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SUPER AUDIO CD

# Super Audio CD System Description

## Part 1 Physical Specification

Version 2.0

December 2004

SONY PHILIPS

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# 1 General

## 1.1 Scope

This document describes the Physical part of the Super Audio CD system. The Super Audio CD System Description consists of three parts:

- Part 1, Physical Specification
- Part 2, Audio Specification
- Part 3, Copy Protection Specification

In this document 3 types of optical discs are described, all of which shall be playable on dedicated Super Audio CD players and one of which on normal CD players as well.
These 3 types are identified as:

- Single Layer disc (type SL), having 1 layer playable on Super Audio CD players only. This type of disc is available in two sizes: 120 mm and 80 mm.
- Dual Layer disc (type DL), having 2 layers both playable on Super Audio CD players only. This type of disc, specially designed for Long Play, is only available in one size: 120 mm.
- Hybrid Layer disc (type HL), one layer of which is playable on Super Audio CD players only and the other layer (conforming to the CD standard) is playable on normal CD players. This type of disc, specially designed for backwards compatibility with existing CD players, is available in two sizes: 120 mm and 80 mm.

## 1.2 General description

### 1.2.1 The Single Layer Super Audio CD

(see 2.1.1 and 2.2.1)
The Single Layer Super Audio CD is a disc consisting of 2 substrates, one representing a High Density (HD) recorded layer and the other being a dummy substrate. The 2 substrates are bonded together with the HD layer at the inside. The HD layer is read-out via the front surface of the substrate representing that layer. The distance from the read-out surface to the HD layer is 0.6 mm. Only the new Super Audio CD players can playback the HD layer.

### 1.2.2 The Dual Layer Super Audio CD

(see 2.1.2 and 2.2.2)
The Dual Layer Super Audio CD is a disc consisting of 2 substrates, both representing a High Density (HD) recorded layer. The 2 substrates are bonded together with both the HD layers at the inside, separated by a Spacer Layer with a defined thickness. Both HD layers are read-out via one and the same surface. The distance from the read-out surface to the HD layers is about 0.6 mm. The second HD layer is read-out through the first HD layer. Only the new Super Audio CD players can playback the HD layers.

### 1.2.3 The Hybrid Layer Super Audio CD

(see 2.1.3 and 2.2.3)
The Hybrid Layer Super Audio CD is a disc consisting of 2 substrates, one representing a High Density (HD) recorded layer and the other representing a CD recorded layer. The 2 substrates are bonded together back to front, with the HD layer at the inside and the CD layer at the outside. Both the HD layer and the CD layer are read-out via one and the same surface. The distance from the read-out surface to the HD layer is 0.6 mm and the distance from the read-out surface to the CD layer is 1.2 mm. The CD layer is read-out through the HD layer. Existing CD players can playback the CD layer of the Super Audio CD, while the new Super Audio CD players can playback the HD layer.

## 1.3 References and conformance

Super Audio CD discs conform to all mandatory requirements specified in this document. All parts in this document are mandatory unless they are specially defined as recommended or optional or informative.
Super Audio CD discs also conform to the applicable parts of the System Descriptions or international standards that are listed below:

- SA-CD part 2: "Scarlet Book" part 2
  **Super Audio CD System Description,**
  part 2: Audio Specification
  Royal Philips Electronics and Sony Corporation

- SA-CD part 3: "Scarlet Book" part 3
  **Super Audio CD System Description,**
  part 3: Copy Protection Specification
  Royal Philips Electronics and Sony Corporation

- CD-DA: Compact Disc Digital Audio, specified in the
  **System Description Compact Disc Digital Audio** ("Red Book"),
  Royal Philips Electronics and Sony Corporation

- IEC 908: **Compact disc digital audio system**

## 1.4 Definitions

For the purpose of this document the following definitions apply.

### 1.4.1 Adhesive layer

A layer of adhesive material bonding together the two parts of the disc.

### 1.4.2 Channel bit

The elements by which, after modulation, the binary values ZERO and ONE are represented on the disc by pits.

### 1.4.3 Clamping Zone

The annular part of the disc within which a clamping force is applied by a clamping device.

### 1.4.4 Digital Sum Value (DSV)

The arithmetic sum obtained from a bit stream by allocating the decimal value 1 to bits set to ONE and the decimal value -1 to bits set to ZERO.

### 1.4.5 Disc Reference Plane

A plane defined by the perfectly flat annular surface of an ideal spindle onto which the Clamping Zone of the disc is clamped, and which is normal to the axis of rotation.

### 1.4.6 Dual Layer disc

An optical disc with one entrance surface, which gives access to two HD recorded layers.

### 1.4.7 Dummy substrate

A layer which may be transparent or not, provided for the mechanical support of the disc and/or of a recorded layer.

### 1.4.8 Entrance surface

The surface of the disc onto which the optical beam first impinges.

### 1.4.9 Hybrid Layer disc

An optical disc with one entrance surface, which gives access to one HD recorded layer and one CD recorded layer.

### 1.4.10 Optical disc

A disc that accepts and retains information in the form of pits in a recorded layer that can be read by an optical beam.

### 1.4.11 Physical sector number

A serial number allocated to physical sectors on the disc.

### 1.4.12 Read-only disc

An optical disc in which the information has been recorded when manufacturing the disc. The information cannot be modified and can only be read from the disc.

### 1.4.13 Recorded layer

A layer of the disc on, or in, which data is recorded.

### 1.4.14 Reed-Solomon code

An error detection and/or correction code for the correction of errors.

### 1.4.15 Reserved field

A field set to all ZEROs unless otherwise stated, and reserved for future standardization.

### 1.4.16 Sector

The smallest part of a track in the Information Zone that can be accessed independently of other addressable parts.

### 1.4.17 Single Layer disc

An optical disc with one entrance surface, which gives access to one HD recorded layer.

### 1.4.18 Spacer

In the case of Dual Layer discs, the transparent layer placed between the two recorded layers accessible through the same entrance surface.

### 1.4.19 Substrate

A transparent layer of the disc, provided for mechanical support of the recorded layer(s), through which the optical beam can access the recorded layer(s).

### 1.4.20 Track

A 360° turn of a continuous spiral. This definition of a track is only valid in this part of the Super Audio CD System Description.

### 1.4.21 Track pitch

The distance between the centrelines of a pair of adjacent tracks, measured in radial direction.

### 1.4.22 Zone

An annular area of the disc.

## 1.5 Conventions and notations

### 1.5.1 Representation of numbers

A measured value is rounded off to the least significant digit of the corresponding specified value. For instance, it implies that a specified value of 1.26 with a positive tolerance of +0.01 and a negative tolerance of -0.02 allows a range of measured values from 1.235 to 1.275.

Numbers in decimal notations are represented by the digits 0 to 9.

Numbers in hexadecimal notation are represented by the hexadecimal digits 0 to 9 and A to F in parentheses.

The setting of bits is denoted by ZERO and ONE.

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.
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.

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

In each data field, the data is recorded so that the most significant byte (MSB), identified as Byte 0, shall be recorded first and the least significant byte (LSB) last.

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

### 1.5.2 Names

The names of entities, e.g. specific tracks, fields, etc., are given with an initial capital.

## 1.6 List of acronyms

| | |
|---|---|
| BP | Byte Position |
| BPF | Band Pass Filter |
| CLV | Constant Linear Velocity |
| DCC | d.c. Component (suppress control) |
| DL | Dual Layer |
| DPD | Differential Phase Detection |
| DSV | Digital Sum Value |
| ECC | Error Correction Code |
| EDC | Error Detection Code |
| EQ | Equalizer |
| FWHM | Full Width at Half Maximum |
| HL | Hybrid Layer |
| HF | High Frequency |
| ID | Identification Data |
| IED | ID Error Detection (code) |
| IR | Index of Refraction |
| LPF | Low-Pass Filter |
| LSB | Least Significant Byte |
| lsb | least significant bit |
| MSB | Most Significant Byte |
| msb | most significant bit |
| NRZ | Non Return to Zero |
| NRZI | Non Return to Zero Inverted |
| OTP | Opposite Track Path |
| PBS | Polarizing Beam Splitter |
| PE | Phase Encoded |
| PI | Parity (of the) Inner (code) |
| PLL | Phase-Locked Loop |
| PO | Parity (of the) Outer (code) |
| PTP | Parallel Track Path |
| PUH | Pick-Up Head |
| RIN | Relative Intensity Noise |
| RS | Reed-Solomon (code) |
| RZ | Return to Zero |
| SL | Single Layer |
| SYNC Code | Synchronisation Code |

 

# 2 Disc specifications

## 2.1 Disc outline

The following figures show schematically the outline of the three disc types.

### 2.1.1 Single Layer disc

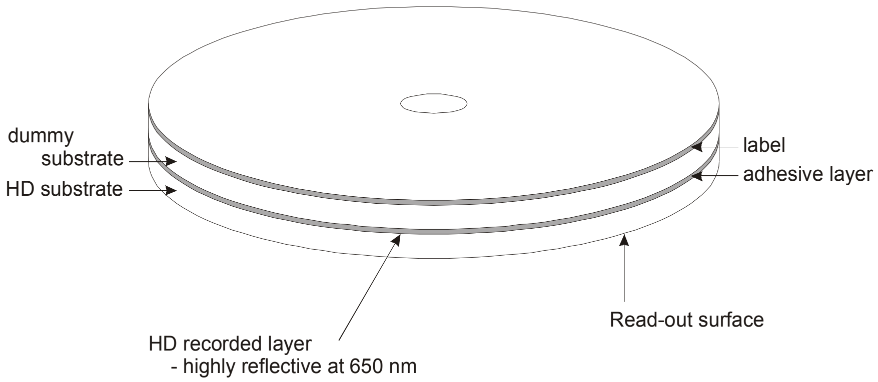


**Figure 2-1 Single Layer disc**

### 2.1.2 Dual Layer disc

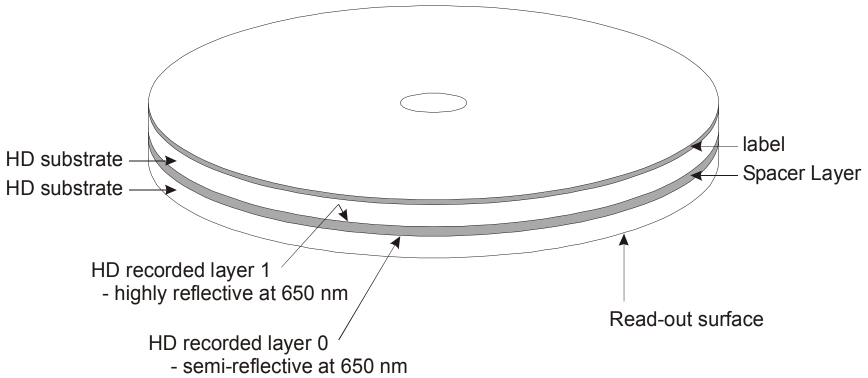


**Figure 2-2 Dual Layer disc**

### 2.1.3 Hybrid Layer disc

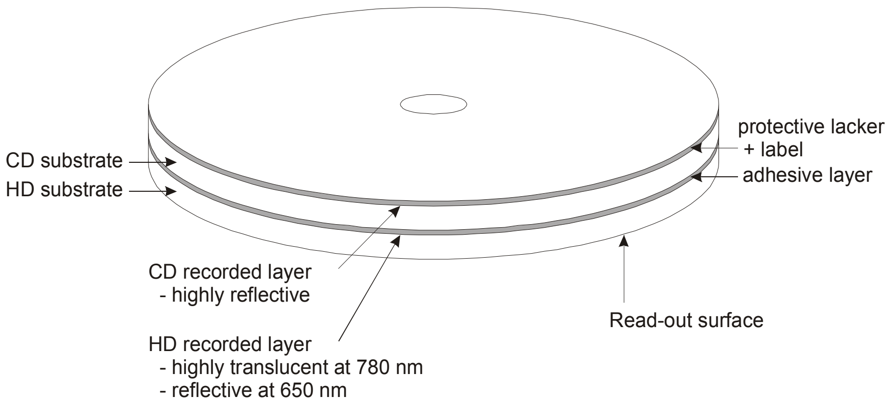


**Figure 2-3 Hybrid Layer disc**

## 2.2 Principle of operation

### 2.2.1 Principle of operation of the Single Layer disc

The HD recorded layer is covered with a layer which has a high reflectivity for a wavelength of 650 nm (the HD laser wavelength). Read-out of the recorded layer takes place in the usual way.

### 2.2.2 Principle of operation of the Dual Layer disc

The HD recorded Layer 0 (closest to the read-out surface) is covered with a layer which has a certain reflectivity for a wavelength of 650 nm (the HD laser wavelength). The HD recorded Layer 1 is covered with a layer which has a high reflectivity for a wavelength of 650 nm.
The transparency/reflectivity of Layer 0 is balanced in such a way that the resulting amount of light reflected from each of the two layers as seen from the read-out surface is about the same.

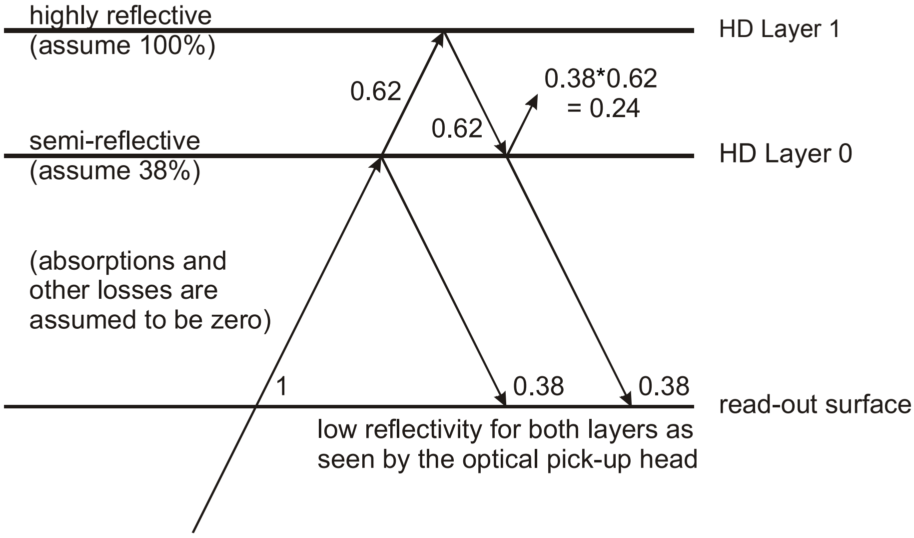


**Figure 2-4 Example of balancing the reflectivity of HD Layer 0 and HD Layer 1**

The two recorded layers are separated by a Spacer Layer of typically 55 µm. When focused on one of the two recorded layers, this Spacer Layer causes sufficient de-focusing of the light beam on the other recorded layer, to suppress the read-out signals of this other layer in the read-out optics.
These two measures make it possible to read-out HD Layer 1 through HD Layer 0 and the Spacer Layer.

### 2.2.3 Principle of operation of the Hybrid Layer disc

The HD recorded layer is covered with a layer which has a certain reflectivity for a wavelength of 650 nm (the HD laser wavelength) and a high transmission for a wave length of 780 nm (the CD laser wavelength).
The CD recorded layer is covered with a layer which has a high reflectivity at 780 nm.
Both layers are read-out from the same side of the disc, which means that the CD layer has to be read-out through the HD layer.

 

## 2.3 Environmental conditions

### 2.3.1 Operating environment

| | |
|---|---|
| temperature | : –25 °C to 70 °C |
| relative humidity | : 3 % to 95 % |
| absolute humidity | : 0.5 g/m$^3$ to 60 g/m$^3$ |
| atmospheric pressure | : 60 kPa to 106 kPa |
| sudden change of temperature | : 50 °C max. |
| sudden change of relative humidity | : 30 % max. |

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

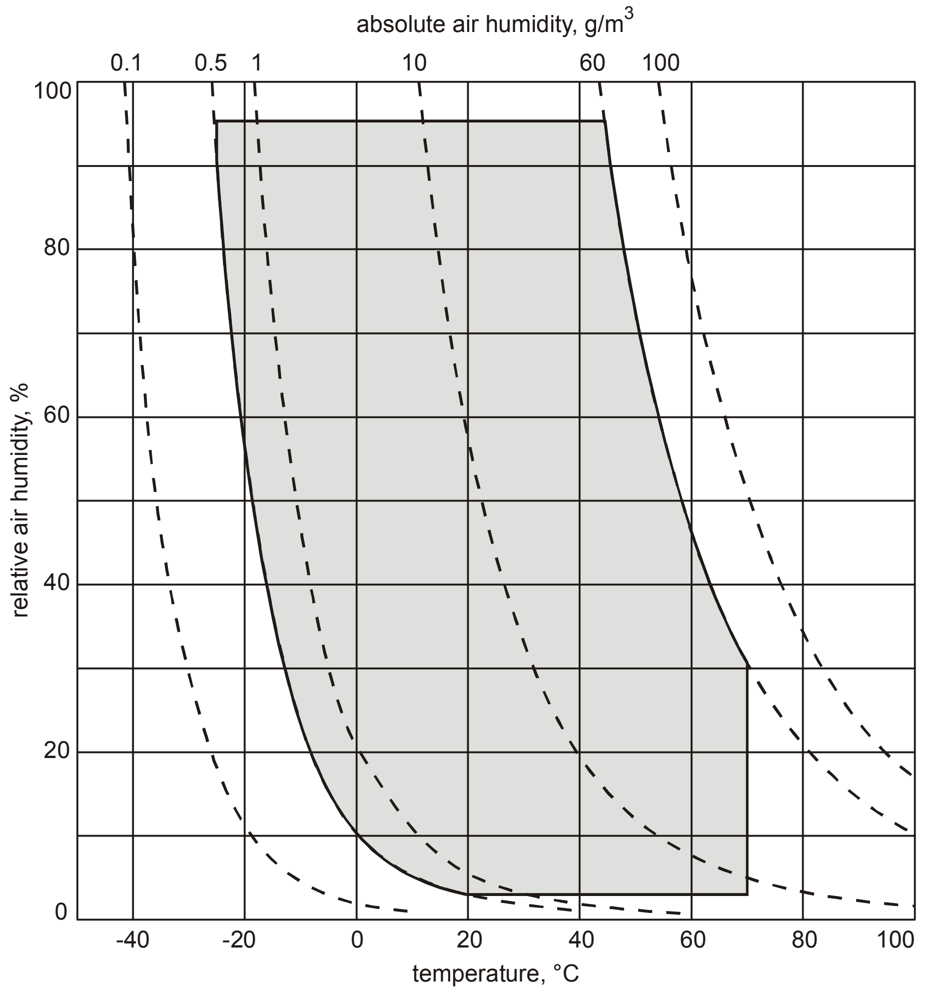


**Figure 2-5 Operating environment**

### 2.3.2 Storage environment

| | |
|---|---|
| temperature | : –20 °C to 50 °C |
| relative humidity | : 5 % to 90 % |
| absolute humidity | : 1 g/m$^3$ to 30 g/m$^3$ |
| atmospheric pressure | : 75 kPa to 106 kPa |
| temperature variation | : 15 °C/h max. |
| relative humidity variation | : 10 %/h max. |

### 2.3.3 Climatic storage tests

Dry heat test according to IEC 68-2-2 Ba:
T = 55 °C, RH = 50%, 96 hrs.

Damp heat cycle test according to IEC 68-2-30 Db:
$T_{high}$ = 40 °C, $T_{low}$ = 25 °C, RH = 95 %, cycle time = 12 + 12 hrs, 6 cycles.

After these tests one should allow for some recovery time before measuring (24 or 48 hrs).

## 2.4 Measuring conditions

### 2.4.1 Environmental conditions

| | for dimensional measurements: | for other measurements: |
|---|---|---|
| temperature: | 23 ± 2 °C | 15 °C to 35 °C |
| relative humidity: | 45 % to 55 % | 45 % to 75 % |
| atmospheric pressure: | 86 kPa to 106 kPa | 86 kPa to 106 kPa |

### 2.4.2 Disc clamping

| | |
|---|---|
| actual clamping area (in diameter): | $22.3^{+0.5}_{-0.0}$ to $32.7^{+0.0}_{-0.5}$ mm |
| clamping force: | $F_1 = 2.0 \pm 0.5$ N |
| top angle of tapered cone for centering of the disc: | 40.0 ± 0.5 ° |
| chucking force exerted by the tapered cone on the rim of the centre hole: | $F_2 < 0.5$ N |

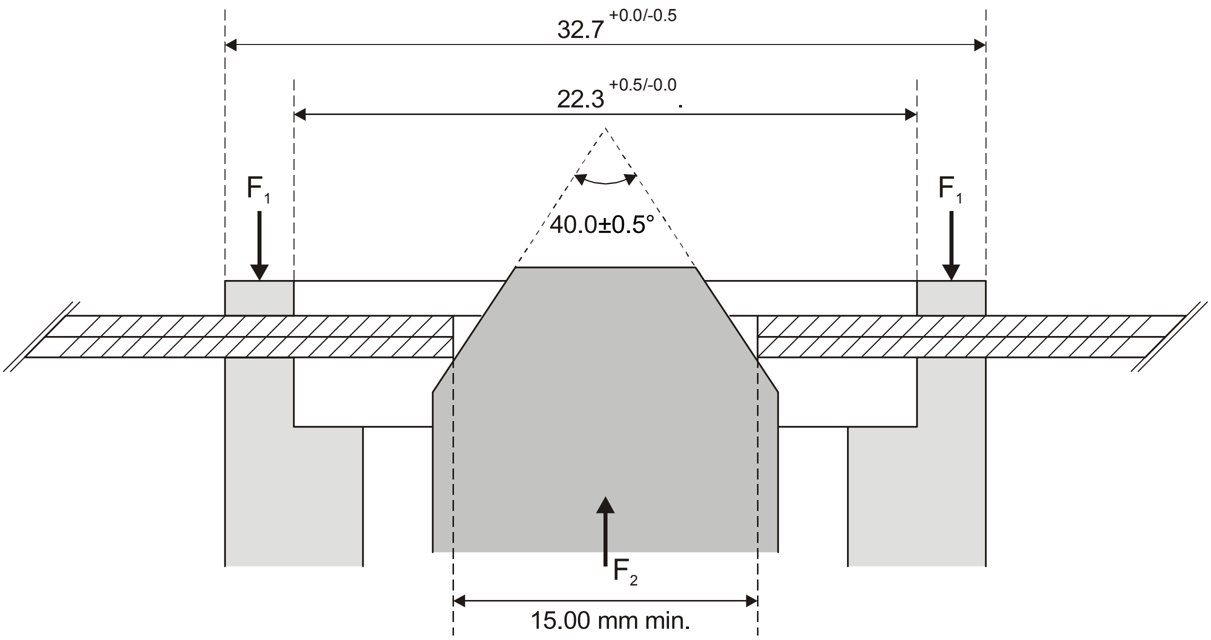


**Figure 2-6 Clamping conditions for measurements**

### 2.4.3 Optical Pick-up Unit

**Table 2-1 Specifications of Optical Pick-up Heads**

| | *for measuring the CD layer* | *for measuring the HD layer* |
|---|---|---|
| wavelength ($\lambda$) | 780 ± 10 nm | 650 ± 5 nm |
| polarization | circular | circular |
| polarizing beam splitter (PBS) | --- | recommended |
| numerical aperture (NA) | 0.45 ± 0.01 | 0.60 ± 0.01 |
| thickness / refractive index of a parallel substrate, for the spherical aberrations of which the objective lens has to be compensated | 1.2 / 1.55 | 0.6 / 1.55 |
| wave front aberration | < 0.05 $\lambda$ | < 0.033 $\lambda$ |
| light intensity at the rim of the pupil of the objective lens | > 70 % in tangential direction<br>50 to 80 % in radial direction | > 90 % in tangential direction<br>60 to 70 % in radial direction |
| relative intensity noise of the laser diode | --- | –134 dB/Hz max.<br>$\left( 10 * \log \left\{ \frac{\text{a.c.lightpowerdensity / Hz}}{\text{d.c.lightpower}} \right\} \right)$ |
| normalized area (S / M$^2$) of the photo detector | --- | 100 $\mu m^2 \leq$ (S / M$^2$) $\leq$ 144 $\mu m^2$<br>(S = total active surface of the 4-quadrant photo detector diode, M = transversal optical magnification from the disc to its conjugate plane near the 4-quadrant photo detector.) |

### 2.4.4 Reference scanning velocity

For measuring the CD layer at a channel bit rate of 4.3218 Mbit/sec: 1.2 to 1.4 m/sec
For measuring the HD layer at a channel bit rate of 26.15625 Mbit/sec:
for Single Layer and Hybrid Layer discs: 3.49 ± 0.03 m/sec
for Dual Layer discs: 3.84 ± 0.03 m/sec

The sense of rotation is counterclockwise as seen by the optical pick-up unit.

CLV rotation servo characteristic for CD layer and HD layer: closed loop –3 dB bandwidth = 5 Hz

### 2.4.5 Measuring conditions for the operational signals

**Table 2-2 Specifications of signal processing**

| | *for measuring the CD layer* | *for measuring the HD layer* |
|---|---|---|
| detection optics and photo-diode pre-amp's | Bandwidth: d.c. to ≥ 3 MHz (-3dB) | Bandwidth: d.c. to ≥ 20 MHz (-3dB) |
| HF signal filtering and equalization | LPF: $5^{th}$ order Bessel filter, $f_{-3dB}$ = 1.5 MHz<br><br>HPF: $1^{st}$ order, $f_{-3dB}$ = 1600 Hz<br><br>EQ: no equalizer shall be used | LPF: $6^{th}$ order Bessel filter, $f_{-3dB}$ = 8.2 MHz<br><br>HPF: $1^{st}$ order, $f_{-3dB}$ = 1 kHz<br><br>EQ: 3-tap transversal filter: $H(z)=1.364*z^{-2} - 0.182*(1+z^{-4})$ |
| HF signal slicer | $1^{st}$ order integrating feedback auto-slicer: closed loop –3 dB bandwidth = 1 kHz | $1^{st}$ order integrating feedback auto-slicer: closed loop –3 dB bandwidth = 5 kHz |
| HF bit clock regeneration PLL | open loop transfer function: $2^{nd}$ order slope crossing 0 dB at 2 kHz, changing into $1^{st}$ order slope crossing 0 dB at 9 kHz | open loop transfer function: $2^{nd}$ order slope crossing 0 dB at 6 kHz, changing into $1^{st}$ order slope crossing 0 dB at 15 kHz |

### 2.4.6 Reference servo systems

#### 2.4.6.1 Normalized servo transfer function

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

$$H_S(i\omega) = \frac{1}{3} * \left(\frac{\omega_0}{i\omega}\right)^2 * \frac{1 + \frac{3*i\omega}{\omega_0}}{1 + \frac{i\omega}{3*\omega_0}}$$

where: $\omega = 2\pi * f$
$\omega_0 = 2\pi * f_0$
$i = \sqrt{-1}$

$f_0$ 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: $f_2 = f_0 * 3$

### 2.4.6.2 Reference servo for axial tracking

#### 2.4.6.2.1 Reference servo for axial tracking of the HD layers

For the open loop transfer function H of the Reference Servo for axial tracking, $|1+H|$ is limited as schematically shown by the shaded area of the Figure 2-7:

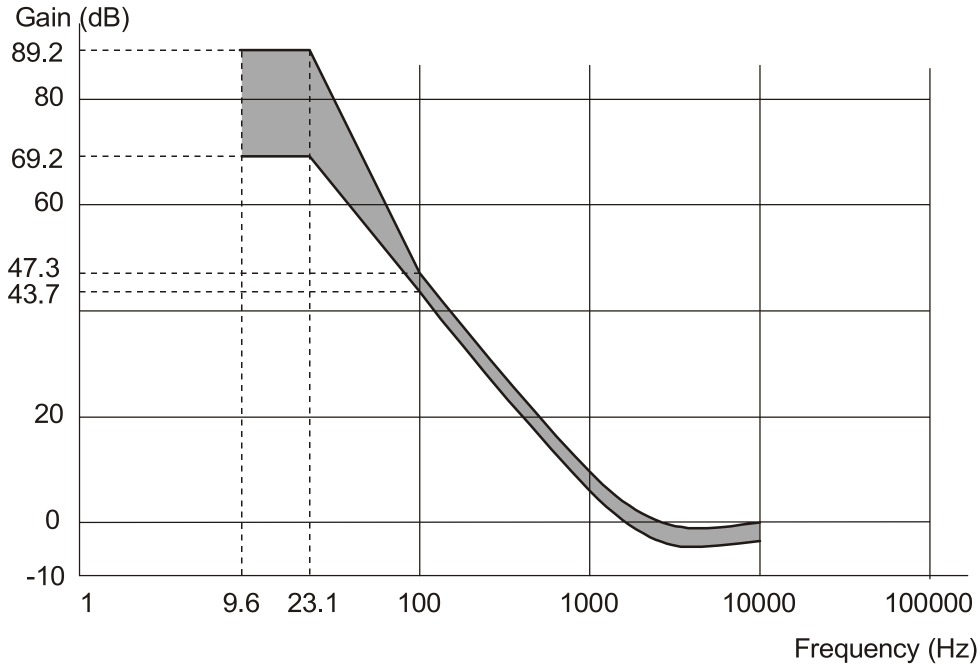


**Figure 2-7 Servo characteristic for axial tracking**

**Frequency range 100 Hz to 10 kHz:**
$|1+H|$ shall be within 20% of $|1+H_S|$
The crossover frequency $f_0$ of $H_S$ is specified by the following equation, where $\alpha_{max}$ is the maximum expected axial acceleration of 15 m/s$^2$.The tracking error $e_{max}$, caused by this $\alpha_{max}$, shall be 0.2 µm. Thus the crossover frequency shall be:

$$f_0 = \frac{1}{2\pi}\sqrt{\frac{3*\alpha_{max}}{e_{max}}} = \frac{1}{2\pi}\sqrt{\frac{3*15}{0.2*10^{-6}}} = 2.4\text{kHz}$$

**Frequency range 23.1 Hz to 100 Hz:**
$|1+H|$ shall within the limits defined by the following four points:

| | |
|---|---|
| 43.7 dB at 100 Hz | ($\lvert 1+H_S \rvert$ at 100 Hz – 20%) |
| 47.3 dB at 100 Hz | ($\lvert 1+H_S \rvert$ at 100 Hz + 20%) |
| 69.2 dB at 23.1 Hz | ($\lvert 1+H_S \rvert$ at 23.1 Hz –20%) |
| 89.2 dB at 23.1 Hz | ($\lvert 1+H_S \rvert$ at 23.1 Hz –20% + 20 dB) |

**Frequency range 9.6 Hz to 23.1 Hz:**
$|1+H|$ shall be between 69.2 dB and 89.2 dB.

#### 2.4.6.2.2 Reference servo for axial tracking of the CD layer

TBD.

 

### 2.4.6.3 Reference servo for radial tracking

#### 2.4.6.3.1 Reference servo for radial tracking of the HD layer

For the open loop transfer function H of the Reference Servo for radial tracking, │1+H│ is limited as schematically shown by the shaded area of the Figure 2-8:

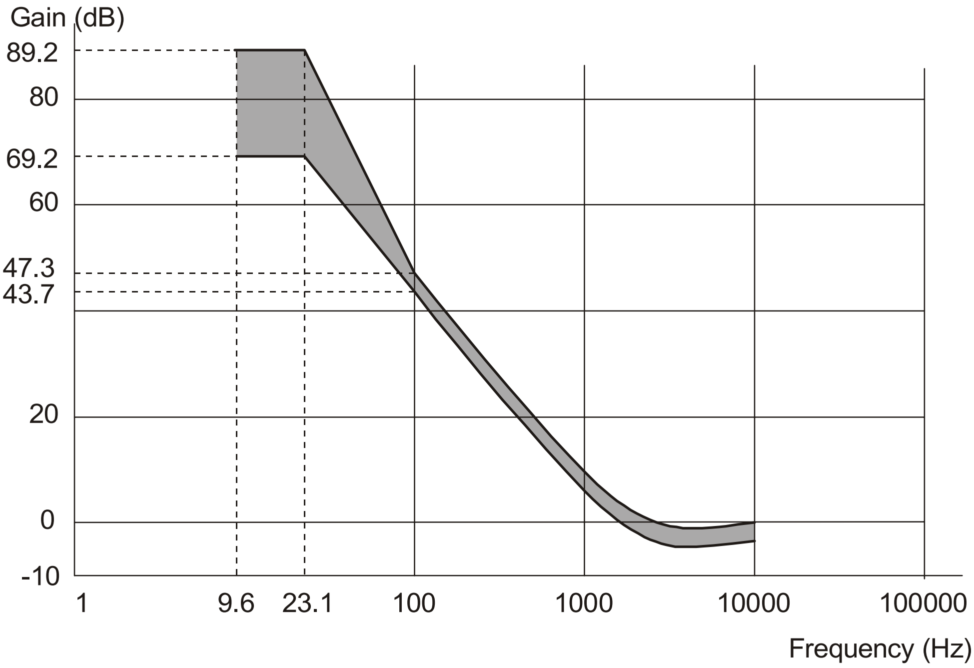


**Figure 2-8 Servo characteristic for radial tracking**

**Frequency range 100 Hz to 10 kHz:**
│1+H│ shall be within 20% of │1+$H_S$│
The crossover frequency $f_0$ of $H_S$ is specified by the following equation, where $\alpha_{max}$ is the maximum expected radial acceleration of 1.5 m/s$^2$.The tracking error $e_{max}$, caused by this $\alpha_{max}$, shall be 0.02 µm. Thus the crossover frequency shall be:

$$f_0 = \frac{1}{2\pi}\sqrt{\frac{3 * \alpha_{max}}{e_{max}}} = \frac{1}{2\pi}\sqrt{\frac{3 * 1.5}{0.02 * 10^{-6}}} = 2.4\text{kHz}$$

**Frequency range 23.1 Hz to 100 Hz:**
│1+H│ shall within the limits defined by the following four points:

| | |
|---|---|
| 43.7 dB at 100 Hz | (│1+$H_S$│ at 100 Hz – 20%) |
| 47.3 dB at 100 Hz | (│1+$H_S$│ at 100 Hz + 20%) |
| 69.2 dB at 23.1 Hz | (│1+$H_S$│ at 23.1 Hz – 20%) |
| 89.2 dB at 23.1 Hz | (│1+$H_S$│ at 23.1 Hz – 20% + 20 dB) |

**Frequency range 9.6 Hz to 23.1 Hz:**
│1+H│ shall be between 69.2 dB and 89.2 dB.

#### 2.4.6.3.2 Reference servo for radial tracking of the CD layer

TBD.

## 2.5 Mechanical parameters

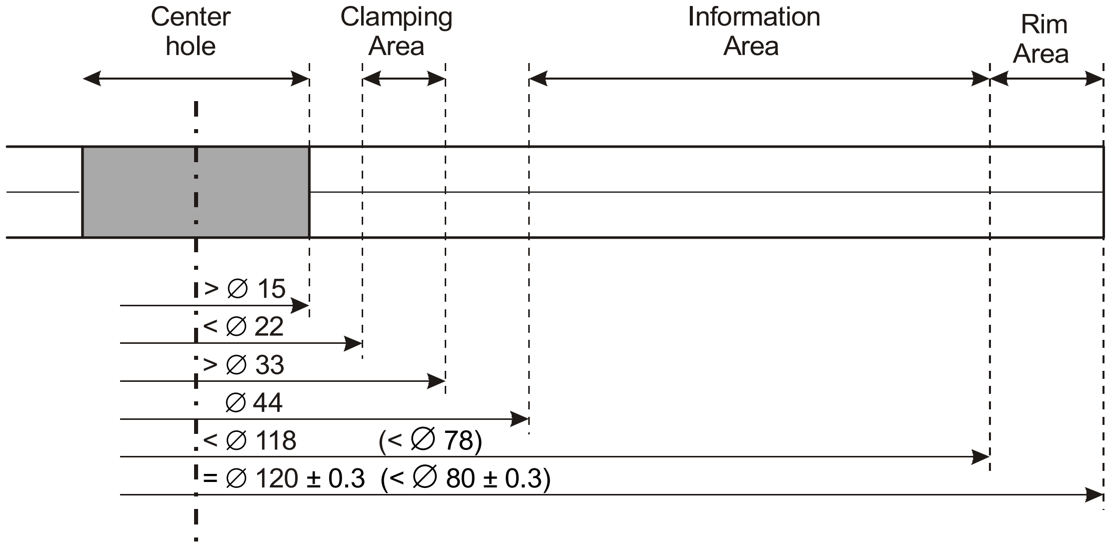


**Figure 2-9 Overview of disc dimensions**

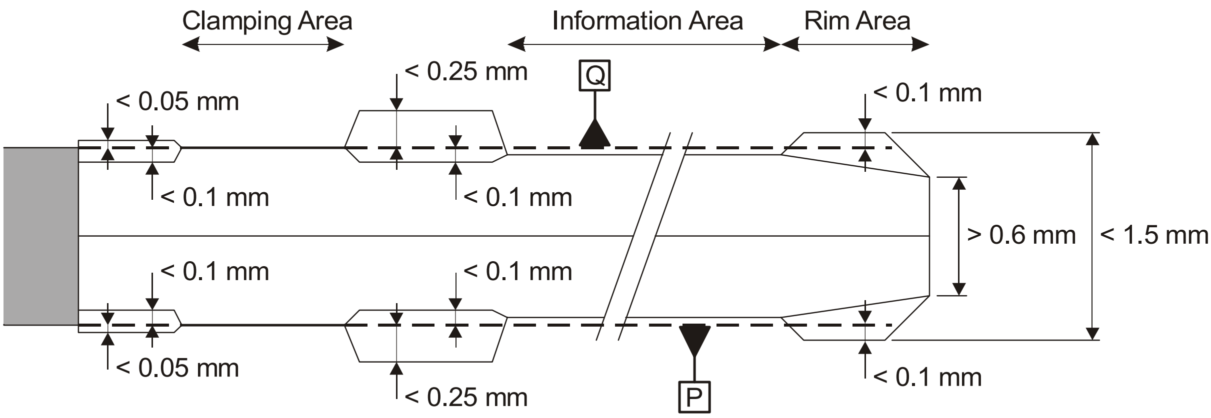


**Figure 2-10 Details of disc dimensions**

### 2.5.1 Reference planes and reference axis

The reference plane P is the plane determined by the surface of the clamping area at the read-out side of the disc.
The reference plane Q is the plane determined by the surface of the clamping area at the label side of the disc.
The reference axis A is the axis through the middle of the center hole, perpendicular to the reference plane P.

### 2.5.2 Outer diameter and run-out of outer edge

| | |
|---|---|
| The overall outer diameter of the disc shall be: | 120.0 ± 0.3 mm |
| The run-out of the outer edge of the disc shall be: | < 0.3 mm (p-p) |

### 2.5.3 Center hole

The diameter of the center hole of each substrate shall be: $15.00^{+0.15}_{-0.00}$ mm

The diameter of the center hole of the assembled disc shall be: ≥ 15.00 mm

There shall be no burr on both edges of the center hole.
The edge of the center hole shall be rounded off or chamfered. The rounding radius shall be 0.1 mm max. The chamfer shall extend over an height of 0.1 mm max.

The inside of the center hole shall be flat within the dimensions defined in Figure 2-11.

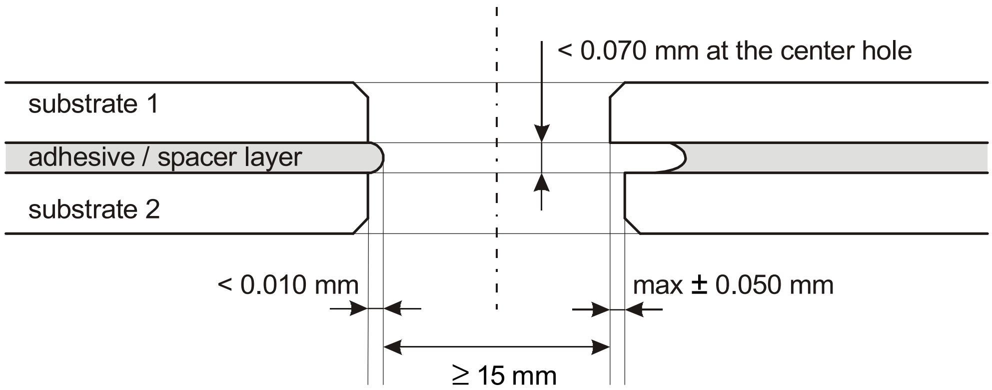


**Figure 2-11 Details of center hole**

### 2.5.4 Thickness of the disc

Total thickness of the disc, including protective layer and label: $1.20^{+0.30}_{-0.06}$ mm

### 2.5.5 Mass of the disc

| | |
|---|---|
| Mass of the disc | 13 - 20 g |
| Moment of inertia | ≤ 0.040 g.m$^2$ |
| Dynamic unbalance | ≤ 7 g.mm |
| | ≤ 5 g.mm recommended |

### 2.5.6 Clamping area

Inner diameter of the disc clamping area: $d_{in} \leq 22.0$ mm
Outer diameter of the disc clamping area: $d_{out} \geq 33.0$ mm

Thickness of the disc within the clamping area: $1.20^{+0.20}_{-0.10}$ mm

Within the clamping area ($d_{in} < d < d_{out}$) both sides of the disc shall be flat within 0.1 mm.
Within the clamping area ($d_{in} < d < d_{out}$) both sides of the disc shall be parallel within 0.1 mm.

In the area inside the clamping area ($d < d_{in}$) the surfaces may be below the clamping area surfaces by 0.1 mm max. These surfaces may be uneven or may have burrs up to 0.05 mm max. above to the clamping area surfaces.

In the area between the clamping area and the Information Area ($d_{out} < d < 44$ mm), the surfaces may be above the clamping area surfaces by 0.25 mm max. or below the clamping area surfaces by 0.1 mm max.

### 2.5.7 Information area

The Information area shall extend from diameter 44 mm to the beginning of the Rim area.
The outer diameter of the Information area shall be: $\leq$ 118 mm
The thickness of the disc in the Information area is as specified in 2.5.4.

#### 2.5.7.1 Use of the Information area in the CD Layer

The Information area in the CD Layer is used as described in the ***Red Book***, chapter on DISC SPECIFICATION / RECORDED AREA / 9, 10, 11 and in the chapter on DISC SPECIFICATION OF THE 8 cm CD / 9.2.

#### 2.5.7.2 Use of the Information area in the HD Layers

The Information area in the HD Layers is used to record the Information Zone.

##### 2.5.7.2.1 Sub-divisions of the Information Zone in the HD Layers

The Information Zone is subdivided in the following main parts:
- the Lead-in Zone
- the Data Zone
- the Lead-out / Middle Zone

The area extending from diameter 44.0 mm to diameter 45.2 mm shall be used as follows:
- it is the beginning of the Lead-in Zone of a Single Layer disc and Layer 0 of a Dual Layer disc;
- it is the end of the Lead-out Zone of Layer 1 of a Dual Layer disc.

In the first case, the Lead-in Zone shall end at diameter: $d_{DZB} = 48.0^{+0.0}_{-0.4}$ mm
which is the beginning of the Data Zone.

In the second case the Data Zone shall not extend toward the centre of the disc beyond diameter $d_{DZB}$.
The Lead-out Zone shall start after the Data Zone and end between diameters 44.0 mm and 45.2 mm.

The Data Zone shall start after the Lead-in Zone at diameter $d_{DZB}$.
It shall extend up to diameter: $d_{DZE}$ = 116.0 mm max.

The zone between diameters $d_{DZE}$ and $d_{LOE}$ constitutes the Lead-out Zone in the case of a Single Layer disc and the Middle Zone in the case of a Dual Layer disc.
The Lead-out / Middle Zone shall start after the Data Zone and end at diameter $d_{LOE}$, the value of which depends on the length of the Data Zone as shown in the Table 2-3:

**Table 2-3 End of the Information Zone**

| Outer diameter of the Data Zone | Outer diameter of the Lead-out / Middle Zone |
|---|---|
| $d_{DZE}$ < 68.0 mm | $d_{LOE} \geq$ 70.0 mm |
| $d_{DZE}$ = 68.0 to 115.0 mm | $d_{LOE} \geq d_{DZE}$ + 2.0 mm |
| $d_{DZE}$ = 115.0 to 116.0 mm | $d_{LOE} \geq$ 117.0 mm |

The outer diameter of the Lead-out Zone of the HD layer on a Hybrid disc shall be larger than the outer diameter of the Lead-out Area of the CD layer.

 

#### 2.5.7.2.2 Track geometry in the HD Layers

In the Information Zone (= Lead-in Zone + Data Zone + Lead-out/Middle Zone) tracks are constituted by a 360° turn of a spiral.

The track pitch shall be: 0.74 µm ± 0.03 µm

The track pitch averaged over the Data Zone shall be: 0.74 µm ± 0.01 µm

#### 2.5.7.2.3 Track modes in the HD Layers

In Single Layer and Hybrid Layer discs, tracks in the HD Layer are read from the inside diameter of the Information Zone to its outside diameter (see Figure 2-12). The track spiral is turning from the inside to the outside.

In Dual Layer discs, tracks are read starting on Layer 0 from the inner diameter of the Information Zone towards the outer diameter, continuing on Layer 1 from the outer diameter towards the inner diameter. Thus, there is a Middle Zone at the outer diameter on both layers (see Figure 2-12). The track spiral is turning from the inside to the outside on Layer 0 and in the reverse direction on Layer 1.

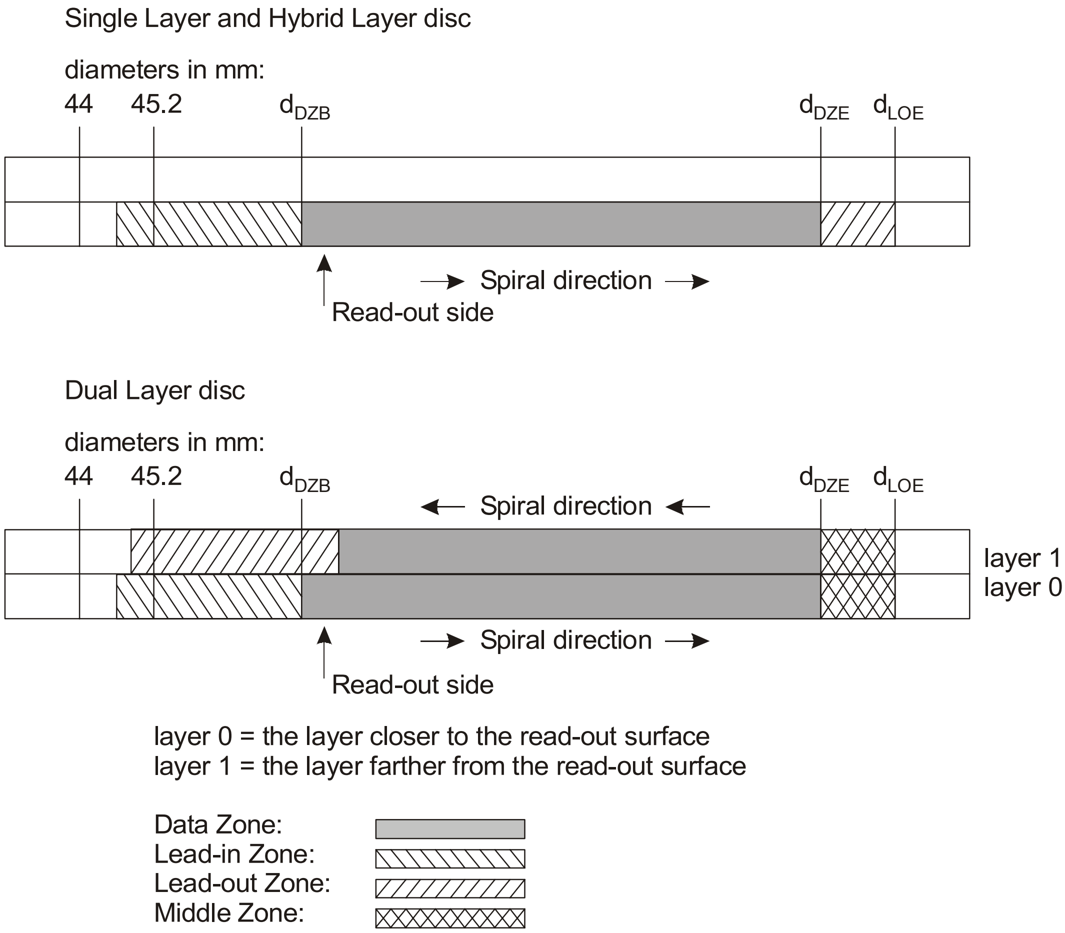


**Figure 2-12 Track modes on Single and Dual Layer discs**

The radial misalignment of the outer edge of the Data Zones of Layer 0 and Layer 1 shall be 0.5 mm max.

The radial misalignment of the outer edge of the Information Zones of Layer 0 and Layer 1 shall be 0.5 mm max.

#### 2.5.7.2.4 Channel bit length in the HD Layers

The Information Zone shall be recorded in CLV mode. The Channel bit length averaged over the Data Zone shall be:

133.3 nm ± 1.4 nm for a Single Layer disc or a Hybrid Layer disc,
146.7 nm ± 1.5 nm for a Dual layer disc.

### 2.5.8 Rim area

The Rim area is the area outside the Information area, starting at diameter $d_{LOE}$ at the end of the Lead-out / Middle Zone and extending to the outer diameter of the disc.
In the Rim area the surfaces shall not extend outside the reference planes P and Q by more than 0.1 mm. The total thickness of this area shall be ≤ 1.5 mm.
The outer edge of the disc shall be either rounded off with a rounding radius of 0.2 mm max. or be chamfered over 0.2 mm max.

### 2.5.9 Run-out

**Table 2-4 Axial run-out**

| | *CD layer* | *HD layer* |
|---|---|---|
| **2.5.9.1 Axial run-out** | As observed by the optical stylus, so including tolerances on thickness, refractive index and deflection. Disc rotating at the reference scanning velocity. | When measured by the PUH with the reference servo for axial tracking. Disc rotating at the reference scanning velocity. |
| Deviation of the recorded layer from its nominal position in the direction of the reference axis | ≤ 0.5 mm peak<br>≤ 0.4 mm rms | ≤ 0.3 mm |
| max. vertical acceleration | for frequencies < 500 Hz:<br>10 $m/s^2$ | for frequencies < 1000 Hz:<br>15 $m/s^2$ |
| residual tracking error below 10 kHz | ≤ 1 µm<br>(for freq. > 500 Hz) | ≤ 0.2 µm<br>Measuring filter:<br>Butterworth LPF,<br>slope = –80 dB/decade<br>with $f_{-3dB}$ = 10 kHz |

**Table 2-5 Radial run-out**

| | *CD layer* | *HD layer* |
|---|---|---|
| **2.5.9.2 Radial run-out** | Disc rotating at the reference scanning velocity. | When measured by the PUH with the reference servo for radial tracking. Disc rotating at the reference scanning velocity. |
| Radial run-out of tracks | ≤ 140 µm (p-p) | ≤ 100 µm (p-p) |
| max. radial acceleration | for frequencies < 500 Hz: 0.4 $m/s^2$ | for frequencies < 1000 Hz: 1.5 $m/s^2$ |
| residual tracking error below 1.1 kHz | --- | ≤ 0.020 µm<br>Measuring filter:<br>Butterworth LPF,<br>slope = –80 dB/decade<br>with $f_{-3dB}$ = 1.1 kHz |
| rms noise value of the residual error signal, measured with an integration time of 20ms | ≤ 0.03 µm<br>Measuring filter:<br>Butterworth BPF,<br>slope = +20 dB/decade<br>with $f_{-3dB}$ = 0.5 kHz,<br>slope = –20 dB/decade<br>with $f_{-3dB}$ = 2.5 kHz<br>(radial servo bandwidth = 200 Hz) | ≤ 0.014 µm<br>Measuring filter:<br>Butterworth BPF,<br>slope = +80 dB/decade<br>with $f_{-3dB}$ = 1.1 kHz,<br>slope = –80 dB/decade<br>with $f_{-3dB}$ = 10 kHz |

### 2.5.10 Mechanical parameters of the 80 mm disc

The 80 mm disc shall have the same dimensional specifications as the 120 mm disc, specified in 2.5.1 to 2.5.9, except for the following parameters:

- (see 2.5.2) The overall outer diameter of the disc shall be: 80.0 ± 0.3 mm
- (see 2.5.5) Mass of the disc: 6 - 9 g
  Moment of inertia ≤ 0.010 $g.m^2$
  Dynamic unbalance ≤ 0.0045 g.m
- (see 2.5.7) Outer diameter of the Information area ≤ 78 mm
- (see 2.5.7.2.1) Outer diameter of the Data Zone: $d_{DZE}$ = 76.0 mm max.

**Table 2-6 End of the Information Zone (80 mm disc)**

| **Outer diameter of the Data Zone** | **Outer diameter of the Lead-out Zone** |
|---|---|
| $d_{DZE}$ < 68.0 mm | $d_{LOE} \geq$ 70.0 mm |
| $d_{DZE}$ = 68.0 to 75.0 mm | $d_{LOE} \geq d_{DZE}$ + 2.0 mm |
| $d_{DZE}$ = 75.0 to 76.0 mm | $d_{LOE} \geq$ 77.0 mm |

**Table 2-7 Axial run-out (80 mm disc)**

| | *CD Layer* | *HD Layer* |
|---|---|---|
| **Axial run-out** | (see 2.5.9.1) | (see 2.5.9.1) |
| Deviation of the recorded layer from its nominal position in the direction of the reference axis | ≤ 0.35 mm peak<br>≤ 0.30 mm rms | ≤ 0.2 mm |

## 2.6 Optical parameters

### 2.6.1 Parameters of the HD layers

The following requirements shall be fulfilled in the disc area specified by the starting diameter of the Lead-in area and the ending diameter of the Lead-out area of the HD layers.

#### 2.6.1.1 Refractive index of the HD substrate and the Spacer Layer

| | |
|---|---|
| Refractive index of the transparent substrate: | 1.55 ± 0.10 |
| Refractive index of the Spacer Layer: | Refractive index of the substrate ± 0.10 |

#### 2.6.1.2 Thickness of the HD substrate for a Single Layer disc

The thickness of the HD substrate for a Single Layer disc shall be as specified by the shaded area in Figure 2-13 (nominal thickness is thickness indicated by the dashed line):

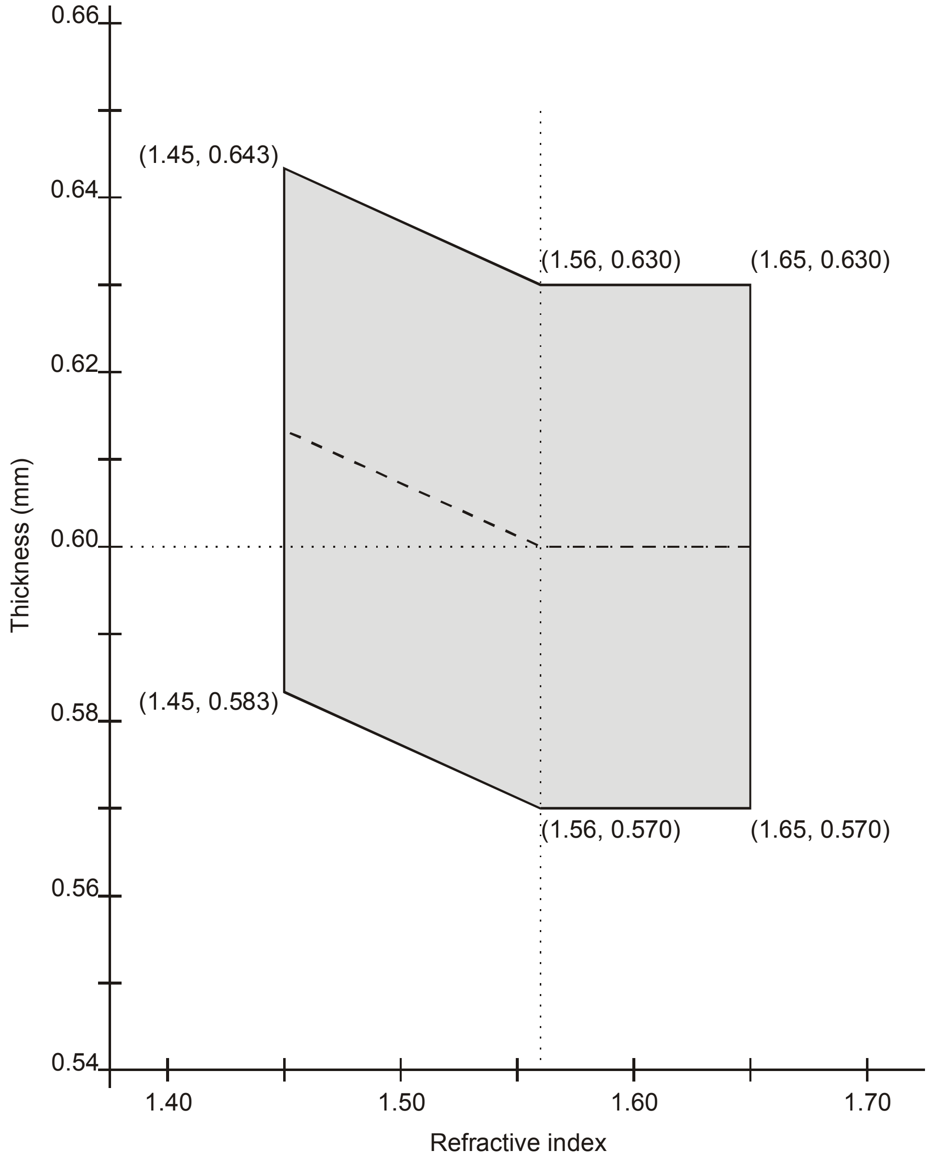


**Figure 2-13 Thickness as a function of the refractive index for a Single Layer disc**

#### 2.6.1.3 Thickness of the HD substrate for a Dual Layer disc

The thickness of the HD substrate for a Dual Layer disc shall be as specified by the shaded area in Figure 2-14 (nominal thickness is thickness indicated by the dashed line):

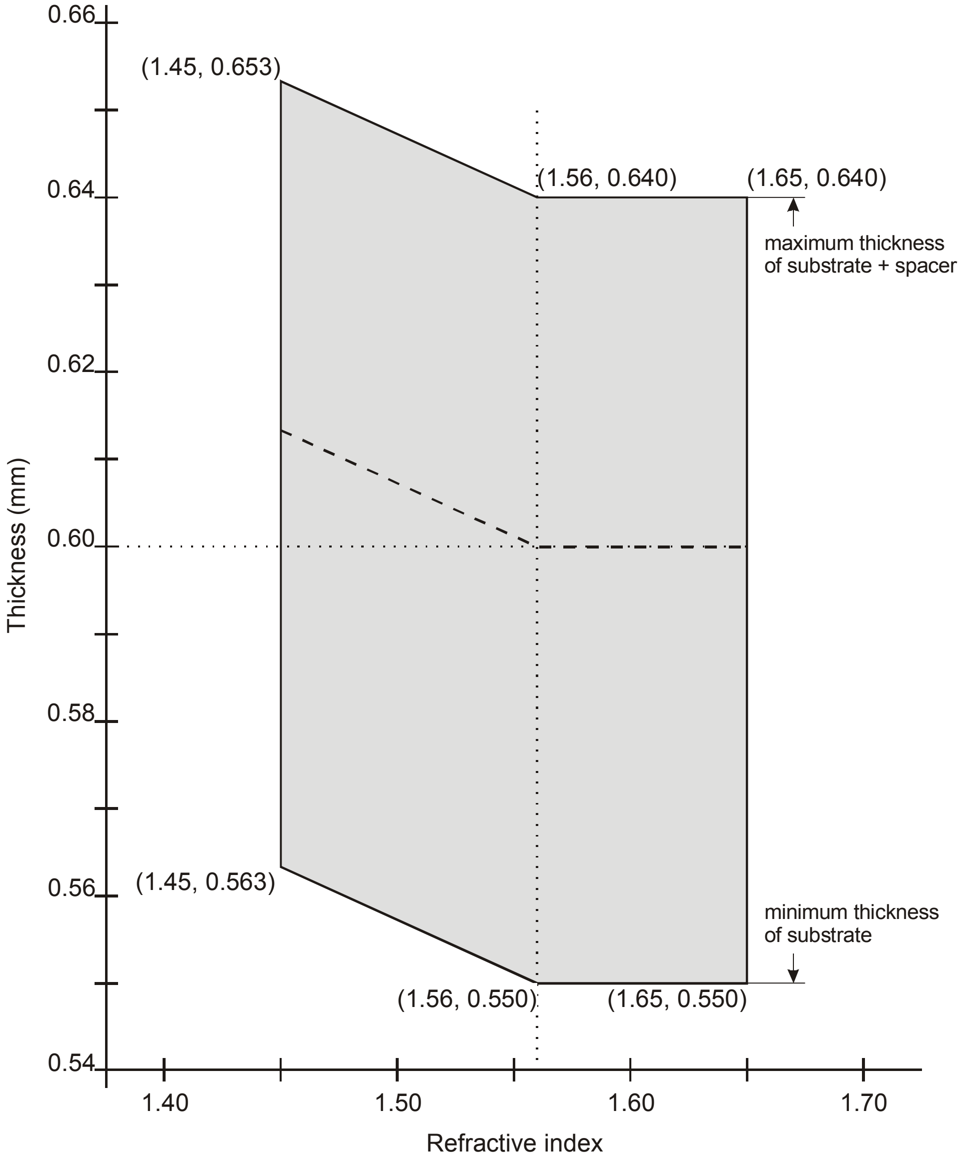


**Figure 2-14 Thickness as a function of the refractive index for a Dual Layer disc**

#### 2.6.1.4 Thickness of the Spacer Layer for a Dual Layer disc

| | |
|---|---|
| The thickness of the Spacer Layer shall be: | 55 µm ± 15 µm |
| Variation of the thickness over one disc: | ≤ 20 µm |
| Variation of the thickness over one revolution: | ≤ 8 µm |

### 2.6.1.5 Max angular deviations of the reflected beam

The angular deviation is the angle $\alpha$ between a parallel incident beam perpendicular to the reference plane P and the reflected beam. The incident beam shall have a diameter in the range 0.3 mm to 3.0 mm. This angle includes deflections due to the entrance surface and to unparallelism of the substrate.

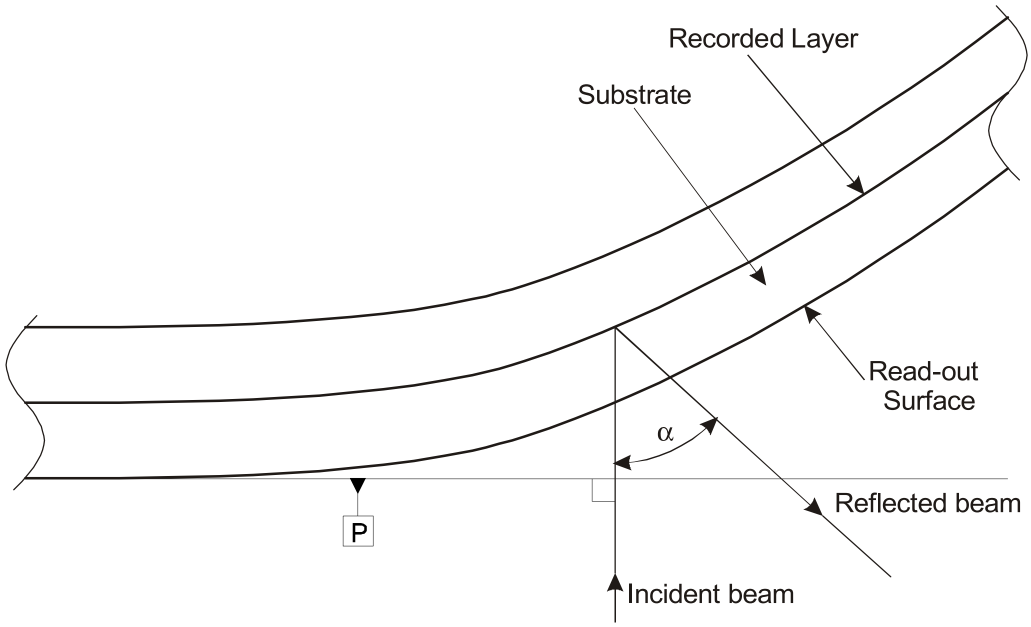


**Figure 2-15 Definition of angular deviation**

| | |
|---|---|
| In radial direction: | $\alpha = 0.80°$ max. |
| In tangential direction: | $\alpha = 0.30°$ max. |

### 2.6.1.6 Reflectivity of the HD layer(s)

The reflectivity of the HD Layer(s) is specified as the fraction of the light collected by the Optical Pick-up Head. Measuring method: see annex A.1, measured with focused reference.
The reflectivity shall fulfil the requirements given under PBS when measured with a PBS (recommended), or fulfil the requirements given under NPBS when measured with a non-polarizing beam splitter.

| | NPBS | PBS |
|---|---|---|
| Single Layer disc: | $R_{top}$ = 60 ~ 85% | $R_{top}$ = 45 ~ 85% |
| Dual Layer disc (for each of the two Layers): | $R_{top}$ = 18 ~ 30% | $R_{top}$ = 18 ~ 30% |
| Hybrid Layer disc: | $R_{top}$ = 15 ~ 30% | $R_{top}$ = 12 ~ 30% |

### 2.6.1.7 Max birefringence of the HD substrate

(see annex A.2, measured at 650 nm)
The birefringence of the transparent substrate of a Single or Dual Layer disc shall be:
≤ 100 nm double pass
The birefringence of the HD substrate of the Hybrid disc shall be: ≤ 100 nm double pass

### 2.6.2 Parameters of the CD layer

The following requirements shall be fulfilled in the disc area specified by the starting diameter of the Lead-in area and the ending diameter of the Lead-out area of the CD layer.

#### 2.6.2.1 Total thickness of both substrates & adhesive layer

The total thickness of the 2 substrates + the adhesive layer is specified by means of the total optical path length:

$$\sum_i n_i * d_i = 1.86 \pm 0.10 (\text{nominal } 1.55 * 1.2)$$

in which: $n_1$ = refractive index of the HD substrate
$n_2$ = refractive index of the CD substrate
$n_3$ = refractive index of the adhesive layer

$d_1$ = thickness of the HD substrate
$d_2$ = thickness of the CD substrate
$d_3$ = thickness of the adhesive layer

#### 2.6.2.2 Refractive index of both substrates & adhesive layer

Refractive index of the substrates and the adhesive layer (for all i = 1..3): $n_i = 1.55 \pm 0.10$
Difference in refractive indices (for any i and j = 1..3): $n_i - n_j < 0.10$

#### 2.6.2.3 Max angular deviations of the reflected beam

(see 2.6.1.5) In any direction: $\alpha = 1.60°$ max.

#### 2.6.2.4 Reflectivity of the CD layer

The reflectivity of the CD layer shall fulfil one of the following two requirements:
$R_{top}$ > 58% at 780 nm (focused beam, focused reference, double pass, see annex A.1)
$R_{top}$ > 65% at 780 nm (focused beam, parallel reference, double pass, see annex A.1)

#### 2.6.2.5 Max birefringence of both substrates & adhesive layer

(see annex A.2, measured at 780 nm)
The total birefringence of both substrates and the adhesive layer shall be: ≤ 100 nm double pass

# 3 CD-layer

For all parameter, signal and format specifications not given in the previous chapters, see ***Red Book***, except for the following Super Audio CD specific items:

## 3.1 Asymmetry

$$\text{asymmetry}: \quad -0.15 \le \left( \frac{I_{SLICE}}{I_{11}} - \frac{1}{2} \right) \le +0.05$$

$$\text{or}: \quad -0.15 \le \left[ \frac{\frac{(I_{3,LAND} + I_{3,PIT})}{2} - \frac{(I_{11,LAND} + I_{11,PIT})}{2}}{I_{11}} \right] \le +0.05$$

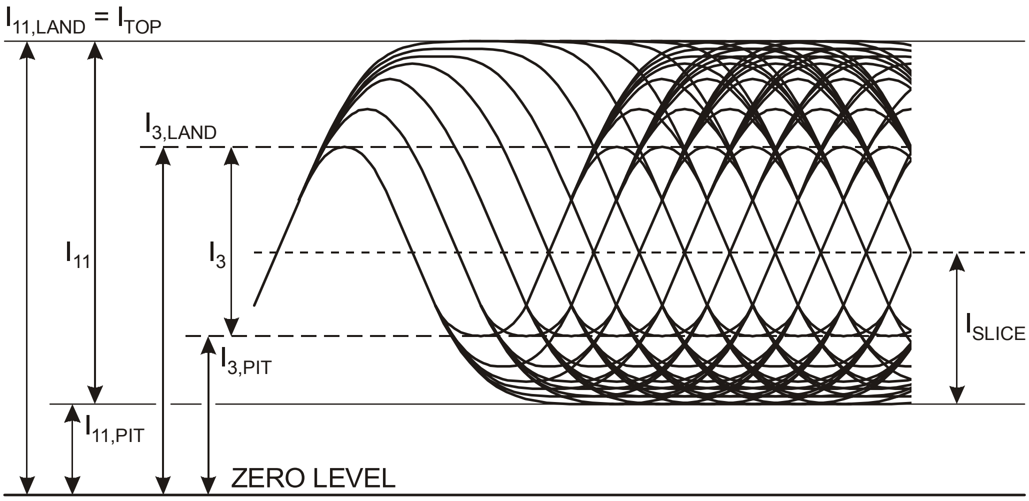


**Figure 3-1 Definitions of HF signal levels for the CD layer**

$I_{SLICE}$ = the detection level at the input of the EFM slicer, which will result in a binarized output with an average duty cycle of 50%.

 

# 4 HD-layer

## 4.1 Operational signals

### 4.1.1 High frequency signals (HF)

The HF signal is obtained by summing the currents of the four elements of the photo detector. These currents are modulated by diffraction of the light beam at the pits representing the information on the recorded layer. Measurements, except for jitter, are executed to HF before equalizing.

#### 4.1.1.1 Modulated amplitude

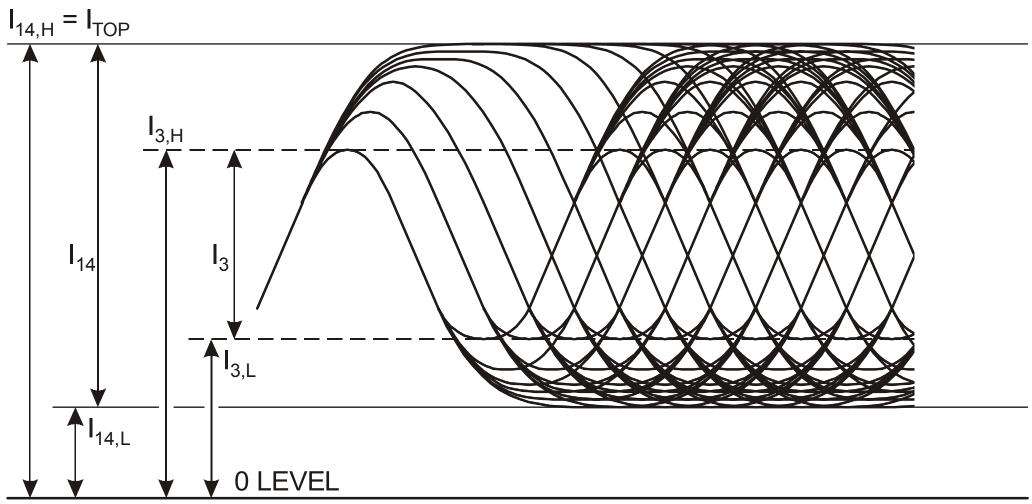


**Figure 4-1 Definitions of HF signal levels for the HD layers**

The modulated amplitude $I_{14}$ is the peak-to-peak value generated by the largest pit or land length. The peak value $I_{14H}$ shall be the peak value corresponding to the HF signal before high-pass filtering. The peak-to-peak value of the shortest pit or land length shall be $I_3$.
The 0 Level is the signal level obtained from the measuring device when no disc is inserted.
These parameters shall meet the following requirements:

| | |
|---|---|
| $I_{14} / I_{14H}$ | = 0.60 min. |
| $I_3 / I_{14}$ | = 0.15 min. for Types SL and HL |
| $I_3 / I_{14}$ | = 0.20 min. for Type DL |

The modulation amplitude shall fulfil the requirements given under PBS when measured with a PBS (recommended), or fulfil the requirements given under NPBS when measured with a non-polarizing beam splitter.

The maximum value of $(I_{14Hmax} - I_{14Hmin}) / I_{14Hmax}$ shall be:

| | NPBS | PBS |
|---|---|---|
| within one disc | 0.20 | 0.33 |
| within one revolution | 0.10 | 0.15 |

For the HL disc, the product of Reflectivity (see 2.6.1.6) and Modulation amplitude, measured with a PBS, shall fulfil the following requirement:

$$R_{top} * (I_{14} / I_{14H}) \geq 0.09$$

#### 4.1.1.2 Signal asymmetry

The signal asymmetry shall meet the following requirement, see Figure 4-1.

$$-0.05 \leq \left[ \frac{\frac{(I_{14H} + I_{14L})}{2} - \frac{(I_{3H} + I_{3L})}{2}}{I_{14}} \right] \leq +0.15$$

where: $(I_{14H} + I_{14L}) / 2$ is the centre level of $I_{14}$
$(I_{3H} + I_{3L}) / 2$ is the centre level of $I_3$

#### 4.1.1.3 Cross-track signal

The cross-track signal shall be derived from the HF signal when low-pass filtered with a cut-off frequency of 30 kHz when the light beam crosses the tracks (see Figure 4-2). The low-pass filter is a 1st order filter. The cross-track signal shall meet the following requirements:

$$\frac{I_T}{I_H} = \frac{I_H - I_L}{I_H} \geq 0.10$$

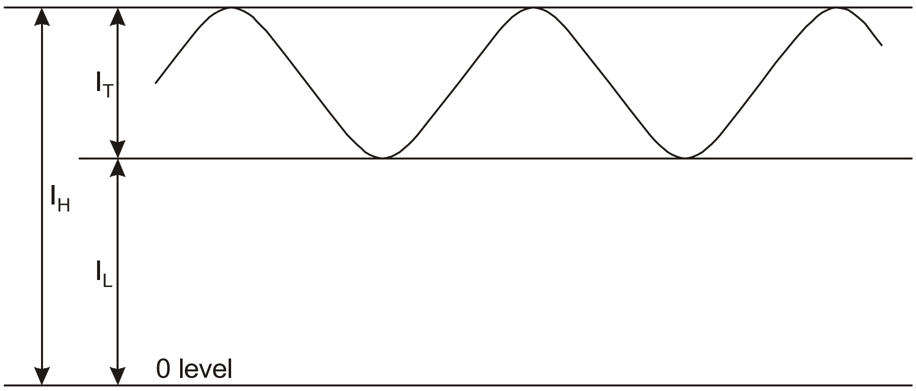


**Figure 4-2 Definition of cross-track signal levels**

#### 4.1.1.4 Quality of signals

##### 4.1.1.4.1 Jitter

Jitter is the standard deviation σ of the time variations of the binarized HF signal. The HF signal is binarized after having passed through the equalizer. The jitter of the leading and trailing edges is measured relative to the PLL bit clock and normalized by the Channel bit clock period.
Jitter shall be less than 8.0 % of the Channel bit clock period, when measured according to annex A.3.

##### 4.1.1.4.2 Random errors

A row of an ECC Block (see 4.2.4) that has at least 1 byte in error constitutes a PI error. In any 8 consecutive ECC Blocks the total number of PI errors before correction shall not exceed 280.

##### 4.1.1.4.3 Defects

Defects are e.g. air bubbles and black spots. Their diameter shall meet the following requirements:

- for air bubbles it shall not exceed 100 µm,
- for black spots causing birefringence it shall not exceed 200 µm,
- for black spots not causing birefringence it shall not exceed 300 µm.

In addition, over a distance of 80 mm in the scanning direction of the tracks, the following requirements shall be met:

- the total length of defects larger than 30 µm shall not exceed 300 µm,
- there shall be at most 6 such defects.

### 4.1.2 Servo signals

The output currents of the four quadrants of the split photo detector are identified by:

$I_a$, $I_b$, $I_c$ and $I_d$.

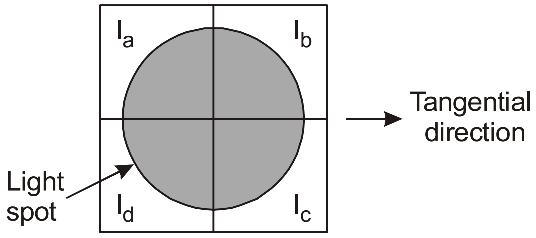


**Figure 4-3 Orientation of 4-quadrant photo detector**

#### 4.1.2.1 Differential phase tracking error signal

The differential phase tracking error signal shall be derived from the phase difference between diagonal pairs of detector elements when the light beam crosses the tracks:

Phase ($I_a + I_c$) - Phase ($I_b + I_d$).

The differential phase tracking error signal shall be low-pass filtered with a cut-off frequency of 30 kHz, see annex A.4. This signal shall meet the following requirements:

**Amplitude:**

At the positive 0 crossing, $\overline{\Delta t}/T$ shall be in the range 0.5 to 1.1 at 0.10 μm radial offset, where $\overline{\Delta t}$ is the average time difference derived from the phase difference between diagonal pairs of detector elements, and T is the Channel bit clock period.

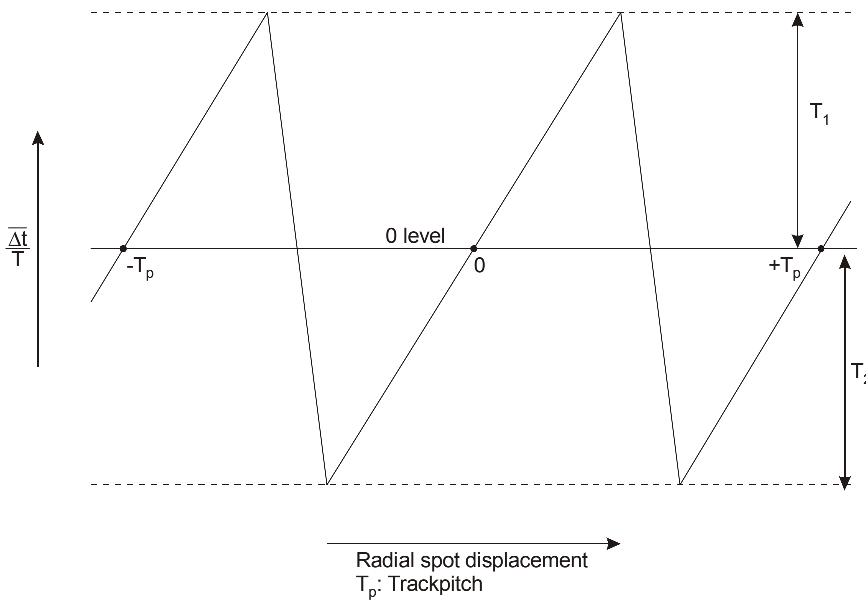


**Figure 4-4 Definition of Differential phase tracking error signal**

**Asymmetry:**
The asymmetry shall meet the following requirement:

$$\frac{|T_1 - T_2|}{|T_1 + T_2|} \leq 0{,}2$$

where: - $T_1$ is the positive peak value of $\overline{\Delta t}/T$

- $T_2$ is the negative peak value of $\overline{\Delta t}/T$

### 4.1.2.2 Tangential push-pull signal

This signal shall be derived from the instantaneous level of the differential output $(I_a + I_d) - (I_b + I_c)$. It shall meet the following requirement:

$$0 \leq \frac{[(I_a + I_d) - (I_b + I_c)]_{pp}}{I_{14}} \leq 0{,}9$$

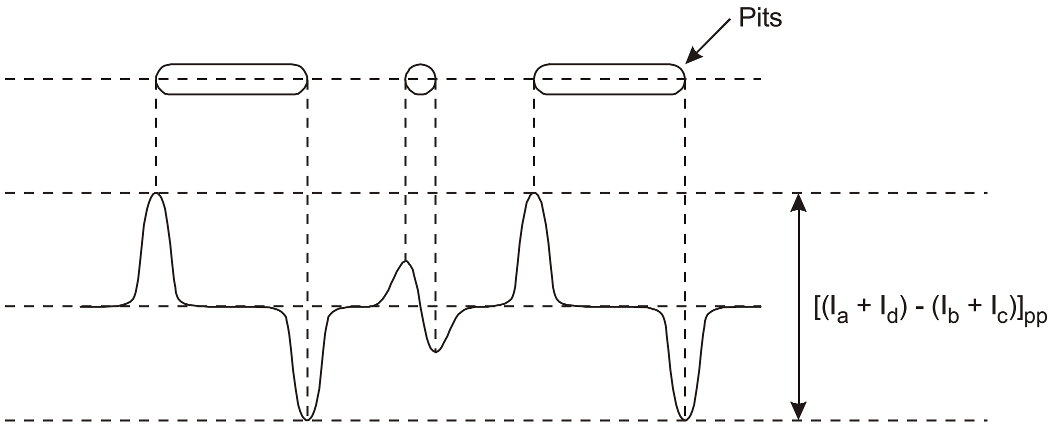


**Figure 4-5 Definition of tangential push-pull signal**

 

## 4.2 Data Format

### 4.2.1 General

The data received from the host, called Main Data, is formatted in a number of steps before being recorded on the disc. It is transformed successively into:

- a Data Frame,
- a Scrambled Frame,
- an ECC Block,
- a Recording Frame,
- a Physical Sector.

These steps are specified in the following chapters.

### 4.2.2 Data Frames

A Data Frame (see Figure 4-6) shall consist of 2064 bytes arranged in an array of 12 rows each containing 172 bytes. The first row shall start with three fields, called Identification Data (ID), ID Error Detection Code (IED), and Copy Protection System Information (CPSI), followed by 160 Main Data bytes. The next 10 rows shall each contain 172 Main Data bytes, and the last row shall contain 168 Main Data bytes followed by four bytes for recording an Error Detection Code (EDC). The 2048 Main Data bytes are identified as $D_0$ to $D_{2047}$.

| | ← 172 bytes → | | | | |
|---|---|---|---|---|---|
| | 4 bytes | 2 bytes | 6 bytes | | |
| ↑ | ID | IED | CPSI | Main Data 160 bytes ($D_0$ to $D_{159}$) | |
| | Main Data 172 bytes ($D_{160}$ to $D_{331}$) | | | | |
| | Main Data 172 bytes ($D_{332}$ to $D_{503}$) | | | | |
| 12 rows | : | | | | |
| | Main Data 172 bytes ($D_{1708}$ to $D_{1879}$) | | | | |
| ↓ | Main Data 168 bytes ($D_{1880}$ to $D_{2047}$) | | | | EDC |
| | | | | | 4 bytes |

**Figure 4-6 Structure of a Data Frame**

#### 4.2.2.1 Identification Data (ID)

This field shall consist of four bytes the bits of which are numbered consecutively from $b_0$ (lsb) to $b_{31}$ (msb), see Figure 4-7.

| $b_{31}$ … $b_{24}$ | $b_{23}$ … $b_0$ |
|---|---|
| Sector Information | Sector Number |

**Figure 4-7 Structure of the Identification Data (ID)**

The least significant three bytes, bits $b_{23}$ to $b_0$, shall specify the sector number in binary notation. The sector number of the first sector of an ECC Block of 16 sectors shall be an integer multiple of 16.

| $b_{31}$ | $b_{30}$ | $b_{29}$ | $b_{28}$ | $b_{27}$ and $b_{26}$ | $b_{25}$ | $b_{24}$ |
|---|---|---|---|---|---|---|
| Sector Format type | Tracking method | Reflectivity | Reserved | Zone type | Data type | Layer number |

**Figure 4-8 Structure of the Sector Information of the Identification Data**

The bits of the most significant byte, the Sector Information, shall be set as follows:

| | | |
|---|---|---|
| Bit $b_{31}$ | shall be set to: | |
| | ZERO | indicating the CLV format for read-only discs |
| Bit $b_{30}$ | shall be set to: | |
| | ZERO | indicating pit tracking |
| Bit $b_{29}$ | shall be set to: | |
| | ZERO | if the reflectivity as seen by the optics is greater than 40 % (SL) |
| | ONE | if the reflectivity as seen by the optics is 40 % max. (DL and HL) |
| Bit $b_{28}$ | shall be set to: | |
| | ZERO | |
| Bits $b_{27}$ and $b_{26}$ | shall be set to: | |
| | ZERO ZERO | in the Data Zone |
| | ZERO ONE | in the Lead-in Zone |
| | ONE ZERO | in the Lead-out Zone |
| | ONE ONE | in the Middle Zone |
| Bit $b_{25}$ | shall be set to: | |
| | ZERO | indicating read-only data |
| Bit $b_{24}$ | shall be set to: | |
| | ZERO | on Layer 0 of DL discs |
| | ONE | on Layer 1 of DL discs |
| | ZERO | on SL and HL discs |

Other settings are prohibited by this document.

#### 4.2.2.2 ID Error Detection Code (IED)

When identifying all bytes of the array shown in Figure 4-6 as $C_{i,j}$ for i = 0 to 11 and j = 0 to 171, the bytes of IED are represented by $C_{0,j}$ for j = 4 to 5.
Their setting is obtained as follows:

$$IED(x) = \sum_{j=4}^{5} C_{0,j} x^{5-j} = I(x)x^2 \bmod G_E(x)$$

where :

$$I(x) = \sum_{j=0}^{3} C_{0,j} x^{3-j}$$

$$G_E(x) = \prod_{k=0}^{1} (x + \alpha^k)$$

$\alpha$ is the primitive root of the primitive polynomial $P(x) = x^8 + x^4 + x^3 + x^2 + 1$

#### 4.2.2.3 Copy Protection System Information (CPSI)

This field shall consist of 6 bytes.
Their setting is specified in part 3 of this document (see chapter 1.3).

#### 4.2.2.4 Error Detection Code (EDC)

This 4-byte field shall contain an Error Detection Code computed over the preceding 2060 bytes of the Data Frame. Considering the Data Frame as a single bit field starting with the most significant bit of the first byte of the ID field and ending with the least significant bit of the EDC field, then this msb will be $b_{16511}$ and the lsb will be $b_0$. Each bit $b_i$ of the EDC is as follows for i = 31 to 0 :

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

where :

$$I(x) = \sum_{i=16511}^{32} b_i x^i$$

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

### 4.2.3 Scrambled Frames

The 2048 Main Data bytes shall be scrambled by means of the circuit shown in Figure 4-9, which shall consist of a feedback bit shift register in which bits $r_7$ (msb) to $r_0$ (lsb) represent a scrambling byte at each 8-bit shift. At the beginning of the scrambling procedure of a Data Frame, positions $r_{14}$ to $r_0$ shall be pre-set to the value(s) specified in Table 4-1. The same pre-set value shall be used for 16 consecutive Data Frames. After 16 groups of 16 Data Frames, the sequence is repeated. The initial pre-set number is equal to the value represented by bits $b_7$ (msb) to bit $b_4$ (lsb) of the ID field of the Data Frame. Table 4-1 specifies the initial pre-set value of the shift register corresponding to the 16 initial pre-set numbers.

**Table 4-1 Initial values of the shift register**

| Initial pre-set number | Initial pre-set value | Initial pre-set number | Initial pre-set value |
|---|---|---|---|
| (0) | (0001) | (8) | (0010) |
| (1) | (5500) | (9) | (5000) |
| (2) | (0002) | (A) | (0020) |
| (3) | (2A00) | (B) | (2001) |
| (4) | (0004) | (C) | (0040) |
| (5) | (5400) | (D) | (4002) |
| (6) | (0008) | (E) | (0080) |
| (7) | (2800) | (F) | (0005) |

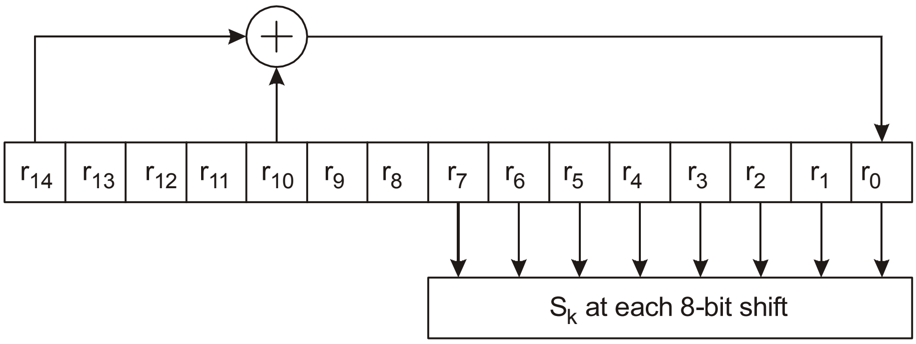


**Figure 4-9 Feedback shift register**

The part of the initial value of $r_7$ to $r_0$ is taken out as scrambling byte $S_0$. After that, 8-bit shift is repeated 2047 times and the following 2047 bytes shall be taken from $r_7$ to $r_0$ as scrambling bytes $S_1$ to $S_{2047}$. The Main Data bytes $D_k$ of the Data Frame become scrambled bytes $D'_k$ where:

$$D'_k = D_k \oplus S_k \quad \text{for } k = 0 \text{ to } 2047$$

$\oplus$ stands for Exclusive OR

 

### 4.2.4 ECC Blocks

An ECC Block is formed by arranging 16 consecutive Scrambled Frames in an array of 192 rows of 172 bytes each (Figure 4-10). To each of the 172 columns, 16 bytes of Parity of Outer Code are added, then, to each of the resulting 208 rows, 10 byte of Parity of Inner Code are added. Thus a complete ECC Block comprises 208 rows of 182 bytes each. The bytes of this array are identified as $B_{i,j}$ as follows, where i is the row number and j the column number.
$B_{i,j}$ for i = 0 to 191 and j = 0 to 171 are bytes from the Scrambled Frames
$B_{i,j}$ for i = 192 to 207 and j = 0 to 171 are bytes of the Parity of Outer Code
$B_{i,j}$ for i = 0 to 207 and j = 172 to 181 are bytes of the Parity of Inner Code

| | ← 172 bytes → | | | | | PI ← 10 bytes → | | | |
|---|---|---|---|---|---|---|---|---|---|
| ↑ | $B_{0,0}$ | $B_{0,1}$ | | | $B_{0,170}$ | $B_{0,171}$ | $B_{0,172}$ | | $B_{0,181}$ |
| | $B_{1,0}$ | $B_{1,1}$ | | | $B_{1,170}$ | $B_{1,171}$ | $B_{1,172}$ | | $B_{1,181}$ |
| | $B_{2,0}$ | $B_{2,1}$ | | | $B_{2,170}$ | $B_{2,171}$ | $B_{2,172}$ | | $B_{2,181}$ |
| | | | | | | | | | |
| 192 rows | | | | | | | | | |
| | | | | | | | | | |
| | $B_{189,0}$ | $B_{189,1}$ | | | $B_{189,170}$ | $B_{189,171}$ | $B_{189,172}$ | | $B_{189,181}$ |
| | $B_{190,0}$ | $B_{190,1}$ | | | $B_{190,170}$ | $B_{190,171}$ | $B_{190,172}$ | | $B_{190,181}$ |
| ↓ | $B_{191,0}$ | $B_{191,1}$ | | | $B_{191,170}$ | $B_{191,171}$ | $B_{191,172}$ | | $B_{191,181}$ |
| ↑ | $B_{192,0}$ | $B_{192,1}$ | | | $B_{192,170}$ | $B_{192,171}$ | $B_{192,172}$ | | $B_{192,181}$ |
| PO | | | | | | | | | |
| 16 rows | | | | | | | | | |
| | | | | | | | | | |
| ↓ | $B_{207,0}$ | $B_{207,1}$ | | | $B_{207,170}$ | $B_{207,171}$ | $B_{207,172}$ | | $B_{207,181}$ |

**Figure 4-10 Structure of an ECC Block**

The PO and PI bytes shall be obtained as follows:
In each of columns j = 0 to 171, the 16 PO bytes are defined by the remainder polynomial $R_j(x)$ to form the outer code RS (208,192,17).

$$R_j(x) = \sum_{i=192}^{207} B_{i,j} x^{207-i} = I_j(x) x^{16} \bmod G_{PO}(x)$$

where :

$$I_j(x) = \sum_{i=0}^{191} B_{i,j} x^{191-i}$$

$$G_{PO}(x) = \prod_{k=0}^{15} (x + \alpha^k)$$

In each of rows i = 0 to 207, the 10 PI bytes are defined by the remainder polynomial $R_i(x)$ to form the inner code RS (182,172,11).

$$R_i(x) = \sum_{j=172}^{181} B_{i,j} x^{181-j} = I_i(x) x^{10} \bmod G_{PI}(x)$$

where :

$$I_i(x) = \sum_{j=0}^{171} B_{i,j} x^{171-j}$$

$$G_{PI}(x) = \prod_{k=0}^{9} (x + \alpha^k)$$

$\alpha$ is the primitive root of the primitive polynomial $P(x) = x^8 + x^4 + x^3 + x^2 + 1$

 

### 4.2.5 Recording Frames

Sixteen Recording Frames shall be obtained by interleaving one of the 16 PO rows at a time after every 12 rows of an ECC Block (Figure 4-11). This is achieved by re-locating the bytes $B_{i,j}$ of the ECC Block as $B_{m,n}$ for

$$m = i + \mathrm{int}[i / 12] \quad \text{and} \quad n = j \quad \text{for } i \leq 191$$
$$m = 13\,(i - 191) - 1 \quad \text{and} \quad n = j \quad \text{for } i \geq 192$$

where int[x] represents the largest integer not greater than x.

Thus the 37856 bytes of an ECC Block are re-arranged into 16 Recording Frames of 2366 bytes. Each Recording Frame consists of an array of 13 rows of 182 bytes.

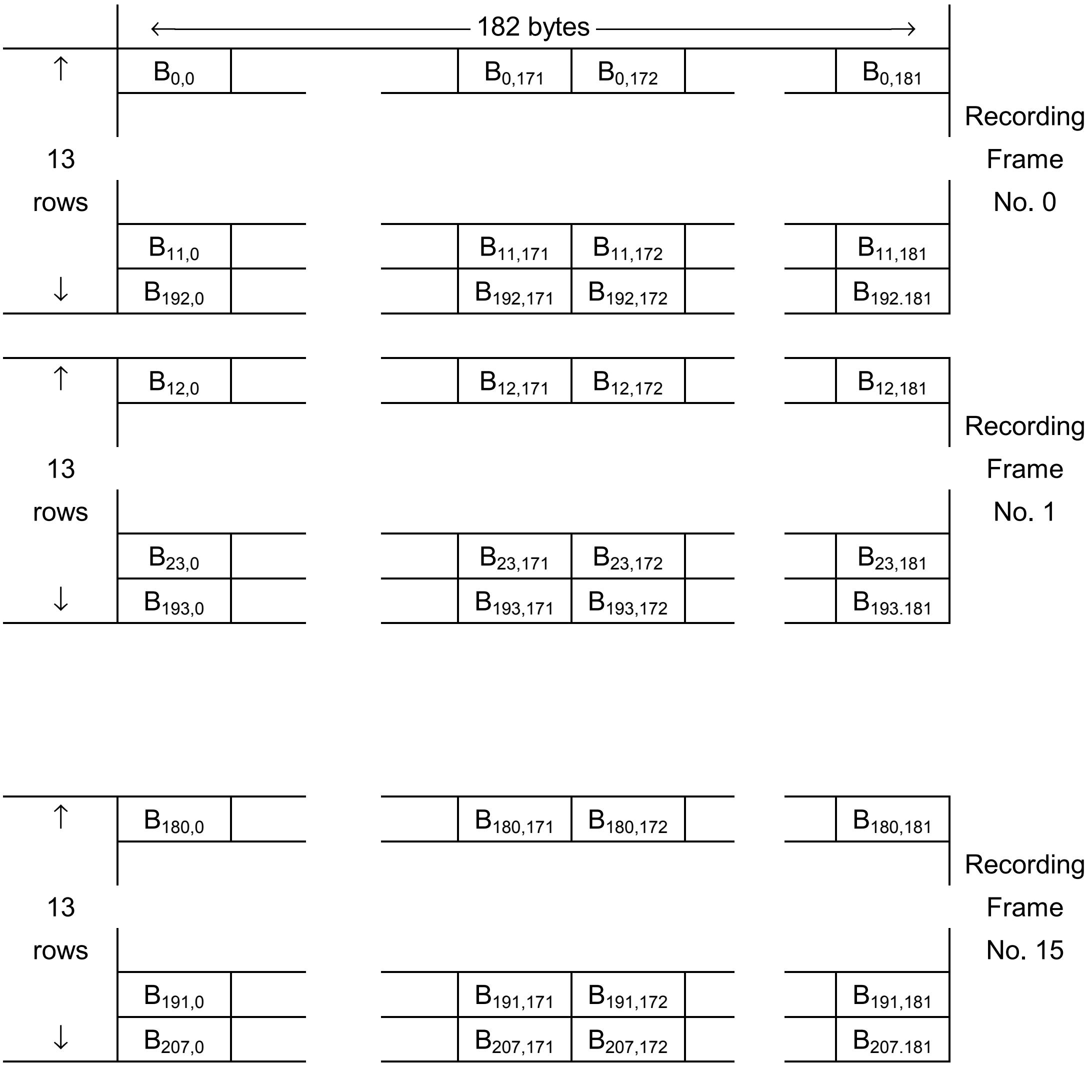


**Figure 4-11 Recording frames obtained from an ECC Block**

### 4.2.6 Modulation

The 8-bit bytes of each Recording Frame shall be transformed into 16-bit Code Words with the run length limitation that between 2 ONEs there shall be at least 2 ZEROs and at most 10 ZEROs (RLL 2,10). Annex A.5 specifies the conversion tables to be applied. The Main Conversion table and the Substitution table specify a 16-bit Code Word for each 8-bit byte with one of 4 States. For each 8-bit byte, the tables indicate the corresponding Code Word, as well as the State for the next 8-bit byte to be encoded.
The 16-bit Code Words shall be NRZI-converted into Channel bits before recording on the disc. (Figure 4-12).

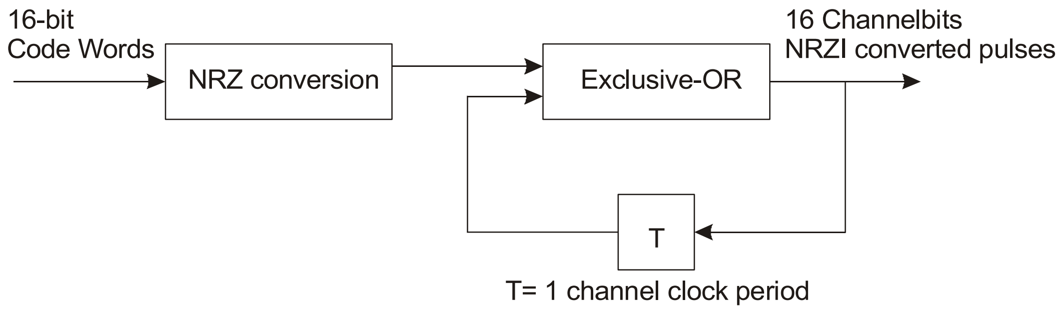


**Figure 4-12 NRZI conversion**

### 4.2.7 Physical Sectors

The structure of a Physical Sector is shown in Figure 4-13. It shall consist of 13 rows, each comprising two Sync Frames. A Sync Frame shall consist of a SYNC Code from Table 4-2 and 1456 Channel bits representing the first, respectively the second 91 8-bit bytes of a row of a Recording Frame. The first row of the Recording Frame is represented by the first row of the Physical Sector, the second by the second, and so on. Recording shall start with the first Sync Frame of the first row, followed by the second Sync Frame of that row, and so on row-by-row.

| | ← 32 → | ←—— 1456 ——→ | ← 32 → | ←—— 1456 ——→ |
|---|---|---|---|---|
| ↑ | SY0 | | SY5 | |
| | SY1 | | SY5 | |
| | SY2 | | SY5 | |
| | SY3 | | SY5 | |
| | SY4 | | SY5 | |
| | SY1 | | SY6 | |
| 13 rows | SY2 | | SY6 | |
| | SY3 | | SY6 | |
| | SY4 | | SY6 | |
| | SY1 | | SY7 | |
| | SY2 | | SY7 | |
| | SY3 | | SY7 | |
| ↓ | SY4 | | SY7 | |
| | ←—— Sync Frame ——→ | | ←—— Sync Frame ——→ | |

**Figure 4-13 Structure of a Physical Sector**

**Table 4-2 Sync codes**

 

| State 1 and State 2 | | | | | |
|---|---|---|---|---|---|
| | | Primary SYNC codes<br>(msb) (lsb) | | Secondary SYNC codes<br>(msb) (lsb) |
| SY0 | = | 0001001001000100 0000000000010001 | / | 0001001000000100 0000000000010001 |
| SY1 | = | 0000010000000100 0000000000010001 | / | 0000010001000100 0000000000010001 |
| SY2 | = | 0001000000000100 0000000000010001 | / | 0001000001000100 0000000000010001 |
| SY3 | = | 0000100000000100 0000000000010001 | / | 0000100001000100 0000000000010001 |
| SY4 | = | 0010000000000100 0000000000010001 | / | 0010000001000100 0000000000010001 |
| SY5 | = | 0010001001000100 0000000000010001 | / | 0010001000000100 0000000000010001 |
| SY6 | = | 0010010010000100 0000000000010001 | / | 0010000010000100 0000000000010001 |
| SY7 | = | 0010010001000100 0000000000010001 | / | 0010010000000100 0000000000010001 |
| **State 3 and State 4** | | | | |
| | | Primary SYNC codes<br>(msb) (lsb) | | Secondary SYNC codes<br>(msb) (lsb) |
| SY0 | = | 1001001000000100 0000000000010001 | / | 1001001001000100 0000000000010001 |
| SY1 | = | 1000010001000100 0000000000010001 | / | 1000010000000100 0000000000010001 |
| SY2 | = | 1001000001000100 0000000000010001 | / | 1001000000000100 0000000000010001 |
| SY3 | = | 1000001001000100 0000000000010001 | / | 1000001000000100 0000000000010001 |
| SY4 | = | 1000100001000100 0000000000010001 | / | 1000100000000100 0000000000010001 |
| SY5 | = | 1000100100000100 0000000000010001 | / | 1000000100000100 0000000000010001 |
| SY6 | = | 1001000010000100 0000000000010001 | / | 1000000001000100 0000000000010001 |
| SY7 | = | 1000100010000100 0000000000010001 | / | 1000000010000100 0000000000010001 |

### 4.2.8 Suppress control of the d.c. component

To ensure a reliable radial tracking and a reliable detection of the HF signals, the low frequency content of the stream of Channel bit patterns should be kept as low as possible. In order to achieve this, the Digital Sum Value (DSV, see 1.4.4) shall be kept as low as possible. At the beginning of the modulation, the DSV shall be set to 0.

The different ways of diminishing the current value of the DSV are as follows:

a) Choice of SYNC Codes between Primary or Secondary SYNC Codes,
b) For the 8-bit bytes in the range 0 to 87, the Substitution table offers an alternative 16-bit Code Word for all States,
c) For the 8-bit bytes in the range 88 to 255, when the prescribed State is 1 or 4, then the 16-bit Code Word can be chosen either from State 1 or from State 4, so as to ensure that the RLL requirement is met.

In order to use these possibilities, two data streams, Stream 1 and Stream 2, are generated. Stream 1 shall start with the Primary SYNC Code and Stream 2 with the Secondary SYNC Code of the same category of SYNC Codes. As both streams are modulated individually, they generate a different DSV because of the difference between the bit patterns of the Primary and Secondary SYNC Codes.

In the cases b) and c), there are two possibilities to represent an 8-bit byte. The DSV of each stream is computed up to the 8-bit byte preceding the 8-bit byte for which there is this choice. The stream with the lowest |DSV| is selected and duplicated to the other stream. Then, one of the representations of the next 8-bit byte is entered into Stream 1 and the other into Stream 2. This operation is repeated each time case b) or c) occurs.

Whilst case b) always occurs at the same pattern position in both streams, case c) may occur in one of the streams and not in the other because, for instance, the next State prescribed by the previous 8-bit byte can be 2 or 3 instead of 1 or 4. In that case the following 3-step procedure shall be applied:

1) Compare the |DSV|s of both streams.
2) If the |DSV| of the stream in which case c) occurs is smaller than that of the other stream, then the stream in which case c) has occurred is chosen and duplicated to the other stream. One of the representations of the next 8-bit byte is entered into this stream and the other into the other stream.
3) If the |DSV| of the stream in which case c) has occurred is larger than that of the other stream, then case c) is ignored and the 8-bit byte is represented according to the prescribed State.

In both cases b) and c), if the |DSV|s are equal, the decision to choose Stream 1 or Stream 2 is implementation-defined.

The procedure for case a) shall be as follows:

1) At the end of each Sync Frame, whether or not case b) and or case c) have occurred, the accumulated DSVs of both streams are compared. The stream with the lower |DSV| is selected and duplicated to the other stream. Then the next Primary SYNC Code and the Secondary SYNC Code of the proper category are inserted each in one of the streams.

Optionally the procedure for case a) can be extended in the following way:

2) If the DSV at the end of the resulting Sync Frame is greater than + 63 or smaller than -64, then the SYNC Code at the beginning of the Sync Frame is changed from Primary to Secondary or vice versa. If this yields a smaller |DSV|, the change is permanent, if the |DSV| is not smaller, the original SYNC Code is retained.

During the DSV computation, the value of the DSV may vary between -1000 and +1000, thus it is recommended that the count range for the DSV be at least from -1024 to +1023.

## 4.3 Format of the information Zone

### 4.3.1 General description of an Information Zone

The Information Zone shall be divided in three parts : the Lead-in Zone, the Data Zone and the Lead-out Zone. In DL discs, there is only one Information Zone extending over two layers; this Information Zone has a Middle Zone in each layer to allow the read-out beam to move from Layer 0 to Layer 1 (see Figure 4-14). The Data Zone is intended for the recording of Main Data. The Lead-in Zone contains control information. The Lead-out Zone allows for a continuous smooth read-out.

### 4.3.2 Layout of the Information Zone

The Information Zone of SL discs shall be sub-divided as shown in Table 4-3. The value of the radii indicated, are the nominal values of the first track of the first Physical Sector and that of the last track of the last Physical Sector of a zone.

**Table 4-3 Lay-out of the Information Zone**

| | Nominal radius in mm | | | Sector Number of the first Physical Sector | Number of Physical Sectors |
|---|---|---|---|---|---|
| **Lead-in Zone** | 22.6 max. to 24.0 | | | | |
| Initial Zone | | | | | |
| Reference Code Zone | | | | (02F000) | 32 |
| Buffer Zone 1 | | | | (02F020) | 480 |
| Control Data Zone | | | | (02F200) | 3072 |
| Buffer Zone 2 | | | | (02FE00) | 512 |
| **Data Zone** | 24.0 to $r_1$ | | | | |
| Application Buffer Zone | | | | (030000) | $n*16$ |
| Application Data Zone | | | | (030000) +(n)∗(10) | |
| **Lead-out Zone** | $r_1$ to 35.0 min. when $r_1 < 34.0$ | $r_1$ to $(r_1+1.0)$ min. when $34.0 \leq r_1 \leq 57.5$ | $r_1$ to 58.5 min. when $57.5 < r_1 < 58.0$ | | |

### 4.3.3 Physical Sector numbering

The first Physical Sector of the Data Zone has the Sector Number (030000), it shall be recorded at the beginning of the Data Zone ( see $d_{DZB}$ in 2.5.7.2.1).
On SL discs, the Sector Number of the Physical Sectors increases by 1 for each Physical Sector (Figure 4-14).
On DL discs, the Sector Number of the Physical Sectors increases by 1 for each Physical Sector from (030000) to the highest Sector Number on Layer 0. The first Sector Number on Layer 1 shall be derived from this highest Sector Number by inverting its bits, viz. changing from ZERO to ONE and vice versa. Further Sector Numbers on Layer 1 increase by 1 for each Physical Sector (Figure 4-14).
The Physical Sector chosen to be that with the highest Sector Number in the Data Zone on Layer 0 shall be such that the inverted value of its Sector Number is a multiple of 16.

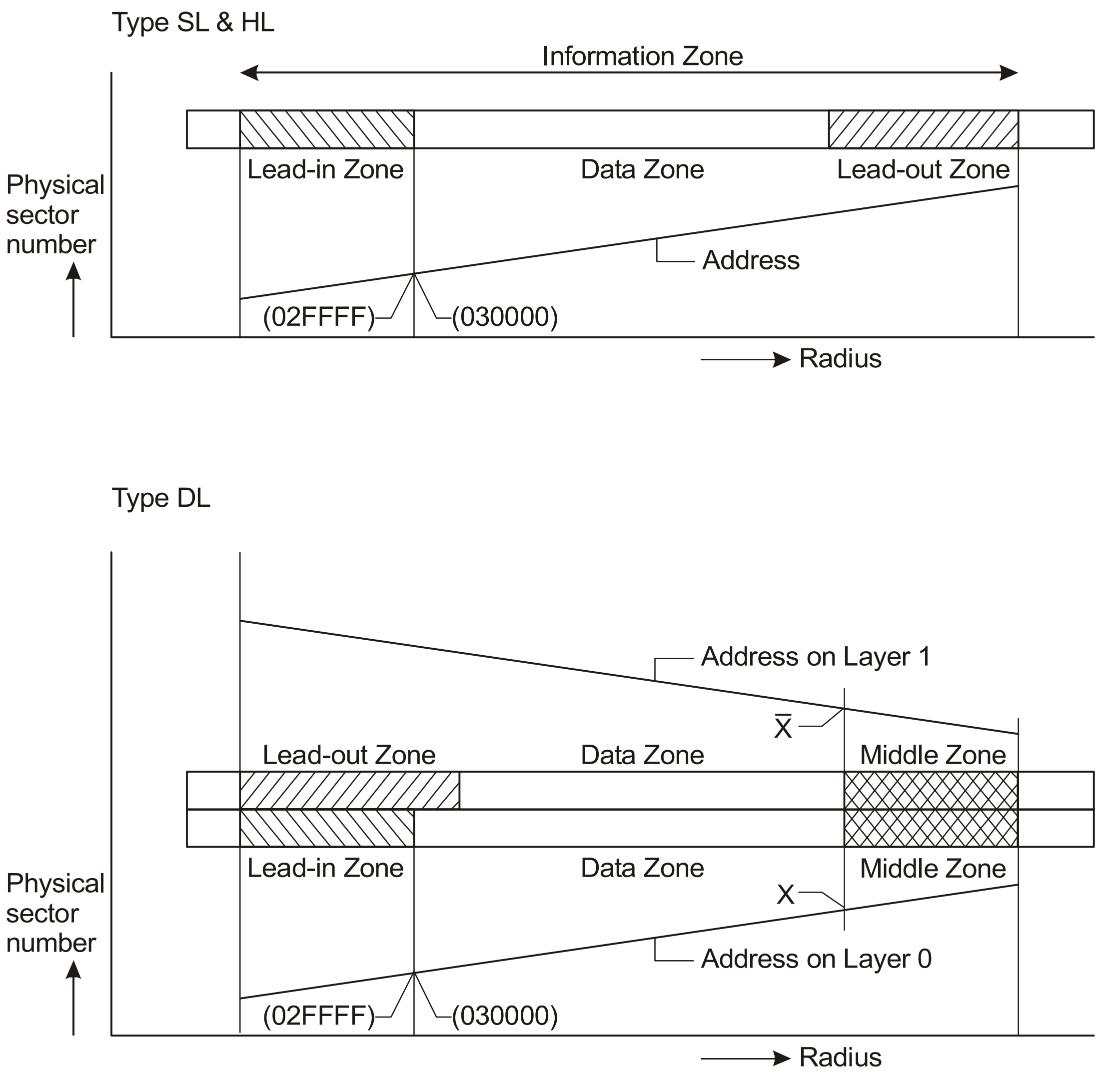


**Figure 4-14 Addressing in the Information Zone**

### 4.3.4 Lead-in Zone

The Lead-in Zone is the innermost zone of the Information Zone. It shall consist of the following parts (Figure 4-15):

- Initial Zone,
- Reference Code Zone,
- Buffer Zone 1,
- Control Data Zone,
- Buffer Zone 2.

The Sector Number of the first Physical Sector of each part is indicated in hexadecimal and in decimal notation.

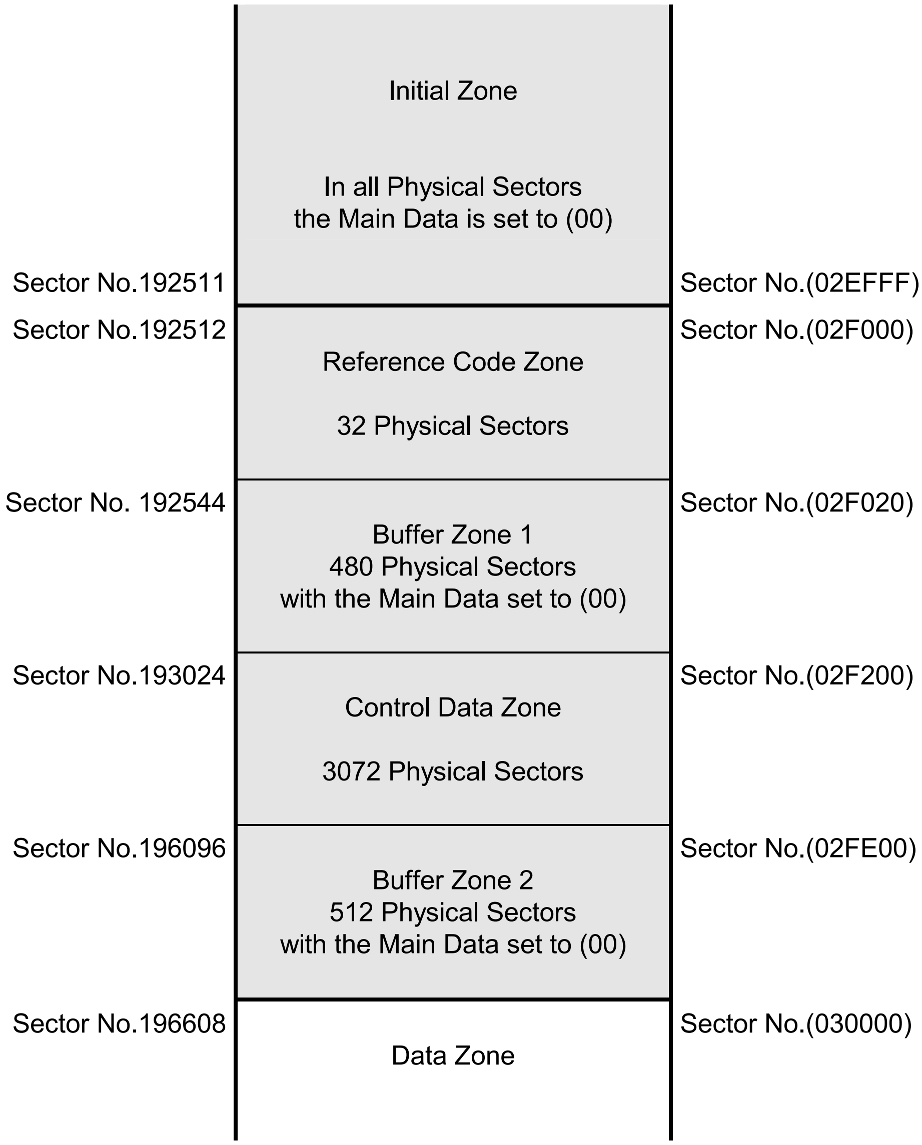


**Figure 4-15 Structure of the Lead-in Zone**

#### 4.3.4.1 Initial Zone

The Main Data of the Data Frames eventually recorded as Physical Sectors in the Initial Zone shall have been set to (00). This document does not specify the number of Physical Sectors in the Initial Zone. However, the Sector Number of the first Physical Sector of the Data Zone is large enough so as to prevent a Sector Number 0 to occur in the Initial Zone.

#### 4.3.4.2 Reference Code Zone

The Reference Code Zone shall consist of the 32 Physical Sectors from two ECC Blocks which generate a specific Channel bit pattern on the disc. This shall be achieved by setting to (AC) all 2048 Main Data bytes of each corresponding Data Frame. Moreover, no scrambling shall be applied to these Data Frames, except to the first 160 Main Data bytes of the first Data Frame of each ECC Block.

#### 4.3.4.3 Buffer Zone 1

This zone shall consist of 480 Physical Sectors from 30 ECC Blocks. The Main Data of the Data Frames eventually recorded as Physical Sectors in this zone shall have been set to (00).

#### 4.3.4.4 Buffer Zone 2

This zone shall consist of 512 Physical Sectors from 32 ECC Blocks. The Main Data of the Data Frames eventually recorded as Physical Sectors in this zone shall have been set to (00).

#### 4.3.4.5 Control Data Zone

This zone shall consist of 3072 Physical Sectors from 192 ECC Blocks. The content of the 16 Physical Sectors of each ECC Block is repeated 192 times. The structure of a Control Data Block shall be as shown in Figure 4-16.

| |
|---|
| Physical format information<br>2048 bytes |
| Disc manufacturing information<br>2048 bytes |
| Content provider information<br>14 × 2048 bytes |

**Figure 4-16 Structure of a Control Block**

#### 4.3.4.5.1 Physical format information

This information shall comprise the 2048 bytes shown in Table 4-4 Physical Format information. Other bit settings than those specified below are not allowed and are reserved for future extensions.

**Table 4-4 Physical Format information**

| Byte number | Content | Number of bytes |
|---|---|---|
| 0 | Disc Category and Version Number | 1 |
| 1 | Disc size and maximum transfer rate | 1 |
| 2 | Disc structure | 1 |
| 3 | Recording density | 1 |
| 4 to 15 | Application Data Zone allocation | 12 |
| 16 | Reserved | 1 |
| 17 to 31 | Reserved | 15 |
| 32 to 2047 | Reserved | 2016 |

**Byte 0 - Disc Category and Version Number**

Bits $b_7$ to $b_4$ shall specify the Disc Category
These bits shall be set to 0000, indicating a read-only disc.

Bits $b_3$ to $b_0$ shall specify the Version Number
They shall be set to 0001, indicating this version of this document

**Byte 1 - Disc size and maximum transfer rate**

Bits $b_7$ to $b_4$ shall specify the disc size
They shall be set to 0000, indicating a 120 mm disc.
They shall be set to 0001, indicating a 80 mm disc.

Bits $b_3$ to $b_0$ shall specify the maximum transfer rate needed by the application.
They shall be set to 1111 indicating no maximum transfer rate is specified.

**Byte 2 - Disc structure**

Bit $b_7$ shall be set to ZERO.

Bits $b_6$ and $b_5$ shall specify the disc Type
if set to 00, they specify Type SL or HL
if set to 01, they specify Type DL

Bit $b_4$ shall specify the track path
if set to ZERO, it specifies a track path from inside to outside on a SL disc or a HL disc.
if set to ONE, it specifies opposite track paths on a DL disc.

Bits $b_3$ to $b_0$ shall specify the type of the recorded layer(s)
They shall be set to 0001, indicating a read-only layer(s)

**Byte 3 - Recording density**

Bits $b_7$ to $b_4$ shall specify the average Channel bit length
if set to 0000, they specify 0.133 µm (SL and HL)
if set to 0001, they specify 0.147 µm (DL)

Bits $b_3$ to $b_0$ shall specify the average track pitch, they shall be set to 0000, indicating an average track pitch of 0.74 µm

**Bytes 4 to 15 – Application Data Zone allocation**

Byte 4 shall be set to (00).

Bytes 5 to 7 shall be set to (030000)+(n)∗(10) to specify the Sector Number 196608+n∗16 of the first Physical Sector of the Application Data Zone

Byte 8 shall be set to (00).

Bytes 9 to 11 shall specify the Sector Number of the last Physical Sector of the Application Data Zone

Byte 12 shall be set to (00)

Byte 13 to 15 shall be set to (00) on SL and HL discs, and to the Sector Number of the last Physical Sector of Layer 0 on DL discs.

**Byte 16 - Reserved**
This byte shall be set to (00).

**Bytes 17 to 31**
These bytes shall be set to (00).

**Bytes 32 to 2047**
These bytes shall be set to (00).

#### 4.3.4.5.2 Disc manufacturing information

This document does not specify the format and the content of these 2048 bytes. They shall be ignored in interchange.

#### 4.3.4.5.3 Content provider information

The format and the content of these 28672 bytes require agreement between the interchange parties, else these bytes shall be set to all (00)s.

### 4.3.5 Data Zone

The Data Zone consists of two parts:

- the Application Buffer Zone,
  which consists of n ECC Blocks (= n∗16 Physical Sectors, n = integer, n ≥ 0).
  The Main Data of the Data Frames eventually recorded as Physical Sectors in the Application Buffer Zone are defined by the application layer or shall be set to (00).
- the Application Data Zone,
  which contains the Main Data for the application.
  In DL discs, the Application Data Zone continues on Layer 1 without interruption (Layer 1 shall not have an Application Buffer Zone).

### 4.3.6 Middle Zone

The Main Data of the Data Frames eventually recorded as Physical Sectors in the Middle Zone shall have been set to (00). This document does not specify the number of Physical Sectors in the Middle Zone.

 

### 4.3.7 Lead-out Zone

The Main Data of the Data Frames eventually recorded as Physical Sectors in the Lead-out Zone shall have been set to (00). This document does not specify the number of Physical Sectors in the Lead-out Zone.

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# Super Audio CD

# Annexes

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# A1 Measurement of light reflectivity (normative)

## A1.1 Calibration method

A good reference disc shall be chosen, for instance 0.6 mm glass disc with a golden reflective mirror. This reference disc shall be measured by a parallel beam as shown in Figure A 1-1

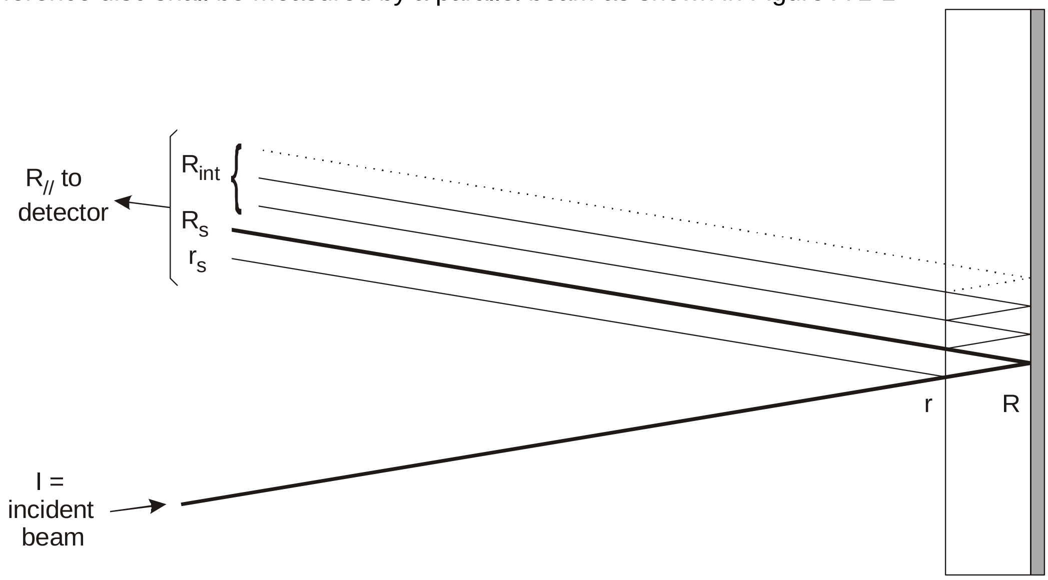


**Figure A 1-1 Reflectivity calibration**

In this figure the following applies:

R = reflectivity of the recording layer (including the double pass substrate transmission)
r = reflectivity of the entrance surface
I = incident beam
$r_s$ = reflectance caused by the reflectivity of the entrance surface
$R_s$ = main reflectance caused by the reflectivity of the recording layer
$R_{int}$ = reflectance caused by the internal reflectances between the entrance surface and the recording layer
$R_{//}$ = measured value ($r_s + R_s + R_{int}$)

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 substrate.

The main reflectance $R_s = R_{//} - r_s - R_{int}$ which leads to:

$$R_S = \left[\frac{(1-r)^2 \times (R_{//} - r)}{1 - r \times (2 - R_{//})}\right]$$

The reference disc shall be measured on a reference drive. The total detector current (the sum of all 4 quadrants = $I_{total}$) obtained from the reference disc, and measured by the focused beam is equated to $R_s$ 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 substrate transmission, independently from the reflectivity of the entrance surface.

## A1.2 Measuring method

Measure the total detector current $(I_{total})_s$ from the reference disc with calibrated reflectivity $R_s$. Measure $I_{14H}$ in the Information Zone of the disc.

In case of a focused beam, focused reference, calculate the reflectivity as follows: $R_{top} = \frac{I_{14H}}{(I_{total})_s} \times R_s$

In case of a focused beam, parallel reference, calculate the reflectivity as follows: $R_{top} = \frac{I_{14H}}{(I_{total})_s} \times R_{//}$

 

# A2 Measurement of birefringence (normative)

## A2.1 Principle of the measurement

In order to measure the birefringence, circularly polarized light in a parallel beam is used. The phase retardation is measured by observing the ellipticity of the reflected light.

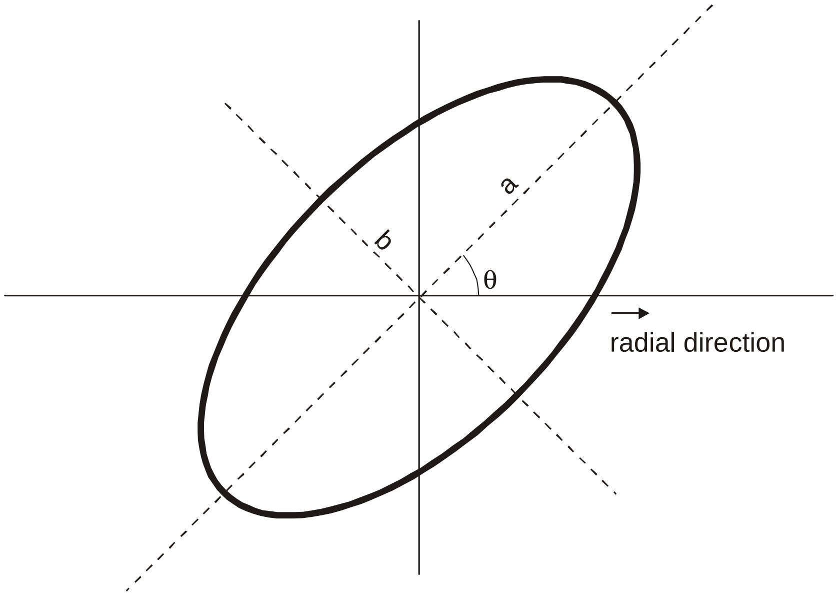


**Figure A 2-1 Ellipse with ellipticity e = b/a and orientation θ**

The orientation θ of the ellipse is determined by the orientation of the optical axis

$$\theta = \gamma - \pi/4 \qquad \text{(I)}$$

where γ is the angle between the optical axis and the radial direction.
The ellipticity e = b/a is a function of the phase retardation δ

$$e = \tan\left(\frac{\pi/2 - \delta}{2}\right) \qquad \text{(II)}$$

When the phase retardation δ is known the birefringence BR can be expressed as a fraction of the wavelength

$$BR = \frac{\lambda}{2\pi}.\,\delta \quad \text{[nm]} \qquad \text{(III)}$$

Thus, by observing the elliptically polarized light reflected from the disc, the birefringence can be measured and the orientation of the optical axis can be assessed as well.

## A2.2 Measurements conditions

The measurement of the birefringence specified above shall be made under the following conditions:

| | |
|---|---|
| Mode of measurement | in reflection, double pass through the substrate |
| Wavelength λ of the laser light | 640 nm ± 15 nm |
| Beam diameter (FWHM) | 1.0 mm ± 0.2 mm |
| Angle β of incidence in radial direction relative to the radial plane perpendicular to Reference Plane P | 7.0° ± 0.2° |
| Disc mounting | horizontally |
| Rotation | less than 1 Hz |
| Temperature and relative humidity | as specified in Chapter 2.4.1 (for dimensional measurements) |

## A2.3 Example of a measuring set-up

Whilst this document does not prescribe a specific device for measuring birefringence, the device shown schematically in Figure A 2-2 as an example, is well suited for this measurement.

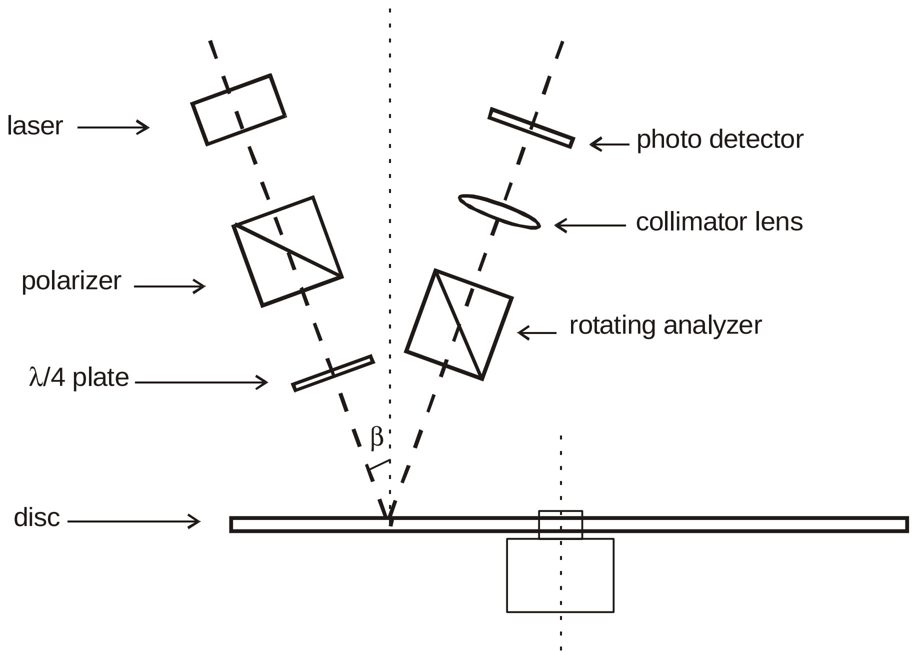


**Figure A 2-2 Example of a device for the measurement of birefringence**

Light from a laser source, collimated into a polarizer ( extinction ratio ≈ $10^{-5}$ ), is made circular by a λ/4 plate. The ellipticity of the reflected light is analyzed by a rotating analyzer and a photo detector. For every location on the disc, the minimum and the maximum values of the intensity are measured. The ellipticity can then be calculated as

$$e^2 = I_{min} / I_{max} \qquad \text{(IV)}$$

Combining equations II, III and IV yields:

$$BR = \frac{\lambda}{4} - \frac{\lambda}{\pi}.\arctan\left(\sqrt{\frac{I_{min}}{I_{max}}}\right) \qquad \text{(V)}$$

This device can be easily calibrated as follows:

$I_{min}$ is set to 0 by measuring a polarizer or a λ/ 4 plate,
$I_{min} = I_{max}$ when measuring a mirror

## A2.4 Interchangeability of measuring results

Various other measuring methods are possible and allowed as long as the measurement conditions stated in A2.2 are obeyed. In order to guarantee interchangeability of measuring results, the following guidelines must be followed:

(1) The angle of incidence determines the amount of vertical birefringence, that is measured in addition to the in-plane birefringence. It is therefor important to control the angle of incidence accurately.

(2) In the measurement method that is used, the orientation of the optical axis in the plane of the substrate has to be taken into account. No assumption can be made on the orientation of the optical axis.

(3) When analysing the reflected light, the light reflected by the substrate front surface must be taken into account.
Apart of the d.c. contribution of the front surface reflection, a.c. components may occur, due to the interference of the reflection(s) of the front surface with the reflection(s) from the recorded layer. These a.c. reflectance effects are significant only if the disc substrate has an extremely accurate flatness and if the light source has a high coherence.

# A3 Measurement of jitter (normative)

Jitter shall be measured under the conditions of Chapter 2.4 with the additional conditions specified in this annex.

## A3.1 System diagram for jitter measurement

The general system diagram for jitter measurement shall be as shown in Figure A 3-1.

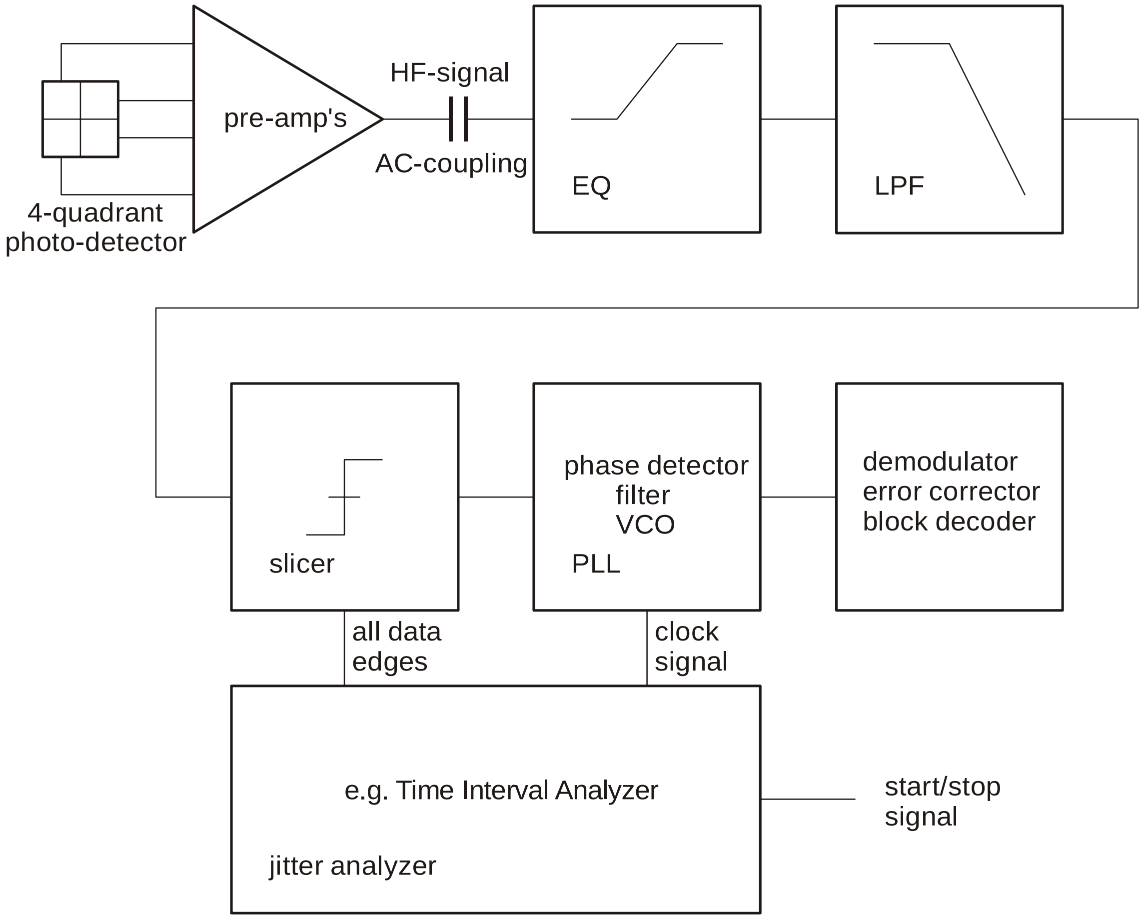


**Figure A 3-1 General diagram for jitter measurement**

## A3.2 Bandwidth requirements

The bandwidth of the pre-amplifier of the photo detector shall be greater than 20 MHz in order to prevent group-delay distortion.

Low-pass filter: $6^{th}$ order Bessel filter, $f_c$ (-3 dB) = 8.2 MHz
Example of an equalizer : 3-tap transversal filter with transfer function:
$H(z) = 1.364\, z^{-2} - 0.182\, (1 + z^{-4})$

Filtering and equalization (see Figure A 3-2):
- Gain variation: 1 dB max. (below 7 MHz)
- Group delay variation: 1 ns max. (below 6.5 MHz)
- (Gain at 5.0 MHz - Gain at 0 Hz) = 3.2 dB ± 0.3 dB

a.c. coupling (high-pass filter) = 1st order, $f_c$ (-3 dB) = 1 kHz

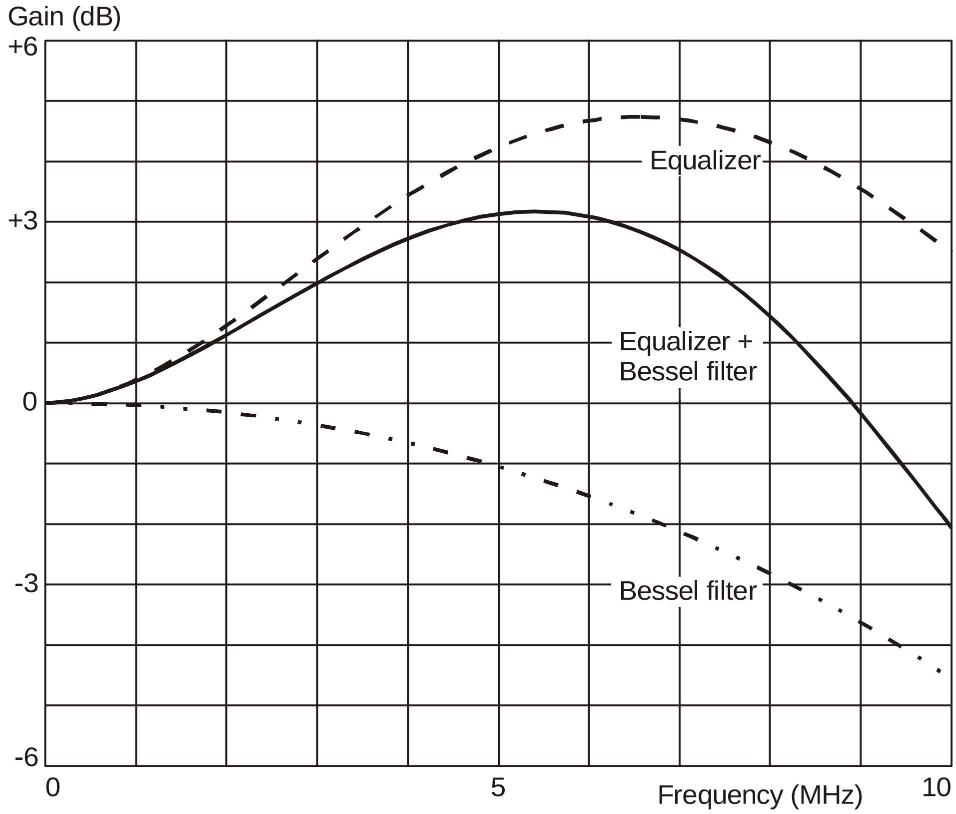


**Figure A 3-2 Frequency characteristics for the equalizer and the low-pass filter**

## A3.3 Slicer

The slicer shall be a 1st order integrating feed-back auto-slicer with a -3 dB closed-loop bandwidth of 5 kHz. The slicer feedback shall control its digital output signal towards an average duty cycle of 50%. Figure A 3-3 shows an example of such a slicer:

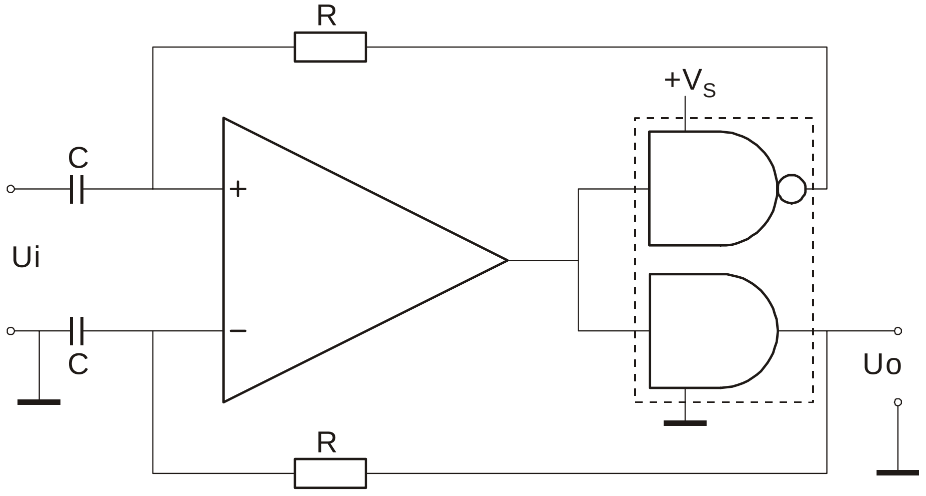


**Figure A 3-3 Example of a feedback auto-slicer**

## A3.4 Open loop transfer function for PLL

The open-loop transfer function for the PLL shown in Figure A 3-1 shall be as shown in Figure A 3-4.

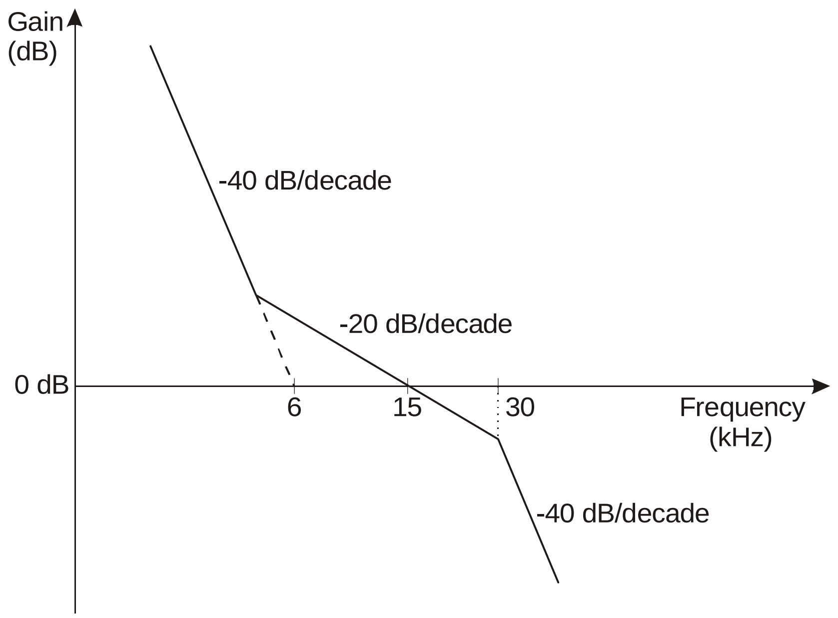


**Figure A 3-4 Schematic representation of the open-loop transfer function for PLL**

## A3.5 Conditions for measurement

All servos shall have fixed gain and offset settings such that:

1) The tilt of the optical pick-up unit shall be adjusted such that the jitter is minimized for the disc under test.

2) The radial tracking servo shall have a d.c.-offset, such that the centre of the lightspot on the recorded layer is within 30 nm from the centre of the track.

3) The d.c.-offset of the focusing servo shall be adjusted such that the objective lens is within 0.1 μm from its optimum position D as indicated in Figure A 3-5. The optimum focus point D corresponds to the bottom jitter on the disc under test.

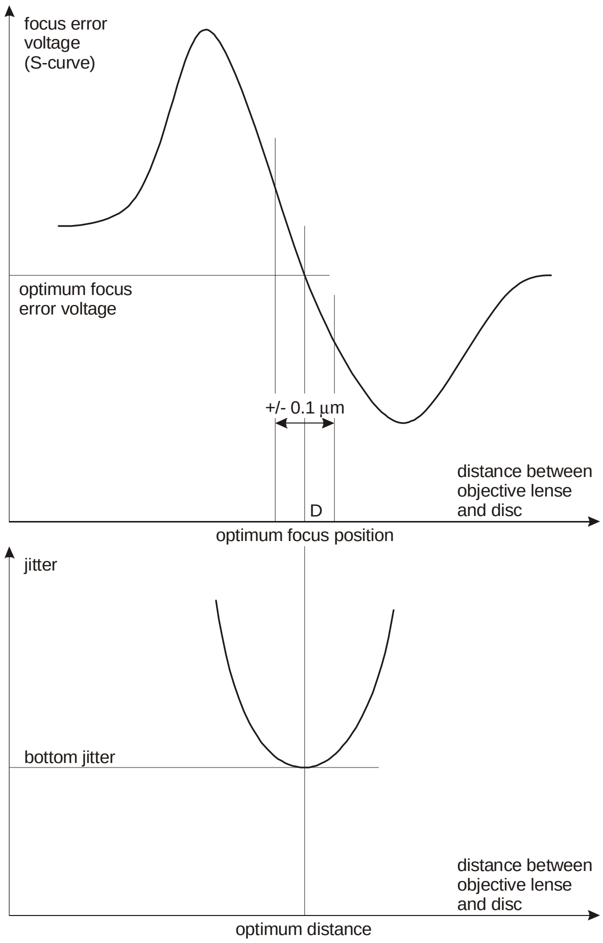


**Figure A 3-5 Example of focus S-curve and jitter curve indicating optimum focus offset**

## A3.6 Measurement

The focus offset is kept at the adjusted optimum position for the time of the jitter measurement on the disc under investigation.
The jitter of all leading and trailing edges over one rotation shall be measured.
Under this measurement, the jitter shall be less than 8.0 % of the Channel bit clock period.

# A4 Measurement of the differential phase tracking error (normative)

## A4.1 Measuring method for the differential phase tracking error

The reference circuit for the measurement of the tracking error shall be that shown in Figure A 4-1. Each output of the diagonal pairs of elements of the quadrant photo detector shall be binarized independently after equalization of the wave form with the transfer function defined by:

$H(i\omega) = (1 + 1.6 \times 10^{-7}\ i\omega) / (1 + 4.7 \times 10^{-8}\ i\omega)$

The gain of the comparators shall be sufficient to reach full saturation on the outputs, even with minimum signal amplitudes. Phases of the binarized pulse signal edges (signals B1 and B2) shall be compared to each other to produce a time-lead signal C1 and a time-lag signal C2. The phase comparator shall react to each individual edge with signal C1 or C2, depending on the sign of $\Delta t_i$.
A tracking error signal shall be produced by smoothing the C1, C2 signals with low-pass filters and by subtracting by means of a unity gain differential amplifier. The low-pass filters shall be 1st order filters with a cut-off frequency (-3 dB) of 30 kHz.
Special attention shall be given to the implementation of the circuit because very small time differences have to be measured, indeed 1 % of T equals only 0.38 ns. Careful averaging is needed.
The average time difference between two signals from the diagonal pairs of elements of the quadrant detector shall be

$$\overline{\Delta t} = \frac{1}{N} * \sum \Delta t_i \ ,$$

where N is the number of edges both rising and falling.

## A4.2 Measurement of $\overline{\Delta t}/T$ without time interval analyzer

The relative time difference $\overline{\Delta t}/T$ is represented by the amplitude of the tracking error signal provided that the amplitudes of the C1 and C2 signals and the frequency component of the read-out signals are normalized. The relation between the tracking error amplitude $\overline{\Delta TVE}$ and the time difference is given by:

$$\overline{\Delta TVE} = \frac{\sum \Delta t_i}{\sum T_i}.Vpc = \frac{\sum \Delta t_i}{N.n.T}.Vpc = \frac{\overline{\Delta t}}{T} \times \frac{Vpc}{n}$$

where:

Vpc is the amplitude of the C1 and C2 signals
$T_i$ is the actual length of the read-out signal in the range 3T to 14T
n.T is the weighted average value of the actual lengths
N.n.T is the total averaging time.

Assuming that Vpc equals ≈ 5 V and that the measured value of n equals ≈ 5, then the above relation between the tracking error amplitude $\overline{\Delta TVE}$ and the time difference $\overline{\Delta t}$ can be simplified to:

$$\overline{\Delta TVE} = \frac{\overline{\Delta t}}{T}$$

The specification for the tracking gain can now be rewritten by using the tracking error amplitude as follows:

$$0.5 \times (Vpc/n) \le \overline{\Delta TVE} \le 1.1 \times (Vpc/n) \quad \text{at } 0.1\ \mu\text{m radial offset.}$$

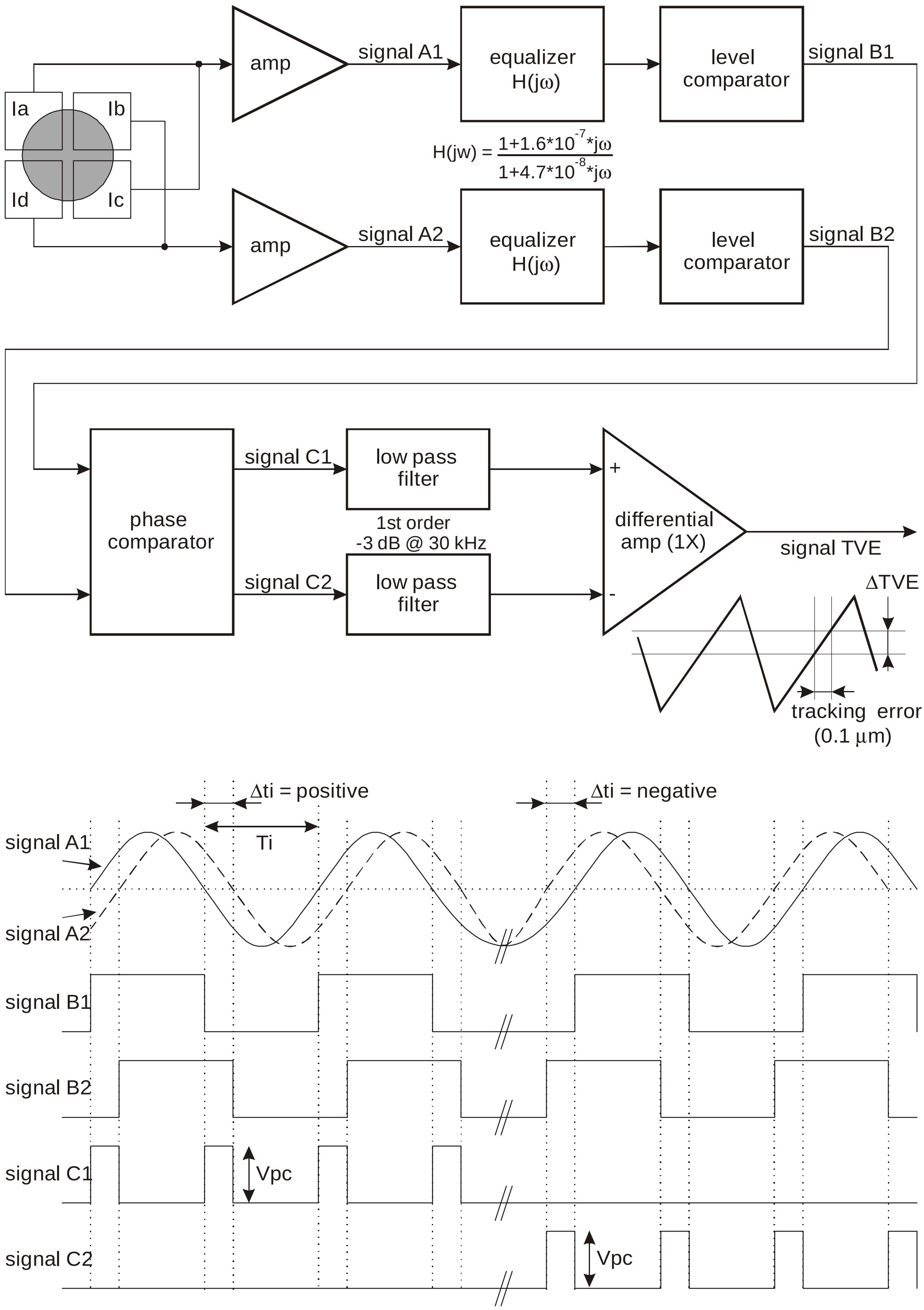


**Figure A 4-1 Circuit for tracking error measurements**

# A5 8-to-16 Modulation with RLL (2,10) requirements (normative)

Table A 5-1 and Table A 5-2 list the 16-bit Code Words into which the 8-bit coded Data bytes have to be transformed. Figure A 5-1 shows schematically how the Code Words and the associated State specification are generated.

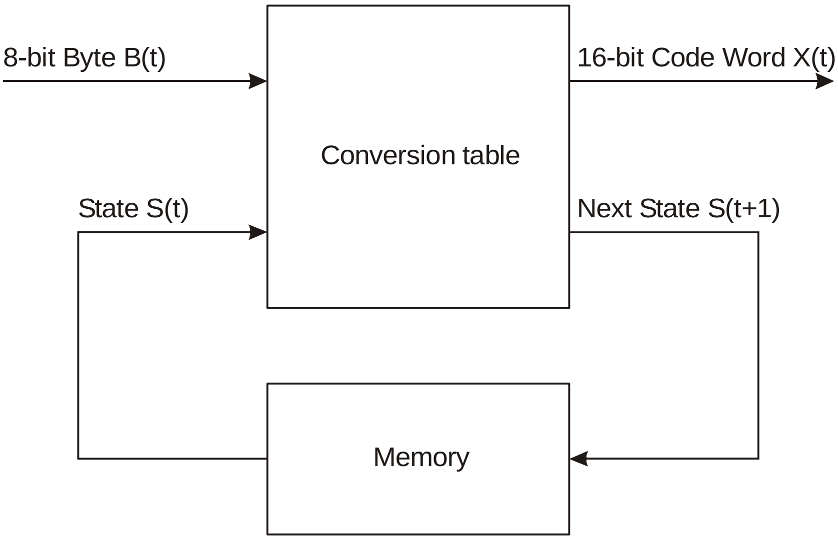


**Figure A 5-1 Code Words generation**

In this figure :

$X(t) = H \{ B(t), S(t) \}$ $X_{15}(t)$ = msb and $X_0(t)$ = lsb
$S(t+1) = G \{ B(t), S(t) \}$
H is the output function
G is the next-state function

The Code Words leaving the States shall be chosen such that the concatenation of Code Words entering a State and those leaving that State satisfy the requirement that between two ONEs there shall be at least 2 and at most 10 ZEROs.
As additional requirements:

- Code Words leaving State 2 shall have both bit $X_{15}$ and bit $X_3$ set to ZERO, and in
- Code Words leaving State 3 bit $X_{15}$ or bit $X_3$ or both shall be set to ONE.

This means that the Code Word sets of States 2 and 3 are disjoint.

| Code Word X(t) | Next State S(t+1) | Code Word X(t+1) |
|---|---|---|
| Ends with 1 or no trailing ZERO | State 1 | Starts with 2 or up to 9 leading ZEROs |
| Ends with 2 or up to 5 trailing ZEROs | State 2 | Starts with 1 or up to 5 leading ZEROs, and $X_{15}(t+1),X_3(t+1) = 0,0$ |
| Ends with 2 or up to 5 trailing ZEROs | State 3 | Starts with none or up to 5 leading ZEROs, and $X_{15}(t+1),X_3(t+1) \neq 0,0$ |
| Ends with 6 or up to 9 trailing ZEROs | State 4 | Starts with 1 or no leading ZERO |

**Figure A 5-2 Determination of States**

Note that when decoding the recorded data, in general knowledge about the encoder is required to be able to reconstitute the original coded Data.

$B(t) = H^{-1} \{ X(t), S(t) \}$

Because of the involved error propagation, such state-dependent decoding is to be avoided. In the case of this 8-to-16 modulation, the conversion tables have been chosen in such a way that knowledge about the State is not required in most cases. As can be gathered from the tables, in some cases, two 8-bit bytes, for instance the 8-bit bytes 5 and 6 in States 1 and 2 in Table A 5-1, generate the same 16-bit Code Words. The construction of the tables allows to solve this apparent ambiguity. Indeed, if two identical Code Words leave a State, one of them goes to State 2 and the other to State 3. Because the setting of bits $X_{15}$ and $X_3$ is always different in these two States, any Code Word can be uniquely decoded by analysing the Code Word itself together with bits $X_{15}$ and $X_3$ of the next Code Word:

$B(t) = H^{-1} \{ X(t), X_{15}(t+1), X_3(t+1) \}$

In the tables, the 8-bit bytes are identified by their decimal value.

**Table A 5-1 Main Conversion Table**

| | State 1 | | State 2 | | State 3 | | State 4 | |
|---|---|---|---|---|---|---|---|---|
| 8-bit byte | Code Word msb lsb | Next State | Code Word msb lsb | Next State | Code Word msb lsb | Next State | Code Word msb lsb | Next State |
| 0 | 0010000000001001 | 1 | 0100000100100000 | 2 | 0010000000001001 | 1 | 0100000100100000 | 2 |
| 1 | 0010000000010010 | 1 | 0010000000010010 | 1 | 1000000100100000 | 3 | 1000000100100000 | 3 |
| 2 | 0010000100100000 | 2 | 0010000100100000 | 2 | 1000000000010010 | 1 | 1000000000010010 | 1 |
| 3 | 0010000001001000 | 2 | 0100010010000000 | 4 | 0010000001001000 | 2 | 0100010010000000 | 4 |
| 4 | 0010000010010000 | 2 | 0010000010010000 | 2 | 1000000100100000 | 2 | 1000000100100000 | 2 |
| 5 | 0010000000100100 | 2 | 0010000000100100 | 2 | 1001001000000000 | 4 | 1001001000000000 | 4 |
| 6 | 0010000000100100 | 3 | 0010000000100100 | 3 | 1000100100000000 | 4 | 1000100100000000 | 4 |
| 7 | 0010000001001000 | 3 | 0100000000010010 | 1 | 0010000001001000 | 3 | 0100000000010010 | 1 |
| 8 | 0010000010010000 | 3 | 0010000010010000 | 3 | 1000010010000000 | 4 | 1000010010000000 | 4 |
| 9 | 0010000100100000 | 3 | 0010000100100000 | 3 | 1001001000000001 | 1 | 1001001000000001 | 1 |
| 10 | 0010010010000000 | 4 | 0010010010000000 | 4 | 1000100100000001 | 1 | 1000100100000001 | 1 |
| 11 | 0010001001000000 | 4 | 0010001001000000 | 4 | 1000000010010000 | 3 | 1000000010010000 | 3 |
| 12 | 0010010010000001 | 1 | 0010010010000001 | 1 | 1000000010010000 | 2 | 1000000010010000 | 2 |
| 13 | 0010001001000001 | 1 | 0010001001000001 | 1 | 1000010010000001 | 1 | 1000010010000001 | 1 |
| 14 | 0010000001001001 | 1 | 0100000000100100 | 3 | 0010000001001001 | 1 | 0100000000100100 | 3 |
| 15 | 0010000100100001 | 1 | 0010000100100001 | 1 | 1000001001000001 | 1 | 1000001001000001 | 1 |
| 16 | 0010000010010001 | 1 | 0010000010010001 | 1 | 1000000100100001 | 1 | 1000000100100001 | 1 |
| 17 | 0010000000100010 | 1 | 0010000000100010 | 1 | 1000001001000000 | 4 | 1000001001000000 | 4 |
| 18 | 0001000000001001 | 1 | 0100000010010000 | 2 | 0001000000001001 | 1 | 0100000010010000 | 2 |
| 19 | 0010000000010001 | 1 | 0010000000010001 | 1 | 1001000100000000 | 4 | 1001000100000000 | 4 |
| 20 | 0001000000010010 | 1 | 0001000000010010 | 1 | 1000100010000000 | 4 | 1000100010000000 | 4 |
| 21 | 0000100000000010 | 1 | 0000100000000010 | 1 | 1000000010010001 | 1 | 1000000010010001 | 1 |
| 22 | 0000010000000001 | 1 | 0000010000000001 | 1 | 1000000001001001 | 1 | 1000000001001001 | 1 |
| 23 | 0010001000100000 | 2 | 0010001000100000 | 2 | 1000000001001000 | 2 | 1000000001001000 | 2 |
| 24 | 0010000100010000 | 2 | 0010000100010000 | 2 | 1000000001001000 | 3 | 1000000001001000 | 3 |
| 25 | 0010000010001000 | 2 | 0100000000100100 | 2 | 0010000010001000 | 2 | 0100000000100100 | 2 |
| 26 | 0010000001000100 | 2 | 0010000001000100 | 2 | 1000000000100010 | 1 | 1000000000100010 | 1 |
| 27 | 0001000100100000 | 2 | 0001000100100000 | 2 | 1000000000010001 | 1 | 1000000000010001 | 1 |
| 28 | 0010000000001000 | 2 | 0100000010010000 | 3 | 0010000000001000 | 2 | 0100000010010000 | 3 |
| 29 | 0001000010010000 | 2 | 0001000010010000 | 2 | 1001001000000010 | 1 | 1001001000000010 | 1 |
| 30 | 0001000001001000 | 2 | 0100000100100000 | 3 | 0001000001001000 | 2 | 0100000100100000 | 3 |
| 31 | 0001000000100100 | 2 | 0001000000100100 | 2 | 1001000100000001 | 1 | 1001000100000001 | 1 |
| 32 | 0001000000000100 | 2 | 0001000000000100 | 2 | 1000100100000010 | 1 | 1000100100000010 | 1 |
| 33 | 0001000000000100 | 3 | 0001000000000100 | 3 | 1000100010000001 | 1 | 1000100010000001 | 1 |
| 34 | 0001000000100100 | 3 | 0001000000100100 | 3 | 1000000000100100 | 2 | 1000000000100100 | 2 |
| 35 | 0001000001001000 | 3 | 0100001001000000 | 4 | 0001000001001000 | 3 | 0100001001000000 | 4 |
| 36 | 0001000010010000 | 3 | 0001000010010000 | 3 | 1000000000100100 | 3 | 1000000000100100 | 3 |
| 37 | 0001000100100000 | 3 | 0001000100100000 | 3 | 1000010001000000 | 4 | 1000010001000000 | 4 |
| 38 | 0010000000001000 | 3 | 0100100100000001 | 1 | 0010000000001000 | 3 | 0100100100000001 | 1 |
| 39 | 0010000001000100 | 3 | 0010000001000100 | 3 | 1001000010000000 | 4 | 1001000010000000 | 4 |
| 40 | 0010000010001000 | 3 | 0100010010000001 | 1 | 0010000010001000 | 3 | 0100010010000001 | 1 |
| 41 | 0010000100010000 | 3 | 0010000100010000 | 3 | 1000010010000010 | 1 | 1000010010000010 | 1 |
| 42 | 0010001000100000 | 3 | 0010001000100000 | 3 | 1000001000100000 | 2 | 1000001000100000 | 2 |
| 43 | 0010010001000000 | 4 | 0010010001000000 | 4 | 1000010001000001 | 1 | 1000010001000001 | 1 |
| 44 | 0001001001000000 | 4 | 0001001001000000 | 4 | 1000001000100000 | 3 | 1000001000100000 | 3 |
| 45 | 0000001000000001 | 1 | 0100010001000000 | 4 | 1000001001000010 | 1 | 0100010001000000 | 4 |

continued

 

**Table A 5-1 Main Conversion Table (continued)**

| | State 1 | | State 2 | | State 3 | | State 4 | |
|---|---|---|---|---|---|---|---|---|
| 8-bit byte | Code Word msb lsb | Next State | Code Word msb lsb | Next State | Code Word msb lsb | Next State | Code Word msb lsb | Next State |
| 46 | 0010010010000010 | 1 | 0010010010000010 | 1 | 1000001000100001 | 1 | 1000001000100001 | 1 |
| 47 | 0010000010001001 | 1 | 0100001001000001 | 1 | 0010000010001001 | 1 | 0100001001000001 | 1 |
| 48 | 0010010001000001 | 1 | 0010010001000001 | 1 | 1000000100010000 | 2 | 1000000100010000 | 2 |
| 49 | 0010001001000010 | 1 | 0010001001000010 | 1 | 1000000010001000 | 2 | 1000000010001000 | 2 |
| 50 | 0010001000100001 | 1 | 0010001000100001 | 1 | 1000000100010000 | 3 | 1000000100010000 | 3 |
| 51 | 0001000001001001 | 1 | 0100000100100001 | 1 | 0001000001001001 | 1 | 0100000100100001 | 1 |
| 52 | 0010000100100010 | 1 | 0010000100100010 | 1 | 1000000100100010 | 1 | 1000000100100010 | 1 |
| 53 | 0010000100010001 | 1 | 0010000100010001 | 1 | 1000000100010001 | 1 | 1000000100010001 | 1 |
| 54 | 0010000010010010 | 1 | 0010000010010010 | 1 | 1000000010010010 | 1 | 1000000010010010 | 1 |
| 55 | 0010000001000010 | 1 | 0010000001000010 | 1 | 1000000010001001 | 1 | 1000000010001001 | 1 |
| 56 | 0010000000100001 | 1 | 0010000000100001 | 1 | 1000000001000010 | 1 | 1000000001000010 | 1 |
| 57 | 0000100000001001 | 1 | 0100000010010001 | 1 | 0000100000001001 | 1 | 0100000010010001 | 1 |
| 58 | 0001001001000001 | 1 | 0001001001000001 | 1 | 1000000000100001 | 1 | 1000000000100001 | 1 |
| 59 | 0001000100100001 | 1 | 0001000100100001 | 1 | 0100000001001001 | 1 | 0100000001001001 | 1 |
| 60 | 0001000010010001 | 1 | 0001000010010001 | 1 | 1001001000010010 | 1 | 1001001000010010 | 1 |
| 61 | 0001000000100010 | 1 | 0001000000100010 | 1 | 1001001000001001 | 1 | 1001001000001001 | 1 |
| 62 | 0001000000010001 | 1 | 0001000000010001 | 1 | 1001000100000010 | 1 | 1001000100000010 | 1 |
| 63 | 0000100000010010 | 1 | 0000100000010010 | 1 | 1000000001000100 | 2 | 1000000001000100 | 2 |
| 64 | 0000010000000010 | 1 | 0000010000000010 | 1 | 0100000001001000 | 2 | 0100000001001000 | 2 |
| 65 | 0010010000100000 | 2 | 0010010000100000 | 2 | 1000010000100000 | 2 | 1000010000100000 | 2 |
| 66 | 0010001000010000 | 2 | 0010001000010000 | 2 | 1000001000010000 | 2 | 1000001000010000 | 2 |
| 67 | 0010000100001000 | 2 | 0100000000100010 | 1 | 0010000100001000 | 2 | 0100000000100010 | 1 |
| 68 | 0010000010000100 | 2 | 0010000010000100 | 2 | 1000000100001000 | 2 | 1000000100001000 | 2 |
| 69 | 0010000000010000 | 2 | 0010000000010000 | 2 | 1000000010000100 | 2 | 1000000010000100 | 2 |
| 70 | 0001000010001000 | 2 | 0100001000100000 | 2 | 0001000010001000 | 2 | 0100001000100000 | 2 |
| 71 | 0001001000100000 | 2 | 0001001000100000 | 2 | 0100000010001000 | 2 | 0100000010001000 | 2 |
| 72 | 0001000000001000 | 2 | 0100000100010000 | 2 | 0001000000001000 | 2 | 0100000100010000 | 2 |
| 73 | 0001000100010000 | 2 | 0001000100010000 | 2 | 1000000001000100 | 3 | 1000000001000100 | 3 |
| 74 | 0001000001000100 | 2 | 0001000001000100 | 2 | 0100000001001000 | 3 | 0100000001001000 | 3 |
| 75 | 0000100100100000 | 2 | 0000100100100000 | 2 | 1000010000100000 | 3 | 1000010000100000 | 3 |
| 76 | 0000100010010000 | 2 | 0000100010010000 | 2 | 1000001000010000 | 3 | 1000001000010000 | 3 |
| 77 | 0000100001001000 | 2 | 0100000001000100 | 2 | 0000100001001000 | 2 | 0100000001000100 | 2 |
| 78 | 0000100000100100 | 2 | 0000100000100100 | 2 | 1000000100001000 | 3 | 1000000100001000 | 3 |
| 79 | 0000100000000100 | 2 | 0000100000000100 | 2 | 1000000010000100 | 3 | 1000000010000100 | 3 |
| 80 | 0000100000000100 | 3 | 0000100000000100 | 3 | 0100000010001000 | 3 | 0100000010001000 | 3 |
| 81 | 0000100000100100 | 3 | 0000100000100100 | 3 | 1000100001000000 | 4 | 1000100001000000 | 4 |
| 82 | 0000100001001000 | 3 | 0100000001000100 | 3 | 0000100001001000 | 3 | 0100000001000100 | 3 |
| 83 | 0000100010010000 | 3 | 0000100010010000 | 3 | 1000000010001000 | 3 | 1000000010001000 | 3 |
| 84 | 0000100100100000 | 3 | 0000100100100000 | 3 | 1001001001001000 | 2 | 1001001001001000 | 2 |
| 85 | 0001000000001000 | 3 | 0100000100010000 | 3 | 0001000000001000 | 3 | 0100000100010000 | 3 |
| 86 | 0001000001000100 | 3 | 0001000001000100 | 3 | 1001001000100100 | 2 | 1001001000100100 | 2 |
| 87 | 0001000010001000 | 3 | 0100001000100000 | 3 | 0001000010001000 | 3 | 0100001000100000 | 3 |
| 88 | 0001000100010000 | 3 | 0001000100010000 | 3 | 1001001001001000 | 3 | 1001001001001000 | 3 |
| 89 | 0001001000100000 | 3 | 0001001000100000 | 3 | 1001000010000001 | 1 | 1001000010000001 | 1 |
| 90 | 0010000000010000 | 3 | 0010000000010000 | 3 | 1000100100010010 | 1 | 1000100100010010 | 1 |
| 91 | 0010000010000100 | 3 | 0010000010000100 | 3 | 1000100100001001 | 1 | 1000100100001001 | 1 |
| 92 | 0010000100001000 | 3 | 0100000000010001 | 1 | 0010000100001000 | 3 | 0100000000010001 | 1 |
| 93 | 0010001000010000 | 3 | 0010001000010000 | 3 | 1000100010000010 | 1 | 1000100010000010 | 1 |
| 94 | 0010010000100000 | 3 | 0010010000100000 | 3 | 1000100001000001 | 1 | 1000100001000001 | 1 |

continued

### Table A 5-1 Main Conversion Table (continued)

| | State 1 | | State 2 | | State 3 | | State 4 | |
|---|---|---|---|---|---|---|---|---|
| 8-bit byte | Code Word msb lsb | Next State | Code Word msb lsb | Next State | Code Word msb lsb | Next State | Code Word msb lsb | Next State |
| 95 | 0000001000000010 | 1 | 0100100100000010 | 1 | 1000010010010010 | 1 | 0100100100000010 | 1 |
| 96 | 0000000100000001 | 1 | 0100100010000001 | 1 | 1000010010001001 | 1 | 0100100010000001 | 1 |
| 97 | 0010010010001001 | 1 | 0100010000100000 | 2 | 0010010010001001 | 1 | 0100010000100000 | 2 |
| 98 | 0010010010010010 | 1 | 0010010010010010 | 1 | 1001001000000100 | 2 | 1001001000000100 | 2 |
| 99 | 0010010001000010 | 1 | 0010010001000010 | 1 | 1001001000100100 | 3 | 1001001000100100 | 3 |
| 100 | 0010010000100001 | 1 | 0010010000100001 | 1 | 1000010001000010 | 1 | 1000010001000010 | 1 |
| 101 | 0010001001001001 | 1 | 0100010010000010 | 1 | 0010001001001001 | 1 | 0100010010000010 | 1 |
| 102 | 0010001000100010 | 1 | 0010001000100010 | 1 | 1000010000100001 | 1 | 1000010000100001 | 1 |
| 103 | 0010001000010001 | 1 | 0010001000010001 | 1 | 1000001001001001 | 1 | 1000001001001001 | 1 |
| 104 | 0010000100010010 | 1 | 0010000100010010 | 1 | 1000001000100010 | 1 | 1000001000100010 | 1 |
| 105 | 0010000010000010 | 1 | 0010000010000010 | 1 | 1000001000010001 | 1 | 1000001000010001 | 1 |
| 106 | 0010000100001001 | 1 | 0100001000010000 | 2 | 0010000100001001 | 1 | 0100001000010000 | 2 |
| 107 | 0010000001000001 | 1 | 0010000001000001 | 1 | 1000000100010010 | 1 | 1000000100010010 | 1 |
| 108 | 0001001001000010 | 1 | 0001001001000010 | 1 | 1000000100001001 | 1 | 1000000100001001 | 1 |
| 109 | 0001001000100001 | 1 | 0001001000100001 | 1 | 1000000010000010 | 1 | 1000000010000010 | 1 |
| 110 | 0001000100100010 | 1 | 0001000100100010 | 1 | 1000000001000001 | 1 | 1000000001000001 | 1 |
| 111 | 0001000100010001 | 1 | 0001000100010001 | 1 | 0100000010001001 | 1 | 0100000010001001 | 1 |
| 112 | 0001000010010010 | 1 | 0001000010010010 | 1 | 1001001001001001 | 1 | 1001001001001001 | 1 |
| 113 | 0001000001000010 | 1 | 0001000001000010 | 1 | 1001001000100010 | 1 | 1001001000100010 | 1 |
| 114 | 0001000010001001 | 1 | 0100010000100000 | 3 | 0001000010001001 | 1 | 0100010000100000 | 3 |
| 115 | 0001000000100001 | 1 | 0001000000100001 | 1 | 1001001000010001 | 1 | 1001001000010001 | 1 |
| 116 | 0000100100100001 | 1 | 0000100100100001 | 1 | 1001000100010010 | 1 | 1001000100010010 | 1 |
| 117 | 0000100010010001 | 1 | 0000100010010001 | 1 | 1001000100001001 | 1 | 1001000100001001 | 1 |
| 118 | 0000100001001001 | 1 | 0100010001000001 | 1 | 0000100001001001 | 1 | 0100010001000001 | 1 |
| 119 | 0000100000100010 | 1 | 0000100000100010 | 1 | 1000100100100100 | 2 | 1000100100100100 | 2 |
| 120 | 0000100000010001 | 1 | 0000100000010001 | 1 | 1000100100000100 | 2 | 1000100100000100 | 2 |
| 121 | 0000010000001001 | 1 | 0100001001000010 | 1 | 0000010000001001 | 1 | 0100001001000010 | 1 |
| 122 | 0000010000010010 | 1 | 0000010000010010 | 1 | 1000100000100000 | 2 | 1000100000100000 | 2 |
| 123 | 0010010010000100 | 2 | 0010010010000100 | 2 | 1000010010000100 | 2 | 1000010010000100 | 2 |
| 124 | 0010010000010000 | 2 | 0010010000010000 | 2 | 1000010000010000 | 2 | 1000010000010000 | 2 |
| 125 | 0010001000001000 | 2 | 0100001000100001 | 1 | 0010001000001000 | 2 | 0100001000100001 | 1 |
| 126 | 0010001001000100 | 2 | 0010001001000100 | 2 | 1000001001000100 | 2 | 1000001001000100 | 2 |
| 127 | 0001000100001000 | 2 | 0100000100100010 | 1 | 0001000100001000 | 2 | 0100000100100010 | 1 |
| 128 | 0010000100100100 | 2 | 0010000100100100 | 2 | 1000001000001000 | 2 | 1000001000001000 | 2 |
| 129 | 0000100010001000 | 2 | 0100000100010001 | 1 | 0000100010001000 | 2 | 0100000100010001 | 1 |
| 130 | 0010000100000100 | 2 | 0010000100000100 | 2 | 1000000100100100 | 2 | 1000000100100100 | 2 |
| 131 | 0010000000100000 | 2 | 0010000000100000 | 2 | 1001001000000100 | 3 | 1001001000000100 | 3 |
| 132 | 0001001000010000 | 2 | 0001001000010000 | 2 | 1000100100100100 | 3 | 1000100100100100 | 3 |
| 133 | 0000100000001000 | 2 | 0100000010010010 | 1 | 0000100000001000 | 2 | 0100000010010010 | 1 |
| 134 | 0001000010000100 | 2 | 0001000010000100 | 2 | 1000100000100000 | 3 | 1000100000100000 | 3 |
| 135 | 0001000000010000 | 2 | 0001000000010000 | 2 | 1000010010000100 | 3 | 1000010010000100 | 3 |
| 136 | 0000100100010000 | 2 | 0000100100010000 | 2 | 1000010000010000 | 3 | 1000010000010000 | 3 |
| 137 | 0000100001000100 | 2 | 0000100001000100 | 2 | 1000001001000100 | 3 | 1000001001000100 | 3 |
| 138 | 0000010001001000 | 2 | 0100000001000010 | 1 | 0000010001001000 | 2 | 0100000001000010 | 1 |
| 139 | 0000010010010000 | 2 | 0000010010010000 | 2 | 1000001000001000 | 3 | 1000001000001000 | 3 |
| 140 | 0000010000100100 | 2 | 0000010000100100 | 2 | 1001000010000010 | 1 | 1001000010000010 | 1 |
| 141 | 0000010000000100 | 2 | 0000010000000100 | 2 | 1000000100000100 | 2 | 1000000100000100 | 2 |
| 142 | 0000010000000100 | 3 | 0000010000000100 | 3 | 1000000100100100 | 3 | 1000000100100100 | 3 |
| 143 | 0000010000100100 | 3 | 0000010000100100 | 3 | 1000000100000100 | 3 | 1000000100000100 | 3 |

continued

 

**Table A 5-1 Main Conversion Table (continued)**

| | State 1 | | State 2 | | State 3 | | State 4 | |
|---|---|---|---|---|---|---|---|---|
| 8-bit byte | Code Word msb lsb | Next State | Code Word msb lsb | Next State | Code Word msb lsb | Next State | Code Word msb lsb | Next State |
| 144 | 0000010001001000 | 3 | 0100000010000100 | 2 | 0000010001001000 | 3 | 0100000010000100 | 2 |
| 145 | 0000010010010000 | 3 | 0000010010010000 | 3 | 1001000001000000 | 4 | 1001000001000000 | 4 |
| 146 | 0000100000001000 | 3 | 0100000000010000 | 2 | 0000100000001000 | 3 | 0100000000010000 | 2 |
| 147 | 0000100001000100 | 3 | 0000100001000100 | 3 | 1000000000100000 | 2 | 1000000000100000 | 2 |
| 148 | 0000100010001000 | 3 | 0100000010000100 | 3 | 0000100010001000 | 3 | 0100000010000100 | 3 |
| 149 | 0000100100010000 | 3 | 0000100100010000 | 3 | 1000000000100000 | 3 | 1000000000100000 | 3 |
| 150 | 0001000000010000 | 3 | 0001000000010000 | 3 | 0100000100001000 | 3 | 0100000100001000 | 3 |
| 151 | 0001000010000100 | 3 | 0001000010000100 | 3 | 1000000001000000 | 4 | 1000000001000000 | 4 |
| 152 | 0001000100001000 | 3 | 0100001000010000 | 3 | 0001000100001000 | 3 | 0100001000010000 | 3 |
| 153 | 0001001000010000 | 3 | 0001001000010000 | 3 | 1001000001000001 | 1 | 1001000001000001 | 1 |
| 154 | 0010000000100000 | 3 | 0010000000100000 | 3 | 0100000100001000 | 2 | 0100000100001000 | 2 |
| 155 | 0010000100000100 | 3 | 0010000100000100 | 3 | 1001000100100100 | 3 | 1001000100100100 | 3 |
| 156 | 0010000100100100 | 3 | 0010000100100100 | 3 | 1000100100100010 | 1 | 1000100100100010 | 1 |
| 157 | 0010001000001000 | 3 | 0100000000100001 | 1 | 0010001000001000 | 3 | 0100000000100001 | 1 |
| 158 | 0010001001000100 | 3 | 0010001001000100 | 3 | 1000100100000100 | 3 | 0100100100000000 | 4 |
| 159 | 0010010000010000 | 3 | 0010010000010000 | 3 | 1001001001000100 | 2 | 1001001001000100 | 2 |
| 160 | 0010010010000100 | 3 | 0010010010000100 | 3 | 1001001000001000 | 2 | 1001001000001000 | 2 |
| 161 | 0000001000010010 | 1 | 0100000000010000 | 3 | 1000100100010001 | 1 | 0100000000010000 | 3 |
| 162 | 0000001000001001 | 1 | 0100100100100100 | 2 | 1000100010010010 | 1 | 0100100100100100 | 2 |
| 163 | 0000000100000010 | 1 | 0100100100100100 | 3 | 1000100010001001 | 1 | 0100100100100100 | 3 |
| 164 | 0000000010000001 | 1 | 0100100100010010 | 1 | 1000100001000010 | 1 | 0100100100010010 | 1 |
| 165 | 0010010010010001 | 1 | 0010010010010001 | 1 | 1001000100100100 | 2 | 1001000100100100 | 2 |
| 166 | 0010010000100010 | 1 | 0010010000100010 | 1 | 1001000100000100 | 2 | 1001000100000100 | 2 |
| 167 | 0010010001001001 | 1 | 0100100100000100 | 2 | 0010010001001001 | 1 | 0100100100000100 | 2 |
| 168 | 0010010000010001 | 1 | 0010010000010001 | 1 | 1001001001000100 | 3 | 1001001001000100 | 3 |
| 169 | 0010001000010010 | 1 | 0010001000010010 | 1 | 1000100000100001 | 1 | 1000100000100001 | 1 |
| 170 | 0010000100000010 | 1 | 0010000100000010 | 1 | 1000010010010001 | 1 | 1000010010010001 | 1 |
| 171 | 0010001000001001 | 1 | 0100100000100000 | 3 | 0010001000001001 | 1 | 0100100000100000 | 3 |
| 172 | 0010000010000001 | 1 | 0010000010000001 | 1 | 1000010001001001 | 1 | 1000010001001001 | 1 |
| 173 | 0001001000100010 | 1 | 0001001000100010 | 1 | 1000010000100010 | 1 | 1000010000100010 | 1 |
| 174 | 0001001000010001 | 1 | 0001001000010001 | 1 | 1000010000010001 | 1 | 1000010000010001 | 1 |
| 175 | 0001000100010010 | 1 | 0001000100010010 | 1 | 1000001000010010 | 1 | 1000001000010010 | 1 |
| 176 | 0001000010000010 | 1 | 0001000010000010 | 1 | 1000001000001001 | 1 | 1000001000001001 | 1 |
| 177 | 0001001001001001 | 1 | 0100100010000010 | 1 | 0001001001001001 | 1 | 0100100010000010 | 1 |
| 178 | 0001000001000001 | 1 | 0001000001000001 | 1 | 1000000100000010 | 1 | 1000000100000010 | 1 |
| 179 | 0000100100100010 | 1 | 0000100100100010 | 1 | 1000000010000001 | 1 | 1000000010000001 | 1 |
| 180 | 0000100100010001 | 1 | 0000100100010001 | 1 | 0100100100001001 | 1 | 0100100100001001 | 1 |
| 181 | 0001000100001001 | 1 | 0100100000100000 | 2 | 0001000100001001 | 1 | 0100100000100000 | 2 |
| 182 | 0000100010010010 | 1 | 0000100010010010 | 1 | 0100010010001001 | 1 | 0100010010001001 | 1 |
| 183 | 0000100001000010 | 1 | 0000100001000010 | 1 | 0100001001001001 | 1 | 0100001001001001 | 1 |
| 184 | 0000100010001001 | 1 | 0100010010000100 | 3 | 0000100010001001 | 1 | 0100010010000100 | 3 |
| 185 | 0000100000100001 | 1 | 0000100000100001 | 1 | 1001000000100000 | 2 | 1001000000100000 | 2 |
| 186 | 0000010010010001 | 1 | 0000010010010001 | 1 | 1000100100001000 | 2 | 1000100100001000 | 2 |
| 187 | 0000010000100010 | 1 | 0000010000100010 | 1 | 1000100010000100 | 2 | 1000100010000100 | 2 |
| 188 | 0000010001001001 | 1 | 0100100001000001 | 1 | 0000010001001001 | 1 | 0100100001000001 | 1 |
| 189 | 0000010000010001 | 1 | 0000010000010001 | 1 | 1000100000010000 | 2 | 1000100000010000 | 2 |
| 190 | 0000001001001000 | 2 | 0100010010000100 | 2 | 1000010010001000 | 2 | 0100010010000100 | 2 |
| 191 | 0000001000100100 | 2 | 0100010000010000 | 2 | 1000010001000100 | 2 | 0100010000010000 | 2 |
| 192 | 0000001000000100 | 2 | 0100001001000100 | 2 | 1000010000001000 | 2 | 0100001001000100 | 2 |

continued

**Table A 5-1 Main Conversion Table (continued)**

| | State 1 | | State 2 | | State 3 | | State 4 | |
|---|---|---|---|---|---|---|---|---|
| 8-bit byte | Code Word msb lsb | Next State | Code Word msb lsb | Next State | Code Word msb lsb | Next State | Code Word msb lsb | Next State |
| 193 | 0010010010001000 | 2 | 0100010000010000 | 3 | 0010010010001000 | 2 | 0100010000010000 | 3 |
| 194 | 0010010001000100 | 2 | 0010010001000100 | 2 | 1000001001001000 | 2 | 1000001001001000 | 2 |
| 195 | 0010010000001000 | 2 | 0100010010010010 | 1 | 0010010000001000 | 2 | 0100010010010010 | 1 |
| 196 | 0010001000100100 | 2 | 0010001000100100 | 2 | 1000001000100100 | 2 | 1000001000100100 | 2 |
| 197 | 0010001000000100 | 2 | 0010001000000100 | 2 | 1000001000000100 | 2 | 1000001000000100 | 2 |
| 198 | 0010001001001000 | 2 | 0100010001000010 | 1 | 0010001001001000 | 2 | 0100010001000010 | 1 |
| 199 | 0001001001000100 | 2 | 0001001001000100 | 2 | 0100001000001000 | 2 | 0100001000001000 | 2 |
| 200 | 0001000100100100 | 2 | 0001000100100100 | 2 | 1001000000100000 | 3 | 1001000000100000 | 3 |
| 201 | 0001000100000100 | 2 | 0001000100000100 | 2 | 1000100100001000 | 3 | 1000100100001000 | 3 |
| 202 | 0001001000001000 | 2 | 0100010000100001 | 1 | 0001001000001000 | 2 | 0100010000100001 | 1 |
| 203 | 0001000000100000 | 2 | 0001000000100000 | 2 | 1000100010000100 | 3 | 1000100010000100 | 3 |
| 204 | 0000100010000100 | 2 | 0000100010000100 | 2 | 1000010010001000 | 3 | 1000010010001000 | 3 |
| 205 | 0000100000010000 | 2 | 0000100000010000 | 2 | 1000010001000100 | 3 | 1000010001000100 | 3 |
| 206 | 0000100100001000 | 2 | 0100001000100010 | 1 | 0000100100001000 | 2 | 0100001000100010 | 1 |
| 207 | 0000010010001000 | 2 | 0100001000010001 | 1 | 0000010010001000 | 2 | 0100001000010001 | 1 |
| 208 | 0000010001000100 | 2 | 0000010001000100 | 2 | 1000001000100100 | 3 | 1000001000100100 | 3 |
| 209 | 0000010000001000 | 2 | 0100000100010010 | 1 | 0000010000001000 | 2 | 0100000100010010 | 1 |
| 210 | 0000001000000100 | 3 | 0100000010000010 | 1 | 1000010000001000 | 3 | 0100000010000010 | 1 |
| 211 | 0000001000100100 | 3 | 0100000100100100 | 2 | 1000001001001000 | 3 | 0100000100100100 | 2 |
| 212 | 0000001001001000 | 3 | 0100000100000100 | 2 | 1000001000000100 | 3 | 0100000100000100 | 2 |
| 213 | 0000010000001000 | 3 | 0100000001000001 | 1 | 0000010000001000 | 3 | 0100000001000001 | 1 |
| 214 | 0000010001000100 | 3 | 0000010001000100 | 3 | 0100001000001000 | 3 | 0100001000001000 | 3 |
| 215 | 0000010010001000 | 3 | 0100000000100000 | 2 | 0000010010001000 | 3 | 0100000000100000 | 2 |
| 216 | 0000100000010000 | 3 | 0000100000010000 | 3 | 1001001000010000 | 3 | 1001001000010000 | 3 |
| 217 | 0000100010000100 | 3 | 0000100010000100 | 3 | 1001000100000100 | 3 | 1001000100000100 | 3 |
| 218 | 0000100100001000 | 3 | 0100000100000100 | 3 | 0000100100001000 | 3 | 0100000100000100 | 3 |
| 219 | 0001000000100000 | 3 | 0001000000100000 | 3 | 0100000100001001 | 1 | 0100000100001001 | 1 |
| 220 | 0001000100000100 | 3 | 0001000100000100 | 3 | 1001001000010000 | 2 | 1001001000010000 | 2 |
| 221 | 0001000100100100 | 3 | 0001000100100100 | 3 | 1001000100001000 | 2 | 1001000100001000 | 2 |
| 222 | 0001001000001000 | 3 | 0100000100100100 | 3 | 0001001000001000 | 3 | 0100000100100100 | 3 |
| 223 | 0001001001000100 | 3 | 0001001001000100 | 3 | 1001001000001000 | 3 | 1001001000001000 | 3 |
| 224 | 0010001000000100 | 3 | 0010001000000100 | 3 | 1000100000010000 | 3 | 1000100000010000 | 3 |
| 225 | 0010001000100100 | 3 | 0010001000100100 | 3 | 1001001001000010 | 1 | 1001001001000010 | 1 |
| 226 | 0010001001001000 | 3 | 0100001001000100 | 3 | 0010001001001000 | 3 | 0100001001000100 | 3 |
| 227 | 0010010000001000 | 3 | 0100100100000100 | 3 | 0010010000001000 | 3 | 0100100100000100 | 3 |
| 228 | 0010010001000100 | 3 | 0010010001000100 | 3 | 1001000100001000 | 3 | 1001000100001000 | 3 |
| 229 | 0010010010001000 | 3 | 0100000000100000 | 3 | 0010010010001000 | 3 | 0100000000100000 | 3 |
| 230 | 0010000001000000 | 4 | 0010000001000000 | 4 | 1001001000100001 | 1 | 1001001000100001 | 1 |
| 231 | 0000001001001001 | 1 | 0100100100100010 | 1 | 1001000100100010 | 1 | 0100100100100010 | 1 |
| 232 | 0000001000100010 | 1 | 0100100010000100 | 2 | 1001000100010001 | 1 | 0100100010000100 | 2 |
| 233 | 0000001000010001 | 1 | 0100100000010000 | 2 | 1001000010010010 | 1 | 0100100000010000 | 2 |
| 234 | 0000000100010010 | 1 | 0100000001000000 | 4 | 1001000010001001 | 1 | 0100000001000000 | 4 |
| 235 | 0000000100001001 | 1 | 0100100100010001 | 1 | 1001000001000010 | 1 | 0100100100010001 | 1 |
| 236 | 0000000010000010 | 1 | 0100100010010010 | 1 | 1001000000100001 | 1 | 0100100010010010 | 1 |
| 237 | 0000000001000001 | 1 | 0100100001000010 | 1 | 1000100100100001 | 1 | 0100100001000010 | 1 |
| 238 | 0010010000010010 | 1 | 0010010000010010 | 1 | 1000100010010001 | 1 | 1000100010010001 | 1 |
| 239 | 0010001000000010 | 1 | 0010001000000010 | 1 | 1001000010000100 | 3 | 1001000010000100 | 3 |
| 240 | 0010010000001001 | 1 | 0100100010000100 | 3 | 0010010000001001 | 1 | 0100100010000100 | 3 |
| 241 | 0010000100000001 | 1 | 0010000100000001 | 1 | 1001000010000100 | 2 | 1001000010000100 | 2 |

continued

 

**Table A 5-1 Main Conversion Table (continued)**

| | State 1 | | State 2 | | State 3 | | State 4 | |
|---|---|---|---|---|---|---|---|---|
| 8-bit byte | Code Word msb lsb | Next State | Code Word msb lsb | Next State | Code Word msb lsb | Next State | Code Word msb lsb | Next State |
| 242 | 0001001000010010 | 1 | 0001001000010010 | 1 | 1000000010000000 | 4 | 1000000010000000 | 4 |
| 243 | 0001000100000010 | 1 | 0001000100000010 | 1 | 1000100001001001 | 1 | 1000100001001001 | 1 |
| 244 | 0001001000001001 | 1 | 0100100000100001 | 1 | 0001001000001001 | 1 | 0100100000100001 | 1 |
| 245 | 0001000010000001 | 1 | 0001000010000001 | 1 | 1000100000100010 | 1 | 1000100000100010 | 1 |
| 246 | 0000100100010010 | 1 | 0000100100010010 | 1 | 1000100000010001 | 1 | 1000100000010001 | 1 |
| 247 | 0000100010000010 | 1 | 0000100010000010 | 1 | 1000010000010010 | 1 | 1000010000010010 | 1 |
| 248 | 0000100100001001 | 1 | 0100010010010001 | 1 | 0000100100001001 | 1 | 0100010010010001 | 1 |
| 249 | 0000100001000001 | 1 | 0000100001000001 | 1 | 1000010000001001 | 1 | 1000010000001001 | 1 |
| 250 | 0000010010010010 | 1 | 0000010010010010 | 1 | 1000001000000010 | 1 | 1000001000000010 | 1 |
| 251 | 0000010001000010 | 1 | 0000010001000010 | 1 | 1000000100000001 | 1 | 1000000100000001 | 1 |
| 252 | 0000010010001001 | 1 | 0100010000100010 | 1 | 0000010010001001 | 1 | 0100010000100010 | 1 |
| 253 | 0000010000100001 | 1 | 0000010000100001 | 1 | 0100100010001001 | 1 | 0100100010001001 | 1 |
| 254 | 0000001001000100 | 2 | 0100010000010001 | 1 | 1001000000010000 | 2 | 0100010000010001 | 1 |
| 255 | 0000001000001000 | 2 | 0100001000010010 | 1 | 1000100100010000 | 2 | 0100001000010010 | 1 |

end of main conversion table

### Table A 5-2 Substitution table

| | State 1 | | State 2 | | State 3 | | State 4 | |
|---|---|---|---|---|---|---|---|---|
| 8-bit byte | Code Word msb lsb | Next State | Code Word msb lsb | Next State | Code Word msb lsb | Next State | Code Word msb lsb | Next State |
| 0 | 0000010010000000 | 4 | 0000010010000000 | 4 | 0100100001001000 | 2 | 0100100001001000 | 2 |
| 1 | 0000100100000000 | 4 | 0000100100000000 | 4 | 0100100001001000 | 3 | 0100100001001000 | 3 |
| 2 | 0001001000000000 | 4 | 0001001000000000 | 4 | 0100100000001001 | 1 | 0100100000001001 | 1 |
| 3 | 0000001001000000 | 4 | 0100010000000001 | 1 | 1000001000000000 | 4 | 0100010000000001 | 1 |
| 4 | 0000000100100000 | 3 | 0100100000000010 | 1 | 1001000000000100 | 3 | 0100100000000010 | 1 |
| 5 | 0000000010010000 | 3 | 0100001000000000 | 4 | 1001000000100100 | 3 | 0100001000000000 | 4 |
| 6 | 0000000001001000 | 3 | 0100100000000100 | 2 | 1001000001001000 | 3 | 0100100000000100 | 2 |
| 7 | 0000000001001000 | 2 | 0100000100000000 | 4 | 1001000000000100 | 2 | 0100000100000000 | 4 |
| 8 | 0000000010010000 | 2 | 0100100010010000 | 3 | 1001000000100100 | 2 | 0100100010010000 | 3 |
| 9 | 0000000100100000 | 2 | 0100100000100100 | 2 | 1001000001001000 | 2 | 0100100000100100 | 2 |
| 10 | 0000010001000000 | 4 | 0000010001000000 | 4 | 1001001001000000 | 4 | 1001001001000000 | 4 |
| 11 | 0000100010000000 | 4 | 0000100010000000 | 4 | 1000100001001000 | 3 | 1000100001001000 | 3 |
| 12 | 0001000100000000 | 4 | 0001000100000000 | 4 | 0100010001001000 | 3 | 0100010001001000 | 3 |
| 13 | 0010001000000000 | 4 | 0010001000000000 | 4 | 1000100000000100 | 3 | 1000100000000100 | 3 |
| 14 | 0000001000100000 | 3 | 0100100000000100 | 3 | 1001000010010000 | 3 | 0100100000000100 | 3 |
| 15 | 0000000100010000 | 3 | 0100100010010000 | 2 | 1001000100100000 | 3 | 0100100010010000 | 2 |
| 16 | 0000000010001000 | 3 | 0100001000000001 | 1 | 0100100000001000 | 3 | 0100001000000001 | 1 |
| 17 | 0000000001000100 | 3 | 0100010000000010 | 1 | 0100100010001000 | 3 | 0100010000000010 | 1 |
| 18 | 0000000001000100 | 2 | 0100100000100100 | 3 | 1001000010010000 | 2 | 0100100000100100 | 3 |
| 19 | 0000000010001000 | 2 | 0100100100100000 | 3 | 1001000100100000 | 2 | 0100100100100000 | 3 |
| 20 | 0000000100010000 | 2 | 0100100100100000 | 2 | 0100010001001000 | 2 | 0100100100100000 | 2 |
| 21 | 0000001000100000 | 2 | 0100100000010010 | 1 | 0100100000001000 | 2 | 0100100000010010 | 1 |
| 22 | 0000010010000001 | 1 | 0000010010000001 | 1 | 1000100000100100 | 3 | 1000100000100100 | 3 |
| 23 | 0000100100000001 | 1 | 0000100100000001 | 1 | 1000100010010000 | 3 | 1000100010010000 | 3 |
| 24 | 0001001000000001 | 1 | 0001001000000001 | 1 | 0100100010001000 | 2 | 0100100010001000 | 2 |
| 25 | 0010010000000001 | 1 | 0010010000000001 | 1 | 1000100000000100 | 2 | 1000100000000100 | 2 |
| 26 | 0000000001001001 | 1 | 0100010000000100 | 3 | 1000010000000001 | 1 | 0100010000000100 | 3 |
| 27 | 0000000010010001 | 1 | 0100000100000001 | 1 | 1000100000000010 | 1 | 0100000100000001 | 1 |
| 28 | 0000000100100001 | 1 | 0100010000000100 | 2 | 1001000000001001 | 1 | 0100010000000100 | 2 |
| 29 | 0000001001000001 | 1 | 0100001000000010 | 1 | 1001000000010010 | 1 | 0100001000000010 | 1 |
| 30 | 0000100001000000 | 4 | 0000100001000000 | 4 | 1000100000100100 | 2 | 1000100000100100 | 2 |
| 31 | 0001000010000000 | 4 | 0001000010000000 | 4 | 1000100001001000 | 2 | 1000100001001000 | 2 |
| 32 | 0010000100000000 | 4 | 0010000100000000 | 4 | 0100010000001001 | 1 | 0100010000001001 | 1 |
| 33 | 0000010000100000 | 3 | 0000010000100000 | 3 | 0100100001001001 | 1 | 0100100001001001 | 1 |
| 34 | 0000001000010000 | 3 | 0100010000010010 | 1 | 1000100100100000 | 3 | 0100010000010010 | 1 |
| 35 | 0000000100001000 | 3 | 0100100000010001 | 1 | 1001000000001000 | 3 | 0100100000010001 | 1 |
| 36 | 0000000010000100 | 3 | 0100000010000000 | 4 | 1001000001000100 | 3 | 0100000010000000 | 4 |
| 37 | 0000010000100000 | 2 | 0000010000100000 | 2 | 1000001000000001 | 1 | 1000001000000001 | 1 |
| 38 | 0000000010000100 | 2 | 0100010000100100 | 3 | 1000100010010000 | 2 | 0100010000100100 | 3 |
| 39 | 0000000100001000 | 2 | 0100010000100100 | 2 | 1000100100100000 | 2 | 0100010000100100 | 2 |
| 40 | 0000001000010000 | 2 | 0100100000100010 | 1 | 1001000000001000 | 2 | 0100100000100010 | 1 |
| 41 | 0000010001000001 | 1 | 0000010001000001 | 1 | 1000010000000010 | 1 | 1000010000000010 | 1 |
| 42 | 0000010010000010 | 1 | 0000010010000010 | 1 | 1000000100000000 | 4 | 1000000100000000 | 4 |
| 43 | 0000100010000001 | 1 | 0000100010000001 | 1 | 1001000001000100 | 2 | 1001000001000100 | 2 |
| 44 | 0000100100000010 | 1 | 0000100100000010 | 1 | 1000100000001001 | 1 | 1000100000001001 | 1 |
| 45 | 0001000100000001 | 1 | 0001000100000001 | 1 | 1001000010001000 | 3 | 1001000010001000 | 3 |
| 46 | 0001001000000010 | 1 | 0001001000000010 | 1 | 1001000100010000 | 3 | 1001000100010000 | 3 |

continued

**Table A 5-2 Substitution table (continued)**

| | State 1 | | State 2 | | State 3 | | State 4 | |
|---|---|---|---|---|---|---|---|---|
| 8-bit byte | Code Word msb lsb | Next State | Code Word msb lsb | Next State | Code Word msb lsb | Next State | Code Word msb lsb | Next State |
| 47 | 0010001000000001 | 1 | 0010001000000001 | 1 | 1000100000010010 | 1 | 1000100000010010 | 1 |
| 48 | 0010010000000010 | 1 | 0010010000000010 | 1 | 0100010000001000 | 3 | 0100010000001000 | 3 |
| 49 | 0000000001000010 | 1 | 0100100010010001 | 1 | 1001000000010001 | 1 | 0100100010010001 | 1 |
| 50 | 0000000010001001 | 1 | 0100100001000100 | 3 | 1001000000100010 | 1 | 0100100001000100 | 3 |
| 51 | 0000000010010010 | 1 | 0100010010010000 | 3 | 1001000001001001 | 1 | 0100010010010000 | 3 |
| 52 | 0000000100010001 | 1 | 0100010010010000 | 2 | 1001000010010001 | 1 | 0100010010010000 | 2 |
| 53 | 0000000100100010 | 1 | 0100100001000100 | 2 | 1001000100100001 | 1 | 0100100001000100 | 2 |
| 54 | 0000001000100001 | 1 | 0100100100100001 | 1 | 1001001001000001 | 1 | 0100100100100001 | 1 |
| 55 | 0000001001000010 | 1 | 0100100100010000 | 3 | 0100001000001001 | 1 | 0100100100010000 | 3 |
| 56 | 0001000001000000 | 4 | 0001000001000000 | 4 | 1001001000100000 | 3 | 1001001000100000 | 3 |
| 57 | 0010000010000000 | 4 | 0010000010000000 | 4 | 1001000010001000 | 2 | 1001000010001000 | 2 |
| 58 | 0010010010010000 | 3 | 0010010010010000 | 3 | 1001000100010000 | 2 | 1001000100010000 | 2 |
| 59 | 0010010001001000 | 3 | 0100100100010000 | 2 | 0010010001001000 | 3 | 0100100100010000 | 2 |
| 60 | 0010010000100100 | 3 | 0010010000100100 | 3 | 1001001000100000 | 2 | 1001001000100000 | 2 |
| 61 | 0010010000000100 | 3 | 0010010000000100 | 3 | 0100001001001000 | 2 | 0100001001001000 | 2 |
| 62 | 0001001001001000 | 3 | 0100000010000001 | 1 | 0001001001001000 | 3 | 0100000010000001 | 1 |
| 63 | 0001001000100100 | 3 | 0001001000100100 | 3 | 0100001001001000 | 3 | 0100001001001000 | 3 |
| 64 | 0001001000000100 | 3 | 0001001000000100 | 3 | 0100010010001000 | 3 | 0100010010001000 | 3 |
| 65 | 0000100100100100 | 3 | 0000100100100100 | 3 | 0100100100001000 | 3 | 0100100100001000 | 3 |
| 66 | 0000100100000100 | 3 | 0000100100000100 | 3 | 1000010000000100 | 3 | 1000010000000100 | 3 |
| 67 | 0000100000100000 | 3 | 0000100000100000 | 3 | 1000010000100100 | 3 | 1000010000100100 | 3 |
| 68 | 0000010010000100 | 3 | 0000010010000100 | 3 | 1000010001001000 | 3 | 1000010001001000 | 3 |
| 69 | 0000010000010000 | 3 | 0000010000010000 | 3 | 1000010010010000 | 3 | 1000010010010000 | 3 |
| 70 | 0000001001000100 | 3 | 0100001000000100 | 2 | 1000100000001000 | 3 | 0100001000000100 | 2 |
| 71 | 0000001000001000 | 3 | 0100100000010000 | 3 | 1000100010001000 | 3 | 0100100000010000 | 3 |
| 72 | 0000000100100100 | 3 | 0100010001000100 | 3 | 1000100100010000 | 3 | 0100010001000100 | 3 |
| 73 | 0000000100000100 | 3 | 0100001000100100 | 3 | 1001000000010000 | 3 | 0100001000100100 | 3 |
| 74 | 0000010000010000 | 2 | 0000010000010000 | 2 | 1000100001000100 | 3 | 1000100001000100 | 3 |
| 75 | 0001001001001000 | 2 | 0100001000000100 | 3 | 0001001001001000 | 2 | 0100001000000100 | 3 |
| 76 | 0000010010000100 | 2 | 0000010010000100 | 2 | 0100010000001000 | 2 | 0100010000001000 | 2 |
| 77 | 0000100000100000 | 2 | 0000100000100000 | 2 | 0100010010001000 | 2 | 0100010010001000 | 2 |
| 78 | 0010010001001000 | 2 | 0100000100000010 | 1 | 0010010001001000 | 2 | 0100000100000010 | 1 |
| 79 | 0000100100000100 | 2 | 0000100100000100 | 2 | 0100100100001000 | 2 | 0100100100001000 | 2 |
| 80 | 0000100100100100 | 2 | 0000100100100100 | 2 | 1000010000000100 | 2 | 1000010000000100 | 2 |
| 81 | 0001001000000100 | 2 | 0001001000000100 | 2 | 1000010000100100 | 2 | 1000010000100100 | 2 |
| 82 | 0001001000100100 | 2 | 0001001000100100 | 2 | 1000010001001000 | 2 | 1000010001001000 | 2 |
| 83 | 0010010000000100 | 2 | 0010010000000100 | 2 | 1000010010010000 | 2 | 1000010010010000 | 2 |
| 84 | 0010010000100100 | 2 | 0010010000100100 | 2 | 1000100000001000 | 2 | 1000100000001000 | 2 |
| 85 | 0010010010010000 | 2 | 0010010010010000 | 2 | 0100010001001001 | 1 | 0100010001001001 | 1 |
| 86 | 0000000100000100 | 2 | 0100001000100100 | 2 | 1000100001000100 | 2 | 0100001000100100 | 2 |
| 87 | 0000000100100100 | 2 | 0100010001000100 | 2 | 1000100010001000 | 2 | 0100010001000100 | 2 |

end of substitution table

# A6 Transportation (informative)

## A6.1 General

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

## A6.2 Packaging

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.

### A6.2.1 Temperature and humidity

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

### A6.2.2 Impact loads and vibrations

a) Avoid mechanical loads that would distort the shape of the disc.
b) Avoid dropping the disc.
c) Discs 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.

 

# A7 SID (Source IDentification) Code (normative)

## A7.1 Introduction

The International Federation of the Phonographic Industry (IFPI) is an organisation representing most of the record producers in most of the countries around the world. The IFPI campaigns for the introduction, improvement and enforcement of copyright and related rights legislation and co-ordinates the Music Industry's anti-piracy activities.
To support their activities in searching for counterfeit CD products, the IFPI has introduced the SID code. This code identifies the Mastering machine (Laser Beam Recorder) and the Mould on which the disc has been produced.
Information about the IFPI and detailed requirements for the SID code can be requested from:

IFPI Secretariat
54 Regent Street,
London W1R 5PJ, UK
tel: +44 – 171 – 878 7900
fax: +44 – 171 – 878 7950
e-mail: info@ifpi.org
web: www.ifpi.org

## A7.2 SID Code on SA-CD

### A7.2.1 Mastering Code

Each Recorded Layer of an SA-CD disc shall carry a Mastering Code:
- the code shall be located between radius 17.0 mm and radius 22.0 mm, preferably on the metallised area on the replicated disc. The codes of the different Recorded Layers should not overlap.
- the height of the characters shall be 0.5 mm minimum and shall be legible without magnification.
- the code shall be readable from the read-out side of the corresponding Recorded Layer.
- the code shall consist of the characters IFPI in uppercase or the registered IFPI trade mark, followed by a four digit alphanumeric code identifying the LBR.

### A7.2.2 Mould Code

Each substrate of an SA-CD disc shall carry a Mould Code:
- the code shall be located between radius 17.0 mm and radius 22.0 mm, and positioned on the read through side of the mould (mirror block).
- the height of the characters shall be between 0.5 mm and 1.0 mm. The depth of the etch shall be such that the characters are legible without magnification. The lay-out of the characters can be linear or radial.
- the code shall be readable from the read-out side of the corresponding substrate.
- the code shall consist of the characters IFPI in uppercase or the registered IFPI trade mark, followed by a four digit alphanumeric code identifying the plant site and the mould.

### A7.2.3 Requests for SID Codes

SID Codes are registered and issued by:

Royal Philips Electronics
System Standards & Licensing
Licensing Support
Building SFF-8
P.O. Box 80002
5600 JB Eindhoven
The Netherlands

Fax.: +31 - 40 - 27 32113
Internet: http://www.licensing.philips.com

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# List of Changes

**Changes from "Super Audio CD System Description Part 1, Version 1.2"**
**to "**Super Audio CD System Description Part 1**, Version 2.0"**

The main changes are:

- The recommended optical pick-up head for measuring the HD layer is changed from NPBS into PBS and measurement values for PBS are added.
- The birefringence requirement for the HD layer of a Hybrid disc is relaxed.
- Parallel reference is added for measuring the reflectivity of the CD layer.
- The reflectivity requirement at a wavelength of 650 nm is removed for the CD layer of a Hybrid disc.
- The jitter requirement is changed.
- Clarification of the jitter measurement conditions.

Unless stated otherwise, the chapter and figure numbers in the following list refer to the numbers found in Version 2.0.

| Chapter | Version 1.2 | Version 2.0 | Remarks |
|---|---|---|---|
| 2.4.3 | polarizing beam splitter (PBS)<br>---<br>shall not be used, unless stated otherwise | polarizing beam splitter (PBS)<br>---<br>recommended | PBS recommended for measuring the HD layer. |
| 2.6.1.6 | (focused beam, focused reference, double pass, no PBS, see annex A.1) | Measuring method, see annex A.1, measured with focused reference. | PBS recommended for measuring the HD layer. |
| 2.6.1.6 | -- | The reflectivity shall fulfil the requirements given under PBS when measured with a PBS (recommended), or fulfil the requirements under NPBS when measured with a non-polarizing beam splitter. | PBS recommended for measuring the HD layer. Values for PBS added. |
| 2.6.1.6 | <br>Rtop=60~85%<br>Rtop=18~30%<br>Rtop=15~30% | NPBS PBS<br>Rtop=60~85% Rtop=45~85%<br>Rtop=18~30% Rtop=18~30%<br>Rtop=15~30% Rtop=12~30% | Measurement values for PBS added. |
| 2.6.1.7 | The birefringence of the HD substrate of the Hybrid disc shall be ≤ 60 nm double pass | The birefringence of the HD substrate of the Hybrid disc shall be ≤ 100 nm double pass | Birefringence spec relaxed. |
| 2.6.2.4 | $R_{top}$ > 58% at 780 nm (focused beam, focused reference, double pass, see annex A.1) | The reflectivity of the CD layer shall fulfil one of the following two requirements:<br>$R_{top}$ > 58% at 780 nm (focused beam, focused reference, double pass, see annex A.1)<br>$R_{top}$ > 65% at 780 nm (focused beam, parallel reference, double pass, see annex A.1) | Parallel reference added for measuring the reflectivity. |
| 2.6.2.4 | $R_{top}$ > 35% at 650 nm (Objective lens ... see annex A.1) | -- | CD layer reflectivity requirement at 650 nm removed. |

| Chapter | Version 1.2 | Version 2.0 | Remarks |
|---|---|---|---|
| 4.1.1.1 | -- | The modulation amplitude shall fulfil ... non-polarizing beam splitter. | Measurement values for PBS added. |
| 4.1.1.1 | 0.20 within one disc<br>010 within one revolution | NPBS PBS<br>within one disc 0.20 0.33<br>within one rev. 010 0.15 | Measurement values for PBS added. |
| 4.1.1.1 | -- | For the HL disc, the product ... $\geq$ 0.09 | Requirement for PBS measurement added. |
| 4.1.1.4.1 | Jitter shall be less than 9.0 % ... | Jitter shall be less than 8.0 % ... | Jitter requirement changed. |
| A1.2 | Calculate the ... Rs | In case of a focused beam, focused reference, calculate the ... In case of a focused beam, parallel reference calculate ... R// | Parallel reference added for measuring the reflectivity. |
| A3.5 | 1) The optical ... reference plane. | 1) The tilt of ... disc under test. | Clarification of jitter measurement conditions. |
| A3.5 | 3) When measured ... the d.c.-offset ... shall be such ... reference disc. | 3) The d.c.-offset ... shall be adjusted such ... reference disc under test. | Clarification of jitter measurement conditions. |
| A3.6 | After calibration with the reference disc, the focus offset is kept at that position ... | The focus offset is kept at the adjusted optimum position ... | Clarification. |
| A3.6 | Under this measurement, the jitter shall be less than 9.0 % ... | Under this measurement, the jitter shall be less than 8.0 % ... | Jitter requirement changed. |

 