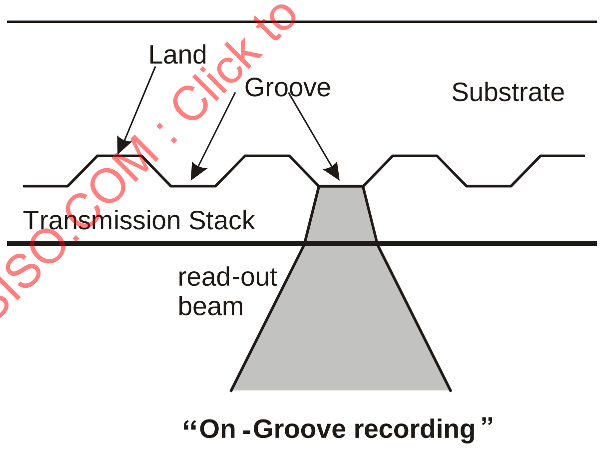


Figure 55 — Outline of Groove geometry
(Radial cross-section of disk)

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.

Tracks on Layers with even layer number *n* shall start at the beginning of Inner Zone *n* and terminate at the end of Outer Zone *n* and shall be continuous in the Information Zone. Tracks on Layer(s) with odd layer number *n* shall start at the beginning of the Outer Zone *n* and terminate at the end of the Inner Zone *n* and shall be continuous in the Information Zone (see and Figure 15 and Figure 16).

15.4 Track Pitch

15.4.1 Track Pitch in Zone reserved for BCA

The Track Pitch in Zone reserved for BCA is the distance between the average centrelines of the Groove in adjacent Tacks, measured in the radial direction.

The Track Pitch in these Zones shall be (2,0 ± 0,1) µm.

In the area between radius r_2 and radius r_3 the Track Pitch has to transition from 2,0 µm to 0,35 µm of the Embossed HFM Area on Layer L0 and to 0,32 µm of the Wobbled Grooves Area on other Layers.

15.4.2 Track Pitch in Embossed HFM Area

The Track Pitch in Embossed HFM Area is the distance between the average centrelines of the HFM Groove in adjacent Tracks, measured in radial direction.

The Track Pitch in this area shall be (0,350 ± 0,010) µm.

The Track Pitch averaged over Embossed HFM Areas shall be (0,350 ± 0,003) µm.

15.4.3 Track Pitch in Recordable Areas

The Track Pitch (TP) in Recordable Areas is the distance between the average centrelines of the Wobbled Groove in adjacent Tacks, measured in radial direction.

The Track Pitch in these areas shall be (0,320 ± 0,010) µm.

The Track Pitch averaged over Recordable Areas shall be (0,320 ± 0,003) µm.

15.4.4 Track Pitch between Embossed HFM Area and Recordable Area

The change in Track Pitch from 0,35 µm to 0,32 µm (on Layer L0) shall be realized within maximum 100 Tracks (revolutions), which Tracks shall be located completely in Protection-Zone 2 (see Figure 85).

15.5 Track layout of HFM Groove

15.5.1 General

In 15.5, only the encoding format of the data will be described. The locations and the content will be defined in Clauses 18 and 18.2.

The data in HFM Groove 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 to build up fully-formatted partitions are very similar to those described in Clause 13.

A reduced combination of LDC+BIS Codes is used as shown schematically in Figure 56.

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

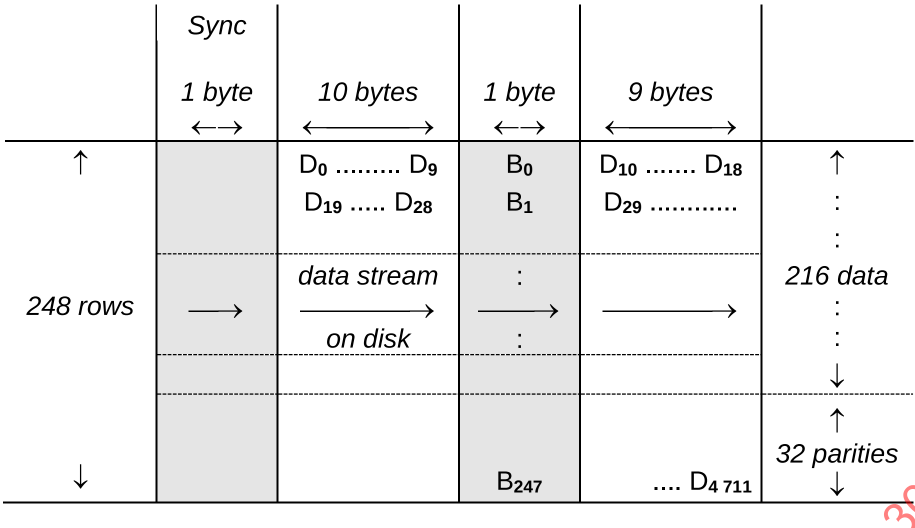


Figure 56 — Schematic representation of 4K PIC Cluster on disk

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 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 26 (only columns 0..18).

15.5.2.4 LDC Block

Next, 32 rows with Error-Correction Parities are added according to the procedure described in 13.5 and 13.6, 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 and subclauses.

Only the second interleaving step described in 13.8.3 is applied. That is each successive row is shifted one more byte position to the left (shift = mod(k,19), where k is the row number, $0 \le k \le 247$). 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 Recordable 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*
	9	$AF_{4,4}$	:	:	:	*addresses*
	10	$AF_{5,1}$	***$AF_{5,0}$***	:	:	
	11	$AF_{5,5}$	:	:	:	
1 BIS	12	$AF_{6,2}$	$AF_{6,1}$	***$AF_{6,0}$***	:	
code-word	13	$AF_{6,6}$	:	:	:	
= 62 bytes	14	$AF_{7,3}$	:	$AF_{7,1}$	***$AF_{7,0}$***	
	15	$AF_{7,7}$	:	:	:	
	16	***$AF_{8,0}$***	:	:	$AF_{8,1}$	
	17	$AF_{8,4}$	$AF_{8,7}$	$AF_{8,6}$	$AF_{8,5}$	↓
	18	$UC_{0,0}$	$UC_{12,0}$	$UC_{0,1}$	$UC_{12,1}$	↑
	19	$UC_{1,0}$	$UC_{13,0}$	$UC_{1,1}$	$UC_{13,1}$	*12 rows*
	:	:	:	:	:	*User Control*
	28	$UC_{10,0}$	$UC_{22,0}$	$UC_{10,1}$	$UC_{22,1}$	*Data*
	29	$UC_{11,0}$	$UC_{23,0}$	$UC_{11,1}$	$UC_{23,1}$	↓
	30	pb $_{30,0}$	pb $_{30,1}$	pb $_{30,2}$	pb $_{30,3}$	↑
	31	pb $_{31,0}$	pb $_{31,1}$	pb $_{31,2}$	pb $_{31,3}$	*32 rows*
	:	:	:	:	:	*parities*
↓	61	pb $_{61,0}$	pb $_{61,1}$	pb $_{61,2}$	pb $_{61,3}$	↓
		code word 0	code word 1	code word 2	code word 3	

Figure 58 — PIC BIS Block

15.5.3.2 Address Fields

Comparable to the Recordable 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 and subclause), each 4K PIC Cluster shall be identified by one Address-Unit Number. These Address-Unit Numbers shall increase by two for each successive 4K PIC Cluster.

Each PIC BIS Block contains eight 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 13.9.2 and sub-chapters):

$AF_{0,S} = PAF_{0,S}$ (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: Reserved
bits b_2 to b_0: 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 definitions 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 one 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 being shifted cyclically one more position to the left.

Mathematically, this mapping of the address bytes into the PIC BIS Cluster can be represented by the following formulae:

byte $AF_{x,y}$ shall be allocated in row $r = 2 \times x + \text{div}(y,4)$

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

15.5.3.3 User Control Data

There are 2 User-Control-Data Units, each consisting of 24 bytes. Bytes 0 to 11 of the first User-Control-Data Unit shall be placed in column 0, rows 18 to 29 of the PIC BIS Block and bytes 12 to 23 in column 1, rows 18 to 29. In the same way bytes 0 to 11 of the second User-Control-Data Unit shall be placed in column 2 and bytes 12 to 23 in column 3 (see Figure 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 to 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 the following formulae:

Let byte $b_{r,c}$ be the byte in row r and column c of the BIS Block,
and byte B_i is the i^{th} byte in the column of the BIS Cluster,

then $r = \mathrm{mod}(2 \times i, 62) + \mathrm{div}(i,124)$,
$c = \mathrm{mod}(i,4)$,

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

As a result of this interleaving, the one-column 248-byte BIS Cluster is divided into eight 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

← 1 byte →	
B_0	↑
:	
:	
:	
:	
B_i	
:	
:	
:	
:	
:	
B_{123}	*248*
B_{124}	*rows*
:	
:	
:	
:	
:	
:	
:	
:	
:	
:	
B_{247}	↓

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 a transition at the start of the bit cell and a bit with value ONE is represented by a transition at the start and in the middle of the bit cell (see example in Figure 60).

The modulation bits are recorded on the disk by a deviation of the Groove from its average centreline 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 Recordable Areas.

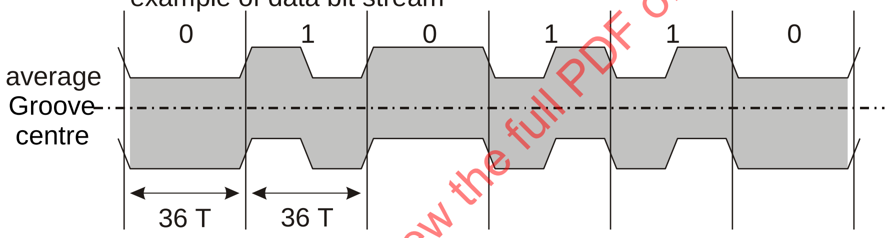


Figure 60 — Biphase modulated HFM Groove

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).

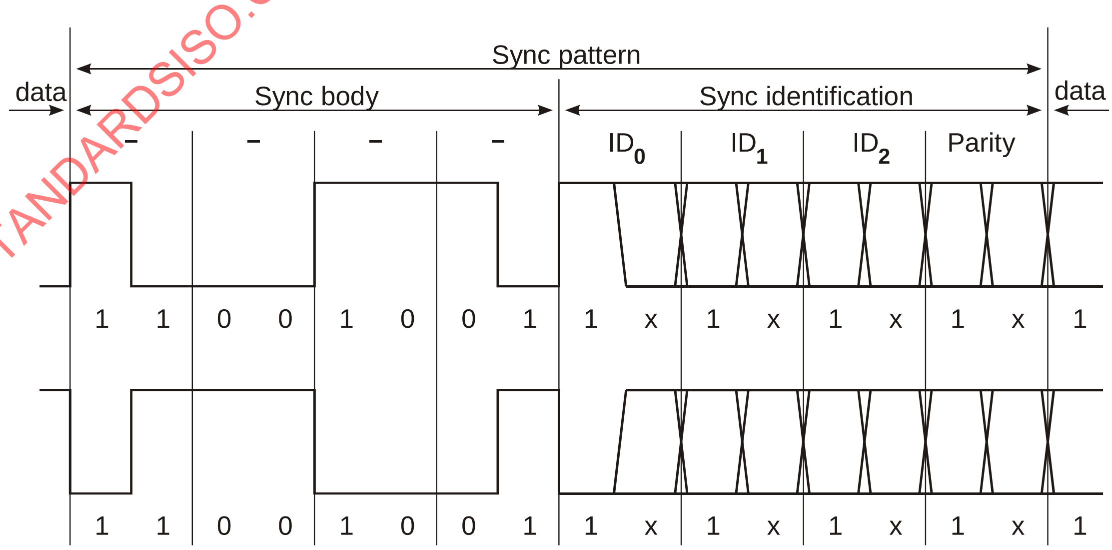


Figure 61 — Biphase Synchronization pattern

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

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

Figure 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 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 centrelines.

The nominal wobble length NWL (equivalent to 69 Channel bits) shall be

(4,020 0 ± 0,005) µm for a disk with a User Data capacity of 32,0 GB per layer,

(3,855 3 ± 0,005) µm for a disk with a User Data capacity of 33,4 GB per layer,

averaged over the Recordable Areas.

This corresponds to a fundamental frequency f_{wob} = 1 913,043 kHz at the 2x Reference Velocity.

15.6.2 Modulation of wobbles

15.6.2.1 General

The basic shape of the wobble 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, where two modulation methods shall be used simultaneously:

— the first modulation method is "MSK-cos" (Minimum-Shift Keying-cosine variant),
— the second modulation method is "HMW" (Harmonic-Modulated Wave).

In the Protection-Zone 3 Area in the Outer Zone(s) (see Clause 16 and 20.2.10) 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 = $1{,}5 \times f_{wob}$.

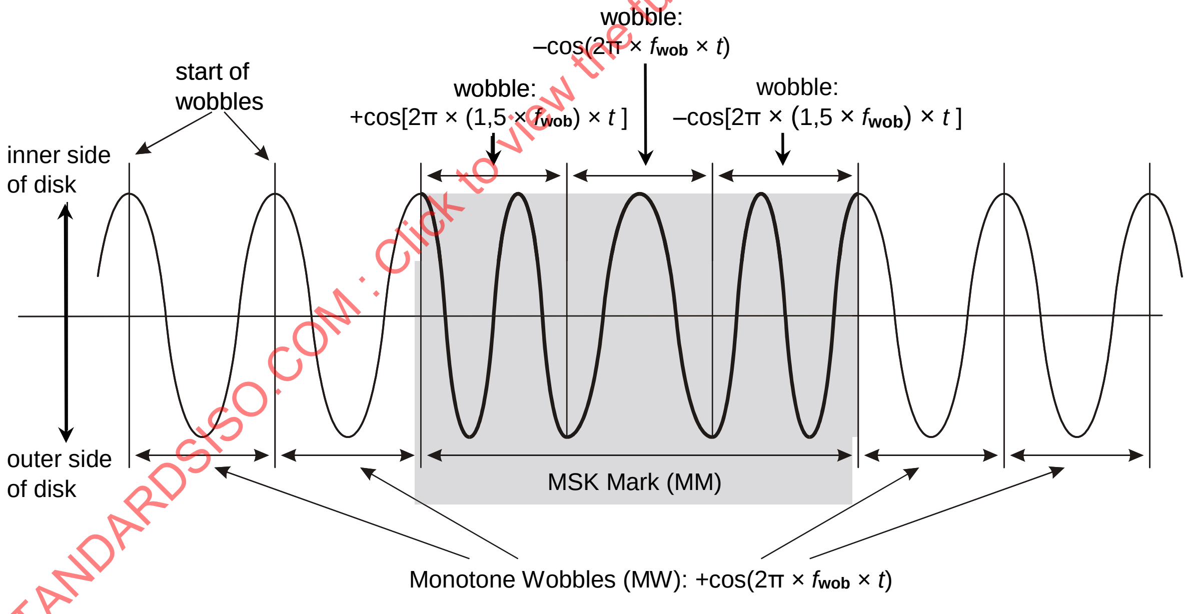


Figure 64 — Definition of MSK Mark (On-Groove)

15.6.2.3 HMW modulation

HMW modulation is applied by replacing a number of consecutive Monotone Wobbles will the same number of Saw-Tooth Wobbles (STW). A Saw-Tooth Wobble is formed by combining the basic cosine with a sine wave of twice the frequency:

$$\cos(2\pi \times f_{wob} \times t) \pm a \times \sin[2\pi \times (2 \times f_{wob}) \times t] \quad \text{in which } a = 0{,}25.$$

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

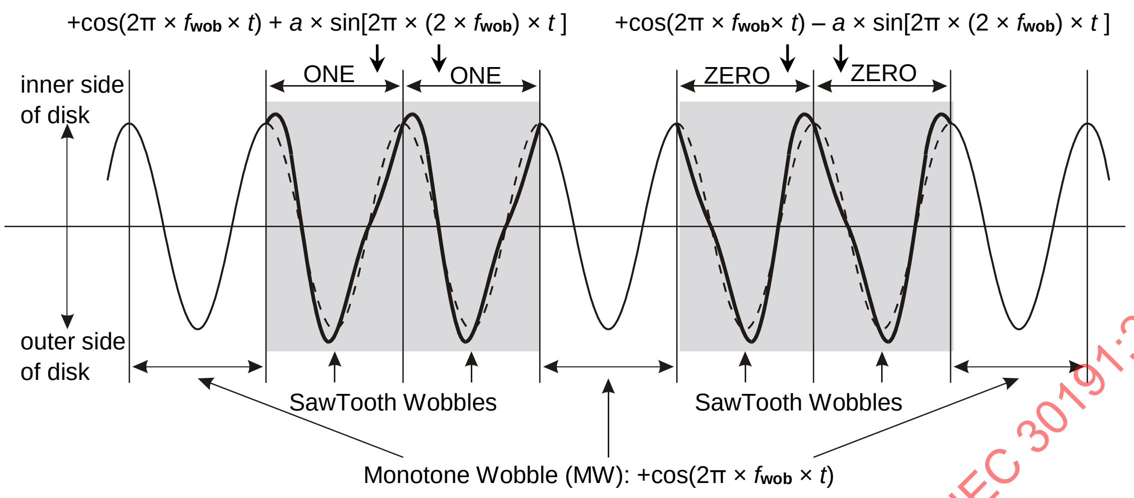


Figure 65 — Definition of Saw-Tooth Wobbles (On-Groove)

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

Data to be recorded onto the disk must be aligned with the ADIP addresses. The ADIP address is derived from ADIP symbols modulated in the wobble, refer to 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).

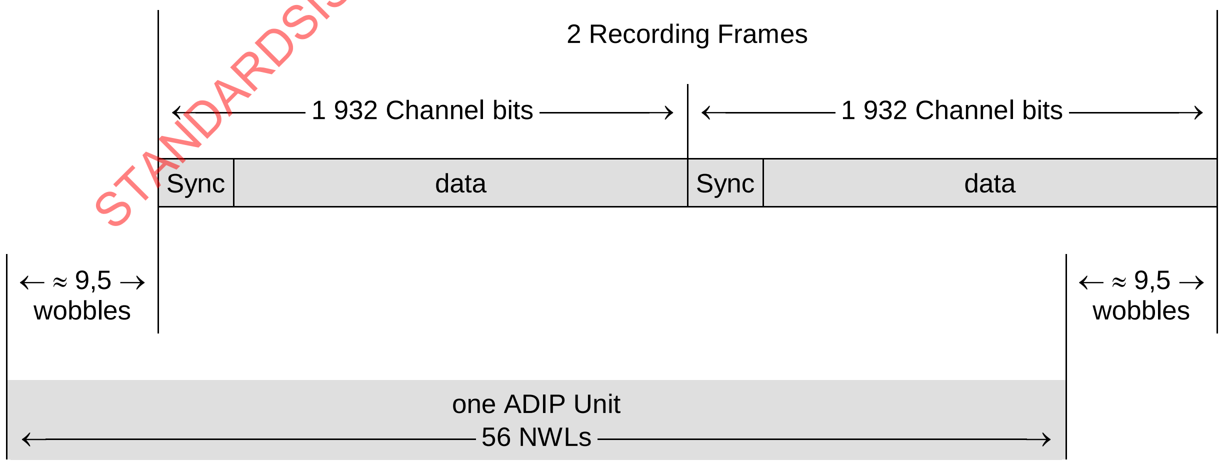


Figure 66 — General ADIP structure

15.7.2 ADIP-Unit Types

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

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

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

The following types of ADIP Units are defined (see Figure 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 one or zero:
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 MWs, 37 STW and one MW.

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

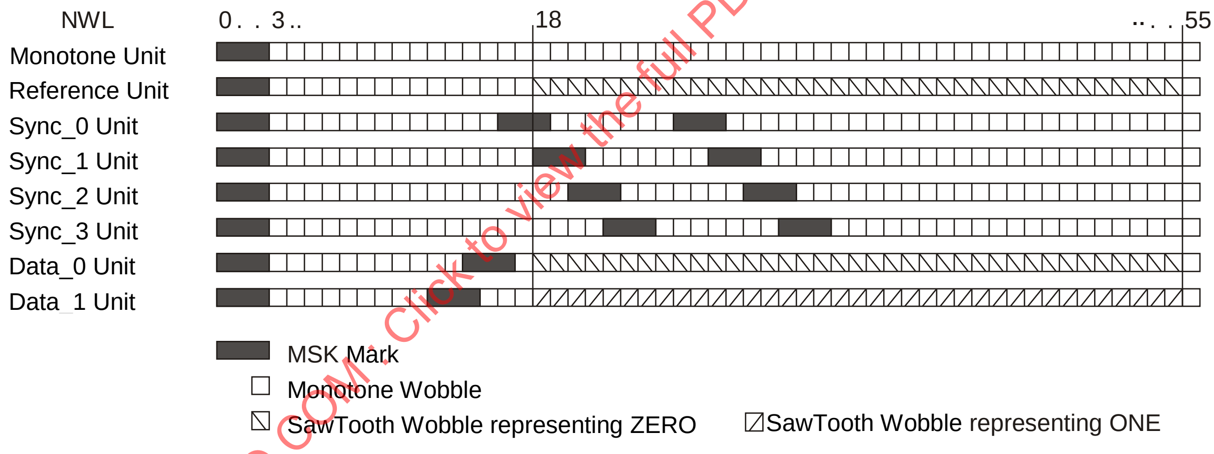


Figure 67 — ADIP-Unit Types

15.7.3 ADIP word structure

83 ADIP Units are grouped into one ADIP word. 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 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 an error correction system(see 15.7.5). Because this error-correction system is non-systematic, there is no simple direct relationship between the bits in the information array and the coded bits in the ADIP Unit.

15.7.4.2 ADIP-information bit assignments

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

— **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:

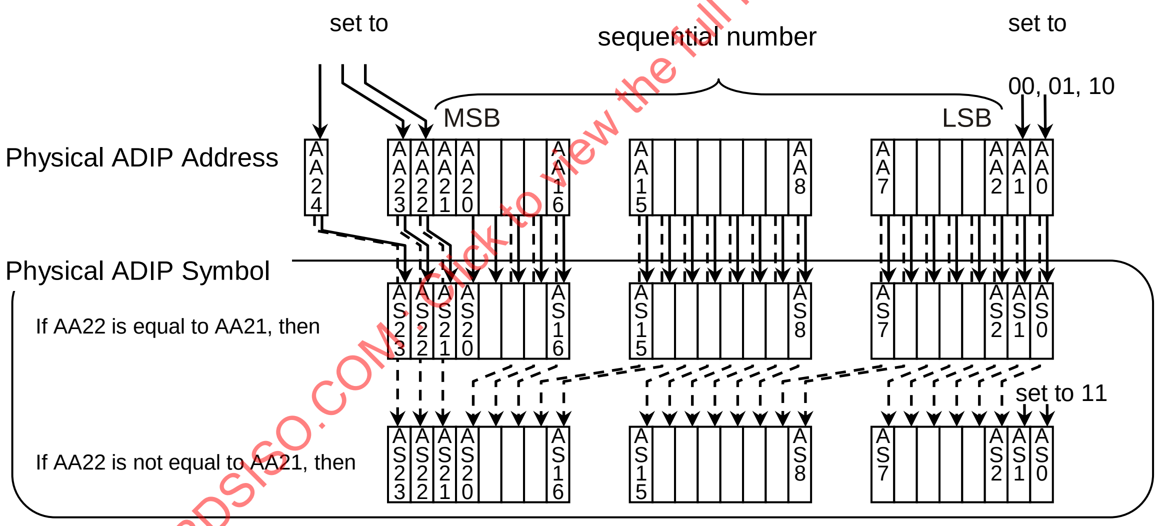


Figure 70 — Relation between PAA and PAS

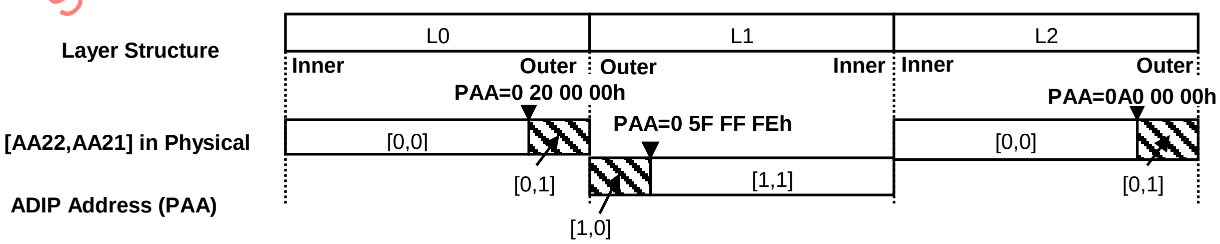


Figure 71 — Combination of AA22 and AA21 for TL disk

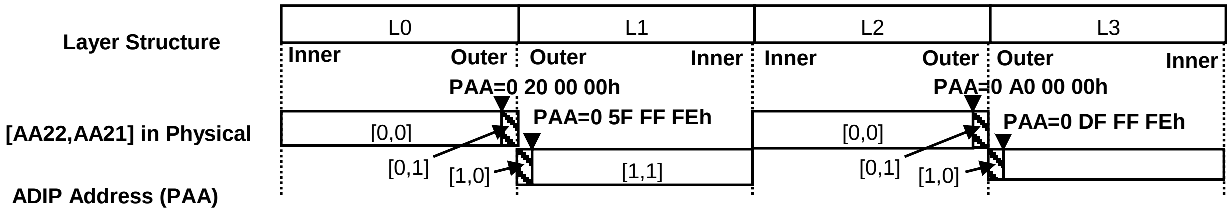


Figure 72 — Combination of AA22 and AA21 for QL disk

— **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 (see Figure 71 and Figure 72):

  — **AA24..AA22**:These 3 bits shall indicate the layer number and shall be set to:000, 001, 010 and 011 on Layer L0, Layer L1, Layer L2 and Layer L3, respectively. All other settings shall be Reserved.

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

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

The first address in the Information Zone on Layer L0 shall be such that the first address in the Data Zone, which is PAA 0 02 00 00h, is located at radius $24{,}0^{\;0{,}0}_{-0{,}1}$ mm.

The last address of the Data Zone on Layer L0 (LAA) shall be located at a radius < 58,1 mm.
The first address of the Data Zone on Layer L1 (FAA) shall be located at a radius < 58,1 mm.
The last address of the Data Zone on Layer L1 (0 7D FF FEh) shall be located at radius $24{,}0^{\;0{,}0}_{-0{,}1}$ mm.

The first address of the Data Zone on Layer L2 (0 82 00 00h) shall be located at radius $24{,}0^{\;0{,}0}_{-0{,}1}$ 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.
The first address of the Data Zone on Layer L3 (FAA + 0 80 00 00h) shall be located at a radius < 58,1 mm.
The last address of the Data Zone on Layer L3 (0 FD FF FEh) shall be located at radius $24{,}0^{\;0{,}0}_{-0{,}1}$ mm.

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

  — In the Data Zone(s) and the Outer Zone(s) of the disk the auxiliary bits shall be set to ZERO.

  — In the Inner Zone(s) of the disk the auxiliary bits shall be used as follows:

    — 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 that is a multiple of 128 (PAA = x xxxx xxxx xxxx xxxx x000 0000).

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

15.7.4.3 Relation between Physical ADIP Addresses on Layers from Layer L0 to Layer L3

There shall be a fixed relation between the PAAs on Layers from Layer L0 to Layer L3. The PAAs on Layer L0 (or Layer L2) and Layer L1 (or Layer L3) located at the same radius (having the same distance in number of ADIP words from their respective Inner Zones) shall have inverted bits AA21 to AA2. The PAAs on Layer L0 and Layer L2 (or on Layer L1 and Layer L3) located at the same radius shall have the same bits AA21 to AA2 (see Figure 73 and Figure 74).

In this way, the PAAs on Layer L1 (or Layer L3) 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 (or PAA_3) have the same relation with the radius as the equivalent non-inverted bits on Layer L0 (or Layer L2).

	Layer number	Sequential 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	$\overline{AA21}$ .. $\overline{AA2}$	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
PAA_3 on Layer L3	AA24 .. AA22 = 011	$\overline{AA21}$ .. $\overline{AA2}$	AA1,AA0 = 00,01,10 from outer to inner

Figure 73 — Relation between Physical ADIP Addresses on Layers from Layer L0 to Layer L3

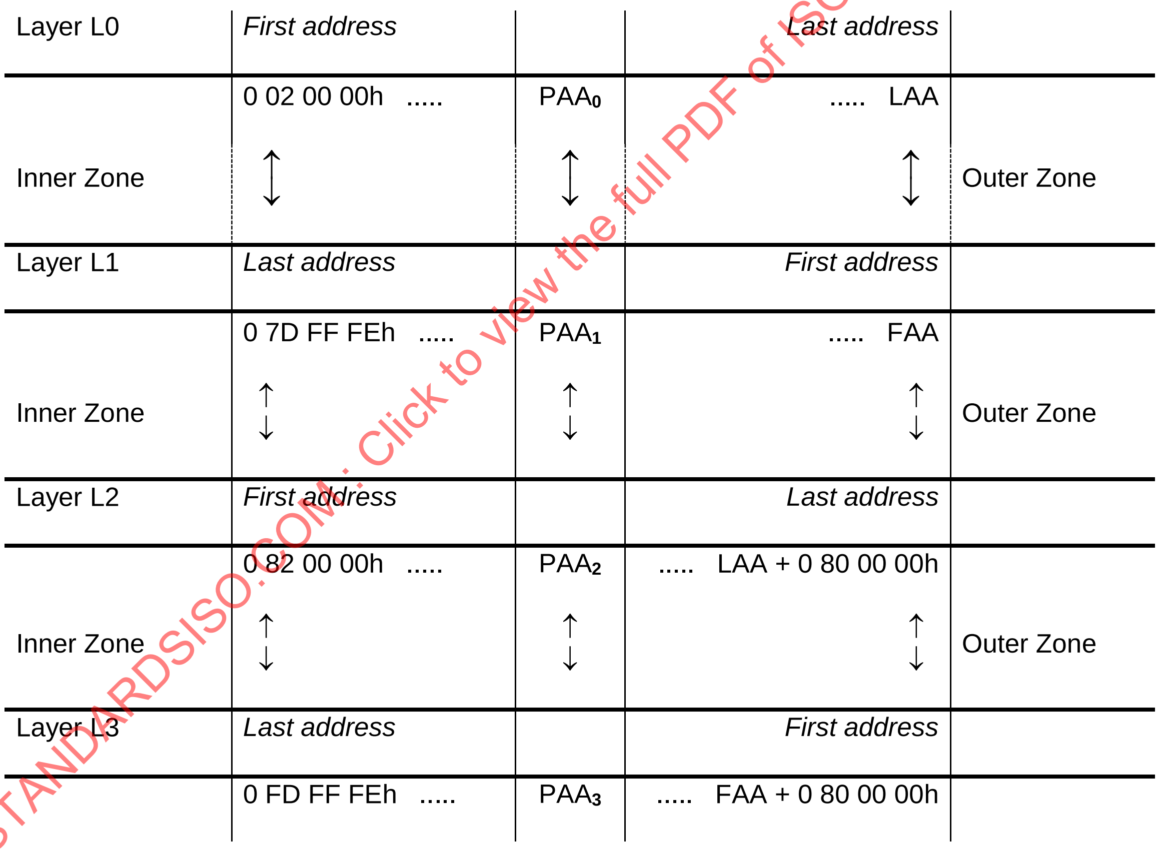


Figure 74 — Illustration of PAA relation among layers

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.

In formula: $PAA_1 = \overline{PAA_0 + 1\,80\,00\,01\,h}$

(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 follows:

$0\ 7D\ FF\ FEh = \overline{0\ 02\ 00\ 00h + 1\ 80\ 00\ 01\ h}$,and the first address of Data Zone 1 is:

$FAA = \overline{LAA + 1\ 80\ 00\ 01\ h}$

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

PAA_3 are obtained by adding 0 80 00 00h to PAA_1.

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 $p(x)$:

$$p(x) = x^4 + x + 1.$$

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:

$$\alpha = 0010.$$

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

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

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

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

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:

$$z_i = \alpha^{i+6}.$$

The generator polynomials are then calculated as follows:

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

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

Before recording on the disk, all bits of the nibbles c_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:

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

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 $g_p(x)$. The following table gives the corresponding zero factor for each information symbol (note that n_8 does not have a corresponding ZERO) (see Figure 75):

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 75 — 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 will increase. For instance if n_0 is known, the Hamming distance will become d = 8. If both n_0 and n_1 are known, the Hamming distance will become 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 76. 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 76 — 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 77). 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.

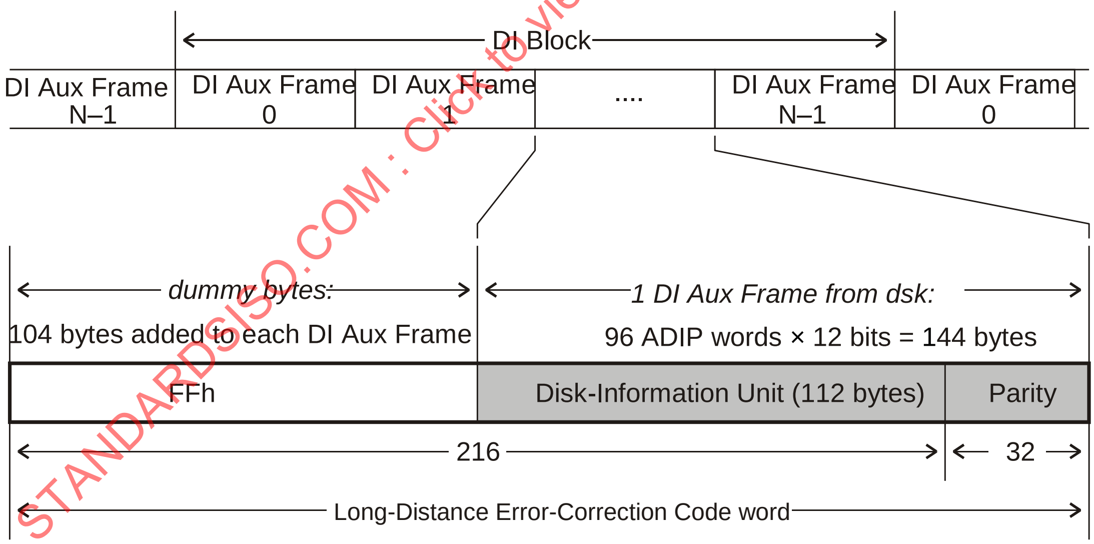


Figure 77 — Disk Information structure and error correction format

15.8.3 Disk-Information Data structure

15.8.3.1 General

A DI Block can consist of a multiple of 144-byte Aux DI Frames (see Figure 77). 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 0 01 B8 00h on Layer L0, from PAA 0 7E 00 00h on Layer L1, from PAA 0 81 B8 00h on Layer L2, and from PAA 0 FE 00 00h on Layer L3 in case of a QL disk.

From the start PAA of Protection-Zone 2 to PAA 0 01 B7 FEh of Layer L0 (see Figure 85 for Layer L0 layout of a TL disk and Figure 88 for Layer L0 layout of a QL disk), from PAA 0 7E 48 00h to the last PAA of Protection-Zone 1 of Layer L1 (see Figure 86 for Layer L1 layout of a TL disk and Figure 89 for Layer L1 layout of a QL disk), from the start PAA of Protection-Zone 1 to PAA 0 81 B7 FEh of Layer L2 (see Figure 87 for Layer L2 layout of a TL disk and Figure 90 for Layer L2 layout of a QL disk), from PAA 0 FE 48 00h to the last PAA of Protection-Zone 1 of Layer L3 (see Figure 91 for Layer L3 layout of a QL disk), 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.

Usage of DI Units for write strategies are given in 15.8.3.6

In future extensions of this International Standard additional DI Aux Frames may be needed, e.g. to define higher recording speeds and new write strategies. Whenever new DI Aux Frames are added, the existing ones can still be used if appropriate, and in that way backwards compatibility with existing drives can be facilitated. Each drive should check all DI Aux Frames present on the disk and, based on the DI-Format Number (byte 2) and the indicated Recording Velocity (bytes 28 to 29), only use the ones that it is supporting (see also 15.8.3.6).

15.8.3.2 General definitions for DI Unit

Each DI Unit shall consist of a header, a body and a footer as depicted in Figure 78.

	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 78 — General DI-Unit format

Bytes 0 to 1: **Disk-Information identifier**

These 2 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.

In future this International Standard may be extended to allow for new features, such as instance higher recording speeds or higher data densities. To prevent backwards-compatibility problems of such newer disks with older drives as much as possible, a Class number and a Version number have been introduced.

The Class number will be incremented if a BD Layer according to the new specifications should not be accessed by legacy drives at all, neither for reading nor for writing (e.g. to prevent possible damage to the disk or to the drive).

If the read compatibility can be made to conform to an existing Class, no new Class number is needed.

The Version number will be incremented if the new specifications imply an extension/change for which no Class-number update is needed (read compatibility is maintained), but for which new specifications will result in a write-compatibility break. Although such a BD Layer is carrying a higher Version number, it still could 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.

As a consequence of this, drives should always check for the presence of a DI Unit with a DI-Format Number known to the drive. In such cases the recording parameters (such as e.g. recording 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 still preventing possible damage to disks and drives.

Each Layer Type (defined by bytes 8 to 10) has its own independent DI Format numbering. The DI-Format Number is also an indication for the write strategy type, which is specified in the DI Unit.

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 shall specify the number of DI Aux Frames N in each DI Block ($1 \leq N \leq 31$).

Bits b_2 to b_0: These 3 bits shall 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 ($0 \leq n \leq N–1$).

The sequence of DI Units shall be ordered (see Figure 79) first according to increasing Nominal Recording Velocity (bytes 28 to 29), second, within each sequence of DI Units with the same Nominal Recording Velocity, according to ascending Layer number (byte 3) and third according to the preference of the write strategy (identified by the DI-Format Number, but need not be in the sequence of DI-Format Numbers).

Sequence number	Recording speed	Layer number	Write strategy
0		0	preferred WS
1			alternative WS
:		1	preferred WS
k–1			alternative WS
k	V_1	:	preferred WS
:			alternative WS
:		*k*–1	preferred WS
2*k*–1			alternative WS
2*k* :		0	most preferred WS :
:	$V_2 > V_1$	:	:
: :		*k*–1	: least preferred WS
:	$V_3 > V_2$	0	:
:	:	:	:
N–1	etc.	etc.	:

Figure 79 — 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 whether 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:

ZERO if the next DI Unit is the start of a new set of parameters,

ONE if the parameter set in this DI Unit is continued in the next DI Unit (see Figure 80).

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 81).

	:	
	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 80 — 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, such as e.g. 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, must 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, must 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 International Standard 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 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 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 at the Nominal Recording Velocity	1
31	Maximum HF-modulated read power at the nominal Recording 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-write-pulse duration	3
59 to 63	dT_S start time of Space-level	5
64	Reserved	1
65 to 72 and 73 (msb 4 bits)	ΔdT_{top} first-write-pulse start time offset	8,5
73 (lsb 4 bits) and 74 to 80	ΔT_{top} first-write-pulse duration offset	7,5
81 to 84 and 85 (msb 4 bits)	ΔdT_{LP} last-pulse start time offset	4,5
85 (lsb 4 bits) and 86 to 89	ΔT_{LP} last-pulse duration offset	4,5
90 to 97 and 98 (msb 4 bits)	ΔdT_S start time offset of the Space level	8,5
98 (lsb 4 bits)	Reserved	0,5
99	Reserved	1
100 to 111	DI Unit footer	12

Figure 81 — 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 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 to indicate that the first 99 bytes of the DI Unit are used and that there is no continuation in the next DI Unit. All remaining bytes of the DI Unit body (excluding the bytes in the DI Unit footer) are unused and shall be set to 00h.

Byte 7: **Reserved**

See 15.8.3.2.

Bytes 8 to 10: **BD Layer-Type identifier**

These 3 bytes identify the type of the BD Layer to which this DI Unit applies and shall be set to 42 44 52h, representing the characters “BDR” in each Recordable 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 to indicate 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 International Standard 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 0010.

Byte 12: **BD structure**

Bits b_7 to b_4: These 4 bits specify the total number of BD Recording/Recorded Layers on the disk.

On a TL disk they shall be set to 0011 to indicate three Recording Layers.

On a QL disk they shall be set to 0100 to indicate four 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 0010 to indicate a recordable Recording Layer.

Byte 13: **Channel-bit length**

Bits b_7 to b_4: These 4 bits shall be set to 0000 on disks.

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

0100, to indicate a Channel-bit length of 58,26 nm (32,0 GB per Layer),

0101, to indicate a Channel-bit length of 55,87 nm (33,4 GB per Layer),

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 Recording Layer L*i* (see 26.1). They shall be set to

ZERO, to indicate that the Push-Pull polarity on Layer *i* is positive

ONE, to indicate that the Push-Pull polarity on Layer *i* is negative.

For Recording Layers that are not present, bit bi shall be set to ZERO.

For this International Standard, 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 *i*.

They shall be set to

ZERO, to indicate a Layer Type on which Recorded Marks have a lower reflectivity than the Unrecorded Layer (HTL disks).

ONE, to indicate a Layer Type on which Recorded Marks have a higher reflectivity than the Unrecorded Layer (Reserved).

For this International Standard, 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 shall indicate the presence of a BCA code on this disk:

0000, indicates that there is no BCA code,

0001, indicates that BCA code 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 specify the first Physical ADIP Address of the Data Zone of the related layer.

In each DI Unit relating to Layer L0 these bytes shall be set to 00 02 00 00h to indicate PAA 131 072 as the first PAA of Data Zone 0.

In each DI Unit relating to Layer L1 these bytes shall be set to a value FAA, which shall be 00 60 32 80h for a disk with a User Data capacity of 32,0 GB per layer, or 00 5E EC 80h for a disk with a User Data capacity of 33,4 GB per layer, to indicate PAA 6 304 384 for 32,0 GB per layer or 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 Data Zone 2.

In each DI Unit relating to Layer L3 these bytes shall be set to the value FAA + 00 80 00 00h, which shall be 00 E0 32 80h for a disk with a User Data capacity of 32,0 GB per layer, to indicate PAA 14 692 992 as the first PAA of Data Zone 3.

Bytes 23 to 26: These bytes specify the last Physical ADIP Address of the Data Zone of the related layer.

In each DI Unit relating to Layer L0 these bytes shall be set to a value LAA, which shall be 00 1F CD 7Eh for a disk with a User Data capacity of 32,0 GB per layer, or 00 21 13 7Eh for a disk with a User Data capacity of 33,4 GB per layer, to indicate PAA 2 084 222 for 32,0 GB per layer or PAA 2 167 678 for 33,4 GB per layer as the last PAA of Data Zone 0.

In each DI Unit relating to Layer L1 these bytes shall be set to 00 7D FF FEh to indicate PAA 8 257 534 as the last PAA of 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 9F CD 7Eh for a disk with a User Data capacity of 32,0 GB per layer, or 00 A1 13 7Eh for a disk with a User Data capacity of 33,4 GB per layer, to indicate PAA 10 472 830 for 32,0 GB per layer or PAA 10 556 286 for 33,4 GB per layer as the last PAA of Data Zone 2.

In each DI Unit relating to Layer L3 these bytes shall be set to 00 FD FF FEh to indicate PAA 16 646 142 as the last PAA of Data Zone 3.

Byte 27: **Reserved**

This byte shall be set to 00h.

Bytes 28 to 29: **Recording Velocity**

These bytes specify the Nominal Recording Velocity, to be used with the parameters as defined in this DI Unit, as a 2-byte binary number (byte 28 is MSB).

It shall specify the Nominal Recording Velocity as a number *n* such that

$n = 100 \times V\text{nom}$.

n shall be equal to

03 01h to indicate a Nominal Recording Velocity of 7,69 m/s (32,0 GB per layer),

02 E2h to indicate a Nominal Recording Velocity of 7,38 m/s (33,4 GB per layer).

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 30.6). Maximum read powers in this section shall be greater than or equal to the read powers defined in 30.6. By default, the powers defined in 30.6 shall be used.

This byte specifies the dc read power P_r at a readout velocity equal to the Nominal Recording Velocity defined in bytes 28 to 29 of this DI Unit. The decimal expression of this byte shall be:

$n = 100 \times P_r$, 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 might be necessary to guarantee 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 the recorded signals (see 30.6). Maximum read powers in this section shall be greater than or equal to the read powers defined in 30.6. By default, the powers defined in 30.6 shall be used.

This byte specifies the maximum HF-modulated read power P_r at the same readout velocity as the Nominal Recording Velocity defined in bytes 28 to 29 of this DI Unit. The decimal expression of this byte shall be:

$n = 100 \times P_r$, where the unit of P_r is milliwatts.

NOTE For reading at lower speeds than the Nominal Recording Velocity specified in this DI Unit a reduction of the read power might be necessary to guarantee 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

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

Bit b_7 of Byte 33 is msb and bit b_0 of Byte 34 is 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: **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_{S}:** This byte shall specify the space/write peak power ratio ε_{S} used in the OPC algorithm (see Annex G) as a number n such that

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

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: **β:** This byte shall specify the target value for β used in the alternative OPC procedure (see Annex G) as a number n such that

$$n = 500 \times (\beta + 0{,}2).$$

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

This byte specifies the duration of the second and higher pulses of the multi-pulse train, of 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 variable part as a fraction of the actual Channel-bit clock period as an unsigned binary number p such that

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

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_S. Anchor position means the leading edge position of each write pulse(see Figure F.1and FigureF.4). 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, of 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} is expressed as a fraction of the actual Channel-bit clock period as a signed two's complement binary number a such that

$$a = 32 \times \frac{dT_{top}}{T_W} \quad (-28 \le a \le 30). \text{ (where } a \text{ is even.)}$$

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 a 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 a 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 a 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 a 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, of the Extended N–1 write strategy, for recording of 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

$$b = 32 \times \frac{T_{top}}{T_w} \qquad (0 \le b \le 60) \text{ (where } b \text{ is even.)}$$

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 a 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 a 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 a 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 a 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, of the Extended N–1 write strategy, for recording Marks with run-lengths 3T, 4Tand ≥ 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

$$c = 32 \times \frac{dT_{LP}}{T_W} \quad (-30 \le c \le 30). \text{ (where } c \text{ is even.)}$$

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 a 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 a 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 a run-length ≥ 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, of 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

$$d = 32 \times \frac{T_{LP}}{T_W} \quad (0 \le d \le 30). \text{ (where } d \text{ is even.)}$$

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 a 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 a 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_S* start time of the Space level**

The first 7 bits (bits b_7 to b_1) of these bytes specify the start time of the Space level of the Extended N–1 write strategy, for the recording Marks of 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 Space level dT_S is expressed as a fraction of the actual Channel-bit clock period as a signed two's complement binary number e such that

$$e = 32 \times \frac{dT_S}{T_W} \qquad (-48 \le e \le 30). \text{ (where } e \text{ is even.)}$$

The last bit (bit b_0) of these bytes is Reserved.

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

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

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

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

Byte 63: This byte shall specify the start time of the Space 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.

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, of the Extended N–1 write strategy, for recording of 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

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

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

(where f is even)

dT_{top}

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

This table 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.

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.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 a 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 a 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 a 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 a run-length 4T that 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 a ≥ 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 a 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 a 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 a 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 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 a 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 a 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 a 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 a 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 a 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 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 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, of 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

$$g = 32 \times \frac{\Delta T_{top}}{T_W} \quad (-8 \le g \le 7) \text{ (where } g \text{ is even)}$$

T_{top}

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

This table 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.

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 a 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 a 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 a 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 a 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 a 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 a 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 Marks of a 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 a 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 a 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 a run-lengths 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 a 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 a 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 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 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, of 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 offset start time 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

$$h = 32 \times \frac{\Delta dT_{LP}}{T_W} \quad (-8 \leq h \leq 7) \text{ (where } h \text{ is even.)}$$

dT_{LP}

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

This table 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.

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 $-30 \leq r \leq 30$.

(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 a 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 a 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 a 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 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 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 a 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 Marks of a 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 a 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, of the Extended N–1 write strategy, for recording Marks with a run-length 3T 4Tand ≥ 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

.

$$v = 32 \times \frac{\Delta T_{LP}}{T_W} \quad (-8 \leq v \leq 7) \text{ (where } v \text{ is even.)}$$

T_{LP}

Mark / Succeeding Space	3M	4M	≥5M
2S		v	
3S		v	
4S		v	
≥5S		d	

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.

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 $0 \leq s \leq 30$.

(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 a 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 a 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 a ≥ 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 a 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 a 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 a 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 a 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_S start time offset of the Space level

These bytes specify the start time offset of the Space level of the Extended N–1 write strategy, for the 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 Space level ΔdT_S is expressed as a fraction of the actual Channel-bit clock period as a signed two's complement binary number *w* such that

$$w = 32 \times \frac{\Delta dT_S}{T_W}$$ (–24 ≤ *w* ≤ 15) for byte 90 and 91 (where *w* is even.)

$$w = 32 \times \frac{\Delta dT_S}{T_W}$$ (–8≤ *w* ≤ 7) for byte 92 to 97 and 98 (msb 4 bits) (where *w* is even.)

dT_S

Mark	2M		3M	4M	≥5M
Preceding Space	2S	≥3S			
Succeeding Space					
2S	*w*				
3S	*w*				
4S	*w*				
≥5S	*e*				

This table shows the dependence of the dT_S 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.

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 Space level for recording Marks of a 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_S 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 Space level for recording Marks of a 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_S 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 Space 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_S 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 Space level 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 62 (dT_S 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 Space 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_S 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 Space level for recording Marks of a 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_S 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 Space level for recording Marks of a 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_S 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 Space level of the multi-pulse train for recording Marks of a 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_S 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 Space level of the multi-pulse train for recording Marks of a run-length 4T with a succeeding 3T Space. In case these bits (bits b_7 to b_4) the anchor position is specified in byte 62 (dT_S 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 Space 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_S 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 Space level for recording Marks of a 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_S 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 Space level for recording Marks of a 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_S 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 Space level of the multi-pulse train for recording Marks of a 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_S 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 Space level of the multi-pulse train for recording Marks of a 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_S 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 Space 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_S 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 Castle write strategy)

The content of the body of DI Units according to format 5 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 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 at the Nominal Recording Velocity	1
31	Maximum HF-modulated read power at the Nominal Recording Velocity	1
32	Reserved	1
33 to 41	Write-power settings	9
42 to 46	dT_{top} leading edge start time of T_{top} level	5
47 to 51	T_{top} write pulse part duration	5
52 to 54	dT_C cooling level start time	3
55 to 56	T_{LP} last-pulse-level duration	2
57 to 61	dT_S start time of the Space level	5
62	Reserved	1
63 to 70 and 71 (msb 4 bits)	ΔdT_{top} leading edge start time offset of T_{top} level	8,5
71 (lsb 4 bits) and 72 to 78	ΔT_{top} write-pulse level duration offset	7,5
79 to 82 and 83 (msb 4 bits)	ΔdT_C cooling level start time offset	4,5
83 (lsb 4 bits) , 84 ,85 and 86 (msb 4 bits)	ΔT_{LP} last-pulse-level duration offset	3
86 (lsb 4 bits)	Reserved	0,5
87 to 94 and 95 (msb 4 bits)	ΔdT_S: start time offset of the Space-level	8,5
95 (lsb 4 bits)	Reserved	0,5
96 to 99	Reserved	4
100 to 111	DI Unit footer	12

Figure 82 — 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 60h to indicate that the first 96 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 3 bytes identify the type of the BD Layer to which this DI Unit applies and shall be set to 42 44 52h, representing the characters “BDR” in each Recordable Layer.

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

Bits b7 to b6: These 2 bits specify the disk size. They shall be set to 00 to indicate a 120 mm disk.

Bits b5 to b4: 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 International Standard shall have these bits b_5 to b_4 set to 01.

Drives that are not familiar with a particular Class of layers should not access the Data Zone of such layers (neither for reading, nor for writing).

Bits b3 to b0: These 4 bits specify the Version number. They shall be set to 0010.

Byte 12: **BD structure**

Bits b7 to b4: These 4 bits specify the total number of BD Recording/Recorded Layers on the disk.

On a TL disk they shall be set to 0011 to indicate three Recording Layers.

On a QL disk they shall be set to 0100 to indicate four Recording Layers.

Bits b3 to b0: These 4 bits specify the type of BD Recording/Recorded Layer to which this DI Unit applies.

Bits b3 to b0 shall be set to 0010 to indicate a recordable Recording Layer.

Byte 13: Channel-bit length

Bits b7 to b4: These 4 bits shall be set to 0000.

Bits b3 to b0: 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

0100, to indicate a Channel-bit length of 58,26 nm (32,0 GB per Layer),

0101, to indicate a Channel-bit length of 55,87 nm (33,4 GB per Layer),

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

ZERO, to indicate that the Push-Pull polarity on Layer L*i* is positive,

ONE, to indicate that the Push-Pull polarity on Layer L*i* is negative.

For Recording Layers that are not present, bit bi shall be set to ZERO.

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 *i*. They shall be set to

ZERO, to indicate a Layer Type on which Recorded-Marks have a lower reflectivity than the Unrecorded Layer (HTL disks).

ONE, to indicate a Layer Type on which Recorded-Marks have a higher reflectivity than the Unrecorded Layer (Reserved).

This byte shall be set to 00h.

Byte 16: **BCA descriptor**

Bits b7 to b4: These 4 bits shall be Reserved.

Bits b3 to b0: These 4 bits shall indicate the presence of BCA code on this disk:

0000, indicates that there is no BCA code,

0001, indicates that the BCA code 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 specify the first Physical ADIP Address of the Data Zone of the related layer.

In each DI Unit relating to Layer L0, these bytes shall be set to 00 02 00 00h to indicate PAA 131 072 as the first PAA of Data Zone 0.

In each DI Unit relating to Layer L1, these bytes shall be set to a value FAA, which shall be 00 60 32 80h for a disk with a User Data capacity of 32,0 GB per layer, or 00 5E EC 80h for a disk with a User Data capacity of 33,4 GB per layer, to indicate PAA 6 304 384 for 32,0 GB per layer or 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 Data Zone 2.

In each DI Unit relating to Layer L3, these bytes shall be set to the value FAA + 00 80 00 00h, which shall be 00 E0 32 80h for a disk with a User Data capacity of 32,0 GB per layer, to indicate PAA 14 692 992 as the first PAA of Data Zone 3.

Bytes 23 to 26: These bytes specify the last Physical ADIP Address of the Data Zone of the related layer.

In each DI Unit relating to Layer L0 these bytes shall be set to a value LAA, which shall be 00 1F CD 7Eh for a disk with a User Data capacity of 32,0 GB per layer, or 00 21 13 7Eh for a disk with a User Data capacity of 33,4 GB per layer, to indicate PAA 2 084 222 for 32,0 GB per layer or PAA 2 167 678 for 33,4 GB per layer as the last PAA of Data Zone 0.

In each DI Unit relating to Layer L1 these bytes shall be set to 00 7D FF FEh to indicate PAA 8 257 534 as the last PAA of 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 9F CD 7E h for a disk with a User Data capacity of 32,0 GB per layer, or 00 A1 13 7E h for a disk with a User Data capacity of 33,4 GB per layer, to indicate PAA 10 472 830 for 32,0 GB per layer or PAA 10 556 286 for 33,4 GB per layer as the last PAA of Data Zone 2.

In each DI Unit relating to Layer L3 these bytes shall be set to 00 FD FF FEh to indicate PAA 16 646 142 as the last PAA of Data Zone 3.

Byte 27: Reserved

This byte shall be set to 00h.

Bytes 28 to 29: Recording Velocity

These bytes specify the Nominal Recording Velocity, to be used with the Parameters as defined in this DI Unit, as a 2-byte binary number (byte 28 is MSB).

It shall specify the Nominal Recording Velocity as a number *n* such that

$$n = 100 \times V\text{nom}$$

n shall be equal to

03 01h to indicate a Nominal Recording Velocity of 7,69 m/s (32,0 GB per layer),
02 E2h to indicate a Nominal Recording Velocity of 7,38 m/s (33,4 GB per layer).

or:

06 02h to indicate a Nominal Recording Velocity of 15,38 m/s (32,0 GB per layer),
05 C3h to indicate a Nominal Recording Velocity of 14,75 m/s (33,4 GB per layer).

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 30.6). Maximum read powers in this section shall be greater than or equal to the read powers defined in 30.6. By default, the powers defined in 30.6 shall be used.

This byte specifies the dc read power P_r at the same readout velocity as the Nominal Recording Velocity defined in bytes 28 to 29 of this DI Unit. The decimal expression of this byte shall be:

$n = 100 \times P_r$, where the unit of P_r is milliwatts.

NOTE For reading at lower speeds than the Nominal Recording Velocity specified in this DI Unit a reduction of the read power might be necessary to guarantee the stability of the 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 the recorded signals (see 30.6). Maximum read powers in this section shall be greater than or equal to the read powers defined in 30.6. By default, the powers defined in 30.6 shall be used.

This byte specifies the maximum HF-modulated read power P_r at the same readout velocity as the Nominal Recording Velocity defined in bytes 28 to 29. The decimal expression of this byte shall be:

$n = 100 \times P_r$, where the unit of P_r is milliwatt.

NOTE For reading at lower speeds than the Nominal Recording Velocity specified in this DI Unit a reduction of the read power might be necessary to guarantee the stability of the recordings on the disk.

Byte 32: Reserved

These byte shall be set to 00h.

Bytes 33 to 41: Write-power settings

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

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

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

Bit b_7 of Byte 33 is msb and bit b_0 of Byte 34 is lsb.

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

This byte shall specify the modulation at P_{IND} as determined by the media manufacturer as a number *n* such that

$$n = 200 \times m_{\mathrm{IND}}.$$

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

$$n = 200 \times \varepsilon_{\mathrm{M}}.$$

Byte 38: $\boldsymbol{\varepsilon_{\mathrm{C}}}$**:** 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

$$n = 200 \times \varepsilon_{\mathrm{C}}.$$

Byte 39: $\boldsymbol{\varepsilon_{\mathrm{S}}}$**:** This byte shall specify the space/write peak power ratio ε_{S} used in the OPC algorithm (see Annex G) as a number *n* such that

$$n = 200 \times \varepsilon_{\mathrm{S}}.$$

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: $\boldsymbol{\beta}$**:** This byte shall specify the target value for β used in the alternative OPC procedure (see Annex G) as a number *n* such that

$$n = 500 \times (\beta + 0{,}2).$$

Bytes 42 to 61: In these bytes, Anchor position or duration time is defined for dT_{top}, T_{top}, dT_{C}, T_{LP} and dT_{S}. Anchor position means the leading edge position of each write pulse(see Figure F.1and FigureF.4). Regarding the duration time, Anchor is specified in a similar way.

Bytes 42 to 46: ***dT_{top}* start time of *T_{top}* level.**

The first 6 bits (bits b_7 to b_2) of these bytes specify the start time of the T_{top} part of the writing pulse of the Extended Castle write strategy, for recording Marks with run-lengths 2T, 3T, 4T and ≥ 5T, with a preceding ≥ 5T 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).

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

$$a = 32 \times \frac{dT_{\text{top}}}{T_{\text{W}}} \quad (-32 \leq a \leq 30). \text{ (where } a \text{ is even.)}$$

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

Byte 42 shall represent the start time of a 2T run-length Mark with a succeeding 2T Space,

Byte 43 shall represent the start time of a 2T run-length Mark with a succeeding ≥ 3T Space,

Byte 44 shall represent the start time of a 3T run-length Mark,

Byte 45 shall represent the start time of a 4T run-length Mark,

Byte 46 shall represent the start time of a ≥ 5T run-length Mark.

Bytes 47 to 51: T_{top} write pulse part duration

The first 7 bits (bits b_7 to b_1) of these bytes specify the duration of the T_{top} level of the write pulses of the Extended Castle write strategy, for recording of Marks with run-lengths 2T, 3T, 4T and ≥ 5T, with a preceding 5T Space (see Annex F).

These bytes shall specify the length of the T_{top} level as a fraction of the actual Channel-bit clock period as an unsigned binary number *b* such that

$$b = 32 \times \frac{T_{top}}{T_w} \qquad (0 \le b \le 92). \text{ (where } b \text{ is even.)}$$

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

Byte 47 shall represent the first pulse of a 2T run-length Mark with a succeeding 2T Space,

Byte 48 shall represent the first pulse of a 2T run-length Mark with a succeeding ≥ 3T Space,

Byte 49 shall represent the first pulse of a 3T run-length Mark,

Byte 50 shall represent the first pulse of a 4T run-length Mark,

Byte 51 shall represent the first pulse of a ≥ 5T run-length Mark.

Bytes 52 to 54: dT_C cooling level start time

The first 7 bits (bits b_7 to b_1) of these bytes specify the cooling level start time for writing pulse of the Extended Castle write strategy with run-lengths of 3T, 4T and ≥ 5T, with a succeeding ≥ 5T Space (see Annex F).
These bytes shall specify the start time as a fraction of the actual Channel-bit clock period as a signed two's complement binary number *c* such that

$$c = 32 \times \frac{dT_C}{T_W} \qquad (-62 \le c \le 16). \text{ (where } c \text{ is even.)}$$

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

Byte 52: This byte shall specify the start time of the cooling level of the writing pulse of the Extended Castle write strategy with a run-length of 3T.

Byte 53: This byte shall specify the start time of the cooling level of the writing pulse of the Extended Castle write strategy with a run-length of 4T.

Byte 54: This byte shall specify the start time of the cooling level of the writing pulse of the Extended Castle write strategy with run-lengths of ≥ 5T.

Bytes 55 to 56: T_{LP} last pulse level duration

The first 6 bits (bits b_7 to b_2) of these bytes specify the last pulse level length of the write pulses of the Extended Castle write strategy, for recording Marks with run-lengths 4T and ≥ 5T, with a succeeding ≥ 5T Space (see Annex F).

These bytes shall specify the length of T_{LP} as 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 shall represent the first pulse of a 4T run-length Mark.

Byte 56 shall represent the first pulse of a ≥ 5T run-length Mark.

Bytes 57 to 61: dT_S start time of the Space level

The first 7 bits (bits b_7 to b_1) of these bytes specify the start time of the Space level of the Extended Castle write strategy, for 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 Space level dT_S is expressed as a fraction of the actual Channel-bit clock period as a signed two's complement binary number e such that

$$e = 32 \times \frac{dT_S}{T_W} \qquad (-62 \le e \le 30). \text{ (where } e \text{ is even.)}$$

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

Byte 57: This byte shall specify the start time of the Space level of a writing pulse of the Extended Castle write strategy with a run-length of 2T and a preceding 2T Space.

Byte 58: This byte shall specify the start time of the Space level of a writing pulse of the Extended Castle write strategy with a run-length of 2T and a preceding ≥ 3T Space.

Byte 59: This byte shall specify the start time of the Space level of a writing pulse of the Extended Castle write strategy with a run-length of 3T.

Byte 60: This byte shall specify the start time of the Space level of a writing pulse of the Extended Castle write strategy with a run-length of 4T.

Byte 61: This byte shall specify the start time of the Space level of a writing pulse of the Extended Castle write strategy with run-lengths of ≥ 5T.

Byte 62: Reserved.

This byte shall be set to 00h.

Bytes 63 to 95: In these bytes, Δ is defined as the offset from the anchor position or duration time which is specified from bytes 42 to 61. Offset means the time difference from the Anchor position. Regarding the duration time, Offset is specified in a similar way.

Bytes 63 to 70 and 71(msb 4 bits): ΔdT_{top} leading edge start time offset of T_{top} level

These bytes specify the leading edge offset of the start time of the T_{top} part of the writing pulse of the Extended Castle write strategy, for recording Marks with run-lengths 2T, 3T, 4T and ≥ 5T, and preceding a 2T, 3T or 4T Space.

The leading edge 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

$$f = 32 \times \frac{\Delta dT_{top}}{T_W} \quad (-31 \le f \le 30). \text{ for bytes 63 to 64 (where } f \text{ is even.)}$$

$$f = 32 \times \frac{\Delta dT_{top}}{T_W} \quad (-8 \le f \le 7). \text{ for bytes 65 to 70 and 71(msb 4 bits) (where } f \text{ is even.)}$$

dT_{top}

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

This table 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.

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 $-32 \le i \le 30$.

(see F.3)

Byte 63: The first 6 bits (bits b_7 to b_2) of this byte shall specify the leading edge offset of the start time of the T_{top} part of the writing pulse of the Extended Castle write strategy, for recording Marks of a 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 42 (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 leading edge offset of the start time of the T_{top} part of the writing pulse of the Extended Castle write strategy, for recording Marks of a 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 43 (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 leading edge offset of the start time of the T_{top} part of the writing pulse of the Extended Castle write strategy, for recording Marks of a 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 44 (dT_{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 leading edge offset of the start time of the T_{top} part of the writing pulse of the Extended Castle write strategy, for recording Marks of a 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 45 (dT_{top} for 4T Mark with a preceding ≥ 5T Space).

Byte 66: The first 4 bits (bits b_7 to b_4) of this byte shall specify the leading edge offset of the start time of the T_{top} part of the writing pulse of the Extended Castle write strategy, 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 46 (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 leading edge offset of the start time of the T_{top} part of the writing pulse of the Extended Castle write strategy, for recording Marks of a run-length 2T with a preceding 3T Space and a succeeding 2T Space. In case these bits (bits b_3 to b_0) apply, the anchor position is specified in byte 42 (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 leading edge offset of the start time of the T_{top} part of the writing pulse of the Extended Castle write strategy, for recording Marks of a 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 43 (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 leading edge offset of the start time of the T_{top} part of the writing pulse of the Extended Castle write strategy, for recording Marks of a 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 44 (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 leading edge offset of the start time of the T_{top} part of the writing pulse of the Extended Castle write strategy, for recording Marks of a 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 45 (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 leading edge offset of the start time of the T_{top} part of the writing pulse of the Extended Castle write strategy, 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 46 (dT_{top} for a ≥ 5T Mark with a preceding ≥ 5T Space).

Byte 69: The first 4 bits (bits b_7 to b_4) of this byte shall specify the leading edge offset of the start time of the T_{top} part of the writing pulse of the Extended Castle write strategy, for recording Marks of a 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 42 (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 leading edge offset of the start time of the T_{top} part of the writing pulse of the Extended Castle write strategy, for recording Marks of a run-length 2T with preceding a 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 43 (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 leading edge offset of the start time of the T_{top} part of the writing pulse of the Extended Castle write strategy, for recording Marks of a 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 44 (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 leading edge offset of the start time of the T_{top} part of the writing pulse of the Extended Castle write strategy, for recording Marks of a 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 45 (dT_{top} for a 4T 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 leading edge offset of the start time of the T_{top} part of the writing pulse of the Extended Castle write strategy, for recording Marks of run-lengths ≥ 5T with a preceding 4T Space. In case these bits (bits b_7 to b_4) apply, the anchor position is specified in byte 46 (dT_{top} for a ≥ 5T Mark with a preceding ≥ 5T Space).

Bytes 71 (lsb 4 bits) and 72 to 78: ΔT_{top} write-pulse level duration offset

These bytes specify the duration offset of the T_{top} level of the write pulses of the Extended Castle write strategy, for recording Marks with run-lengths 2T, 3T, 4T and ≥ 5T, with preceding a 2T, 3T or 4T Space.

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

$$g = 32 \times \frac{\Delta T_{top}}{T_W} \quad (-8 \leq g \leq 7). \text{ (where } g \text{ is even.)}$$

T_{top}

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

This table 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.

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 T_{top} part of the writing pulse of the Extended Castle write strategy, for recording Marks of a run-length 2T with a preceding 2T Space and a succeeding 2T Space. In case these bits (bits b_3 to b_0) apply, the anchor duration time is specified in byte 47 (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 T_{top} part of the writing pulse of the Extended Castle write strategy, for recording Marks of a run-length 2T with a preceding 2T Space and a succeeding ≥ 3T Space. 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 ≥ 3T Space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the duration offset of the T_{top} part of the writing pulse of the Extended Castle write strategy, for recording Marks of a run-length 3T with a preceding 2T Space. In case these bits (bits b_3 to b_0) apply, the anchor duration time is specified in byte 49 (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 T_{top} part of the writing pulse of the Extended Castle write strategy, for recording Marks of a run-length 4T with a preceding 2T Space. In case these bits (bits b_7 to b_4) apply, the anchor duration time is specified in byte 50 (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 T_{top} part of the writing pulse of the Extended Castle write strategy, for recording Marks of run-lengths ≥ 5T with a preceding 2T Space. In case these bits (bits b_3 to b_0) apply, the anchor duration time is specified in byte 51 (T_{top} for a ≥ 5T 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 T_{top} part of the writing pulse of the Extended Castle write strategy, for recording Marks of a run-length 2T with a preceding 3T Space and a succeeding 2T Space. In case these bits (bits b_7 to b_4) apply, the anchor duration time is specified in byte 47 (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 T_{top} part of the writing pulse of the Extended Castle write strategy, for recording Marks of a run-length 2T with a preceding 3T and a succeeding ≥ 3T Space. 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 ≥ 3T Space).

Byte 75: The first 4 bits (bits b_7 to b_4) of this byte shall specify the duration offset of the T_{top} part of the writing pulse of the Extended Castle write strategy, for recording Marks of a run-length 3T with a preceding 3T Space. In case these bits (bits b_7 to b_4) apply, the anchor duration time is specified in byte 49 (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 T_{top} part of the writing pulse of the Extended Castle write strategy, for recording Marks of a run-length 4T with a preceding 3T Space. In case these bits (bits b_3 to b_0) apply, the anchor duration time is specified in byte 50 (T_{top} for a 4T 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 T_{top} part of the writing pulse of the Extended Castle write strategy, for recording Marks of run-lengths ≥ 5T with a preceding 3T Space. In case these bits (bits b_7 to b_4) apply, the anchor duration time is specified in byte 51 (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 T_{top} part of the writing pulse of the Extended Castle write strategy, for recording Marks of a run-length 2T with a preceding 4T Space and a succeeding 2T Space. In case these bits (bits b_3 to b_0) apply, the anchor duration time is specified in byte 47 (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 T_{top} part of the writing pulse of the Extended Castle write strategy, for recording Marks of a run-length 2T with a preceding 4T Space and a succeeding ≥ 3T Space. 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 ≥ 3T Space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the duration offset of the T_{top} part of the writing pulse of the Extended Castle write strategy, for recording Marks of a run-length 3T with a preceding 4T Space. In case these bits (bits b_3 to b_0) apply, the anchor duration time is specified in byte 49 (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 T_{top} part of the writing pulse of the Extended Castle write strategy, for recording Marks of a run-length 4T with a preceding 4T Space. In case these bits (bits b_7 to b_4) apply, the anchor duration time is specified in byte 50 (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 T_{top} part of the writing pulse of the Extended Castle write strategy, for recording Marks of run-lengths ≥ 5T with a preceding 4T Space. In case these bits (bits b_3 to b_0) apply, the anchor duration time is specified in byte 51 (T_{top} for a ≥ 5T Mark with a preceding ≥ 5T Space).

Bytes 79 to 82 and 83 (msb 4 bits): ΔdT_C cooling level start time offset

These bytes specify the leading edge offset of the start time of the cooling level of the Extended Castle write strategy, for recording Marks with run-lengths 3T, 4T and ≥ 5T, with a succeeding 2T, 3T or 4T Space.

The leading edge offset ΔdT_C is expressed as a fraction of the actual Channel-bit clock period as a signed two's complement binary number h such that

$$h = 32 \times \frac{\Delta dT_C}{T_W} \qquad (-8 \le h \le 7). \text{ (where } h \text{ is even)}$$

dT_C

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

This table shows the dependence of the dT_C 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.

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 "$k = h + c$" shall satisfy $-62 \le k \le 16$.

(see F.3)

Byte 79: The first 4 bits (bits b_7 to b_4) of this byte shall specify the leading edge offset of the start time of the cooling level of the writing pulse of the Extended Castle write strategy, for recording Marks of a 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 52 (dT_C 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 leading edge offset of the start time of the cooling level of the writing pulse of the Extended Castle write strategy, 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 53 (dT_C for a 4T Mark with a succeeding ≥ 5T Space).

Byte 80: The first 4 bits (bits b_7 to b_4) of this byte shall specify the leading edge offset of the start time of the cooling level of the writing pulse of the Extended Castle write strategy, 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 54 (dT_C 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 leading edge offset of the start time of the cooling level of the writing pulse of the Extended Castle write strategy, for recording Marks of a 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 52 (dT_C for a 3T Mark with a succeeding ≥ 5T Space).

Byte 81: The first 4 bits (bits b_7 to b_4) of this byte shall specify the leading edge offset of the start time of the cooling level of the writing pulse of the Extended Castle write strategy, for recording Marks of a 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 53 (dT_C 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 leading edge offset of the start time of the cooling level of the writing pulse of the Extended Castle write strategy, 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 54 (dT_C for a ≥ 5T Mark with a succeeding ≥ 5T Space).

Byte 82: The first 4 bits (bits b_7 to b_4) of this byte shall specify the leading edge offset of the start time of the cooling level of the writing pulse of the Extended Castle write strategy, for recording Marks of a 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 52 (dT_C 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 leading edge offset of the start time of the cooling level of the writing pulse of the Extended Castle write strategy, for recording Marks of a 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 53 (dT_C for a 4T Mark depending on succeeding ≥ 5T Space).

Byte 83 (msb 4 bits):

The first 4 bits (bits b_7 to b_4) of this byte shall specify the leading edge offset of the start time of the cooling level of the writing pulse of the Extended Castle write strategy, 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 54 (dT_C for ≥ a 5T Mark with a succeeding ≥ 5T Space).

Bytes 83 (lsb 4 bits) and 84 to 86: ΔT_{LP} last-pulse-level duration offset

These bytes specify the duration offset of the last pulse level length of the write pulses of the Extended Castle write strategy, for recording Marks with run-lengths 4T and ≥ 5T, with a succeeding 2T, 3T or 4T Space.

These bytes shall specify a fraction of the actual Channel-bit clock period as a signed two's complement binary number v such that

$$v = 32 \times \frac{\Delta T_{LP}}{T_W} \quad (-8 \le v \le 7). \text{ (where } v \text{ is even.)}$$

T_{LP}

Mark / Succeeding Space	4M	≥5M
2S	v	v
3S	v	v
4S	v	v
≥5S	d	d

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.

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 "$p=v+d$" shall satisfy $0 \le p \le 62$.

(see F.3)

Byte 83 (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 level length of the writing pulse of the Extended Castle write strategy, 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 duration time is specified in byte 55 (T_{LP} for a 4T 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 level length of the writing pulse of the Extended Castle write strategy, 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 duration time is specified in byte 56 (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 level length of the writing pulse of the Extended Castle write strategy, for recording Marks of a run-length 4T with a succeeding 3T Space. In case these bits (bits b_3 to b_0) apply, the anchor duration time is specified in byte 55 (T_{LP} for a 4T Mark with a succeeding ≥ 5T Space).

Byte 85: The first 4 bits (bits b_7 to b_4) of this byte shall specify the duration offset of the last pulse level length of the writing pulse of the Extended Castle write strategy, for recording Marks of run-lengths ≥ 5T with a succeeding 3T Space. In case these bits (bits b_7 to b_4) apply, the anchor duration time is specified in byte 56 (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 level length of the writing pulse of the Extended Castle write strategy, for recording Marks of a run-length 4T with a succeeding 4T Space. In case these bits (bits b_3 to b_0) apply, the anchor duration time is specified in byte 55 (T_{LP} for a 4T 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 level length of the writing pulse of the Extended Castle write strategy, 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 duration time is specified in byte 56 (T_{LP} for a ≥ 5T Mark with a succeeding ≥ 5T Space).

The last 4 bits (bits b_3 to b_0) of this byte (Reserved).

These bits shall be set to 0000.

Bytes 87 to 94 and 95 (msb 4 bits): ΔdT_S: start time offset of the Space-level

These bytes specify the leading edge offset of the start time of the Space level of the writing pulse of the Extended Castle write strategy, for recording Marks with run-lengths 2T, 3T, 4T and ≥ 5T, with a succeeding 2T, 3T or 4T Space.

The leading edge offset ΔdT_S is expressed as a fraction of the actual Channel-bit clock period as a signed two's complement binary number w such that

$$w = 32 \times \frac{\Delta dT_S}{T_W}$$ (–31 ≤ w ≤ 30). for byte 87 and 88 (where w is even.)

$$w = 32 \times \frac{\Delta dT_S}{T_W}$$ (–8 ≤ w ≤ 7). for byte 89 to 94 and 95 (msb 4 bits) (where w is even.)

dT_S

Mark	2M		3M	4M	≥5M
Preceding Space	2S	≥3S			
Succeeding Space					
2S	w				
3S	w				
4S	w				
≥5S	e				

This table shows the dependence of the dT_S 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.

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 "$q=w+e$" shall satisfy $-62 \le q \le 30$.

(see F.3)

Byte 87: The first 6 bits (bits b_7 to b_2) of this byte shall specify the leading edge offset of the start time of the Space level of the writing pulse of the Extended Castle write strategy, for recording Marks of a 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_S for a 2T Mark with succeeding ≥ 5T Space and a preceding a 2T Space).

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

Byte 88: The first 6 bits (bits b_7 to b_2) of this byte shall specify the leading edge offset of the start time of the Space level of the writing pulse of the Extended Castle write strategy, for recording Marks of a 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_S for a 2T Mark with a succeeding ≥ 5T Space and a preceding a ≥ 3T Space).

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

Byte 89: The first 4 bits (bits b_7 to b_4) of this byte shall specify the leading edge offset of the Space level of the writing pulse of the Extended Castle write strategy, for recording Marks of a 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 59 (dT_S 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 leading edge offset of the start time of the Space level of the writing pulse of the Extended Castle write strategy, 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 60 (dT_S for a 4T Mark with a succeeding ≥ 5T Space).

Byte 90: The first 4 bits (bits b_7 to b_4) of this byte shall specify the leading edge offset of the Space level of the writing pulse of the Extended Castle write strategy, 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 61 (dT_S for ≥ 5T Mark with a succeeding 2T Space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the leading edge offset of the start time of the Space level of the writing pulse of the Extended Castle write strategy, for recording Marks of a 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_S for a 2T Mark with a succeeding ≥ 5T Space and a preceding 2T Space).

Byte 91: The first 4 bits (bits b_7 to b_4) of this byte shall specify the leading edge offset of the Space level of the writing pulse of the Extended Castle write strategy, for recording Marks of a 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_S for a 2T Mark with a succeeding ≥ 5T Space and a preceding a ≥ 3T Space).

The last 4 bits (bits b_3 to b_0) of this byte shall specify the leading edge offset of the start time of the Space level of the writing pulse of the Extended Castle write strategy, for recording Marks of a 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_S for a 3T Mark with a succeeding ≥ 5T Space).

Byte 92: The first 4 bits (bits b_7 to b_4) of this byte shall specify the leading edge offset of the Space level of the writing pulse of the Extended Castle write strategy, for recording Marks of a 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 60 (dT_S 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 leading edge offset of the start time of the Space level of the writing pulse of the Extended Castle write strategy, 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 61 (dT_S for a ≥ 5T Mark with a succeeding ≥ 5T Space).

Byte 93: The first 4 bits (bits b_7 to b_4) of this byte shall specify the leading edge offset of the Space level of the writing pulse of the Extended Castle write strategy, for recording Marks of a 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_S 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 leading edge offset of the start time of the Space level of the writing pulse of the Extended Castle write strategy, for recording Marks of a run-length 2T with a succeeding 4T Space and a preceding ≥ 3T. In case these bits (bits b_3 to b_0) apply, the anchor position is specified in byte 58 (dT_S for a 2T Mark with a succeeding ≥ 5T Space and a preceding ≥ 3T Space).

Byte 94: The first 4 bits (bits b_7 to b_4) of this byte shall specify the leading edge offset of the Space level of the writing pulse of the Extended Castle write strategy, for recording Marks of a 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_S 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 leading edge offset of the start time of the Space level of the writing pulse of the Extended Castle write strategy, for recording Marks of a 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 60 (dT_S for a 4T Mark with a succeeding ≥ 5T Space).

Byte 95 (msb:4 bits):

The first 4 bits (bits b_7 to b_4) of this byte shall specify the leading edge offset of the Space level of the writing pulse of the Extended Castle write strategy, 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 61 (dT_S for a ≥ 5T Mark with a succeeding ≥ 5T Space).

Byte 95 (lsb:4 bits): Reserved

These bits shall be set to 0000.

Bytes 96 to 99: Reserved

These bytes shall be set to all 00h.

Bytes 100 to 111: DI Unit footer

See 15.8.3.2.

15.8.3.5 Write-strategy requirements

The write-strategy requirements for disks according to this specification are depicted in Figure 83.

Disk type TL QL	Recording Velocity	Write strategy	
		Ex N–1	Ex Castle
	2x	Optional [a]	Optional [a]
	4x	---	Mandatory

[a] At least one of the two write strategies shall be present and they shall be defined as most preferred write strategy.
2x only disk can not be allowed.

Figure 83 — Write strategy type requirements

15.8.3.6 Usage of DI Units for write strategies

By using the concept of multiple DI Units, identified by their DI-Format Number (byte 2), the BD system facilitates the (future) use of disks for different Recording Velocities and with three, four or more Recording Layers, while keeping backwards compatibility in the best possible way.

Generally each different Recording Velocity might need a different write strategy (different set of parameters), which write strategy furthermore can depend on the applied technology.

Additionally each Recording Layer might need a different set of values for the write strategy parameters.

Reference Velocity is the velocity correspond to 66 MHz Channel clock frequency.

The Recording Velocity is referred to Nominal Recording Velocity of DI.

Parameters in this International Standard have been defined for the so-called “4x” disk (applicable Recording Velocities shall be, 2x and 4x Reference Velocity) (see Figure 84). Each Recording Layer shall fulfill the write strategy requirements as indicated in Figure 83.

These disks shall contain at least two DI Units for each Recording Layer, one containing the parameters for the 2x Recording Velocity and one containing the parameters for the 4x Recording Velocity.

Additional DI Units, containing alternative write strategy parameter sets, may be added in order of preference, see Figure 79.

In the DI Unit defining parameters for the 2x Recording Velocity, bytes 28 to 29 are set to as follows:

bytes 28 to 29: 03 01h to indicate a Nominal Recording Velocity of 7,69 m/s (32,0 GB per layer),
02 E2h to indicate a Nominal Recording Velocity of 7,38 m/s (33,4 GB per layer).

In the DI Unit defining the parameters for 4x Recording Velocity, bytes 28 to 29 are set to as follows:

bytes 28 to 29: 06 02h to indicate a Nominal Recording Velocity of 15,38 m/s (32,0 GB per layer),
05 C3h to indicate a Nominal Recording Velocity of 14,75 m/s (33,4 GB per layer).

4x disk (TL) with 2x EX N–1& Castle and 4x EX Castle write strategy		4x disk (QL) with 2x EX N–1& Castle and 4x EX Castle write strategy	
byte 2: DI-Format Number	4	byte 2: DI-Format Number	4
byte 3: # of DI's/L#	9/0	byte 3: # of DI's/L#	12/0
byte 4: ---	00h	byte 4: ---	00h
byte 5: sequence #	0	byte 5: sequence #	0
msb of byte 6:	0	msb of byte 6:	0
bytes 28 to 29: Velocity	2x	bytes 28 to 29: Velocity	2x
bytes 42 to 98:WS	EX_N–1	bytes 42 to 98:WS	EX_N–1

byte 2: DI-Format Number	5	byte 2: DI-Format Number	5
byte 3: # of DI's/L#	9/0	byte 3: # of DI's/L#	12/0
byte 4: ---	00h	byte 4: ---	00h
byte 5: sequence #	1	byte 5: sequence #	1
msb of byte 6:	0	msb of byte 6:	0
bytes 28 to 29: Velocity	2x	bytes 28 to 29: Velocity	2x
bytes 42 to 95:WS	EX_Castle	bytes 42 to 95:WS	EX_Castle

byte 2: DI-Format Number	4	byte 2: DI-Format Number	4
byte 3: # of DI's/L#	9/1	byte 3: # of DI's/L#	12/1
byte 4: ---	00h	byte 4: ---	00h
byte 5: sequence #	2	byte 5: sequence #	2
msb of byte 6:	0	msb of byte 6:	0
bytes 28 to 29: Velocity	2x	bytes 28 to 29: Velocity	2x
bytes 42 to 98:WS	EX_N–1	bytes 42 to 98:WS	EX_N–1

byte 2: DI-Format Number	5	byte 2: DI-Format Number	5
byte 3: # of DI's/L#	9/1	byte 3: # of DI's/L#	12/1
byte 4: ---	00h	byte 4: ---	00h
byte 5: sequence #	3	byte 5: sequence #	3
msb of byte 6:	0	msb of byte 6:	0
bytes 28 to 29: Velocity	2x	bytes 28 to 29: Velocity	2x
bytes 42 to 95:WS	EX_Castle	bytes 42 to 95:WS	EX_Castle

byte 2: DI-Format Number	4	byte 2: DI-Format Number	4
byte 3: # of DI's/L#	9/2	byte 3: # of DI's/L#	12/2
byte 4: ---	00h	byte 4: ---	00h
byte 5: sequence #	4	byte 5: sequence #	4
msb of byte 6:	0	msb of byte 6:	0
bytes 28 to 29: Velocity	2x	bytes 28 to 29: Velocity	2x
bytes 42 to 98:WS	EX_N–1	bytes 42 to 98:WS	EX_N–1

byte 2: DI-Format Number	5	byte 2: DI-Format Number	5
byte 3: # of DI's/L#	9/2	byte 3: # of DI's/L#	12/2
byte 4: ---	00h	byte 4: ---	00h
byte 5: sequence #	5	byte 5: sequence #	5
msb of byte 6:	0	msb of byte 6:	0
bytes 28 to 29: Velocity	2x	bytes 28 to 29: Velocity	2x
bytes 42 to 95:WS	EX_Castle	bytes 42 to 95:WS	EX_Castle

Figure 84 — Example of DI sequence for 4x disks

byte 2: DI-Format Number	5
byte 3: # of DI's/L#	9/0
byte 4: ---	00h
byte 5: sequence #	6
msb of byte 6:	0
bytes 28 to 29: Velocity	4x
bytes 42 to 95:WS	EX_Castle

byte 2: DI-Format Number	5
byte 3: # of DI's/L#	9/1
byte 4: ---	00h
byte 5: sequence #	7
msb of byte 6:	0
bytes 28 to 29: Velocity	4x
bytes 42 to 95:WS	EX_Castle

byte 2: DI-Format Number	5
byte 3: # of DI's/L#	9/2
byte 4: ---	00h
byte 5: sequence #	8
msb of byte 6:	0
bytes 28 to 29: Velocity	4x
bytes 42 to 95:WS	EX_Castle

Repeat

byte 2: DI-Format Number	4
byte 3: # of DI's/L#	12/3
byte 4: ---	00h
byte 5: sequence #	6
msb of byte 6:	0
bytes 28 to 29: Velocity	2x
bytes 42 to 98:WS	EX_N–1

byte 2: DI-Format Number	5
byte 3: # of DI's/L#	12/3
byte 4: ---	00h
byte 5: sequence #	7
msb of byte 6:	0
bytes 28 to 29: Velocity	2x
bytes 42 to 95:WS	EX_Castle

byte 2: DI-Format Number	5
byte 3: # of DI's/L#	12/0
byte 4: ---	00h
byte 5: sequence #	8
msb of byte 6:	0
bytes 28 to 29: Velocity	4x
bytes 42 to 95:WS	EX_Castle

byte 2: DI-Format Number	5
byte 3: # of DI's/L#	12/1
byte 4: ---	00h
byte 5: sequence #	9
msb of byte 6:	0
bytes 28 to 29: Velocity	4x
bytes 42 to 95:WS	EX_Castle

byte 2: DI-Format Number	5
byte 3: # of DI's/L#	12/2
byte 4: ---	00h
byte 5: sequence #	10
msb of byte 6:	0
bytes 28 to 29: Velocity	4x
bytes 42 to 95:WS	EX_Castle

byte 2: DI-Format Number	5
byte 3: # of DI's/L#	12/3
byte 4: ---	00h
byte 5: sequence #	11
msb of byte 6:	0
bytes 28 to 29: Velocity	4x
bytes 42 to 95:WS	EX_Castle

Repeat

Figure 84 — Example of DI sequence for 4x disks (continued)

16 General description of Information Zone

16.1 General

The Information Zone, which contain 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 14).

The inner part of Inner Zone 0 (Protection-Zone 1 + PIC) shall contain HFM Groove which can hold replicated information about the disk. The outer part of Inner Zone 0, other Inner Zones, Data Zones and Outer Zones constitute the Recordable Areas in which the information can be recorded on the Wobbled Grooves.

16.2 Format of Information Zone on Triple-Layer disk

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, and Outer Zone 1, Data Zone 1 and Inner Zone 1 on Layer L1, and Inner Zone 2, Data Zone 2 and Lead-out Zone on Layer L2 (see Figure 85, Figure 86, and Figure 87).

Data Zone 0, Data Zone 1 and Data Zone 2 are intended for recording User Data. The Lead-in Zone contains replicated and Recordable Control Information and an area for disk and drive testing. The 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.

16.3 Format of Information Zone on Quadruple-Layer disk

The Information Zone is divided into twelve parts: a Lead-in Zone (part of Inner Zone 0), Data Zone 0 and Outer Zone 0 on Layer L0, and Outer Zone 1, the Data Zone 1 and Inner Zone 1 on Layer L1, and Inner Zone 2, Data Zone 2 and Outer Zone 2 on Layer L2, and Outer Zone 3, Data Zone 3 and Lead-out Zone on Layer L3 (see Figure 88, Figure 89, Figure 90 and Figure 91).

Data Zone 0, Data Zone 1, Data Zone 2 and Data Zone 3 are intended for recording User Data. The Lead-in Zone contains replicated and Recordable Control Information and an area for disk and drive testing. The Inner Zone 1, Inner Zone 2, Inner Zone 3, Outer Zone 0, Outer Zone 1, Outer Zone 2 and Outer Zone 3 allow for a smooth run-in/run-out for the respective Layers and also contain Control Information.

17 Layout of Recordable Area of Information Zone

The Recordable Area of the Information Zone is constituted from part of the Inner Zones, Data Zones and Outer Zones. The start radii for the Zones indicated in Figure 85, Figure 86, Figure 87, Figure 88, Figure 89, Figure 90 and Figure 91 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				Descrip-tion	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 radius11,5 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 (×4 KB)
		Recordable *(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 Zone	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
				TDMA 0	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 85 — Layout of Information Zone on Layer L0 of TL disk

Layer L1				Descrip-tion	Nominal ending radius (mm)	Last PAA of Zone : First PAA of Zone	Number of Phys. Clusters
	ending radius 21,0 mm	*"wide pitch" Grooves*					
Information Area	Information Zone (*tracking direction* ↑)	*Wobbled Groove*		Protection -Zone 1	22,2	: 0 7E C5 B8h	---
		Recordable *(Wobbled Groove)*	**Inner Zone 1**	Buffer Zone	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
				TDMA 1	23,498	0 7E 43 FEh : 0 7E 24 00h	2 048
				Reserved	23,736	0 7E 23 FEh : 0 7E 04 00h	2 048
				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] $FAA = \overline{LAA} + 1\ 80\ 00\ 01h$ (see 15.7.4.3)

Figure 86 — Layout of Information Zone on Layer L1 of TL disk

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" Grooves*					
	Information Zone ↓ *tracking direction*	*Wobbled Groove*		Protection -Zone 1	22,2	---	---
		Recordable *(Wobbled Groove)*	**Inner Zone 2**	Buffer Zone	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
				TDMA 2	23,004	0 81 7A 68h : 0 81 9A 66h	2 048
				Buffer Zone	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 00h (see 15.7.4.3)

Figure 87 — Layout of Information Zone on Layer L2 of TL disk

Layer L0				Descrip-tion	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 Area	Information Zone *tracking direction*	***Embossed HFM*** *(HFM Groove)*		Protection -Zone 1	22,2	---	---
Information Area	Information Zone	***Embossed HFM*** *(HFM Groove)*		PIC	22,510	(First AUN = 00 0C 45 40h : Last AUN = 00 0C 5A 7Eh)	2720 (×4 KB)
Information Area	Information Zone	Recordable *(Wobbled Groove)*	**Lead-in Zone (part of Inner Zone 0)**	Protection -Zone 2	23,091	0 01 8B 50h : 0 01 8F FEh	300
Information Area	Information Zone	Recordable *(Wobbled Groove)*	**Lead-in Zone (part of Inner Zone 0)**	Buffer Zone	23,132	0 01 90 00h : 0 01 9C B6h	814
Information Area	Information Zone	Recordable *(Wobbled Groove)*	**Lead-in Zone (part of Inner Zone 0)**	INFO 2	23,232	0 01 9C B8h : 0 01 A0 B6h	256
Information Area	Information Zone	Recordable *(Wobbled Groove)*	**Lead-in Zone (part of Inner Zone 0)**	OPC 0	23,263	0 01 A0 B8h : 0 01 C0 B6h	2 048
Information Area	Information Zone	Recordable *(Wobbled Groove)*	**Lead-in Zone (part of Inner Zone 0)**	Buffer Zone	23,513	0 01 C0 B8h : 0 01 FB FEh	3 794
Information Area	Information Zone	Recordable *(Wobbled Groove)*	**Lead-in Zone (part of Inner Zone 0)**	INFO 1	23,970	0 01 FC 00h : 0 01 FF FEh	256
Information Area	Information Zone	Recordable *(Wobbled Groove)*	**Data Zone 0**		24,000	0 02 00 00h : : LAA	488 288
Information Area	Information Zone	Recordable *(Wobbled Groove)*	**Outer Zone 0**	INFO 3/4	58,000	LAA + 2h : LAA + 4 98h	294
Information Area	Information Zone	Recordable *(Wobbled Groove)*	**Outer Zone 0**	DCZ 0	58,014	LAA + 4 9Ah : LAA + 10 08h	732
Information Area	Information Zone	Recordable *(Wobbled Groove)*	**Outer Zone 0**	Protection -Zone 3	58,050	LAA + 10 0Ah :	---
Information Area	ending radius 58,5 mm						
Rim Area	starting radius 58,5 mm						

Figure 88 — Layout of Information Zone on Layer L0 of QL disk

Layer L1				Descrip-tion	Nominal ending radius (mm)	Last PAA of Zone : First PAA of Zone	Number of Phys. Clusters
	ending radius 21,0 mm	*"wide pitch" Grooves*					
Information Area	*tracking direction* ↑ Information Zone ↑	*Wobbled Groove*		Protection -Zone 1	22,2	: 0 7E BD B8h	---
			Inner Zone 1	Buffer Zone	22,509	0 7E BD B6h : 0 7E 96 A8h	2 500
				OPC 1	22,824	0 7E 96 A6h : 0 7E 76 A8h	2 048
		Recordable *(Wobbled Groove)*		INFO 2	23,079	0 7E 76 A6h : 0 7E 72 A8h	256
				TDMA 0	23,111	0 7E 72 A6h : 0 7E 4E A8h	2 304
				Buffer Zone	23,394	0 7E 4E A6h : 0 7E 04 00h	4 778
				INFO 1	23,970	0 7E 03 FEh : 0 7E 00 00h	256
			Data Zone 1		24,000	0 7D FF FEh : : FAA [a]	488 288
			Outer Zone 1	INFO 3/4	58,000	FAA – 2h : FAA – 4 98h	294
				DCZ 1	58,014	FAA – 4 9Ah : FAA – 10 08h	732
				Protection -Zone 3	58,050	FAA – 10 0Ah :	---
	starting radius 58,5 mm						

[a] $FAA = \overline{LAA + 1\,80\,00\,01h}$ (see 15.7.4.3)

Figure 89 — Layout of Information Zone on Layer L1 of QL disk

Layer L2				Descrip-tion	Nominal starting radius (mm)	First PAA of Zone : Last PAA of Zone	Number of Phys. Clusters
	starting radius 21,0 mm	*"wide pitch" Grooves*					
Information Area	Information Zone ↓ *tracking direction*	*Wobbled Groove*		Protection-Zone 1	22,2	: 0 81 42 46h	---
		Recordable *(Wobbled Groove)*	**Inner Zone 2**	Buffer Zone	22,509	0 81 42 48h : 0 81 75 56h	3 268
				INFO 2	22,920	0 81 75 58h : 0 81 79 56h	256
				TDMA 1	22,952	0 81 79 58h : 0 81 8D 56h	1 280
				Buffer Zone	23,111	0 81 8D 58h : 0 81 C7 FEh	3 754
				OPC 2	23,570	0 81 C8 00h : 0 81 E7 FEh	2 048
				TDMA 2	23,817	0 81 E8 00h : 0 81 FB FEh	1 280
				INFO 1	23,970	0 81 FC 00h : 0 81 FF FEh	256
			Data Zone 2		24,000	0 82 00 00h : : LAA2 [a]	488 288
			Outer Zone 2	INFO 3/4	58,000	LAA2 + 2h : LAA2 + 4 98h	294
				DCZ 2	58,014	LAA2 + 4 9Ah : LAA2 + 10 08h	732
				Protection-Zone 3	58,050	LAA2 + 10 0Ah :	---
	ending radius 58,5 mm						

[a] LAA2 = LAA + 0 80 00 00h (see 15.7.4.3)

Figure 90 — Layout of Information Zone on Layer L2 of QL disk

Layer L3				Descrip-tion	Nominal ending radius (mm)	Last PAA of Zone : First PAA of Zone	Number of Phys. Clusters
	ending radius 21,0 mm	*"wide pitch" Grooves*					
Information Area	*tracking direction* ↑ Information Zone ↑	*Wobbled Groove*		Protection -Zone 1	22,2	: 0 FE BD B8h	---
			Lead-out Zone (part of Inner Zone 3)	OPC 3	22,509	0 FE BD B6h : 0 FE 9D B8h	2 048
				Buffer Zone	22,768	0 FE 9D B6h : 0 FE 3C 00h	6 254
		Recordable *(Wobbled Groove)*		INFO 2	23,539	0 FE 3B FEh : 0 FE 38 00h	256
				TDMA 3	23,570	0 FE 37 FEh : 0 FE 04 00h	3 328
				INFO 1	23,970	0 FE 03 FEh : 0 FE 00 00h	256
			Data Zone 3		24,000	0 FD FF FEh : : FAA3 [a]	488 288
			Outer Zone 3	INFO 3/4	58,000	FAA3 – 2h : FAA3 – 4 98h	294
				DCZ 3	58,014	FAA3 – 4 9Ah : FAA3 – 10 08h	732
				Protection -Zone 3	58,050	FAA3 – 10 0Ah :	---
	starting radius 58,5 mm						

[a] $FAA3 = \overline{LAA + 1\ 00\ 00\ 01h}$ (see 15.7.4.3)

Figure 91 — Layout of Information Zone on Layer L3 of QL disk

Physical-Sector numbering
Each Cluster contains 32 Physical Sectors, 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 PSNs increase by one for each successive Physical Sector in the tracking direction of the related Recording Layer.

The PSN of the first Physical Sector of each Physical Cluster is a multiple of 32.

Bits PS_{31} to PS_{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 on a TL disk,

= 00 FE 6B FFh on a QL disk.

The first PSN in the Data Zone 1 is 8 × FAA, which is

= 02 F7 64 00h on a TL disk,

= 03 01 94 00h on a QL disk.

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 on a TL disk,

= 04 FE 6B FFh on a QL disk.

The first PSN in the Data Zone 3 is 8 × FAA3, which is

= 07 01 94 00h on a QL disk.

The last PSN in the Data Zone 3 is 07 EF FF FFh.

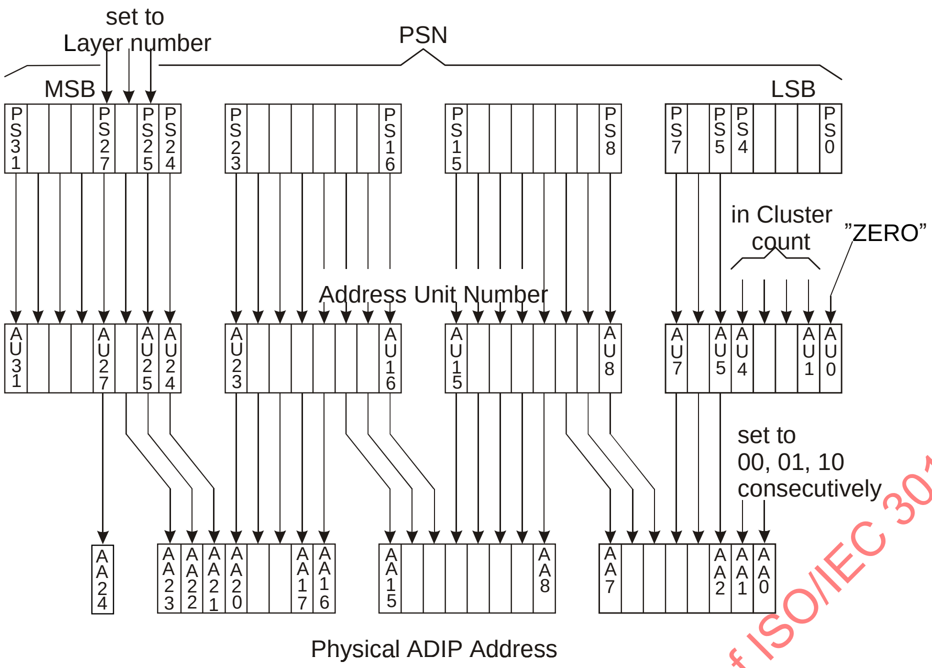


Figure 92 — Physical ADIP Addresses derived from PSN's

These PSNs are converted to the Address-Unit Numbers, which shall be recorded in the BIS columns of the ECC Clusters (see 13.9.2.2).

Finally a Physical ADIP Address is derived from the PSN/AUN as defined in Figure 92. This PAA identifies the location on the disk where the data shall be recorded.

18 Inner Zone(s)

18.1 General

On Layer L0 the innermost Zone of the Information Zone is called the Lead-in Zone (part of the Inner Zone 0). On Layer L1 and Layer L2 they are called Inner Zone 1 and Inner Zone 2. On Layer L3 of a QL disk it is called the Lead-out Zone (part of the Inner Zone 3).

Inner Zone 0 (in its Lead-in Zone part) contains an Embossed HFM Area and a Recordable Area. Inner Zone 1, Inner Zone 2 and Inner Zone 3 (in its Lead-out Zone part) contain an embossed wobbled parts and Recordable Areas (see Figure 93, Figure 94, Figure 95,Figure 96,Figure 97,Figure 98 and Figure 99).

In the Embossed HFM Area on Layer L0, all Groove shall be encoded according to the format as defined in 15.5 and subclause.

On Layer L0 this encoding shall start at a radius $22{,}2^{\,0{,}0}_{-0{,}1}$ mm, such that the AUN of the first Cluster shall be

— AUN = 00 0B F8 E2h if disk is a TL disk.

— AUN = 00 0C 3A 1Ch if disk is a QL disk.

The addresses shall be continuously increasing as described in 15.5.3.2 and shall end with AUN = 00 0C 19 BEh for a TL disk, 00 0C 5A 7Eh for a QL disk 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 as a Protection Area against overwriting of the PIC Zone by the BCA code.

In the Permanent Information & Control Data (PIC) Zone, general information about the disk and various other information can be stored in the Embossed HFM Groove.

In the Recordable Area and the Wobbled Grooved Area (Protection Zone 1 on Layer L1, Layer L2 and Layer L3 for a QL disk), all Grooves shall be wobbled as defined in 15.6.

The Recordable Areas of each Inner Zone(s) are used to execute OPC (Optimum Power Control) procedures and to store specific information about the disk, such as e.g. 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
↓ Recordable ↓ *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	2 044	OPC testing
		OPC 0 Buffer	0 01 DB F0h	4	buffer
	TDMA 0	---	0 01 DC 00h	2 048	Temporary Disk-Management Area
	INFO 1	Pre-write Area	0 01 FC 00h	32	Drive calibration
		Drive Area	0 01 FC 80h	32	drive specific information
		Drive Area	0 01 FD 00h	32	drive specific information
		Drive Area	0 01 FD 80h	32	drive specific information
		Drive Area	0 01 FE 00h	32	drive specific information
		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 93 — Lead-in Zone of TL disk

Inner Zone 1		Description	First PAA of Zone	Number of Phys. Clusters	Purpose
		(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
		Drive Area	0 7E 01 80h	32	drive specific information
		Drive Area	0 7E 02 00h	32	drive specific information
		Drive Area	0 7E 02 80h	32	drive specific information
		Drive Area	0 7E 03 00h	32	drive specific information
		Pre-write Area	0 7E 03 80h	32	Drive calibration
	Reserved	---	0 7E 04 00h	2 048	future extension
	TDMA 1	---	0 7E 24 00h	2 048	Temporary Disk-Management Area
↓	INFO 2	Buffer 2	0 7E 44 00h	32	---
Recordable		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
tracking direction		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 94 — Inner Zone 1 of TL disk

Inner Zone 2		Description	First PAA of Zone	Number of Phys. Clusters	Purpose
Wobbled Grooves		Protection -Zone 1	---	---	---
↓ Recordable ↓ *tracking direction*	Buffer	---	0 81 3A 48h	200	---
	OPC 2	Test Zone	0 81 3D 68h	2 044	OPC testing
		OPC 2 Buffer	0 81 5D 58h	4	buffer
	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	---
	TDMA 2	---	0 81 7A 68h	2 048	Temporary Disk-Management Area
	Buffer	---	0 81 9A 68h	6 246	---
	INFO 1	Pre-write Area	0 81 FC 00h	32	Drive calibration
		Drive Area	0 81 FC 80h	32	drive specific information
		Drive Area	0 81 FD 00h	32	drive specific information
		Drive Area	0 81 FD 80h	32	drive specific information
		Drive Area	0 81 FE 00h	32	drive specific information
		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 95 — Inner Zone 2 of TL disk

Lead-in Zone		Description	First PAA of Zone	Number of Phys. Clusters	Purpose
Embossed HFM		Protection Zone 1	---	---	---
		PIC	---	---	Permanent Information & Control Data Zone
↓ Recordable ↓ *tracking direction*	---	Protection Zone 2	0 01 8B 50h	300	---
	Buffer	---	0 01 90 00h	814	---
	INFO 2	Reserved 8	0 01 9C B8h	32	future extension
		Reserved 7	0 01 9D 38h	32	future extension
		Reserved 6	0 01 9D B8h	32	future extension
		Reserved 5	0 01 9E 38h	32	future extension
		PAC 2	0 01 9E B8h	32	Physical-Access Control
		DMA 2	0 01 9F 38h	32	Disk Management
		Control Data 2	0 01 9F B8h	32	data information
		Buffer 2	0 01 A0 38h	32	---
	OPC 0	Test Zone	0 01 A0 B8h	2 048	OPC testing
	Buffer	---	0 01 C0 B8h	3 794	---
	INFO 1	Pre-write Area	0 01 FC 00h	32	Drive calibration
		Drive Area	0 01 FC 80h	32	drive specific information
		Drive Area	0 01 FD 00h	32	drive specific information
		Drive Area	0 01 FD 80h	32	drive specific information
		Drive Area	0 01 FE 00h	32	drive specific information
		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 96 — Lead-in Zone of QL disk

Inner Zone 1		Description	First PAA of Zone	Number of Phys. Clusters	Purpose
		(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
		Drive Area	0 7E 01 80h	32	drive specific information
		Drive Area	0 7E 02 00h	32	drive specific information
		Drive Area	0 7E 02 80h	32	drive specific information
		Drive Area	0 7E 03 00h	32	drive specific information
		Pre-write Area	0 7E 03 80h	32	Drive calibration
	Buffer	---	0 7E 04 00h	4 778	future extension
	TDMA 0	---	0 7E 4E A8h	2 304	Temporary Disk-Management Area
↓	INFO 2	Buffer 2	0 7E 72 A8h	32	---
Recordable		Control Data 2	0 7E 73 28h	32	data information
↓		DMA 2	0 7E 73 A8h	32	Disk Management
		PAC 2	0 7E 74 28h	32	Physical-Access Control
		Reserved 5	0 7E 74 A8h	32	future extension
		Reserved 6	0 7E 75 28h	32	future extension
		Reserved 7	0 7E 75 A8h	32	future extension
tracking direction		Reserved 8	0 7E 76 28h	32	future extension
	OPC 1	Test Zone	0 7E 76 A8h	2 048	OPC testing
	Buffer	---	0 7E 96 A8h	2 500	---
Wobbled Grooves		Protection Zone 1	0 7E BD B8h	---	---

Figure 97 — Inner Zone 1 of QL disk

Inner Zone 2		Description	First PAA of Zone	Number of Phys. Clusters	Purpose
Wobbled Grooves		Protection Zone 1	---	---	---
↓ Recordable ↓ *tracking direction*	Buffer	---	0 81 42 48h	3 268	---
	INFO 2	Reserved 8	0 81 75 58h	32	future extension
		Reserved 7	0 81 75 D8h	32	future extension
		Reserved 6	0 81 76 58h	32	future extension
		Reserved 5	0 81 76 D8h	32	future extension
		Reserved	0 81 77 58h	32	future extension
		DMA 2	0 81 77 D8h	32	Disk Management
		Control Data 2	0 81 78 58h	32	data information
		Buffer 2	0 81 78 D8h	32	---
	TDMA 1	---	0 81 79 58h	1 280	Temporary Disk-Management Area
	Buffer	---	0 81 8D 58h	3 754	---
	OPC 2	Test Zone	0 81 C8 00h	2 044	OPC testing
		OPC 2 Buffer	0 81 E7 F0h	4	buffer
	TDMA 2	---	0 81 E8 00h	1 280	Temporary Disk-Management Area
	INFO 1	Pre-write Area	0 81 FC 00h	32	Drive calibration
		Drive Area	0 81 FC 80h	32	drive specific information
		Drive Area	0 81 FD 00h	32	drive specific information
		Drive Area	0 81 FD 80h	32	drive specific information
		Drive Area	0 81 FE 00h	32	drive specific information
		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 98 — Inner Zone 2 of QL disk

Lead-out Zone		Description	First PAA of Zone	Number of Phys. Clusters	Purpose
↓ Recordable ↓ *tracking direction*		(Data Zone 3)			
	INFO 1	Reserved	0 FE 00 00h	32	future extension
		Control Data 1	0 FE 00 80h	32	data information
		DMA 1	0 FE 01 00h	32	Disk Management
		Drive Area	0 FE 01 80h	32	drive specific information
		Drive Area	0 FE 02 00h	32	drive specific information
		Drive Area	0 FE 02 80h	32	drive specific information
		Drive Area	0 FE 03 00h	32	drive specific information
		Pre-write Area	0 FE 03 80h	32	Drive calibration
	TDMA 3	---	0 FE 04 00h	3 328	Temporary Disk-Management Area
	INFO 2	Buffer 2	0 FE 38 00h	32	---
		Control Data 2	0 FE 38 80h	32	data information
		DMA 2	0 FE 39 00h	32	Disk Management
		Reserved	0 FE 39 80h	32	future extension
		Reserved 5	0 FE 3A 00h	32	future extension
		Reserved 6	0 FE 3A 80h	32	future extension
		Reserved 7	0 FE 3B 00h	32	future extension
		Reserved 8	0 FE 3B 80h	32	future extension
	Buffer	---	0 FE 3C 00h	6 254	---
	OPC 3	Test Zone	0 FE 9D B8h	2 048	OPC testing
Wobbled Grooves		Protection Zone 1	0 FE BD B8h	---	---

Figure 99 — Lead-out Zone of QL disk

18.2 Permanent Information & Control Data (PIC) Zone

18.2.1 Genarel

The Permanent Information & 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. The Permanent Information & Control Data (PIC) is only present on Layer L0.

18.2.2 Content of PIC Zone

The PIC Zone shall consist of five repetitions of a PIC-Info Fragment, where each PIC-Info Fragment consists of 544 PIC Clusters (for a total of 2 720, see Figure 100 for a TL disk and Figure 101 for a QL disk).

The PIC Clusters shall be formatted as described in 15.5.

The PIC-Info Fragments shall start on Layer L0 for a TL disk at AUNs: 00 0C 04 80h, 00 0C 08 C0h, 00 0C 0D 00h, 00 0C 11 40h and 00 0C 15 80h.

The PIC-Info Fragments shall start on Layer L0 for a QL disk at AUNs: 00 0C 45 40h, 00 0C 49 80h, 00 0C 4D C0h, 00 0C 52 00h and 00 0C 56 40h.

PIC-Info Fragment number	PIC Cluster number	AUN on Layer L0
IF0	0	00 0C 04 80h
	1	00 0C 04 82h
	2	00 0C 04 84h
	:	:
	543	00 0C 08 BEh
IF1	0	00 0C 08 C0h
	:	:
	543	00 0C 0C FEh
IF2	0	00 0C 0D 00h
	:	:
	543	00 0C 11 3Eh
IF3	0	00 0C 11 40h
	:	:
	543	00 0C 15 7Eh
IF4	0	00 0C 15 80h
	:	:
	543	00 0C 19 BEh

Figure 100 — PIC Zone for TL disk

PIC-Info Fragment number	PIC Cluster number	AUN on Layer L0
IF0	0	00 0C 45 40h
	1	00 0C 45 42h
	2	00 0C 45 44h
	:	:
	543	00 0C 49 7Eh
IF1	0	00 0C 49 80h
	:	:
	543	00 0C 4D BEh
IF2	0	00 0C 4D C0h
	:	:
	543	00 0C 51 FEh
IF3	0	00 0C 52 00h
	:	:
	543	00 0C 56 3Eh
IF4	0	00 0C 56 40h
	:	:
	543	00 0C 5A 7Eh

Figure 101 — PIC Zone for QL disk

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 102). 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 15.8.3 and Figure 102.

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 102 — First PIC Cluster of each Info Fragment

All other PIC Clusters shall be Reserved, unless specified otherwise (e.g. in other Applications).

18.2.3 Emergency Brake

As a protective measure, a data set is defined that can be used by specific drive models to recognize disks that need special handling to prevent destructive malfunction.

This data is called Emergency Brake (EB) data.

The EB data is specified in bytes 3 584 to 4 095 of the first PIC Cluster of each Info Fragment. It consists of an EB Header, EB-data field(s) and an EB Footer. EB-data fields shall be included only after mutual agreement between the disk manufacturer and the drive manufacturer involved, when specific drives require special actions when handling such disks, e.g. to prevent damage to the disk or the drive. Up to a maximum of 62 EB-data fields may be applied.

The Emergency-Brake data shall be implemented as depicted in Figure 103.

Byte number	Function	Definition	Number of bytes
3 584 to 3 585	EB Header	Identifier	2
3 586		Version	1
3 587		Reserved	1
3 588		List length	1
3 589 to 3 591		Reserved	3
3 592 to 3 593	EB Data field 1	Drive-Manufacturer ID	2
3 594 to 3 595		Drive Model	2
3 596 to 3 597		Firmware Version	2
3 598 to 3 599		Drive Actions	2
: :	: :	: :	: :
(3 584 + *i* × 8) to (3 584 +*i* × 8) + 1	EB Data field *i* (1 ≤ *i* ≤ *N*)	Drive-Manufacturer ID	2
(3 584 + *i* × 8) + 2 to (3 584 + *i* × 8) + 3		Drive Model	2
(3 584 + *i* × 8) + 4 to (3 584 + *i* × 8) + 5		Firmware Version	2
(3 584 + *i* × 8) + 6 to (3 584 + *i* × 8) + 7		Drive Actions	2
: :	: :	: :	: :
(3 584 + *N* × 8) to (3 584 + *N* × 8) + 1	EB Data Field *N* (*N* ≤ 62)	Drive-Manufacturer ID	2
(3 584 + *N* × 8) + 2 to (3 584 + *N* × 8) + 3		Drive Model	2
(3 584 + *N* × 8) + 4 to (3 584 + *N* × 8) + 5		Firmware Version	2
(3 584 + *N* × 8) + 6 to (3 584 + *N* × 8) + 7		Drive Actions	2
[3 584 + (*N*+1) × 8] to [3 584 + (*N*+1) × 8] + 7	EB Footer	Terminator	8
[3 584 + (*N*+2) × 8] to 4 095	Unused	Reserved	512 – (*N* + 2) × 8

Figure 103 — 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 ($1 \le i \le N$): 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 ($1 \le i \le N$): Drive-Model number

These 2 bytes represent the Drive-Model number and shall be defined by the drive manufacturer. This International Standard does not specify the format and the content of this byte. It shall be ignored in interchange.

Bytes (3 584 + i × 8) + 4 to (3 584 + i × 8) + 5 ($1 \le i \le N$): Drive-Firmware Version

These 2 bytes represent the Drive-Firmware Version and shall be defined by the drive manufacturer. This International Standard does not specify the format and the content of this byte. It shall be ignored in interchange.

Bytes (3 584 + i × 8) + 6 to (3 584 + i × 8) + 7 ($1 \le i \le N$): Drive-Manufacturer Actions

These 2 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 International Standard does not specify the format and the content of this byte. It shall be ignored in interchange.

Bytes [3 584 + (N+1) × 8] to [3 584 + (N + 1) × 8] + 7 ($0 \le N \le 62$): 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 ($0 \le N \le 62$): Reserved

These bytes shall be Reserved.

18.3 Recordable Area of Lead-in Zone of TL disk

18.3.1 Protection-Zone 2

This Zone of 300 Physical Clusters starts at PAA 0 01 83 38h and is intended to be a buffer Zone for the transition from the Embossed HFM Area to the Recordable Area (see 15.4.4).

18.3.2 Buffer

This Zone of 3 078 Physical Clusters starts at PAA 0 01 87 E8h and shall be unrecorded.

18.3.3 INFO 2 / Reserved 8

This Zone comprising 32 Physical Clusters starts at PAA 0 01 B8 00h and is Application dependent.
For the disks with BCA code, this Zone shall be left unrecorded unless otherwise specified by the Application.
For the disks without BCA code, this Zone shall be recorded all 00h before shipping.

18.3.4 INFO 2 / Reserved 7

This Zone comprising 32 Physical Clusters starts at PAA 0 01 B8 80h and shall be unrecorded.

18.3.5 INFO 2 / Reserved 6

This Zone comprising 32 Physical Clusters starts at PAA 0 01 B9 00h and shall be left unrecorded.

18.3.6 INFO 2 / Reserved 5

This Zone comprising 32 Physical Clusters starts at PAA 0 01 B9 80h and is Application dependent.

For the disks with BCA code, this Zone shall be left unrecorded unless otherwise specified by the Application.

For the disks without BCA code, this Zone shall be recorded all 00h before shipped.

18.3.7 INFO 2 / PAC 2

This Zone comprising 32 Physical Clusters starts at PAA 0 01 BA 00h on Layer L0 and is intended to be used for storing Physical-Access Control (PAC) Clusters (see 21.2). Unused Clusters in this Zone shall be left unrecorded.

18.3.8 INFO 2 / DMA 2

This Zone comprising 32 Physical Clusters starts at PAA 0 01 BA 80h and is intended for use by the Disk Management system. Until the disk is closed (see 22.6) these Clusters shall be left unrecorded.

18.3.9 INFO 2 / Control Data 2

This Zone comprising 32 Physical Clusters starts at PAA 0 01 BB 00h and is intended to store Control Information. Unused Clusters shall be left unrecorded until the disk is closed.

18.3.10 INFO 2 / Buffer 2

This Zone comprising 32 Physical Clusters starts at PAA 0 01 BB 80h and shall be left unrecorded.

18.3.11 OPC 0 / Test Zone

The Test Zone comprising 2 044 Physical Clusters starts at PAA 0 01 BC 00h and is reserved for testing and/or OPC procedures. The OPC 0 Area shall be used according to 18.3.12.

18.3.12 Usage of OPC Areas

18.3.12.1 OPC procedure order

The OPC Areas shall be used consecutively in descending PAA order. The first area used for an OPC procedure ends at the end of the last PAA. The last usable Physical Cluster of the OPC Area is located at the first PAA of the OPC Area, see Figure 104.

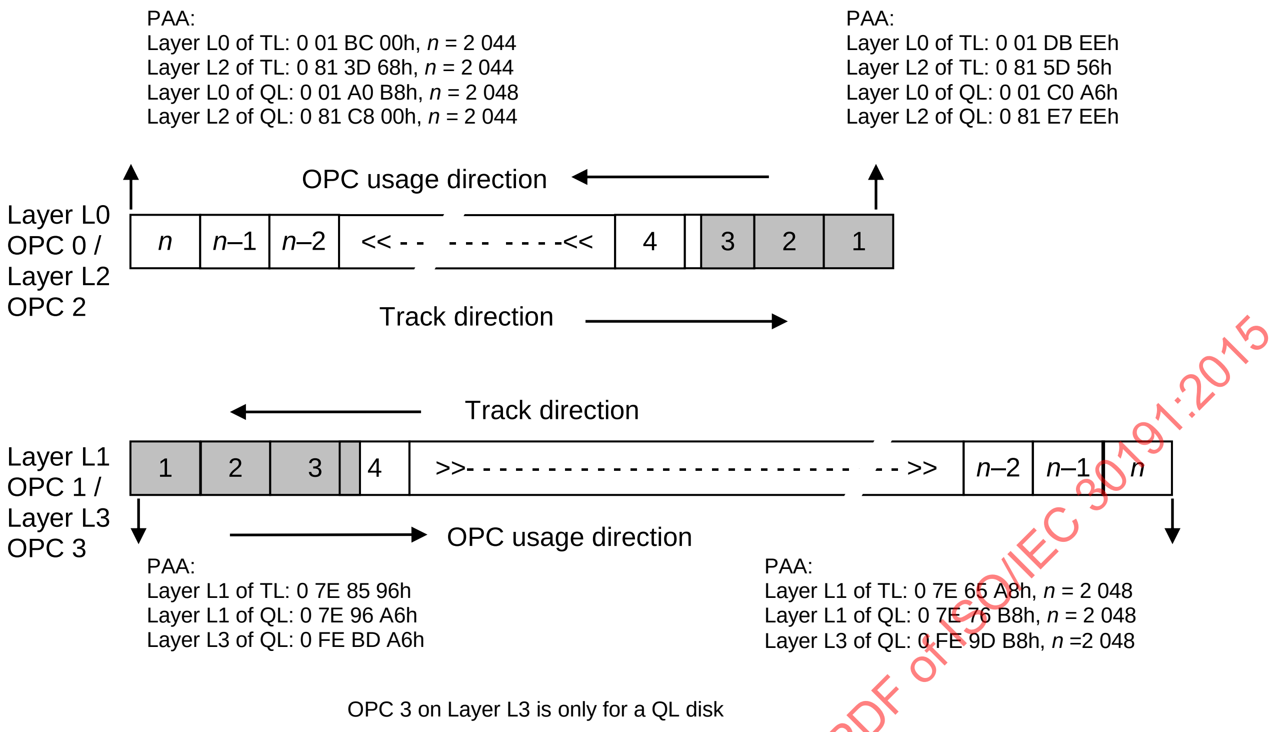
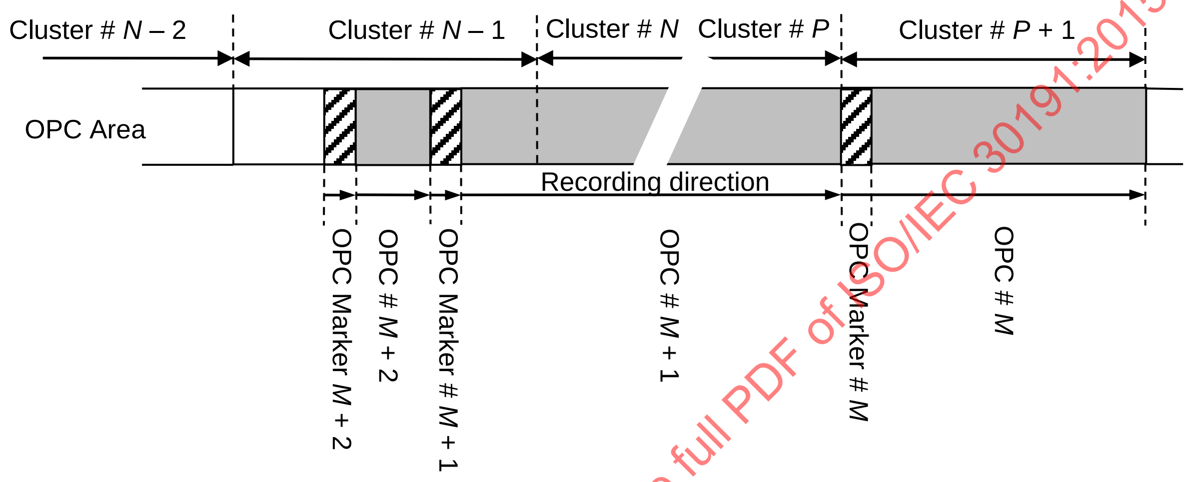


Figure 104 — Direction of usage of OPC Area of Layer L0, Layer L1, Layer L2 and Layer L3

18.3.12.2 OPC Physical Cluster usage

The length of one OPC procedure may be chosen by the drive and is not restricted to an integer number of Physical Clusters (see Figure 105). The transition between the used and unused OPC Area shall be indicated by an OPC Marker. The distance between any two consecutive OPC Markers shall not exceed 16 Physical Clusters. In case an OPC procedure needs more than 16 Physical Clusters, OPC Markers shall be inserted to fulfill this requirement. The OPC Marker shall have a length of at least 868 NWLs (equal to one AUN) and its modulation shall be such that $I_{8pp} / I_{8H} \geq 0{,}30$.



OPC #*M* occupies exactly one Cluster; OPC #*M*+1 exceeds one Cluster;
OPC #*M*+2 is smaller than one Cluster

Figure 105 — Example of position of OPC Markers

18.3.12.3 OPC update in the TDMA

Each OPC procedure shall be completed by updating the corresponding “next available PSN of Test Zone on Layer L*x*” (*x* = 0, 1, 2 and 3) in the TDDS, see 22.4.4.

18.3.13 OPC 0 / OPC 0 Buffer

This Zone of 4 Physical Clusters starts at PAA 0 01 DB F0h and is intended as a buffer Zone for the transition from OPC 0 Area to the TDMA 0 Area and shall be unrecorded.

18.3.14 TDMA 0

This Zone of 2 048 Physical Clusters starts at PAA 0 01 DC 00h and is intended for use as a Temporary Disk-Management Area.

18.3.15 INFO 1 / Pre-write Area

This Zone of 32 Physical Clusters starts at PAA 0 01 FC 00h and all 32 Physical Clusters shall be recorded by the first drive that writes on Layer L0 and shall contain all 00h.

Drives that write the INFO 1 / Pre-write Area shall update Pre-write Area flags of the TDDS (see 22.4.4).

18.3.16 INFO 1 / Drive Area

18.3.16.1 General

The use of this Zone, divided into four parts of 32 Physical Clusters each starting at PAA 0 01 FC 80h is optional.

This Zone can be used by drives to store drive-specific information, restricted to be used only by the drive that has created the information. To guarantee that drives can allocate their own information, the following format shall be used. These Clusters in this Zone shall be ignored in interchange.

18.3.16.2 Format of Drive-specific Information

Each Drive-specific Information shall be contained in one 2K Data Frame. The first 128 bytes of such a Data Frame shall contain a signature of the drive that has created the related Data Frame, according to the following format:

- 48 bytes for the Manufacturers name, represented by characters from the ISO 646 character set,
- 48 bytes of additional identification, represented by characters from the ISO 646 character set,
- 32 bytes for a unique serial number of the drive.

The format of the remaining 1 920 bytes of the Data Frame is not defined and can be chosen freely by each drive designer.

Drive-specific Information of the last 32 drives that have used this option shall be stored in the newest recorded Physical Cluster. Each time a new drive is going to write its Drive-specific Information in a new Physical Cluster, the oldest Drive-specific Information, which is located in Data Frame 31 of the last Physical Cluster is removed, the content of Data Frames 0 to 30 of the last Physical Cluster is are copied into Data Frames 1 to 31 in the new Physical Cluster and the new information is written in Data Frame 0 in the new Physical Cluster (see Figure 106). Initially the Physical Cluster starting at PAA 0 01 FC 80h shall be used to store the Drive-specific Information.

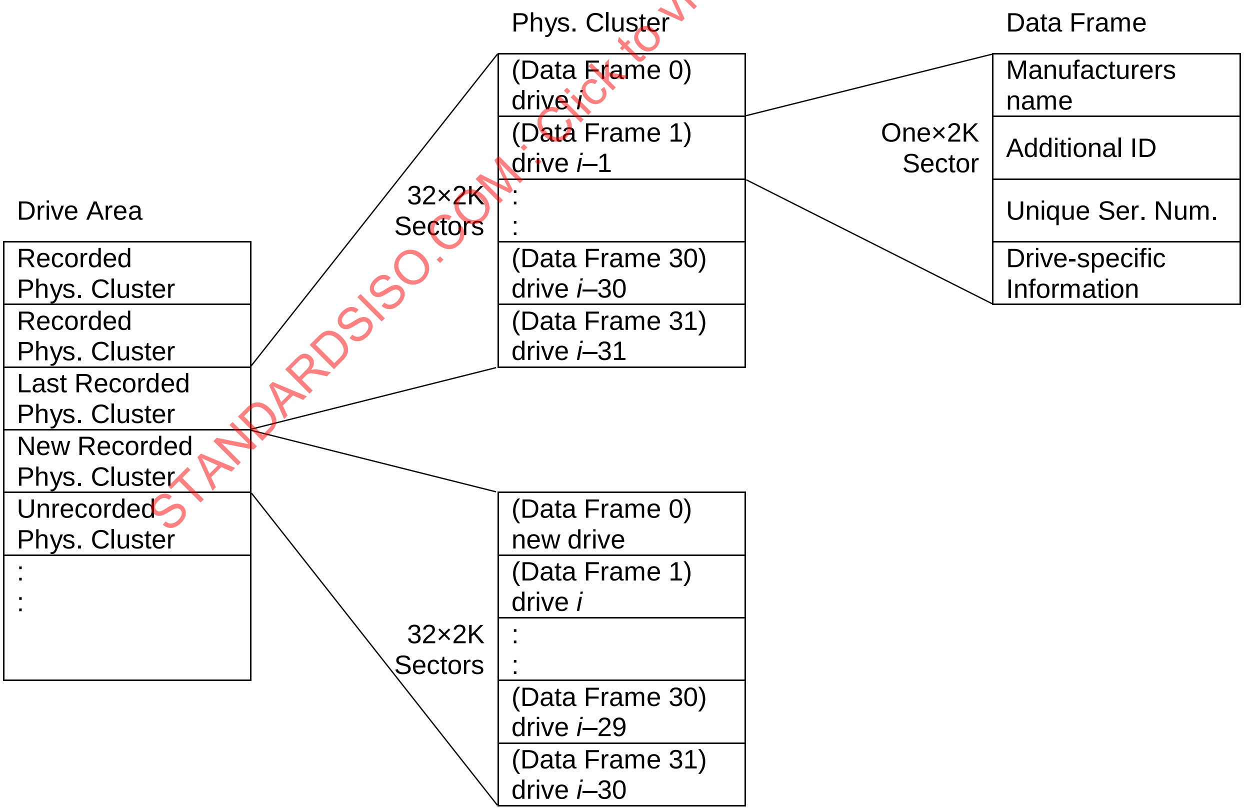


Figure 106 — Format of Drive Area (example)

18.3.17 INFO 1 / DMA 1

This Zone comprising 32 Physical Clusters starts at PAA 0 01 FE 80h and is intended for use by the Disk Management system. Until the disk is closed (see 22.6) these Clusters shall be left unrecorded.

18.3.18 INFO 1 / Control Data 1

This Zone comprising 32 Physical Clusters starts at PAA 0 01 FF 00h and is intended to store Control Information. Unused Clusters shall be left unrecorded until the disk is closed.

18.3.19 INFO 1 / PAC 1

This Zone comprising 32 Physical Clusters starts at PAA 0 01 FF 80h on Layer L0 and is intended to be used for storing Physical-Access Control (PAC) Clusters (see 21.2). Unused Clusters in this Zone shall be left unrecorded.

18.4 Recordable Area of Inner Zone 1 of TL disk

18.4.1 Buffer

This Zone comprising 4 104 Physical Clusters starts at PAA 0 7E 85 98h and shall be left unrecorded.

18.4.2 OPC 1 / Test Zone

This Zone comprising 2 048 Physical Clusters starts at PAA 0 7E 65 98h is reserved for testing and/or OPC procedures. The OPC 1 Area shall be used according 18.3.12.

18.4.3 Reserved

This Zone comprising 1 894 Physical Clusters starts at PAA 0 7E 48 00h and shall be unrecorded.

18.4.4 INFO 2 / Reserved 8

This Zone comprising 32 Physical Clusters starts at PAA 0 7E 47 80h and is Application dependent.

For the disks with BCA code, this Zone shall be left unrecorded unless otherwise specified by the Application.

For the disks without BCA code, this Zone shall be recorded all 00h before shipped.

18.4.5 INFO 2 / Reserved 7

This Zone comprising 32 Physical Clusters starts at PAA 0 7E 47 00h and shall be left unrecorded.

18.4.6 INFO 2 / Reserved 6

This Zone comprising 32 Physical Clusters starts at PAA 0 7E 46 80h and shall be left unrecorded.

18.4.7 INFO 2 / Reserved 5

This Zone comprising 32 Physical Clusters starts at PAA 0 7E 46 00h and is Application dependent.

For the disks with BCA code, this Zone shall be left unrecorded unless otherwise specified by the Application.

For the disks without BCA code, this Zone shall be recorded all 00h before shipped.

18.4.8 INFO 2 / PAC 2

This Zone comprising 32 Physical Clusters starts 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 be left unrecorded.

18.4.9 INFO 2 / DMA 2

This Zone comprising 32 Physical Clusters starts at PAA 0 7E 45 00h and is intended for use by the Disk Management system. Until the disk is closed (see 22.6) these Clusters shall be left unrecorded.

18.4.10 INFO 2 / Control Data 2

This Zone comprising 32 Physical Clusters starts at PAA 0 7E 44 80h and is intended to store Control Information. Unused Clusters shall be left unrecorded until the disk is closed.

18.4.11 INFO 2 / Buffer 2

This Zone comprising 32 Physical Clusters starts at PAA 0 7E 44 00h and shall be left unrecorded.

18.4.12 TDMA 1

This Zone comprising 2 048 Physical Clusters starts at PAA 0 7E 24 00h and is intended for use as a Temporary Disk-Management Area.

18.4.13 Reserved

This Zone comprising 2 048 Physical Clusters starts at PAA 0 7E 04 00h and shall be left unrecorded.

18.4.14 INFO 1 / Pre-write Area

This Zone comprising 32 Physical Clusters starts at PAA 0 7E 03 80h and all 32 Physical Clusters shall be recorded by the first drive that writes on Layer L1 and shall contain all 00h. Drives that write the INFO 1 / Pre-write Area shall update Pre-write Area flags of the TDDS (see 22.4.4).

18.4.15 INFO 1 / Drive Area

The use of this Zone, divided into four parts of 32 Physical Clusters, starting at PAA 0 7E 01 80h is optional.

This Zone can be used by drives to store drive-specific information, restricted to be used only by the drive that has created the information. To guarantee that drives can allocate their own information, the format specified in 18.3.16 shall be used. The Clusters in this Zone shall be ignored in interchange.

18.4.16 INFO 1 / DMA 1

This Zone comprising 32 Physical Clusters starts at PAA 0 7E 01 00h and is intended for use by the Disk Management system. Until the disk is closed (see 22.6) these Clusters shall be left unrecorded.

18.4.17 INFO 1 / Control Data 1

This Zone comprising 32 Physical Clusters starts at PAA 0 7E 00 80h and is intended to store Control Information.

Unused Clusters shall be left unrecorded until the disk is closed.

18.4.18 INFO 1 / PAC 1

This Zone of 32 Physical Clusters starts at PAA 0 7E 00 00h 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 be left unrecorded.

18.5 Recordable Area of Inner Zone 2 of TL disk

18.5.1 Buffer

This Zone comprising 200 Physical Clusters starts at PAA 0 81 3A 48h and shall be unrecorded.

18.5.2 OPC 2 / Test Zone

The Test Zone comprising 2 044 Physical Clusters starts at PAA 0 81 3D 68h and is reserved for testing and/or OPC procedures. The OPC 2 Area shall be used according to 18.3.12.

18.5.3 OPC 2 / OPC 2 Buffer

This Zone comprising 4 Physical Clusters starts at PAA 0 81 5D 58h and is intended as a buffer Zone for the transition from OPC 2 Area to the Reserved Area and shall be left unrecorded.

18.5.4 Reserved

This Zone comprising 1 600 Physical Clusters starts at PAA 0 81 5D 68h and shall be left unrecorded.

18.5.5 INFO 2 / Reserved 8

This Zone comprising 32 Physical Clusters starts at PAA 0 81 76 68h and is Application dependent.

For the disks with BCA code, this Zone shall be left unrecorded unless otherwise specified by the Application.

For the disks without BCA code, this Zone shall be recorded all 00h before shipped.

18.5.6 INFO 2 / Reserved 7

This Zone comprising 32 Physical Clusters starts at PAA 0 81 76 E8h and shall be left unrecorded.

18.5.7 INFO 2 / Reserved 6

This Zone comprising 32 Physical Clusters starts at PAA 0 81 77 68h and shall be left unrecorded.

18.5.8 INFO 2 / Reserved 5

This Zone comprising 32 Physical Clusters starts at PAA 0 81 77 E8h and is Application dependent.

For the disks with BCA code, this Zone shall be left unrecorded unless otherwise specified by the Application.

For the disks without BCA code, this Zone shall be recorded all 00h before shipped.

18.5.9 INFO 2 / Reserved

This Zone comprising 32 Physical Clusters starts at PAA 0 81 78 68h and shall be left unrecorded.

18.5.10 INFO 2 / DMA 2

This Zone comprising 32 Physical Clusters starts at PAA 0 81 78 E8h and is intended for use by the Disk Management system. Until the disk is closed (see 22.6) these Clusters shall be left unrecorded.

18.5.11 INFO 2 / Control Data 2

This Zone comprising 32 Physical Clusters starts at PAA 0 81 79 68h and is intended to store Control Information.

Unused Clusters shall be left unrecorded until the disk is closed.

18.5.12 INFO 2 / Buffer 2

This Zone comprising 32 Physical Clusters starts at PAA 0 81 79 E8h and shall be unrecorded.

18.5.13 TDMA 2

This Zone comprising 2 048 Physical Clusters starts at PAA 0 81 7A 68h and is intended for use as a Temporary Disk-Management Area.

18.5.14 Buffer

This Zone comprising 6 246 Physical Clusters starts at PAA 0 81 9A 68h and shall be left unrecorded.

18.5.15 INFO 1 / Pre-write Area

This Zone comprising 32 Physical Clusters starts at PAA 0 81 FC 00h and all 32 Physical Clusters shall be recorded by the first drive that writes on Layer L2 and shall contain all 00h.

Drives that write the INFO 1 / Pre-write Area shall update Pre-write Area flags of the TDDS (see 22.4.4).

18.5.16 INFO 1 / Drive Area

The use of this Zone, divided into four parts of each 32 Physical Clusters starting at PAA 0 81 FC 80h is optional. This Zone can be used by drives to store drive-specific information, restricted to be used only by the drive that has created the information. To guarantee that drives can allocate their own information, the format specified in 18.3.16 shall be used. These Clusters in this Zone shall be ignored in interchange.

18.5.17 INFO 1 / DMA 1

This Zone comprising 32 Physical Clusters starts at PAA 0 81 FE 80h and is intended for use by the Disk Management system. Until the disk is closed (see 22.6) these Clusters shall be left unrecorded.

18.5.18 INFO 1 / Control Data 1

This Zone comprising 32 Physical Clusters starts at PAA 0 81 FF 00h and is intended to store Control Information.

Unused Clusters shall be left unrecorded until the disk is closed.

18.5.19 INFO 1 / Reserved

This Zone comprising 32 Physical Clusters starts at PAA 0 81 FF 80h and shall be unrecorded.

18.6 Recordable Area of Lead-in Zone of QL disk

18.6.1 Protection-Zone 2

This Zone comprising 300 Physical Clusters starts at PAA 0 01 8B 50h and is meant as a buffer Zone for the transition from the Embossed HFM Area to the Recordable Area (see 15.4.4).

18.6.2 Buffer

This Zone comprising 814 Physical Clusters starts at PAA 0 01 90 00h and shall be unrecorded.

18.6.3 INFO 2 / Reserved 8

This Zone comprising 32 Physical Clusters starts at PAA 0 01 9C B8h and is Application dependent.

For the disks with BCA code, this Zone shall be left unrecorded unless otherwise specified by the Application.

For the disks without BCA code, this Zone shall be recorded all 00h before shipped.

18.6.4 INFO 2 / Reserved 7

This Zone comprising 32 Physical Clusters starts at PAA 0 01 9D 38h and shall be left unrecorded.

18.6.5 INFO 2 / Reserved 6

This Zone comprising 32 Physical Clusters starts at PAA 0 01 9D B8h and shall be left unrecorded.

18.6.6 INFO 2 / Reserved 5

This Zone comprising 32 Physical Clusters starts at PAA 0 01 9E 38h and is Application dependent.

For the disks with BCA code, this Zone shall be left unrecorded unless otherwise specified by the Application.

For the disks without BCA code, this Zone shall be recorded all 00h before shipped.

18.6.7 INFO 2 / PAC 2

This Zone comprising 32 Physical Clusters starts at PAA 0 01 9E B8h on Layer L0 and is intended to be used for storing Physical-Access Control (PAC) Clusters (see 21.2). Unused Clusters in this Zone shall be left unrecorded.

18.6.8 INFO 2 / DMA 2

This Zone comprising 32 Physical Clusters starts at PAA 0 01 9F 38h and is intended for use by the Disk Management system. Until the disk is closed (see 22.6) these Clusters shall be left unrecorded.

18.6.9 INFO 2 / Control Data 2

This Zone comprising 32 Physical Clusters starts at PAA 0 01 9F B8h and is intended to store Control Information.

Unused Clusters shall be left unrecorded until the disk is closed.

18.6.10 INFO 2 / Buffer 2

This Zone comprising 32 Physical Clusters starts at PAA 0 01 A0 38h and shall be left unrecorded.

18.6.11 OPC 0 / Test Zone

The Test Zone comprising 2 048 Physical Clusters starts at PAA 0 01 A0 B8h and is reserved for testing and/or OPC procedures. The OPC 0 Area shall be used according to 18.3.12.

18.6.12 Buffer

This Zone comprising 3 794 Physical Clusters starts at PAA 0 01 C0 B8h and shall be left unrecorded.

18.6.13 INFO 1 / Pre-write Area

This Zone comprising 32 Physical Clusters starts at PAA 0 01 FC 00h and all 32 Physical Clusters shall be recorded by the first drive that writes on Layer L0 and shall contain all 00h.

Drives that write the INFO 1 / Pre-write Area shall update Pre-write Area flags of the TDDS (see 22.4.4).

18.6.14 INFO 1 / Drive Area

The use of this Zone, divided into four parts of each 32 Physical Clusters starting at PAA 0 01 FC 80h is optional. This Zone can be used by drives to store drive-specific information, restricted to be used only by the drive that has created the information. To guarantee that drives can allocate their own information, the format specified in 18.3.16 shall be used. These Clusters in this Zone shall be ignored in interchange.

18.6.15 INFO 1 / DMA 1

This Zone comprising 32 Physical Clusters starts at PAA 0 01 FE 80h and is intended for use by the Disk Management system. Until the disk is closed (see 22.6) these Clusters shall be left unrecorded.

18.6.16 INFO 1 / Control Data 1

This Zone comprising 32 Physical Clusters starts at PAA 0 01 FF 00h and is intended to store Control Information.

Unused Clusters shall be left unrecorded until the disk is closed.

18.6.17 INFO 1 / PAC 1

This Zone comprising 32 Physical Clusters starts at PAA 0 01 FF 80h on Layer L0 and is intended to be used for storing Physical-Access Control (PAC) Clusters (see 21.2). Unused Clusters in this Zone shall be left unrecorded.

18.7 Recordable Area of Inner Zone 1 of QL disk

18.7.1 Buffer

This Zone comprising 2 500 Physical Clusters starts at PAA 0 7E 96 A8h and shall be left unrecorded.

18.7.2 OPC 1 / Test Zone

This Zone comprising 2 048 Physical Clusters starts at PAA 0 7E 76 A8h is reserved for testing and/or OPC procedures. The OPC 1 Area shall be used according 18.3.12.

18.7.3 INFO 2 / Reserved 8

This Zone comprising 32 Physical Clusters starts at PAA 0 7E 76 28h and is Application dependent.

For the disks with BCA code, this Zone shall be left unrecorded unless otherwise specified by the Application.

For the disks without BCA code, this Zone shall be recorded all 00h before shipped.

18.7.4 INFO 2 / Reserved 7

This Zone comprising 32 Physical Clusters starts at PAA 0 7E 75 A8h and shall be left unrecorded.

18.7.5 INFO 2 / Reserved 6

This Zone comprising 32 Physical Clusters starts at PAA 0 7E 75 28h and shall be left unrecorded.

18.7.6 INFO 2 / Reserved 5

This Zone comprising 32 Physical Clusters starts at PAA 0 7E 74 A8h and is Application dependent.

For the disks with BCA code, this Zone shall be left unrecorded unless otherwise specified by the Application.

For the disks without BCA code, this Zone shall be recorded all 00h before shipping.

18.7.7 INFO 2 / PAC 2

This Zone comprising 32 Physical Clusters starts at PAA 0 7E 74 28h 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 be left unrecorded.

18.7.8 INFO 2 / DMA 2

This Zone comprising 32 Physical Clusters starts at PAA 0 7E 73 A8h and is intended for use by the Disk Management system. Until the disk is closed (see 22.6) these Clusters shall be left unrecorded.

18.7.9 INFO 2 / Control Data 2

This Zone comprising 32 Physical Clusters starts at PAA 0 7E 73 28h and is intended to store Control Information. Unused Clusters shall be left unrecorded until the disk is closed.

18.7.10 INFO 2 / Buffer 2

This Zone comprising 32 Physical Clusters starts at PAA 0 7E 72 A8h and shall be left unrecorded.

18.7.11 TDMA 0

This Zone comprising 2 304 Physical Clusters starts at PAA 0 7E 4E A8h and is intended for use as a Temporary Disk-Management Area.

18.7.12 Buffer

This Zone comprising 4 778 Physical Clusters starting at PAA 0 7E 04 00h and shall be left unrecorded.

18.7.13 INFO 1 / Pre-write Area

This Zone comprising 32 Physical Clusters starts at PAA 0 7E 03 80h and all 32 Physical Clusters shall be recorded by the first drive that writes on Layer L1 and shall contain all 00h.

Drives that write the INFO 1 / Pre-write Area shall update Pre-write Area flags of the TDDS (see 22.4.4).

18.7.14 INFO 1 / Drive Area

The use of this Zone, divided into four parts of 32 Physical Clusters, starting at PAA 0 7E 01 80h is optional. This Zone can be used by drives to store drive-specific information, restricted to be used only by the drive that has created the information. To guarantee that drives can allocate their own information, the format specified in 18.3.16 shall be used. These Clusters in this Zone shall be ignored in interchange.

18.7.15 INFO 1 / DMA 1

This Zone comprising 32 Physical Clusters starts at PAA 0 7E 01 00h and is intended for use by the Disk Management system. Until the disk is closed (see 22.6) these Clusters shall be left unrecorded.

18.7.16 INFO 1 / Control Data 1

This Zone comprising 32 Physical Clusters starts at PAA 0 7E 00 80h and is intended to store Control Information.

Unused Clusters shall be left unrecorded until the disk is closed.

18.7.17 INFO 1 / PAC 1

This Zone comprising 32 Physical Clusters starts at PAA 0 7E 00 00h 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 be left unrecorded.

18.8 Recordable Area of Inner Zone 2 of QL disk

18.8.1 Buffer

This Zone comprising 3 268 Physical Clusters starts at PAA 0 81 42 48h and shall be left unrecorded.

18.8.2 INFO 2 / Reserved 8

This Zone comprising 32 Physical Clusters starts at PAA 0 81 75 58h and is Application dependent.

For the disks with BCA code, this Zone shall be left unrecorded unless otherwise specified by the Application.

For the disks without BCA code, this Zone shall be recorded all 00h before shipping.

18.8.3 INFO 2 / Reserved 7

This Zone comprising 32 Physical Clusters starts at PAA 0 81 75 D8h and shall be unrecorded.

18.8.4 INFO 2 / Reserved 6

This Zone comprising of 32 Physical Clusters starts at PAA 0 81 76 58h and shall be left unrecorded.

18.8.5 INFO 2 / Reserved 5

This Zone of 32 Physical Clusters starting at PAA 0 81 76 D8h is Application dependent.

For the disks with BCA code, this Zone shall be left unrecorded unless otherwise specified by the Application.

For the disks without BCA code, this Zone shall be recorded all 00h before shipped.

18.8.6 INFO 2 / Reserved

This Zone of 32 Physical Clusters starting at PAA 0 81 77 58h and shall be unrecorded.

18.8.7 INFO 2 / DMA 2

This Zone comprising 32 Physical Clusters starts at PAA 0 81 77 D8h and is intended for use by the Disk Management system. Until the disk is closed (see 22.6) these Clusters shall be left unrecorded.

18.8.8 INFO 2 / Control Data 2

This Zone comprising 32 Physical Clusters starts at PAA 0 81 78 58h and is intended to store Control Information.

Unused Clusters shall be left unrecorded until the disk is closed.

18.8.9 INFO 2 / Buffer 2

This Zone comprising 32 Physical Clusters starts at PAA 0 81 78 D8h and shall be unrecorded.

18.8.10 TDMA 1

This Zone comprising 1 280 Physical Clusters starts at PAA 0 81 79 58h and is intended for use as a Temporary Disk-Management Area.

18.8.11 Buffer

This Zone comprising 3 754 Physical Clusters starts at PAA 0 81 8D 58h and shall be unrecorded.

18.8.12 OPC 2 / Test Zone

The Test Zone comprising 2 044 Physical Clusters starts at PAA 0 81 C8 00h and is reserved for testing and/or OPC procedures. The OPC 2 Area shall be used according to 18.3.12.

18.8.13 OPC 2 / OPC 2 Buffer

This Zone comprising 4 Physical Clusters starts at PAA 0 81 E7 F0h and is intended as a buffer Zone for the transition from OPC 2 Area to the TDMA 2 Area and shall be left unrecorded.

18.8.14 TDMA 2

This Zone comprising 1 280 Physical Clusters starts at PAA 0 81 E8 00h and is intended for use as a Temporary Disk-Management Area.

18.8.15 INFO 1 / Pre-write Area

This Zone comprising 32 Physical Clusters starts at PAA 0 81 FC 00h and all 32 Physical Clusters shall be recorded by the first drive that writes on Layer L2 and shall contain all 00h.

Drives that write the INFO 1 / Pre-write Area shall update Pre-write Area flags of the TDDS (see 22.4.4).

18.8.16 INFO 1 / Drive Area

The use of this Zone, divided into four parts of each 32 Physical Clusters starting at PAA 0 81 FC 80h is optional. This Zone can be used by drives to store drive-specific information, restricted to be used only by the drive that has created the information. To guarantee that drives can allocate their own information, the format specified in 18.3.16 shall be used. These Clusters in this Zone shall be ignored in interchange.

18.8.17 INFO 1 / DMA 1

This Zone comprising 32 Physical Clusters starts at PAA 0 81 FE 80h and is intended for use by the Disk Management system. Until the disk is closed (see 22.6) these Clusters shall be left unrecorded.

18.8.18 INFO 1 / Control Data 1

This Zone comprising 32 Physical Clusters starts at PAA 0 81 FF 00h and is intended to store Control Information.

Unused Clusters shall be left unrecorded until the disk is closed.

18.8.19 INFO 1 / Reserved

This Zone comprising 32 Physical Clusters starts at PAA 0 81 FF 80h and shall be unrecorded.

18.9 Recordable Area of Lead-out Zone of QL disk

18.9.1 OPC 3 / Test Zone

This Zone comprising 2 048 Physical Clusters starts at PAA 0 FE 9D B8h is reserved for testing and/or OPC procedures. The OPC 3 Area shall be used according 18.3.12.

18.9.2 Buffer

This Zone comprising 6 254 Physical Clusters starts at PAA 0 FE 3C 00h and shall be unrecorded.

18.9.3 INFO 2 / Reserved 8

This Zone comprising 32 Physical Clusters starts at PAA 0 FE 3B 80h and is Application dependent.

For the disks with BCA code, this Zone shall be left unrecorded unless otherwise specified by the Application.

For the disks without BCA code, this Zone shall be recorded all 00h before shipping.

18.9.4 INFO 2 / Reserved 7

This Zone comprising 32 Physical Clusters starts at PAA 0 FE 3B 00h and shall be unrecorded.

18.9.5 INFO 2 / Reserved 6

This Zone comprising 32 Physical Clusters starts at PAA 0 FE 3A 80h and shall be unrecorded.

18.9.6 INFO 2 / Reserved 5

This Zone comprising 32 Physical Clusters starts at PAA 0 FE 3A 00h and is Application dependent.

For the disks with BCA code, this Zone shall be left unrecorded unless otherwise specified by the Application.

For the disks without BCA code, this Zone shall be recorded all 00h before shipping.

18.9.7 INFO 2 / Reserved

This Zone comprising 32 Physical Clusters starts at PAA 0 FE 39 80h and shall be left unrecorded.

18.9.8 INFO 2 / DMA 2

This Zone comprising 32 Physical Clusters starts at PAA 0 FE 39 00h and is intended for use by the Disk Management system. Until the disk is closed (see 22.6) these Clusters shall be left unrecorded.

18.9.9 INFO 2 / Control Data 2

This Zone comprising 32 Physical Clusters starts at PAA 0 FE 38 80h and is intended to store Control Information. Unused Clusters shall be left unrecorded until the disk is closed.

18.9.10 INFO 2 / Buffer 2

This Zone comprising 32 Physical Clusters starts at PAA 0 FE 38 00h and shall be unrecorded.

18.9.11 TDMA 3

This Zone comprising 3 328 Physical Clusters starts at PAA 0 FE 04 00h and is intended for use as a Temporary Disk-Management Area.

18.9.12 INFO 1 / Pre-write Area

This Zone comprising 32 Physical Clusters starts at PAA 0 FE 03 80h and all 32 Physical Clusters shall be recorded by the first drive that writes on Layer L3 and shall contain all 00h.

Drives that write the INFO 1 / Pre-write Area shall update Pre-write Area flags of the TDDS (see 22.4.4).

18.9.13 INFO 1 / Drive Area

The use of this Zone, divided into four parts of 32 Physical Clusters, starting at PAA 0 FE 01 80h is optional. This Zone can be used by drives to store drive-specific information, restricted to be used only by the drive that has created the information. To guarantee that drives can allocate their own information, the format specified in 18.3.16 shall be used. These Clusters in this Zone shall be ignored in interchange.

18.9.14 INFO 1 / DMA 1

This Zone comprising 32 Physical Clusters starts at PAA 0 FE 01 00h and is intended for use by the Disk Management system. Until the disk is closed (see 22.6) these Clusters shall be left unrecorded.

18.9.15 INFO 1 / Control Data 1

This Zone comprising 32 Physical Clusters starts at PAA 0 FE 00 80h and is intended to store Control Information.

Unused Clusters shall be left unrecorded until the disk is closed.

18.9.16 INFO 1 / Reserved

This Zone comprising 32 Physical Clusters starts at PAA 0 FE 00 00h on Layer L3 and shall be left unrecorded.

19 Data Zone

The Data Zone can contain a total of

1 527 456 Clusters of User Data on a TL disk, and

1 953 152 Clusters of User Data on a QL disk.

20 Outer Zones

20.1 General

On a TL disk the Outer Zone 0 and Outer Zone 1 are meant as a Transition Area between the Data Zones on Layer L0 and Layer L1. The Outer Zone 2 has the function of Lead-out Zone (see Figure 107 and Figure 108).

On a QL disk Outer Zone 0 and Outer Zone 1 function as a Transition Area between the Data Zones on Layer L0 and Layer L1. The Outer Zone 2 and Outer Zone 3 are also meant as a Transition Area between the Data Zones on Layer L2 and Layer L3 (see Figure 109 and Figure 110).

Outer Zone 0 / 2		Description	First PAA of Zone	Number of Phys. Clusters	Purpose
↓ Recordable ↓ *tracking direction*	INFO 3	Buffer 4	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 6	LAA*n* + 4 1Ah	32	---
	DCZ0 / 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 107 — Outer Zone 0 / 2 (Lead-out Zone) of TL disk

Outer Zone 1		Description	First PAA of Zone	Number of Phys. Clusters	Purpose
	---	Protection-Zone 3	---	---	---
↓ Recordable ↓ *tracking direction*	DCZ 1	Test Zone	FAA – 10 78h	760	Drive calibration
	INFO 4	Buffer 6	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 4	FAA – 80h	32	---

Figure 108 — Outer Zone 1 of TL disk

Outer Zone 0 / 2		Description	First PAA of Zone	Number of Phys. Clusters	Purpose
↓ Recordable ↓ *tracking direction*	INFO 3	Buffer 4	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 6	LAA*n* + 4 1Ah	32	---
	DCZ 0 / 2	Test Zone	LAA*n* + 4 9Ah	732	Drive calibration
	---	Protection-Zone 3	LAA*n* + 10 0Ah	---	---

LAA*n* is LAA in Outer Zone 0 and LAA2 in Outer Zone 2.

Figure 109 — Outer Zone 0 / 2 of QL disk

Outer Zone 1 / 3		Description	First PAA of Zone	Number of Phys. Clusters	Purpose
	---	Protection-Zone 3	---	---	---
↓ Recordable ↓ *tracking direction*	DCZ 1 / 3	Test Zone	FAA*n* – 10 08h	732	Drive calibration
	INFO 4	Buffer 6	FAA*n* – 4 98h	32	---
		Control Data 4	FAA*n* – 4 18h	32	data information
		DMA 4	FAA*n* – 3 98h	32	Disk Management
	---	Angular buffer	FAA*n* – 3 18h	102	---
	INFO 3	Control Data 3	FAA*n* – 1 80h	32	data information
		DMA 3	FAA*n* – 1 00h	32	Disk Management
		Buffer 4	FAA*n* – 80h	32	---

FAA*n* is FAA in Outer Zone 1 and FAA3 in Outer Zone 3.

Figure 110 — Outer Zone 1 / 3 of QL disk

20.2 Recordable Area of Outer Zones

20.2.1 INFO 3 / Buffer 4

This Zone comprising 32 Physical Clusters shall be left unrecorded.

20.2.2 INFO 3 / DMA 3

This Zone comprising 32 Physical Clusters is intended for use by the Disk Management system. Until the disk is closed (see 22.6) these Clusters shall be left unrecorded on Layer L0 and Layer L1.

20.2.3 INFO 3 / Control Data 3

This Zone comprising 32 Physical Clusters is intended to store Control Information. Unused Clusters shall be left unrecorded until the disk is closed.

20.2.4 Angular buffer

This Zone comprising 102 Physical Clusters shall be left unrecorded.

20.2.5 INFO 4 / DMA 4

This Zone comprising 32 Physical Clusters is intended for use by the Disk Management system. Until the disk is closed (see 22.6) these Clusters shall be left unrecorded on Layer L0 and Layer L1.

20.2.6 INFO 4 / Control Data 4

This Zone comprising 32 Physical Clusters is intended to store Control Information. Unused Clusters shall be left unrecorded until the disk is closed.

20.2.7 INFO 4 / Buffer 6

This Zone comprising 32 Physical Clusters shall be left unrecorded.

20.2.8 DCZ 0 / Test Zone, DCZ 1 / Test Zone, DCZ 2 / Test Zone and DCZ 3 / Test Zone

These Test Zones comprising 760 Physical Clusters for a TL disk and 732 Physical Clusters for a QL disk are reserved for drive calibrations. The DCZ Areas shall be used according to 20.2.9.

20.2.9 Usage of DCZ Area

20.2.9.1 DCZ procedure order

The Drive-Calibration Zone shall be used consecutively in descending PAA order. The first area used for a calibration procedure ends at the end of the last PAA. The last usable Physical Cluster of the DCZ Area is located at the first PAA of the DCZ Area, see Figure 111.

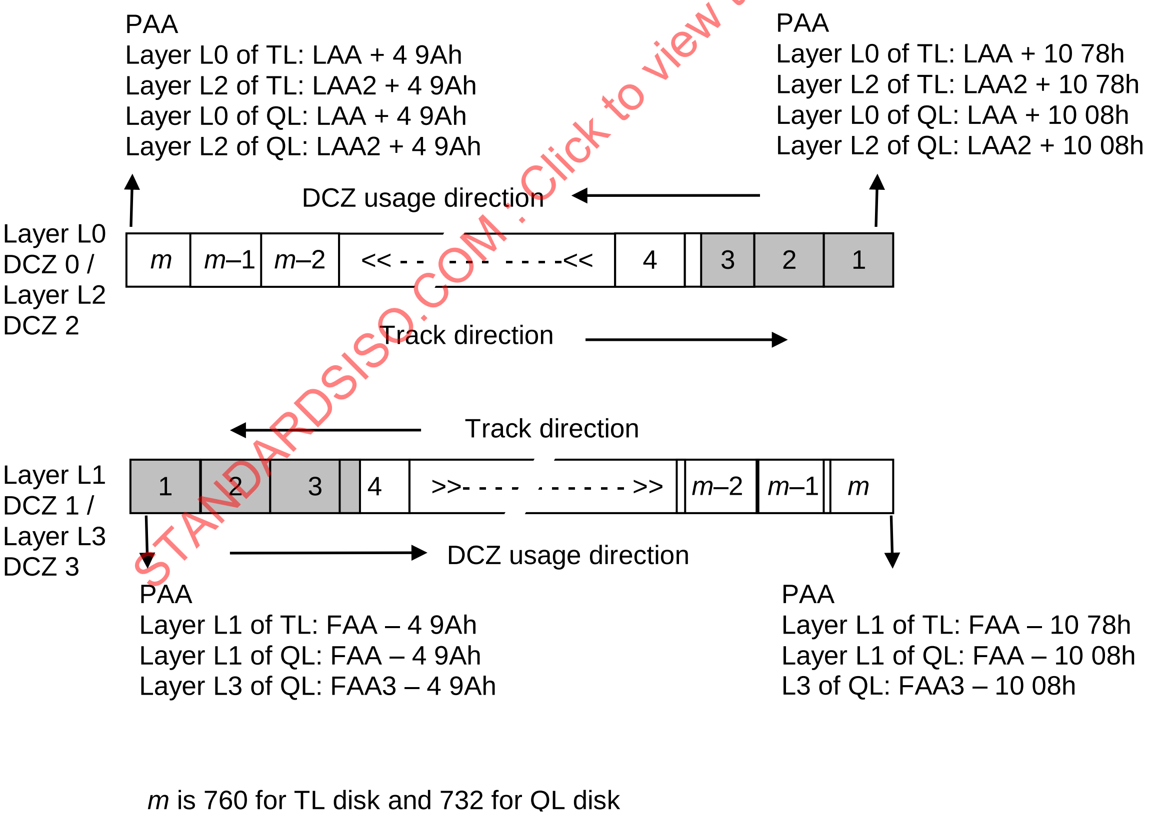
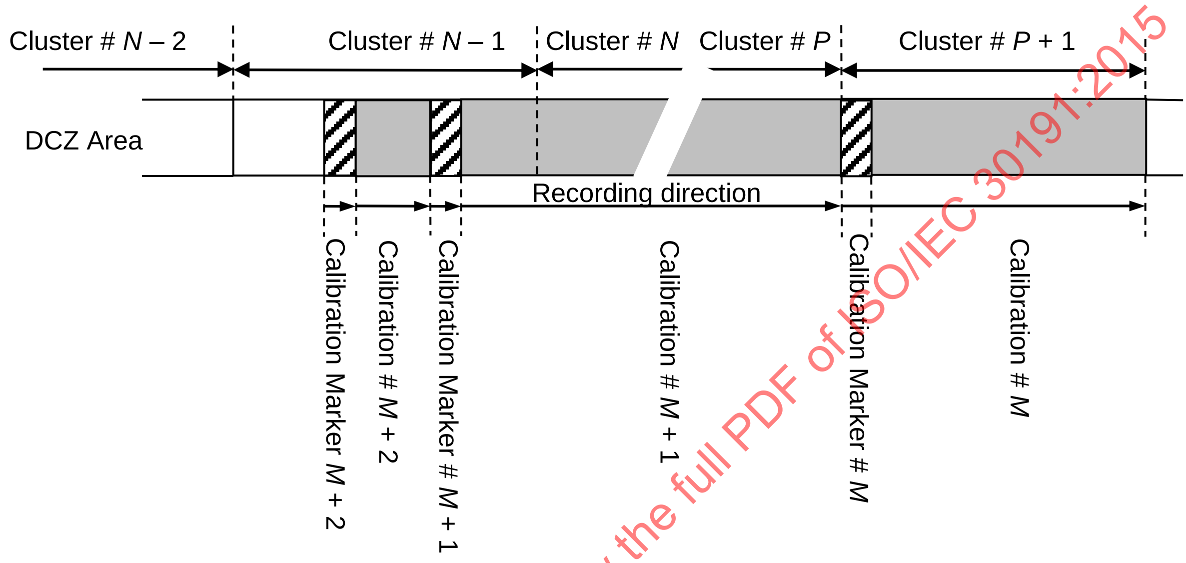


Figure 111 — Direction of usage of DCZ Area of Layer L0, Layer L1, Layer L2 and Layer L3

20.2.9.2 DCZ Physical Cluster usage

The length of one calibration procedure may be chosen by the drive and is not restricted to an integer number of Physical Clusters (see Figure 112). The transition between the used and unused Calibration Areas shall be indicated by a Calibration Marker. The distance between any two consecutive Calibration Markers shall not exceed 16 Physical Clusters. In case a calibration procedure needs more than 16 Physical Clusters, Calibration Markers shall be inserted to fulfill this requirement. The Calibration Marker shall have a length of at least 868 NWLs (equal to one AUN) and its modulation shall be such that $I_{8pp} / I_{8H} \geq 0{,}30$.



Calibration # *M* occupies exactly one Cluster; Calibration # *M*+1 exceeds one Cluster; Calibration # *M*+2 is smaller than one Cluster

Figure 112 — Example of position of Calibration Markers

20.2.9.3 Update of TDMA

Each calibration procedure permitted at any of the DCZ Zones shall be completed by updating the corresponding “next available PSN of Drive-Calibration Zone on Layer Ln ” (*n* = 0, 1, 2 and 3) in the TDDS, see 22.4.4.

20.2.10 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 future new PACs can be defined for specific applications/functions.

Drives designed before the introduction date of such new PACs will in general not be able to interpret and therefore shall treat such a PACs as a so-called “Unknown PAC”. By obeying standard “Unknown-PAC Rules”, defined in the header of the PACs, compatibility problems with and unwanted destruction of data for specific applications can be avoided as much as possible.

Drives designed after the introduction date of a new PAC can be assumed to be familiar with the specific application/function connected to the new PAC. Such drives can therefore ignore the “Unknown-PAC Rules” and apply the rules defined in the “PAC-specific information” fields of the PAC. For such “Known PACs” there are no physical-access restrictions unless specified otherwise in the “PAC-specific information” fields.

NOTE To keep compatibility;

— from a point of view of a Zone layout, the PAC 1 and PAC 2 are allocated only on Layer L0 and Layer L1, and the corresponding Zones on Layer L2 and Layer L3 are reserved,
— from a point of view of PAC content, PAC has no additional Unknown-PAC Rules for these reserved Zones and these reserved Zones are out of control by PAC.

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 will always be two 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.

The status of all locations in both the INFO 1 / PAC 1 and INFO 2 / PAC 2 Zones shall be indicated in the TDDS (see 22.4.4) 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	--- (this bit setting is Reserved)
10	contains an invalid PAC [a]
11	contains a valid PAC

[a] PAC Clusters with status 10 as indicated in the TDDS are not allowed to be transferred outside the drive (independent on the setting of bit b_0 and b_1 of the Unknown-PAC Rules)

Figure 113 — Status of PAC locations

If the PAC Cluster is found to be defective during recording, then the Defective Cluster shall be skipped and indicated as invalid in the TDDS (see Figure 113) and the PAC shall be recorded at the next available Cluster.

If a PAC has to be updated, the new version of the PAC shall be recorded in the next available Cluster and the previous location containing the old version of the PAC shall be indicated as invalid in the TDDS.

21.3 General structure of PAC Clusters

The User Data of PAC Clusters shall be formatted according to Figure 114. 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 114 — General layout of PAC Clusters

The **PAC_ID** shall identify the specific type of PAC Cluster.

— If set to 49 53 31h the PAC Cluster is the IS1 PAC as defined in 21.4.

— If set to 49 53 32h the PAC Cluster is the IS2 PAC as defined in 21.4.

Other values for the PAC_ID can be assigned in future releases of this document.

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 in the TDDS, see Figure 113).

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 updated.

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 115). The actions described for the User-Data Area shall be taken only within the specified Segments if Segments have been defined; else these actions shall be taken for any Cluster contained within the full User-Data Area.

If a drive encounters multiple unknown PACs on one disk, it shall use the OR-function of the Unknown-PAC Rules (in other words, if one of the PACs excludes an action, the same rule of the other PACs is irrelevant).

Area		Bits	Control type	Mandatory setting
		b_{31} to b_{24}	Reserved	0000 0000
INFO 2	Reserved 8	b_{23}	write	-
		b_{22}	read	-
	Reserved 7	b_{21}	write	ONE
		b_{20}	read	-
	Reserved 6	b_{19}	write	ONE
		b_{18}	read	-
	Reserved 5	b_{17}	write	-
		b_{16}	read	-
INFO 1	Drive Area (part 4)	b_{15}	write	ZERO
		b_{14}	read	ZERO
	Drive Area (part 3)	b_{13}	write	ZERO
		b_{12}	read	ZERO
	Drive Area (part 2)	b_{11}	write	ZERO
		b_{10}	read	ZERO
	Drive Area (part 1)	b_9	write	ZERO
		b_8	read	ZERO
TDMA Zones (not including the TDDS; see 22.4.2)		b_7	write	-
		b_6	Reserved unless otherwise specified by the Application	-
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	-

"-" means: no mandatory setting specified, as well ZERO as ONE can be allowed depending on specific PAC

Figure 115 — 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: to indicate that writing in the related Zone/area is allowed,

  — if set to ONE: to indicate that writing in the related Zone/area shall not be allowed.

— Control type = **read**

  — if set to ZERO: to indicate that reading in the related Zone/area is allowed,

  — if set to ONE: to indicate 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).

For the **PAC Cluster**, the bits have the following meaning:

— Control type = **write**

  — if set to ZERO: to indicate that re-writing the current PAC Cluster or changing its status bits in theTDDS is allowed,

  — if set to ONE: to indicate that re-writing the current PAC Cluster and changing its status bits in the TDDS shall not be allowed.

— Control type = **read**

  — if set to ZERO: to indicate that reading and transferring the content of the current Cluster outside the drive is allowed,

  — if set to ONE: to indicate 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, such 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.

— Bits b_7 to b_1 : These bits shall be Reserved.

— Bit b_0 : This bit shall be set ONE to indicate Re-initialization is not possible.

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.

$$\left(\sum_{\text{over all PACs}} \text{number of Segments in } \text{PAC}_i \leq 32 \right)$$

The **Segment_*i*** field shall specify the start and end 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 4 bytes of the Segment_i field, if used, shall contain the first PSN of the first Cluster belonging to the Segment, and

— the last 4 bytes shall contain the last PSN of the last Cluster belonging to the Segment.

These Segments shall only be applied to the Unknown-PAC Rules. If overlapping Segments in different PAC Clusters are encountered, the drive shall apply the OR-function to the related Unknown-PAC Rules in the overlap areas.

The **Known-PAC Entire_Disk_Flags byte** specifies rules for the entire disk in case the drive is able to interpret the PAC.

— Bits b_7 to b_1 : These bits shall be Reserved.

— Bit b_0 : This bit shall be set ONE to indicate Re-initialization is not possible.

21.4 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 being shipped. When BCA code is recorded on an Unrecorded disk, IS1/IS2 PAC structures shall not be recorded.

The layout of the IS1 PAC and IS2 PAC Cluster shall be formatted as depicted in Figure 116.

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 116 — 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 to indicate this is a version 0.

The **PAC-Update Count** shall be set to 00 00 00 00h.

The **Unkown-PAC Rules** shall be set 00 AA 00 00h for IS1 PAC and shall be set 00 AA 00 CBh for IS2 PAC.

The **Unkown-PAC Entire_Disk_Flags byte** shall be set to 01h.

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 01h.

22 Disk Management

22.1 General

Disk Management defines and controls method of recording User Data on the disk.

22.2 Recording Management

The BD Recordable system supports a Sequential-Recording Mode (SRM), which is managed by means of a Sequential-Recording Range Information (SRRI) structure.

22.2.1 Sequential-Recording Mode (SRM)

The disk has a continuous area, referred to as the Sequential-Recording Ranges (SRR). Inside the SRR the User Data shall be recorded sequentially in the direction of increasing addresses.

Information about the location and status of the SRR shall be stored in a Sequential-Recording Range Information (SRRI) structures. The SRRI shall be recorded in the Temporary Disk-Management Areas (TDMAs, see 22.3). On a Recorded disk the final SRRI is recorded in a Disk -Management Area (DMA).

The SRR shall start at a Cluster boundary and has only one point from where new data can be recorded.

22.2.2 Recording User Data in SRR.

During continuous sequential recording, User Data, presented by the host in 2KB Logical Sectors, shall be added immediately after the last-written Sector in the SRR. However when the host computer asks for the next address available for recording in the SRR, the drive shall return the first PSN of the next-available completely-Unrecorded Cluster in the SRR. This address is called the Next-Writable Address (NWA). During the sequential recording process, the NWA is dynamically incremented in Units of Physical Clusters, according to the size of the written User Data.

When Sequential Recording is terminated and the size of the User Data is not matching with the boundaries of a Physical Cluster, the remaining part of the last Physical Cluster shall be padded with ZERO data, where each individual Data Frame containing Padding Data shall be identified by setting its status bits $Sa_{i,1}/Sa_{i,0}$ to 11 (see 13.9.2.5). The NWA shall point to the first Sector of the next Unrecorded Cluster.

The SRR entry (see 22.4.6.4) contains a Last Recorded User Data Address (LRA) to indicate the last Sector in the SRR filled with User Data (non-Padding Data) (see Figure 117).

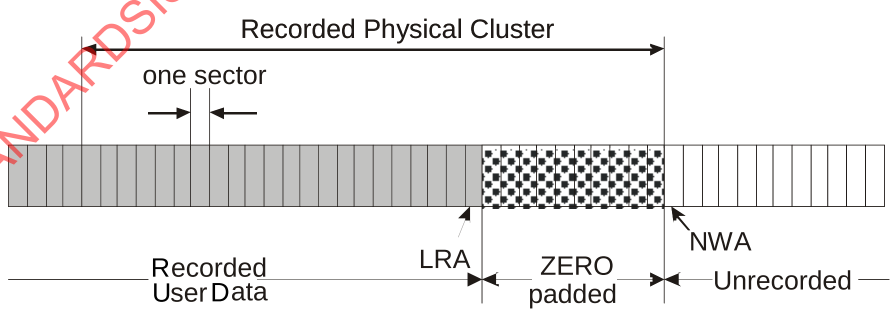


Figure 117 — Example of last RUB with Recorded User Data and padded ZEROs

22.2.3 SRR status

An SRR can have one of the following states:

— Open : the SRR has a valid NWA and data can be appended

— Closed : the SRR does not have an NWA and appending data is not allowed

The number of Open SRR shall be one. During recording in the DMA of the disk the SRR shall have the status Closed.

22.2.4 Closing SRR

When an Open SRR was closed the Open SRR number bytes shall be set to 00h (see 22.4.6.3). Optionally one or more Clusters can be padded with all bytes set to 00h and the status bits $Sa_{i,1}/Sa_{i,0}$ for all Data Frames set to 11.

It is not necessary to record the remaining Unrecorded Clusters of the SRR on closing. The LRA of the Closed SRR shall be correct.

22.3 Temporary Disk-Management Areas (TDMA)

22.3.1 General

The Recording Management Information may need to be updated many times during use. For this purpose a special area is available in the Inner Zone called the Temporary Disk-Management Area (TDMA).

For a TL disk there are 3 TDMAs. TDMA 0 in the Lead-in Zone of Layer L0, TDMA 1 in the Inner Zone1 of Layer L1 and TDMA 2 in the Inner Zone2 of Layer L2 shall have a fixed size of 2 048 Physical Clusters each.

For a QL disk there are 4 TDMAs. TDMA 0 in the Inner Zone1 of Layer L1 shall has a fixed size of 2 304 Physical Clusters. TDMA 1 and TDMA 2 in the Inner Zone2 of Layer L2 shall have a fixed size of 1 280 Physical Clusters each. TDMA 3 in the Inner Zone3 of Layer L3 shall has a fixed size of 3 328 Physical Clusters.

In the case of a TL disk, TDMA 0,TDMA 1 and TDMA 2 shall be used sequentially in the following order: TDMA 0 → TDMA 1 → TDMA 2

In the case of a QL disk the TDMA 0,TDMA 1,TDMA 2 and TDMA 3 shall be used sequentially in the following order: TDMA 0 → TDMA 1 → TDMA 2 → TDMA 3

Each TDMA shall be filled contiguously and in the direction of ascending PSNs. All elements of the actual TDMS (see 22.4.2) shall be located in one TDMA. If insufficient space is left in the actual TDMA, then a new complete TDMS set shall be created in the next available TDMA and the indicator for this next TDMA (see 22.3.2) shall be recorded.

All remaining unused Clusters in full TDMA shall be recorded with all 00h data while the status bits $Sa_{i,1}/Sa_{i,0}$ for all Data Frames shall be set to 11.

22.3.2 TDMA Access Indicators

To find out quickly which TDMA is currently in use, the first Clusters of TDMA 0 shall be used as indicators. On a TL disk the first 9 Clusters shall be reserved for this purpose and on a QL disk the first 12 Clusters. These TDMA Access indicator Clusters shall be used in the direction of descending addresses as indicated in Figure 118 and Figure 119.

If TDMA *n* is in use [TDMA 0 .. TDMA (*n*–1) having been completely used] then all indicators for TDMA 1 up to and including TDMA *n* shall be recorded.

When the disk is closed also the first indicator Cluster of TDMA 0, to indicate the DMA, shall be recorded.

Moreover, to find out quickly the location of the TDMA that is currently in use, the TDMA Access indicator Clusters shall contain the TDDS according to the status of the disk at the moment when the TDMA Access indicator Cluster was recorded. For robustness, all 32 Data Frames in the indicator Clusters shall contain a copy of the first TDDS recorded in the TDMA related to the actual indicator Cluster.

The first indicator Cluster of TDMA 0, to indicate that the DMA has been recorded, shall contain 32 repetitions of the DDS as this is recorded in DMA 1 (see 22.5.4).

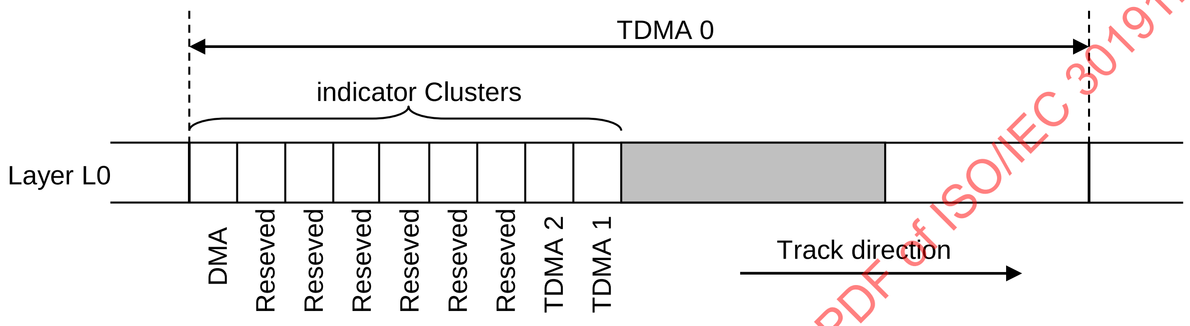


Figure 118 — TDMA Indicator Clusters on TL disk

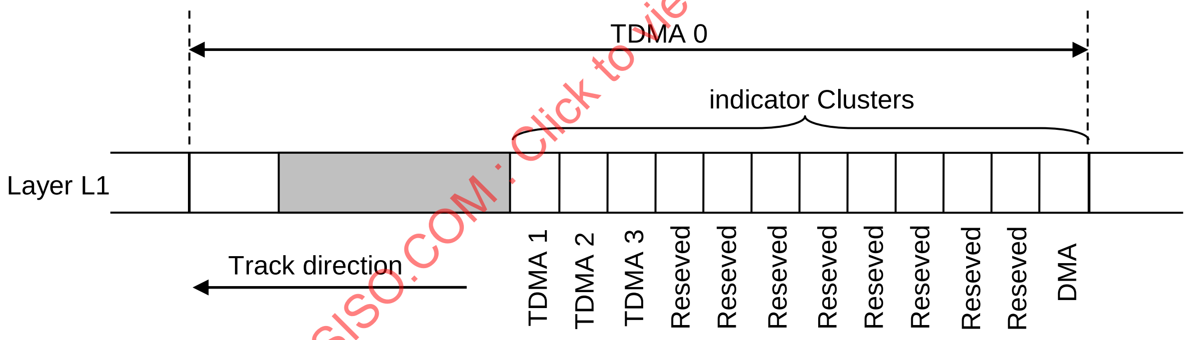


Figure 119 — TDMA Indicator Clusters on QL disk

22.4 Disk-Management Structure (DMS)

22.4.1 General

The DMS holds structures for Disk Management and Recording Mode information. There are two kinds of Disk-Management Structure s:

— Disk-Management Structure s (DMS; see 22.6.3), recorded in the DMA Zones when a disk is closed (to preserve all Disk Management information contained in the last Temporary Disk-Management Structure),

— Temporary Disk-Management Structure s (TDMS), recorded in the TDMA Zones as long as the disk has not been closed.

22.4.2 Temporary Disk-Management Structure (TDMS)

The Temporary Disk-Management Structure consists of the following three elements depending on the recording mode. All of these elements shall be present in the same TDMA *n* that is actually in use.

For Sequential-Recording Mode the TDMS consists of:

— Temporary Disk-Definition Structure (TDDS),

— Temporary Defect List (TDFL),

— Sequential-Recording Range Information (SRRI).

The last Data Frame of the last of the Clusters constituting a TDMS Update Unit shall always contain a TDDS. This TDDS contains pointers to the latest recorded TDFL Clusters, SRRI. After an update of one or more of these elements, the TDDS pointers shall be updated.

The TDMS shall consist of the latest recorded versions of the TDDS, the TDFL and the SRRI.

The TDMS Update Units shall be recorded sequentially in the direction of ascending PSNs in each TDMA (see 22.3). If a Physical Cluster is perceived as defective during recording, this Cluster shall be skipped and the data recording shall continue in the next available Physical Cluster in the TDMA. If Defective Clusters are detected immediately after writing of the full TDMS Update Unit (verify-after-write) then it is allowed to only rewrite the Defective Clusters and the last Cluster of the TDMS Update Unit (for updating of the TDFL pointers in the TDDS) at the next available locations (as a consequence of this the order of the TDFL Clusters as recorded on the disk need not to be the same as their order in the Defect List. This last one shall be indicated by the pointers in the TDDS).

22.4.3 TDMS in Sequential-Recording Mode

In the Sequential-Recording Mode, the TDMS Update Units for the SRRI shall always contain a Temporary Disk-Definition Structure (TDDS) in the last Data Sector and a Sequential-Recording Range Information (SRRI) block in the Sectors immediately preceding the TDDS (see Figure 120). The SRRI block shall start at a Sector boundary and the length of the SRRI block is limited to 31 Data Sectors. The SRRI block is terminated with an SRRI terminator (see Figure 129).

Cluster	Data Frame	Content
One Cluster	0 .. 29	Set to 00h
	30	**SRRI** (one Sectors)
	31	**TDDS** (one Sector)

Figure 120 — Example of TDMS Update Unit for SRRI for SRM

The TDFL always starts in the first Data Sector of the first Cluster of a TDMS Update Unit (see Figure 121). The TDFL shall be terminated with a Defect-List Terminator (see Figure 127). The last Data Sector of the last Cluster of the TDMS Update Unit for the TDFL shall contain a TDDS. If both the SRRI and TDFL are recorded, the two structures can be combined in one TDMS Update Unit as indicated in Figure 121, where the TDFL is located at the top of the TDMS Update Unit and the SRRI at the bottom, immediately preceding the TDDS.

.Cluster	Data Frame	Content
One Cluster	0	**TDFL** (one Sector)
	1 .. 29	Set to 00h
	30	**SRRI** (one Sector)
	31	**TDDS** (one Sector)

Single-Cluster TDMS Update Unit

Figure 121 — Examples of TDMS Update Units for TDFL

22.4.4 Temporary Disk-Definition Structure (TDDS)

The TDDS contains information about the format and status of the disk. The last recorded TDDS is the anchor to the addresses of the other parts/elements of the TDMS. Pointers in the TDDS shall only point to addresses of previously written structures (no forward pointers), which all shall be in the same TDMA *n* as the TDDS itself. The format of the TDDS is defined in Figure 122.

The **TDDS Identifier** shall be set to 44 53h, representing the characters “DS”.

The **TDDS format field** shall be set to 00h.

The **TDDS Update Count** shall specify the total number of update operations on TDDS. This field shall be set to 00 00 00 00h during the initialization operation, and shall be incremented by one each time a TDDS is recorded on the disk.

Data Frame	Byte position in Data Frame	Content	Number of bytes
31	0 to 1	TDDS identifier	2
31	2	TDDS format	1
31	3	Reserved	1
31	4 to 7	TDDS-Update Count	4
31	8 to 15	Reserved	8
31	16 to 19	First PSN of Drive Area (P_DA)	4
31	20 to 23	Reserved	4
31	24 to 27	First PSN of Defect List (P_DFL)	4
31	28 to 31	Reserved	4
31	32 to 35	Location of LSN 0 of User-Data Area	4
31	36 to 39	Last LSN of User-Data Area	4
31	40 to 51	Reserved unless otherwise specified by the Application	12
31	52	Flag A	1
31	53 to 55	Reserved	3
31	56	Pre-write Area flags	1
31	57 to 63	Reserved	7
31	64 to 71	Status bits of INFO 1 / PAC 1 locations on Layer L0	8
31	72 to 79	Status bits of INFO 2 / PAC 2 locations on Layer L0	8
31	80 to 87	Status bits of INFO 1 / PAC 1 locations on Layer L1	8
31	88 to 95	Status bits of INFO 2 / PAC 2 locations on Layer L1	8
31	96 to 1 023	Reserved	928
31	1 024	Recording Mode	1
31	1 025 to 1 027	Reserved unless otherwise specified by the Application.	3
31	1 028 to 1 031	Reserved	4
31	1 032 to 1 035	Last-Recorded Address of User-Data Area	4
31	1 036 to 1 039	Reserved	4
31	1 040 to 1 051	Reserved unless otherwise specified by the Application.	12
31	1 052 to 1 087	Reserved	36
31	1 088 to 1 091	Next available PSN of Test Zone on Layer L0 (P_TZ0)	4
31	1 092 to 1 095	Next available PSN of Test Zone on Layer L1 (P_TZ1)	4
31	1 096 to 1 099	Next available PSN of Test Zone on Layer L2 (P_TZ2)	4
31	1 100 to 1 103	Next available PSN of Test Zone on Layer L3 (P_TZ3)	4
31	1 104 to 1 107	Next available PSN of Drive-Calibration Zone on Layer L0 (P_CZ0)	4
31	1 108 to 1 111	Next available PSN of Drive-Calibration Zone on Layer L1 (P_CZ1)	4
31	1 112 to 1 115	Next available PSN of Drive-Calibration Zone on Layer L2 (P_CZ2)	4
31	1 116 to 1 119	Next available PSN of Drive-Calibration Zone on Layer L3 (P_CZ3)	4
31	1 120 to 1 123	First PSN of first Cluster of Defect List (P_first DFL)	4
31	1 124 to 1 151	Reserved unless otherwise specified by the Application	28
31	1 152 to 1 183	Reserved	32
31	1 184 to 1 187	First PSN of Sequential-Recording Range Information	4
31	1 188 to 1 211	Reserved unless otherwise specified by the Application.	24
31	1 212 to 1 215	Reserved	4
31	1 216 to 1 247	Reserved unless otherwise specified by the Application.	32
31	1 248 to 1 915	Reserved	668

Figure 122 — Format of TDDS

Data Frame	Byte position in Data Frame	Content	Number of bytes
31	1 916 to 1 919	Reserved unless otherwise specified by the Application.	4
31	1 920 to 2 047	Drive ID: Manufacturers Name Additional ID Unique Serial Number	48 48 32

Figure 122 — Format of TDDS (continued)

The **First PSN of Drive Area** field shall specify the first Physical Sector Number (PSN) of the Cluster that contains the latest 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 be set to 00 00 00 00h in all TDDS Sectors appearing in the TDMAs.

When the disk is being closed and the final DDS is written in the DMA, this field shall specify the first PSN of the first Defect List that can be retrieved error free in the DMA Zone containing the particular DDS. If no Defect List could be stored error free, this field shall be set to FF FF FF FFh.

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 Application.

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 for a TL disk and 03 B9 AF FFh for a QL disk unless otherwise specified by the Application.

The 8-bit **Flag A** field specifies the status of a TL disk or a QL disk. On a TL disk, bits b_7 and b_6 shall be set to ZERO and bits b_5, b_4, b_3, b_2, b_1 and b_0 shall be set to ONE, and on a QL disk, bits b_7, b_6, b_5, b_4, b_3, b_2, b_1 and b_0 shall be set to ONE ,unless otherwise specified by the Application.

The 8-bit **Pre-write Area flags** field specifies the status of the INFO 1 / Pre-write Areas for each Recording Layer. If the Pre-write Area on Layer *i* is recorded then bit bi shall set to ONE, else bit bi shall be set to ZERO.

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 123). 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 123 — 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 124). The bit pairs shall be set as defined in 21.2.

Byte position	Bits	INFO 2 / PAC 2 location PAA on TL disks	INFO 2 / PAC 2 location PAA on QL disks
72	b_7 b_6	0 01 BA 00h	0 01 9E B8h
72	b_5 b_4	0 01 BA 04h	0 01 9E BCh
72	b_3 b_2	0 01 BA 08h	0 01 9E C0h
72	b_1 b_0	0 01 BA 0Ch	0 01 9E C4h
73	b_7 b_6	0 01 BA 10h	0 01 9E C8h
:	:	:	:
:	:	:	:
78	b_1 b_0	0 01 BA 6Ch	0 01 9F 24h
79	b_7 b_6	0 01 BA 70h	0 01 9F 28h
79	b_5 b_4	0 01 BA 74h	0 01 9F 2Ch
79	b_3 b_2	0 01 BA 78h	0 01 9F 30h
79	b_1 b_0	0 01 BA 7Ch	0 01 9F 34h

Figure 124 — 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 125). 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 125 — 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 126). The bit pairs shall be set as defined in 21.2.

Byte position	Bits	INFO 2 / PAC 2 location PAA on TL disks	INFO 2 / PAC 2 location PAA on QL disks
88	b_7 b_6	0 7E 45 80h	0 7E 74 28h
88	b_5 b_4	0 7E 45 84h	0 7E 74 2Ch
88	b_3 b_2	0 7E 45 88h	0 7E 74 30h
88	b_1 b_0	0 7E 45 8Ch	0 7E 74 34h
89	b_7 b_6	0 7E 45 90h	0 7E 74 38h
:	:	:	:
:	:	:	:
94	b_1 b_0	0 7E 45 ECh	0 7E 74 94h
95	b_7 b_6	0 7E 45 F0h	0 7E 74 98h
95	b_5 b_4	0 7E 45 F4h	0 7E 74 9Ch
95	b_3 b_2	0 7E 45 F8h	0 7E 74 A0h
95	b_1 b_0	0 7E 45 FCh	0 7E 74 A4h

Figure 126 — Status bits and related INFO 2 / PAC 2 address locations on Layer L1

The **Recording Mode field** specifies the mode in which User Data is going to be recorded in the User-Data Area. This field shall be set to 00h to indicate Sequential-Recording Mode unless otherwise specified by the Application.

The **Last-Recorded Address of User-Data Area** field shall specify the PSN of the highest numbered Physical Sector in the User-Data Area recorded with data supplied by the host. This address shall be equal to the LRA of the highest numbered SRR containing User Data (see 22.4.6.4). If no User Data is recorded in User-Data Area, the value of this field shall be set to 00 00 00 00h.

The **Next available PSN of Test Zone on Layer L0** field shall specify the first PSN of the next usable Cluster available for testing and OPC procedures in the Test Zone on Layer L0. The initial value for this field in case of an unused Test Zone is 00 0E DF 60h on TL disks (the highest addressed 4 Clusters of the Test Zone on Layer L0 shall be reserved as a buffer zone on TL disks) or 00 0E 05 A0h on QL disks. If the Test Zone on Layer L0 has no free Cluster, this field shall be set to FF FF FF FFh.

NOTE If an OPC procedure fails, the drive might not be able to correctly update the TDMS.

The **Next available PSN of Test Zone on Layer L1** field shall specify the first PSN of the next usable Cluster available for testing and OPC procedures in the Test Zone on Layer L1. The initial value for this field in case of an unused Test Zone is 03 F4 2C A0h on TL disks or 03 F4 B5 20h on QL disks. If the Test Zone on Layer L1 has no free Cluster, this field shall be set to FF FF FF FFh.

NOTE If an OPC procedure fails, the drive might not be able to correctly update the TDMS.

The **Next available PSN of Test Zone on Layer L2** field shall specify the first PSN of the next usable Cluster available for testing and OPC procedures in the Test Zone on Layer L2. The initial value for this field in case of an unused Test Zone is 04 0A EA A0h on TL disks or 04 0F 3F 60h on QL disks (the highest addressed 4 Clusters of the Test Zone on Layer L2 shall be reserved as a buffer zone on QL disks). If the Test Zone on Layer L2 has no free Cluster, this field shall be set to FF FF FF FFh.

NOTE If an OPC procedure fails, the drive might not be able to correctly update the TDMS.

The **Next available PSN of Test Zone on Layer L3** field shall specify the first PSN of the next usable Cluster available for testing and OPC procedures in the Test Zone on Layer L3. In case of TL disks, this field shall be set to 00 00 00 00h. The initial value for this field in case of an unused Test Zone is 07 F5 ED A0h. If the Test Zone on Layer L3 has no free Cluster, this field shall be set to FF FF FF FFh.

NOTE If an OPC procedure fails, the drive might not be able to correctly update the TDMS.

The **Next available PSN of Drive-Calibration Zone on Layer L0** field shall specify the first PSN of the next usable Cluster available for drive calibration procedures in the Drive-Calibration Zone on Layer L0. The initial value for this field in case of an unused Drive-Calibration Zone is 8 × (LAA + 10 76h) on TL disks or 8 × (LAA + 10 06h) on QL disks. If the Drive-Calibration Zone on Layer L0 has no free Cluster, this field shall be set to FF FF FF FFh.

NOTE If an OPC procedure fails, the drive might not be able to correctly update the DCZ.

The **Next available PSN of Drive-Calibration Zone on Layer L1** field shall specify the first PSN of the next usable Cluster available for drive calibration procedures in the Drive-Calibration Zone on Layer L1. The initial value for this field in case of an unused Drive-Calibration Zone is 8 × (FAA – 4 9Ch). If the Drive-Calibration Zone on Layer L1 has no free Cluster, this field shall be set to FF FF FF FFh.

NOTE If an OPC procedure fails, the drive might not be able to correctly update the DCZ.

The **Next available PSN of Drive-Calibration Zone on Layer L2** field shall specify the first PSN of the next usable Cluster available for drive calibration procedures in the Drive-Calibration Zone on Layer L2. The initial value for this field in case of an unused Drive-Calibration Zone is 8 × (LAA + 0 80 00 00h + 10 76h) on TL disks or 8 × (LAA + 0 80 00 00h + 10 06h) on QL disks. If the Drive-Calibration Zone on Layer L2 has no free Cluster, this field shall be set to FF FF FF FFh.

NOTE If an OPC procedure fails, the drive might not be able to correctly update the DCZ.

The **Next available PSN of Drive-Calibration Zone on Layer L3** field shall specify the first PSN of the next usable Cluster available for drive calibration procedures in the Drive-Calibration Zone on Layer L3. In case of TL disks, this field shall be set to 00 00 00 00h. The initial value for this field in case of an unused Drive-Calibration Zone is 8 × (FAA + 0 80 00 00h – 4 9Ch). If the Drive-Calibration Zone on Layer L3 has no free Cluster, this field shall be set to FF FF FF FFh.

NOTE If an OPC procedure fails, the drive might not be able to correctly update the DCZ.

The **First PSN of first Cluster of Defect List** field shall specify the first PSN of the first Cluster of the latest Temporary Defect List in the TDMA Zone.

The **First PSN of Sequential-Recording Range Information** field shall indicate the PSN of the first Sector of the latest Sequential-Recording Range Information in the TDMA Zone,

The **Drive ID: Manufacturers Name / Additional ID / Unique Serial Number** fields shall uniquely identify the drive that has recorded this TDDS. These 128 bytes shall contain a drive signature according to the following format (see 18.3.16: Drive Area):

— 48 bytes Manufacturers Name, represented by characters from the ISO 646 character set,

— 48 bytes Additional Identification, represented by characters from the ISO 646 character set,

— 32 bytes Unique Serial Number of the drive.

22.4.5 Temporary Defect List (TDFL)

22.4.5.1 General

The first Data Frame of the TDFL contains the Defect-List Header followed by a List of Defects. The List of Defects shall be terminated by a Defect-List Terminator.

The List of Defects is Reserved unless otherwise specified by the Application.

22.4.5.2 TDFL data structure

The TDFL Data Frame shall be composed as shown in Figure 127.

Data Frame	Byte position in Data Frame	Content	Number of bytes
0	0 to 63	Defect-List Header	64
	64 to 71	Defect-List Terminator	8
	72 to 2 047	set 00h	1 976

Figure 127 — Format of Temporary Defect List

The **Defect-List Header** (DLH) identifies the Defect List and contains information about the composition of the List of Defects (see22.4.5.3).

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 shall be located in the last Data Frame of the TDFL.

All remaining bytes following the Defect-List Terminator in the last Data Frame shall be set to 00h.

22.4.5.3 Defect-List Header

Figure 128 shows the format of the Defect-List Header.

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 23	Reserved unless otherwise specified by the Application	12
0 / 0	24 to 63	Reserved	40

Figure 128 — Format of Defect-List Header

The **DFL Identifier** shall be set to 44 4Ch, representing the characters "DL".

The **DFL format** field shall be set to 00h..

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 Initialization operation, and shall be incremented by one each time the DFL is recorded on the disk.

22.4.5.4 Defect-List Terminator

The **Defect-List Terminator** shall be composed of two 4-byte parts:

— the first 4 bytes shall be set FF FF FF FFh,

— the second 4 bytes shall be equal to the TDFL-Update Count in the header of the TDFL (can be used to check the validity of the Defect List).

22.4.6 Sequential-Recording Range Information (SRRI)

22.4.6.1 General

The SRRI Structure specifies the recording status for Sequential-Recording Mode (SRM). One structure covers TL and QL disks. The data structure of the SRRI is described in 22.4.6.2.

22.4.6.2 SRRI Data Structure

The SRRI structure, consisting of one Sector, contains an SRRI Header followed by a list of SRR entries. An SRRI terminator shall terminate the List of SRR entries.

Relative Data Frame	Byte position in Data Frame	Content	Number of bytes
30	0 to 63	SRRI Header	64
	64 to 71	SRR entry	8
	72 to 79	SRRI Terminator	8
	80 to 2 047	set 00h	1 968
(31)		(TDDS)	

Figure 129 — Format of SRRI table

The **SRRI Header** identifies the SRRI and contains information about the composition of the List of SRR entries (See 22.4.6.3).

The **SRR entry** contains a list of SRRs and their related information (See 22.4.6.4). The number of SRRs is one unless otherwise specified by the Application.

The **SRRI Terminator** closes the List of SRR entries and shall be written immediately following the actual last entry in the List of SRR entries (see 22.4.6.5).

All remaining bytes following the SRRI Terminator until the Data Frame boundary shall be set to 00h.

22.4.6.3 SRRI Header

The SRRI Header shall be composed as shown in Figure 130.

Relative Data Frame	Byte position in Data Frame	Content	Number of bytes
30	0 to 1	SRRI identifier	2
	2	SRRI format	1
	3	Reserved	1
	4 to 7	SRRI Update Count	4
	8 to 11	Reserved	4
	12 to 15	number of SRR entries	4
	16	number of Open SRRs	1
	17 to 19	Reserved	3
	20 to 21	Open SRR numbers	2
	22 to 51	Reserved unless otherwise specified by the Application	30
	52 to 63	Reserved	12

Figure 130 — SRRI Header

The **SRRI Identifier** field shall be set to 53 52h, representing the characters “SR”.

The **SRRI format** field shall be set to 00h..

The **SRRI Update Count** shall specify the total number of update operations of the SRRI structure. This field shall be set to 00 00 00 00h during the Initialization operation, and shall be incremented by one each time the SRRI structure is updated.

The **number of SRR entries** (N_SRR) shall indicate the total number of SRR entries in the SRRI. The number of SRRs is one unless otherwise specified by the Application.

The **number of Open SRRs** field shall indicate the number of SRRs with status Open. The maximum value of this field is one unless otherwise specified by the Application. The value of this field shall be set to 00h after the disk is recorded.

The **Open SRR numbers** shall indicate all SRR numbers with status Open.

22.4.6.4 SRR entry

The **SRR entry** shall be formatted as shown in Figure 131.

SRR entry consists of 8 bytes and is recorded contiguously.

The bytes of the SRR entry are converted into a 64-bit sequence with the msb first. The List of SRR entries shall be sorted in ascending order as if each entry were a single 64-bit unsigned integer. SRR Numbers shall be assigned as one unless otherwise specified by the Application.

byte 0 / bit 7..4 of SRR entry	byte 0 / bit 3..0 & bytes 1 to 3 of SRR entry	byte 4 / bit 7 of SRR entry	byte 4 / bit 6..4 of SRR entry	byte 4 / bit 3..0 & bytes 5 to 7 of SRR entry
b_{63} .. b_{60}	b_{59} .. b_{32}	b_{31}	b_{30} .. b_{28}	b_{27} .. b_0
Reserved	Start PSN of the SRR	Session start	Reserved	LRA in the SRR

Figure 131 — SRR entry

The **Start PSN of the SRR *#i*** shall specify the first PSN of the first Cluster of the SRR *#i* and shall be set to 00 10 00 00h unless otherwise specified by the Application.

The **Session start** bit shall indicate if this SRR is the first SRR in a Session and shall be set to ONE unless otherwise specified by the Application.

The **LRA in the SRR** shall specify the PSN of the last Sector in the SRR recorded with data supplied by the host. For an empty SRR, the value of this field shall be set to 0 00 00 00h. For an Open SRR, the relation between *NWA* and *LRA* shall be given by the following formulae:

$NWA = 32 \times [\text{floor}(LRA/32) + 1]$ if the $LRA \neq$ 0 00 00 00h
NWA = Start PSN of the SRR if the LRA = 0 00 00 00h

22.4.6.5 SRRI Terminator

The SRRI Terminator shall be composed of two 4-byte parts:

- the first 4 bytes shall be set FF FF FF FFh,
- the second 4 bytes shall be equal to the SRRI Update Count in the header of the SRRI structure.

22.5 Unrecorded (blank) disk structure

22.5.1 General

Some Zones of a Unrecorded disk may be pre-recorded before shipment of the disk. The status of Zones on an Unrecorded (blank) disk is summarized in 22.5.

22.5.2 Pre-recorded Areas on Unrecorded disk

The areas on the Unrecorded (blank) disk that are specified in Figure 132, Figure 133, Figure 134, Figure 135, Figure 136, Figure 137 and Figure 138 may be pre-recorded.

	Description	First PAA of Zone	Number of Phys. Clusters	Pre-recorded condition	Reference
BCA	BCA			either [a]	See Clause 35
	Protection Zone 1	---	---	---	
PIC	PIC	---	---	recorded	
---	Protection Zone 2	0 01 83 38h	300	---	
Buffer	---	0 01 87 E8h	3 078	unrecorded	
INFO 2	Reserved 8	0 01 B8 00h	32	either [a]	See 18.3.3
	Reserved 7	0 01 B8 80h	32	unrecorded	
	Reserved 6	0 01 B9 00h	32	unrecorded	
	Reserved 5	0 01 B9 80h	32	either [a]	See 18.3.6
	PAC 2	0 01 BA 00h	32	either [a]	See 18.3.7
	DMA 2	0 01 BA 80h	32	unrecorded	
	Control Data 2	0 01 BB 00h	32	unrecorded	
	Buffer 2	0 01 BB 80h	32	unrecorded	
OPC 0	Test Zone	0 01 BC 00h	2 044	either [a]	See 18.3.11
	OPC 0 Buffer	0 01 DB F0h	4	unrecorded	
TDMA 0	---	0 01 DC 00h	2 048	either [a]	See 18.3.14
INFO 1	Pre-write Area	0 01 FC 00h	32	either [a]	See 18.3.15
	Drive Area	0 01 FC 80h	32	unrecorded	
	Drive Area	0 01 FD 00h	32	unrecorded	
	Drive Area	0 01 FD 80h	32	unrecorded	
	Drive Area	0 01 FE 00h	32	unrecorded	
	DMA 1	0 01 FE 80h	32	unrecorded	
	Control Data 1	0 01 FF 00h	32	unrecorded	
	PAC 1	0 01 FF 80h	32	either [a]	See 18.3.19
	(Data Zone 0)	0 02 00 00h		unrecorded	

[a] either means that the Zone may or may not be pre-recorded according to its description.

Figure 132 — Pre-recorded Areas in Lead-in Zone of TL disk

	Description	First PAA of Zone	Number of Phys. Clusters	Pre-recorded condition	Reference
	(Data Zone 1)			unrecorded	
INFO 1	PAC 1	0 7E 00 00h	32	either [a]	See 18.4.18
	Control Data 1	0 7E 00 80h	32	unrecorded	
	DMA 1	0 7E 01 00h	32	unrecorded	
	Drive Area	0 7E 01 80h	32	unrecorded	
	Drive Area	0 7E 02 00h	32	unrecorded	
	Drive Area	0 7E 02 80h	32	unrecorded	
	Drive Area	0 7E 03 00h	32	unrecorded	
	Pre-write Area	0 7E 03 80h	32	either [a]	See 18.4.14
Reserved	---	0 7E 04 00h	2 048	unrecorded	
TDMA 1	---	0 7E 24 00h	2 048	unrecorded	
INFO 2	Buffer 2	0 7E 44 00h	32	unrecorded	
	Control Data 2	0 7E 44 80h	32	unrecorded	
	DMA 2	0 7E 45 00h	32	unrecorded	
	PAC 2	0 7E 45 80h	32	either [a]	See 18.4.8
	Reserved 5	0 7E 46 00h	32	either [a]	See 18.4.7
	Reserved 6	0 7E 46 80h	32	unrecorded	
	Reserved 7	0 7E 47 00h	32	unrecorded	
	Reserved 8	0 7E 47 80h	32	either [a]	See 18.4.4
Reserved	---	0 7E 48 00h	1 894	unrecorded	
OPC 1	Test Zone	0 7E 65 98h	2 048	either [a]	See 18.4.2
Buffer	---	0 7E 85 98h	4 104	unrecorded	
	Protection Zone 1	0 7E C5 B8h	---		

[a] either means that the Zone may or may not be pre-recorded according to its description.

Figure 133 — Pre-recorded Areas in Inner Zone 1 of TL disk

	Description	First PAA of Zone	Number of Phys. Clusters	Pre-recorded condition	Reference
	Protection Zone 1	---	---		
Buffer	---	0 81 3A 48h	200	unrecorded	
OPC 2	Test Zone	0 81 3D 68h	2 044	either [a]	See 18.5.2
	OPC 2 Buffer	0 81 5D 58h	4	unrecorded	
Reserved	---	0 81 5D 68h	1 600	unrecorded	
INFO 2	Reserved 8	0 81 76 68h	32	either [a]	See 18.5.5
	Reserved 7	0 81 76 E8h	32	unrecorded	
	Reserved 6	0 81 77 68h	32	unrecorded	
	Reserved 5	0 81 77 E8h	32	either [a]	See 18.5.8
	Reserved	0 81 78 68h	32	unrecorded	
	DMA 2	0 81 78 E8h	32	unrecorded	
	Control Data 2	0 81 79 68h	32	unrecorded	
	Buffer 2	0 81 79 E8h	32	unrecorded	
TDMA 2	---	0 81 7A 68h	2 048	unrecorded	
Buffer	---	0 81 9A 68h	6 246	unrecorded	
INFO 1	Pre-write Area	0 81 FC 00h	32	either [a]	See 18.5.15
	Drive Area	0 81 FC 80h	32	unrecorded	
	Drive Area	0 81 FD 00h	32	unrecorded	
	Drive Area	0 81 FD 80h	32	unrecorded	
	Drive Area	0 81 FE 00h	32	unrecorded	
	DMA 1	0 81 FE 80h	32	unrecorded	
	Control Data 1	0 81 FF 00h	32	unrecorded	
	Reserved	0 81 FF 80h	32	unrecorded	
	(Data Zone 2)	0 82 00 00h		unrecorded	

[a] either means that the Zone may or may not be pre-recorded according to its description.

Figure 134 — Pre-recorded Areas in Inner Zone 2 of TL disk

	Description	First PAA of Zone	Number of Phys. Clusters	Pre-recorded condition	Reference
BCA	BCA			either [a]	See Clause 35
	Protection Zone 1	---	---		
	PIC	---	---	recorded	
---	Protection Zone 2	0 01 8B 50h	300		
Buffer	---	0 01 90 00h	814	unrecorded	
INFO 2	Reserved 8	0 01 9C B8h	32	either [a]	See 18.6.3
	Reserved 7	0 01 9D 38h	32	unrecorded	
	Reserved 6	0 01 9D B8h	32	unrecorded	
	Reserved 5	0 01 9E 38h	32	either [a]	See 18.6.6
	PAC 2	0 01 9E B8h	32	either [a]	See 18.6.7
	DMA 2	0 01 9F 38h	32	unrecorded	
	Control Data 2	0 01 9F B8h	32	unrecorded	
	Buffer 2	0 01 A0 38h	32	unrecorded	
OPC 0	Test Zone	0 01 A0 B8h	2 048	either [a]	See 18.6.11
Buffer	---	0 01 C0 B8h	3 794	unrecorded	
INFO 1	Pre-write Area	0 01 FC 00h	32	either [a]	See 18.6.13
	Drive Area	0 01 FC 80h	32	unrecorded	
	Drive Area	0 01 FD 00h	32	unrecorded	
	Drive Area	0 01 FD 80h	32	unrecorded	
	Drive Area	0 01 FE 00h	32	unrecorded	
	DMA 1	0 01 FE 80h	32	unrecorded	
	Control Data 1	0 01 FF 00h	32	unrecorded	
	PAC 1	0 01 FF 80h	32	either [a]	See 18.6.17
	(Data Zone 0)	0 02 00 00h		unrecorded	

[a] either means that the Zone may or may not be pre-recorded according to its description.

Figure 135 — Pre-recorded Areas in Lead-in Zone of QL disk

	Description	First PAA of Zone	Number of Phys. Clusters	Pre-recorded condition	Reference
	(Data Zone 1)			unrecorded	
INFO 1	PAC 1	0 7E 00 00h	32	either [a]	See 18.7.17
	Control Data 1	0 7E 00 80h	32	unrecorded	
	DMA 1	0 7E 01 00h	32	unrecorded	
	Drive Area	0 7E 01 80h	32	unrecorded	
	Drive Area	0 7E 02 00h	32	unrecorded	
	Drive Area	0 7E 02 80h	32	unrecorded	
	Drive Area	0 7E 03 00h	32	unrecorded	
	Pre-write Area	0 7E 03 80h	32	either [a]	See 18.7.13
Buffer	---	0 7E 04 00h	4 778	unrecorded	
TDMA 0	---	0 7E 4E A8h	2 304	either [a]	See 18.7.11
INFO 2	Buffer 2	0 7E 72 A8h	32	unrecorded	
	Control Data 2	0 7E 73 28h	32	unrecorded	
	DMA 2	0 7E 73 A8h	32	unrecorded	
	PAC 2	0 7E 74 28h	32	either [a]	See 18.7.7
	Reserved 5	0 7E 74 A8h	32	either [a]	See 18.7.6
	Reserved 6	0 7E 75 28h	32	unrecorded	
	Reserved 7	0 7E 75 A8h	32	unrecorded	
	Reserved 8	0 7E 76 28h	32	either [a]	See 18.7.3
OPC 1	Test Zone	0 7E 76 A8	2 048	either [a]	See 18.7.2
Buffer	---	0 7E 96 A8h	2 500	unrecorded	
	Protection Zone 1	0 7E BD B8h	---		

[a] either means that the Zone may or may not be pre-recorded according to its description.

Figure 136 — Pre-recorded Areas in Inner Zone 1 of QL disk

	Description	First PAA of Zone	Number of Phys. Clusters	Pre-recorded condition	Reference
	Protection Zone 1	---	---		
Buffer	---	0 81 42 48h	3 268		
INFO 2	Reserved 8	0 81 75 58h	32	either [a]	See 18.8.2
	Reserved 7	0 81 75 D8h	32	unrecorded	
	Reserved 6	0 81 76 58h	32	unrecorded	
	Reserved 5	0 81 76 D8h	32	either [a]	See 18.8.5
	Reserved	0 81 77 58h	32	unrecorded	
	DMA 2	0 81 77 D8h	32	unrecorded	
	Control Data 2	0 81 78 58h	32	unrecorded	
	Buffer 2	0 81 78 D8h	32	unrecorded	
TDMA 1	---	0 81 79 58h	1 280	unrecorded	
Buffer	---	0 81 8D 58h	3 754	unrecorded	
OPC 2	Test Zone	0 81 C8 00h	2 044	either [a]	See 18.8.12
	OPC 2 Buffer	0 81 E7 F0h	4	unrecorded	
TDMA 2	---	0 81 E8 00h	1 280	unrecorded	
INFO 1	Pre-write Area	0 81 FC 00h	32	either [a]	See 18.8.15
	Drive Area	0 81 FC 80h	32	unrecorded	
	Drive Area	0 81 FD 00h	32	unrecorded	
	Drive Area	0 81 FD 80h	32	unrecorded	
	Drive Area	0 81 FE 00h	32	unrecorded	
	DMA 1	0 81 FE 80h	32	unrecorded	
	Control Data 1	0 81 FF 00h	32	unrecorded	
	Reserved	0 81 FF 80h	32	unrecorded	
	(Data Zone 2)	0 82 00 00h		unrecorded	

[a] either means that the Zone may or may not be pre-recorded according to its description.

Figure 137 — Pre-recorded Areas in Inner Zone 2 of QL disk

	Description	First PAA of Zone	Number of Phys. Clusters	Pre-recorded condition	Reference
	(Data Zone 3)			unrecorded	
INFO 1	Reserved	0 FE 00 00h	32	unrecorded	
	Control Data 1	0 FE 00 80h	32	unrecorded	
	DMA 1	0 FE 01 00h	32	unrecorded	
	Drive Area	0 FE 01 80h	32	unrecorded	
	Drive Area	0 FE 02 00h	32	unrecorded	
	Drive Area	0 FE 02 80h	32	unrecorded	
	Drive Area	0 FE 03 00h	32	unrecorded	
	Pre-write Area	0 FE 03 80h	32	either [a]	See 18.9.12
TDMA 3	---	0 FE 04 00h	3 328	unrecorded	
INFO 2	Buffer 2	0 FE 38 00h	32	unrecorded	
	Control Data 2	0 FE 38 80h	32	unrecorded	
	DMA 2	0 FE 39 00h	32	unrecorded	
	Reserved	0 FE 39 80h	32	unrecorded	
	Reserved 5	0 FE 3A 00h	32	either [a]	See 18.9.6
	Reserved 6	0 FE 3A 80h	32	unrecorded	
	Reserved 7	0 FE 3B 00h	32	unrecorded	
	Reserved 8	0 FE 3B 80h	32	either [a]	See 18.9.3
Buffer	---	0 FE 3C 00h	6 254	unrecorded	
OPC 3	Test Zone	0 FE 9D B8h	2 048	either [a]	See 18.9.1
	Protection Zone 1	0 FE BD B8h	---		

[a] either means that the Zone may or may not be pre-recorded according to its description.

Figure 138 — Pre-recorded Areas in Lead-out Zone of QL disk

22.5.3 Pre-recorded BCA

BCA code may or may not be recorded. The BCA code is not recorded unless otherwise specified by the Application. The Modulation and Format of the BCA code are not specified in this document. See Clause 35.

22.5.4 Pre-recorded INFO 2 / Reserved 5, Reserved 8 and Pre-recorded INFO 1 / Pre-write Area

When BCA code is not recorded on an Unrecorded disk, Zones of INFO 2 / Reserved 5, Reserved 8 and INFO 1 / Pre-write Area in both Inner Zone 0 and Inner Zone 1 are recorded with all 00h. When BCA code is recorded on an Unrecorded disk, these Zones are unrecorded. See 18.3.6, 18.4.7, 18.5.8, 18.6.6, 18.3.3, 18.4.4, 18.5.5, 18.6.3, 18.3.15, 18.4.14, 18.5.15 and 18.6.13.

22.5.5 Pre-recorded INFO 1 / PAC 1 and Pre-recorded INFO 2 / PAC 2

When BCA-code is not recorded on an Unrecorded disk, IS1/IS2 PAC structures are recorded in INFO 1 / PAC 1 and INFO 2 / PAC 2. When BCA code is recorded on an Unrecorded disk, these Zones are unrecorded and IS1/IS2 PAC structures are not recorded. See 21.4.

22.5.6 OPC 0 / Test Zone , OPC 1 / Test Zone, OPC 2 / Test Zone and OPC 3 / Test Zone

When BCA code is not recorded on an Unrecorded disk, some Clusters in OPC 0 Test Zone, OPC 1 Test Zone, OPC 2 Test Zone, and OPC 3 Test Zone may be used to perform OPC to record the Pre-recorded Zones. See 18.3.11, 18.4.2, 18.5.2, 18.6.11, 18.7.2, 18.8.12 and 18.9.1.

22.5.7 TDMA 0

When BCA code is not recorded on an Unrecorded disk, Zones that specified in Figure 132, Figure 133, Figure 134, Figure 135, Figure 136, Figure 137 and Figure 138 may be recorded. When some Zones are recorded on the Unrecorded disk, TDMS in the TDMA 0 is recorded to specify;

- Zones are recorded,
- An empty SRR is created from LSN 0,
- Some OPC Clusters are used.

22.5.8 Initialization of disk

BD Recordable disks are initialized before use. When a Temporary Disk-Management Structure and Pre-write Area(s) (see 18.3.15, 18.4.14, 18.5.15, 18.6.13, 18.7.13, 18.8.15 and 18.9.12) are not recorded on an Unrecorded disk, these areas shall be recorded before recording in the User-Data Area.

A newly created TDMS shall have all Update Count fields set to ZERO. The TDMS shall be recorded starting from the first Cluster of TDMA 0.

BD Recordable disks may be formatted for the Sequential-Recording Mode unless otherwise specified by the Application. A newly created a single-Cluster TDMS contains the following elements (see 22.4.3 and Figure 121):

- an empty TDFL, containing only a header, no DFL entries and a Terminator,
- an SRRI with at least one Open SRR (the first SRRI entry shall have the Session start bit set to ONE),
- a TDDS with all relevant information like (see Figure 122).

22.6 Recorded (Closed) disk structure

22.6.1 General

The Recorded disk structure is summarized in 22.6. When data recording on an Unrecorded disk is finished the areas of the disk shall be recorded as specified. If all Clusters in all TDMAs have been used the disk shall be considered a Recorded disk.

The four DMA Zones of the Recorded disk and the DMA Access Indicator (see 22.3.2) shall be recorded (closed).

22.6.2 DMA Zones

The structures in the DMA Zone describes the exact status of the disk at the moment when data recording was finished. The SRR status shall be set to Closed, the TDMS structures shall be updated and written to the TDMA on the Recorded disk. Optionally all remaining Clusters in the TDMAs can be recorded with all 00h data (see Figure 139).

Other unwritten areas on the disk need not to be recorded.

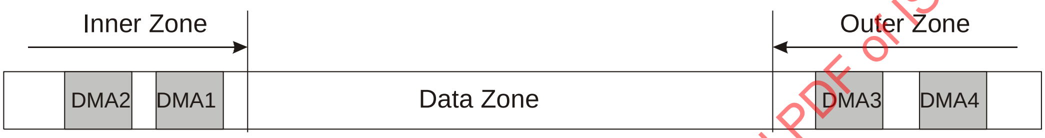


Figure 139 — Disk-Management Areas

The DMAs 1, 2, 3 and 4 shall be recorded with copies of the information contained in the latest TDMS.

The DDS in the DMA Zones preserves the references to these TDMS.

22.6.3 Disk-Management Structure (DMS)

22.6.3.1 General

A Disk-Management Structure (DMS) is made up of a Disk-Definition Structure (DDS) and a Defect List (DFL). The DDS is combined in one Cluster with an SRRI and shall be repeated for robustness reasons. The DFL consists of 8 consecutive Clusters on a TL disk or a QL disk and can be repeated seven times.

All four occurrences of the DMS, recorded in the DMA Zones in the Inner and Outer Zone(s), shall contain the same information, except for the First PSN of Defect List (see 22.4.4, byte 24 of Data Frame 0 of the DDS).

The DMA Zones shall be updated in the order DMA 1, DMA 2, DMA 3, and DMA 4 for ease of handling possible power-down failures.

22.6.3.2 Disk-Management Structure (DMS) on TL disk

On a TL disk the DMAs consist of 96 Clusters divided over the three Recording Layers as indicated in Figure 140:

Tracking direction →

Layer L0	Cluster 1	Cluster 2	Cluster 3	...	Cluster 31	Cluster 32

← Tracking direction

Layer L1	Cluster 64	Cluster 63	...	Cluster 35	Cluster 34	Cluster 33

Tracking direction →

Layer L2	Cluster 65	Cluster 66	Cluster 67	...	Cluster 95	Cluster 96

Figure 140 — Clusters of DMAs on TL disk

The DDS + SRRI shall be recorded in a specific sequence (see Figure 141) in the first 6 Clusters of each DMA. The DFL is recorded in Clusters 9 to 16 of each DMA and may be optionally repeated in the Clusters 17 to 64 (if no repetition is applied, Clusters 17 to 64 shall contain all 00h).

Cluster 1 to 6	DDS + SRRI	Six repetitions
Cluster 7 to 8	Reserved	These Clusters shall be left unrecorded
Cluster 9 to 16	1st position of DFL	DFL
Cluster 17 to 24	2nd position of DFL	optional copy of DFL or 00h User Data
Cluster 25 to 32	3rd position of DFL	optional copy of DFL or 00h User Data
:	:	:
Cluster 57 to 64	7th position of DFL	optional copy of DFL or 00h User Data
Cluster 65 to 96	Reserved	These Clusters shall be left unrecorded

Figure 141 — Example of DMA Zone on TL disk

The first Data Frame (0) of each of the Clusters 1 to 6 is designated as the DDS and shall contain a copy of the latest TDDS, except for the First PSN of Defect List, which address shall be set to the first PSN of Cluster 9, 17 .. or 57 of the DMA Zone containing this DDS. The indicated address shall identify the occurrence of the first full DFL that can be retrieved error free.

Data Frames 1 (see 22.4.3) of each of the Clusters 1 to 6 are designated as the SRRI and shall contain a copy of the latest SRRI from the TDMS. All remaining Data Frames 2 to 31 shall contain all 00h.

The DFL, recorded in Clusters 9 to 16, shall contain a copy of the latest TDFL, which TDFL shall be padded with ZERO data up to a length of 8 Clusters. The DFL may be repeated up to seven copies for robustness reasons in each following group of 8 Clusters in each DMA.

22.6.3.3 Disk-Management Structure (DMS) on QL disk

On a QL disk the DMAs consist of 128 Clusters divided over the four Recording Layers as indicated in Figure 142:

Tracking direction →

Layer L0	Cluster 1	Cluster 2	Cluster 3	...	Cluster 31	Cluster 32

← Tracking direction

Layer L1	Cluster 64	Cluster 63	...	Cluster 35	Cluster 34	Cluster 33

Tracking direction →

Layer L2	Cluster 65	Cluster 66	Cluster 67	...	Cluster 95	Cluster 96

← Tracking direction

Layer L3	Cluster 128	Cluster 127	...	Cluster 99	Cluster 98	Cluster 97

Figure 142 — Clusters of DMAs on QL disk

The DDS + SRRI shall be recorded in a specific sequence (see Figure 143) in the 4 Clusters that locate at the odd Cluster number from the beginning of each DMA (Cluster 1, 3, 5 and 7).

The DFL is recorded in Clusters 9 to 16 of each DMA and may be optionally repeated in the Clusters 17 to 64 (if no repetition is applied, Clusters 17 to 64 shall contain all 00h).

Cluster 1	DDS + SRRI	
Cluster 2	Reserved	This Cluster shall be left unrecorded
Cluster 3	DDS+SRRI	
Cluster 4	Reserved	This Cluster shall be left unrecorded
Cluster 5	DDS+SRRI	
Cluster 6	Reserved	This Cluster shall be left unrecorded
Cluster 7	DDS+SRRI	
Cluster 8	Reserved	This Cluster shall be left unrecorded
Cluster 9 to 16	1st position of DFL	DFL
Cluster 17 to 24	2nd position of DFL	optional copy of DFL or 00h User Data
Cluster 25 to 32	3rd position of DFL	optional copy of DFL or 00h User Data
:	:	:
Cluster 57 to 64	7th position of DFL	optional copy of DFL or 00h User Data
Cluster 65 to 128	Reserved	These Clusters shall be left unrecorded

Figure 143 — Example of DMA Zone for on QL disk

The first Data Frame (0) of each of the Clusters 1, 3, 5 and 7 is designated as the DDS and shall contain a copy of the latest TDDS, except for the First PSN of Defect List, which address shall be set to the first PSN of Cluster 9, 17 .. or 57 of the DMA Zone containing this DDS. The indicated address shall identify the occurrence of the first full DFL that can be retrieved error free.

Data Frames 1 of each of the Clusters 1, 3, 5 and 7 is designated as the SRRI and shall contain a copy of the latest SRRI from the TDMS. All remaining Data Frames 2 to 31 shall contain all 00h.

The DFL, recorded in Clusters 9 to 16, shall contain a copy of the latest TDFL, which TDFL shall be padded with ZERO data up to a length of 8 Clusters. The DFL may be repeated up to seven copies for robustness reasons in each following group of 8 Clusters in each DMA Zone.

23 Assignment of Logical-Sector Numbers (LSNs)

Logical-Sector Numbers shall be assigned contiguously over all Clusters available for storage of User Data, starting from LSN 0 and increasing by one for each successive User Data Frame (See Figure 144).

LSN 0 is assigned to the first User Data Frame in the first Cluster after the 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 00h).

The last LSN on Layer L2 is equal to 24 × LAA + 47 – 00 30 00 00h and is assigned to the last User Data Frame in the last Cluster before the Outer Zone 2
(at PSN = 04 00 00 00h + 8 × LAA + 15 = X + 04 00 00 00h).

The first LSN on Layer L3 shall be one higher than the last LSN on Layer L2 and is assigned to the first User Data Frame in the first Cluster after the Outer Zone 3
(at PSN = 04 00 00 00h + 8 × FAA = $\overline{X + F8\ 00\ 00\ 00h}$).

The last LSN on Layer L3 is equal to 32 × LAA + 63 – 00 40 00 00h and is assigned to the last User Data Frame in the last Cluster before the Lead-out Zone
(at PSN = 07 EF FF FFh).

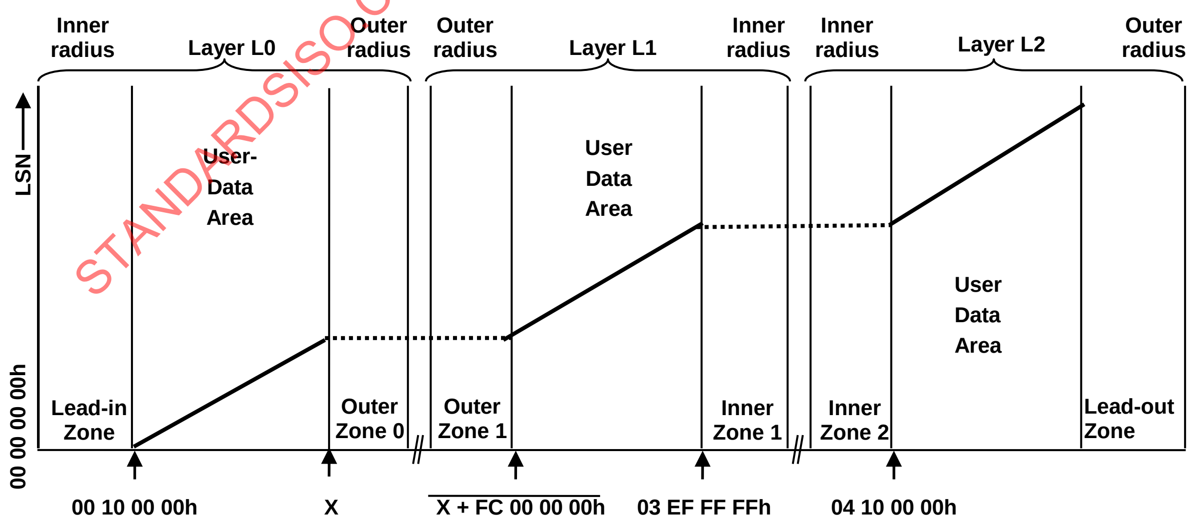


Figure 144 — Assignment of Logical-Sector Numbers

24 Characteristics of Grooved Areas

The signal values specified in Clause 24 to Clause 27 are valid for all disk capacities, unless specified otherwise.

In this International Standard, two types of signals are distinguished:

— signals generated by the Groove structures on the disk, and
— signals generated by User-written Marks.

In Clause 25 to Clause 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 Clause 25 to Clause 27 shall be fulfilled in all layers independent of the recording status of other Recording Layer (whether unrecorded, recorded or partially recorded) from the inner radius of the Embossed HFM Area(s) (start/end of the PIC Zone) at nominal radius 22,4 mm up to the inner radius of the Outer Zone(s) + 20 µm ($d_{\mathbf{DZO}}$/ 2 + 20 µm). It is recommended that the requirements are also fulfilled in the remainder of the Outer Zone(s).

25 Method of testing for Grooved Area

25.1 General

When measuring the signals, the influence of local defects, such as dust and scratches, are excluded. Local defects might cause tracking errors, erroneous ADIP information or uncorrectable Data (see Clause 34).

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 (1,20 ± 0,10) mW for Layer L0 and Layer L1 of a TL disk and Layer L0, Layer L1 and Layer L2 of a QL disk and (1,10 ± 0,10) mW for Layer L2 of a TL disk and Layer L3 of a QL disk except when measuring Push-Pull signals. For measurement of Push-Pull signals, the read power shall be (0,70 ± 0,10) mW for a TL and QL disks.

25.3.3 Read channels

The drive shall have two read channels as defined in 9.5 and 9.6. The HF signal from the HF read channel shall not be equalized.

For measurement of the Push-Pull signals, the radial PP read channels shall be filtered by a first order LPF with $f_{\mathbf{-3dB}}$ = 30 kHz.

For measurement of the wobble signals, the radial PP read channels shall be filtered by a first order LPF with $f_{\mathbf{-3dB}}$ = 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: e_{max} (axial) = 80 nm,

and the radial tracking error between the focus of the optical beam and the centre of the Track shall be: e_{max} (radial) = 20 nm.

For 4x disks local defects that cause large axial tracking errors shall be taken into account as described in I.10.

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 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

$I_G = (I_1 + I_2)_{groove}$.

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 5), when the focus of the optical beam crosses the Tracks. The Push-Pull signal can be used by the drive for radial tracking (see Figure 145).

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:

$$PP_{norm} = \left[\frac{I_1(t) - I_2(t)}{I_1(t) + I_2(t)}\right]_{peak-peak} \equiv \frac{(I_1 - I_2)_{at\,t_2}}{(I_1 + I_2)_{at\,t_2}} - \frac{(I_1 - I_2)_{at\,t_1}}{(I_1 + I_2)_{at\,t_1}}$$

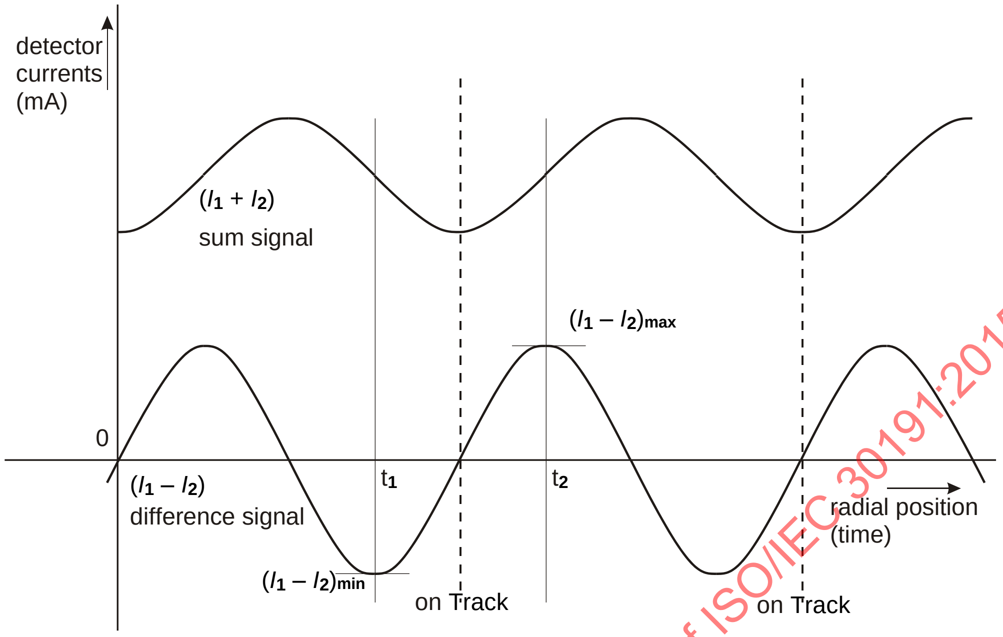


Figure 145 — Definition of Push-Pull signals

In these BD Recordable system specifications, the real-time normalized Push-Pull signal (PP_{norm}) shall be converted for the photodetector size of 25 µm²(see I.9).

Wobble signal:

The wobble signal I_{Wpp} is the peak-to-peak value of the sinusoidal difference signal (I_1–I_2) in the radial PP read channel (see Figure 5), when the focus of the optical beam follows the Tracks according to 25.3.4. See also Annex M and Annex E for a measurement method.

The signal shall be normalized by the peak-to-peak value of the Push-Pull signal $(I_1–I_2)_{pp}$:

$$NWS = \frac{I_{Wpp}}{(I_1 - I_2)_{pp}} .$$

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 $(PP_{\text{norm,HFM}})_{\text{conv}}$ shall meet the following requirements:

— in the Embossed HFM Areas $0{,}26 \leq (PP_{\text{norm,HFM}})_{\text{conv}} \leq 0{,}52$

26.3 Wobble signal

The Normalized HFM-Wobble Signal is a measure of the deviation of the Groove Track from its average centre line. Due to interference with the wobbles of adjacent tracks, the amplitude of the HFM wobble signal shows a variation (called "wobble beat").

At locations where the HFM wobble signal shows minimum amplitudes due to the wobble beat, the Normalized HFM-Wobble Signal (*NHWS*) shall be: $0{,}30 \leq NHWS_{\text{min}} \leq 0{,}60$.

At locations where the HFM wobble signal shows maximum amplitudes due to the wobble beat, the Normalized HFM-Wobble Signal shall be: $NHWS_{\text{max}} \leq 3 \times NHWS_{\text{min}}$.

NOTE Because the shape of the HFM wobble signal detected in the Embossed HFM Areas differs significantly from the wobble signal in the Recordable 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 Groove 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, $f_{-3\text{dB}} = 20$ kHz,

— no equalization,

— 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 $(PP_{\mathbf{norm}})_{\mathbf{conv}}$ shall meet the following requirements in each layer:

— in Unrecorded Areas (all neighboring Tracks unrecorded):

$$0{,}21 \le (PP_{\text{norm,unrec.}})_{\text{conv}} \le 0{,}45$$

— maximum variation of Push-Pull signal within 150 Tracks in Unrecorded Areas:

$$\frac{(PP_{\text{norm,unrec.}})_{\text{max}} - (PP_{\text{norm,unrec.}})_{\text{min}}}{(PP_{\text{norm,unrec.}})_{\text{max}} + (PP_{\text{norm,unrec.}})_{\text{min}}} \le 0{,}18$$

— maximum variation of Push-Pull signal within one Layer in Unrecorded Areas:

$$\frac{(PP_{\text{norm,unrec.}})_{\text{max}} - (PP_{\text{norm,unrec.}})_{\text{min}}}{(PP_{\text{norm,unrec.}})_{\text{max}} + (PP_{\text{norm,unrec.}})_{\text{min}}} \le 0{,}25$$

— in Recorded Areas (all neighboring Tracks recorded):

$$0{,}21 \le (PP_{\text{norm,rec.}})_{\text{conv}} \le 0{,}45$$

— ratio of average Push-Pull signals in Recorded and Unrecorded Areas within one layer:

$$0{,}75 \le \frac{(PP_{\text{norm,rec.}})_{\text{conv}}}{(PP_{\text{norm,unrec.}})_{\text{conv}}} \le 1{,}25$$

27.3 Wobble signal

27.3.1 General

The normalized wobble signal is a measure for the deviation of the Groove Track from its average centreline. The distance that the actual centre of the Wobbled Groove Track deviates from the average Track centre line can be calculated according to 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), the Normalized Wobble Signal shall be: $0{,}20 \le NWS_{\mathbf{min}} \le 0{,}55$.

At locations where the wobble signal shows maximum amplitudes due to the wobble beat, the Normalized Wobble Signal shall be: $NWS_{\mathbf{max}} \le 3 \times NWS_{\mathbf{min}}$.

27.3.3 Measurement of wobble CNR

The narrow band SNR (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 to 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. Both 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, or

— *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

The signal values specified in Clause 28 to Clause 31 are valid for all disk capacities, unless specified otherwise.

In this International Standard, two types of signals are distinguished:

— signals generated by Groove structures on the disk, and

— signals generated by User-written Marks.

Clause 28 to Clause 31 specifies a series of tests to assess the recording properties of the Recording Layer, as used for writing data.

All requirements in Clause 28 to Clause 31 shall be fulfilled in all layers independent of the recording status of other Recording Layer (whether unrecorded, recorded or partially recorded) from the inner radius of the Recordable 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 Recordable 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 might cause tracking errors, or uncorrectable Data (see Clause 34).

29.2 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.

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 (1,20 ± 0,10) mW for Layer L0 and Layer L1 of a TL disk and Layer L0, Layer L1 and Layer L2 of a QL disk and (1,10 ± 0,10) mW for Layer L2 of a TL disk and Layer L3 of a QL disk.

29.3.3 Read channels

The drive shall have two read channels as defined in 9.5 and 9.6. The HF signal from the HF read channel shall not be equalized, except when measuring 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 80 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.

For 4x disks local defects that cause large axial tracking errors shall be taken into account as described in I.10.

29.3.5 Scanning velocities

Write tests shall be carried out at the speeds defined in the DI Units that are present on the disk (see 15.8.3).

During reading, the actual rotation velocities 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.

29.4 Write conditions

29.4.1 Write-pulse waveform

Marks and Spaces are written on the disk by pulsing a laser. The laser power is modulated according to one of the write-pulse waveforms given in Annex F. A 2T to 9T NRZI run-length is written by applying a multi-pulse train of write pulses.

The laser power during recording has four levels:

- the write peak power P_W,
- the bias write power P_{BW},
- the space power P_S,
- the middle power P_M,
- the cooling power P_C,

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 space power P_S.

The values of P_W, P_{BW}, P_S, P_M and P_C shall be optimized according to Annex G.

The actual powers P_W, P_{BW}, P_S, P_M and P_C for testing shall be within ± 5 % of their optimum values, where P_{BW}, P_C, P_M and P_S shall be proportional to P_W according to the ratios ε as specified in the Disk Information (see 15.8.3).

29.4.2 Write powers

The optimized write powers P_{WO}, P_{BWO}, P_{SO}, P_{MO} and P_{CO} shall meet the conditions as shown in Figure 146.

Velocities	Disk Type	TL		QL	
	Power (mW)	Min.	Max.	Min.	Max.
2x	P_{WO} (mW)	8,0	28,0	8,0	28,0
	P_{BWO} (mW)	0,10	16,8	0,10	16,8
	P_{SO} (mW)	0,60	16,8	0,60	16,8
	P_{CO} (mW)	0,10	16,8	0,10	16,8
	P_{MO} (mW) [a]	5,4	28,0	5,4	28,0
4x	P_{WO} (mW)	8,0	28,0	8,0	28,0
	P_{BWO} (mW)	---	---	---	---
	P_{SO} (mW)	0,60	16,8	0,60	16,8
	P_{CO} (mW)	0,10	16,8	0,10	16,8
	P_{MO} (mW)	5,4	28,0	5,4	28,0

[a] Only when Castle strategy is applied

Figure 146 — Write power requirements for Triple and/or Quadruple Layer disk

In addition to the conditions shown in Figure 146, the write powers shall be such that:

— At 2×V_{ref} : $P_{WO} \geq P_{MO} > P_{SO} \geq P_{CO}$ and $P_{WO} \geq P_{BWO}$.

— At 4×V_{ref} : $P_{WO} \geq P_{MO} > P_{SO} \geq P_{CO}$.

29.4.3 Average power

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 Recordable Areas of the disk.

The five Tracks are recorded with random data with a write power $P_W = P_{WO}$ as specified in 29.4.1. To measure the i-MLSE, all five Tracks are written with random data with a write power $P_W = P_{WO}$.

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 147).

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.

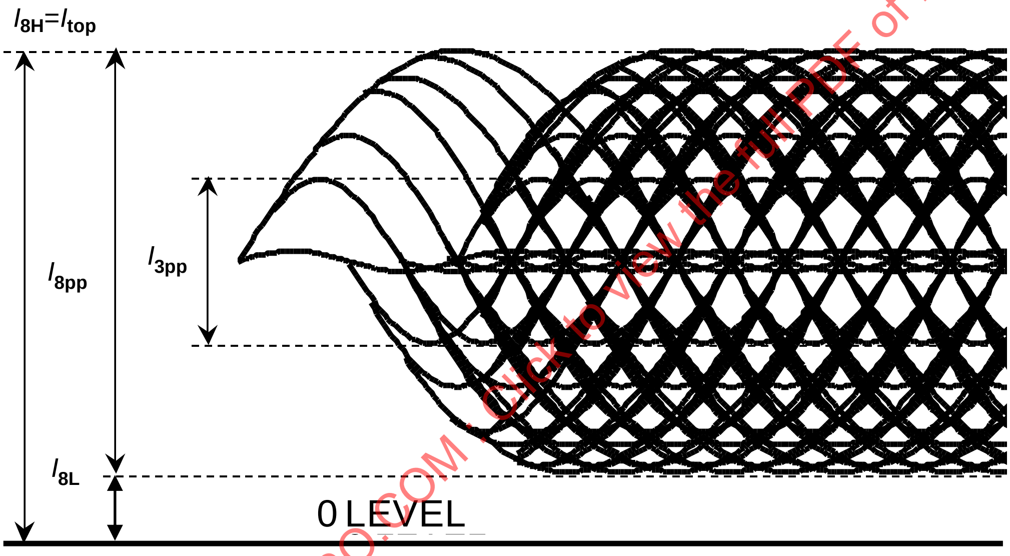


Figure 147 — Schematic representation of HF signal from Marks and Spaces

Because the I_{3pp} is a relatively small signal, its amplitude can not 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.

In these BD Recordable system specifications, 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:

— $(I_{8pp} / I_{8H})_{conv} \geq 0{,}40$,

— $I_{3pp} / I_{8pp} \geq 0{,}040$.

The variations of the modulation signals shall be:

— $(I_{8Hmax} – I_{8Hmin}) / I_{8Hmax} \leq 0{,}33$ within one layer (continuously recorded),

— $(I_{8Hmax} – I_{8Hmin}) / I_{8Hmax} \leq 0{,}15$ within one revolution (continuously recorded).

The ratio between the actual modulation signals (I_{8Ha}) on each layer shall be:

$- 0{,}25 \leq (I_{8Ha,Lj} – I_{8Ha,Lk}) / (I_{8Ha,Lj} + I_{8Ha,Lk}) \leq + 0{,}25$ (continuously recorded),

where;

— $I_{8Ha,Lj}$ and $I_{8Ha,Lk}$ are measured at the same position, both in radial and in tangential direction,

— $I_{8Ha} = R_{8H} \times$ Read power,

— $j = 1, 2$ $k = 0, 1$ $j > k$ for a TL disk and $j = 1, 2, 3$ $k = 0, 1, 2$ $j > k$ for a QL disk.

The ratio between the reflectivity on each layer shall be,

$- 0{,}33 \leq (R_{8H,Lj} – R_{8H,Lk}) / (R_{8H,Lj} + R_{8H,Lk}) \leq + 0{,}33$ (continuously recorded),

where;

— ($R_{8H,Lj}$ and $R_{8H,Lk}$ are measured at the same position, both in radial and in tangential direction,

— $j = 1, 2$ $k = 0, 1$ $j > k$ for a TL disk and $j = 1, 2, 3$ $k = 0, 1, 2$ $j > k$ for a QL disk.

30.3 Reflectivity-Modulation product

The reflectivity of the disk multiplied by the I_8 Modulation (= normalized I_{8pp} modulated amplitude) shall be :

$$R \times M = R_{8H} \times \left(\frac{I_{8pp}}{I_{8H}}\right)_{conv}$$

, with: $0{,}0073 \leq R \times M \leq 0{,}022$ for Layer L0 and Layer L1 of a TL disk and Layer L0, Layer L1 and Layer L2 of a QL disk,

$0{,}0082 \leq R \times M \leq 0{,}025$ for Layer L2 of a TL disk and Layer L3 of a QL disk.

The reflectivity of the disk multiplied by the I_3 Modulation (= normalized I_{3pp} modulated amplitude) shall be (see Annex B and Annex I):

$$R \times I_3 = R_{8H} \times \left(\frac{I_{3pp}}{I_{8H}}\right)_{conv}$$

, with: $R \times I_3 \geq 0{,}00055$ for Layer L0 and Layer L1 of a TL disk and Layer L0, Layer L1 and Layer L2 of a QL disk,

$R \times I_3 \geq 0{,}00062$ for Layer L2 of a TL disk and Layer L3 of a QL disk.

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 shall meet the following requirement:

$$-0{,}10 \leq \text{Asymmetry} \leq +0{,}15$$

30.5 i-MLSE

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 the 2x Reference Velocity.

The i-MLSE in Track *m* shall fulfill the following requirements:

On Layer L0 of TL disk and on Layer L0 and Layer L1 of QL disk:

for all disks, independent on capacity:

≤ 11,0 % when measured using the circuit specified in Annex H.

On Layer L1 of TL disk and on Layer L2 of QL disk:

for all disks, independent on capacity:

≤ 11,5 % when measured using the circuit specified in Annex H.

On Layer L2 of TL disk and on Layer L3 of QL disk:

for all disks, independent on capacity:

≤ 12,0 % when measured using the circuit specified in Annex H.

30.6 Read stability

Up to 10^6 successive reads from a single Track with a DC read power and an HF-modulated read power as indicated in Figure 148.

Read Velocity	Layer	Read power	
		TL	QL
2x	Layer L0	1,20 mW	1,20 mW
	Layer L1	1,20 mW	1,20 mW
	Layer L2	1,10 mW	1,20 mW
	Layer L3	---	1,10 mW
4x	Layer L0	1,70 mW	1,70 mW
	Layer L1	1,70 mW	1,70 mW
	Layer L2	1,55 mW	1,70 mW
	Layer L3	---	1,55 mW

Figure 148 — Read power values for read stability testing

The disk must 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 byte 30 and byte 31 (see 15.8.3.3 and 15.8.3.4).

The modulation should fulfill the following requirements (see Figure 149):

— modulation frequency (= $1/T_{\text{HF-laser}}$) (400 ± 40) MHz

— ratio of peak power and average power (2,0 ± 0,2)

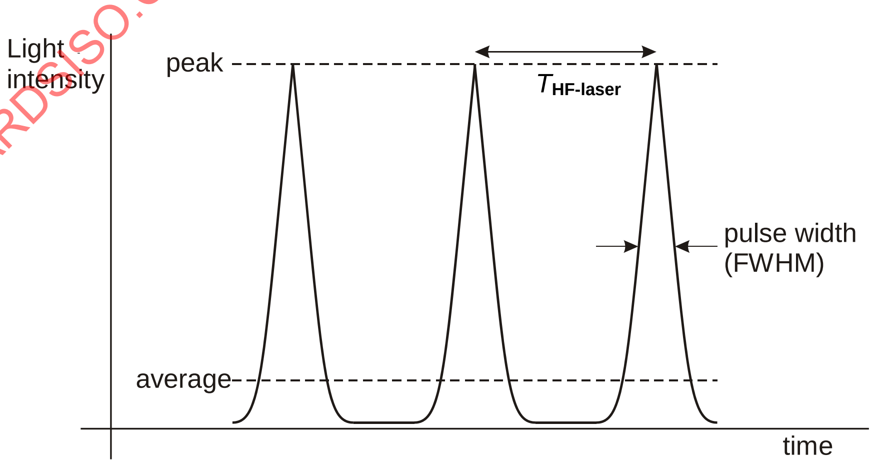


Figure 149 — Schematic representation of light pulses from Laser Diode

Additionally the SER (see 34.1) shall be < 4,2 × 10^{-3} in any LDC Block.
[Equivalent to < 317 counts (= 4,2 × 10^{-3} × 75 392 bytes)].

NOTE 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 byte 30 and 31 at 2x Reference Velocity and 4x Reference Velocity defined at bytes 28 and 29.

31 Local defects

Defects on the Recording Layer or in the Transmission Stack, such as “air bubbles” or “black dots” (such as dust enclosures in the Transmission Stack or pin holes in the Reflective Layer) shall not cause any unintended Track jumping or uncorrectable errors (see also 33.4 and Clause 34).

The size of such defects shall be:

- air bubbles: diameter < 100 µm
- black dots with birefringence: diameter < 150 µm
- black dots without birefringence: diameter < 150 µm

32 Characteristics of User Data

Clause 32 to Clause 34 describe a series of measurements to test conformance of the 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 Clause 32 to Clause 34shall be performed on the Reference drive.

Whereas Clause 24 to Clause 30 disregard local defects, Clause 32 to Clause 34 includes 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 Clause 32 to Clause 34 define a minimum quality of the data, necessary for data interchange.

33.2 Environment

All signals shall be within their specified ranges if the disk is in its range of allowed environmental conditions as defined in 9.2.

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 (1,20 ± 0,10) mW for Layer L0 and Layer L1 of a TL disk and Layer L0, Layer L1 and Layer L2 of a QL disk and (1,10 ± 0,10) mW for Layer L2 of a TL disk and Layer L3 of a QL disk.

33.3.3 Read channels

The drive shall have two read channels as defined in 9.5 and 9.6.

The HF signal from the HF read channel shall not be equalized and filtered before processing. For measurement of the disk quality, the characteristics of an 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 the measurement of the signals, the axial tracking error between the focus of the optical beam and the Recording Layer shall be maximum 80 nm, and the radial tracking error between the focus of the optical beam and the centre of the Track shall be maximum 20 nm.

For 4x disks local defects that cause large axial tracking errors shall be taken into account as described in I.10.

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 150).

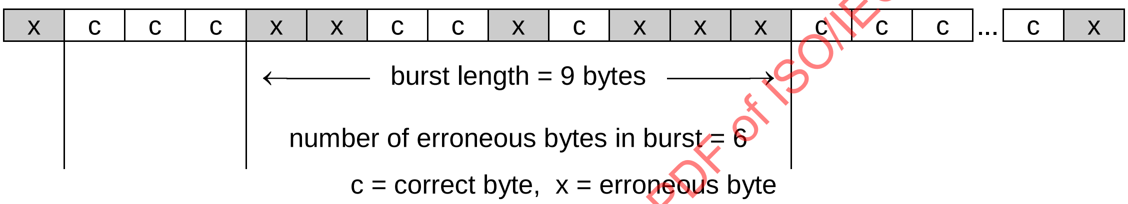


Figure 150 — Example of burst error

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:

$$\frac{\sum_{i=1}^{N} E_{\mathbf{a}i}}{N \times 75\,392}$$

where E_{a_i} = number of all erroneous bytes in LDC Block i

N = number of LDC Blocks.

Random Symbol Error Rate:
The Random Symbol Error Rate is defined as the Symbol Error Rate where all erroneous bytes contained in burst errors of length ≥ 40 bytes are counted neither in the numerator nor in the denominator of the SER calculation:

$$\frac{\sum_{i=1}^{N} \left(E_{\mathbf{a}i} - E_{\mathbf{b}i}\right)}{N \times 75\,392 - \sum_{i=1}^{N} E_{\mathbf{b}i}}$$

where E_{a_i} = number of all erroneous bytes in LDC Block i

E_{b_i} = number of all erroneous bytes in bursts ≥ 40 bytes in LDC Block i

N = number of LDC Blocks.

34 Minimum quality of recorded information

34.1 Symbol Error Rate

When checking the quality of the disk, including defects, the area selecting for determining the SER shall be written with arbitrary User Data. The SER shall fulfill the requirements as specified in 34.1.

The quality of continuously and discontinuously written sequences

Random SER averaged over any 10 000 consecutive LDC Blocks with the condition that all Blocks are recorded in a continuously written sequence, see Figure 47 in a discontinuously written sequence, see Figure 46, excluding disk defects, shall fulfill the following requirements:

Random SER < $2{,}0 \times 10^{-4}$ averaged over any 10 000 consecutive LDC Blocks.

34.2 Maximum burst errors

In each Recording-Unit Block the number of burst errors with length ≥ 40 bytes shall be less than 8 and the sum of the lengths of these burst errors shall be ≤ 600 bytes.

34.3 User-written Data

User-written Data in a Recording-Unit Block (RUB) as read in the HF read channel shall not contain any byte errors that cannot be corrected by the error correction system defined in Clause 13.

35 BCA

The Zone between r_1 and r_3 is reserved to be used as 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 in case of Recordable 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 151).

The BCA code shall be located between radius $21{,}3\,^{0{,}0}_{-0{,}3}$ mm and radius $22{,}0\,^{+0{,}2}_{0{,}0}$ mm on Layer L0 (the BCA code is allowed to overlap the Protection-Zone 1 partially).

The BCA code shall be written on Layer L0, but some effect of writing the BCA code on Layer L0 could 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 code in the radial direction.

The information in the BCA code can be read by a drive at any radius inside the BCA.

The decision to record the BCA code is Application dependent. The BCA code shall not be recorded in the BCA unless otherwise specified by the Application. The format and the content of the BCA code is defined by agreement between the interchange parties.

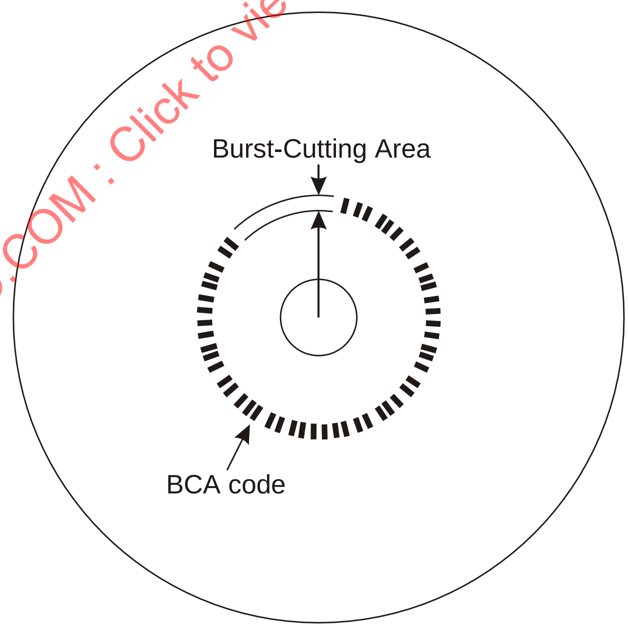


Figure 151 — Schematic representation of BCA

Annex A
(normative)

Thickness of Transmission Stacks in case of multiple layers

A.1 General

In case the total Transmission Stack consists of k layers, the following procedure shall be applied in determining the thickness of the individual layers:

— the values d_1 .. d_k represent the thicknesses of Layers 1 ..k,

— the values n_1 .. n_k represent the refractive indices of Layers 1 ..k,

— let $D(n)$ be the nominal thickness at refractive index n according to Figure 17 for a TL disk and Figure 19 for a QL disk. The curves show the thickness of equivalent spherical aberration.

$D(n)$ can be expressed using the function g in Clause 12, as

$D(n) = D(1,6) \times g(n)$

then the thickness d_k of Layer k should be equal to: $d_k = D(n_k) \times \left(1 - \sum_{i=1}^{k-1} \frac{d_i}{D(n_i)} \right)$

A.2 Refractive index n_i of all 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 variations of Transmission Stack for TL disk

The Relative Thickness of the Transmission Stack j is defined as: $RT_j = \sum_{i=1}^{k} \frac{d_i}{D(n_i)}$

The Relative Thickness RT of the Transmission Stacks, measured over the whole disk, shall fulfill the following requirements:

a) The Relative Thickness RT_0 of the Transmission Stack TS0 shall be: $94,0 \le 100,0 \times RT_0 \le 106,0$,

b) The Relative Thickness RT_1 of the Transmission Stack TS1 shall be: $69,0 \le 75,0 \times RT_1 \le 81,0$, and

c) The Relative Thickness RT_2 of the Transmission Stack TS2 shall be: $52,0 \le 57,0 \times RT_2 \le 62,0$.

NOTE The thickness of the Recording Layers are very thin and can be negligible in the calculation of the thickness.

A.4 Thickness variations of Transmission Stack for QL disk

The Relative Thickness of the Transmission Stack j is defined as: $RT_j = \sum_{i=1}^{k} \frac{d_i}{D(n_i)}$

The Relative Thickness RT of the Transmission Stacks, measured over the whole disk, shall fulfill the following requirements:

a) The Relative Thickness RT_0 of the Transmission Stack TS0 shall be: $94{,}0 \leq 100{,}0 \times RT_0 \leq 106{,}0$,

b) The Relative Thickness RT_1 of the Transmission Stack TS1 shall be: $78{,}5 \leq 84{,}5 \times RT_1 \leq 90{,}5$,

c) The Relative Thickness RT_2 of the Transmission Stack TS2 shall be: $60{,}5 \leq 65{,}0 \times RT_2 \leq 69{,}5$, and

d) The Relative Thickness RT_3 of the Transmission Stack TS3 shall be: $50{,}5 \leq 53{,}5 \times RT_3 \leq 56{,}5$.

A.5 Thickness variations of Spacer Layers for TL disk

The effective thickness of the Spacer Layer *j* is defined as: $ES_j = \sum_{i=1}^{k} d_i \times f(n_i)$

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 18. 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 arbitrary 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 section, 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 $ES_C - (ES_1 + ES_2) \geq 1{,}0$ µm, $ES_1 - ES_2 \geq 1{,}0$ µm.

A.6 Thickness variations of Spacer Layers for QL disk

The effective thickness *ES* of the Spacer Layer j is defined as: $ES_j = \sum_{i=1}^{k} d_i \times f(n_i)$

ES_1: Effective thickness of the Spacer Layer 1

ES_2: Effective thickness of the Spacer Layer 2

ES_3: Effective thickness of the Spacer Layer 3

ES_C: Effective thickness of TS2 or Cover Layer

Function *f*(*n*) is defined in Clause 12 and shown by Figure 18. 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 arbitrary 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 section, 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 $ES_C - (ES_1 + ES_2 + ES_3) \geq 1{,}0$ µm, $ES_1 - ES_3 \geq 1{,}0$ µm , $ES_2 - ES_1 \geq 1{,}0$ µm and $ES_3 \geq 10{,}0$ µm.

A.7 Example of thickness calculation for TL disk

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 thicknesses of Cover Layer at index n_1 = 1,52 and 1,58 are calculated as follows.

$D(1{,}52) = D(1{,}6) \times g(1{,}52) = 56{,}35$ μm,

$D(1{,}58) = D(1{,}6) \times g(1{,}58) = 56{,}81$ μm.

Where

$D(1{,}6) = 57{,}0$ μm , $g(1{,}52) = 0{,}988\,6$ and $g(1{,}58) = 0{,}996\,6$ (see 12.3)

Then the nominal thickness of the gluing sheet is calculated as follows.

$$d_2 = 56{,}81 \times \left(1 - \frac{55}{56{,}35}\right) = 1{,}36\,\mu\text{m}\,.$$

and the effective thickness of Cover Layer (ES_c: cover sheet + gluing sheet) is calculated as follows.

$$ES_C = 55 \times 1{,}0757 + 1{,}36 \times 1{,}0177 = 60{,}55\,\mu\text{m}$$

where

$f(1{,}52) = 1{,}075\,7$ and $f(1{,}58) = 1{,}017\,7$ (see Clause 12)

The result shows that effective thickness ES_C is larger when refractive index n is smaller. Then it is better that refractive index of Cover Layer (n_c) is smaller than those of Spacer Layers (n_{S1}, n_{S2}, n_{S3}) from the view point of requirement of $ES_C - (ES_1 + ES_2) \geq 1{,}0$μm for a TL disk

and $ES_C - (ES_1 + ES_2 + ES_3) \geq 1{,}0$μm for a QL disk and following conditions are preferable;

In case of a TL disk from the view point of the requirement of $ES_1 - ES_2 \geq 1{,}0$ μm

$n_{S2} > n_{S1} > n_c$

In case of a QL disk from the view point of the requirement of $ES_1 - ES_3 \geq 1{,}0$μm and $ES_2 - ES_1 \geq 1{,}0$ μm

$n_{S3} > n_{S1} > n_{S2} > n_c$

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:

— parallel method,

— focused method.

The reflectivity of the disk is measured by the focused method with the help of a Reference disk with known reflectivity, while the reflectivity of the Reference disk is calibrated by the parallel method.

When measuring the reflectivity in the focused way, only the light returned by the Reflective Layer of the disk (R_m) will fall 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 will mainly fall 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.

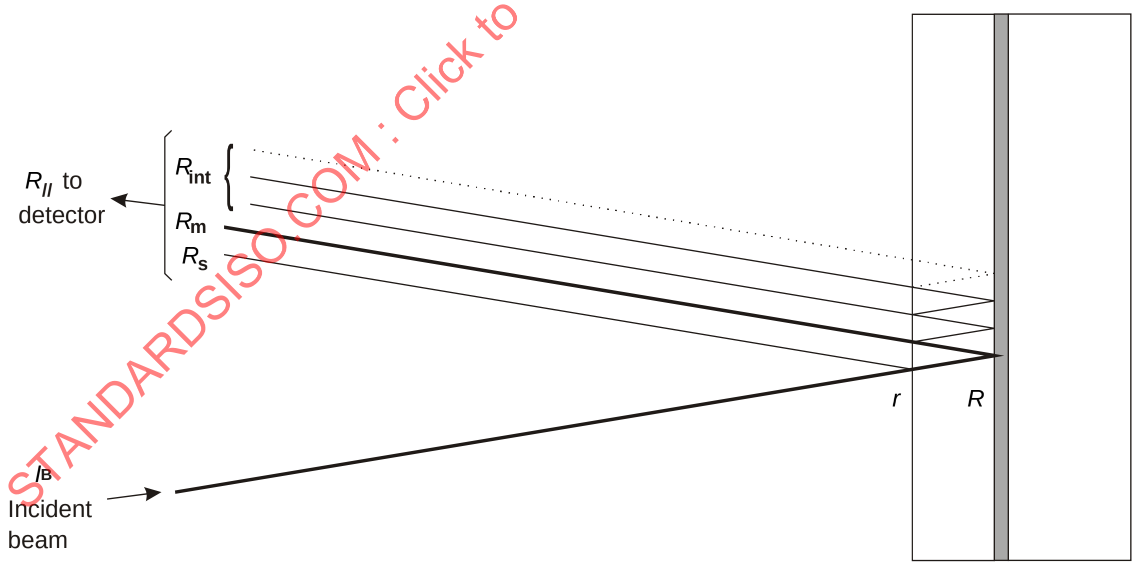


Figure B.1 — Reflectivity calibration

In this figure the following applies:

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 focused 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 ($R_s + R_m + R_{int}$)

The reflectivity of the Entrance surface is defined by:

$$r = \left(\frac{n-1}{n+1}\right)^2$$, where n is the index of refraction of the Cover Layer.

The main reflectance $R_m = R_{//} - R_s - R_{int}$ which leads to:

$$R_{ref} = \frac{R_m}{I_B} = \left[\frac{(1-r)^2 \times \left(\frac{R_{//}}{I_B} - r\right)}{1 - r \times \left(2 - \frac{R_{//}}{I_B}\right)}\right]$$

The Reference disk shall be measured on a Reference drive. The total detector current (the sum of all four elements of the photodetector = 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 Recordable Area

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.

c) Calculate the unrecorded virgin disk reflectivity $R_{g\text{-}v}$ in the Groove Tracks of the Recordable Area as follows: $R_{g\text{-}v} = \frac{(I_1+I_2)_G}{(I_1+I_2)_{ref}} \times R_{ref}$.

Reflectivity in Recorded Recordable 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 G.1).

c) Calculate the recorded disk reflectivity R_{8H} in the Groove Tracks of the Recordable Area as follows: $R_{8H} = \frac{I_{8H}}{(I_1 + I_2)_{ref}} \times R_{ref}$.

Remark: 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.

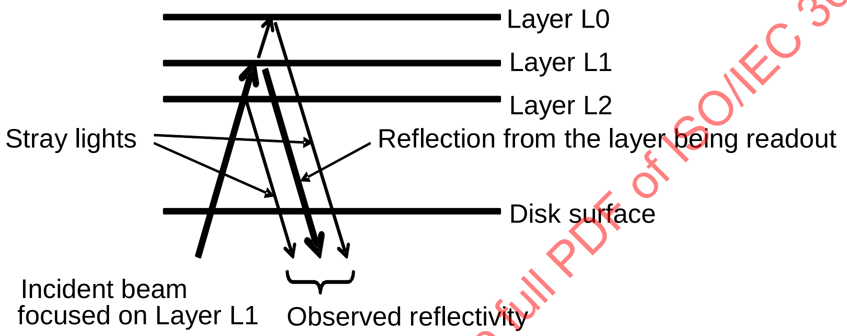


Figure B.2 — Influence of stray lights from other layers

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.

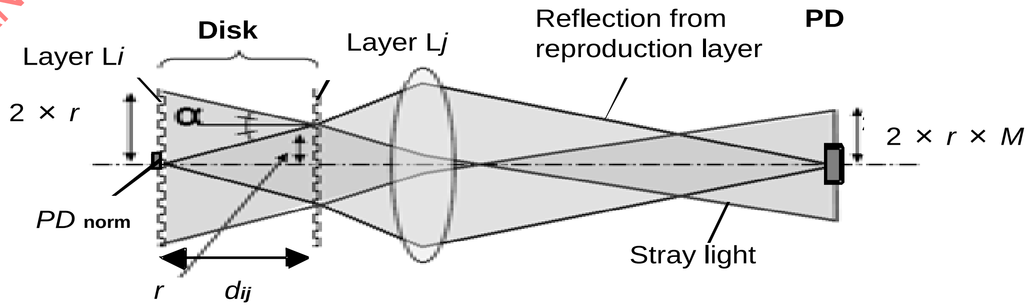


Figure B.3 — Ray trace of stray light

i : Layer index of reproduction layer
j : Layer index of other layer
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 Layers Li and Lj
r : spot radius on the other Layer: $r = d_{ij} \tan\alpha$
$PD_{\mathbf{norm}}$: size of detector projected on the reproduction layer (see 9.4)
M : transversal optical magnification of the optical system,

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 Lj and the detector, both projected on the reproduction layer is then derived as bellow:

$$A_{ij} = \frac{PD_{\mathbf{norm}}}{\pi(2r)^2} = \frac{PD_{\mathbf{norm}}}{\pi(2d_{ij}\tan\alpha)^2}$$

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 the following formula.

$$S_i = R_i + \sum_{\substack{j=0 \\ [j \neq i]}}^{N} R_j A_{ij} \quad (N = 2, 3)$$

where,

S_i= observed reflectivity ($R_{\mathbf{m,g\text{-}v}}$, $R_{\mathbf{m,8H}}$) of Layer Li (including influence of stray light),
R_i = compensated reflectivity ($R_{\mathbf{g\text{-}v}}$, $R_{\mathbf{8H}}$) of Layer Li,
N = number of Recording Layers of disk (2 for a TL disk, 3 for a QL disk).

For $R_{\mathbf{g\text{-}v}}$,

this formula can be rewritten as $\boldsymbol{S}_{\mathbf{g\text{-}v}} = \boldsymbol{A} \cdot \boldsymbol{R}_{\mathbf{g\text{-}v}}$ using the vector and matrix representation where

$\boldsymbol{S}_{\mathbf{g\text{-}v}}$ is the observed reflectivity vector in the Unrecorded Virgin Layer, $\boldsymbol{R}_{\mathbf{g\text{-}v}}$ is the compensated reflectivity vector in the Unrecorded Virgin Layer, and $\boldsymbol{A}$ is the areal ratio matrix.

Thus, the compensated reflectivity vector $\boldsymbol{R}_{\mathbf{g\text{-}v}}$ can be derived as:

$$\boldsymbol{R}_{g\text{-}v} = \boldsymbol{A}^{-1} \bullet \boldsymbol{S}_{g\text{-}v} .$$

For $R_{\mathbf{8H}}$,

the compensated reflectivity in the Recorded Layer ($R_{\mathbf{8H}}$) can be expressed as the following formula.

$$R_{\mathbf{8H},i} = S_{\mathbf{8H},i} - \sum_{\substack{j=0 \\ [j \neq i]}}^{N} R_{\mathbf{g\text{-}v},j} A_{ij} \quad (N = 2, 3)$$

where $S_{\mathbf{8H}}$ 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).

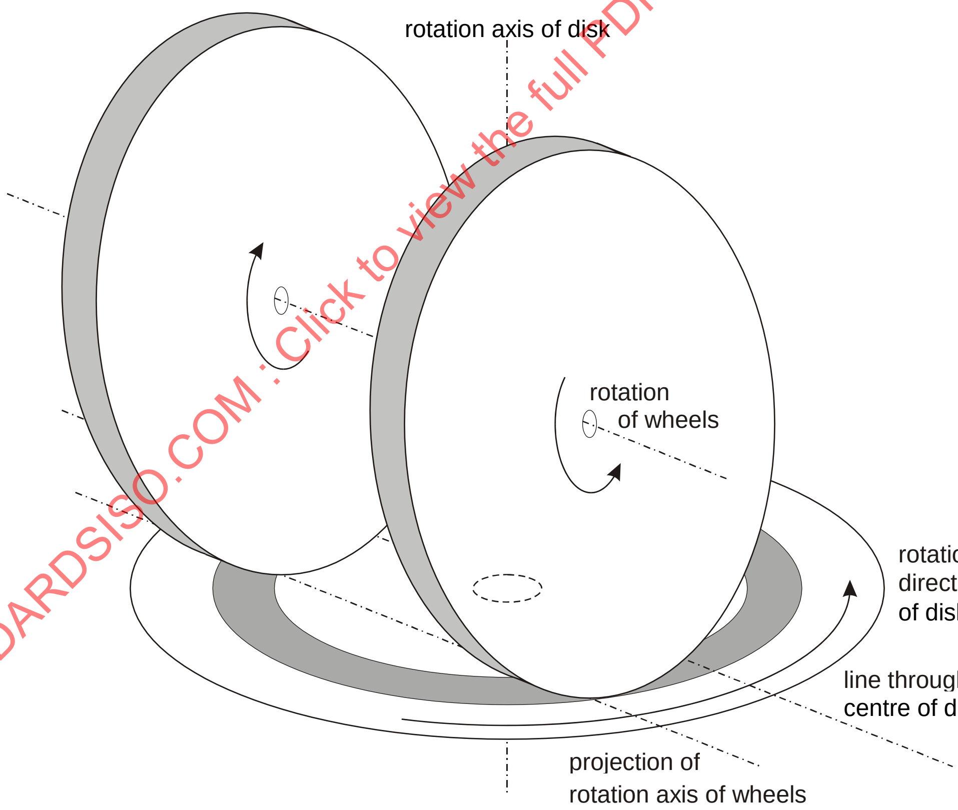


Figure C.1 — Typical abrasive test setup

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:

— new wheels shall be refaced for 100 cycles,

— 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 for 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.

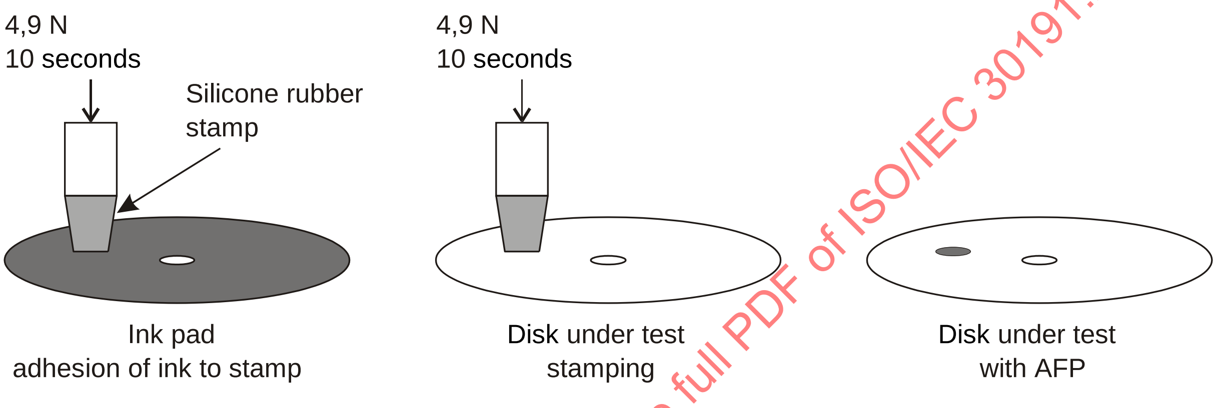


Figure D.1 — Applying AFP to disk

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 ∅ 16 mm × ∅ 12 mm × 20 mm height,

— Shore hardness is A60.

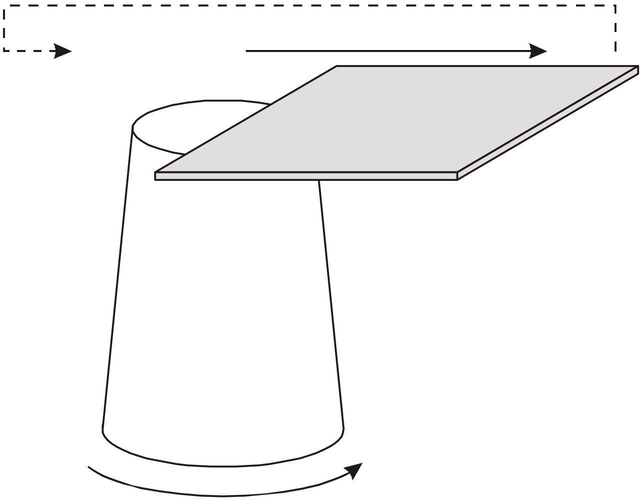


Figure D.2 — Stamp shape and preparation

To provide the stamp with random scratches it shall be abraded with a 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 8901, selected grade: class 11 (KANTO loam). For further information contact: (Association of Powder Process Industry and Engineering, JAPAN; http://www.appie.or.jp/english/).

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 seconds 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 seconds.

While rotating the Substrate on a spinner at 60 revolutions per minute, within 10 seconds at least 2 ml of the ink solution is applied on it at a radius of about 12 mm (see Figure D.3).

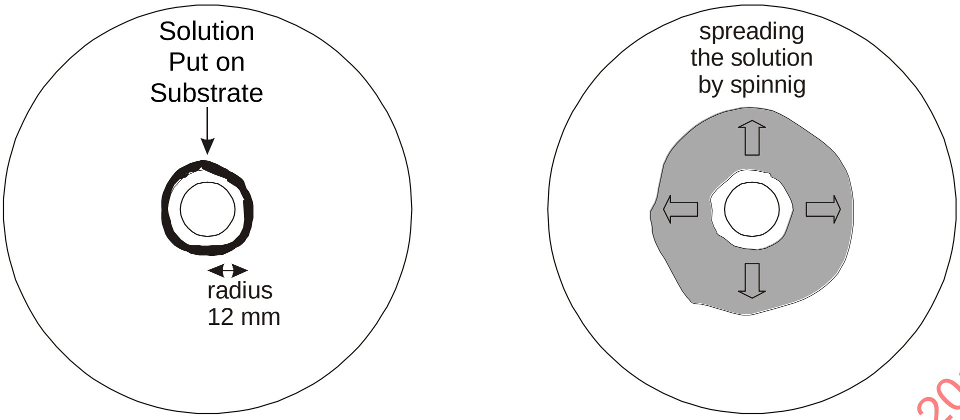


Figure D.3 — Spin coating ink pad

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 minutes in 5 seconds, which speed shall be held for one second (see Figure D.4). The spin-down time is not critical.

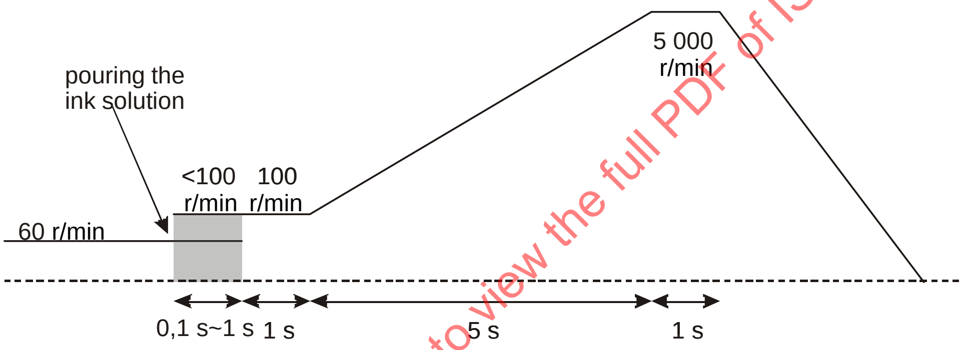


Figure D.4 — Speed profile for spin coating ink pad

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 an 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-normalized 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: 1 913,043 kHz,
— Span: zero span,
— Resolution bandwidth: 30 kHz,
— Video bandwidth: 100 Hz,
— Sweeptime: 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).

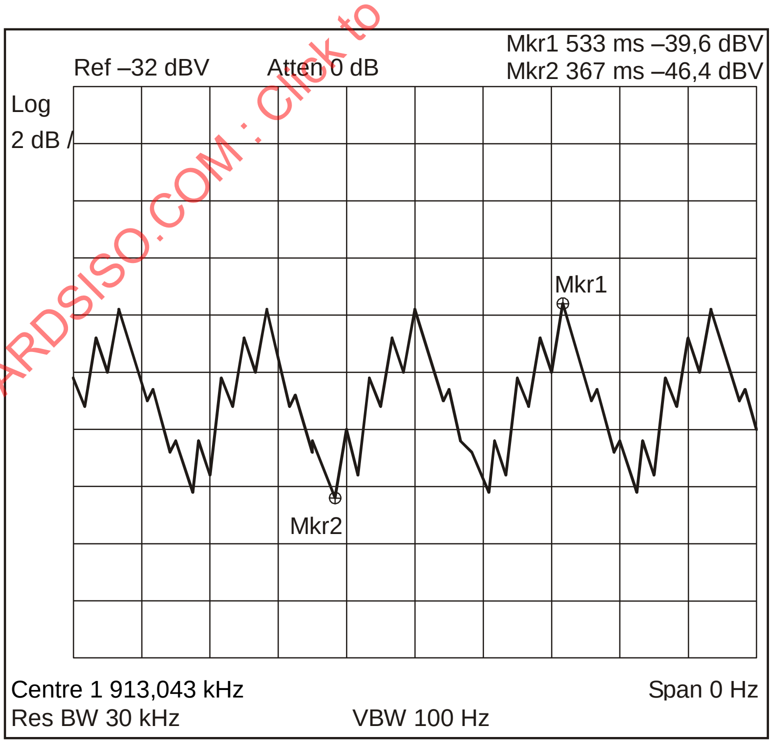


Figure E.1 — Example of spectrum analyzer showing wobble signal

The signal level at marker Mkr2 represents the minimum wobble signal $WS_{\mathbf{min}}$ in dBV. Because the spectrum analyzer measures RMS values, a multiplication factor of $2\times\sqrt{2}$ shall be added to translate the measured value into volts peak (–46,4 dBV in the example corresponds to 13,5 mVpeak).

Step 2) measurement of the non-normalized Push-Pull signal

Next the open loop Push-Pull signal $(I_1 - I_2)_{\mathbf{pp}}$ is measured (see 25.4):

suppose for this example the value is 30 mVpp.

Step 3) calculate the normalized wobble signal

$$NWS_{\mathbf{min}} = \frac{WS_{\mathbf{min}}}{(I_1 - I_2)_{\mathbf{pp}}} = \frac{13{,}5}{30} = 0{,}45$$

Step 4) determine the wobble beat

The signal level at marker *Mkr1* represents the maximum wobble signal $WS_{\mathbf{max}}$ in dBV.

The wobble beat is now:

$$WS_{\mathbf{max}} - WS_{\mathbf{min}} = 6{,}8\ \text{dB} \quad \text{or} \quad NWS_{\mathbf{max}} = 2{,}2 \times NWS_{\mathbf{min}}$$

Step 5) measurement of the carrier to noise ratio 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,
- Sweeptime: 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).