

Audio recording — Compact disc digital audio system

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National foreword

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The UK participation in its preparation was entrusted by Technical Committee EPL/100, Audio, Video and Multimedia Systems and Equipment, to Subcommittee EPL/100/2, Recording, which has the responsibility to:

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, the EN title page, pages 2 to 92 and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

This British Standard, having been prepared under the direction of the Electrotechnical Sector Committee, was published under the authority of the Standards Committee and comes into effect on 15 May 1999

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Contents

	Page
National foreword	Inside front cover
Foreword	2
Text of EN 60908	5

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English version

Audio recording Compact disc digital audio system

(IEC 60908:1999)

Enregistrement audio
Système audionumérique à disque compact
(CEI 60908:1999)

Tonaufzeichnung
Digital-Audio-System Compact Disc
(IEC 60908:1999)

This European Standard was approved by CENELEC on 1998-10-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application, to the Central Secretariat or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

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CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: rue de Stassart 35, B-1050 Brussels

Foreword

The text of document 100B/173/FDIS, future amendment to IEC 60908:1987, prepared by SC 100B, Recording, of IEC TC 100, Audio, video and multimedia systems and equipment, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as amendment A2 to EN 60908:1992 on 1998-10-01.

The text of this document, together with that of IEC 60908:1987 and its amendment 1:1992, was published by IEC as the second edition of IEC 60908 in February 1999. According to a decision of principle taken by the Technical Board of CENELEC, the approval of EN 60908:1992/A2 has been converted into the approval of a new EN 60908.

The following dates were fixed:

- latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 1999-11-01
- latest date by which the national standards conflicting with the EN have to be withdrawn (dow) 2001-11-01

Annexes designated “normative” are part of the body of the standard.

Annexes designated “informative” are given for information only.

In this standard, Annex B and Annex ZA are normative and Annex A, Annex C, Annex D, Annex E and Annex F are informative.

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 60908:1987 was approved by CENELEC as a European Standard without any modification.

Contents

	Page
Foreword	2
1 Scope and object	5
2 Normative references	5
3 Description of system	5
4 Requirements for measurements	6
4.1 Conditions of measurement	6
4.2 Requirements for the measuring pick-up	6
4.3 Requirements for the clamping of the disc	6
5 Mechanical parameters	6
5.1 Outer dimensions of disc	6
5.2 Centre hole dimensions	6
5.3 Thickness of disc	6
5.4 Labelling	7
5.5 Reference plane	7
5.6 Clamping area	7
5.7 Mass of disc	7
5.8 Limits for the deflections of the read-out side of the disc	7
6 Optical parameters	7
6.1 Thickness of transparent substrate	7
6.2 Refractive index	7
6.3 Limits for the angular deviation of the reflected beam (α)	8
6.4 Birefringence of transparent substrate	8
6.5 Reflectivity	8
6.6 Limits for reflectivity variation in program area	8
7 Recording parameters	8
7.1 Rotation during playback	8
7.2 Track	8
7.3 Limits for deviations of information layer perpendicular to reference plane	8
7.4 Limits for radial deviations of the track	9
8 Environmental conditions for playing the compact disc	9
8.1 Playing the compact disc	9
8.2 Temperature and humidity requirements	9
9 High-frequency signal	10
9.1 Measurement conditions	10
9.2 Modulation amplitude	10
9.3 Signal asymmetry	10

	Page		Page
9.4 Cross-talk	10	21.3 LINE-GRAPHICS mode FONT format	23
9.5 Frequency modulation of the channel bit frequency (see clause 13)	10	21.4 LINE-GRAPHICS mode SCREEN format	23
10 Radial differential (RD) signal	10	21.5 LINE-GRAPHICS mode colour table	24
10.1 Measurement conditions	10	21.6 LINE-GRAPHICS mode instructions	24
10.2 Shape of the radial differential signal	10	22 TV-GRAPHICS mode (MODE = 1, ITEM = 1)	25
10.3 Sensitivity to radial offset	11	22.1 General	25
10.4 Noise	11	22.2 TV-GRAPHICS mode PACK format	26
11 Defects	11	22.3 TV-GRAPHICS mode FONT format	26
11.1 Block error rate (BLER)	11	22.4 TV-GRAPHICS mode SCREEN format	27
11.2 Local defects	11	22.5 TV-GRAPHICS mode instructions	27
12 General — Recorded parameters	11	23 EXTENDED TV-GRAPHICS mode (MODE = 1, ITEM = 1 & 2)	34
13 Eight to 14 modulation code (EFM-code)	12	23.1 General	34
14 Frame format	12	23.2 EXTENDED TV-GRAPHICS mode PACK format	35
15 EFM-modulator	13	23.3 EXTENDED TV-GRAPHICS mode FONT format	35
16 Error correction	13	23.4 EXTENDED TV-GRAPHICS mode SCREEN and MEMORY formats	35
16.1 General	13	23.5 EXTENDED TV-GRAPHICS mode instructions	35
16.2 Structure	13	24 MIDI mode (MODE = 3, ITEM = 0)	40
16.3 CIRC encoder and decoder	14	24.1 General	40
17 Subcode/control and display system	14	24.2 MIDI mode PACK format	41
17.1 General	14	25 USER mode (MODE = 7, ITEM = 0)	41
17.2 Data format	14	25.1 General	41
17.3 Subcode structure	14	25.2 USER mode PACK format	42
17.4 Channel P	15	26 CD TEXT mode (MODE = 2, ITEM = 1, 2, 3, 5, 6, 7 or MODE = 4)	42
17.5 Channel Q	15	26.1 General	42
17.6 Channels R to W inclusive	19	26.2 CD TEXT mode for the lead-in area (MODE = 4)	42
18 General	19	26.3 CD TEXT mode for the program area (MODE = 2)	49
19 General data organization	19	26.4 Mandatory, recommended and optional items	53
19.1 Basic format	19	26.5 Repetition rate and skew	54
19.2 PACK format	19	Annex A (informative) Examples of the combination of the EFM-code with 3 extra channel bits	83
19.3 Error correction parity P	20	Annex B (normative) Abbreviations	84
19.4 Interleaving	21	Annex C (informative) Recommendations	85
19.5 <i>P</i> -parity encoder and interleave sequence	21	Annex D (informative) Aperture specification for 8 cm-CD	85
19.6 <i>P</i> -parity decoder and de-interleave sequence	21	Annex E (informative) TV-GRAPHICS mode implementation aspects	86
19.7 Error-correction parity <i>Q</i>	21		
19.8 <i>Q</i> -parity encoder	21		
19.9 <i>Q</i> -parity decoder	21		
20 ZERO mode (MODE = 0, ITEM = 0)	21		
20.1 General	21		
20.2 ZERO mode PACK format	22		
21 LINE GRAPHICS mode (MODE = 1, ITEM = 0)	22		
21.1 General	22		
21.2 LINE-GRAPHICS mode PACK format	22		

	Page		Page
Annex F (informative) EXTENDED TV-GRAPHICS mode implementation aspects	87	Figure 28 — CD TEXT mode PACK format for the lead-in area	81
Annex ZA (normative) Normative references to international publications with their corresponding European publications	92	Figure 29 — CD TEXT mode PACK format for the program area	81
Bibliography	92	Figure 30 — Example of partial interleaving of PACKS	81
Figure 1 — Pre-emphasis characteristic	54	Figure 31 — Maximum allowed mode transition skew	82
Figure 2 — Overall disc layout	57	Figure A.1	83
Figure 3 — HF signal	58	Figure A.2	83
Figure 4 — Typical shape of the RD signal used for tracking versus radial spot position	59	Figure A.3	84
Figure 5 — Transfer function	59	Figure D.1 — Adaptor including disc	85
Figure 6 — Eight to 14 modulation code (EFM code)	60	Figure F.1 — Memory organization of EXTENDED TV-GRAPHICS	89
Figure 7 — EFM conversion table	62	Figure F.2 — CLUT structure of EXTENDED TV-GRAPHICS	90
Figure 8 — Frame format	63	Figure F.3 — Relationship of colours between TV-GRAPHICS and EXTENDED TV-GRAPHICS	91
Figure 9 — Block structure	64		
Figure 10 — Column vectors	65		
Figure 11 — Parity check matrices	66		
Figure 12 — CIRC encoder	67		
Figure 13 — CIRC decoder	68		
Figure 14 — Example of encoding in channels P and Q	69		
Figure 15 — Example of encoding of table of contents with six tracks (program items)	70		
Figure 16 — Angular deviation	71		
Figure 17 — Operating conditions of disc	72		
Figure 18 — Time error versus modulation frequency	73		
Figure 19 — Basic format subcode channels R to W	74		
Figure 20 — General organization of a PACK	75		
Figure 21 — P-parity and interleave sequence	76		
Figure 22 — P-parity and de-interleave sequence	77		
Figure 23 — Q-parity encoder	78		
Figure 24 — Q-parity decoder	79		
Figure 25 — Block diagram of a video/graphics mixing unit	80		
Figure 26 — Example of encoding 3 bytes in 4 SYMBOLS	80		
Figure 27 — Text group and BLOCK structure	80		

1 Scope and object

This standard is applicable to a prerecorded optical reflective digital audio disc system.

This standard defines those parameters of compact disc that affect interchangeability between discs and players. It is also intended as a reference for manufacturers wishing to produce discs and/or players that conform to the system described in this standard. It deals with discs of 80 mm in diameter as well as those of 120 mm in diameter.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 60068-2-2:1974, *Environmental testing — Part 2: Tests — Tests B: Dry heat*.

IEC 60068-2-30:1980, *Environmental testing — Part 2: Tests — Test Db and guidance: Damp heat, cyclic (12 + 12-hour cycle)*.

IEC 60721-3-5:1997, *Classification of environmental conditions — Part 3: Classification of groups of environmental parameters and their severities — Section 5: Ground vehicle installations*.

IEC 61104:1992, *Compact disc video system — 12 cm CD-V*.

IEC 61866:1997, *Audiovisual systems — Interactive text transmission system (ITTS)*.

IEC 61938:1996, *Audio, video and audiovisual systems — Interconnections and matching values — Preferred matching values of analogue signals*.

ISO/IEC 646:1991, *Information technology — ISO 7-bit coded character set for information interchange*.

ISO 3901:1986, *Documentation — International Standard Recording Code (ISRC)*.

ISO/IEC 8859-1:1998, *Information technology — 8-bit single-byte coded graphic character sets — Part 1: Latin alphabet No. 1*.

EBU Tech 3258-E:1991, *Specification of the systems of the MAC/packet family*.

UPC/EAN, *Universal product code/International article numbering association*.

RIAJ Document RS506, *Music shift Kanji character set*.

CD EXTRA Enhanced music CD specification, Version 1.0, December 1995, Sony/Philips

3 Description of system

The information carrier is a transparent disc, the substrate, one side of which carries the information. This side, the encoded side, is covered in turn by a reflective and a protective layer.

The information of the disc is stored in a spiral-shaped track consisting of successive shallow depressions (pits). When the disc is playing and viewed from the read-out side, the spiral starts near the centre of the disc and finishes near its edge.

The lengths of the pits and the spaces between them can take discrete values only, and represent the encoded two-channel audio information.

The information is read out by means of a beam of light which passes through the plain, i.e. the non-encoded side of the transparent disc to the encoded side, where it is reflected and modulated by the recorded information (see Figure 2b, detail B).

The information is followed by means of a servo-system for tracking and focusing.

4 Requirements for measurements

4.1 Conditions of measurement

Measurements and mechanical checks shall be carried out within the following limits unless otherwise specified:

- ambient temperature: 15 °C to 35 °C;
- relative humidity: 45 % to 75 %;
- air pressure: 86 kPa to 106 kPa.

4.2 Requirements for the measuring pick-up

The optical pick-up to be used for disc measurement shall comply with the following requirements:

- wavelength: 780 ± 10 nm;
- polarization: circular;
- numerical aperture (NA): $0,45 \pm 0,01$;
- intensity at the rim of the pupil of the objective lens: > 50 % of the maximum intensity value;
- diffraction limited performance of the optical system: within the Maréchal criterion, preferably equally divided between disc and player.

4.3 Requirements for the clamping of the disc

The disc shall be fixed between two equally sized concentric rings, having inner diameters of 29 mm and outer diameters of 31 mm, the clamping force being between 1 N and 2 N (see Figure 2b).

Parameters to be specified		Requirements	Methods and/or conditions of measurement
5	Mechanical parameters	Figure 2a, Figure 2b and Figure 2c, specify the dimensions of the disc, including reflective layer, protective layer and label	
5.1	Outer dimensions of disc		
5.1.1	Outer diameter	$120 \pm 0,3$ mm $80 \pm 0,2$ mm	To be measured at 23 ± 2 °C and (50 ± 5) % relative humidity
5.1.2	Radial run-out of outer edge	0,4 mm max.	Relative to the inscribed circle of centre hole
5.1.3	Edge shape	Edges shall be free from burrs; chamfer or radius is permitted on both sides	
5.2	Centre hole dimensions	For 8 cm-CD, see Figure 2c and Figure 2d.	
5.2.1	Diameter	$15^{+0,1}_0$ mm	To be measured at 23 ± 2 °C and (50 ± 5) % relative humidity
5.2.2	Shape	Cylindrical	
5.2.3	Edge shape	Burrs are permitted on the label side, but not on the read-out side. Chamfer or radius is permitted (see Figure 2b, detail C)	
5.3	Thickness of disc	$1,2^{+0,3}_{-0,1}$ mm	Including protective layer and labelling

Parameters to be specified		Requirements	Methods and/or conditions of measurement
5.4	Labelling		
5.4.1	<i>Label dimensions</i>	Shall not project over edge of centre hole or outer edge of disc	May be applied by printing or by means of a label
5.4.2	<i>Label information</i>	At least the following information shall be given: a) Title of program b) Catalogue number of disc c) Sequence number of and total number of discs if complete program occupies more than one disc (e.g.: disc 2 of 4)	
5.5	Reference plane	Ring between diameters of 26 mm and 33 mm (see Figure 2a and Figure 2b)	On the read-out side
5.6	Clamping area		
5.6.1	<i>Inner diameter of clamping area</i>	26 mm max. ^a	
5.6.2	<i>Outer diameter of clamping area</i>	33 mm min. ^a	
5.6.3	<i>Thickness of disc in clamping area</i>	Within the requirements given in 5.3 and Figure 2b	
5.6.4	<i>Adaptor clamping area for 8 cm-CD</i>	An outer ring with 1,5 mm in width	
5.6.5	<i>Thickness in clamping area for 8 cm-CD adaptor</i>	1,2 ± 0,1 mm	
5.7	Mass of disc	14 g to 33 g 6 g to 16 g for 8 cm-CD	
5.8	Limits for the deflections of the read-out side of the disc		Within the information area (45 mm to 118 mm maximum diameter) (see Figure 2c)
5.8.1	<i>Peak deflection</i>	± 0,4 mm ± 0,3 mm for 8 cm-CD	
5.8.2	<i>Deflection averaged over one revolution</i>	± 0,3 mm ± 0,2 mm for 8 cm-CD	
5.8.3	<i>Angular deviation (β)</i>	± 0,6°	See Figure 16.
6	Optical parameters		
6.1	Thickness of transparent substrate	1,2 ± 0,1 mm	Within the information area (see Figure 2a, Figure 2b and Figure 2c). Excluding reflective layer, protective layer, and labelling
6.2	Refractive index	1,55 ± 0,1	

^a These dimensions ensure that the ring between 26 mm and 33 mm is available for clamping.

Parameters to be specified		Requirements	Methods and/or conditions of measurement
6.3	Limits for the angular deviation of the reflected beam (α)	$\pm 1,6^\circ$	Referred to reference plane E (see Figure 2a and Figure 16) including disc deflection and substrate unparallelism
6.4	Birefringence of transparent substrate	100 nm max. 70 % min. }	Double pass through transparent substrate
6.5	Reflectivity		
6.6	Limits for reflectivity variation in program area	3 % for $f < 100$ Hz	The reflectivity variation is measured by observing the variation of A_{top} , during one revolution of the disc at scanning velocity (see 7.1.2)
7	Recording parameters		
7.1	Rotation during playback		
7.1.1	<i>Sense of rotation of disc as seen from read-out side</i>	Counter-clockwise	
7.1.2	<i>Scanning velocity</i>	1,2 m/s min. 1,4 m/s max.	
7.1.3	<i>Limits for the velocity variation on any one disc</i>	$\pm 0,01$ m/s	
7.2	Track		
7.2.1	<i>Track path</i>	Continuous spiral from inside (start of the lead-in) to outside (end of the lead-out) of disc	
7.2.2	<i>Starting diameter of lead-in area</i>	46 mm max.	See Figure 2c
7.2.3	<i>Starting diameter of program area</i>	$50 \begin{smallmatrix} 0 \\ -0,4 \end{smallmatrix}$ mm	See Figure 2c To be measured at $23 \pm 2^\circ\text{C}$ and (50 ± 5) % relative humidity
7.2.4	<i>Maximum diameter of program area</i>	116 mm 75 mm for 8 cm-CD	
7.2.5	<i>Minimum outer diameter of lead-out area</i>	Outer diameter of program area plus 1 mm	See Figure 2c
7.2.6	<i>Pitch of track: distance between any two adjacent turns</i>	$1,6 \pm 0,1$ μm	
7.3	Limits for deviations of information layer perpendicular to reference plane		As observed by the measuring pick-up, the disc rotating at scanning velocity (see 7.1.2)
7.3.1	<i>For frequencies below 500 Hz</i>		

Parameters to be specified		Requirements	Methods and/or conditions of measurement
7.3.1.1	<i>Deviation from nominal value</i>	$\pm 0,5$ mm	The nominal position is defined by an ideal disc of substrate thickness 1,2 mm and refractive index of 1,55
7.3.1.2	<i>RMS value</i>	$\pm 0,35$ mm for 8 cm-CD $\pm 0,4$ mm max. $\pm 0,8$ mm max. for 8 cm-CD	
7.3.1.3	<i>Acceleration</i>	10 m/s ² max.	
7.3.2	<i>For frequencies above 500 Hz</i>	2 μ m peak-to-peak max.	
7.4	Limits for radial deviations of the track		Disc rotating at scanning velocity (see 7.1.2)
7.4.1	<i>For frequencies below 500 Hz</i>		
7.4.1.1	<i>Radial run-out of tracks</i>	140 μ m peak-to-peak max.	Relative to the inscribed inner circle of centre hole
7.4.1.2	<i>Radial acceleration (eccentricity and unroundness)</i>	0,4 m/s ² max.	
7.4.2	<i>For frequencies above 500 Hz</i>	See 10.4	
8	Environmental conditions for playing the compact disc		
8.1	Playing the compact disc	The disc shall be played under the following conditions: Temperature: -25 °C to $+70$ °C Relative humidity: 10 % to 95 % Absolute humidity: 0,5 g/m ³ to 60 g/m ³ Max. temperature change: 50 °C Max. humidity change: 30 % RH (see also climatogram, Figure 17 below)	Sudden changes in temperature and humidity within these ranges may temporarily cause too large a deflection. Recovery time up to several hours has to be taken into account (see also IEC 60721-3-5, class 5K2). Parameters to be measured in accordance with clause 4.
8.2	Temperature and humidity requirements	After these tests, some time should be left for recovery before measuring (24 h or 48 h)	
8.2.1	<i>Dry heat test in accordance with IEC 60068-2-2 Ba</i>	Temperature: 55 °C Relative humidity: 50 % max. at 35 °C Storage time: 96 h	
8.2.2	<i>Cyclic damp heat test in accordance with IEC 60068-2-30 Db</i>	Severity: a; number of cycles: 6 Temperature: max. 40 °C ± 2 °C Relative humidity: 95 % Temperature: min. 25 °C ± 3 °C Cycle time: 12 h + 12 h	

9 High-frequency signal

The scanning light spot is diffracted by the information pits in the reflective layer. The high-frequency (h.f.) signal is defined as the modulation of the optical power that is diffracted back into the objective lens.

9.1 Measurement conditions

9.1.1 Time constant: $t = 100 \mu\text{s}$

9.1.2 Filtering: high-pass

9.1.3 Scanning velocity between 1,2 m/s and 1,4 m/s

9.2 Modulation amplitude

The lowest fundamental frequency of the modulation code is 196 kHz which corresponds to T_{max} . (See clause 13.) The peak-to-peak value of this component is A_{11} (see Figure 3) and the peak value of the corresponding high-frequency signal before high-pass filtering is A_{top} .

The highest fundamental frequency of the modulation code is 720 kHz which corresponds to T_{min} . (See clause 13.) Its peak-to-peak amplitude is A_3 (see Figure 3).

These parameters shall fulfil the following specifications:

$$\frac{A_3}{A_{\text{top}}} = 0,3 \text{ to } 0,7; \quad \frac{A_{11}}{A_{\text{top}}} \geq 0,6$$

9.3 Signal asymmetry

9.3.1 Definitions

The asymmetry is defined by:

$$\left(\frac{A_D}{A_{11}} - \frac{1}{2} \right) \cdot 100 \%$$

where A_D is the decision level (see Figure 3).

The absolute value of the asymmetry shall be less than or equal to 20 %.

9.4 Cross-talk

The ratio of the amplitude of the h.f. signal when the spot focuses between two adjacent turns of the track to the amplitude of the h.f. signal when the spot focuses on the track shall be less than 0,5 (50 %).

9.5 Frequency modulation of the channel bit frequency (see clause 13)

Unintentional frequency modulation of the channel bit frequency during mastering may cause clock regeneration problems in CD players. The maximum time error of the channel bit frequency as a function of the modulation frequency shall be below the values given in Figure 18. This time error is measured with a constant linear velocity.

10 Radial differential (RD) signal

A slightly off-track position of the scanning light spot results in a diffraction pattern that is asymmetrical in the radial direction of the disc. The radial differential signal is defined as the difference of the optical powers diffracted into the two halves (positioned on opposite sides of the track) of the aperture of the objective lens.

10.1 Measurement conditions

Time constant: $t = 15 \mu\text{s}$

Filtering: low-pass

10.2 Shape of the radial differential signal

See Figure 4. The zero-crossing with a positive slope corresponds to the correct radial position of the scanning spot. Detail B of Figure 2b prescribes shallow pits, and defines the sign of the signal.

10.3 Sensitivity to radial offset

The sensitivity is equal to $\frac{|P_1 - P_2|}{A_{\text{top}}}$ at a radial offset of 0,1 μm , where $P_1 - P_2$ is the optical power difference in the two halves of the reflected beam measured at far field and where A_{top} is the peak optical power (see 9.2).

The sensitivity shall be within 0,04 and 0,07.

The variation on any one disc shall be within $\pm 15\%$.

10.4 Noise

When the RD signal is used for tracking, with a servo-bandwidth of 200 Hz (see Figure 5), the noise in the RD signal is measured in the frequency band 500 Hz to 10 000 Hz.

The r.m.s. value measured with an integration time of 20 ms shall correspond to a tracking error of less than 0,03 μm .

Optional measurement

Single-frequency noise contributions should be avoided in the RD signal. It is recommended to measure the r.m.s. value of the noise in the residual error signal with a real-time frequency analyser (bandwidth of 100 Hz) over the frequency range 500 Hz to 10 000 Hz.

The tracking error corresponding to the measured r.m.s. value should be less than 0,01 μm .

11 Defects

11.1 Block error rate (BLER)

11.1.1 Definitions

The block error rate is measured at the input of the C_1 -decoder (see Figure 13).

A block (see Figure 9) is called erroneous if one or more symbols of that block are erroneous.

A symbol (see 16.2) is called erroneous if one or more bits of that symbol are erroneous.

11.1.2 Specification of random errors

BLER averaged over any 10 s shall be less than 3×10^{-2} .

11.1.3 Specification of burst errors

Burst errors in the h.f. signal due to local defects shall not induce audible effects for any error-correcting decoding strategy.

The most simple error-correcting decoder consists of a C_1 and C_2 single-error corrector. No more than one symbol error shall occur in a data block measured at the input of the C_2 decoder.

In any case, the number of successive C_1 -uncorrectable blocks shall be less than 7.

11.2 Local defects

Maximum dimensions of local defects that are allowed are:

- air bubbles, diameter 100 μm
- black spots, diameter 200 μm
- black spots without birefringent area, diameter 300 μm

The minimum distance, measured between adjacent defects (of maximum diameter) along the track, is at least 20 mm.

Black spot may be dirt enclosures in the substrate or “pin-holes” in the reflective layer.

12 Recorded parameters — General

The recorded area on the disc shall be divided into three parts, viz:

- the lead-in area;
- the program area;
- the lead-out area.

The data to be recorded shall consist of 16-bits wide words encoded as 2's-complement numbers.

In the lead-in and the lead-out areas these encoded words are 2's-complement zero ± 15 LSB.

In the program area the data word contains audio information only, encoded in a two-channel format.

The sampling frequency (f_s) of the information in the program area shall be 44,1 kHz, both channels being simultaneously sampled.

The audio samples are linear encoded in a 16-bit, 2's-complement format.

The encoding is carried out either without pre-emphasis or with the first order pre-emphasis shown in Figure 1.

The recording and error protection process basically consists of

- a) splitting each 16-bit audio sample word into two 8-bit symbols;
- b) introducing extra 8-bit parity symbols for error detection and correction (in accordance with CIRC encoding);
- c) building up a frame consisting of the previously defined 8-bit symbols, with one 8-bit symbol for control and display;
- d) representing these 8-bit symbols by particular channel bit sequences which are appropriate for recording on the disc (in accordance with the EFM encoding);
- e) adding specific synchronization patterns different from EFM-codes.

13 8 to 14 modulation code (EFM-code)

After modulation, each group of 8 data bits (symbol) is represented by a succession of 14 channel bits. The information is contained in the position of the transitions between channel bits.

The EFM encoding is carried out in accordance with Figure 6 and Figure 7. In the NRZ-I representation used to describe the EFM encoding, "0" indicates the absence of transitions between two successive channel bits whereas "1" indicates the presence of transitions.

For merging the blocks and for low-frequency (l.f.) suppression, three extra channel bits (merging bits) are added between two blocks of 14 channel bits.

Minimum requirements for l.f. suppression are under consideration.

The EFM-code is such that the minimum run length (the distance between two transitions) is 3 channel bits ($T_{\min.}$) and the sampling window (eye pattern) is 1 channel bit.

The maximum length is 11 channel bits ($T_{\max.}$).

The merging bits do not need to contain a transition, so that between the blocks the requirements for $T_{\min.}$ can always be fulfilled.

Examples for the combination of the EFM-code with the merging bits are given in Annex A.

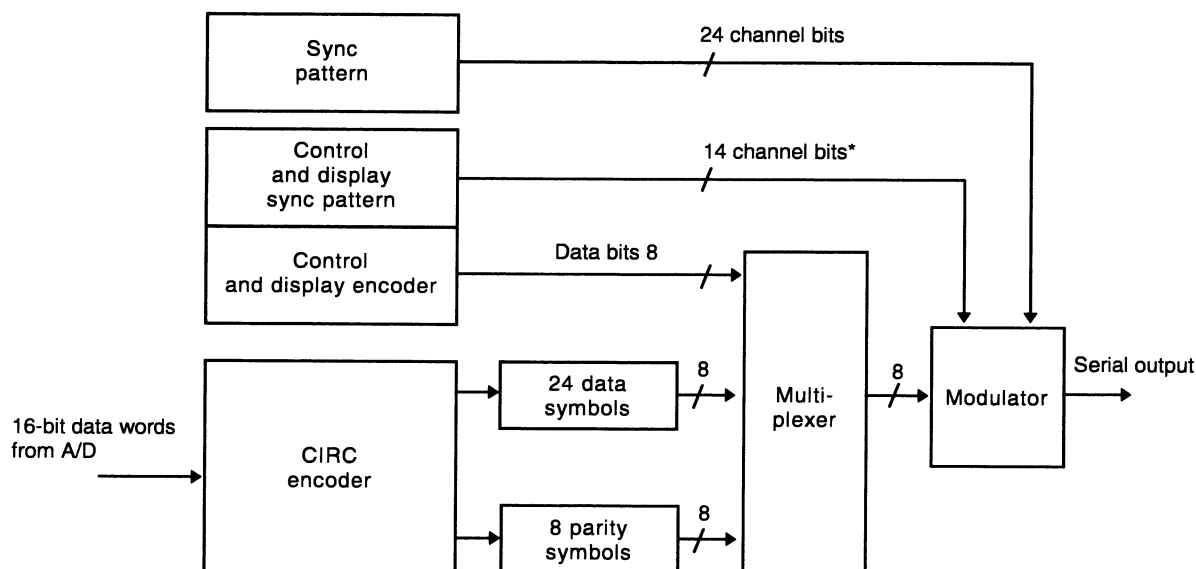
14 Frame format

After modulation (see clause 15), one frame shall contain 588 channel bits, consisting of

- a synchronization pattern of 24 channel bits;
- control and display symbols of 14 channel bits (clause 17);
- 24 data symbols coded in the EFM-code of 14 channel bits (clause 13);
- 8 symbols for parity of 14 channel bits (clause 16);
- 34 groups of merging bits of 3 channel bits (clause 13).

The composition of a frame is given in Figure 8.

15 EFM-modulator



* Twice per 98 frames for synchronization of control and display channel.

The proper sequence of symbols from data, error correction and control and display units is generated by the time multiplexer.

The modulator then converts the symbol sequence into a channel bit sequence according to the EFM-code as given in clause 13 and adds the merging bits and sync pattern, resulting in a serial output of frames as given in clause 14.

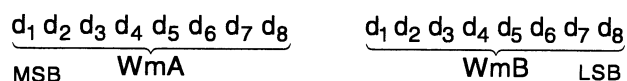
16 Error correction

16.1 General

The error correction shall be carried out using the Cross Interleave Reed-Solomon Code (CIRC).

16.2 Structure

Each data word consists of two symbols which are designated as WmA and WmB. WmA includes the higher and WmB the lower 8 bits of the data word.



Each frame (see clause 14) recorded on a disc results, after demodulation, in a block of 32 symbols, of which 24 are data symbols and 8 are parity symbols, named Pm or Qm; these parity symbols are recorded inverted ($\overline{P_m}$ and $\overline{Q_m}$).

The symbol names and their sequences are given in Figure 9.

The definition of the 8 parity symbols:

$$\left. \begin{array}{l} - P_{12n}, P_{12n+1}, P_{12n+2}, P_{12n+3} \\ - Q_{12n}, Q_{12n+1}, Q_{12n+2}, Q_{12n+3} \end{array} \right\} \quad (\text{see Figure 9 and Figure 10})$$

is such that the following equations are satisfied:

$$\left. \begin{array}{l} H_p \cdot V_p = 0 \\ H_q \cdot V_q = 0 \end{array} \right\} \quad (\text{see Figure 10 and Figure 11})$$

The calculation is defined on GF (2^8) (Galois Field) by the following polynomial:

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

and a primitive element α of GF (2^8) is defined as follows:

$$\alpha = [0\ 0\ 0\ 0\ 0\ 1\ 0]$$

↑

LSB

16.3 CIRC encoder and decoder

The CIRC consists of two Reed-Solomon Codes, C_1 and C_2 .

C_1 is a (32,28) Reed-Solomon Code over GF (2^8).

C_2 is a (28,24) Reed-Solomon Code over GF (2^8).

A CIRC encoder is given in Figure 12, a CIRC decoder in Figure 13.

17 Subcode/control and display system

17.1 General

After demodulation, eight bits per frame are available for control and display purpose (see also clause 14). These bits are named P-Q-R-S-T-U-V-W and are used as eight different subcoding channels.

The following channels are defined:

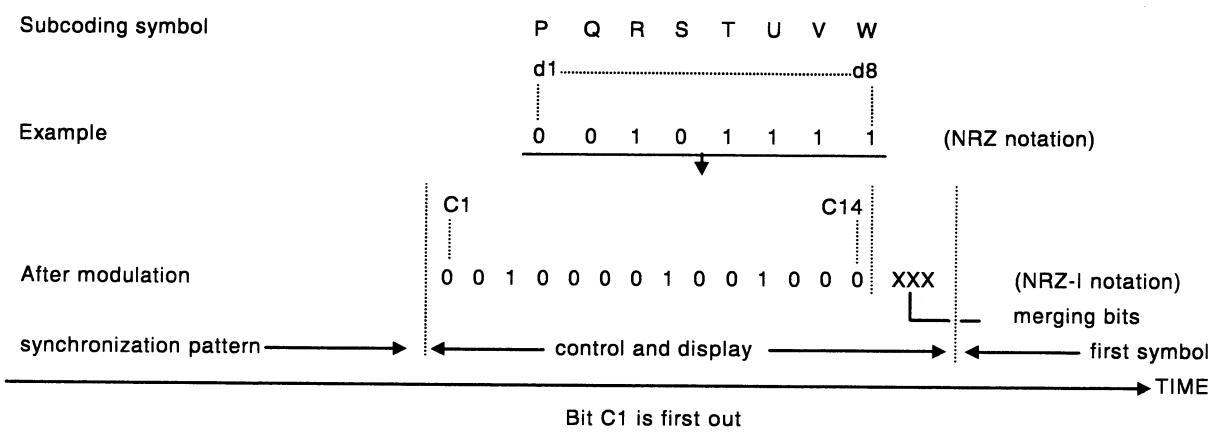
- Channel P: a simple track (program item) separator flag (see 17.4);
- Channel Q: for control purposes, for example, track (program item) number and time (see 17.5);

An example of the encoding in channels P and Q is given in Figure 14.

Channels R up to W inclusive have not yet been defined (see 17.6).

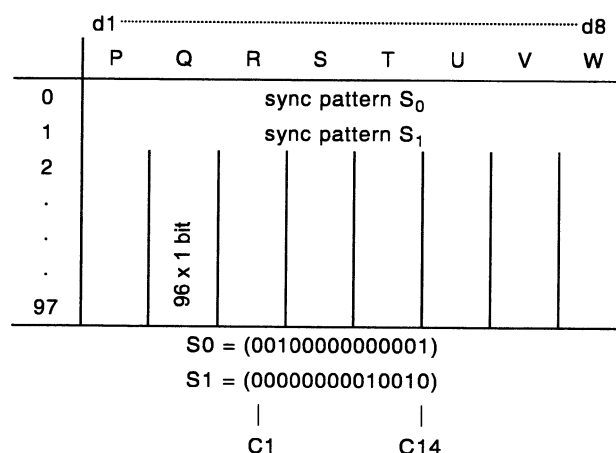
17.2 Data format

The data format of the control and display symbols shall be as follows:



17.3 Subcode structure

One subcoding block shall consist of 98 subcoding symbols. The repetition frequency of one block is 75 Hz. The first two subcoding symbols are replaced by the subcoding sync patterns, S0 and S1, and thus channels P to W inclusive cannot be encoded or decoded during this time interval.



17.4 Channel P

Channel P is a flag bit that indicates the start of a track (program item) with the following code rules:

audio: P = 0

start flag: P = 1

The minimum length of the encoded start flag in channel P shall be 2 s; the end of the encoded start flag shall indicate the start of the next track (program item).

If the actual pause exceeds 2 s, the length of the start flag shall give the actual pause length.

In the lead-in track channel P is encoded as for audio. The first audio track (program item) shall be preceded by a start flag of 2 s to 3 s.

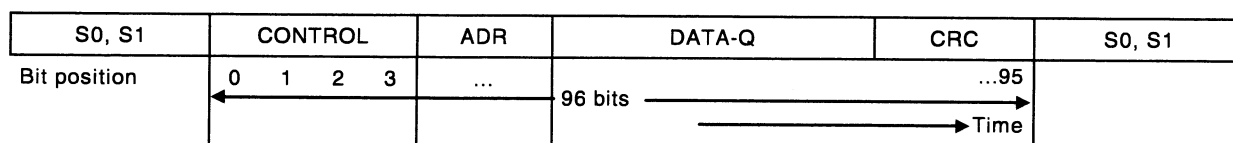
The lead-out track shall be preceded by a start flag of 2 s to 3 s (during the last audio track on the disc).

The end of the start flag shall indicate the beginning of the lead-out track. Channel P shall remain zero for 2 s to 3 s after the start of the lead-out track, next P switches between 0 and 1 in a $2 \text{ Hz} \pm 2 \%$ rhythm (duty cycle $50 \% \pm 10 \%$).

A change in channel P may take place only immediately after the subcoding sync pattern S0 and S1. The encoding of channel P is delayed by one subcoding block with respect to the encoding of channel Q.

17.5 Channel Q

The general data format of channel Q shall be:



CONTROL:

The control field contains 4 flag bits to define the kind of information in a track (program item), bit 0 is first out (MSB).

MBS LSB

| |

0 0 X 0 — 2 audio channels without pre-emphasis;

0 0 X 1 — 2 audio channels with pre-emphasis 50/15 μs ;

0 X 0 X — copy prohibited;

0 X 1 X — copy permitted.

The bits of the control field (except for the copy bit) can change during an actual pause (X = 0 0) of at least 2 s and during the lead-in area only.

NOTE 1 The four bits of the control field of the Q channel should be copied to the control field of the channel status of the digital audio interface for domestic use. (Under consideration.)

NOTE 2 For non-audio applications of the compact disc the following control codes have been defined:

- 0 1 X 0: Digital data;
- 1 X X X: Broadcasting use.

All other combinations will be defined later on.

ADR: 4-address bits, MSB is first out:
0000: ADR 0, mode 0 for DATA-Q (see 17.5.4);
0001: ADR 1, mode 1 for DATA-Q (see 17.5.1);
0010: ADR 2, mode 2 for DATA-Q (see 17.5.2);
0011: ADR 3, mode 3 for DATA-Q (see 17.5.3);
0100: ADR 4, mode 4 for DATA-Q (see 17.5.4 of IEC 61104).

DATA-Q: 72-data bits, MSB is first out. For this block three modes are defined (see 17.5.1, 17.5.2 and 17.5.3).

CRC: A 16-bit CRC on CONTROL, ADR and DATA-Q, MSB is first out. On the disc the parity bits are inverted. The syndrome shall be compared with 0.

Polynomial:
 $P(X) = X^{16} + X^{12} + X^5 + 1$

17.5.1 Mode 1 for DATA-Q

ADR = 1 = (0001)
Mode 1 occupies at least 9 out of 10 successive subcoding blocks.
Two different data formats are possible in mode 1.
During the lead-in track, the data format shall be:

S0, S1	CONTROL	1	00	POINT	MIN	SEC	FRAME	ZERO	P MIN	P SEC	P FRAME	CRC
		ADR	TNO									

During the audio and lead-out tracks the data format shall be:

S0, S1	CONTROL	1	TNO	X	MIN	SEC	FRAME	ZERO	A MIN	A SEC	A FRAME	CRC
		ADR										

TNO: Track number (program item) expressed as two digits (4 bits encoded)
00: Lead-in track, BCD encoded.
The end of the lead-in track is at the starting diameter of the program area.
01–99: Track numbers, BCD encoded.
A track may be preceded by a pause with the same track number. The track numbering shall start with the value 01 and shall increment by one.
In the case of a program stored on several discs, the numbering may be continued. The minimum length of a track is 4 s, not including the pause length preceding this track.
AA: Lead-out track, hexadecimal code AA.
The lead-out track starts at the end of the last audio track on a disc, without a preceding pause encoding.

X: Index to TNO, two digits BCD.
During the lead-in track, the index X is not encoded.
00: Pause encoding.

The pause encoding in channel Q coincides with the actual pauses in the audio program. The first audio track is preceded by a pause encoding of 2 s to 3 s (see channel P in 17.4). The lead-out track is encoded as audio.

01–99: Subdivision numbers.

During the lead-out track X is 01.

Within an audio track (TNO = 01–99 and $X \neq 00$), the first value of X is 01. The value of X may only increase in increments of 1.

MIN, SEC, FRAME: Running time within a track (TIME) is expressed as six digits BCD: MIN, SEC, and FRAME two digits each. The time is set to zero at the start of a track. Time increases during the audio and decreases during the pause, ending with the value zero at the end of the pause. During the lead-in and lead-out tracks the time increases.

The minutes are stored in MIN, the seconds in SEC. One second is subdivided into 75 FRAMEs (running from 00 to 74).

ZERO: These eight bits are zero.

AMIN, ASEC, AFRAME: Running time on the disc (ATIME) is expressed as six digits BCD: AMIN, ASEC and AFRAME two digits each.

At the starting diameter of the program area the running time is set to zero and TNO takes the value of the first track on the disc. The minutes are stored in AMIN, the seconds in ASEC. One second is subdivided into 75 AFRAMEs (running from 00 to 74).

POINT, PMIN, PSEC, PFRAME: On the lead-in track a table of contents is stored in these locations. This table of contents is continuously repeated in the lead-in area (TNO = 00).

In each table of contents, the items are repeated three times (see Figure 15). At the end of the lead-in area, the table of contents may be ended with any value of POINT.

The value of PMIN, PSEC and PFRAME gives the starting-point of the track number pointed to by POINT. These values give the start position of the track on the absolute time scale (AMIN, ASEC and AFRAME) with an accuracy of ± 1 s. The start position of a track is the first position with the new track number and ($X \neq 00$).

If POINT = A0, the value of PMIN gives the TNO of the first track on the disc, PSEC and PFRAME are zero.

If POINT = A1, the value of PMIN gives the TNO of the last track on the disc, PSEC and PFRAME are zero.

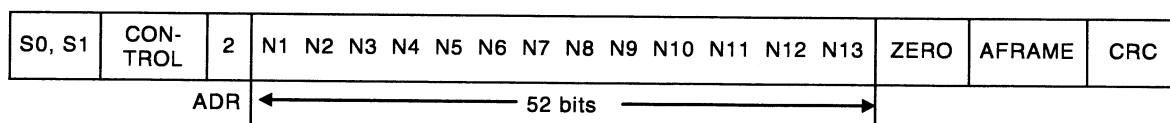
If POINT = A2, in PMIN, PSEC and PFRAME the starting-point of the lead-out track is given.

17.5.2 Mode 2 for DATA-Q

ADR = 2 = (0010)

If mode 2 is present, it occupies at least 1 out of 100 successive subcoding blocks.

The data format shall be:



N1–N13: Catalogue number of the disc expressed in 13 digits BCD according to the UPC/EAN code (under consideration).

The catalogue number does not change on a disc. In case no catalogue number is encoded according to the UPC/EAN-code, N1–N13 are all zero, or mode 2 can be deleted from the disc.

ZERO: These 12 bits are zero.

AFRAME: The continuation of AFRAME in mode 1 (two digits BCD running from 00 to 74). During the lead-in area (TNO = 00), these eight bits are zero.

17.5.3 Mode 3 for DATA-Q

ADR = 3 = (0011)

If mode 3 is present, it occupies at least 1 out of 100 successive subcoding blocks.

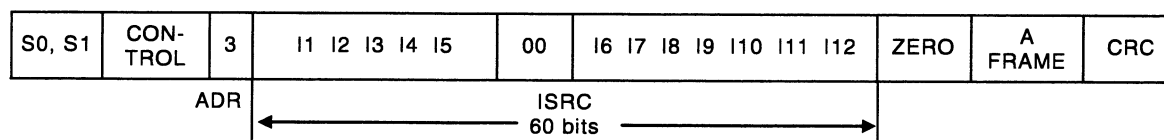
Mode 3 is used to give a unique number to an audio track.

This is done by means of the ISRC having 12 characters represented by I1 to I12 (see ISO 3901).

If no ISRC is used, mode 3 shall be deleted. During the lead-in and lead-out tracks, mode 3 is not present on the disc.

The ISRC can only change immediately after the TNO has been changed.

The data format shall be:



I1-I2 give the country code;

I2-I5 give the owner code;

I6-I7 give the year of recording;

I8-I12 give the serial number of the recording.

The characters I1–I5 are coded in a 6-bit format as given below; the characters I6–I12 are 4-bit BCD numbers.

Character	Binary	Octal	Character	Binary	Octal
0	000000	00	I	011001	31
1	000001	01	J	011010	32
2	000010	02	K	011011	33
3	000011	03	L	011100	34
4	000100	04	M	011101	35
5	000101	05	N	011110	36
6	000110	06	O	011111	37
7	000111	07	P	100000	40
8	001000	10	Q	100001	41
9	001001	11	R	100010	42
A	010001	21	S	100011	43
B	010010	22	T	100100	44
C	010011	23	U	100101	45
D	010100	24	V	100110	46
E	010101	25	W	100111	47
F	010110	26	X	101000	50
G	010111	27	Y	101001	51
H	011000	30	Z	101010	52

00: These 2 bits are zero.

ZERO: These 4 bits are zero.

AFRAME: The continuation of AFRAME in mode 1 (see 17.5.1).

17.5.4 Mode 0 for DATA-Q

ADR = 0 = (0000)

Subcode channel mode 0 for DATA-Q shall contain, if used, only the CONTROL and CRC bits, all other bits are zero.

NOTE If the CD data format is used on non-CD information channels this mode can be used to replace mode-1. In these cases, the rule "Mode-1 occupies at least 9 out of 10 successive subcoding blocks" (see 17.5.1) is no longer valid.

The data format of Mode 0 for DATA-Q shall be:

	S0, S1	CONTROL	ADR	DATA-Q	CRC	S0, S1	
--	--------	---------	-----	--------	-----	--------	--

S0, S1 See subcode CONTROL AND DISPLAY SYSTEM, clause 17.

CONTROL: See CONTROL AND DISPLAY SYSTEM, 17.5.

ADR: These 4 bits are zero, the MODE number.

DATA-Q: These 72 bits are zero.

CRC: See 17.5.

During the time subcode channel-Q Mode 0 is present, subcode channel-P is zero.

17.6 Channels R to W inclusive

These channels are under consideration and are all zero.

18 Control system and display data — General

The following clauses defines the basic format and the organization of the control and display data on the disc, and the control and display formats of different graphics modes.

19 General data organization

19.1 Basic format

The maximum available data rate in the subcoding channels R to W is 43,2 kbit/s.

The basic format is presented in Figure 19. The data is synchronized with the subcode sync patterns S0 and S1. Each group of 6 bits (R to W) is called a SYMBOL. A group of 24 SYMBOLs is called a PACK. A PACKET consists of 4 PACKs. The SYMBOL following the syncs S0 and S1 is the first SYMBOL of the first PACK in a PACKET.

To protect the data in the subcoding channels R to W, a (24, 20) Reed-Solomon error correction code is used. To improve the burst error correction capability, 8 times interleaving is added to this error-correction system.

The first two symbols in a PACK have additional protection with a (4, 2) Reed-Solomon error correction code.

The first symbol of a PACK contains a MODE switch of 3 bits and a 3-bit subdivision of MODE called ITEM.

The defined MODE-ITEM combinations are:

MODE	ITEM	
0 (000)	0 (000)	:ZERO mode
1 (001)	0 (000)	: LINE-GRAPHICS mode
1 (001)	1 (001)	: TV-GRAPHICS mode
1 (001)	2 (010)	: EXTENDED-TV-GRAPHICS mode
2 (010)	4 (100)	: CD TEXT mode
3 (011)	0 (000)	: MIDI mode
7 (111)	0 (000)	: USER mode.

All MODE-ITEM combinations not defined are reserved for future use.

19.2 PACK format

For the organization of a PACK, see Figure 20.

19.3 Error correction parity P

(24, 20) Reed-Solomon code over GF(2⁶)

Polynomial: $P(X) = X^6 + X + 1$

1 symbol = 6 bits

The parity matrix WH_p is:

$$H_p = \begin{bmatrix} 1 & 1 & 1 & . & . & . & 1 & 1 \\ a^{23} & a^{22} & a^{21} & . & . & . & a^1 & 1 \\ a^{46} & a^{44} & a^{42} & . & . & . & a^2 & 1 \\ a^{69} & a^{66} & a^{63} & . & . & . & a^3 & 1 \end{bmatrix}$$

The primitive element α of GF(2⁶) is:

$$\begin{array}{cc} \text{msb} & \text{lsb} \\ \alpha = (0 & 0 & 0 & 0 & 1 & 0) \end{array}$$

The parity symbols $P0 = P - S_{24n+20}$, $P1 = P - S_{24n+21}$, $P2 = P - S_{24n+22}$ and $P3 = P - S_{24n+23}$ are defined to satisfy the following equation:

$$H_p \times V_p = 0$$

where

$$V_p = \begin{bmatrix} D - S_{24n} \\ D - S_{24n+1} \\ D - S_{24n+2} \\ D - S_{24n+3} \\ D - S_{24n+4} \\ D - S_{24n+5} \\ D - S_{24n+6} \\ D - S_{24n+7} \\ D - S_{24n+8} \\ D - S_{24n+9} \\ D - S_{24n+10} \\ D - S_{24n+11} \\ D - S_{24n+12} \\ D - S_{24n+13} \\ D - S_{24n+14} \\ D - S_{24n+15} \\ D - S_{24n+16} \\ D - S_{24n+17} \\ D - S_{24n+18} \\ D - S_{24n+19} \\ D - S_{24n+20} \\ D - S_{24n+21} \\ D - S_{24n+22} \\ D - S_{24n+23} \end{bmatrix}$$

19.4 Interleaving

The sequences of interleaving and de-interleaving are described in Figure 21 and Figure 22.

The capacity of this interleaved error correction system is:

- 8 symbol burst error correction on the disc with a single-symbol correction strategy;
- 16 symbol burst error correction on the disc with a two-symbol correction strategy.

19.5 *P*-parity encoder and interleave sequence

For the organization of a *P*-parity encoder and interleave sequence, see Figure 21.

19.6 *P*-parity decoder and de-interleave sequence

For the organization of a *P*-parity decoder and de-interleave sequence, see Figure 22.

19.7 Error-correction parity *Q*

(4, 2) Reed-Solomon code over GF(2⁶)

Polynomial: $P(X) = X^6 + X + 1$

1 symbol = 6 bits

The parity matrix WH_q is:

$$H_q = \begin{Bmatrix} 1 & 1 & 1 & 1 \\ a3 & a2 & a1 & 1 \end{Bmatrix}$$

The primitive element a of GF(2⁶) is:

$$\begin{matrix} \text{msb} & & & & \text{lsb} \\ a = (0 & 0 & 0 & 0 & 1 & 0) \end{matrix}$$

The parity symbols $Q0 = D - S_{24n+2}$ and $Q1 = D - S_{24n+3}$ are defined to satisfy the following equation:

$$H_q \times V_q = 0$$

where

$$V_q = \begin{Bmatrix} D - S_{24n} \\ D - S_{24n} + 1 \\ D - S_{24n} + 2 \\ D - S_{24n} + 3 \end{Bmatrix}$$

This *Q*-parity system combined with scrambling and interleaving can correct an error burst of 59 subcoding symbols on the disc by using a single symbol correcting strategy (symbols 0, 1, 2 and 3 only).

19.8 *Q*-parity encoder

For the organization of a *Q*-parity encoder, see Figure 23.

19.9 *Q*-parity decoder

For the organization of a *Q*-parity decoder, see Figure 24.

20 ZERO mode (MODE = 0, ITEM = 0)

20.1 General

All bits in the PACK with this mode are zero. This mode is used for empty channel purposes. So, if no data is transferred in a PACK, the ZERO mode can be used.

The PACK format in the ZERO mode is:

Bit		R	S	T	U	V	W
Symbol	0	0	0	0	0	0	0
	1	0	0	0	0	0	0
	.	.	.	.	.	.	.
	.	.	.	.	.	.	.
	.	.	.	.	.	.	.
	.	.	.	.	.	.	.
	.	.	.	.	.	.	.
	.	.	.	.	.	.	.
	23	0	0	0	0	0	0

- write a FONT with two colours (foreground/background) into memory,
- soft scroll the SCREEN.

Bit	R	S	T	U	V	W
Symbol	0	0	1	0	0	0
1	INSTRUCTION					
2	PARITY Q0					
3	PARITY Q1					
4	DATA field					
.						
.						
.						
.						
19	PARITY P0 PARITY P1 PARITY P2 PARITY P3					
20						
21						
22						
23						

21.3 LINE-GRAPHICS mode FONT format

The location of the pixels in a FONT is:

Pixel COLUMN		0	1	2	3	4	5	
Pixel ROW	0							Pixel (0,0) is the upper-left pixel in a FONT
	1							
	2							
	3							
	4							
	5							
	6							
	7							
	8							
	9							
	10							
	11							

21.4 LINE-GRAPHICS mode SCREEN format

The visible part of the graphics memory is called the SCREEN area. The position (ROW, COLUMN) of the FONTs in the LINE-GRAPHICS memory is:

COLUMN	0	1	2	3	.	.	.	.	46	47	48	49	
ROW 0	•	•	•	•	•	•	•	•	•	•	•	•	•
1	•	•	•	•	•	•	•	•	•	•	•	•	•
2	•	•	•	•	•	•	•	•	•	•	•	•	•
3	•	•	•	•	•	•	•	•	•	•	•	•	•

• ↕ 12 pixels

• ↔ •
6 pixels

The graphics memory contains ROWs 0 .. 3 and COLUMNs 0 .. 49. The SCREEN area consists of 288 (horizontal) × 24 (vertical) pixels. The soft scroll pointers determine which pixel from FONT (1, 1) is the upper-left pixel from memory that is visible.

To facilitate soft scroll, screen pointers are available to define the shift (in pixels) on the screen of the data in memory. The following pointers are available:

- PH: (horizontal screen pointer) defines the horizontal shift in pixels of all pixel data in memory. The pixels with PIXEL-COLUMN = PH of FONTs (1 .. 3, 1) are the left-most pixels from memory that are visible;
- PV: (vertical screen pointer) defines the vertical shift in pixels of all pixel data in memory. The pixels with PIXEL-ROW = PV of FONTs (1, 1 .. 49) are the upper pixels from memory that are visible.

21.5 LINE-GRAPHICS mode colour table

	(msb)		(lsb)	
	R	G	B	
0 =	0	0	0	: black
1 =	0	0	1	: blue
2 =	0	1	0	: green
3 =	0	1	1	: cyan
4 =	1	0	0	: red
5 =	1	0	1	: magenta
6 =	1	1	0	: yellow
7 =	1	1	1	: white

21.6 LINE-GRAPHICS mode instructions

	R	S	T	U	V	W	
4 =	0	0	0	1	0	0	: Write FONT
12 =	0	0	1	1	0	0	: Soft scroll SCREEN

21.6.1 Write FONT instruction (4)

If the instruction is Write FONT, the format of the DATA field in the PACK is:

Bit
Symbol

4
5
6
7
8
.
.
.
19

R	S	T	U	V	W
0	0	0	COL0		
0	0	0	COL1		
0	0	0	0	ROW	
COLUMN				1 lsb	
y					
FONT					
z					

COL0
COL1
ROW
COLUMN
FONT

: background colour number (see 21.5)
(lsb on bit W)
: foreground colour number (see 21.5)
(lsb on bit W)
= 0 .. 3 (lsb on W)
= 0 .. 49 (lsb on W)
: y = top-left pixel in the FONT
z = bottom-right pixel in the FONT
Pixel with value = 0: background colour (COL0)
Pixel with value = 1: foreground colour (COL1)

} memory address

The instruction Write FONT writes the data defined in FONT on address (ROW, COLUMN) into the LINE-GRAPHICS memory. On a monochrome display, the pixels with value 0 are off and the pixels with value 1 are on. On a colour display, the pixels with value 0 are displayed with colour COL0 and the pixels with value 1 with colour COL1.

21.6.2 Write Scroll SCREEN instruction (12)

If the instruction is Scroll SCREEN the format of the DATA field in the PACK is:

Bit		R	S	T	U	V	W
Symbol	4	0		0	COLOR		
	5	COPH		0	PH		
	6	COPV		PV			
	7	0	0	0	0	0	0
	.	.	.	.	.	.	.
	.	.	.	.	.	.	.
	.	.	.	.	.	.	.
	.	.	.	.	.	.	.
	.	.	.	.	.	.	.
	19	0	0	0	0	0	0

COLOR	:	background colour number (see 21.5) (lsb on bit W)
COPH	=	0: no horizontal copy
	=	1: copy right
	=	2: copy left (lsb on bit S)
PH	=	0 .. 5 (lsb on bit W): horizontal shift pointer (in pixels)
COPV	=	0: no vertical copy
	=	1: copy down
	=	2: copy up (lsb on bit S)
PV	=	0 .. 11 (lsb on bit W): vertical shift pointer (in pixels)

The instruction Scroll SCREEN gives new values to the screen pointers PH and PV. The screen pointer PH is given the new value PH and the screen pointer PV is given the new value PV, for all values of COPH and COPV. Depending on the values of COPH and COPV, all FONTS can be copied to the next (or previous) ROW and COLUMN positions.

If COPH = 1 (scroll right) then all FONTS are shifted one COLUMN to the right in memory. The contents of FONT (i,j) is copied to position ($i,j + 1$) for $i = 0 .. 3$ and $j = 0 .. 48$. The original data of positions ($i, 49$) is lost ($i = 0 .. 3$). On a monochrome display, the FONTS with position ($i, 0$) are set to background and on a colour display, these FONTS are set to the colour defined in COLOR ($i = 0 .. 3$).

If COPH = 2 (scroll left) then all FONTS are shifted one COLUMN to the left in memory. The contents of FONT (i,j) is copied to position ($i,j - 1$) for $i = 0 .. 3$ and $j = 1 .. 49$. The original data of positions ($i,0$) is lost ($i = 0 .. 3$). On a monochrome display, the FONTS with position ($i,49$) are set to background and, on a colour display, these FONTS are set to the colour defined in COLOR ($i = 0 .. 3$).

If COPV = 1 (scroll down) then all FONTS are shifted one ROW down in memory. The contents of FONT (i,j) is copied to position ($i + 1,j$) for $i = 0 .. 2$ and $j = 0 .. 49$. The original data of positions ($3,j$) are lost ($j = 0 .. 49$). On a monochrome display, the FONTS with position ($0,j$) are set to background, and, on a colour display, these FONTS are set to the colour defined in COLOR ($j = 0 .. 49$).

If COPV = 2 (scroll up) then all FONTS are shifted one ROW up in memory. The contents of FONT (i,j) is copied to position ($i - 1,j$) for $i = 1 .. 3$ and $j = 0 .. 49$. The original data for positions ($0,j$) are lost ($j = 0 .. 49$). On a monochrome display the FONTS with position ($3,j$) are set to background, and, on a colour display, these FONTS are set to the colour defined in COLOR ($j = 0 .. 49$).

22 TV-GRAPHICS mode (MODE = 1, ITEM = 1)

22.1 General

The TV GRAPHICS system gives the possibility to display text and graphics pictures. The data is displayed in a field of 48 (horizontal) $\times$ 16 (vertical) FONTS. A FONT is an array of 6 (horizontal) $\times$ 12 (vertical) pixels. A pixel is the smallest possible picture element.

The memory size of the display page is 50 $\times$ 18 FONTS. The outer ROWs and COLUMNs of the memory are intended for scroll actions. These ROWs and COLUMNs are not visible.

The display area outside the visible part of 48 $\times$ 16 FONTS can be preset with a colour. This area is called the BORDER.

The FONT data is provided with a channel number (0 .. 15). This channel number gives a decoder the (optional) possibility to select a specific part of the incoming data. If no channel selector is available, the channels 0 and 1 are displayed. With a selector, a combination can be made from all available channels.

The data is displayed in maximum 16 colours. These 16 colours are defined in a colour look-up table (CLUT) of 16 × 12 bits. The colours of the CLUT can be chosen from a maximum of 4096 bits (12 bits in RED, GREEN and BLUE, 4 bits each). The CLUT is loaded from the disc.

- INSTRUCTIONS are available to
- preset the memory with a colour,
 - preset the BORDER with a colour,
 - write a FONT with two colours (foreground/background) into memory,
 - EXCLUSIVE-OR a FONT with two colours,
 - load the CLUT. Load the colour 0 .. 7 and 8 .. 15,
 - soft scroll the SCREEN,
 - define colour transparency.

22.2 TV-GRAPHICS mode PACK format

Bit	R	S	T	U	V	W
Symbol	0	0	1	0	0	1
1	INSTRUCTION					
2	PARITY Q0					
3	PARITY Q1					
4	DATA field					
.						
.						
.						
.						
.						
.						
.						
.						
.						
.						
19						
20	PARITY P0					
21	PARITY P1					
22	PARITY P2					
23	PARITY P3					

22.3 TV-GRAPHICS mode FONT format

The location of the pixels in a FONT is:

Pixel-COLUMN		0	1	2	3	4	5	
Pixel-ROW	0							Pixel (0,0) is the upper-left pixel in a FONT
	1							
	2							
	3							
	4							
	5							
	6							
	7							
	8							
	9							
	10							
	11							