BRITISH STANDARD

BS ISO 11073-91064:2009

Health informatics — Standard communication protocol

Part 91064: Computer-assisted electrocardiography

ICS 35.240.80

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Part 91064: Computer-assisted electrocardiography

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Partie 91064: Protocole de communication standard pour l'électrocardiographie assistée par ordinateur

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Foreword

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ISO 11073-91064 was prepared by Technical Committee ISO/TC 215, *Health informatics*.

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Introduction

The electrocardiogram (ECG) is a recording of voltage changes transmitted to the body surface by electrical events in the heart muscle, providing direct evidence of cardiac rhythm and conduction, and indirect evidence of certain aspects of myocardial anatomy, blood supply and function. During its propagation to the surface, extracardiac tissues may intervene and influence the ECG.

Electrocardiography has been used for many years as a key, non-invasive method in the diagnosis and early detection of coronary heart disease, which is the leading cause of mortality in western countries. In 1993, it was estimated that more than 100 million standard ECGs are recorded yearly in the European Community (EC) for routine diagnostic and screening purposes at an estimated cost of more than 1,2 billion € per year.

Almost all newer electrocardiographs nowadays use digital recording, interpretation and communication techniques. These stand-alone, microcomputer based machines can be connected to each other, and to larger minicomputer-based management servers for long-term storage and serial comparison. To this end, various manufacturers have used different techniques.

It is in the general public interest for users not to be restricted in their options by incompatible technical features and services of different systems. ECG processing is increasingly being integrated with various other data processing in health care. This evolution shall have considerable impact on the storage and communication of ECG data. There are many different end-users who for different purposes (support of patient care, management, research and education) want to obtain a copy of the signal data, of the interpretive report and/or measurement results. Being one of the very first systems for medical decision support, computerized ECG interpretation stretches from departments of cardiology in hospitals, to general practitioners in primary care and health care centres. In life-threatening acute myocardial infarction, ECGs are being used in ambulances by paramedical personnel to assess the necessity for administering thrombolytic agents, with long-distance monitoring whenever possible.

To enable the exchange of information between various systems it was of utmost importance that a standard communications protocol for computer-aided electrocardiography (SCP-ECG) had to be established, as defined in this document. The primary aim of this document is to specify a data format for transferring ECG reports and data from any vendor's computerized ECG recorder to any other vendor's central ECG management system. The same standard should also allow standardized transfer of digitized ECG data and results between various computer systems.

Under the standard communication protocol (SCP) the contents and format of the ECG waveform data and the measurements from ECG devices of different manufacturers are not expected to be identical. As a result, the determination of the suitability of a device and/or system for any particular application remains with the user/purchaser. The following possible uses of ECG records require special attention:

— serial comparison of ECGs and interpretations;

— plot formats of ECGs;

— maintaining audit trail of edits;

— bi-directional communication and remote query.

The user is cautioned to make sure that the data contents and format of the waveform data, measurements, and the interpretive statements meet his or her specific needs. If more than one type of ECG device and/or database management system are interconnected, the user is also advised to verify with the manufacturers that the data from different systems are compatible with each other and with the user's needs.

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In order to understand this document, the reader needs some basic understanding of electrocardiology, electrocardiography and signal processing.

This part of ISO 11073 relates to the conventional recording of the electrocardiogram, i.e. the so-called standard 12-lead electrocardiogram and the vectorcardiogram (VCG). Initially, the electrical connections used for recording the ECG were made to the limbs only. These connections to the right arm (RA), left arm (LA), left leg (LL) and right leg (RL) were introduced by Einthoven. The electrical variations detected by these leads are algebraically combined to form the bipolar leads I, II and III. Lead I, for example, records the difference between the voltages of the electrodes placed on the left arm and the right arm. The unipolar electrocardiographic leads (aVR, aVL, aVF and the precordial leads V1 to V6) were introduced much later, starting in 1933. In these leads, potentials are recorded at one location with respect to a level which does not vary significantly in electrical activity during cardiac contraction. The “augmented” limb lead potentials are recorded with reference to the average potential of (L+F), (R+F) and (L+R) respectively. The unipolar chest leads are recorded with reference to the average potential of $\frac{(RA+RL+LL)}{3}$ which is called the Wilson “central terminal” (CT). In vectorcardiography, recordings are made of three mutually perpendicular leads, running parallel to one of the rectilinear coordinate axes of the body. The axes are the X-axis going right to left, the Y-axis with a top to bottom orientation and the Z or front to back axis.

In some research centres, so-called body surface maps are obtained by placing many (from 24 to 124 or even more) closely-spaced electrodes around the torso. This part of ISO 11073 has not been designed to handle exchanges of such recordings, although future extensions could be made to this end. This part of ISO 11073 has also not been designed to exchange specialized recordings of intracardiac potentials or of the so-called Holter or other long-term ECG recordings made for monitoring cardiac rhythm. This part of ISO 11073 also does not address exercise ECG recordings.

ECG computer processing can be reduced to three principal stages:

1) data acquisition, encoding, transmission and storage;

2) pattern recognition and feature extraction, i.e. ECG measurement;

3) diagnostic classification.

In each of these stages there are important needs for standardization and quality assurance testing. The scope of this part of ISO 11073 is confined to the first of these three stages.

The various data sections that shall be transmitted by means of the standard ECG communications protocol are defined in Clause 5. Minimum requirements for data encoding and compression are defined in Clause 6.

The compliance categories defined in Annex B provide users and manufacturers of ECG devices and/or systems with a relatively simple codification of SCP-ECG related features and information content that may be provided by a specific device. Two data format categories have been defined based on information content as in Table 1.

Table 1 — Data format categories for compliance specifications

Category	Data sections required	Content description
I	0, 1, [2], 3, 6, (7), (8), (10)	Demographics, and ECG rhythm data (uncompressed or with lossless compression)
II	0, 1, [2], 3, 4, 5, 6, (7), (8), (10)	Demographics, ECG rhythm data (uncompressed, with lossless compression or with high compression), and reference beats
NOTE 1 Square brackets [ ] indicate that data section 2 is required if Huffman encoding has been used.		
NOTE 2 Parentheses ( ) indicate that these data sections are optional for export.		

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A further category may be added in future versions in order to fulfil the specific needs of ECG devices used in other applications (such as telemedicine or homecare).

All devices stating an SCP-ECG data format category shall import at minimum data sections 0, 1, 3, 6, 7 and 8. All categories may have additional sections added (e.g. 9, 10, 11). Manufacturer-specific data shall be optionally included only in manufacturer-specific fields, bytes and data blocks that have been defined in the document. Reserved, unspecified and undefined fields, bytes or data blocks shall not be used for manufacturer-specific data.

For a particular device, an SCP-ECG compliance statement lists data format category(ies) for export (i.e. acquiring and making available an SCP-ECG record) and import (i.e. accepting, and making available to a user, an SCP-ECG record). A device may also state its ability to transfer (i.e. making available an SCP-ECG record without changing its data format, for example, exporting a record that was previously imported). (These terms are precisely defined in Annex B for the purpose of this part of ISO 11073).

The selection and definition of ECG-specific high-level syntaxes for transfer of messages and data host-to-hosts, such as EDIFACT or ASN.1, are beyond the scope of this part of ISO 11073.

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Health informatics — Standard communication protocol —

Part 91064: Computer-assisted electrocardiography

1 Scope

This part of ISO 11073 specifies the common conventions required for the cart-to-host as well as cart-to-cart interchange of specific patient data (demographic, recording, ...), ECG signal data, ECG measurement and ECG interpretation results.

This part of ISO 11073 specifies the content and structure of the information that is to be interchanged between digital ECG carts and computer ECG management systems, as well as other computer systems where ECG data can be stored.

2 Normative references

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

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

ISO/IEC 2022:1994, *Information technology — Character code structure and extension techniques*

ISO/IEC 4873, *Information technology — ISO 8-bit code for information interchange — Structure and rules for implementation*

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

JIS X 0201-1976, *Code for Information Interchange*

JIS X 0208-1997, *Code of the Japanese Graphic Character Set for Information Interchange*

3 Terms and definitions

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

3.1
acquiring cardiograph
cardiograph recording the original ECG signal

3.2
bimodal compression
use of low pass filtering and sample decimation outside of a protected zone containing the QRS complex, with no decimation or filtering within the protected zone, indicated by 5.9.3 byte 6

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3.3
confirming
process whereby a trained and experienced cardiologist reviews the computer-generated (or overread) interpretation of an ECG in order to confirm the computer-generated (or overread) interpretation or to make the final changes to the interpretation text

NOTE The confirmed ECG is the final clinically acceptable version for diagnosis and treatment.

3.4
CSE Project
project supported by DG XII of the European Commission aiming at the development of Common Standards for (Quantitative) Electrocardiography

3.5
downsampling factor
decimation factor
factor that gives the reduction of samples in data sections where the sampling rate is reduced with reference to the original sampling rate.

NOTE This applies for bimodal data compression.

EXAMPLE Original sampling rate 500 S/s (equivalent to a sample interval of 2 ms) is reduced to 125 S/s (equivalent to a sample interval of 8 ms). The downsampling factor is then 4.

3.6
interpretive device
device (cart, computer) analysing the ECG signal

3.7
message
textual body of information

3.8
overreading
process whereby a cardiologist or a cardiology fellow reviews the computer-generated interpretation of an ECG in order to verify the accuracy or to make changes to the interpretation text

NOTE An overread ECG is generally not the final clinically acceptable version for diagnosis and treatment. Usually, the overreading process precedes the confirming process.

3.9
record
entire data file to be transmitted, including the ECG data and associated information, such as patient identification, demographic and other clinical data

3.10
reference beat
reference/representative ECG cycle computed through any (but not specified) algorithm comprising the P, QRS and the ST-T waves

3.11
residual data
remaining original ECG data after “proper” subtraction of the reference beat where the adjective “proper” refers to accurate beat alignment

3.12
rhythm data
full original ECG data, or the decompressed and reconstructed ECG data at reduced resolution

NOTE Rhythm data is typically 10 s in length.

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3.13
section
aggregate of data elements related to one aspect of the electrocardiographic recording, measurement or interpretation

3.14
universal statement codes
ECG interpretation codes

See Annex F.

NOTE See Glossary in Annex G for other technical terms related to this part of ISO 11073.

4 Abbreviations

AAMI	American Association for the Advancement of Medical Instrumentation
AC	Alternating current
AHA	American Heart Association
AIM	Advanced Informatics for Medicine Programmes of the European Commission Directorate General XIII
ANSI	American National Standards Institute
ASCII	American Standard Code for Information Interchange
ASN.1	Abstract Syntax Notation One
AVM	Amplitude Value Multiplier (see 5.8.3)
BS	Backspace (control character)
CCITT	International Telegraph and Telephone Consultative Committee
CEN	Comité Européen de Normalisation/European Committee for Standardization
CR	Carriage return (control character)
CRC	Cyclic redundancy check
CSE	Common standards for quantitative electrocardiography
DG	Directorate General (of the European Commission)
EC	European Community
ECG	Electrocardiogram
ECU	European currency unit (€)
EDIFACT	Electronic Data Interchange for Administration, Commerce and Transport
EN	Europäische Norm (European Standard)
ENV	Europäische Norm Vorausgabe (European Pre-standard)
ESC	Escape (control character)

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FF	Form feed (control character)
HT	Horizontal Tab (control character)
ICD	International Classification of Diseases
ID	Identification
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronic Engineers
IMIA	International Medical Informatics Association
ISO	International Organization for Standardization
JIS	Japanese Industrial Standard
LF	Line feed (control character)
LSB	Least significant bit
MSB	Most significant bit
RMS	Root mean square
SCP	Standard Communications Protocol
SCP-ECG	Standard Communications Protocol for Computerized Electrocardiography
TC	Technical Committee
VCG	Vectorcardiogram
VT	Vertical tab (control character)

5 Definition of the data contents and format

5.1 General considerations

5.1.1 The data record which is to be interchanged shall be divided into different sections. The contents and format of each of these sections are defined in this part of ISO 11073.

5.1.2 All text data (character strings) shall comply to the limited conformance requirements of ISO/IEC 2022, described in Annex A. Latin-1 (ISO/IEC 8859-1) shall be the default character set.

5.1.3 All character strings shall be NULL terminated (not part of ISO/IEC 2022).

5.1.4 For all signed binary values 2's-complement coding shall be applied.

5.1.5 All single and multiple byte binary values are regarded as unsigned integers, if not otherwise specified.

5.1.6 Binary values spanning more than 1 byte shall be transmitted in ascending order of significance (the least significant byte is transmitted first, the most significant byte last).

5.1.7 Consecutive bytes are numbered from left to right (starting with 1). Bits of a byte are numbered from right to left (0 = LSB, 7 = MSB).

5.1.8 The first byte in the record (i.e. the first byte of the checksum) is defined as Byte 1.

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5.1.9 ECG samples are indexed and numbered starting with sample number 1. Sample index 0 is not used in this part of ISO 11073. The sample index is a ones-based 16-bit index. The first sample starts at time 0. The second sample is at time (0 + 2) ms in case of 500 samples/s sampling rate.

5.1.10 Sections are numbered starting from 0 (the Pointer Section) to 32 767.

5.1.11 The term “Reference Beat” used in this part of ISO 11073 refers to an ECG complex that is chosen as representative of a class of such complexes. No specific statistical meaning is implied by this term; for example, it may be an averaged beat, a “Median Beat”, a selected or any other representative single cycle taken from the total ECG recording. This “Reference Beat” does include the P-wave if present (not in case of atrial fibrillation), the ST-T segment and the T wave of this beat.

An ECG may have multiple reference beats. The term “Beat type” used in this part of ISO 11073 refers to any one of an ordered list of reference beats, starting with reference beat type 0 (zero). Reference beat type 0 is, by definition, the reference beat used for classification of the ECG, and for reference beat subtraction, if reference beat subtraction is used in compression. The ordering of the list of reference beats does not imply a temporal sequence within the rhythm data.

The term “Rhythm Data” is used to indicate the ECG recording over the entire recording time, usually 10 s in most recorders. A description of these terms and of the recommended data compression methodology, including numerical examples and the methods for conformance testing on the minimum requirements of data compression and signal distortion are given in Clause 6, Annex B and Annex C.

Reference Beat type 0 data in 5.8 are intended to be used for display, (re)analysis and, if reference beat subtraction has been used for data compression, for Rhythm Data reconstruction.

5.1.12 All indexes or pointers to a field are defined in bytes and are ones-based (start at 1) if not otherwise specified.

5.1.13 1 KByte = 1 024 bytes.

5.2 Specifications for the data structure

5.2.1 All sections shall start on an odd index (even offset) boundary. This implies that all sections shall contain an even number of bytes. A padding byte has to be added to the end of any section containing an odd number of bytes. Padding bytes shall always be set to NULL. Blocks of data within a section may contain either odd or even numbers of bytes. Padding occurs only at the end of a section if needed.

5.2.2 All sections are given identification numbers. Section ID numbers 0 to 11 are currently defined in the SCP-ECG protocol, numbers 12 to 127, as well as numbers above 1 024 are reserved for future use. Numbers 128 to 1 023 are for manufacturer-specific sections. The combination of the manufacturer code (see 5.4.3.1, tag 14) and section numbers 128 to 1 023 uniquely defines the content of the manufacturer-specific sections. There are no specific rules for the layout and format of these sections. However, use of the structure defined in 5.2.7 is recommended.

5.2.3 Inclusion of Sections 2, 4, 5, 7 to 11 (5.2.7 and 5.2.8) is optional. Any SCP-ECG data record shall contain Section 0 (Pointers), Section 1 (Header), Section 3 (ECG Lead Definition) and Section 6 (Rhythm Data). No other consistency checking among the presence of different sections is assumed. Specifically, if any of the Sections 8, 9 or 11 is present, it is not assumed that all three shall be present.

5.2.4 The ECG record starts with a 6-byte record header, consisting of a 2-byte CRC followed by a 4-byte record length. These are defined as follows:

1) the 2-byte cyclic redundancy check (CRC) is calculated as a CRC-CCITT, the algorithm of which is described in E.5.5, and is calculated over the entire range starting with the first byte following the CRC and ending with the last byte in the record;

2) the 4-byte record length denotes the number of bytes in the total record, including the 6 bytes of this record header.

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5.2.5 Record overview:

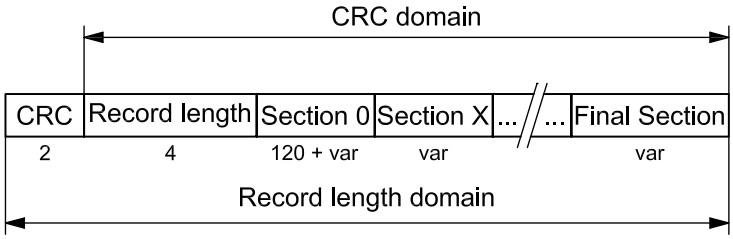

Figure 1 — Record overview

5.2.6 The sequence order of the sections of a record is free, with the exception of Section 0 (zero) which shall immediately follow the record header. However, a maximum of one instance of any section is allowed in an SCP-ECG data record.

5.2.7 Each section consists of:

1) a Section Identification Header (Section ID Header);

2) a Section Data Part.

Any section shall start with a “Section ID Header” (16 bytes) defined below:

Bytes	**Contents**
1 to 2	16 bit CRC-CCITT over the entire section except these 2 bytes.
3 to 4	**Section ID number** as defined in 5.2.2 (see also 5.3.3.1).
5 to 8	**Section length** in bytes including the “Section ID Header” (5.3.3.2).
9	**Version number of the Section**.
10	**Version number of the Protocol** (see 5.4.3.1 tag 14, byte 15).
11 to 16	**Reserved** (for data section 0 see 5.3.1).

Each section shall have a Section Protocol Version Number (see bytes 9 and 10) which may be used to specify different levels of compatibility with the standard when this is updated in the future (see Annex B). For data Sections 1 to 11, Section Version Numbers (byte 9) shall be the Protocol Version under which the section was approved. For data Sections 12 to 1 023, Section Version shall refer to the manufacturer’s version for that section, independent of the Protocol version.

5.2.8 Reserved fields shall always be set to NULL (zero).

5.2.9 Section layout overview:

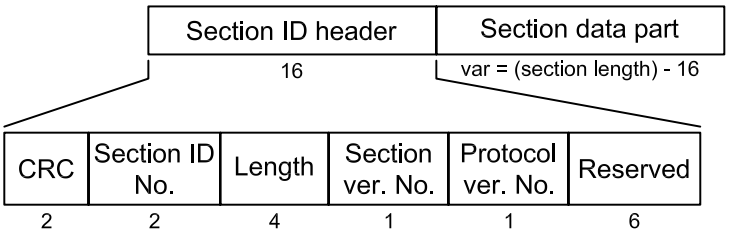

Figure 2 — Section layout overview

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5.2.10 The numbers in italic in the layout overviews (in 5.2.5, 5.2.9 and below) indicate the length in bytes of the corresponding field or indicated block (var = variable length).

5.2.11 A global overview of the SCP-ECG data structure is presented in Table 2.

Table 2 — SCP-ECG data structure

Requirement status	Content
Required	2 BYTES - CHECKSUM - CRC - CCITT OVER THE ENTIRE RECORD (EXCLUDING THIS WORD)
Required	4 BYTES - (UNSIGNED) SIZE OF THE ENTIRE ECG RECORD (IN BYTES)
Required	(Section 0) POINTERS TO DATA AREAS IN THE RECORD
Required	(Section 1) HEADER INFORMATION – PATIENT DATA/ECG ACQUISITION DATA
Dependent	(Section 2) HUFFMAN TABLES USED IN ENCODING OF ECG DATA (IF USED)
Required	(Section 3) ECG LEAD DEFINITION
Optional	(Section 4) QRS LOCATIONS (IF REFERENCE BEATS ARE ENCODED)
Optional	(Section 5) ENCODED REFERENCE BEAT DATA IF REFERENCE BEATS ARE STORED
Required	(Section 6) “RESIDUAL SIGNAL” IF REFERENCE BEAT SUBTRACTION AND REFERENCE BEATS STORAGE ARE PERFORMED, OTHERWISE ENCODED RHYTHM DATA
Optional	(Section 7) GLOBAL MEASUREMENTS
Optional	(Section 8) TEXTUAL DIAGNOSIS FROM THE “INTERPRETIVE” DEVICE
Optional	(Section 9) MANUFACTURER-SPECIFIC DIAGNOSTIC AND OVERREADING DATA FROM THE “INTERPRETIVE” DEVICE
Optional	(Section 10) LEAD MEASUREMENT RESULTS
Optional	(Section 11) UNIVERSAL STATEMENT CODES RESULTING FROM THE INTERPRETATION

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5.2.12 The following remarks apply to the data areas identified above.

0 This section contains pointers to the start of each of the following sections. This section is required.

1 This section contains information of general interest concerning the patient (e.g. patient's name, patient's ID, age, etc.) and the ECG (acquisition date, time, etc.). This section is required.

2 This section contains all of the Huffman tables used in the encoding of rhythm (or “residual signal”) and reference beat data. The tables shall be referenced by Sections 5 and 6 by their numerical order in this section. Thus, when reference is made in the reference beat encoding section to Table 2, this shall refer to the second table defined in Section 2. This section is required, dependent upon Huffman encoding being used in the encoding of rhythm (or “residual signal”) and of reference beat (if stored).

3 This section specifies which ECG leads are contained within the record. This section is required.

4 If reference beats are encoded, then this section shall identify the position of these reference beats relative to the “residual” signal contained in Section 6. This section is optional.

5 Reference beats for each lead are encoded if the originating device has identified those complexes. This section is optional.

6 This section contains the “residual” signal that remains for each lead after the reference beats have been subtracted, or if no reference beats have been subtracted, the entire rhythm signal. This section is required.

7 This section contains global measurements for each reference beat type or for each QRS contained in the record and a list of possible pacemaker spikes in the record. This section is optional.

8 This section contains the latest actual text of the diagnostic interpretation of the recorded ECG data, including all overreadings if performed. Only the text of the most recent interpretation and overreading shall be included in this section. No manufacturer-specific codes should be used in the text. Mnemonic codes as listed in the Universal Statement Codes may be used if necessary. The data contained in this section shall be consistent with the data in Section 9 and Section 11. This section is optional.

9 This section contains the manufacturer-specific diagnostic statements of the analysing device and overreading trails of the interpretations. The source of the analysing device and the name of the latest confirming physician (or device) are defined in the “Header section” (Section 1). This section is optional.

10 A set of basic measurements and manufacturer-specific measurements (if any) for each recorded lead are presented in this section. This section is optional.

11 This section contains the most recent interpretation and overreading data, coded according to the Universal Statement Codes and Coding rules (Annex F). The data contained in this section shall be consistent with the data in Sections 8 and 9. This section is optional.

5.3 Pointer section – Section 0

5.3.1 The purpose of this section is to store pointers at the remaining sections in the record. All sections are given identification numbers, as listed in 5.2.2.

5.3.2 The section starts with a “Section ID Header” as defined in 5.2.7. Bytes 11 to 16 of the Section ID Header shall contain the six-character ASCII string: “SCPECG”.

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5.3.3 To provide a flexible way of section management, the data part of the pointer section are defined as follows.

— One pointer field for each of Sections 0 to 11 defined by SCP-ECG protocol shall be provided in the pointer section, whether the optional sections are present or not. For any optional section not included in an SCP-ECG data record, the special codes defined in 5.3.3.2 and 5.3.3.3 for the pointer field shall be used.

— Manufacturer specific sections, if present, shall have a pointer field in Section 0.

— The first pointer field included in this section shall be the field for Section 0 (this section).

Each pointer field contains three parts:

a) A Section Identification (see 5.3.3.1).

b) A Section Length (see 5.3.3.2).

c) An Index to the Section (see 5.3.3.3).

5.3.3.1 The Section Identification number is stored in 2 bytes containing the section number, as listed in 5.2.2. Section ID numbers 0 to 11 are currently defined in this SCP-ECG protocol, numbers 12 to 127, as well as numbers above 1 023 are reserved for future use, numbers 128 to 1 023 are codes for manufacturer-specific sections.

5.3.3.2 The length, in bytes, of a section (= an even number, see 5.2.1) is presented in this unsigned 4 byte integer field part. The length includes the “Section ID Header” bytes (see 5.2.7). The 4 byte integer is necessary to allow sections to be larger than 32 KBytes. For data Sections 2 to 11 a pointer field shall be included. If no data are transmitted for any of these sections, set the section length to 0.

5.3.3.3 An index to the first byte of a section shall be presented in this unsigned 4 byte integer field part. The index is calculated relative to the start of the record, i.e. byte 1 of the record (first byte of the CRC). For example, if Section 11 begins at an offset of 128 900 bytes from the beginning of the ECG record, the index to Section 11 would be set to 128 901. The 4 byte integer is necessary to allow an SCP-ECG record to be larger than 32 KBytes. If a section is not included in the SCP-ECG record the index shall be set to NULL (0). The index to Section 0 shall always be set to 7, since Section 0 is always preceded by the Checksum (2 bytes) and the Record Length (4 bytes).

5.3.3.4 The pointer fields shall be in numerical order. However, the sections themselves do not necessarily have to follow in numerical order.

5.3.4 Pointer section data part overview:

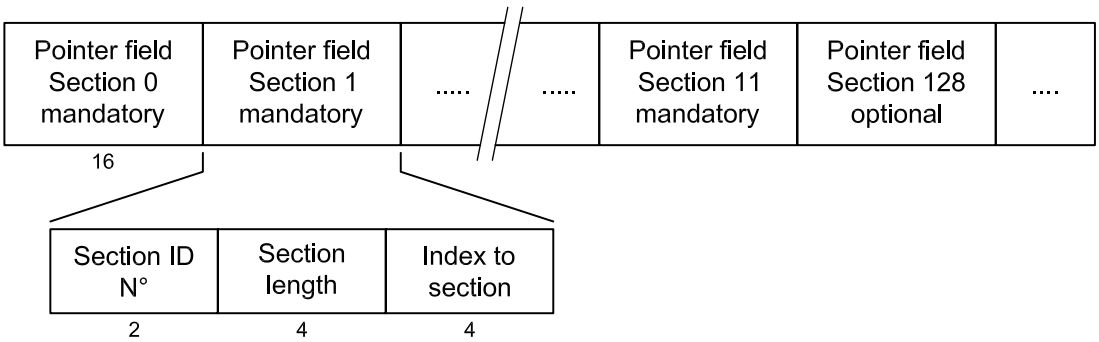

Figure 3 — Pointer section data part overview

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5.4 Header information – Patient data/ECG acquisition data – Section 1

5.4.1 General

The section shall start with a “Section ID Header” as defined in 5.2.7.

5.4.2 Introduction to the section data part

The following layout details the format that should be used to transmit patient demographic and ECG administrative data as part of the standard (SCP-ECG) communications protocol for digital ECG data.

5.4.3 Basic methodology

5.4.3.1 It is recognized that, although a large number of parameters may be transmitted, most devices will only send a subset of that number. As a result, it was agreed that the format of the patient demographic area should be made flexible.

Each parameter shall be stored in a separate field. Including a field in this section shall be optional, with the single provision that the following parameters (1 to 4) shall be present.

	Tag	Parameter
1	2	Patient ID (used as primary key in the ECG management database)
2	14	ID of the acquiring device
3	25	Date of acquisition
4	26	Time of acquisition

In addition, the SCP-ECG Working Group highly recommends the following parameters for uniquely identifying the patient and time of acquisition.

	Tag	Parameter
5	0	Patient's last name
6	1	Patient's first name
7	5	Patient's date of birth (the date of birth shall in principle be given AD)
8	8	Patient's sex
9	15	ID of the analysing device
10	34	Date time zone

5.4.3.2 Flexibility is achieved by identifying each field by the following means.

a) One leading specification byte, referred to as “tag”, indicating the contents of the parameter field.

b) A 2-byte unsigned integer, referred to as “length”, containing the length of the field value in bytes, allowing variable length text entries and use of multiple byte character sets (as the Japanese character set). The NULL terminator character of a text string shall be included to calculate the field length. For example, for the last name “Menuel” the length shall be listed as 7, the NULL included. A length field value of 0 is allowed, which is equivalent to “not defined”.

c) Zero or more parameter bytes, referred to as “value”, containing the actual parameter data.

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The field tag (1 binary byte) permits a total of 255 different field types to be defined (0 to 254; 255 is used as terminator), of which 55 (200 to 254) are reserved for use by an individual manufacturer. Any field identified by a value of 200 to 254 is not defined within the specification of this protocol and permits a manufacturer to define its own set of fields.

The field length (2 binary bytes) shall contain the actual length of the field value. The tag and length bytes (first 3 bytes of any field) are not included in the field length. The maximum possible length of each field value is 65 535 bytes (unsigned 2 bytes). However, for practical reasons the maximum length of a field shall not exceed 64 bytes, except for the free text items (see 5.4.3.5).

The field value, containing the actual parameter data, can be of any combination of binary bytes and text characters.

5.4.3.3 A maximum of one instance of any field defined in 5.4.5 is allowed to be included in the “Header” section, except for the following fields listed below:

Tag	Value description	Max. instances
10	Drugs	no limit
13	Diagnosis or referral indication	no limit
30	Free text	no limit
32	History diagnostic codes	no limit
35	Free-text Medical History	no limit

5.4.3.4 The first 16 characters of the patient identification number shall be unique.

5.4.3.5 In order to facilitate the implementation of the protocol, a maximum field length, i.e. 64 (except for tag 13, tag 30 and tag 35, where the limit is 80) and reasonable values for the length of the different free text fields have been determined, as shown in Table 3.

Table 3 — Maximum and reasonable length of free text fields

Section	Tag	Contents	Instance > once	Reasonable length
1	0	Last name	–	40
1	1	First name	–	40
1	2	Patient identification number	–	40
1	3	Second last name	–	40
1	10	Drugs	yes	40[a]
1	13	Diagnosis or referral indication	yes	80[a]
1	14	Acquiring device identification number	–	40
1	15	Analysing device ID number	–	40
1	16	Acquiring institution description	–	40
1	17	Analysing institution description	–	40
1	18	Acquiring department description	–	40
1	19	Analysing department description	–	40

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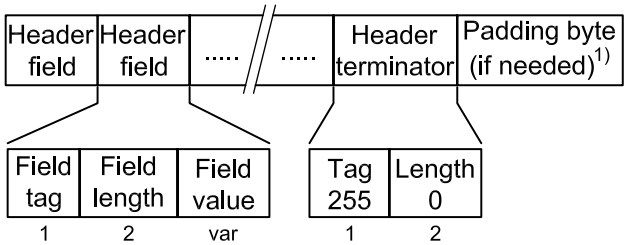
Table 3 (*continued*)

Section	Tag	Contents	Instance > once	Reasonable length
1	20	Referring physician	–	60
1	21	Latest confirming physician	–	60
1	22	Technician description	–	40
1	23	Room description	–	40
1	30	Free text field	yes	80[a]
1	31	ECG sequence number	–	12
1	35	Free-text medical history	yes	80[a]

[a] Multiple instances are allowed for these fields, each with 40 or 80 characters, NULL terminated.

5.4.4 An overview of the "Header" section data part is presented below:



NOTE Padding bytes (if any) should be set to zero. This applies to all sections, but will not be shown in all the following diagrams.

Figure 4 — Overview of the "Header" section data part

5.4.5 For specification of the defined parameters, see Table 4.

Table 4 — Specification of the defined parameters

Tag	Length	Value (parameter data)
0	length	**Last name** (text characters) This shall also be used to transmit the entire name if the originating unit does not explicitly determine a first name.
1	length	**First name** (text characters)
2	length	**Patient ID** (text characters)
3	length	**Second last name** (text characters) The field value may be defined as appropriate for the country or area where the ECG-device is used. For instance in the USA this field may hold the family member prefix code, in France it may contain the patient's maiden name, and in Portugal as well as in Spain and several Latin American countries, the second last name of the patient.

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Table 4 (*continued*)

Tag	Length	Value (parameter data)
4	3	**Age** (binary) This field has the following format: Byte — Contents 1 to 2 — Binary: Age in units as indicated in byte 3. 3 — Binary: Units of age as defined below: Value — Unit 0 — Unspecified 1 — Years 2 — Months 3 — Weeks 4 — Days 5 — Hours If all 3 bytes are zero, then age is not specified.
5	4	**Date of birth** (binary) This field has the following format: Byte — Contents 1 to 2 — Binary: Year (full integer notation, as in 1 990). 3 — Binary: Month (range 01 to 12; 01 = January). 4 — Binary: Day (range 01 to 31). If all 4 bytes are zero, then date of birth is not specified.
6	3	**Height** (binary) This field has the following format: Byte — Contents 1 to 2 — Binary: Height in units as indicated in byte 3. 3 — Binary: Units of height as defined below: Value — Unit 0 — Unspecified 1 — Centimetres 2 — Inches 3 — Millimetres If all 3 bytes are zero, then height is not specified.
7	3	**Weight** (binary) This field has the following format: Byte — Contents 1 to 2 — Binary: Weight in units as indicated in byte 3. 3 — Binary: Units of weight as defined below: Value — Unit — Value — Unit 0 — Unspecified — 3 — Pound 1 — Kilogram — 4 — Ounce 2 — Gram If all 3 bytes are zero, then height is not specified.

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Table 4 (*continued*)

Tag	Length	Value (parameter data)
8	1	**Sex** (binary) This has the following format: Byte — Contents 1 — Binary: Sex indication defined as: Value — Sex — Value — Meaning 1 — Male — 0 — Not Known 2 — Female — 9 — Unspecified
9	1	**Race** (binary) This has the following format: Byte — Contents 1 — Binary: Race indication defined as: Value — Race 0 — Unspecified 1 — Caucasian 2 — Black 3 — Oriental 4 to 9 — Reserved 10 to 255 — Other (manufacturer specific)
10	length	**Drugs** (binary bytes and text characters) Each drug entered in the patient demographic area shall be described by the following structure: Byte — Contents 1 — Binary: Drug code table indicator. If byte 1 is set to 0 then the following table applies. 2 — Binary: Class code. 3 — Binary: Specific drug code within the specified class. 4 to *** — Text characters: Text description of the drug (optional). The following classes are defined: 0 - Unspecified — 5 - Antianginal 1 - Digitalis — 6 - Antithrombotic 2 - Antiarrhythmic — 7 - Beta blockers 3 - Diuretics — 8 - Psychotropic 4 - Antihypertensive — 9 - Calcium blockers 10 - Antihypotensive — 100 - Not taking drugs 11 - Anticholesterol — 101 - Drugs, but unknown type 12 - ACE- Inhibitors — 102 - Other medication 13 to 99 - Reserved — 103 to 255 - Manufacturer specific codes
		NOTE 1 A class code of 0 is always followed by a drug code of 0, indicating that the drug is undefined within this document, and that the text in bytes 4 to *** is the only description available. NOTE 2 A non-zero class code together with a drug code of 0 always indicates that a drug of that particular class has been applied, but that it is either unknown or not defined within this document. Even if a non-zero class and drug code are applied, a text description of the drug may also be sent in bytes 4 to ***. There are no standardized naming conventions. NOTE 3 There is no limit on the number of drugs which can be coded. NOTE 4 Within each class, subcode 9 shall be used for “other”.

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Table 4 (*continued*)

Tag	Length	Value (parameter data)	
10, *cont.*		CLASS 1: DIGITALIS PREPARATION 0 – Unspecified 1 – Digoxin-Lanoxin 2 – Digitoxin-Digitalis CLASS 2: ANTIARRHYTHMIC 0 – Unspecified 1 – Dysopyramide 2 – Quinidine 3 – Procainamide 4 – Lidocaine 5 – Phenytoin 6 – Dilantin 7 – Amiodarone 8 – Tocainide 9 – Other 10 – Encainide 11 – Mexitil/Mexilitine 12 – Flecainide 13 – Lorcainide CLASS 3: DIURETICS 0 – Unspecified 1 – Thiazide 2 – Furosemide (Lasix) 3 – Potassium Chloride CLASS 4: ANTIHYPERTENSIVE 0 – Unspecified 1 – Clonidine 2 – Prasozin 3 – Hydralazine CLASS 5: ANTIANGINAL 0 – Unspecified 1 – Isosorbide 2 – Calcium Blockers 3 – Nitrates	CLASS 6: ANTITHROMBOTIC AGENTS 0 – Unspecified 4 – Warfarin 1 – Aspirin 5 – Streptokinase 2 – Coumadin 6 – t-PA 3 – Heparin CLASS 7: BETA BLOCKERS 0 – Unspecified 4 – Metoprolol 1 – Propranolol 5 – Pindolol 2 – Corgard 6 – Acebutolol 3 – Atenolol CLASS 8: PSYCHOTROPIC 0 – Unspecified 1 – Tricyclic antidepressant 2 – Phenothiazide 3 – Barbiturate CLASS 9: CALCIUM BLOCKERS 0 – Unspecified 1 – Nifedipine 2 – Verapamil CLASS 10: ANTIHYPOTENSIVE 0 – Unspecified 1 – Asthmatic drug 2 – Aminophyline 3 – Isuprel CLASS 11: ANTICHOLESTEROL 0 – Unspecified 1 – Colestid 2 – Lovastatin 3 – Simvastatin 4 – Fibrates CLASS 12: ACE- INHIBITORS 0 – Unspecified 1 – Captopril	
11	2	**Systolic blood pressure (binary)** Byte Contents 1 to 2 Binary: Systolic blood pressure in millimetres of mercury.	
12	2	**Diastolic blood pressure** (binary) Byte Contents 1 to 2 Binary: Diastolic blood pressure in millimetres of mercury.	
13	length	**Diagnosis or referral indication** (text characters) This field contains a text description of the patient's diagnosis or the referral indication.	

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Table 4 (*continued*)

Tag	Length	Value (parameter data)
14	length	**Machine ID acquiring device** (binary bytes and text characters) This field uniquely identifies the device that acquired the ECG. It uses the following generic data structure for device characterization, which is also used in tag 15: Byte — Contents 1 to 2 — Binary: Institution number 3 to 4 — Binary: Department number 5 to 6 — Binary: Device ID 7 — Binary: Device type Value — Type 0 — Cart 1 — System (or Host)
		8 — Binary: set equal to 255 - see manufacturer character string at end of tag 14. NOTE — Legacy devices used this byte to specify a manufacturer code. These codes shall no longer be used except for identifying legacy files. For historical purposes the assigned codes were as follows: 0 – Unknown 1 – Burdick 2 – Cambridge 3 – Compumed 4 – Datamed 5 – Fukuda 6 – Hewlett-Packard 7 – Marquette electronics 8 – Mortara instruments 9 – Nihon Kohden 10 – Okin 11 – Quinton 12 – Siemens 13 – Spacelabs 14 – Telemed 15 – Hellige 16 – ESA-OTE 17 – Schiller 18 – Picker-Schwarzer 19 – et medical devices (ex Elettronica-Trentina) 20 – Zwönitz 21 to 99 – Reserved 100 – Other
		9 to 14 — Text characters: Text model description. Up to 5 bytes of text and NULL terminator.
		15 — Binary: SCP-ECG protocol revision number (the decimal point shall be deleted; version 1.0 becomes 10; the revisions shall as far as possible be backward compatible). This number shall exactly refer to the written document describing the actual protocol revision.
		16 — Binary: SCP-ECG protocol compatibility level (1 byte). Detailed specifications are given in Annex B (see B.4).

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Table 4 (*continued*)

Tag	Length	Value (parameter data)
14, *cont.*		17 Binary: Language support code (1 byte). This bit map indicates the supported character sets:

Bit 0	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Meaning
0	x	x	x	x	x	x	x	8-bit ASCII-only
1	0	x	x	x	x	x	x	ISO-8859-1 Latin-1
1	1	0	0	0	0	0	0	ISO-8859-2 Latin-2 (Central and Eastern European)
1	1	0	1	0	0	0	0	ISO-8859-4 Latin-4 (Baltic)
1	1	0	0	1	0	0	0	ISO-8859-5 Cyrillic
1	1	0	1	1	0	0	0	ISO-8859-6 Arabic
1	1	0	0	0	1	0	0	ISO-8859-7 Greek
1	1	0	1	0	1	0	0	ISO-8859-8 Hebrew
1	1	0	0	1	1	0	0	ISO-8859-11 Thai
1	1	0	1	1	1	0	0	ISO-8859-15 Latin-9 (update to Latin-1, also called “Latin-0”)
1	1	1	0	0	0	0	0	ISO/IEC 10646
1	1	1	1	0	0	0	0	JIS X 0201-1976 (Japanese)
1	1	1	0	1	0	0	0	JIS X 0208-1997 (Japanese)
1	1	1	1	1	0	0	0	JIS X 0212-1990 (Japanese)
1	1	1	0	0	1	0	0	GB 2312-80 (Chinese)
1	1	1	1	0	1	0	0	KS C5601-1987 (Korean)
1	1	1	0	1	1	0	0	Reserved
1	1	1	1	1	1	0	0	Reserved
x	x	x	x	x	x	0	1	Reserved
x	x	x	x	x	x	1	0	Reserved
x	x	x	x	x	x	1	1	Reserved (except for following entry)
1	1	1	1	1	1	1	1	Manufacturer-specific

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Table 4 (*continued*)

Tag	Length	Value (parameter data)
14, *cont.*		18 Binary: Capabilities of the ECG Device (1 byte bit map). This bit map indicates the supported functions: Bit — Contents Reset (0) — Set (1) 0 to 3 — Reserved — Reserved 4 — No printing — Can print ECG reports 5 — No analysis — Can interpret ECG 6 — No storage — Can store ECG records 7(MSB) — No acquisition — Can acquire ECG data 19 Binary: AC mains frequency environment (1 byte): Value — Meaning 0 — Unspecified 1 — 50 Hz 2 — 60 Hz 20 to 35 Reserved for future use. 36 Binary: Length of the string for analysing program revision number. Byte 36 shall be equal to or greater than 1. The character strings following byte 36 are required. If a particular character string is empty, a single NULL is required to be present. 37 to *** Character string: Analysing program revision number. The string has to be NULL terminated. *** to *** Character string: Serial number of the acquisition device. The character string has to be NULL terminated. *** to *** Character string: Acquisition device system software identifier. The character string has to be NULL terminated. *** to *** Character string: Acquisition device SCP implementation software identifier (maximum 24 characters plus NULL terminator). The character string has to be NULL terminated. *** to *** Character string: Manufacturer of the acquisition device. Contains the manufacturer's registered trade name. The character string has to be NULL terminated.
15	length	**Machine ID analysing device** (binary bytes and text characters) This field uniquely identifies the device that analysed the ECG (if other than the acquiring cardiograph). The format of this field is identical to that utilized by tag 14 above.
16	length	**Acquiring institution description** (text characters) This field provides a text description of the institution where the ECG was acquired.
17	length	**Analyzing institution description** (text characters) This field provides a text description of the institution where the ECG was analysed.
18	length	**Acquiring department description** (text characters) This field provides a text description of the department where the ECG was acquired.
19	length	**Analyzing department description** (text characters) This field provides a text description of the department where the ECG was analysed.

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Table 4 (*continued*)

Tag	Length	Value (parameter data)
20	length	**Referring physician** (text characters) This field provides a text description of the referring physician.
21	length	**Latest confirming physician** (text characters) This field provides a text description of the latest confirming physician.
22	length	**Technician description** (text characters) This field provides a text description of the technician.
23	length	**Room description** (text characters) This field provides a text description of the room where the ECG was recorded.
24	1	**Stat code** (binary) Byte — Contents 1 — Binary: Level of emergency. Value 0 refers to “routine” and higher values to increasing levels of emergency as defined by the user. For this, codes in the range of 1 to 10 are recommended.
25	4	**Date of acquisition** (binary) This field has the following format: Byte — Contents 1 to 2 — Binary: year (full integer notation, as in 1990). 3 — Binary: month (range 01 to 12; 01 = January). 4 — Binary: day (range 01 to 31).
26	3	**Time of acquisition** (binary) This field has the following format: Byte — Contents 1 — Binary: hours (range 0 to 23). 2 — Binary: minutes (range 0 to 59). 3 — Binary: seconds (range 0 to 59). The time of acquisition shall be expressed as local time in the time zone of acquisition (see tag 34).
27	2	**Baseline filter** (binary) This field contains the “cut-off” frequency (–3 db) of the high pass baseline filter in units of (1/100) Hertz.
28	2	**Low-pass filter** (binary) This field contains the “cut-off” frequency (-3 db) of the low pass filter in units of Hertz.

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Table 4 (*continued*)

Tag	Length	Value (parameter data)
29	1	**Filter bit map** (binary) This field indicates if other filters, which were not defined within tag 27 and 28, have been used during the processing of the ECG. The definition of these bits are: 0 60 Hertz notch filter 1 50 Hertz notch filter 2 Artifact filter 3 Baseline filter (e.g. adaptive filter or spline filter) 4 to 7 Undefined If all bits are zero then the filter setting was not specified.
30	length	**Free text field** (text characters) This field permits free text comments to be carried along with the ECG.
31	length	**Sequence number** (text characters) ECG sequence number.
32	length	**Medical history codes** (binary) This field contains a description of the patient's clinical problems and diagnoses. There is no limit on the number of diagnoses. Each diagnosis shall be represented by 1 byte. Byte 1 is used to designate the Medical History Code Table which is applied. If Byte 1 is not equal to zero, the designated Medical History Code Table is undefined. In case this byte is equal to zero (0) then the following set of codes apply: Value Contents 0 Diagnoses or clinical problems not specified 1 Apparently healthy 10 Acute myocardial infarction 11 Myocardial infarction 12 Previous myocardial infarction 15 Ischemic heart disease 18 Peripheral vascular disease 20 Cyanotic congenital heart disease 21 Acyanotic congenital heart disease 22 Valvular heart disease 25 Hypertension 27 Cerebrovascular accident 30 Cardiomyopathy 35 Pericarditis 36 Myocarditis 40 Post-operative cardiac surgery 42 Implanted cardiac pacemaker 45 Pulmonary embolism 50 Respiratory disease 55 Endocrine disease 60 Neurological disease 65 Alimentary disease 70 Renal disease 80 Pre-operative general surgery 81 Post-operative general surgery 90 General medical 100 Other 128 to 255 Manufacturer specific The missing numbers in the series from 1 to 100 have been reserved for future extension of some categories.

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Table 4 (*continued*)

Tag	Length	Value (parameter data)
33	2	Electrode configuration code (binary) This field is used to identify the placement and system of electrodes: Byte — Contents 1 — Binary: Code representing the definitions for system of electrode placements for 12-lead ECG (standard, Mason-Likar, Omnitrode, etc.). Value — Electrode placement system 0 — Unspecified Note: carts that do not record the electrode placement information should use 0. 1 — Standard 12-lead positions: RA, RL, LA, and LL are placed at limb extremities. V1 to V6 at standard positions on the chest. All electrodes are placed individually. 2 — RA, RL, LA, and LL are placed on the torso (Mason-Likar positions). V1 to V6 are placed at standard positions on the chest. All electrodes are placed individually. 3 — RA, RL, LA, and LL are placed on the torso (Mason-Likar positions). These limb electrodes are individually placed. V1 to V6 are placed on the chest as part of a single electrode pad (V1 to V6 are NOT placed individually). 4 — RA, RL, LA, LL, and V1 to V6 (all electrodes) are placed on the chest in a single electrode pad (such as Omnitrode). (None of the electrodes is placed individually). 5 — 12-lead ECG is derived from Frank XYZ leads. 6 — 12-lead ECG is derived from non-standard leads. 7 to 255 — Undefined now. Reserved for later use. 2 — Binary: Code representing the definitions for system of electrode placements for XYZ leads such as Frank, Cube, McFee-Parungao, Bipolar, etc. [see chapter 1 of Vectorcardiography by Alberto Benchimol (Williams & Wilkins, Baltimore, 1973) for location of electrodes on the torso and weighting resistors]. Value — Electrode placement system 0 — Unspecified Note: carts that do not record the electrode placement information should use 0. 1 — Frank lead system (Frank, 1956; 13:737). 2 — McFee-Parungao lead system (see Benchimol, Vectorcardiography, Williams & Wilkins, Baltimore, 1973, fig. 1.6 on page 6). 3 — Cube lead system (Grishman et al, *Amer. Heart J.* 1951; **41**, p. 483). 4 — Bipolar uncorrected XYZ lead system. 5 — Pseudo-orthogonal XYZ lead system (as used in Holter recording). 6 — XYZ leads derived from standard 12-lead ECG. 7 to 255 — Undefined now. Reserved for later use.

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Table 4 (*continued*)

Tag	Length	Value (parameter data)
34	length	**Date time zone** (binary bytes and text characters) The contents of this tag identify the global time zone in which the acquired data were obtained, thus allowing the date/time value specified by tags 25 and 26 to be converted to any time zone (e.g. UTC). The following parameter bytes of this tag provide three ways to indicate time zone. Byte / Name / Type / Notes 1 to 2 / Offset / signed binary / Time zone specified as an offset from UTC in minutes [Note 1]. 3 to 4 / Index / unsigned binary / Time zone specified by a manufacturer-defined mapping (until a consensus mapping is defined using bytes 1 to 1 000) using this value as a lookup-table index [Note 2]. Value / Meaning 0 / = Index not used 1 to 1 000 / = Reserved for future use 1 001 to 32 766 / = Manufacturer-specific 32 767 / = Reserved 5 to *** / Description / Text string / Time zone specified by a null-terminated string [Note 3]. NOTE 1 Allowable values for offset are -780 to 780 (i.e., ± 13 h) and hexadecimal 0x7FFF. 0x7FFF indicates that the field is not initialized or is unused. If the offset field contains an allowed value other than 0x7FFF, the index and description fields are considered redundant and may be ignored. NOTE 2 The index value specifies time zone only if the offset value is 0x7FFF. An index value of zero indicates that the field is not used or not initialized. Use of this byte as currently defined is manufacturer-specific. NOTE 3 The description field specifies time zone only if the offset value is 0x7FFF. This string should be in the format of the TZ environment variable as standardized by Posix (Unix). Reference: 'C/C++' language subroutine name tzset(), environment variable “TZ”, and associated data structures. The description field must be 1 byte at a minimum (i.e., the null terminator). NOTE 4 If time zone is not defined for the device, Tag 34 may be omitted from the data record. Similarly, an instance of Tag 34 containing values for the offset = 0x7FFF, index = 0, and description = null terminator is also allowed if time zone is not defined.
35	length	**Free text medical history** (text characters) This field permits free text for entering the medical history.
255	0	**None (demographic section terminator).**

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5.5 Huffman tables – Section 2

5.5.1 If present, the section shall start with a “Section ID Header” as defined in 5.2.7.

5.5.2 The scheme for signal compression presented below is based on the Huffman method of encoding. This method is not the only one possible, but is the recommended one.

5.5.3 This section of the ECG record contains the definition of the Huffman Code Tables that were used to encode the ECG. The provision of a number of tables permits optimum encoding of the data (e.g. the reference beats and rhythm data will probably use different tables). It shall be assumed that the encoded data within each entity shall be encoded using table # 1 (i.e. the first table defined within this Section 2). Escape codes should be provided within each table to enable a change to another table.

5.5.4 The following basic values are used:

1) The fundamental sample time, as defined in the section containing the coded data (i.e. Section 5 “Reference Beat data” and Section 6 “Rhythm data”).

2) The fundamental of ECG amplitude, as defined in the section containing the coded data (i.e. Section 5 “Reference Beat data” and Section 6 “Rhythm data”).

The structure of the data part of this Section is then as follows:

Byte	**Contents**
1 to 2	Number of Huffman Tables defined (if 19 999 then the default table, defined in C.3.7.6, is used).
3 to 4	Number of code structures in table # 1.
5 to ***	The structures defining each code in table # 1. Each structure has the following layout:

1 byte	Number of bits in prefix
1 byte	Number of bits in entire code
1 byte	Table mode switch

Value	Content
0	Switch to another Huffman table
1	Huffman coding if # of bits in prefix = # of bits in entire code
1	Original data if # of bits in prefix < # of bits in entire code

2 bytes	Base value represented by base code (in AVM units).
4 bytes	Base code - 1st bit in code represented by least significant bit of the 4 byte area.

***+1 to ***+2 Number of structures in table # 2.

***+3 to *** Structures representing table # 2.

etc.

5.5.5 The Huffman codes have been defined to permit a single structure described above to specify a series of consecutive amplitude values. The “prefix” mentioned above is common to all of the codes describing the consecutive values - the remaining bit field changes by 1 LSB in incrementing through the indicated range.

Structures that define the Huffman code for just one value shall have no remainder and hence the prefix length shall equal the total code length.

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An example byte structure of the Huffman code is then:

Table 5 — Example byte structure (Huffman code)

	MSB							**LSB**
Received Byte 1	P1	P2	P3	P4	C1	C2	C3	C4
Received Byte 2	C5	C6	P5	P6	P7	C7	C8	C9
Received Byte 3	C10	C11	P8	P9	P10	C12	C13	C14
etc.	…	…	…	…	…	…	…	…

NOTE This represents the following coded values:

P1 P2 P3 P4 C1 C2 C3 C4 C5 C6

4 bit prefix with total code length of 10.

P5 P6 P7 C7 C8 C9 C10 C11

3 bit prefix with total code of 8.

P8 P9 P10 C12 C13 C14

3 bit prefix with total code length of 6.

It shall be seen that the “picking” of bits in a given byte proceeds from the most significant bit to the least significant bit and that the bytes are processed in the order received.

5.5.6 Escape codes, i.e. codes that shall dictate a change of Huffman table, shall include a zero (0) value for the “Table mode switch”. The “Base Value” shall then contain the number of the table to which a switch is desired.

5.5.7 An overview of the data part of this section is presented in Figure 5.

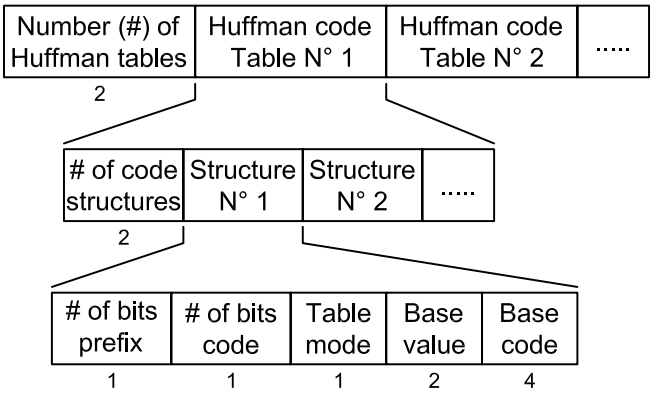

Figure 5 — Overview of the data part of the Huffman tables section

5.6 ECG lead definition – Section 3

5.6.1 This section defines the leads that are transmitted, together with some general administrative information.

5.6.2 If present, the section shall start with a “Section ID Header” as defined in 5.2.7.

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5.6.3 The section data part is defined below:

Byte	Contents	
1	Number of leads enclosed	
2	Flag byte:	
	Bit 0 (LSB)	Set = Reference beat subtraction used for compression Reset = Reference beat subtraction not used for compression
	Bit 1	Reserved
	Bit 2	Set = Leads all simultaneously recorded Reset = Leads not all simultaneously recorded
	Bits 3 to 7	The number of simultaneously recorded leads
3 to 11	Detail for first lead (see 5.6.4)	
12 to 20	Detail for second lead (see 5.6.4)	
etc.		

In case not all leads are recorded simultaneously, the leads shall be presented in groups corresponding to those recorded simultaneously.

EXAMPLE Three leads are recorded simultaneously: e.g. first leads I, aVF, V2; second leads X, Y, Z, etc. Lead details should be listed in above listed order: Lead I in the first segment (3 to 11), Lead aVF in the second segment (12 to 20), Lead V2 in the third segment (21 to 29), Lead X in the fourth segment (30 to 38), etc.

5.6.4 The detailed information for each lead is as follows:

Byte	**Contents**
1 to 4	(Unsigned) Starting sample number
5 to 8	(Unsigned) Ending sample number
9	Lead identification. The numbering scheme shown in Table 6 shall be used.

Table 6 — Lead identification codes

SCP-ECG name	SCP-ECG Code	Description	VITAL[12] Ref ID MDC_ECG_LEAD_xxx
	0	Unspecified lead	MDC_ECG_LEAD_CONFIG
I	1	Lead I	MDC_ECG_LEAD_I
II	2	Lead II	MDC_ECG_LEAD_II
V1	3	V1	MDC_ECG_LEAD_V1
V2	4	V2	MDC_ECG_LEAD_V2
V3	5	V3	MDC_ECG_LEAD_V3
V4	6	V4	MDC_ECG_LEAD_V4
V5	7	V5	MDC_ECG_LEAD_V5
V6	8	V6	MDC_ECG_LEAD_V6
V7	9	V7	MDC_ECG_LEAD_V7
V2R[a]	10	V2R	MDC_ECG_LEAD_V2R

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Table 6 (*continued*)

SCP-ECG name	SCP-ECG Code	Description	VITAL[12] Ref ID MDC_ECG_LEAD_xxx
V3R	11	V3R	MDC_ECG_LEAD_V3R
V4R	12	V4R	MDC_ECG_LEAD_V4R
V5R	13	V5R	MDC_ECG_LEAD_V5R
V6R	14	V6R	MDC_ECG_LEAD_V6R
V7R	15	V7R	MDC_ECG_LEAD_V7R
X	16	X[b]	MDC_ECG_LEAD_X
Y	17	Y[b]	MDC_ECG_LEAD_Y
Z	18	Z[b]	MDC_ECG_LEAD_Z
CC5[c]	19	CC5, per V5 and V5R placement	MDC_ECG_LEAD_CC5
CM5	20	CM5, per V5 placement	MDC_ECG_LEAD_CM5
LA	21	Left arm	MDC_ECG_LEAD_LA
RA	22	Right arm	MDC_ECG_LEAD_RA
LL	23	Left leg	MDC_ECG_LEAD_LL
fI[d]	24	fI	MDC_ECG_LEAD_fI
fE	25	fE	MDC_ECG_LEAD_fE
fC	26	fC	MDC_ECG_LEAD_fC
fA	27	fA	MDC_ECG_LEAD_fA
fM	28	fM	MDC_ECG_LEAD_fM
fF	29	fF	MDC_ECG_LEAD_fF
fH	30	fH	MDC_ECG_LEAD_fH
dI	31	Derived lead I	MDC_ECG_LEAD_dI
dII	32	Derived lead II	MDC_ECG_LEAD_dII
dV1	33	Derived lead V1	MDC_ECG_LEAD_dV1
dV2	34	Derived lead V2	MDC_ECG_LEAD_dV2
dV3	35	Derived lead V3	MDC_ECG_LEAD_dV3
dV4	36	Derived lead V4	MDC_ECG_LEAD_dV4
dV5	37	Derived lead V5	MDC_ECG_LEAD_dV5
dV6	38	Derived lead V6	MDC_ECG_LEAD_dV6
dV7	39	Derived lead V7	
dV2R	40	Derived lead V2R	
dV3R	41	Derived lead V3R	
dV4R	42	Derived lead V4R	
dV5R	43	Derived lead V5R	
dV6R	44	Derived lead V6R	
dV7R	45	Derived lead V7R	
dX	46	Derived lead X	
dY	47	Derived lead Y	
dZ	48	Derived lead Z	
dCC5	49	Derived lead CC5	
dCM5	50	Derived lead CM5	
dLA	51	Derived lead LA	
dRA	52	Derived lead RA	
dLL	53	Derived lead LL	
dfI	54	Derived lead fI	
dfE	55	Derived lead fE	
dfC	56	Derived lead fC	

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Table 6 (*continued*)

SCP-ECG name	SCP-ECG Code	Description	VITAL[12] Ref ID MDC_ECG_LEAD_xxx
dfA	57	Derived lead fA	
dfM	58	Derived lead fM	
dfF	59	Derived lead fF	
dfH	60	Derived lead fH	
III	61	Lead III	MDC_ECG_LEAD_III
aVR	62	aVR, augmented voltage, right	MDC_ECG_LEAD_AVR
aVL	63	aVL, augmented voltage, left	MDC_ECG_LEAD_AVL
aVF	64	aVF, augmented voltage, foot	MDC_ECG_LEAD_AVF
aVRneg	65	aVRneg	MDC_ECG_LEAD_AVRneg
V8	66	V8	MDC_ECG_LEAD_V8
V9	67	V9	MDC_ECG_LEAD_V9
V8R	68	V8R	MDC_ECG_LEAD_V8R
V9R	69	V9R	MDC_ECG_LEAD_V9R
D	70	D (Nehb – Dorsal)	MDC_ECG_LEAD_D
A	71	A (Nehb – Anterior)	MDC_ECG_LEAD_A
J	72	J (Nehb – Inferior)	MDC_ECG_LEAD_J
Defib	73	Defibrillator lead: anterior-lateral	MDC_ECG_LEAD_DEFIB
Extern	74	External pacing lead: anterior-posterior	MDC_ECG_LEAD_EXTERN
A1	75	A1 (Auxiliary unipolar lead #1)	MDC_ECG_LEAD_A1
A2	76	A2 (Auxiliary unipolar lead #2)	MDC_ECG_LEAD_A2
A3	77	A3 (Auxiliary unipolar lead #3)	MDC_ECG_LEAD_A3
A4	78	A4 (Auxiliary unipolar lead #4)	MDC_ECG_LEAD_A4
dV8	79	Derived lead V8	
dV9	80	Derived lead V9	
dV8R	81	Derived lead V8R	
dV9R	82	Derived lead V9R	
dD	83	Derived lead D (Nehb – Dorsal)	
dA	84	Derived lead A (Nehb – Anterior)	
dJ	85	Derived lead J (Nehb – Inferior)	
Chest	86	Chest lead	MDC_ECG_LEAD_C
V	87	Precordial lead	MDC_ECG_LEAD_V
VR	88	VR, nonaugmented voltage, vector of RA	MDC_ECG_LEAD_VR
VL	89	VL, nonaugmented voltage, vector of LA	MDC_ECG_LEAD_VL
VF	90	VF, nonaugmented voltage, vector of LL	MDC_ECG_LEAD_VF
MCL	91	Modified chest lead (left arm indifferent)	MDC_ECG_LEAD_MCL
MCL1	92	MCL, per V1 placement	MDC_ECG_LEAD_MCL1
MCL2	93	MCL, per V2 placement	MDC_ECG_LEAD_MCL2
MCL3	94	MCL, per V3 placement	MDC_ECG_LEAD_MCL3
MCL4	95	MCL, per V4 placement	MDC_ECG_LEAD_MCL4
MCL5	96	MCL, per V5 placement	MDC_ECG_LEAD_MCL5
MCL6	97	MCL, per V6 placement	MDC_ECG_LEAD_MCL6
CC	98	Chest lead (symmetric placement)	MDC_ECG_LEAD_CC
CC1	99	CC1, per V1 and V1R placement	MDC_ECG_LEAD_CC1
CC2	100	CC2, per V2 and V2R placement	MDC_ECG_LEAD_CC2
CC3	101	CC3, per V3 and V3R placement	MDC_ECG_LEAD_CC3
CC4	102	CC4, per V4 and V4R placement	MDC_ECG_LEAD_CC4
CC6	103	CC6, per V6 and V6R placement	MDC_ECG_LEAD_CC6
CC7	104	CC7, per V7 and V8R placement	MDC_ECG_LEAD_CC7

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Table 6 (*continued*)

SCP-ECG name	SCP-ECG Code	Description	VITAL[12] Ref ID MDC_ECG_LEAD_xxx
CM	105	Chest-manubrium	MDC_ECG_LEAD_CM
CM1	106	CM1, per V1 placement	MDC_ECG_LEAD_CM1
CM2	107	CM2, per V2 placement	MDC_ECG_LEAD_CM2
CM3	108	CM3, per V3 placement	MDC_ECG_LEAD_CM3
CM4	109	CM4, per V4 placement	MDC_ECG_LEAD_CM4
CM6	110	CM6, per V6 placement	MDC_ECG_LEAD_CM6
dIII	111	Derived lead III	MDC_ECG_LEAD_dIII
daVR	112	Derived lead aVR	MDC_ECG_LEAD_daVR
daVL	113	Derived lead aVL	MDC_ECG_LEAD_daVL
daVF	114	Derived lead aVF	MDC_ECG_LEAD_daVF
daVRneg	115	Derived lead aVRneg	
dChest	116	Derived lead Chest	
dV	117	Derived lead V	
dVR	118	Derived lead VR	
dVL	119	Derived lead VL	
dVF	120	Derived lead VF	
CM7	121	CM7, per V7 placement	MDC_ECG_LEAD_CM7
CH5	122	CH5	MDC_ECG_LEAD_CH5
CS5	123	Negative: right infraclavicular fossa	MDC_ECG_LEAD_CS5
CB5	124	Negative: low right scapula	MDC_ECG_LEAD_CB5
CR5	125	CR5	MDC_ECG_LEAD_CR5
ML	126	ML, modified limb lead, ~ Lead II	MDC_ECG_LEAD_ML
AB1	127	AB1 (auxiliary bipolar lead #1)	MDC_ECG_LEAD_AB1
AB2	128	AB2 (auxiliary bipolar lead #2)	MDC_ECG_LEAD_AB2
AB3	129	AB3 (auxiliary bipolar lead #3)	MDC_ECG_LEAD_AB3
AB4	130	AB4 (auxiliary bipolar lead #4)	MDC_ECG_LEAD_AB4
ES	131	EASI™ ES[e]	MDC_ECG_LEAD_ES
AS	132	EASI AS	MDC_ECG_LEAD_AS
AI	133	EASI AI	MDC_ECG_LEAD_AI
S	134	EASI upper sternum lead	MDC_ECG_LEAD_S
dDefib	135	Derived lead Defib: Defibrillator lead: anterior-lateral	
dExtern	136	Derived lead Extern: External pacing lead: anterior-posterior	
dA1	137	Derived lead A1 (Auxiliary unipolar lead #1)	
dA2	138	Derived lead A2 (Auxiliary unipolar lead #2)	
dA3	139	Derived lead A3 (Auxiliary unipolar lead #3)	
dA4	140	Derived lead A4 (Auxiliary unipolar lead #4)	
dMCL1	141	Derived lead MCL1: MCL, per V1 placement	
dMCL2	142	Derived lead MCL2: MCL, per V2 placement	
dMCL3	143	Derived lead MCL3: MCL, per V3 placement	
dMCL4	144	Derived lead MCL4: MCL, per V4 placement	
dMCL5	145	Derived lead MCL5: MCL, per V5 placement	
dMCL6	146	Derived lead MCL6: MCL, per V6 placement	
RL	147	Right leg	MDC_ECG_LEAD_RL
CV5RL	148	Canine, fifth right intercostal space near the edge of the sternum at the most curved part of the costal cartilage	MDC_ECG_LEAD_CV5RL

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Table 6 (*continued*)

SCP-ECG name	SCP-ECG Code	Description	VITAL[12] Ref ID MDC_ECG_LEAD_xxx
CV6LL	149	Canine, sixth left intercostal space near the edge of the sternum at the most curved part of the costal cartilage	MDC_ECG_LEAD_CV6LL
CV6LU	150	Canine, sixth left intercostal space at the costochondral junction	MDC_ECG_LEAD_CV6LU
V10	151	Canine, over dorsal spinous process of the seventh thoracic vertebra	MDC_ECG_LEAD_V10
dMCL	152	Derived lead MCL: Modified chest lead (left arm indifferent)	
dCC	153	Derived lead CC: Chest lead (symmetric placement)	
dCC1	154	Derived lead CC1, per V1 and V1R placement	
dCC2	155	Derived lead CC2, per V2 and V2R placement	
dCC3	156	Derived lead CC3, per V3 and V3R placement	
dCC4	157	Derived lead CC4, per V4 and V4R placement	
dCC6	158	Derived lead CC6, per V6 and V6R placement	
dCC7	159	Derived lead CC7, per V7 and V8R placement	
dCM	160	Derived lead CM Chest-manubrium	
dCM1	161	Derived lead CM1, per V1 placement	
dCM2	162	Derived lead CM2, per V2 placement	
dCM3	163	Derived lead CM3, per V3 placement	
dCM4	164	Derived lead CM4, per V4 placement	
dCM6	165	Derived lead CM6, per V6 placement	
dCM7	166	Derived lead CM7, per V7 placement	
dCH5	167	Derived lead CH5	
dCS5	168	Derived lead CS5: negative: right infraclavicular fossa	
dCB5	169	Derived lead CB5: negative: low right scapula	
dCR5	170	Derived lead CR5	
dML	171	Derived lead ML, modified limb lead, ~ Lead II	
dAB1	172	Derived lead AB1 (auxiliary bipolar lead #1)	
dAB2	173	Derived lead AB2 (auxiliary bipolar lead #2)	
dAB3	174	Derived lead AB3 (auxiliary bipolar lead #3)	
dAB4	175	Derived lead AB4 (auxiliary bipolar lead #4)	
dES	176	Derived lead ES: EASI^{e} ES	
dAS	177	Derived lead AS: EASI AS	
dAI	178	Derived lead AI: EASI AI	
dS	179	Derived lead S: EASI upper sternum lead	
dRL	180	Derived lead RL: right leg	
dCV5RL	181	Derived lead CV5RL: Canine, fifth right intercostal space near the edge of the sternum at the most curved part of the costal cartilage	
dCV6LL	182	Derived lead CV6LL: Canine, sixth left intercostal space near the edge of the sternum at the most curved part of the costal cartilage	
dCV6LU	183	Derived lead CV6LU: Canine, sixth left intercostal space at the costochondral junction	

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Table 6 (*continued*)

SCP-ECG name	SCP-ECG Code	Description	VITAL[12] Ref ID MDC_ECG_LEAD_xxx
dV10	184	Derived lead V10: Canine, over dorsal spinous process of the seventh thoracic vertebra	
	185 to 199	Reserved for future expansion	
	200 to 255	Manufacturer specific	

[a] V2R is identical to lead V1. Similarly, lead V1R (not listed in the lead table) is identical to lead V2.

[b] Leads X, Y and Z can be recorded by an orthogonal system, such as Frank or McFee lead systems, etc.

[c] CM5, CH5, CS5, CC5, CB5, CR5 bipolar leads used in conjunction with stress testing. Macfarlane, Volume 1, page 323. [CX5?].

[d] Frank leads indicated by 'f' for clarity and label uniqueness.

[e] EASI™ trademark owned by Philips, invented by Dr. Gordon Dower. Leads: S, upper sternum; E, lower sternum (Frank lead fE); A, under left arm, above V6 (Frank lead fA); I, under right arm, above V6R (Frank lead fI).

NOTE 1 Extension of the lead numbering scheme may be done in future revisions of the protocol.

NOTE 2 Users of this part of ISO 11073 are advised to refer to documents [6], [12] and other current standards in the ISO/IEEE nomenclature series to avoid unintended duplication in these code ranges.

5.6.5 The sample numbering shall start with sample number 1 and refers to all leads recorded simultaneously. In order to convert these values to time, the sampling rate of the proper data section (see 5.8.3) should be consulted.

For example, if 8 leads (I, II, V1 to V6) are recorded simultaneously over 10 seconds at 500 samples/s and stored this way, then each lead begins with sample number 1 and ends with sample number 5 000.

If the leads are recorded in groups of three, for example over 2,5 s at 500 samples/s, then leads I, II and III begin with sample number 1 to sample 1 250, and leads aVR, aVL and aVF begin with sample number 1 251.

5.6.6 An overview of the data part of this section is presented in Figure 6.

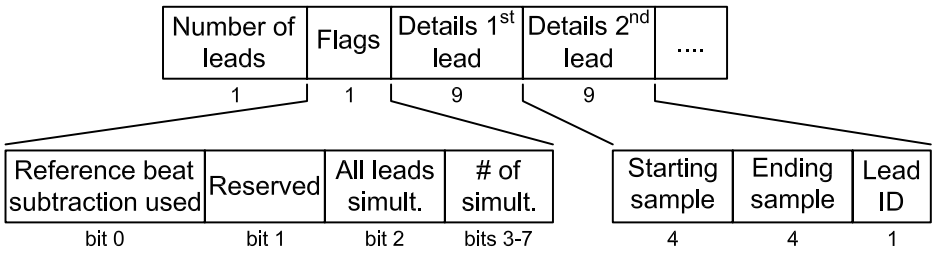

Figure 6 — Overview of the data part of the ECG lead definition section

5.7 QRS locations, reference beat subtraction zones and protected areas – Section 4

5.7.1 If present, this section defines the locations and width of the various QRS complexes. For a definition of reference beats, beat types and the significance of reference beat type 0, see 5.1.11. For a detailed description of the overall process, see Annex C.

5.7.2 The section shall start with a "Section ID Header" as defined in 5.2.7.

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5.7.3 The header area of the section data part defines certain quantities that are common to the type 0 reference beat for all leads. The remaining data indicate the reference beat type and location of each QRS relative to the "residual" signal. The section data part header area has the following contents:

Byte	Contents
1 to 2	Length of reference beat type 0 data in milliseconds.

NOTE The number of samples N is obtained by dividing the length L of the reference beat (in milliseconds) by the sample time interval SI (in microseconds, see 5.9.3, bytes 3 to 4) using the following equation:

$$N = \text{truncation}\left[\frac{(1\,000\,\mu\text{s/ms} \times L)}{\text{SI}}\right]$$

The manufacturer shall assign a length (in bytes 1 to 2) such that when this equation is used, the intended number of samples in the reference beat is obtained. For example, 1 000 ms of data at 2 000 µs per sample results in an N of 500 samples.

3 to 4	(Unsigned) sample number of the fiducial (QRS trigger point) relative to the beginning of reference beat type 0. This location is abbreviated as fcM in Annex C. The first sample is numbered 1.
5 to 6	Total number of QRS complexes within the entire ECG record.

5.7.4 The following information on location of reference beat subtraction zones is stored, consisting of one block of 14 bytes for each QRS complex. The total number of blocks is equal to the number of QRSs stored in 5.7.3 bytes 5 to 6.

Byte	Contents
1 to 2	Beat type of 1st QRS (see 5.1.11 for definition of "Beat type")
3 to 6	(Unsigned) sample number[1)] on residual data for the start of subtraction/addition of reference beat 0 for 1st QRS, if the QRS is of type 0, otherwise a value of 0 (zero).[2), 3)]
7 to 10	(Unsigned) sample number[1)] on residual data for location of fiducial point for 1st QRS.[4)] This location is abbreviated as fc(1) in Annex C.
11 to 14	(Unsigned) sample number[1)] on residual data for end of subtraction/addition of reference beat 0 for 1st QRS, if the QRS is of type 0, otherwise a value of 0 (zero).[2,3)]
15 to 16	Beat type of 2nd QRS etc.

1) All sample numbers in this clause refer to the original samples before processing them for decimation and/or compression. The first sample of the original data is numbered 1.

2) If bytes 1 to 2 indicate reference beat type 0, then bytes 3 to 6 and 11 to 14 bound the area around the QRS for reference beat type 0 subtraction or addition, as specified and illustrated in Annex C. These locations are abbreviated in Annex C as SB(k) and SE(k), respectively.

3) If bytes 1 to 2 indicate a reference beat type other than 0, then reference beat subtraction is not used, in which case bytes 3 to 6 and 11 to 14 contain 0 (zero).

4) 5.7.4 and 5.7.5 may also be used to indicate location of the protected zones in case bimodal compression is used but not reference beat subtraction. In this case, 5.7.4 bytes 3 to 6 and 11 to 14 shall be set to zero.

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5.7.5 The following information on location of protected areas (QRS complexes) is stored, consisting of one block of 8 bytes for each QRS complex. The total number of blocks is equal to the number of QRSs stored in 5.7.3 bytes 5 to 6.[4)]

Byte	Contents
1 to 4	(Unsigned) sample number[1)] on residual data for the start of the protected area of the 1st QRS. This location is abbreviated as QB(1) in Annex C.
5 to-8	(Unsigned) sample number[1)] on residual data for the end of the protected area of the 1st QRS. This location is abbreviated as QE(1) in Annex C.
9 to 12	(Unsigned) sample number[1)] on residual data for the protected area of the start of the 2nd QRS. This location is abbreviated as QB(2) in Annex C.
13 to 16	(Unsigned) sample number[1)] on residual data for the end of the protected area of the 2nd QRS. This location is abbreviated as QE(2) in Annex C.

etc.

5.7.6 An overview of the data part of this section is presented in Figure 7.

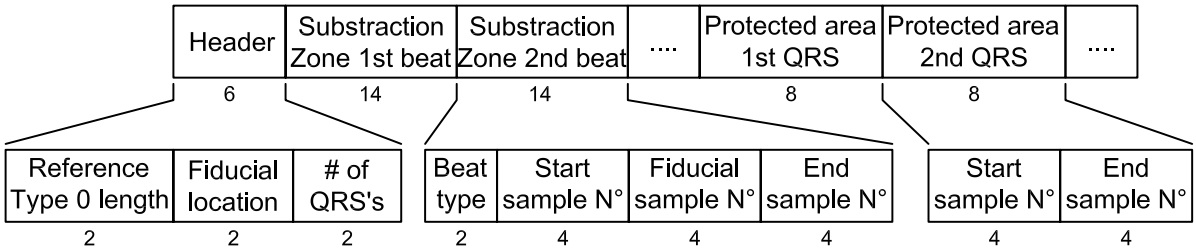

Figure 7 — Overview of the data part of Section 4

5.8 Encoded type 0 reference beat data – Section 5

5.8.1 This section provides details of reference beat type 0. For a definition of reference beats, reference beat types, and the significance of reference beat type 0, see 5.1.11. For a detailed description of the overall process see Annex C.

5.8.2 If present, the section shall start with a “Section ID Header” as defined in 5.2.7.

5.8.3 The section data part begins with a header that has the following format:

Byte	Contents
1 to 2	Multiplier for amplitude value (AVM). This operates as follows: The amplitude value multiplier is expressed in nanovolt (1×10^{-9} V). Example: 1 250 → 1 amplitude quantum = 1,250 µV 2 441 → 1 amplitude quantum = 2,441 µV
3 to 4	The sample time interval for this section in microseconds (1×10^{-6} s). Example: 4 000 → 250 samples/s. 1 250 → 800 samples/s.

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5 This value indicates the encoding of the sample data as follows:

0 = Real (zero difference) data used for reference beat 0 data.

1 = First difference data used for reference beat 0 data.

2 = Second difference data used for reference beat 0 data.

6 Reserved.

NOTE 1 Difference data are defined as: [sample value (difference) for time t] – (sample value (difference) for time t–1).

NOTE 2 For the first two samples in each lead, second differences are not computed in the SCP-ECG protocol. The original value amplitudes of these samples are retained. The first sample value is similarly retained in the encoded data stream using first differences.

NOTE 3 An example of the encoded results using second differences is given in Table 8 for a series of eight sample data.

NOTE 4 An example of the encoded results using first differences is given in Table 9 using the same series of eight sample data.

Table 7 — Difference data

Original data	First differences	Second differences
X(1)	D1(1)=X(1)	D2(1)=X(1)
X(2)	D1(2)=X(2)-X(1)	D2(2)=X(2)
X(3)	D1(3)=X(3)-X(2)	D2(3)=D1(3)-D1(2)=X(3)-2*X(2)+X(1)
X(4)	D1(4)=X(4)-X(3)	D2(4)=D1(4)-D1(3)=X(4)-2*X(3)+X(2)

So the general formula for the first difference is as follows: D1(n) = X(n) – X(n–1).

The general formula for the second difference is as follows: D2(n) = X(n) – 2*X(n–1) + X(n–2).

Decoding of the 2nd difference data is performed using the following formula: X(n) = D2(n) + 2*X(n–1) – X(n–2).

Table 8 — Example of encoded results using 2nd differences

Sample Number:	n	1	2	3	4	5	6	7	8
Sample Value:	X(n)	10	12	13	15	18	22	20	15
2nd Difference:	D2(n)	–	–	–1	1	1	1	–6	–3
Encoded data:		10	12	–1	1	1	1	–6	–3

Table 9 — Example of encoded results using 1st differences

Sample Number:	n	1	2	3	4	5	6	7	8
Sample Value:	X(n)	10	12	13	15	18	22	20	15
1st Difference:	D1(n)	–	2	1	2	3	4	–2	–5
Encoded data:		10	2	1	2	3	4	–2	–5

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5.8.4 The section data part contains the byte lengths of the encoded leads. Its format is as follows:

Byte	Contents
1 to 2	(Unsigned) number of bytes in compressed reference beat 0 data for first encoded lead.
3 to 4	(Unsigned) number of bytes in compressed reference beat 0 data for second encoded lead.
etc.	

5.8.5 The encoded reference beat 0 data then follows. If Section 2 has been provided, the data is coded as a series of Huffman codes taken from Section 2. The leads are encoded in the order specified in Section 3. If Section 2 is not provided, ECG data (either differenced or non-differenced) shall be formatted as signed, two-byte integers.

Other formats may be accommodated by providing a “dummy” Huffman table with one code structure. The number of bits in the prefix shall be set to zero. The number of bits in the entire code shall be set to the desired number of bits per sample.

5.8.6 An overview of the data part of this section is presented in Figure 8.

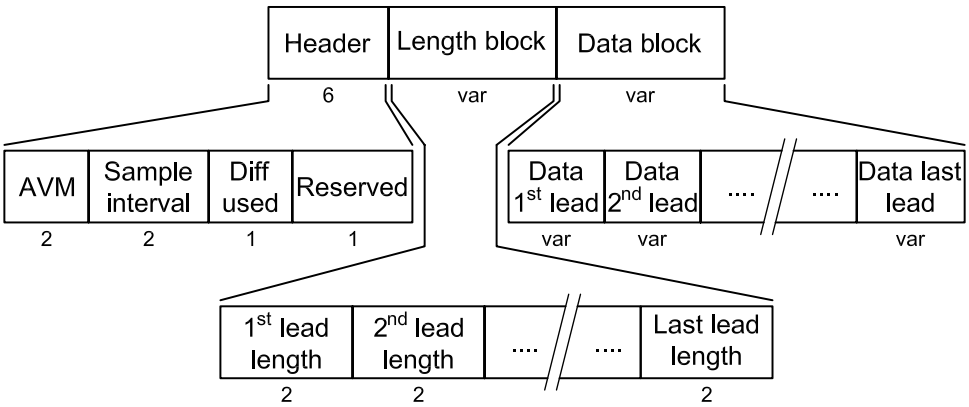

Figure 8 — Overview of the data part of the encoded type 0 reference beat section

5.9 Rhythm data – Section 6

5.9.1 This section contains either:

i) the entire ECG rhythm data, if no reference beats have been subtracted (5.6.3, byte 2),

or

ii) the residual signal after reference beats have been subtracted.

5.9.2 If present, the section shall start with a “Section ID Header” as defined in 5.2.7.

5.9.3 The section data part begins with a header that has the following format:

Byte	**Contents**
1 to 2	Multiplier for amplitude value (AVM). This operates as follows:
	The amplitude value multiplier is expressed in nanovolt (1×10^{-9} Volt).

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Example: 1 250 → 1 amplitude quantum = 1,250 μV
2 441 → 1 amplitude quantum = 2,441 μV

3 to 4 The sample time interval for this section in microseconds (1×10^{-6} s).

Example: 4 000 → 250 samples/s.
1 250 → 800 samples/s.

5 This value indicates the encoding of the sample data as follows:

0 = Real (zero difference) data used for rhythm data.
1 = First difference data used for rhythm data.
2 = Second difference data used for rhythm data.

6 This value indicates how rhythm data is compressed, as follows:

0 = Bimodal compression not used.
1 = Bimodal compression used.

NOTE If bimodal compression is used, the protected region sample time interval is as in 5.8.3, but AVM is as in 5.9.3 bytes 1 to 2. Outside the protected region, AVM and sample time interval are as in 5.9.3 bytes 1 to 2 and 3 to 4.

5.9.4 The section data part contains the byte lengths of the encoded leads. Its format is as follows:

Byte	**Contents**
1 to 2	(Unsigned) number of bytes in compressed rhythm data for first encoded lead.
3 to 4	(Unsigned) number of bytes in compressed rhythm data for second encoded lead.
etc.	

5.9.5 The rhythm data then follows. If Section 2 has been provided, the data is coded as a series of Huffman codes taken from Section 2. The leads are encoded in the order specified in Section 3. If Section 2 is not provided, ECG data (either differenced or non-differenced) shall be formatted as signed, 2-byte integers.

Other formats may be accommodated by providing a “dummy” Huffman table with one code structure. The number of bits in the prefix shall be set to zero. The number of bits in the entire code shall be set to the desired number of bits per sample.

5.9.6 An overview of the data part of this section is presented in Figure 9.

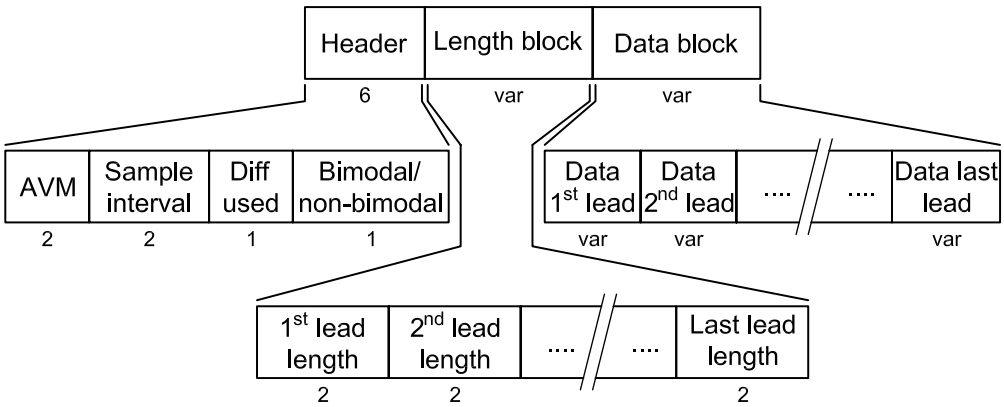

Figure 9 — Overview of the data part of the rhythm data section

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5.10 Global measurements – Section 7

5.10.1 General

This section contains either global measurements for each reference beat type or for each QRS in the record, and a list of pacemaker spikes in the record. If measurements are provided for each QRS, then the first measurement block shall contain global measurements of beat type 0. The term “global” refers to measurements taken across all leads of the ECG, but not necessarily representing more than one individual beat. See 5.1.11 for a discussion of beat types.

5.10.2 Section Header ID

If present, the section shall start with a “Section ID Header” as defined 5.2.7.

5.10.3 Global ECG measurement data and pacemaker spike measurement data

5.10.3.1 General

The section data part contains global ECG measurement data and pacemaker spike measurement data if any.

Special codes, as defined in the CSE Project, have been reserved to indicate:

29 999 (decimal)	Measurement not computed by the program.
29 998 (decimal)	Measurement result not found due to rejection of the lead by the measurement program.
19 999 (decimal)	Measurement not found because wave was not present (e.g. P wave during atrial fibrillation).

These codes shall replace the measurement data when appropriate.

5.10.3.2 Global ECG measurement data

Byte	Contents
1	This byte contains either the number of reference beat types or the number of QRS’s + 1 (compare to 5.10.3.5 byte 1 to 2). This byte refers to the number of measurement blocks stored, where the first block (bytes 7 to 22) always contains measurements for reference beat type 0. If this byte contains the number of reference beat types (i.e., it is not equal to 5.10.3.5 byte 1 to 2 plus 1), then each subsequent block contains the global measurements for each subsequent reference beat type. If this byte contains the number of QRS’s + 1, then the subsequent blocks contain the measurements for each individual beat in sequence.
2	The number of pacemaker spikes for which location times are sent.
3 to 4	Average RR interval in milliseconds for all QRS's.
5 to 6	Average PP interval in milliseconds for all QRS's.
7 to 22	Measurements for reference beat type 0 (see 5.10.4).
23 to 38	Measurements for reference beat type 1, or for first QRS (see byte 1).
etc.	

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5.10.3.3 Pacemaker spike measurement data (if any)

Byte	Contents
1 to 2	1st spike time in milliseconds from start of rhythm record (unsigned integer).
3 to 4	1st spike amplitude in microvolts (1×10^{-6} V) (signed integer).
5 to 6	2nd spike time in milliseconds from start of rhythm record (unsigned integer).
7 to 8	2nd spike amplitude in microvolts (1×10^{-6} V) (signed integer).
etc.	

Time and amplitude of these pacemaker spikes shall be given as signed quantities, which give a range of 0 to 65,535 s and ± 32,767 mV, respectively.

The time resolution for the pacemaker spikes shall be less than or equal to 2 ms.

5.10.3.4 Pacemaker spike information

For each pacemaker spike identified in 5.10.3.2, byte 2, and in 5.10.3.3, this section shall contain one 6-byte block providing additional information about the pacemaker spike. The order of the blocks corresponds to the order of the spikes identified in 5.10.3.3.

Byte	Contents	
1	Spike type of Pacemaker Spike #1:	
	0	Unknown
	1	Spike triggers neither P-wave nor QRS
	2	Spike triggers a QRS
	3	Spike triggers a P-wave
	4 to 127	Reserved
	128 to 254	Manufacturer-specific
	255	No spike type analysis performed
2	Source of Pacemaker Spike #1:	
	0	Unknown
	1	Internal
	2	External
	3 to 255	Reserved
3 to 4	Index of triggered QRS complex for pacemaker spike #1:	
	0	No link
	1	Link to QRS #1 first QRS complex
	2	Link to QRS #2 second QRS complex etc.
5 to 6	Pulse width in microseconds – 0 is unknown or uncomputed (unsigned).	

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5.10.3.5 QRS type information

This section identifies the reference beat type for each QRS complex in the ECG. Complexes are addressed in order. Reference beat types are numbered according to their appearance in the Global ECG measurement data section (5.10.3.2).

Byte	Contents
1 to 2	Number of QRS complexes.
3	Reference beat type of first QRS complex (0-??).
4	Reference beat type of second QRS complex (0-??).
etc.	

5.10.3.6 Additional global measurements

This section provides for additional measurements beyond those defined 5.10.3.2. It is placed here so as not to render inoperable any implementations of previous versions of the protocol.

Byte	Contents
1 to 2	Ventricular rate, in beats per minute (unsigned integer).
3 to 4	Atrial rate, in beats per minute (unsigned integer).
5 to 6	QT corrected (milliseconds) (unsigned integer).
7	Formula type used for HR correction:
	0 Unknown or unspecified
	1 Bazett
	2 Hodges
	3 to 127 Reserved
	128 to 254 Manufacturer-specific
	255 Measurement not available
8 to 9	Number of bytes in tagged fields, which follow (zero if no tagged fields).
10 to ***	Tagged fields, as in the following table. Valid tags are 0 to 254, tag 255 is a terminator. Each tag has at least a 1-byte tag identifier and a 1-byte length specifier (tag 255 length is 0).

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Table 10 — Tagged fields

Tag	Length	Value (parameter data)
0	5	**QT end All-lead Dispersion** (Binary) QT Intervals measured in milliseconds, from QRS onset to T wave offset. All ECG leads are used in measurement. Valid values are 0 to 254 (milliseconds); 255 = measurement not provided. Byte Contents 1 Dispersion = maximum QT interval – minimum QT interval. 2 Heart rate corrected Dispersion: max.–min. 3 Dispersion = standard deviation of the QT intervals. 4 Heart rate corrected Dispersion: standard deviation. 5 Heart rate correction formula (see definition of byte 7 for valid values).
1	5	**QT peak All-lead Dispersion** (Binary) QT Intervals measured in milliseconds, from QRS onset to T wave peak. All ECG leads are used in measurement. Valid values are 0 to 254 (milliseconds); 255 = measurement not provided. Byte Contents 1 Dispersion = maximum QT peak interval – minimum QT peak interval. 2 Heart rate corrected Dispersion: max.–min. 3 Dispersion = standard deviation of the QT peak intervals. 4 Heart rate corrected Dispersion: standard deviation. 5 Heart rate correction formula (see definition of byte 7 for valid values).
2	5	**QT end Precordial Dispersion** (Binary) QT Intervals measured in milliseconds, from QRS onset to T wave offset. Precordial ECG leads only are used in measurement. Valid values are 0 to 254 (milliseconds); 255 = measurement not provided. Byte Contents 1 Dispersion = maximum QT interval – minimum QT interval. 2 Heart rate corrected Dispersion: max.–min. 3 Dispersion = standard deviation of the QT intervals. 4 Heart rate corrected Dispersion: standard deviation. 5 Heart rate correction formula (see definition of byte 7 for valid values).
3	5	**QT peak Precordial Dispersion** (Binary) QT Intervals measured in milliseconds, from QRS onset to T wave peak. Precordial ECG leads only are used in measurement. Valid values are 0 to 254 (milliseconds); 255 = measurement not provided. Byte Contents 1 Dispersion = maximum QT peak interval – minimum QT peak interval. 2 Heart rate corrected Dispersion: max.–min. 3 Dispersion = standard deviation of the QT peak intervals. 4 Heart rate corrected Dispersion: standard deviation. 5 Heart rate correction formula (see definition of byte 7 for valid values).
4 to 254	(none)	**Reserved**
255	0	**None (section terminator)**

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5.10.4 The format of the measurement block for each reference beat type or for each individual QRS

Byte	Contents
1 to 2	P onset
3 to 4	P offset
5 to 6	QRS onset
7 to 8	QRS offset
9 to 10	T offset
11 to 12	P axis in the frontal plane (angular degrees, 999 if undefined)
13 to 14	QRS axis in the frontal plane (angular degrees, 999 if undefined)
15 to 16	T axis in the frontal plane (angular degrees, 999 if undefined)

NOTE 1 If the measurement block contains measurements for a reference beat type, then measurements for onset/offset are given in milliseconds from the beginning of the reference beat. If the measurement block contains measurements for an individual beat, then measurements for onset/offset are given in milliseconds from the beginning of the ECG record. Wave durations and intervals can be computed from wave or interval offset minus onset.

NOTE 2 For the axes (P, QRS, T) in the frontal plane the convention shown in Figure 10 is used.

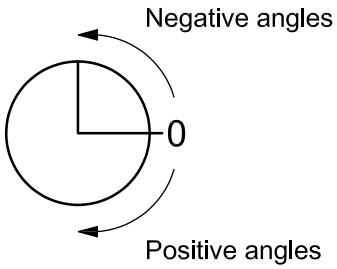

Figure 10 — Angle definition

5.10.5 Manufacturer specific global measurement block

— A block with variable length for manufacturer-specific global measurements can be added to this section, after the data on pacemaker spikes.

— The start of the manufacturer-specific block (counting from the beginning of the Section ID Header) shall be derived from the information given for the global ECG measurement data. For example, if the measurement blocks contain global measurements for each reference beat type, the start of the manufacturer specific block will be 16 (i.e. 5.2.7) + 6 + (Number of reference beat types times 16) + (Number of pacemaker spikes times 4) + (Number of pacemaker spikes times 6) + (2 + Number of QRSs) + (9 + the number of bytes in tagged global measurements) + 1. The end shall be given in the Section ID Header by the total length of the section, including the Section ID Header (see 5.2.7).

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