List of Titles

American National Standard

ANSI/AAMI EC71:2001

Standard communications protocol for computer-assisted electrocardiography

AAMI Association for the Advancement of Medical Instrumentation

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A voluntary *standard* for a *medical device* recommends to the manufacturer the information that should be provided with or on the product, basic safety and performance criteria that should be considered in qualifying the device for clinical use, and the measurement techniques that can be used to determine whether the device conforms with the safety and performance criteria and/or to compare the performance characteristics of different products. Some standards emphasize the information that should be provided with the device, including performance characteristics, instructions for use, warnings and precautions, and other data considered important in ensuring the safe and effective use of the device in the clinical environment. Recommending the disclosure of performance characteristics often necessitates the development of specialized test methods to facilitate uniformity in reporting; reaching consensus on these tests can represent a considerable part of committee work. When a drafting committee determines that clinical concerns warrant the establishment of *minimum* safety and performance criteria, referee tests must be provided and the reasons for establishing the criteria must be documented in the rationale.

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Despite periodic review and revision (at least once every five years), a standard or recommended practice is necessarily a static document applied to a dynamic technology. Therefore, a standards user must carefully review the reasons why the document was initially developed and the specific rationale for each of its provisions. This review will reveal whether the document remains relevant to the specific needs of the user.

Particular care should be taken in applying a product standard to existing devices and equipment, and in applying a recommended practice to current procedures and practices. While observed or potential risks with existing equipment typically form the basis for the safety and performance criteria defined in a standard, professional judgment must be used in applying these criteria to existing equipment. No single source of information will serve to identify a particular product as "unsafe". A voluntary standard can be used as one resource, but the ultimate decision as to product safety and efficacy must take into account the specifics of its utilization and, of course, cost-benefit considerations. Similarly, a recommended practice should be analyzed in the context of the specific needs and resources of the individual institution or firm. Again, the rationale accompanying each AAMI standard and recommended practice is an excellent guide to the reasoning and data underlying its provision.

In summary, a standard or recommended practice is truly useful only when it is used in conjunction with other sources of information and policy guidance and in the context of professional experience and judgment.

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American National Standard ANSI/AAMI EC71:2001

Standard communications protocol for computer-assisted electrocardiography

Developed by
Association for the Advancement of Medical Instrumentation

Approved 11 May 2001 by
American National Standards Institute, Inc.

Abstract: This standard specifies the content and structure of information for interchange between digital electrocardiographs (ECG carts) and computer ECG management systems, as well as other computer systems where ECG-related data can be stored. Standard data formats are specified for demographics, ECG rhythm data, reference beats, global measurements, and interpretation. Practical compression of the ECG rhythm data is also standardized. This standard also specifies the two-way digital transmission of remote requests and results between digital ECG carts and heterogeneous computer systems (hosts). It specifies conventions required for cart-to-host and cart-to-cart interchange of patient data. Compliance with this standard is defined separately for data format, query messaging, and data transport.

Keywords: electromedical equipment, diagnostic, monitoring, communications protocol, computer-assisted ECG, ECG

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Committee representation

Association for the Advancement of Medical Instrumentation

Electrocardiograph (ECG) Committee

This standard was developed by the ECG/Standard Communications Protocol (SCP) Working Group of the AAMI ECG Committee. Committee approval of the standard does not necessarily imply that all committee members voted for its approval.

The **AAMI ECG Committee** has the following members:

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	David Mortara, PhD
Members:	James J. Bailey, MD, National Institutes of Health
	David Daly, U.S. Food and Drug Administration
	Arthur R. Eddy, Jr., Conmed Corp.
	Stacy Gehman, Quinton Instrument Company
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The committee's **ECG/Standard Communications Protocol (SCP) Working Group** has the following members:

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NOTE—Participation by federal agency representatives in the development of this standard does not constitute endorsement by the federal government or any of its agencies.

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Foreword

This document represents work carried out by the Standard Communications Protocol Working Group of the AAMI Electrocardiograph (ECG) Committee, based on CEN's prENV 1064, "Standard Communications Protocol for Computer-Assisted Electrcardiography".

Development of a universal ECG transmission protocol was first started during a series of discussions involving computerized electrocardiograph manufacturers (principal participants included Marquette Electronics, Mortara Instruments, Hewlett-Packard, Compumed, Burdick, and Siemens) and the United States Veterans Administration in 1986 and 1987. The results of these discussions, the so-called "Universal Protocol," were used as the starting point in AIM's SCP-ECG Project.

In 1989, the Advanced Informatics for Medicine (AIM) Project Nr 1015, entitled "A standard communications protocol for computerized electrocardiography" (SCP-ECG) was initiated. The project team consisted of six main SCP-ECG partners (J.L.Willems, Leuven; Chr. Zywietz, Hannover; P. Rubel, Lyon; J. H. van Bemmel, Rotterdam; R. Degani, Padova and P. W. Macfarlane, Glasgow) and representatives from manufacturers of computerized electrocardiographs (including Cardionics, Elettronica-Trentina, ESA-OTE Biomedica, Fukuda-Denshi, Hellige, Hewlett-Packard, Marquette Electronics, Medis, Mortara Instruments, Mortara-Rangoni, Nihon-Kohden, Picker-Schwarzer, Schiller, Siemens-Elema [also representing Burdick]) and a number of program developers, as well as users from different universities. The resulting document, prENV 1064 was prepared by the members of Project Team 007 of CEN/TC 251 (J.L.Willems, Project Team Leader; P. Rubel & Chr. Zywietz, Core Team; and Extended Team members R. Bedini, K. Hedstrœm, P. W. Macfarlane, C. Monroe, F. Pinciroli, L. Rystrœm, and S. Scheirman) and draft version 1.0 was published February 9, 1993.

The current draft proposal represents the contents of ENV 1064, updated to incorporate the comments and changes recommended by the AAMI SCP-ECG WG. Over the course of three meetings, the first January 27, 1997 in Washington, DC, the second April 24-25 in Palm Coast, Florida, the third June 7, 1997, in Washington DC, the AAMI SCP-ECG Working Group discussed and proposed changes to the CEN prENV 1064 document. These changes, captured in Revision 1.0 of the AAMI draft, reflected the findings of the WG members during implementation of the protocol, and were intended to address shortcomings and inconsistencies in the original document. Comments were reviewed by the AAMI SCP-ECG WG members and the parent AAMI ECG Committee members, and Revision 1.1 of the draft, incorporating these recommendations, was presented to CEN on August 19, 1997. Over the course of three more AAMI SCP-ECG WG meetings in Orlando, Florida, November 6-7, 1997, Keystone, Colorado, April 23-24, 1998, and Cleveland, Ohio, September 12-13 1998, a new version of the then labeled Annex D (Compliance) was prepared and refined. This, plus additional changes resulting from comments on the earlier version, comprised Revision 1.2 of this draft. Revision 1.2 was reviewed at an AAMI-SCP WG meeting in Boston, Massachusetts on June 5, 1999, and recommended changes, including the reordering of the Annexes so that all normative annexes precede any informative annexes, were incorporated into Revision 1.3, dated September 11, 1999.

Current voting members of the AAMI SCP-ECG WG are: Stacy Gehman, Industry Co-Chair, Quinton Instrument Co.; Robert Bain, Johns Hopkins Hospital; Alan Berson, NIH NHLBI; Damon Coffman, Instromedix; Matthew Connell, Burdick; David Geraghty, Fukuda Denshi America; Charles Ho, FDA/CDRH; Peter W. Macfarlane, Univ. of Glasgow; Charles Monroe, Hewlett-Packard; Shankara Reddy, GE Marquette Medical Systems; Johann-Jakob Schmid, Schiller AG; Ward Silver, Physio Control; Christoph Zywietz, Medical School of Hannover.

Other participating members of the WG include: Stig Andersson, Siemens-Elema; James Bailey, NIH; Eric Brinster, Quinton Instrument Co.; Fabrizio Conforti, Elettronica Trentina; Steve Duke, Physio Control; Ronald Fischer, Medical School of Hannover; Kurt Hedstrom, Siemens-Elema; Ed Jones, GE Marquette Medical Systems; Kevin Katzenmaier, 3M Health; Gary Laube, Burdick; Cesare Malossi, Elettronica Trentina; Gordon Neff, Datascope; Paul Rubel, INSERM; Eugene Salber, Braemar; Glenn Sherman, Instromedix; Katherine Stankus, Spacelabs Medical.

The AAMI-SCP Working Group gratefully acknowledges the extensive work of Charlie Monroe, of Hewlett-Packard, as editor of the AAMI-WG version of the SCP document.

Note: Participation by the United States of America Food and Drug Administration representatives in the development of this standard does not constitute endorsement by the United States federal government or any of its agencies.

Introduction and field of application

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 ECU 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 centers. 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 standard is to specify a data format and means for transmitting ECG reports and data from any vendor's computerized ECG recorder on a direct connected serial line to any other's vendor central ECG management system. The same standard should also allow standardized transmission 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 devices and/or database management systems 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.

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

This standard relates to the conventional recording of the electrocardiogram, i.e. the so-called standard 12-lead electrocardiogram and the vectorcardiogram (VCG). Initially, the electric 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 (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

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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 centers, so-called body surface maps are obtained by placing many (from 24 to 124 or even more) closely spaced electrodes around the torso. This standard has not been designed to handle transmission of such recordings, although future extensions could be made to this end. The standard has also not been designed to transmit specialised recordings of intracardiac potentials or of the so-called Holter or other long-term ECG recordings made for monitoring cardiac rhythm. This standard also does not address exercise ECG recordings.

ECG computer processing can be reduced to 3 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 the standard 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 of this Standard.

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. Compliance is defined separately for data format, query messaging, and data transport. Four Data Format Categories have been defined based on information content as follows:

Category	Data Sections Required [1]	Content Description
I	0, 1, 7, 8	Demographics, global measurements and interpretation
II	0, 1, 2, 3, 6, (7), (8)	Demographics and ECG rhythm data [2]
III	0, 1, 2, 3, 5, (7), (8)	Demographics and reference beats [2]
IV	0, 1, 2, 3, 4, 5, 6, (7), (8)	Demographics, ECG rhythm data, and reference beats [2]

Note 1: All devices stating a SCP-ECG Data Format Category import data sections 0, 1, 7, 8. All Categories may have additional sections added (e.g. 9, 10, 11). A device may export at more than one Category. Manufacturer specific data shall be optionally included only in manufacturer specific fields, bytes and data blocks that have been defined in the standard. Reserved, unspecified and undefined fields, bytes or data blocks will not be used for manufacturer specific data.

Note 2: (7) and (8) mean that these data sections are optional for export.

For a particular device, a SCP-ECG compliance statement lists Data Format Category(ies) for export (i.e. acquiring and making available a SCP-ECG record) and import (i.e. accepting, and making available to a user, a SCP-ECG record). A device may also state its ability to transfer (i.e. making available a 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 standard).

Clause 7 specifies query messaging, and Clause 8 specifies data transport. A device should state one of three options: “Query Messaging and Data Transport not supported”, “Query Messaging supported”, or “Query Messaging and Data Transport supported”. It is recognized that other mechanisms for transfer of a SCP-ECG formatted file exist. This standard neither restricts nor supports use of any mechanism other than SCP-ECG Query Messaging and Data Transport defined in Document Clauses 7 and 8.

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

List of Titles

Standard communications for computer assisted electrocardiography

1 Scope

This standard covers the two-way digital transmission of remote requests and results between digital electrocardiographs (ECG carts) and heterogeneous computer systems (hosts). It documents 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 standard specifies the content and structure of the information which is to be interchanged between digital ECG carts and computer ECG management systems (ECG DBMS), as well as other computer systems where ECG data can be stored. It enables any two such systems to establish a logical link for communicating ECG related data in a standard and interpretable form.

2 Normative references

CCITT Blue Book, ed. 1988, Volume VIII.2., Recommendations for X.25 and Specifications for the CCITT-CRC Calculations

CCITT Blue Book, ed. 1988, Volume VIII.1., Specifications for the V series, including XMODEM

GB 2312-80 Code of Chinese Graphic Character Set for Information Interchange - Primary Set

ISO 2022 Information Processing - ISO 7-bit and 8-bit coded character sets- With code extension techniques (1986) . For all text fields the limited conformance to the ISO 2022 standard shall be applied, as described in ANNEX A.

ISO-8859 Information Processing - 8-bit single-byte coded graphic character sets.

ISO 2375 Data processing - Procedure for registration of escape sequences.

ISO 646 Information processing - ISO 7-bit coded character set for information interchange

ISO 4873 Information processing - ISO 8-bit code for information interchange – Structure and rules for implementation.

ISO 6429 Information processing - ISO 7-bit and 8-bit coded character sets – Additional control functions for character-imaging devices.

ISO 60646 Unicode

IEC 601-1 Safety of Medical Electrical Equipment, Part 1. General Requirements - 1979

IEC 601-2 The Particular Requirements for Safety, Part 2. (Electrocardiographs), 62D(CO17) –1979

JIS X0201-1976 Code for Information Interchange

JIS X0208-1998 Code of the Japanese Graphic Character Set for Information Interchange

JIS X0212-1990 Code of the Supplementary Japanese Graphic Character Set for Information Interchange

KS C5601-1987 Code for Information Interchange

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3 Definitions

3.1 Description of terms specific to this standard

3.1.1 Acquiring Cardiograph: Cardiograph recording the original ECG signal.

3.1.2 Bimodal Compression: The 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, is called bimodal compression, and is indicated by 5.9.2 byte 6.

3.1.3 Confirming: The 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. The confirmed ECG is the final clinically acceptable version for diagnosis and treatment.

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

3.1.5 Interpretive Device: Device (cart, computer) analyzing the ECG signal.

3.1.6 Message: A textual body of information.

3.1.7 Overreading: The 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. An overread ECG is generally not the final clinically acceptable version for diagnosis and treatment. Usually, the Overreading process precedes the Confirming process.

3.1.8 Record: The entire data file which has to be transmitted, including the ECG data and associated information, such as patient identification, demographic and other clinical data.

3.1.9 Reference Beat: Reference/representative ECG cycle computed through any (but not specified) algorithm. This comprises the P, QRS and the ST-T waves.

3.1.10 Residual Data: The remaining original ECG data after "proper" subtraction of the reference beat. The adjective "proper" refers to accurate beat alignment.

3.1.11 Rhythm Data: The full original ECG data, or the decompressed and reconstructed ECG data at reduced resolution. (Rhythm data is typically 10 seconds in length.)

3.1.12 Section: An aggregate of data elements related to one aspect of the electrocardiographic recording, measurement or interpretation

3.1.13 Universal Statement Codes: ECG interpretation codes described in ANNEX D of this document.

3.2 Description of other technical terms related to this standard

See Glossary in ANNEX E.

3.3 Description of general medical informatics terms

See Vocabulary of Medical Informatics Terms developed by Project Team 001 of CEN/TC 251.

4 Abbreviations

AAMI	Association for the Advancement of Medical Instrumentation
AC	Alternating Current
A/D	Analog to Digital
AHA	American Heart Association
AIM	Advanced Informatics for Medicine Programme of the European Commission Directorate General XIII
ANSI	American National Standards Institute
AVM	Amplitude Value Multiplier (see 5.8.2)
ASCII	American Standard Code for Information Interchange

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ASN.1	Abstract Syntax Notation One
BS	Backspace (control character)
CCITT	International Telegraph and Telephone Consultative Committee
CEC	Commission of the European Communities
CEN	Comité Européen de Normalisation - European Committee for Standardisation
CENELEC	Comité Européen de Normalisation Electrotechnique
CR	Carriage Return (control character)
CRC	Cyclic Redundancy Check
CSE	Common Standards for Quantitative Electrocardiography
CTS	Conformance Testing Service
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	Européenne Norme (European Standard)
ENV	Européeene Norme Vorausgabe (European Pre-standard)
ESC	Escape (control character)
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 Standardisation
JIS	Japanese Industrial Standard
LAN	Local Area Network
LF	Line Feed (control character)
LSB	Least significant bit
MSB	Most significant bit
OSI	Open Systems Interconnection
PT	Project Team
PTT	Post, Telegraph and Telephone Administration
RMS	Root Mean Square
SCP	Standard Communications Protocol

SCP-ECG	Standard Communications Protocol for Computerized Electrocardiography
TC	Technical Committee
TCP/IP	Transmission Control Protocol/ Internet Protocol
VCG	Vectorcardiogram
VT	Vertical Tab (control character)
WG	Working Group

5 Definition of the data contents and format within the standard ECG communications protocol

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 document.

5.1 General considerations

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

5.1.2 All character strings shall be NULL terminated (not part of ISO 2022).

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

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

5.1.5 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).

5.1.6 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).

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

5.1.8 ECG samples are indexed and numbered starting with sample number 1. Sample index 0 is not used in the present document. 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.

5.1.9 Sections are numbered starting from 0 (the Pointer Section) to 32767.

5.1.10 The term "Reference Beat" used in this document refers to an ECG complex which 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 document 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-seconds 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 C, and ANNEX B.

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.

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

5.1.12 One KByte = 1024 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 otherwise containing an odd number of bytes.

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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 through 11 are currently defined in the SCP-ECG protocol, numbers 12 through 127, as well as numbers above 1024 are reserved for future use. Numbers 128 to 1023 are for manufacturer specific sections. The combination of the manufacturer code (see 5.4.5, tag 14) and section numbers 128 to 1023 uniquely define the content of the manufacturer-specific sections. There are no specific rules for the lay-out and format of these sections. However, use of the structure defined in 5.2.7 is recommended.

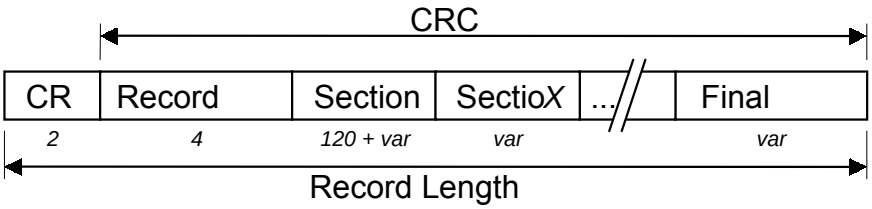
5.2.3 Inclusion of sections 2 - 11 (see 5.2.7 and 5.2.8) are optional. Any SCP-ECG data record shall contain Section 0 (Pointers) and Section 1 (Header). No consistency checking among the presence of different sections is assumed. Specifically, if any of sections 8, 9, or 11 is present, it is not assumed 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 8.4.5, 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.

5.2.5 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 a SCP-ECG data record

5.2.7 Each section consists of:

1) A Section Identification Header (Section ID Header)

2) A Section Data Part.

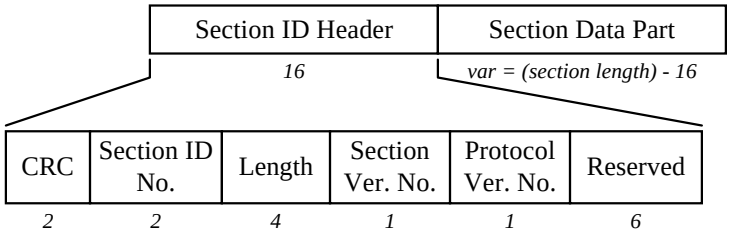
Any section shall start with a "Section ID Header" (16 bytes) defined below:

Bytes	Contents
1-2	16 bit CRC-CCITT over the entire section except these 2 bytes.
3-4	**Section ID number** as defined in 5.2.2 (see also paragraph 5.3.2.1).
5-8	**Section length** in bytes including the "Section ID Header" (see 5.3.2.2).
9	**Version Number of the Section**
10	**Version Number of the Protocol** (see 5.4.5 tag 14, byte 15).
11-16	**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 1-11, Section Version Numbers (byte 9) shall be the Protocol Version under which the section was approved. For data sections 12-1023, 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 lay-out overview:



5.2.10 The numbers in italic in the lay-out 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 the Table below:

Mandatory	2 BYTES – CHECKSUM - CRC - CCITT OVER THE ENTIRE RECORD (EXCLUDING THIS WORD)
Mandatory	4 BYTES – (UNSIGNED) SIZE OF THE ENTIRE ECG RECORD (IN BYTES)
Mandatory	(Section 0) POINTERS TO DATA AREAS IN THE RECORD
Mandatory	(Section 1) HEADER INFORMATION - PATIENT DATA/ECG ACQUISITION DATA
Optional	(Section 2) HUFFMAN TABLES USED IN ENCODING OF ECG DATA (IF USED)
Optional	(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
Optional	(Section 6) "RESIDUAL SIGNAL" AFTER REFERENCE BEAT SUBTRACTION IF REFERENCE BEATS ARE STORED, 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:

Section	Contents
(0)	This section contains pointers to the start of each of the following sections. This section is **mandatory**.
(1)	This section contains information of general interest concerning the patient (e.g. patient name, patient ID, age, etc.) and the ECG (acquisition date, time, etc.). This section is **mandatory**.
(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 **optional**.
(3)	This section specifies which ECG leads are contained within the record. This section is **optional**.
(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 below. 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 **optional**.
(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 analyzing device and overreading trails of the interpretations. The source of the analyzing 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 D). The data contained in this section shall be consistent with the data in Sections 8 and 9. This section is **optional**.

5.3 Specification of the pointer section – Section 0

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

5.3.1 The section starts with a "Section ID Header" as defined in 5.2.7. Bytes 11-16 of the Section ID Header shall contain the six-character ASCII string: "**SCPECG**".

5.3.2 To provide a flexible way of section management, the data part of the pointer section is defined as follows :

- One pointer field for each section 0 - 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 a SCP-ECG data record, the special codes defined in 5.3.2.2 and 5.3.2.3 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 5.3.2.1)

b) A Section Length (see 5.3.2.2)

c) An Index to the Section (see 5.3.2.3)

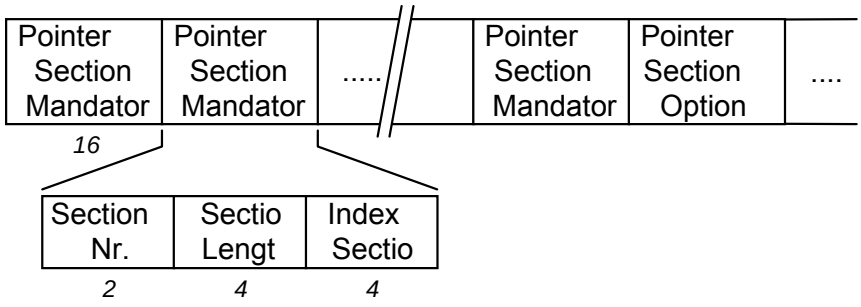
5.3.2.1 The Section Identification number is stored in two bytes containing the section number, as listed in 5.2.2. Section ID numbers 0 through 11 are currently defined in this SCP-ECG protocol, numbers 12 through 127, as well as numbers above 1023 are reserved for future use, numbers 128 through 1023 are codes for manufacturer specific sections.

5.3.2.2 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 65535 (64K – 1)bytes. For data Sections 2 - 11 a pointer field must be included. If no data is transmitted for any of these sections, set the section length to 0.

5.3.2.3 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 preceeded by the Checksum (2 bytes) and the Record Length (4 bytes).

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

5.3.3 Pointer section data part overview



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5.4 Specification of the header information – Patient data / ECG acquisition data – Section 1

5.4.1 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 -> 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:

(5)	0	Patient Last Name
(6)	1	Patient First Name
(7)	5	Patient Date of Birth (the date of birth shall in principle be given AD)
(8)	8	Patient Sex
(9)	15	ID of the Analyzing Device
(10)	34	Date Time Zone

5.4.3.2 Flexibility is achieved by identifying each field by:

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.

The field *tag* (1 binary byte) permits a total of 255 different field types to be defined (0 -> 254; 255 is used as terminator), of which 55 (200-254) are reserved for use by an individual manufacturer. Any field identified by a value of 200-254 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 65535 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.

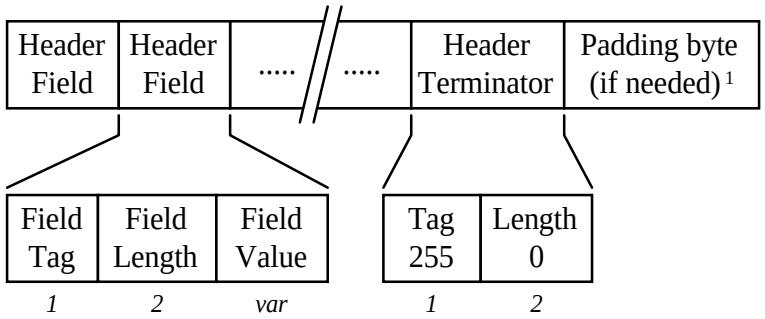
5.4.3.5 Maximum and reasonable length of free text fields

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 the table below.

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 (1)
1	13	Diagnosis or Referral Indication	yes	80 (1)
1	14	Acquiring Device Identification Number	-	40
1	15	Analyzing Device ID Number	-	40
1	16	Acquiring Institution Description	-	40
1	17	Analyzing Institution Description	-	40
1	18	Acquiring Department Description	-	40
1	19	Analyzing Department Description	-	40
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 (1)
1	31	ECG Sequence Number	-	12
1	35	Free-text Medical History	yes	80

NOTE:

1) Multiple instances are allowed for these fields, each with 40 or 80 characters, NULL terminated.



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

NOTE:

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

5.4.5 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 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.
4	3	Age (Binary) This field has the following format : Byte Contents 1-2 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 1-2 Binary: Year (Full integer notation, as in 1990) 3 Binary: Month (range 01 - 12; 01 = January) 4 Binary: Day (range 01 - 31) If all 4 bytes are zero, then date-of-birth is not specified.

TAG	LENGTH	VALUE (Parameter data)
6	3	Height (Binary) This field has the following format : Byte Contents 1-2 Binary: Height in units as indicated in byte 3 3 Binary: Units of height as defined below. Value Unit 0 Unspecified 1 Centimeters 2 Inches 3 Millimeters If all 3 by tes are zero, then height is not specified.
7	3	Weight (Binary) This field has the following format: Byte Contents 1-2 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 weight is not specified.
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

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TAG	LENGTH	VALUE (Parameter data)
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 4-9 Reserved 10-255 Other (manufacturer specific)
10	**length**	**Drugs** (Two binary and Text characters) Each drug entered in the patient demographic area shall be described by the following structure: Byte Contents 1 Drug code table indicator. If Byte 1 is set to 0 then the following table applies 2 Class code 3 Specific drug code within the specified class 4-*** 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 13-99 Reserved 103-255 – 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–*** 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–***. 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”.
		The following list is optional and by far incomplete. The list could be much improved.

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 1-2 Binary: Systolic blood pressure in mmHg.	

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TAG	LENGTH	VALUE (Parameter data)
12	**2**	**Diastolic blood pressure** (Binary) Byte Contents 1-2 Binary: Diastolic blood pressure in mmHg.
13	**length**	**Diagnosis or Referral indication** (Text characters) This field contains a text description of the patient's diagnosis or the referral indication.
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 1-2 Binary: Institution number 3-4 Binary: Department number 5-6 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 11 - Quinton 1 – Burdick 12 - Siemens 2 – Cambridge 13 - Spacelabs 3 – Compumed 14 - Telemed 4 – Datamed 15 - Hellige 5 – Fukuda 16 - ESA-OTE 6 – Hewlett-Packard 17 - Schiller 7 – Marquette Electronics 18 - Picker-Schwarzer 8 – Mortara Instruments 19 - Elettronica-Trentina 9 – Nihon Kohden 20 - Zwönitz 10 – Okin 21-99 Reserved 100 - Other 9-14 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 (one byte). Detailed specifications are given in ANNEX B (see B.3).

<table>
<tr><th>TAG</th><th>LENGTH</th><th>VALUE (Parameter data)</th></tr>
<tr><td>14,
cont.</td><td></td><td>
17 Binary: Language Support Code (one byte). This bit map indicates the supported character sets:
<table>
<tr><th>Bit 0</th><th>Bit 1</th><th>Bit 2</th><th>Bit 3</th><th>Bit 4</th><th>Bit 5</th><th>Bit 6</th><th>Bit 7</th><th>Meaning</th></tr>
<tr><td>0</td><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td><td>8-bit ASCII-only</td></tr>
<tr><td>1</td><td>0</td><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td><td>ISO-8859-1 Latin-1</td></tr>
<tr><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>ISO-8859-2 Latin-2 (Central and Eastern European)</td></tr>
<tr><td>1</td><td>1</td><td>0</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>ISO-8859-4 Latin-4 (Baltic)</td></tr>
<tr><td>1</td><td>1</td><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td><td>0</td><td>ISO-8859-5 Cyrillic</td></tr>
<tr><td>1</td><td>1</td><td>0</td><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td><td>ISO-8859-6 Arabic</td></tr>
<tr><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td><td>ISO-8859-7 Greek</td></tr>
<tr><td>1</td><td>1</td><td>0</td><td>1</td><td>0</td><td>1</td><td>0</td><td>0</td><td>ISO-8859-8 Hebrew</td></tr>
<tr><td>1</td><td>1</td><td>0</td><td>0</td><td>1</td><td>1</td><td>0</td><td>0</td><td>ISO-8859-11 Thai</td></tr>
<tr><td>1</td><td>1</td><td>0</td><td>1</td><td>1</td><td>1</td><td>0</td><td>0</td><td>ISO-8859-15 Latin-9 (update to Latin-1, also called “Latin-0”)</td></tr>
<tr><td>1</td><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>Unicode (ISO-60646)</td></tr>
<tr><td>1</td><td>1</td><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>JIS X0201-1976 (Japanese)</td></tr>
<tr><td>1</td><td>1</td><td>1</td><td>0</td><td>1</td><td>0</td><td>0</td><td>0</td><td>JIS X0208-1997 (Japanese)</td></tr>
<tr><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td><td>JIS X0212-1990 (Japanese)</td></tr>
<tr><td>1</td><td>1</td><td>1</td><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td><td>GB 2312-80 (Chinese)</td></tr>
<tr><td>1</td><td>1</td><td>1</td><td>1</td><td>0</td><td>1</td><td>0</td><td>0</td><td>KS C5601-1987 (Korean)</td></tr>
<tr><td>1</td><td>1</td><td>1</td><td>0</td><td>1</td><td>1</td><td>0</td><td>0</td><td>Reserved</td></tr>
<tr><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>0</td><td>0</td><td>Reserved</td></tr>
<tr><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td><td>0</td><td>1</td><td>Reserved</td></tr>
<tr><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td><td>1</td><td>0</td><td>Reserved</td></tr>
<tr><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td><td>1</td><td>1</td><td>Reserved (except for following entry)</td></tr>
<tr><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>Manufacturer-Specific</td></tr>
</table>
18 Binary: Capabilities of the ECG Device (one byte bit map) This bit map indicates the supported functions:
<table>
<tr><th>Bit</th><th>Contents</th><th></th></tr>
<tr><td></td><td>Reset (0)</td><td>Set (1)</td></tr>
<tr><td>0-3</td><td>Reserved</td><td>Reserved</td></tr>
<tr><td>4</td><td>No printing</td><td>Can print ECG reports</td></tr>
<tr><td>5</td><td>No analysis</td><td>Can interpret ECG</td></tr>
<tr><td>6</td><td>No storage</td><td>Can store ECG records</td></tr>
<tr><td>7(MSB)</td><td>No acquisition</td><td>Can acquire ECG data</td></tr>
</table>
19 Binary: AC Mains Frequency Environment (one byte)
<table>
<tr><th>Value</th><th>Meaning</th></tr>
<tr><td>0</td><td>Unspecified</td></tr>
<tr><td>1</td><td>50 Hz</td></tr>
<tr><td>2</td><td>60 Hz</td></tr>
</table>
</td></tr>
<tr><td></td><td></td><td>20-35 Reserved for future use.
36 Binary: Length of the string for Analysing Program Revision Number. Byte 36 must 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.</td></tr>
</table>

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TAG	LENGTH	VALUE (Parameter data)
14, *cont.*		37-** Character String: Analysing Program Revision Number. The string has to be NULL terminated. **-** Character string: Serial number of the Acquisition Device. The character string has to be NULL terminated **-** Character string: Acquisition device system software identifier. The character string has to be NULL terminated. **-** Character string: Acquisition device SCP implementation software identifier (maximum 24 characters plus NULL terminator). The character string has to be NULL terminated. **-** 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 Analyzing Device** (Binary bytes and Text characters) This field uniquely identifies the device that analyzed the ECG (if other than the acquiring cardiograph). The format of this field is identical to that utilized by parameter 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 analyzed.
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 analyzed.
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. 0 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.

TAG	LENGTH	VALUE (Parameter data)
25	**4**	**Date of Acquisition** (Binary) This field has the following format: Byte Contents 1-2 Binary: Year (Full integer notation, as in 1990) 3 Binary: Month (range 01 - 12; 01 = January) 4 Binary: Day (range 01 - 31)
26	**3**	**Time of Acquisition** (Binary) This field has the following format: Byte Contents 1 Binary: Hours (range 0 - 23) 2 Binary: Minutes (range 0 - 59) 3 Binary: Seconds (range 0 - 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; 2 bytes) 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; 2 bytes) This field contains the "cut-off" frequency (-3 db) of the low pass filter in units of Hertz.
29	**1**	**Filter Bit Map** (Binary; 1 byte) This field indicates if other filters 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 4 - 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 one byte.

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TAG	LENGTH	VALUE (Parameter data)
		Byte 0 is used to designate the Medical History Code Table which is applied. 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
32, *cont.*		Value Contents 60 Neurological disease 65 Alimentary disease 70 Renal disease 80 Pre-operative general surgery 81 Post-operative general surgery 90 General medical 100 Other 128-255 Manufacturer specific The missing numbers in the series from 1 to 100 have been reserved for future extension of some categories.

TAG	LENGTH	VALUE (Parameter data)
33	**2**	**Electrode Configuration Code** 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 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 on the chest in a single electrode pad (such as Omnitrode). (None of the electrodes are placed individually) 5 12-lead ECG is derived from Frank XYZ leads 6 12-lead ECG is derived from non-standard leads 7-255 Undefined now. Reserved for later use
33, *cont.*		Byte Contents 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 l ocation 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; 41:483). 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 7-255 Undefined now. Reserved for later use
34	**length**	**DateTime Zone** The contents of this tag identify the global time zone in which the acquired data was 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 1-2 Offset signed integer Time Zone specified as an offset from UTC in minutes. [Note 1]

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TAG	LENGTH	VALUE (Parameter data)
		3-4 Index unsigned byte Time Zone specified by a manufacturer-defined mapping (until a consensus mapping is defined using bytes 1-1000) using this value as a lookup-table index. [Note 2] Value Meaning 0 Index not used 1-1000 = Reserved for future use 1001 – 32766 = Manufacturer-specific 32767 = Reserved
34, *cont.*		Byte Name Type Notes 5-x Description Text String Time Zone specified by a null-terminated string. [Note 3] Note 1 - Allowable values for Offset are -780 through 780 (i.e., +/-13 hours) 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 presently 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** This field permits free text for entering the medical history.
255	**0**	None (demographic section terminator).

5.5 Specification of the 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). Escape codes should be provided within each Table to enable a change to another Table.

5.5.4 The following basic values are used:

i) 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").

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

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

Byte	Contents
1-2	Number of Huffman Tables defined (if 19999 then the default Table, defined in C.2.7.4, is used)
3-4	Number of code structures in Table # 1.
5-???	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 entire code
1	Original data if # of bits in prefix < # of bits 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 - ???+2	Number of structures in Table # 2.
???+3 - ****	Structures representing Table # 2.
	etc.

5.5.6 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:

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

etc.

Note that 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.

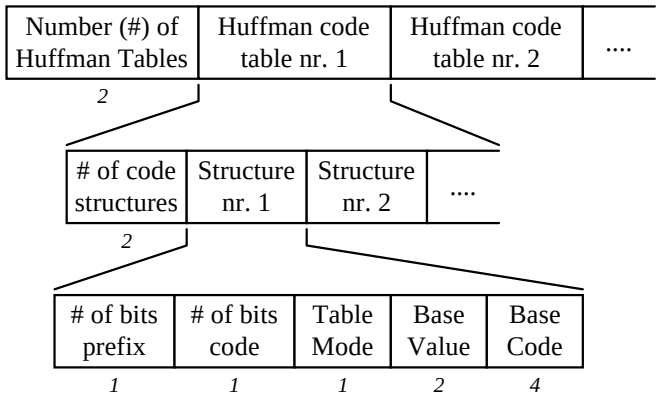
P8 P9 P10 C12 C13 C14

- 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.

5.5.7 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.

5.5.8 An overview of the data part of this section is presented below.



5.6 Specification of the ECG lead definition – Section 3

This section defines the leads that are transmitted, together with some general administrative information, thus:

5.6.1 If present, the section shall start with a "Section ID Header" as defined in 5.2.7.

5.6.2 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[1)]	Set	= Leads all simultaneously recorded
		Reset	= Leads not all simultaneously recorded.
	Bits 3 -> 7[1)]	The number of simultaneously recorded leads.	
3-11	Detail for first lead (see 5.6.3)		
12-20	Detail for second lead (see 5.6.3) etc.		

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 (3-11), Lead aVF in the second segment (12-20), Lead V2 in the third segment (21-29), Lead X in the fourth segment (30-38), etc.

5.6.3 The detailed information for each lead is as follows :

Byte	Contents
1-4	(Unsigned) Starting sample number
5-8	(Unsigned) Ending sample number
9	Lead identification. The following numbering scheme shall be used:

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Lead Identification Table:

1 = I[2)]
2 = II
3 = V1
4 = V2
5 = V3
6 = V4
7 = V5
8 = V6
9 = V7
10 = V2R
11 = V3R
12 = V4R
13 = V5R
14 = V6R
15 = V7R
16 = X[3)]
17 = Y[3)]
18 = Z[3)]
19 = CC5
20 = CM5
21 = Left Arm
22 = Right Arm
23 = Left Leg
24 = I[2)]
25 = E
26 = C
27 = A
28 = M
29 = F
30 = H
31 = I[2)] -cal
32 = II-cal
33 = V1-cal
34 = V2-cal
35 = V3-cal
36 = V4-cal
37 = V5-cal
38 = V6-cal
39 = V7-cal
40 = V2R-cal
41 = V3R-cal
42 = V4R-cal
43 = V5R-cal
44 = V6R-cal
45 = V7R-cal
46 = X-cal
47 = Y-cal
48 = Z-cal
49 = CC5-cal
50 = CM5-cal
51 = Left Arm-cal
52 = Right Arm-cal
53 = Left Leg-cal
54 = I-cal[2)]
55 = E-cal
56 = C-cal
57 = A-cal
58 = M-cal
59 = F-cal
60 = H-cal
61 = III
62 = aVR

63 = aVL
64 = aVF
65 = −aVR
66 = V8
67 = V9
68 = V8R
69 = V9R
70 = D (Nehb – Dorsal)
71 = A (Nehb – Anterior)
72 = J (Nehb – Inferior)
73 = Defibrillator lead: anterior-lateral
74 = External pacing lead: anterior-posterior
75 = A1 (Auxiliary unipolar lead 1)
76 = A2 (Auxiliary unipolar lead 2)
77 = A3 (Auxiliary unipolar lead 3)
78 = A4 (Auxiliary unipolar lead 4)
79 = V8-cal
80 = V9-cal
81 = V8R-cal
82 = V9R-cal
83 = D-cal (cal for Nehb – Dorsal)
84 = A-cal (cal for Nehb – Anterior)
85 = J-cal (cal for Nehb – Inferior)[4)]

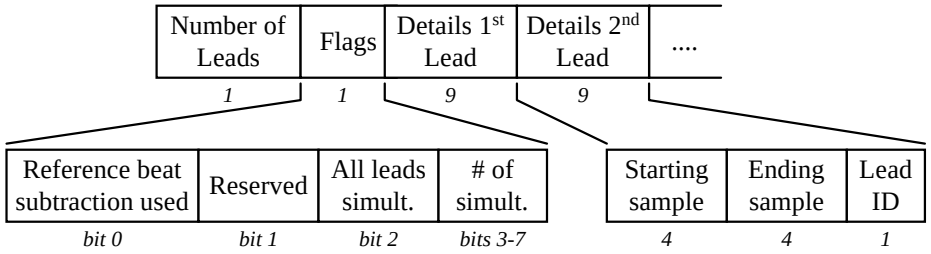
0	- Unspecified lead
86 -> 99	- Reserved for future expansion[4)]
100 -> 255	- Manufacturer specific

5.6.4 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 5.8.2) 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 5000.

If the leads are recorded in groups of three, for example over 2.5 seconds at 500 samples/s, then leads I,II,and III begin with sample number 1 to sample 1250, and leads aVR, aVL, and aVF begin with sample number 1251.

5.6.5 An overview of the data part of this section is presented below.



NOTES:

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

2) The Einthoven lead one (coded with the Roman I; lead ID's 1 and 31) should not be confused with the Frank electrode I (eye; lead ID's 24 and 54).

3) Leads X, Y and Z can be recorded by any orthogonal system, such as Frank or McFee lead systems, etc. Clause 5.4.5 tag 33 may be used to define the lead system used.

4) Extensions of the lead numbering scheme may be done in future revisions of the protocol.

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

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 5.1.10. For a detailed description of the overall process, see ANNEX C.

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

5.7.2 QRS location definition

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 indicates 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
1-2	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 clause 5.9.2, bytes 3-4) using the following equation: N = truncation [(1000 µs/ms * L) / SI]. The manufacturer shall assign a length (in bytes 1-2) such that when this equation is used, the intended number of samples in the reference beat is obtained. For example, 1000 ms of data at 2000 µs per sample results in an N of 500 samples.
3-4	(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.
5-6	Total number of QRS complexes within the entire ECG record.

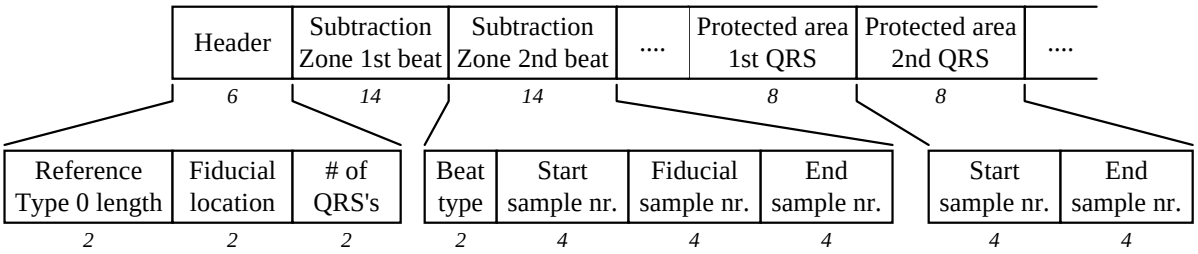
5.7.3 The following information on location of reference beat subtraction zones is stored, consisting of one block of 14 bytes for each QRS complex. The total number of blocks is equal to the number of QRSs stored in 5.7.2 bytes 5-6.

1-2	Beat type of 1st QRS (see 5.1.10 for definition of “Beat type”)
3-6	(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)]
7-10	(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.
11-14	(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)]
15-16	Beat type of 2nd QRS
etc.	

5.7.4 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 5.7.2 bytes 5-6.[4)]

1-4	(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.
5-8	(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.
9-12	(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.
13-16	(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.	

5.7.5 An overview of the data part of this section is presented below.



NOTES:

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

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

4) Clauses 5.7.3 and 5.7.4 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, 5.7.3 bytes 3-6 and 11-14 shall be set to zero.

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5.8 Specification of the encoded type 0 reference beat data – Section 5

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, see5.1.10. For a detailed description the overall process see ANNEX C.

5.8.1 If present, the section shall start with a "Section ID Header" as defined in 5.2.7.

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

Byte Contents

1-2 Multiplier for amplitude value (AVM). This operates as follows:

The Amplitude Value Multiplier is expressed in nano Volt ($1 * 10^{-9}$ V).

Example: 1250 -> 1 amplitude quantum = 1.250 µV

2441 -> 1 amplitude quantum = 2.441 µV

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

Example: 4000 -> 250 samples/s.

1250 -> 800 samples/s.

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[1-4] data used for reference beat 0 data

2 = Second difference[1-3] data used for reference beat 0 data

6 Reserved.

NOTES:

1) Difference data are defined as:

(Sample value(difference) for time [t]) – (Sample value(difference) for time [t-1])

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)

2) For the first 2 samples in each lead, second differences are not computed in the SCP-ECG Protocol. The original value amplitudes of these samples shall be retained. The first sample value shall similarly be retained in the encoded data stream using 1st differences.

3) An example of the encoded results using 2nd differences is given in the table below for a series of 8 sample data:

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

4) An example of the encoded results using 1st differences is given in the table below using the same series of 8 sample data:

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

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

Byte Contents

1-2 (Unsigned) Number of bytes in compressed reference beat 0 data for first encoded lead

3-4 (Unsigned) Number of bytes in compressed reference beat 0 data for second encoded lead

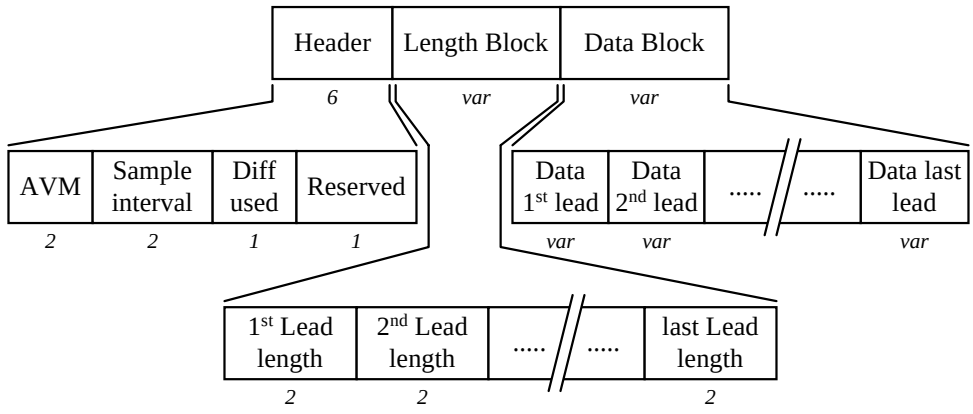
etc.

5.8.4 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.[1)]

NOTE:

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

5.8.5 An overview of the data part of this section is presented below.



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5.9 Specification of the rhythm data – Section 6

This section contains either:

(i) the entire ECG rhythm data, if no reference beats have been subtracted (see 5.6.2, byte 2), or

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

5.9.1 If present, the section shall start with a "Section ID Header" as defined in 5.2.7.

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

Byte	Contents
1-2	Multiplier for amplitude value (AVM). This operates as follows: The Amplitude Value Multiplier is expressed in nano Volt ($1 * 10^{-9}$ Volt). Example: 1250 -> 1 amplitude quantum = 1.250 µV 2441 -> 1 amplitude quantum = 2.441 µV
3-4	The sample time interval for this section in microseconds ($1 * 10^{-6}$ s). Example: 4000 -> 250 samples/s. 1250 -> 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 5.8.2, but AVM is as in 5.9.2 Bytes 1-2. Outside the protected region, AVM and sample time interval are as in 5.9.2 bytes 1-2 and 3-4.

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

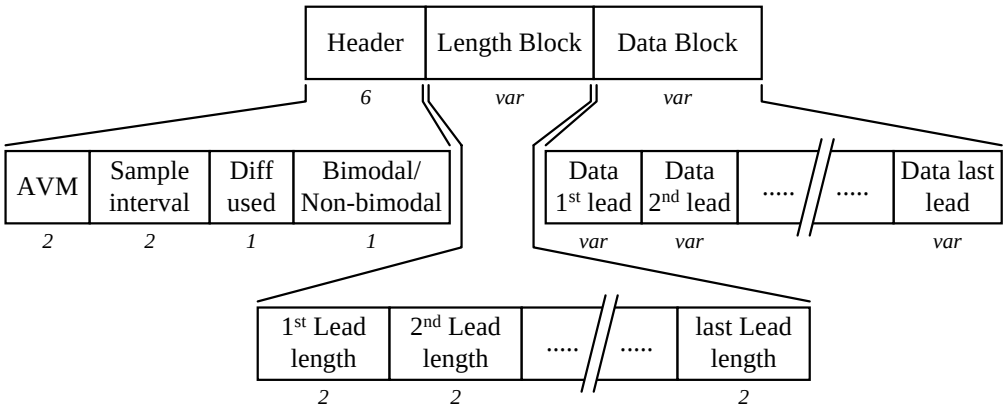
Byte	Contents
1-2	(Unsigned) Number of bytes in compressed rhythm data for first encoded lead
3-4	(Unsigned) Number of bytes in compressed rhythm data for second encoded lead
etc.	

5.9.4 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, two-byte integers.[1)]

NOTE:

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

5.9.5 An overview of the data part of this section is presented below.



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5.10 Specification of the global measurements – Section 7

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 clause 5.1.10 for a discussion of beat types.

5.10.1 If present, the section shall start with a "Section ID Header" as defined in 5.2.7.

5.10.2 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:

29999 (decimal) – Measurement not computed by the program

29998 (decimal) – Measurement result not found due to rejection of the lead by the measurement program

19999 (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.

5.10.2.1 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 5.10.2.4 byte 1). This byte refers to the number of measurement blocks stored, where the first block (bytes 7-22) always contain measurements for reference beat type 0. If this byte contains the number of reference beat types (i.e., it is not equal to 5.10.2.4 byte 1 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.
3-4	Average RR interval in milliseconds for all QRS's
5-6	Average PP interval in milliseconds for all QRS's
7-22	Measurements for reference beat type 0 (see 5.10.3).
23-38	Measurements for reference beat type 1, or for first QRS (see byte 1).
etc.	

5.10.2.2 Pacemaker spike measurement data (if any):

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

NOTES:

1) Time and amplitude of these pacemaker spikes shall be given as signed quantities, which gives a range of 0-65.535 seconds and ±32.767 mV, respectively.

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

5.10.2.3 Pacemaker Spike Information

For each pacemaker spike identified in 5.10.2.1, byte 2, and in 5.10.2.2, 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 5.10.2.2.

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
	4-127 Reserved
	128-254 Manufacturer-specific
	255 No spike type analysis performed
2	Source of Pacemaker Spike #1:
	0 Unknown
	1 Internal
	2 External
	3-255 Reserved
3-4	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.
5-6	Pulse width in microseconds – 0 is unknown or uncomputed (unsigned).

5.10.2.4 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 (5.10.2.1).

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

5.10.2.5 Additional Global measurements

This section provides for additional measurements beyond those defined in 5.10.2.1. It is placed here so as not to render inoperable any implementations of previous versions of the protocol.

Byte	Contents
1-2	Ventricular rate, in beats per minute (unsigned integer).
3-4	Atrial rate, in beats per minute (unsigned integer).
5-6	QT corrected (milliseconds) (unsigned integer).
7	Formula type used for HR correction:

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0 Unknown or unspecified

1 Bazett

2 Hodges

3-127 Reserved

128-254 Manufacturer specific

255 Measurement not available

8-9 Number of bytes in tagged fields which follow (zero if no tagged fields).

10- Tagged fields, as follows. Valid Tags are 0 - 254, tag 255 is a terminator. Each tag has at least a one byte tag identifier and a one byte length specifier (tag 255 length is 0).

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 – 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 – 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 – 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.)

TAG	LENGTH	VALUE (Parameter data)
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 – 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 - 254	(none)	Reserved
255	**0**	None (section terminator).

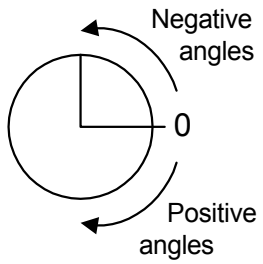
5.10.3 The format of the measurement block for each reference beat type or for each individual QRS.

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

NOTES:

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.

2) For the axes (P, QRS, T) in the frontal plane the convention shown in the diagram below shall be used.



5.10.4 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.

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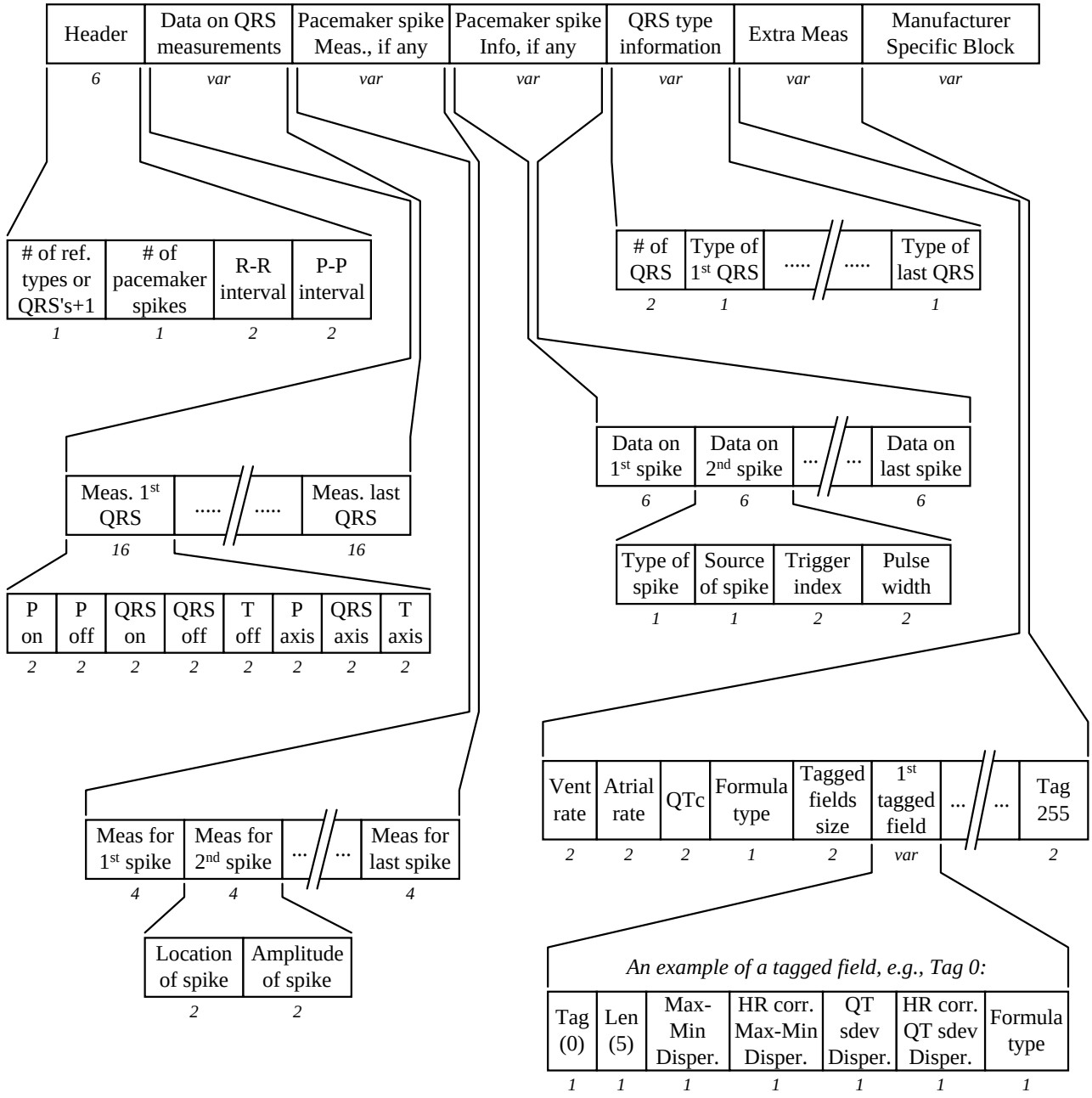
The start of the manufacturer specific block (counting from the beginning of the Section ID Header) shall be derived from the information given for the global ECG measurement data. For example, if the measurement blocks contain global measurements for each reference beat type, the start of the manufacturer 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 Section 5.2.7).

5.10.5 An overview of the data part of Section 7 is presented below.



5.11 Specifications for the storage of full text electro-cardiographic interpretive statements – Section 8

This section contains a text version of the latest diagnostic interpretation of the ECG

5.11.1 If present, the section shall start with a "Section ID Header" as defined in 5.2.7.

5.11.2 The data portion of this section includes a data header followed by multiple statements.

5.11.3 Header:

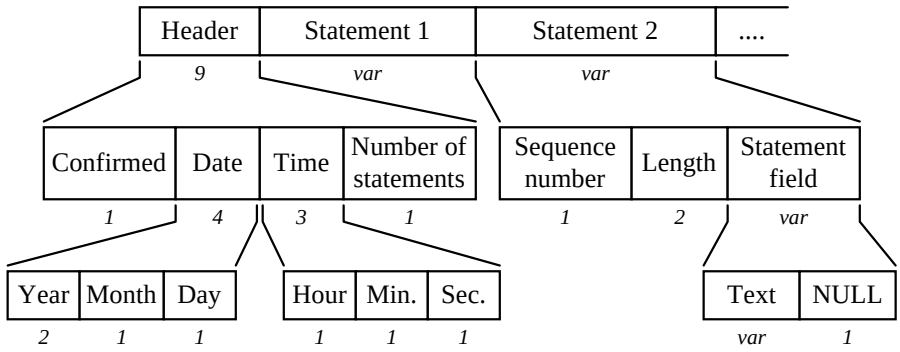
Byte	Contents
1	Binary: Confirmed/Nonconfirmed report:
	Value Type
	0 Original report (not overread)
	1 Confirmed report
	2 Overread report, but not confirmed
2-3	Binary: Year (Full integer notation, as in 1990)
4	Binary: Month (range 01 - 12; 01 = January)
5	Binary: Day (range 01 - 31)
6	Binary: Hours (range 00 - 23)
7	Binary: Minutes (range 00 - 59)
8	Binary: Seconds (range 00 - 59)
9	Binary: Number of statements in this section

5.11.4 Statement data:

Byte	Contents
1	Binary: Statement sequence number, starting with 1.
2-3	Binary: Statement field length (number of bytes in the statement, starting with the first byte following, and including the NULL terminator)
4-***	Statement body: text terminated by NULL.

5.11.5 No codes are allowed in the statements, unless accompanied by descriptive text.

5.11.6 The section data part lay-out:



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5.12 Specifications for storing manufacturer specific interpretive statements and data related to the overreading trail – Section 9

This section is reserved for manufacturer specific diagnostic statements of the analyzing device and overreading trail of the interpretation. The source of the analyzing device and the name of the overreading physician (or device) are defined in the "Header Section" (Section 1).

5.12.1 If present, the section shall start with a "Section ID Header" as defined in 5.2.7.

5.12.2 The structure and format of the data part of this section are manufacturer specific.

5.13 Specification of the lead measurement block – Section 10

This section contains the measurements of each recorded lead separately. The mandatory measurements and their format are listed below. A manufacturer specific area, and escape codes for special conditions have been provided.

5.13.1 If present, the section shall start with a "Section ID Header" as defined in 5.2.7.

5.13.2 The lead measurement section data part shall consist of one record for each measured lead. Each record shall consist of four fields:

a) Lead identifier (Binary 2 bytes). Refer to 5.6.3, byte 9, for lead numbering scheme.

b) Length (unsigned integer) of record in bytes, excluding bytes 1-4 (Binary; 2 bytes)

c) Up to 50 basic measurements (signed integers) (Binary fields; 2 bytes each),

d) Manufacturer measurement area, starting from byte 105 on (Binary). No specific guidelines are included for the lay-out or format of this block.

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

29999 (decimal) Measurement not computed by the program

29998 (decimal)- Measurement result not found due to rejection of the lead by measurement program

19999 (decimal)- Measurement not found because wave (e.g. Q wave) was not present in the corresponding lead

5.13.4 The header of the data part of this Section contains the number of leads for which a measurement block is transmitted (binary, 2 bytes), followed by 2 bytes of manufacturer-specific information.

5.13.5 Each lead measurement block shall consist of:

Byte	Contents
1-2	Lead ID
3-4	Length of record
5-6	P-duration (ms) (total P-duration, including P+ and P- components)
7-8	PR-interval (ms)
9-10	QRS-duration (ms)
11-12	QT-interval (ms)
13-14	Q-duration (ms)
15-16	R-duration (ms)
17-18	S-duration (ms)
19-20	R'-duration (ms)
21-22	S'-duration (ms)
23-24	Q-amplitude (µV)
25-26	R-amplitude (µV)
27-28	S-amplitude (µV)
29-30	R'-amplitude (µV)
31-32	S'-amplitude (µV)
33-34	J-point-amplitude (µV) (amplitude of the J-point = amplitude of end of QRS)
35-36	P(+)-amplitude (µV)

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37-38	P(-) -amplitude (µV)
39-40	T(+)-amplitude (µV)
41-42	T(-)-amplitude (µV)
43-44	ST-slope (µV/s)
45-46	P morphology description, as defined below
47-48	T morphology description, as defined below
49-50	Iso-electric segment at onset of QRS (in ms) (Segment I)[1)]
51-52	Iso-electric segment at the end of QRS (in ms) (Segment K)[1)]
53-54	Intrinsicoid deflection (in ms)
55-56	Quality code reflecting ECG recording conditions, as defined below
57-58	ST-amplitude at the J-point plus 20 ms
59-60	ST-amplitude at the J-point plus 60 ms
61-62	ST-amplitude at the J-point plus 80 ms
63-64	ST-amplitude at the J-point plus 1/16 average R-R interval
65-66	ST-amplitude at the J-point plus 1/8 average R-R interval
67-104	Reserved for future use[2)]
105-***	Manufacturer specific block for measurement results

5.13.5.1 The P and T morphology description codes (Bytes 45 - 48) are defined as follows:

Value	Content
0	unknown
1	positive
2	negative
3	positive/negative
4	negative/positiv
5	positive/negative/positive
6	negative/positive/negative
7	notched M-shaped
8	notched W-shaped

5.13.5.2 The Quality Code (Bytes 55-56) is defined as follows:

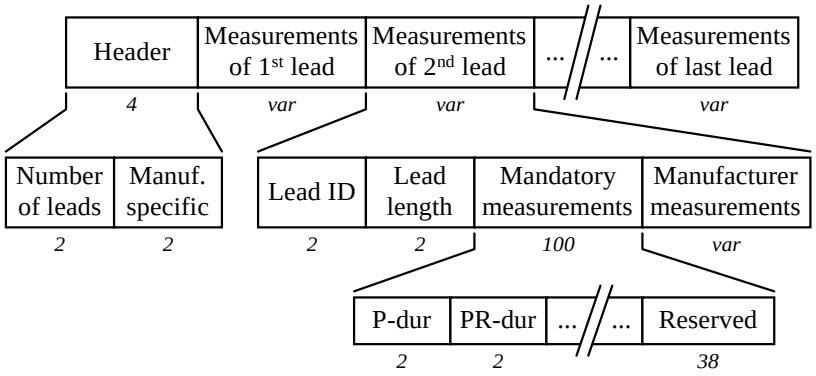
2 binary bytes per lead, consisting of 8 two-bit-fields. Each two-bit pair represents the noise level in one of four classes.

The least significant bit of byte 55 is defined as bit 0. The most significant bit of byte 56 is defined as bit 15.

Bit	Contents	Level	Class
0-1	AC (mains) noise	0	none/no
2-3	overrange	1	moderate/yes
4-5	wander	2	severe

6-7	tremor or muscle artifact	3	unknown
8-9	spikes or sudden jumps		
10-11	electrode loose or off		
12-13	pacemaker		
14-15	interchanged lead		

5.13.6 An overview of the data part of this section is presented below.



NOTES:

1) For the definition of the iso-electric segments I and K see European Heart Journal 1985; vol.6, pages 815-825. Briefly, "I" is the interval between the global onset of QRS derived from all simultaneously recorded leads and the onset of QRS in a specific lead. Conversely, "K" is the time between the end of QRS in a specific lead and the global end of QRS.

2) Bytes 67-104 have to be set to zero and need to be transmitted if a manufacturer specific measurement block is included.

3) All measurements have to be expressed as signed integers. The amplitudes of the Q, S , S', T(-) and P(-) waves shall be expressed as negative integers, as well as the J-point amplitude and J+20, J+60 and J+80 amplitudes, when they are negative. Note that the J-point (J) is the same as the QRS-end location.

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5.14 Specifications for the storage of the universal ECG interpretive statement codes – Section 11

This section contains the most recent interpretation and overreading data, coded according to the Universal Statement Codes and Coding Rules, defined in ANNEX D.

The data contained in this section shall be consistent with the data in Sections 8 and 9 .

5.14.1 If present, the section shall start with a "Section ID Header" as defined in 5.2.7.

5.14.2 Structure and format definition:

Data shall be stored on a statement-by-statement basis. There are three types of statements possible:

1) Universal Statement Codes (as defined in ANNEX D)

2) Full Text (as used in Section 8)

3) Statement Logic (identifying logical relationships between statements)

To store the three types of statements, three separate statement fields were defined.

Only one field of type "Statement Logic" is allowed to identify the logical relationships between statements of the other types. If no "Statement Logic" type field is included in the section, it is assumed that all statements are equally valid, and have no "special" relationship to each other, except for what is declared in the statement. The number of fields of the types "Universal Statement Codes" and "Full Text" are not restricted.

5.14.3 The lay-out of the data part of this section is presented in 5.14.4, and is explained below:

5.14.3.1 Header:

Byte	Contents
1	Binary: Confirmed/Non confirmed report:

Value	Type
0	Original report (not overread)
1	Confirmed report
2	Overread report, but not confirmed.

Byte	Contents
2-3	Binary: Year (Full integer notation, as in 1990)
4	Binary: Month (range 01 - 12; 01 = January)
5	Binary: Day (range 1 - 31)
6	Binary: Hours (range 0 - 23) (time is always local time)
7	Binary: Minutes (range 0 - 59)
8	Binary: Seconds (range 0 - 59)
9	Binary: Number of statements in this section

5.14.3.2 Statement data:

Byte	Contents
1	Binary: Statement sequence number. Each statement has been given a sequence number to allow easy binding by the Type 3 logical operands.
2-3	Binary: Statement field length (number of bytes in the statement, starting with the statement field type byte, and including the NULL terminator.)

4-*** Statement field:

Byte	Contents
1	Binary: Statement field type:

Value	Type
1	Coded statement type, using the Universal Statement Codes
2	Full text type, as used in Section 8
3	Statement logic type, as described below.
2-	Data depending on the field type, terminated by NULL (0).

5.14.3.3 Statement type:

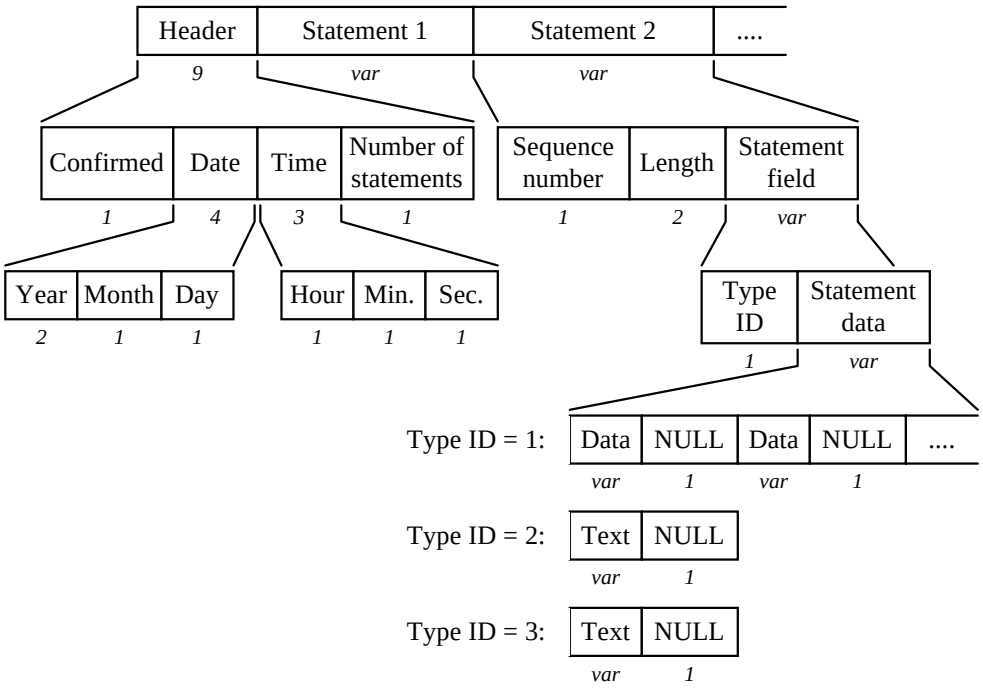
Type 1: This type shall contain one coded statement optionally followed by one or more modifiers, according to the Universal Statement Codes. The coded statement and modifiers shall each occupy one data part terminated by a NULL (0). The data parts are of variable length and the number of data parts is not restricted. The only restriction is the total length of all data parts together, which is 65535 bytes maximum.

Type 2: This type has one data part containing only text characters, and is NULL (0) terminated.

Type 3: This type has one data part containing only text characters, and is NULL (0) terminated. The contents of this field identifies the logical relationships between statements by using logical operands acting on statements referred to by their sequence number.

Example: "**(1+2);3**" with "+" = or, ";" = and, "(...)" marking precedence this means: statement nr. 1 OR statement nr. 2. AND statement nr. 3.

5.14.4 Lay-out of the data part of Section 11:



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6 Minimum requirements for encoding and compression of the electrocardiographic signal data

6.1 Scope and field of application

As described in the **General Scope and Field of Application (Clause 1)** of the present standard, ECGs are taken in routine clinical practice with the patient being at rest, during defined periods of exercise or over long-term periods during regular daily activity, i.e. during ambulatory (so-called Holter) monitoring or in intensive care-units for cardiac arrhythmia monitoring. Recommendations for compression of data from long-term ECG recordings have been excluded from the present document. The specifications for encoding and compression described in this document are restricted to the routine resting electrocardiogram.

6.2 Introduction

ECG recordings made at rest have typically a length of 10 seconds. If digitized within accuracy limits recommended by the International Committees on Electrocardiology of AHA, AAMI, CSE and others, namely 500 samples/s and maximum 5μV/LSB, for each ECG lead per second 1,000 bytes of data is obtained with 16 bits/samples. This results in 80,000 bytes of data for a standard 12-lead 10-second ECG. (In this case, redundancy of limb leads which can be reconstructed from lead I and lead II has already been removed.)

Although less than medical imaging, electrocardiography thus results in large amounts of digital data compared to other medical data such as patient history, diagnostic codes and biomedical laboratory data. Although technology has nowadays significantly increased the available capacity and transmission speed, data reduction is still desirable, if not an economic necessity especially when transmission is performed over the normal telephone network.

Indeed, there are two compelling reasons to compress digital ECG data:

1. to reduce the (magnetic) storage requirements for medical databases and hospital information systems,
2. to reduce the time (and telephone expense) of ECG data transmission.

Although the semantic diagnostic ECG information can in theory be stored in a few bytes, re-analysis and comparison with consecutive ECG recordings is a frequent need, particularly for cardiac patients. Small changes in the morphology of an ECG may be sensitive indicators for the course of a disease. They may be recognizable within ECG serial comparison, but they may be lost if only major diagnostic findings of ECG analysis are documented as textual information.

Various ECG compression algorithms have been developed during the past decades. Compression of ECGs was - except where in specific environment only redundancy reduction was applied - always accompanied by some deterioration of the original record. Since there are no standards for accuracy limits, data formats or compression methods, compressed ECG data could be re-analyzed and compared only within processing systems of the same manufacturer. Neither could data be exchanged between systems of different manufacturers nor was quantitative information available on the deterioration of the data from compression and decompression procedures.

The major goal and achievement obtained under the activities of Workpackage 2 within the SCP-ECG Project of the Preliminary AIM Programme (1989-1990) of the European Community was to define and to agree on accuracy limits and specifications for compression of ECG data, and to define encoding of data in such a way that compressed ECGs can be transmitted and re-analyzed in systems of different manufacturers. The recommendations resulting from this activity form the basis of this Standard.

6.3 ECG compression methodology

The following principles applied to ECG data compression can be identified:

1. redundancy reduction within the digital record (reproducible data compression),
2. bandwidth limitation and reduction of sampling rate,
3. information reduction by irreversible data compression with and without defined accuracy limits.

A review of various algorithms developed during the past 20 years for compression of resting as well as Holter ECGs has been prepared during the SCP-ECG Project. Relevant contributions to ECG data compression can be found in the References listed in ANNEX F.

The major conclusions from this review were:

1. Redundancy reduction is the only method to avoid deterioration of the signal. Redundancy reduction results in compression ratios in the order of magnitude of 2-5.

2. Other compression schemes allow compression between 5 and 12.

3. The error measures for signal reconstruction are mainly given in RMS values. The RMS figures, however, are averages and even at small RMS figures unpredictably high absolute errors in significant signal parts may occur.

4. Therefore validation of compression schemes should always include the analysis of absolute amplitude errors since they may be 10...20 times larger than the RMS figures.

5. Signal transformation (discrete Fourier transformation, Karhunen-Loeve transformation, Walsh transformation) has been applied as well. Compression ratios reported range from 6...12. However, for these methods the reconstruction fidelity is given only in terms of RMS figures. Results reported indicate that transform compression may be used for data reduction of one typical ECG cycle rather than compression of complete ECG records.

6. Measurability of minimum waves and reproducibility of notches/slurs determine the possible compression of ECGs. At present the CSE recommendations require, that minimum waveforms down to 20 μV / 6 ms should be measurable. Clinically significant notches of ~ 4 ms have been reported. However, as a result of recent experiments, the duration requirement for minimum waves has for practical reasons been adjusted to 10 ms. With a sampling rate of 500 samples/s shorter waves can indeed not be reliably measured.

7. Standardization of ECG data compression requires:

    a) harmonization of hardware specifications, amplifier noise, input voltage range, analog to digital converter precision, LSB-value etc.,

    b) definition of reproducibility limits and maximum error tolerances.

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6.4 Main results from the investigations on ECG data compression in the SCP ECG project

6.4.1 Proposed solution for compression

Except for the redundancy reduction, any compression results in reduction of signal resolution. However, from a practical point of view, not every μV resolution and not every bit respectively is significant. More important is that measurements, obtained at a reasonable degree of amplitude and time resolution, match with each other before and after compression.

A compression scheme was therefore developed by investigators of some companies, where a reference beat is processed from the original data and is stored or transmitted in such a way that reprocessing would provide the same measurements as before. This could be achieved:

a) by a compression which makes use of redundancy reduction only and

b) by transmission of pointers (wave recognition points) which allow re-measurement based on exactly the same references.

Besides the reference beat, a residual record is stored and transmitted. The residual record is obtained by subtracting the reference beat from the original ECG record at each cycle location. The residual record is low-pass filtered, truncated and the sampling rate is reduced. From this record first or second amplitude differences are Huffman encoded and stored or transmitted. Reconstitution of the ECG record for visual inspection is possible by adding the reference beat to the residual record at the respective cycle locations. For this method overall compression ratios in the order of twenty could be obtained.

A detailed analysis of this compression scheme in the SCP-ECG Project has revealed, that within the reconstructed record relatively large errors may occur within QRS. These errors result from low-pass filtering. Particularly the QRS sections of the residual record contain high frequency components which are removed by low-pass filtering, truncation and sample rate reduction by the methods proposed and used in some commercial programs.

In the SCP-ECG Project a method was therefore designed which applies basically the same compression scheme, but whereby the QRS-section is protected from low pass filtering and sample rate reduction. In this way all the details of the QRS-T complex are maintained on which the main morphology diagnosis shall be made. In the residual record needed to reconstruct the ECG recording on which the rhythm diagnosis has to be made, only almost invisible changes to the human eye can be seen with the compression scheme developed in SCP-ECG. These changes had no effect on the rhythm diagnosis of the studied cases.

The major advantage of the new compression scheme is that essential details of sensitive QRS data sections are protected and that the overall accuracy could be substantially improved. A detailed description of the methodology is given in ANNEX C, with numerical examples.

6.4.2 Testing methodology for the proposed solutions

To investigate the behaviour of this and various other compression algorithms at first a set (test set 1) of 11 ECGs from the CSE database for assessment of wave recognition accuracy has been used. These ECGs were selected according to rhythm (sinus rhythm, atrial fibrillation, atrial flutter)," normal" beats and extrasystoles, with different QRS-morphology including normals, myocardial infarction, left ventricular hypertrophy and other. These ECGs represent various types of ECG waveforms and contain low and high levels of low frequency (baseline) and high frequency (line frequency, muscle tremor) noise. Essential observations could be made on this data set. To get statistically relevant data a second set (test set 2) of 89 + 19 ECGs from the CSE diagnostic studies has been evaluated. These data were selected according to amplitude distributions, which had to be multiples of 1μV. It also consists of cases with normal and abnormal rhythm, extrasystoles and normal and pathological QRS-morphology.

In some situations it was helpful to use artificial waveforms (e.g. simulating atrial flutter waves) and a number of artificial ECGs with normal P-QRS-T morphology. To avoid unrealistic results because of signal edges etc., care was taken that in all leads first and second derivatives are continuous. The advantage of the synthetic signals is that true amplitudes and intervals are known and that results from compression experiments are not masked by effects from noise removal or noise reproduction.

In ANNEX C a set of test ECGs is presented by which conformance testing and error evaluation of ECG compression algorithms can be done with respect to the requirements described in the present Standard.

6.5 Minimum requirements for ECG data compression

Based upon the results from the investigations in the SCP-ECG Project the following quantization and error limits have been chosen as standard for digital ECG encoding and compression

6.5.1 Categories of compression schemes

Basically three categories of compression of ECG information can be identified:

Category A: Only a set of measurement parameters and diagnostic statements shall be stored or transmitted from an original ECG record.

Category B: A set of measurements, diagnostic statements and a Reference Beat with the residual record from which the original ECG can be reconstituted within error limits is stored/transmitted.

Category C: A set of measurements and diagnostic statements and the only redundancy reduced compressed original ECG is stored /transmitted. Besides, a Reference Beat (as processing result) may be compressed, stored and transmitted as well.

6.5.2 Minimum requirements for ECG data encoding and compression[1)]

6.5.2.1 If reference beat subtraction is used for data compression, all leads of an ECG record shall be recorded simultaneously.

6.5.2.2 Digitization: SR ≥ 500 samples/s; LSB ≤ 5µV

6.5.2.3 Reference Beat: SR ≥ 500 samples/s; LSB ≤ 5µV

6.5.2.4 Residual Record: Truncation Error ≤ ±15µV

6.5.2.5 Residual Record: Sampling Interval ≤ 8ms

6.5.2.6 Reconstruction Error: RMS ≤ 10µV

6.5.2.7 Absolute Error: ≤ 100µV in a single sample outside P-QRS-T

6.5.2.8 Absolute Error within QRS ≤ ±15µV in a single sample

NOTES:

1) It is left open to the manufacturers in which way they do the data compression. However, reference beat type 0 and the residual record shall be provided if reference beat subtraction is applied. The reconstruction RMS error and the absolute errors shall be verifiable on the SCP test set. This is a set of at least 13 ECGs selected from the CSE database. The test data set is described in ANNEX C. Error measures shall be calculated from the beginning of the first subtraction to the end of the last subtraction.

2) For pure redundancy reduction the reconstruction errors (RMS and absolute errors) have to be 0 with reference to a 500 samples/s and 5 µV/LSB record.

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7 Definition of a minimum set of control and query messages for the interchange of ECG data

7.1 Introduction

The messaging part of the SCP-ECG standard describes the type of information that can be requested and transmitted, at the application layer level, between devices, and what the formats of the message headers are. This document defines the structures for data messages and gives the sequences needed for data transfers and queries required by the protocol along with the format of each message type. Also described is the use of advisory messages. The data content is described in Chapter 5, entitled: DEFINITION OF THE DATA CONTENTS AND FORMAT WITHIN A STANDARD ECG COMMUNICATIONS PROTOCOL. Knowledge of the data content for the protocol is necessary to understand the messaging part.

7.2 Message formats

Each message block is 256 bytes long. The first byte of each message block is an ASCII character specifying the message type. The types currently defined (minimum set) are I, R, S, A and D. Default binary data and reserved fields should be filled with zero's. Text character strings should be NULL terminated. The implementer is responsible for insuring that all messages have a length of 256 bytes or less. Data fields containing free-format strings (Section 1, Tag 14, for example) may need to be truncated to comply with this restriction. Messages longer than 256 bytes will be treated as improperly formatted.

All numbered notes in the following message description tables refer to notes in section 7.2.6.

7.2.1 Identification data interchange (Message type = "I").

	Byte number
Message Type = "I" (ASCII,1 byte)	1
Institution Identification Number[1)] (binary)	2-3
Department Identification Number[1)] (binary)	4-5
Device Identification Number (ID)[1)] (binary)	6-7
Device Type[1)] (0=Cart,1=System) (binary)	8
Manufacturer Code[2)] (binary)	9
Model Description[2)] (up to 5 ASCII characters e.g., "0107B","MAC15","4760A"+ NULL)	10-15
SCP-ECG Protocol Revision Number (binary)	16
SCP-ECG Protocol Compatibility Level (binary)	17
Language Support Code[3)] (1-byte bit mapped)	18
Capabilities[4)] (binary)	19
AC Mains Frequency Environment (binary)	20
Reserved	21-128
Acquisition device SCP implementation software identifier. Maximum 24 characters plus NULL terminator from 5.4.5 tag 14.	129 - 153
Manufacturer of acquisition device – registered trade name. Maximum 24 characters plus NULL terminator from 5.4.5 tag 14.	154 - 178
SPARE[12)]	179-256

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7.2.2 Request (Message type = "R")

	Byte number
Generic Request Contents (bytes 1 - 14)	
Message Type = "R" (ASCII, 1 byte)	1
Processing Request[5)] (ASCII,1 byte)	2
Sub-request[6)] (1 binary byte)	3
Request Sequence Number (1 unsigned integer; 1 - 65535)	4-5
Password, 9 ASCII characters. (Optional)[7)]	6-14
(See notes below, and clauses 1.2.2.1 – 1.2.2.3 for definitions)	15-256

Notes on the Request Message:

- For security reasons, any request should be processed only if the ID messages of the 2 communicating systems (cart and host) have been exchanged successfully.
- Unknown or don't care fields shall be set to NULL.
- Each request message shall start with a 14 byte long "Generic Request" field followed by a 242 byte field (bytes 15 – 256) which shall contain patient data as specified in 7.2.2.1 – 7.2.2.3. Each parameter shall be stored in a separate field, each identified by a leading specification byte, referred to as a “tag”, followed by the length (an unsigned integer) referred to as “length”, followed by zero or more parameter bytes, referred to as “value” (see 5.4.3 – 5.4.5).
- A Request Sequence Number counter should be incremented for each “Request” message and may rollover to a value of 1 (one). Reset to 1 (one) with each “ID” message from receiving machine. A value of 0 (zero) is not allowed.
- Request Sequence Numbers are intended to be used to detect redundant and/or missing “Request” messages.

7.2.2.1 ECG List Request (Subrequest type "E" or "L")

	field length in bytes
Generic Request (See 7.2.2)	14
Institution Number (1 binary integer)	2
Department Number (1 binary integer)	2
Patient ID, Tag = 2 (binary)	1
Patient ID Length (binary)	1
Patient ID - Text (text characters)	variable
Patient Last Name, Tag = 0 (binary)	1
Patient Last Name Length (binary)	1
Patient Last Name (text characters)	variable
Patient First Name, Tag = 1 (binary)	1
Patient First Name Length (binary)	1
Patient First Name (text characters)	variable
Patient Sex Tag = 8 (binary)	1
Patient Sex Length = 1 (binary)	1
Patient Sex (byte)	1
Patient Date-of-Birth (DOB), Tag = 5 (binary)	1
Patient DOB Length = 4 (binary)	1
Patient DOB (4 byte binary)[8)]	4
SPARE[12)]	variable

Total 256 Bytes

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7.2.2.2 Patient List Request (Subrequest type "I" or "P")

	field length in bytes
Generic Request (See 7.2.2)	14
Institution Number (binary)	2
Department Number (binary)	2
Patient ID, Tag = 2 (binary)	1
Patient ID Length (binary)	1
Patient ID - Text (text characters)	variable
Patient Last Name, Tag = 0 (binary)	1
Patient Last Name Length (binary)	1
Patient Last Name (text characters)	variable
Patient First Name, Tag = 1 (binary)	1
Patient First Name Length (binary)	1
Patient First Name (text characters)	variable
SPARE[12)]	variable

Total 256 Bytes

7.2.2.3 Test Request (Subrequest type "R" or "S")

	field length in bytes
Generic Request (See 7.2.2)	14
Institution Number (binary)	2
Department Number (binary)	2
Patient ID, Tag = 2 (binary)	1
Patient ID Length (binary)	1
Patient ID (text characters)	variable
Patient Last Name,Tag = 0 (binary)	1
Patient Last Name Length (binary)	1
Patient Last Name (text characters)	variable
Patient First Name, Tag = 1 (binary)	1
Patient First Name Length (binary)	1
Patient First Name (text characters)	variable
Patient Sex, Tag = 8 (binary)	1
Patient Sex Length = 1 (binary)	1
Patient Sex (binary)	1
Patient Date-of-birth (DOB), Tag = 5 (binary)	1
Patient DOB Length = 4 (binary)	1
Patient DOB (4 byte binary)	4
Date of Acquisition, Tag = 25 (binary)	1
Date of Acquisition Length = 4 (binary)	1
Date of Acquisition (4 Byte Binary, format same as DOB)	4
Time of Acquisition, Tag = 26 (binary)	1
Time of Acquisition Length = 3 (binary)	1
Time of Acquisition (3 byte binary)[9)]	3
SPARE[12)]	variable
	Total 256 bytes

The data sent in response to "L" and "P" requests consists of a series of SCP-ECG header sections, consisting of Sections 0 and 1 only, for each report or patient which matches the search criteria.

7.2.2.4 Search Rules for Subrequest Types “L” and “P”

1) When requesting to receive an ECG list (subrequest type "L") or a patient list (subrequest type "P") the following search rules are applied:

   a) Any field may or may not be specified.

   b) If a field is unspecified, it is assumed to be "don't care" and shall not be used as part of the search criteria.

   c) If a field is specified without wildcards (see below), an exact match is required.

   d) The patient ID and name fields may include "wildcards". These are determined as follows:

      ? : matches exactly one character to that location,

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* : matches zero or more characters at that location.

Both * and ? may be literally interpreted by preceeding either with a backslash (\).

e) All searches are case insensitive (shall accept upper or lower case characters)

EXAMPLES:

1) Patient ID = 123, patient last name and first name not specified matches all patient names with patient ID=123

2) Patient last name = "M*CFARL*" matches "MCFARLEY", "MacFarlane", "Macfarlane", "Mcfarlane", etc.

3) Patient ID = "*FAR?" matches "*FAR1", "*FAR2", but not "*FAR99".

2) These search rules apply only to requests for lists, and do not apply to requests for ECGs (subrequest type "R") for which the search criteria shall be exact for the required parameters (institution, department, patient ID, date and time of acquisition).

3) A Tag of type 255 with length 0 is used to mark the end of the Tag data in a “List Request” message.

7.2.3 Status (Message type = "S")

The format of the status Message is as follows:

	byte number
Message Type = "S" (ASCII character)	1
Status Flag [10] (ASCII character)	2
Error-Reason Code [11] (binary)	3
Request Sequence Number (binary): 1 – 65535	4-5
SPARE[12]	6-256

The Request Sequence Number (RSN) in this message is the RSN of the "Request" message to which the Status message responds.

Spurious “STATUS OK” messages received prior to an expected “DONE” message shall be ignored.

7.2.4 Advisory (Message type = "A")

The format of the Advisory Message is as follows:

	byte number
Message Type = "A" (ASCII character)	1
Reserved	2-3
Advisory Message (text character string, NULL terminated)	4-256

Guidelines for the use of Advisory Messages are given in 1.5.

7.2.5 Done (Message type = "D")

A “DONE” message indicates the completion of a command. The format of the Done Message is as follows:

	byte number
Message Type = "D" (ASCII character)	1
Reserved	2-3
SPARE[12]	4-256

Notes on the Done Message:

- A "pending termination"(PT) flag shall be maintained by each device.
- A Master device changes its status to Slave by sending the "D" message and setting its PT flag.

- A Slave device changes its status to Master and sets its PT flag on the reception of a "D" message.
- The reception by a Slave device of a "D" message, without an intervening "R" message and with its PT flag set, shall cause the end of the session and the termination of the link.
- A Slave device without the PT flag set may send a "D" message without changing to a Master device and without modifying the state of the PT flag in either the Master or the Slave device.
- A Master device, on receipt of a "D" message without its PT flag set, shall set its PT flag.
- A Master device with its PT flag set, on receipt of a "D" message, shall terminate the link.

7.2.6 Numbered Notes for clauses 7.2.1 – 7.2.5

1) These fields uniquely identify the requesting device and its location.

2) Manufacturer codes and the ECG recorder's Model Designation are defined in the patient demographic and acquisition data fields of Section 1 (see clauses 5.4.3.1 and 5.4.5).

3) The Language Support Code is as defined in clause 5.4.5, Section 1, tag 14, byte 17.

4) Device capabilities are bit-encoded as follows:

1 (LSB)	Spare
2	Spare
4	Spare
8	Spare
16	Print ECG
32	Interpret ECG
64	Store ECG
128 (MSB)	Acquire ECG

5) Processing request is one ASCII character, defined as follows:

"E" - Request to Send ECG List for Specified Patient

"I" - Request to Send Patient List for Specified Name

"L" - Request to Receive ECG List for Specified Patient

"P" - Request to Receive Patient List for Specified Name

"R" - Request to receive ECGs

"S" - Request to send ECGs

"X" - Escape to Vendor specific request

6) This field is only used for "R" and "X" requests. For these types of request the receiver looks here for the request subcode.

For "R" requests, this field allows multiple tests to be requested without the need for multiple requests, or the need to necessarily know the Date and Time of the test. This field is a bit map. Values are defined as follows.

0 (no bits set)	= No request mask needed: send all ECGs
1 (LSB)	= Requested ECG, shall have Date and Time
2	= Latest ECG
4	= 1st Previous ECG
8	= 2nd Previous ECG
16	= Baseline ECG if present, otherwise oldest ECG

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32 = All Since, shall have Date and Time

For "X" requests, sub-request codes are vendor specific extensions and are not defined here.

7) This field contains an 9 character NULL terminated ASCII password, if required by the receiving system.

8) The Format for Dates (see 5.4.5, Section 1, tag 5 and 25) is as follows:

Bytes 1-2 Binary : Year

Byte 3 Binary : Month (01-12)

Byte 4 Binary : Day of Month (01-31)

9) The Format for Time (see 5.4.5, Section 1, tag 26) is as follows:

Byte 1 Binary : Hours (0-23)

Byte 2 Binary : Minutes (0-59)

Byte 3 Binary : Seconds (0-59)

10) The Status flag is one Character (ASCII) defined as follows:

"G" – OK (go ahead); error code not used. Receiver should resume and send the next message.

"E" – Not OK, Error :

– if ID error, call is terminated immediately.

– if Request or ECG data error, receiver may send another Request or send Done

11) For a Status "E" (Error Status) flag, this field contains a binary code indicating the reason for the error. Codes are as follows:

0 = non specific error

1 = last message type not recognized

2 = last message invalid

3 = invalid location code. The location (i.e.the Institution or Department number) sent is not defined.

4 = invalid password

5 = processing request not recognized: processing device does not understand request

6 = processing request not supported: processing device does not support request

7 = processing request not supported: processing device has insufficient memory.

10 = patient ID invalid

11 = patient name invalid

12 = patient demographic data invalid: Data other than ID or name is not of a valid type or range

13 = patient demographic data inconsistent: The data does not agree with that currently stored for the patient

These codes all pertain to the signal data and the support for it in the receiving device

20 = incorrect sample rate

21 = incorrect lead combination

22 = incorrect lead duration

23 = incorrect data compression

24 = other ECG data error

30 = measurements invalid: One or more of the measurement was invalid

31 = diagnosis invalid

40 = output device not ready

41 = storage device not ready

42 = database error

43 = other system error

44 = insufficient memory error

50 = no ECGs for this location

60 = no data matches request

Codes in the range of 128 -255 are reserved for manufacturer specific error codes.

12) Areas defined as “SPARE” in message data blocks are available for manufacturer-specific implementation.

7.2.7 Minimum Functionality

To be compliant with the specifications of this section, a system consisting of a cart and host must be able to:

1) Exchange "ID" messages

2) Respond to an "RR" request with a subcode of 0 as defined in Note 6 of 7.2.6.

3) Transfer "All" ECGs as defined in Note 5 or 6 of 7.2.6.

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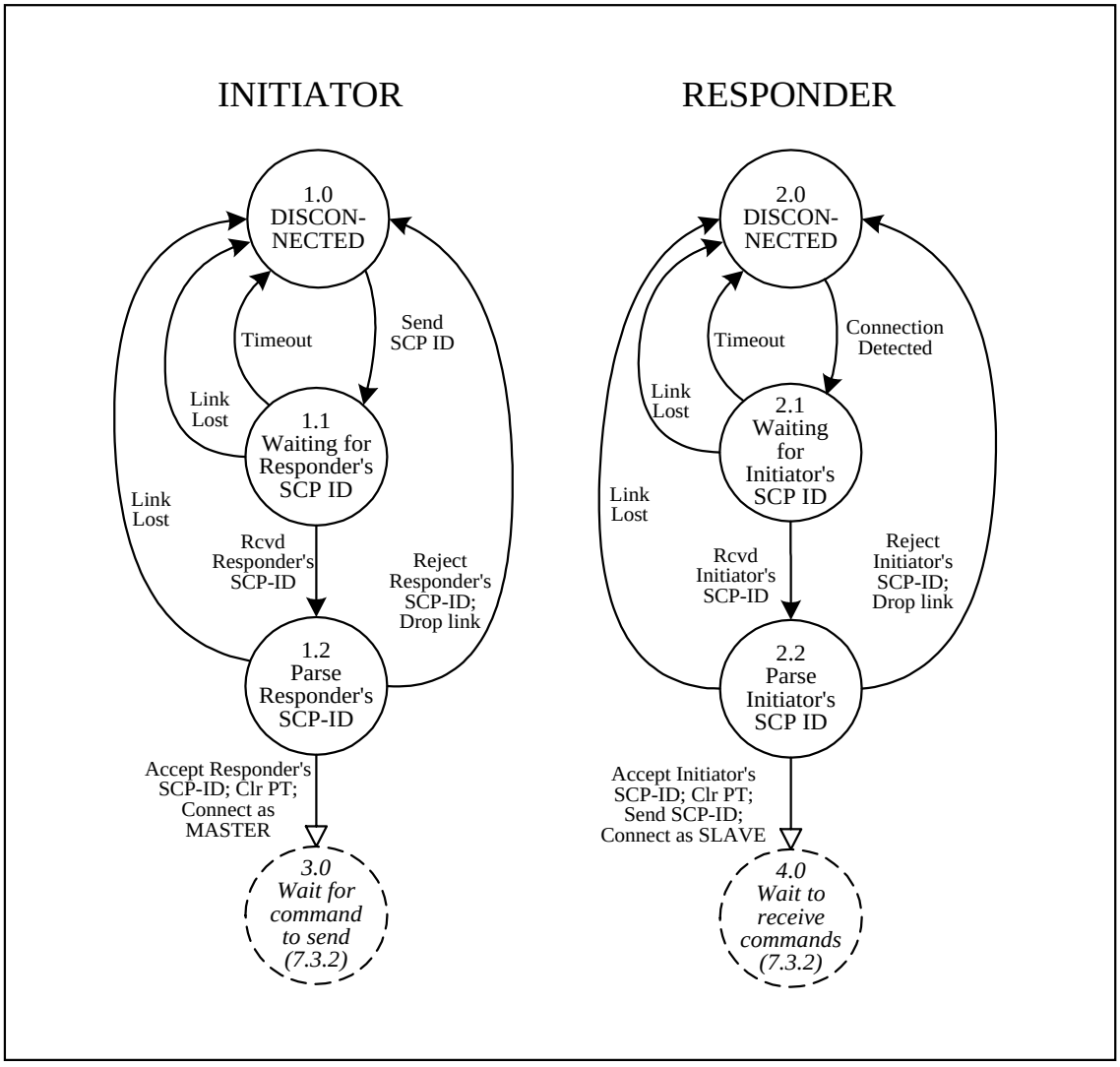
7.3 State diagrams

7.3.1 Establishment of Session State Diagram

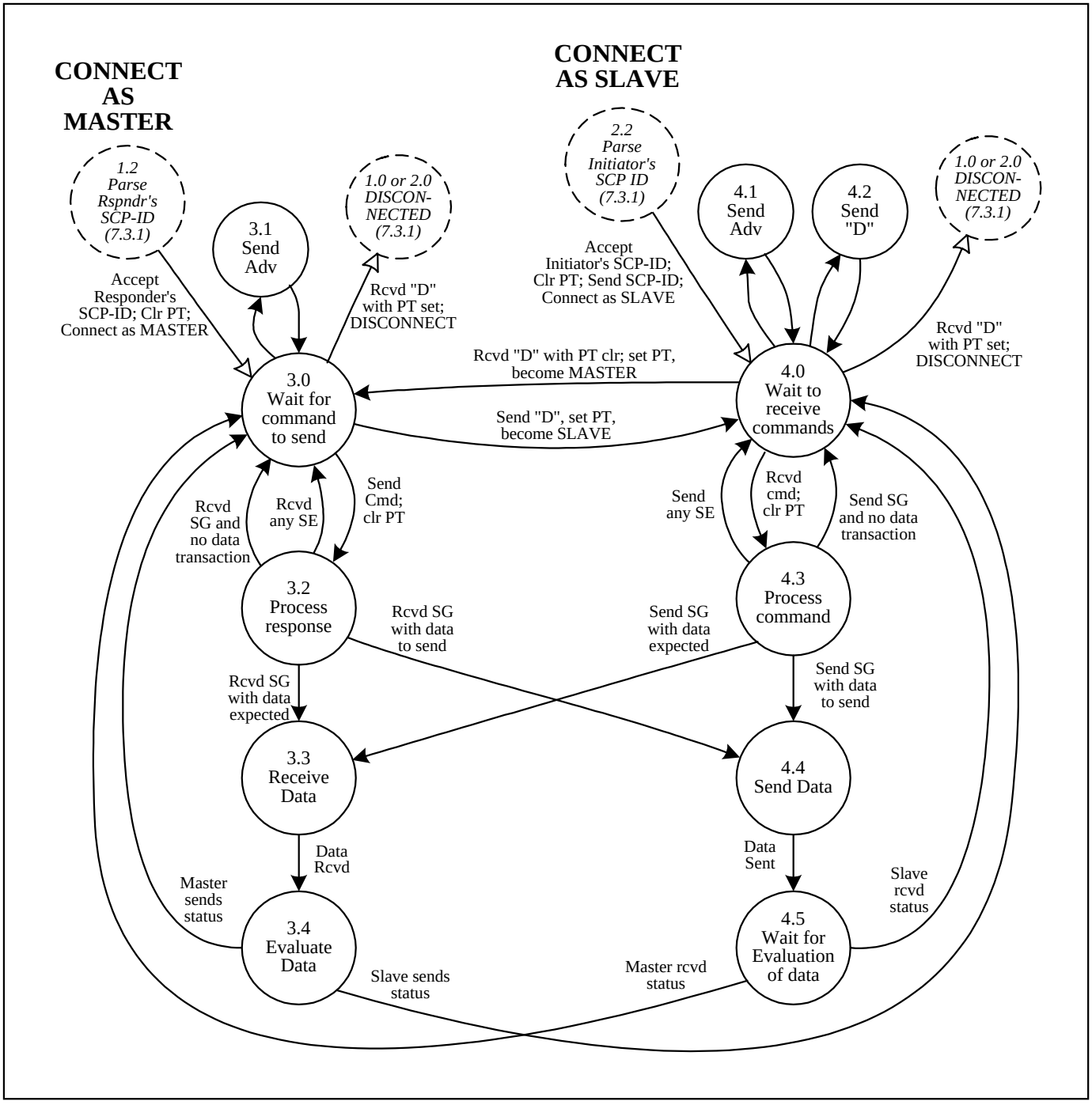
The following diagram describes the process by which ID messages are exchanged by cart and host devices in order to establish an SCP-ECG Query-Messaging session. Note that the session does not enter the "connected" state until ID messages (7.2.1) have been successfully exchanged. Refer to 7.3.2 for a description of operation after the session has been established.



7.3.2 Query Messaging System State Diagram

The following state diagram illustrates the proper operation of the Query Messaging system following the exchange of "ID" messages as described in 7.3.1. A device exists in one of two states while executing the Query Messaging system: *Master* or *Slave*. A Master device is allowed to send commands. A Slave device may only respond to commands.

Manufacturer-specific messages and responses are not required to adhere to this diagram.



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7.4 Message sequence examples

In the following examples, "ECG Data" refer to an SCP-ECG formatted data file, and ID, Request, Status, Done and Advisory refer to SCP-ECG messages defined in 7.2.

7.4.1 ECG Transfer

The normal message sequence for sending an ECG from an initiator to a responder is as follows:

	Initiator	Responder	Comment
a)	ID		Log-on: Exchange of Identification Data
b)		ID	via message type "I".
c)	Request		Initiator requests to send an ECG (message type "R")
d)		Status	Responder replies: ready to receive (message type "S")
e)	ECG Data		Initiator sends data
f)[2]		Status	Responder replies: received data are OK[2)]
g)	Request		Initiator sends another request[1)]
			(go to 'd' above or 1.4.2 – 1.4.4, below)
		or Done	or says "no more data" (message type "D")
h)		Request (or done)	Responder sends its own request (go to 7.4.4, below)
			or terminates the call

7.4.2 Patient List Request

The normal message sequence for requesting a list of patients who match the request mask is as follows:

	Initiator	Responder	Comment
a)	ID		Log-on, exchange of identification data
b)		ID	
c)	Request		Initiator requests a patient list
d)		Status	Responder replies OK
		.	
		.	Responder shall keep line alive until request can be fulfilled
e)		Request	Responder requests to send a patient list
f)	Status		Initiator replies ready to receive
g)		Data	Responder sends ECG data
h)	Status		Initiator replies received data are OK[2)]
i)		Done	Responder says no more data
j)	Request		Initiator sends another request[1)]
			go to 'd' above or 7.4.3 – 7.4.4, below)
		or Done	or says "no more data"
k)		Request (or done)	Responders sends its own request (go to 7.4.4, below)
			or terminates the call

7.4.3 ECG List Request

The message sequence for requesting a list of ECG reports for a known patient from a responder is as follows:

	Initiator	Responder	Comment
a)	ID		Log-on, exchange of idenfication data
b)		ID	
c)	Request		Initiator requests a list of ECGs
d)		Status	Responder replies OK
		.	
		.	Responder shall keep line alive until request can be fulfilled
e)		Request	Responder requests to send the list of ECGs
f)	Status		Initiator replies ready to receive data
g)		Data	Responder sends data
h)[2)]	Status		Initiator replies received data are OK[2)]
i)		Done	Responder says "no more data"
j)	Request or Done		Initiator sends another request (go to 'd' above or to 7.4.2 – 7.4.4)[1)] or says "no more data"
k)		Request or (done)	Responder sends its own request (go to 7.4.4) or terminates call

7.4.4 ECG Report Request

The message sequence for requesting a specific report or reports for a known patient from a responder is as follows:

	Initiator	Responder	Comment
a)	ID		Log-on, exchange of identification data
b)		ID	
c)	Request		Initiator requests to receive an ECG
d)		Status or Request	Responder returns an error status if no ECG to send or a request to send an ECG
e)	Status		Initiator replies ready to receive
f)		ECG Data	Responder sends data
g)	Status		Initiator replies received data are OK[2)]
h)		Request or Done	Responder sends another request (go to ‘e’ above)[1)] or says "no more data"
i)	Request or (done)		Initiator sends its own request (go to 7.4.1 – 7.4.3) or terminates the call

NOTE:

1) Through this mechanism a "batch" of ECGs or a "set of patient lists" can be transmitted, respectively. See also Example 2 in 7.5.

2) If the received data are not OK, the responder shall reply with an error code (see 7.2.3). The initiator shall then request ((g) above) to retransmit the same data, other (new) data or send "done".

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7.5 Use of advisory messages

At any point in the above sequence where a control message (ID, Request, Status or Done) could be sent, one or more Advisory messages may be interjected. An Advisory message has no effect on the processing sequences. It is a means of providing additional information to a human operator.

An Advisory message does not end with a line turn around. When an Advisory message is received instead of another control message, the receiver processes the Advisory (normally by displaying a message to the operator) and continues in the same state, waiting for the originally expected control message before proceeding.

Examples of the use of Advisory messages are as follows:

EXAMPLE 1:

	Initiator	Responder	Comment
a)	ID		Log-on, Exchange identification data
b)		ID	
c)	Request		Initiator requests to send an ECG
d)		Status	Responder replies ready to receive
e)	ECG Data		Initiator sends data
		Advisory	"Default used for patient age"
		Advisory	"Please wait 30 seconds"
f)		Status	Responder replies received data are OK
g)	Done		Initiator says "no more data"
h)		(done)	Responder terminates the call

EXAMPLE 2:

	Initiator	Responder	Comment
a)	ID		Log-on, exchange of identification data
b)		ID	
c)	Request		Initiator requests to receive an ECG
		Advisory	"Sending #1 of 1 ECGs queued"
d)		Request	Responder requests to send an ECG
e)	Status		Initiator replies ready to receive
f)		ECG Data	Responder sends data
g)	Status		Initiator replies received data are OK
h)		Done	Responder says "no more requests"
i)	(done)		Initiator terminates the call

8 Standard low-level ECG-cart to host transport protocol

8.1 Scope

The specification for this low-level transport protocol for communication of ECGs between digital ECG carts and computerized ECG management (storage) systems consists of two functional layers:

- the data link function layer, and the
- physical function layer.

Communication between two ECG management systems, and communication between these systems and other hosts is not within the scope of this specification.

8.2 Datalink and physical functional layers

In the clause on the physical function layer a brief description shall be given of the minimum requirements for local and remote connection and transfer of ECG related data, permitting the use of low cost, high speed asynchronous modems or simple RS-232-C local lines. Its purpose is to ensure that devices utilizing this standard protocol are able to communicate.

The clause on the data link functional layer describes the methods used to ensure that the two devices communicating are synchronized and that the data are not corrupted during the transfer process. The document describes the states necessary to handle the exception conditions.

When communicating data between devices, especially between compressed binary data which are particularly susceptible to corruption by errors during transmission, it is important to employ some device or software by which the integrity of the data and data link is ensured. Such devices or software are available in many formats, e.g. lower-level network protocols, error correcting modems, etc. In this Chapter a Standard Low-Level Protocol is described, which can be used when no other adequate protocol is available or appropriate.

Also included are state transition diagrams to aid in the understanding of this layer, the algorithm for the CRC of each data packet and the format of each of the defined data blocks. Basically the data link layer is an enhanced XMODEM protocol.

8.3 Physical functional layer

8.3.1 General description

In this clause a description shall be given of the physical layer of the standard protocol for the transmission of ECGs. Minimum requirements for both 'Local' and 'Remote' connections are given. Local connections are defined as a point to point direct connection. Remote connections are those that utilize public switched telephone networks or the equivalent.

Individual manufacturers may select to exceed the requirements given here or use other physical layers. The standards described here are not meant to impede future system development or degrade system performance but rather to provide a common interface which provides reasonable performance with minimal cost of implementation while maintaining a common method of ECG transmission between vendors.

8.3.2 Local connections

The local connection consists of an RS-232-C link. The link shall be able to support the following parameter set:

9600 BAUD

8 Data Bits

1 Stop Bit

No Parity

8.3.3 Remote connection

The minimum requirement for a remote connection is a V.22bis modem with the appropriate government approval(s) for the installed country. The V.22bis standard calls for a 2400 baud full duplex asynchronous modem. MNP Level 5 error detection and correction is not a requirement since the Error Handling Layer is designed to be able to handle that function. Other requirements are the same as those for local connections.

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8.4 Data link functional layer

8.4.1 General description

This clause defines the error correcting and line arbitration layer of the standard protocol for the transmission of ECGs. The purpose of this clause is to define a minimal standard to allow carts and systems from different manufacturers to communicate. It is not intended as a definition or suggested method for system to system communications. This protocol level shall be referred to as the data link layer.

The data link layer is a modified (enhanced) version of XMODEM. It is intended to be easy to implement using 'standard' asynchronous communications devices, and yet address the performance requirements for ECG communications.

Specifically these were as follows:

8.4.1.1 Timeouts were reduced from 10 seconds to 2.5 (t1) and 3.5 (t2) seconds, thereby reducing execution time when either machine's performance is less than optimum.

8.4.1.2 A Temporary Text Delay was introduced to allow a machine to keep the link alive when there is no data to send. This supports the situation where a transmitting device is expected to transmit a data block, but the data is not ready due to processing delays. Under normal XMODEM the receiver would timeout several times waiting for data, then abort the link.

8.4.1.3 The ability for a transmitting device to request retransmission of the latest data block acknowledgement message was added, to cover the situation in which the receiver's ACK or NAK was garbled. Under standard XMODEM, the transmitting station simply retransmits its data block, a potentially lengthy process.

8.4.1.4 The block size is larger, 256 bytes.

8.4.1.5 The protocol allows "line turn around" to allow data to be transferred in both directions during a single session.

For the purposes of identifying the participating station in the following description, the two devices shall be referred to as the "transmitter" and the "receiver". The device that is transmitting data or that last transmitted data is the master. These roles can change during a communications session (see also the diagram in 2.4.6.1).

During each state described below, except for TRANSMIT WAKE-UP and RECEIVE WAKE-UP, both stations have the capability of receiving or transmitting an EOT termination code. EOT capability at any time is necessary to handle abnormal terminations. The same mechanism may be used for normal termination because there is no difference between the two methods at the level of the data link layer.

8.4.2 Transmit machine

For graphical representation of the Transmit Machine, see the diagrams in 2.4.6.2.

8.4.2.1 The transmit machine consists of three states: TRANSMIT WAKE-UP, NO DATA WAIT, and WAIT FOR ACKNOWLEDGE.

8.4.2.2 TRANSMIT WAKE-UP: This is the entry state for the calling device. The answering device is expected to send an ASCII 'ENQ'. Upon receipt of an ENQ, if data is ready to be sent, the caller sends the data and switches to the WAIT FOR ACK state. If there is no data ready when the ENQ is received, then NO DATA WAIT becomes the current state. If no ENQ is received within one minute the process aborts.

8.4.2.3 NO DATA WAIT: In this state the transmitter is waiting for data to send. When this occurs, the transmit station is expected to send a data block but the data block has not yet been prepared by the higher level application. This state has only a 2.5 second time-out.

If the 2.5 second timer goes off, the transmit machine checks for data. If it exists, the data is sent, and the current state becomes the WAIT FOR ACK state. If no data is present, a Temporary Text Delay is sent to prevent the receiving station from timing out, and control remains in the NO DATA WAIT state. If data becomes available before the 2.5 seconds have elapsed, it may be sent as described above.

8.4.2.4 WAIT FOR ACK: In this state the transmitting device waits for a response from the receiver to the last data block sent. Proper responses are ACK or NAK.

8.4.2.4.1 If an ACK is received and the transmitter is instructed by the application layer to turn the line around, it transmits an ENQ and control is transferred to the Receive state, WAIT FOR TURNAROUND.

8.4.2.4.2 If an ACK is received and the transmitter is not expecting turnaround, it checks for the presence of data to send. If data is present it is sent and the transmit machine remains in the WAIT FOR ACK state. If no data is available, the current state becomes the NO DATA WAIT state.

8.4.2.4.3 If a NAK is received the last data block is retransmitted. The state remains WAIT FOR ACK. If ten consecutive NAKs have been received, an EOT with error code **006** shall be sent, and the link aborted.

8.4.3.4.4 If 2.5 seconds passes without a response, the last packet is retransmitted. After 10 transmissions of the same packet have been sent with no response, an EOT is sent with error code **001** and the link shall be aborted.

8.4.3 Receive machine

For graphical representation of the Receive Machine see the diagrams in 2.4.6.3.

8.4.3.1 The receive machine has four states: RECEIVE WAKE-UP, WAIT FOR TURNAROUND, WAIT ON DATA, and BAD DATA.

8.4.3.2 RECEIVE WAKE-UP: This is the entry state for the receive machine. Upon wake-up, the device transmits an ENQ and enters the WAIT FOR TURNAROUND state.

8.4.3.3 WAIT FOR TURNAROUND: In this state the receiver waits for the transmission of the first data block from the transmitting device. Two inputs are valid: a data block or a TTD.

8.4.3.3.1 If data is received, it is checked for accuracy based on its block number and its CRC. If the data is good an ACK is sent and the current state becomes WAIT ON DATA. If the data is bad a NAK is sent and the receive machine enters the BAD DATA state.

8.4.3.3.2 If a TTD is received no action is taken (other than resetting the time-out clock).

8.4.3.3.3 If no data is received within 3.5 seconds, the ENQ is retransmitted. If after 10 ENQs have been sent with no response the link is aborted and EOT is sent with an error code **002**.

8.4.3.4 WAIT ON DATA: This is the normal receive state. The receiver waits here while receiving data blocks from the transmitting device. Four inputs are valid: data, TTD, SYN and ENQ. Non-valid inputs are discarded.

8.4.3.4.1 If data is received it is checked for accuracy based on block number and CRC. If the block is good an ACK is sent and the machine remains in the WAIT ON DATA state. If the data is bad a NAK is sent and the current state becomes BAD DATA.

8.4.3.4.2 If the new packet just received is the same as the previous packet, send an ACK and discard the packet. After receiving ten consecutive copies of the same packet, an EOT is sent with an error code of **005** and the link is aborted.

8.4.3.4.3 If a TTD is received no action is taken (other than resetting the time-out clock).

8.4.3.4.4 If a SYN is received an ACK is retransmitted and the WAIT ON DATA state remains valid.

8.4.3.4.5 If an ENQ is received, the receiver is about to become a transmitter. The presence of data to send is checked. If no data is present, the receive machine becomes a Transmit machine, in the NO DATA WAIT state. If data is present, it is sent and control passes to the Transmit state, WAIT FOR ACK state.

8.4.3.4.6 If no data is received within 3.5 seconds, a NAK is transmitted. This ensures that the transmitting station resends the last data block if it was lost. A NAK is sent rather than an ACK because resending an ACK may result in a loss of data, if the transmitting station sent a data block which the receiver failed to get. The machine enters the BAD DATA state.

8.4.3.5 BAD DATA: After the receiver sends a NAK it waits in the BAD DATA state. Valid inputs are data, SYN, and ENQ.

8.4.3.5.1 If good data is received an ACK is sent and the machine enters the WAIT ON DATA state. If the data is bad a NAK is sent. After ten NAKs have been sent and another bad data block is received, an EOT is sent with an error code **003** and the link is aborted.

8.4.3.5.2 If a SYN is received the last NAK is retransmitted. The state remains BAD DATA.

8.4.3.5.3 If no data is received within 3.5 seconds a NAK is transmitted. If ten NAKs have been sent due to lack of input as opposed to bad data and another 3.5 seconds pass without input the link is aborted and an EOT is sent with error code **004**.

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8.4.3.5.4 If an ENQ is received, the receiver is about to become a transmitter. The presence of data to send is checked. If no data is present, the receive machine becomes a Transmit machine, in the NO DATA WAIT state. If data is present, it is sent and control passes to the Transmit state, WAIT FOR ACK state.

8.4.4 Format of the data blocks

8.4.4.1 The control codes should be sent as follows:

ENQ:	ENQ DC2
ACK:	ACK DC2
NAK:	NAK DC2
SYN:	SYN DC2
TTD:	CAN DC2
EOT:	EOT $FF CHAR CHAR CHAR DC2

(Where the three characters (CHAR's) are ASCII digits representing the termination code, i.e. the error codes **001** to **006** mentioned in 2.4.2 and 2.4.3. For normal termination, an error code of **000** shall be sent.)

8.4.4.2 The format of the data blocks are as follows:

a) Message: SOH
- Block # (1-255, incremental, recirculating)[1)]
- 255 - Block# (1's complement of Block #)
- data (256 bytes of data)
- CRCHI
- CRCLO

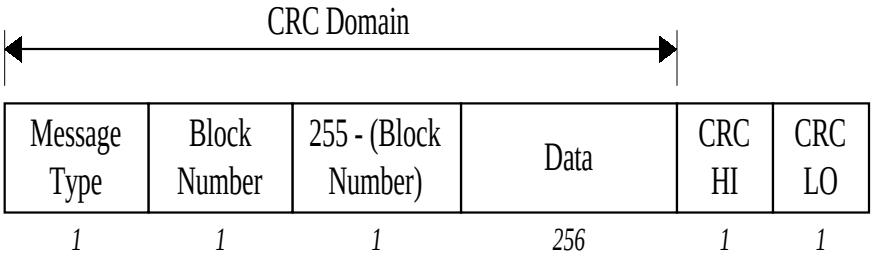
b) Data: STX
- Block # (1-255, incremental, recirculating)[1)]
- 255 - Block# (1's complement of Block #)
- data (256 bytes of data)
- CRCHI
- CRCLO

NOTE:

1) The same block counter is used for message and data blocks, and should be incremented for each occurrence of either type of block.

8.4.5 CRC error detection algorithm

The CRC is based on CRC-CCITT ($X^{16} + X^{12} + X^5 + 1$). The CRC is a 16-bit quantity and should be preset to all 1's (FFFF hex) at the start of the calculation for each block of data. The CRC is calculated over the entire data block up to the CRC itself:



Note: all operations are on bytes.

NOTES:

A = new byte

B = temp byte

CRCHI = High byte (most significant) of the 16-bit CRC

CRCLO = Low byte (least significant) of the 16-bit CRC

START:

FOR A = FIRST_BYTE TO LAST_BYTE IN BLOCK DO:

A = A XOR CRCHI	
CRCHI = A	
SHIFT A RIGHT FOUR TIMES	(ZERO FILL)
A = A XOR CRCHI	{ I J K L M N O P }
CRCHI = CRCLO	{ swap CRCHI, CRCLO }
CRCLO = A	
ROTATE A LEFT 4 TIMES	{ M N O P I J K L }
B = A	{ temp save }
ROTATE A LEFT ONCE	{ N O P I J K L M }
A = A AND $1F	{ 0 0 0 I J K L M }
CRCHI = A XOR CRCHI	
A = B AND $F0	{ M N O P 0 0 0 0 }
CRCHI = A XOR CRCHI	{ CRCHI complete }
ROTATE B LEFT ONCE	{ N O P 0 0 0 0 M }
B = B AND $ E0	{ N O P 0 0 0 0 0 }
CRCLO = B XOR CRCLO	(CRCLO complete }

DOEND;

FINISH.

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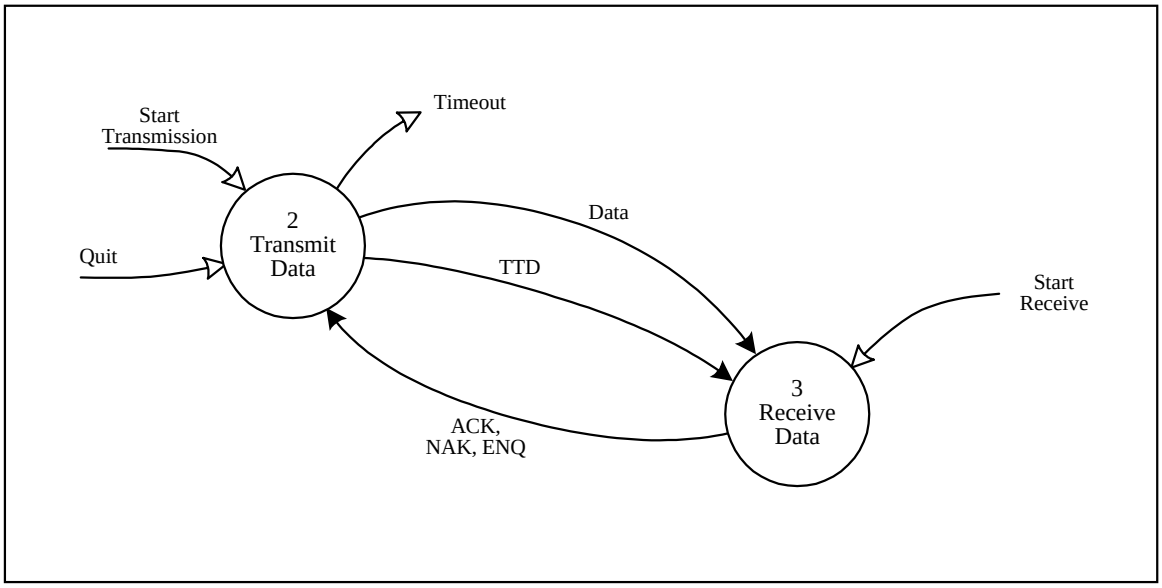
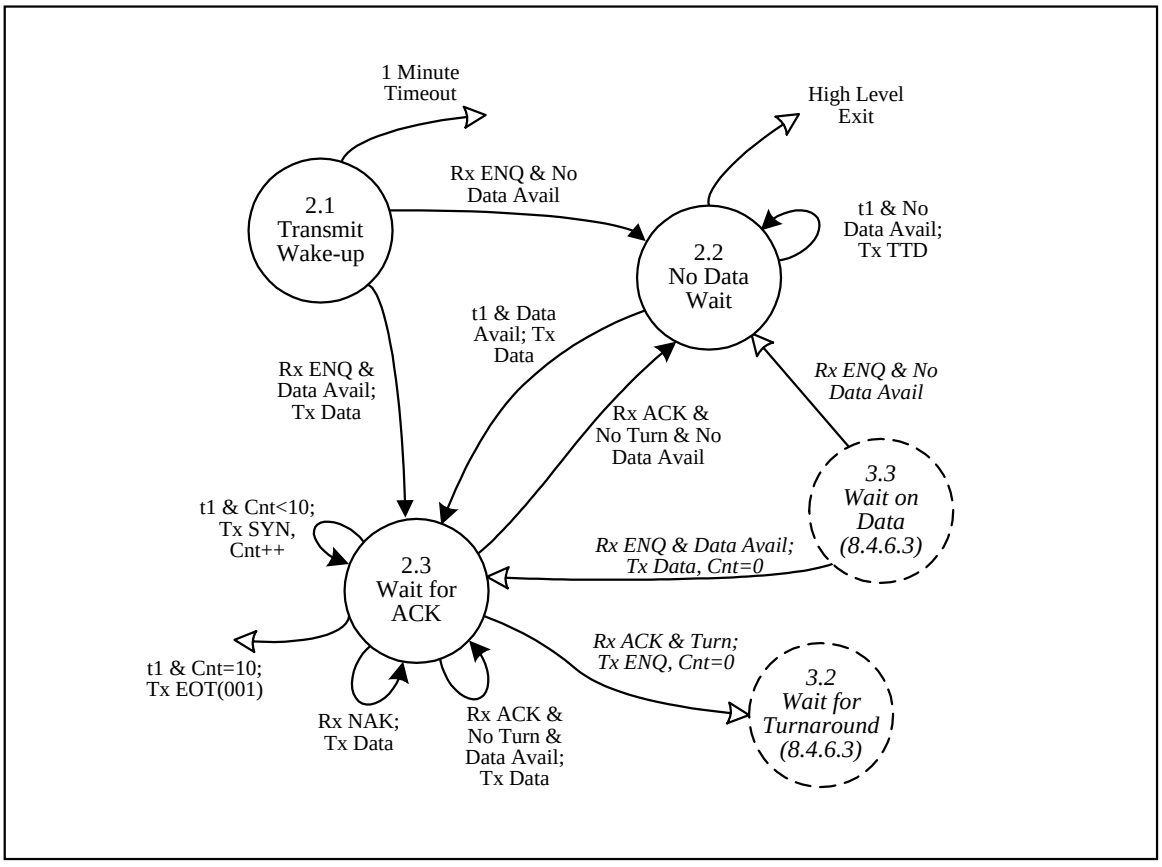
Final check on the CRC is accomplished by adding or concatenating CRCHI and CRCLO at the end of the data stream. Calculating the CRC of the resulting data stream shall result in a zero CRC if the data was correctly received.

8.4.6 State Transition Diagrams (STD)

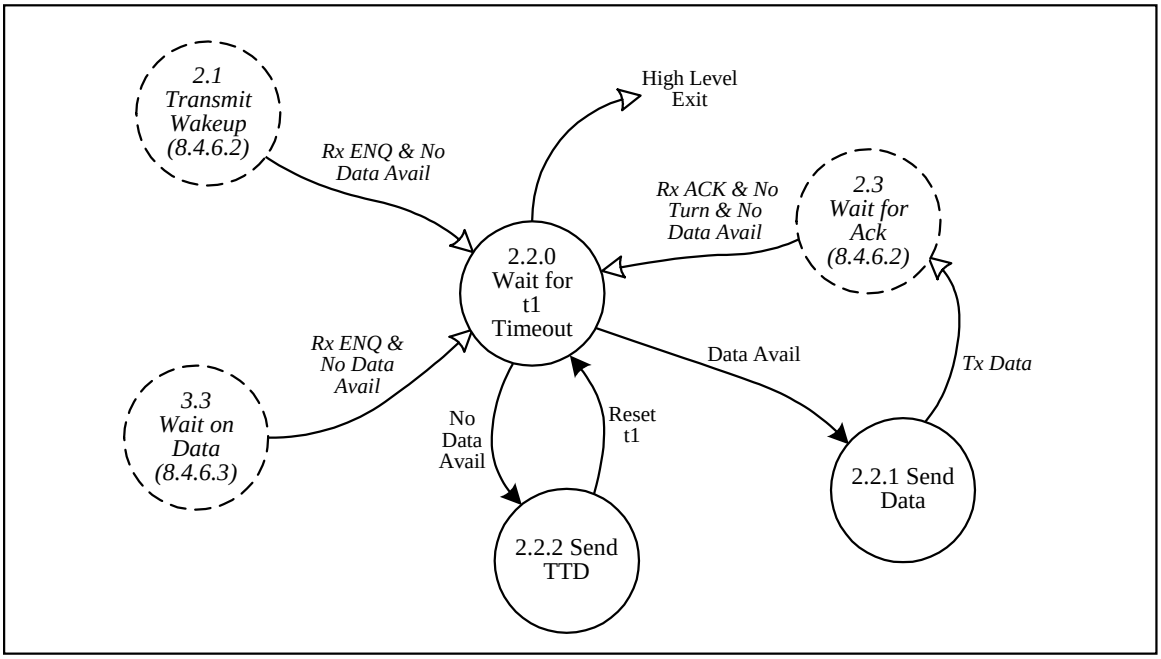
8.4.6.1 Data Flow Diagram (not a STD)



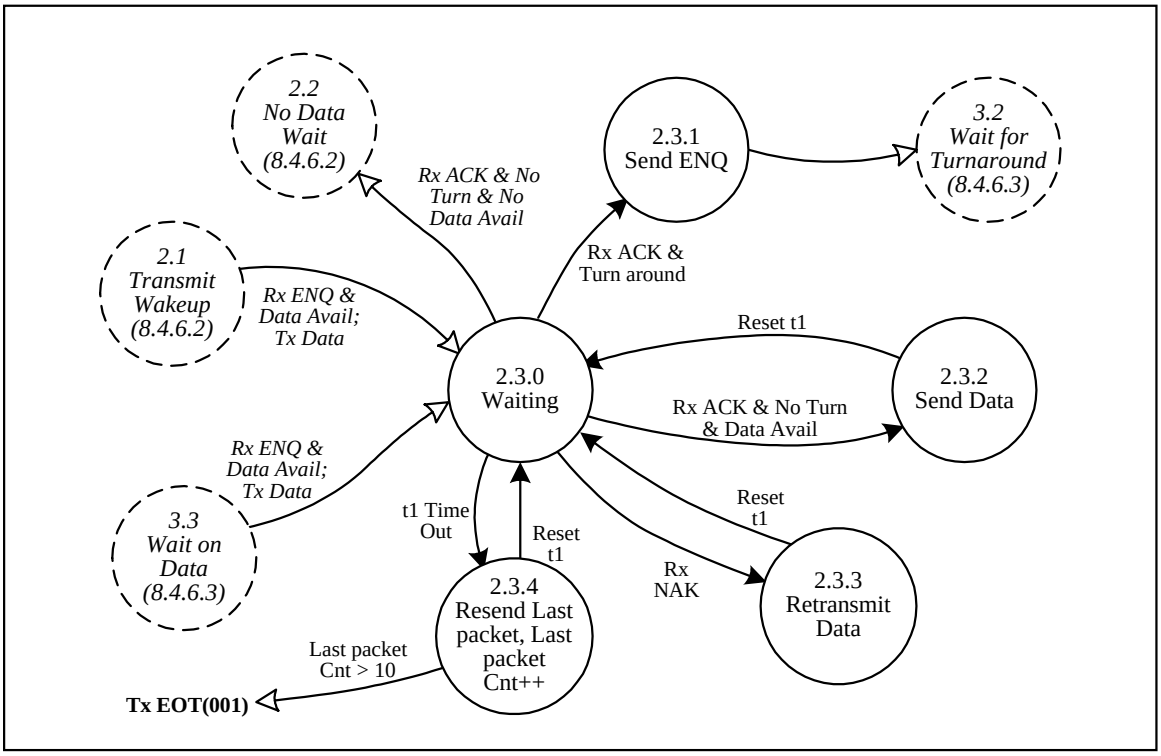
8.4.6.2 Transmit Machine STD



8.4.6.2.1 No Data Wait STD



8.4.6.2.2 Wait for ACK STD



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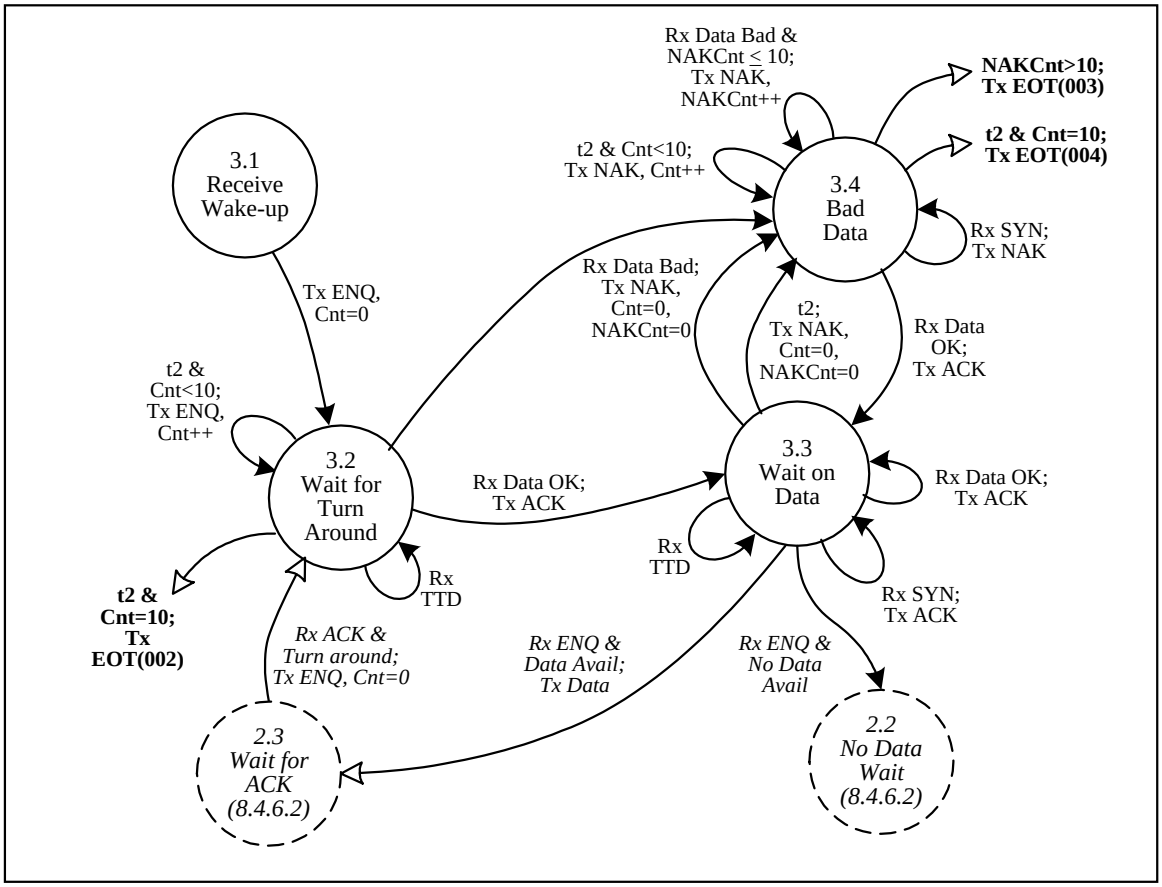
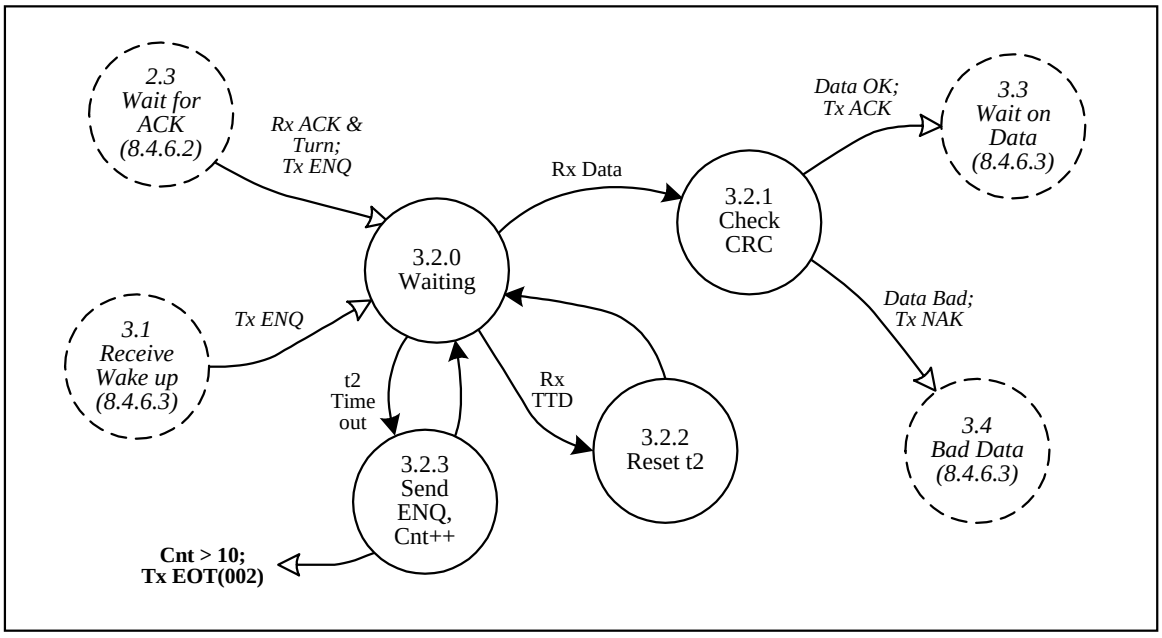
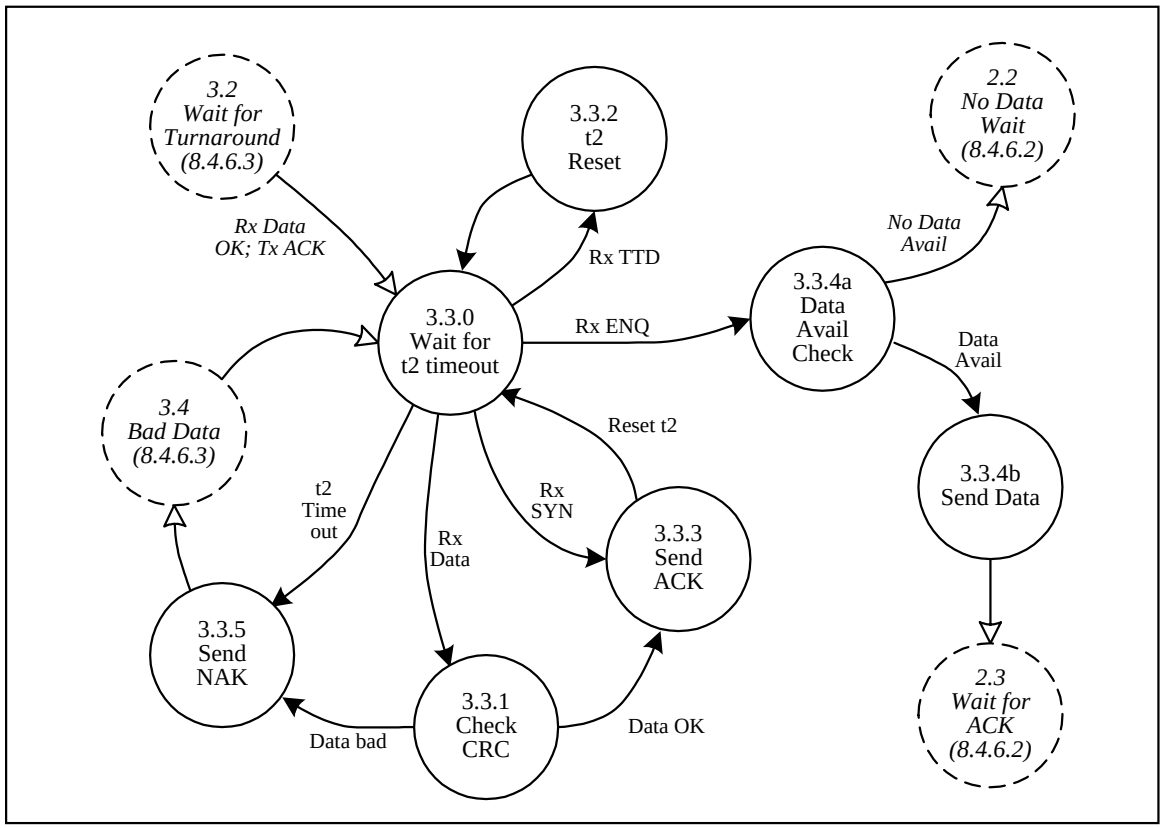
8.4.6.3 Receive Machine STD



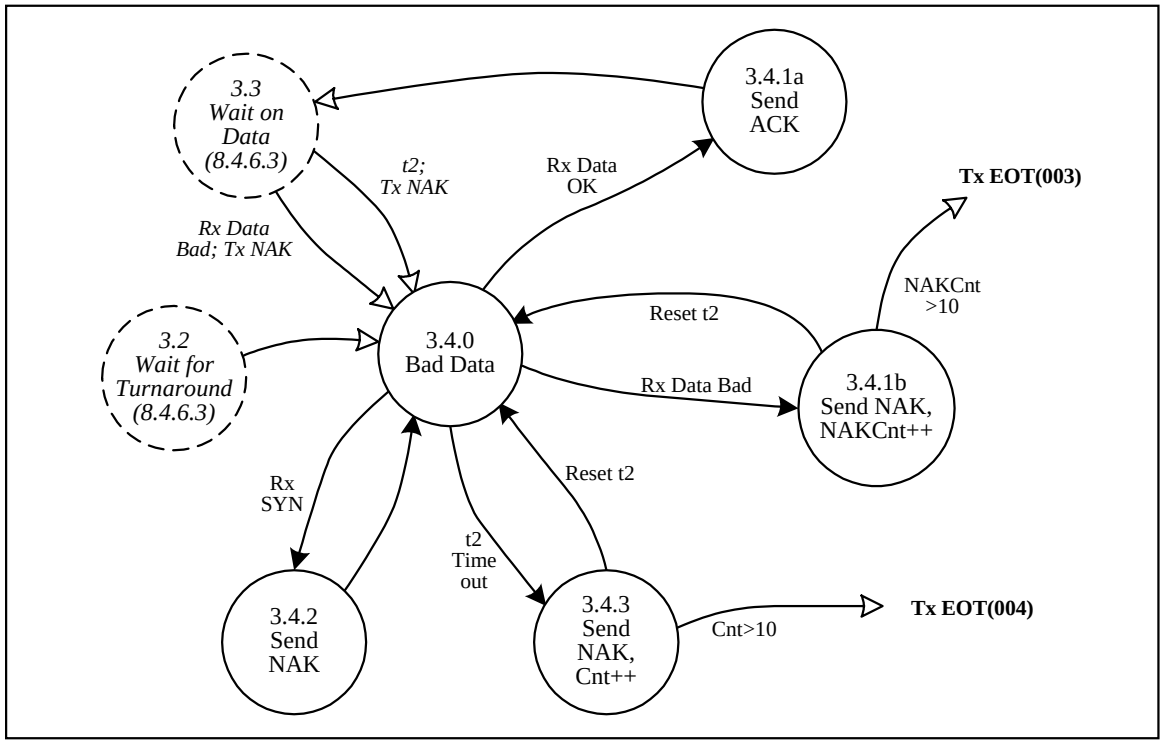
8.4.6.3.1 Wait for Turnaround STD



8.4.6.3.2 Wait on Data STD



8.4.6.3.3 Bad Data STD



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8.4.7 Communication scenario

Scenario of an electrocardiograph sending an ECG to a central ECG management system.

	Cart (initiator)	System (responder)	Comment
a)		ENQ	Ready to receive
b)	SOH		ID (Log on)
c)		ACK	Acknowledge
d)	ENQ		Turn line around
e)		SOH	ID (Complete log on)
f)	ACK		Acknowledge
g)		ENQ	Turn line around
h)	SOH		Cart requests to send ECG
i)		ACK	Acknowledge
j)	ENQ		Turn line around
k)		SOH	Status (System received OK)
l)	ACK		Acknowledge
m)		ENQ	Turn line around
n)	STX		Transmit ECG
o)		ACK	Acknowledge
p)	STX		ECG Data
.			
q)……the ECG record is transmitted			
.			
r)		ACK	Acknowledge
s)	ENQ		Turn line around (Done with ECG)
t)		SOH	Status (System received OK)
u)	ACK		Acknowledge
v)		ENQ	Turn line around
w)	SOH		Done (no more data)
x)		ACK	Acknowledge
y)	ENQ		Turn line around
z)		SOH or EOT	Request (System can send its own request) or terminate call (see 8.4.1.5).

ANNEX A
(Normative)

Encoding of alphanumeric electrocardiographic data in a multi-lingual environment

A.0 Introduction

The encoding method to be used for text fields in SCP-ECG is explained in this Annex. The method is taken from the ISO standards which describe the use of multiple character sets. For a better understanding of the present Annex, the reader should consult the structure and extension rules of the ISO 8-bit code, documented in ISO Standards 4873 and 2022.

Multiple character sets are required, not only in the case of the Japanese but also in European languages which use non-ASCII characters (e.g., " ä " in German, " ç " in French, " å " in Danish etc.). Thus, use of extended character sets shall ensure that the SCP-ECG protocol can be accepted internationally.

A text string which includes unknown character sets may cause serious problems with patient identification in some machines. Therefore, a method for handling unsupported character sets shall also be described in this Annex.

A.1 Scope

A.1.1 Text encoding should be applied to the fields of the SCP-ECG protocol listed below.

Section	Contents	Tag
8+11	Free text diagnostic report information	-
9	Manufacturer specific diagnostic report information	-
1	Last Name	0
1	First Name	1
1	Patient Identification Number	2
1	Second Last Name	3
1	Drugs	10
1	Diagnosis or Referral Indication	13
1	Acquiring Device ID Number	14
1	Analyzing Device ID Number	15
1	Acquiring Institution Description	16
1	Analyzing Institution Description	17
1	Acquiring Department Description	18
1	Analyzing Department Description	19
1	Referring Physician	20
1	Overreading Physician	21
1	Technician Description	22
1	Room Description	23
1	Free Text Field	30
1	ECG Sequence Number	31
1	History Diagnostic Codes	32
1	Electrode Configuration Code	33
1	DateTime Zone	34
1	Free Text Medical History	35

A.1.2 This encoding is intended as an interchange format, not as an internal representation. It is expected (but not required) that each ECG computer system shall convert this format to some internal representation for processing and rendering, and convert from that internal representation to this format for data communication.

A.2 References and definitions

A.2.1 References

ISO 2022 Information processing - ISO 7-bit and 8-bit coded character sets - Code extension techniques.

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ISO 2375 Data processing - Procedure for registration of escape sequences.

ISO 646 Information processing - ISO 7-bit code for information interchange

ISO 4873 Information processing - ISO 8-bit code for information interchange – Structure and rules for implementation.

ISO 6429 Information processing - ISO 7-bit and 8-bit coded character sets – Additional control functions for character-imaging devices.

ISO-8859-1 Latin-1 defined in the ISO-8859-1 complement to the ISO 2022 Standard shall be used as the default character set in the Standard defined in the current Document.

JIS X 0202 Code Extension Techniques for Use with the Code for Information Interchange; Japanese Industrial Standard (JIS).

Robert W. Scheifler, "Compound Text Encoding version 1.1", MIT X Consortium Standard.

A.2.2 Definitions

For the purpose of this Annex, the following definitions were taken over from ISO 4873 and JIS X 0202, until March 1, 1987 labeled JIS C 6228.

coded character set; code A set of unambiguous rules that establishes a character set and the one-to-one relationship between each character of the set and its coded representation by one or more bit combinations.

control character A control function, the coded representation of which consists of a single bit combination.

graphic character A character, other than a control function, that has a visual representation normally handwritten, printed or displayed, and that has a coded representation consisting of one or more bit combinations.

control function An action that affects the recording, processing, transmission or interpretation of data, and that has a coded representation consisting of one or more bit combinations.

format effector A control character which controls the layout and positioning of information on character-imaging devices such as printing and display devices.

to designate To identify a set of characters that are to be represented, in some cases immediately and in others on the occurrence of a further control function, in a prescribed manner.

to invoke To cause a designated set of characters to be represented by the prescribed bit combinations whenever those bit combinations occur, until an appropriate extension function occurs.

to represent a) To use a prescribed bit combination with the meaning of a character in a set of characters that has been designated and invoked; or

b) To use an escape sequence with the meaning of an additional control function.

A.3 Values

A.3.1 Byte values are represented in this Annex as two decimal numbers in the form column/row as defined in the ISO Standards. This means that the value can be calculated as (col*16) + row, e.g. 01/11 corresponds to the value 27 (1B hex).

A.3.2 The byte encoding space is divided into four ranges:

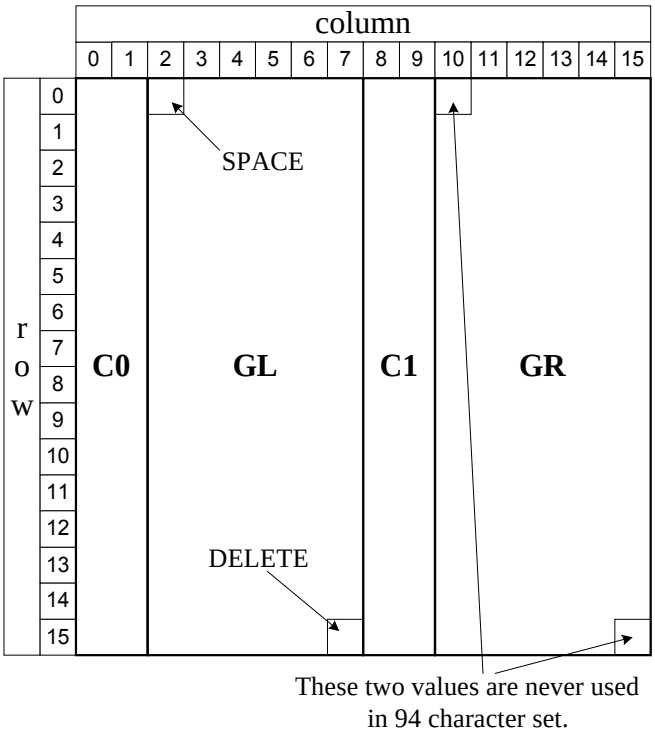
C0 bytes from 00/00 to 01/15

GL bytes from 02/00 to 07/15

C1 bytes from 08/00 to 09/15

GR bytes from 10/00 to 15/15

C0 and C1 are "control character" sets, while GL and GR are "graphic character"sets. For GL, byte 02/00 is always defined as SPACE, and byte 07/15 (normally DELETE) is never used.



The 16-by-16 array of columns numbered 00 to 15, and rows numbered 0 to 15 contains 256 code positions. Columns 00 to 07 of this array contain 128 character positions which are in one-to-one correspondence with the characters of the 7-bit set. Their coded representation is the same as in the 7-bit environment with the addition of an eight bit that is ZERO. Columns 08 to 15 contain 128 more positions. The eighth bit of their coded representation is ONE. Columns 08 and 09 are used to indicate control characters, and columns 10 to 15 graphic characters, with the exception of positions 10/0 and 15/15.

A.3.3 The 8-bit code table can be extended through various code extension facilities, one of which is by means of an appropriate escape sequence, as summarized in A.5.2.

A.4 Control characters

The definition of each control character comes from ISO 646-1983 and ISO 4873-1986.

As shown in the table below, only a subset of the control characters of C0 shall be used for the encoding of free text in SCP-ECG. No values of the control set C1 shall be used.

The interchange of text string data (such as Section 8, 10 and 11) may require some formatting information. To this end format effectors (as listed in the Table) should be used, but their usage should be kept to a minimum since some machines may handle them inappropriately.

Category	Acronym	Name	Coded
Format effector	BS	BACKSPACE	00/08
Format effector	HT	HORIZONTAL TAB	00/09
Format effector	LF	LINE FEED	00/10
Format effector	VT	VERTICAL TAB	00/11
Format effector	FF	FORM FEED	00/12
Format effector	CR	CARRIAGE RETURN	00/13
Code extension	ESC	ESCAPE	01/11

1) BS

Backspace may be used for making composed characters by overstriking (ISO 646 allows this kind of representation). However, some machines have no overstriking facility, so it is better to use adequate character sets (e.g. ISO 8859-x) to represent compound characters.

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2) HT,VT

Specification of tabulation width settings is not part of this proposal.

3) CR

CARRIAGE RETURN may also be used for composite characters. The same can be said for BACKSPACE.

4) LF

Some machines (such as UNIX based machines) may interpret LINEFEED (00/10) as a NEWLINE. This can be thought of as using the (deprecated) NEW LINE mode, described in E.1.3 in ISO 6429.

In this proposal, NEWLINE is represented as CR+LF. So under such an environment, it is expected that this format is converted to an internal representation (i.e. convert CR+LF to LF).

NULL is used for a string terminator in the SCP-ECG protocol. But it is not a part of the text string. This is consistent with ISO 646 and 4873.

A.5 Character set encoding

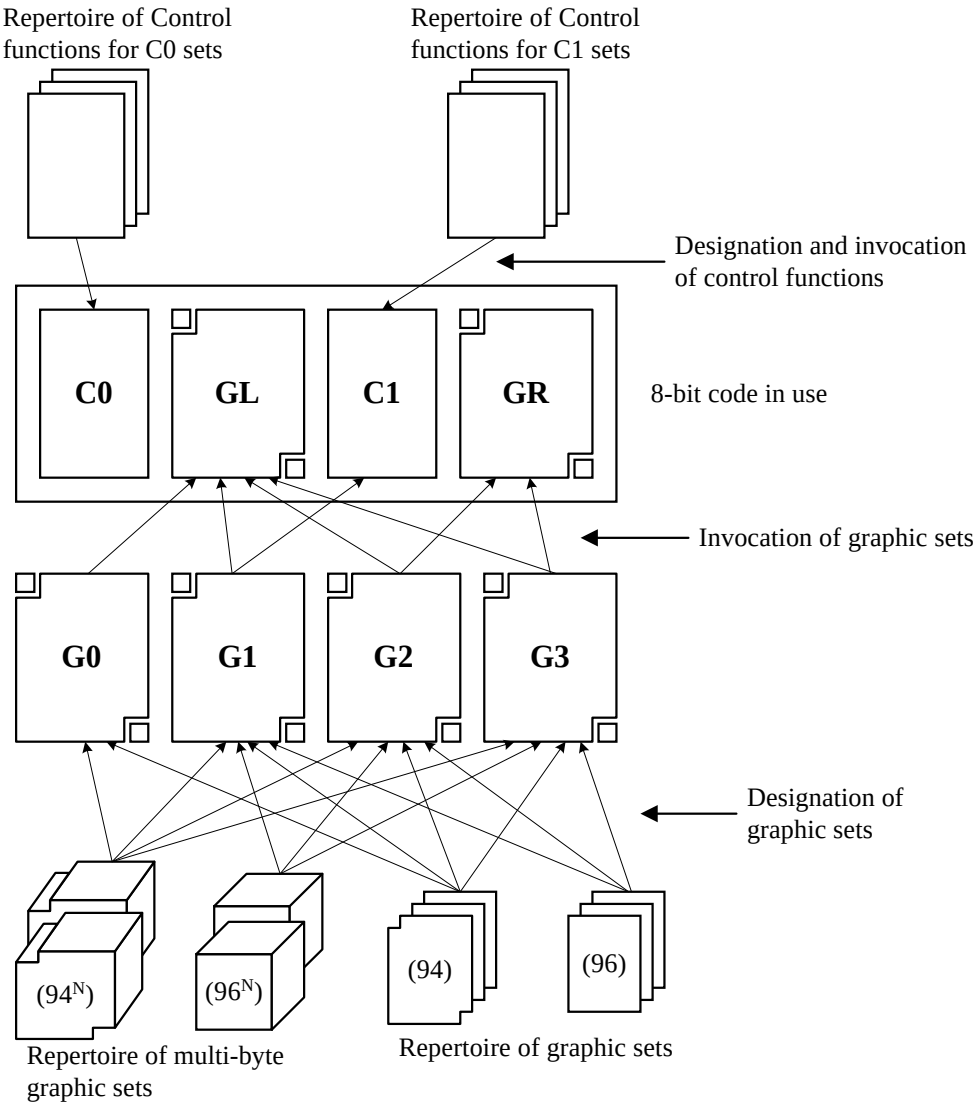
A.5.1 General principle of multi-lingual text encoding

In order to realize a multi-lingual environment, a switching facility for different character sets in a text string is required. Some graphic characters have different visual representation with the same code, e.g. both lower case "a" with a tilde in ISO 8859-1 and lower case "a" with a brave in ISO 8859-2 have the same code i.e. 14/03. In addition, there are some multi-byte character sets such as Japanese Kanji and Chinese Hanzi which have thousands of characters, in which case single byte encoding is impossible.

The ISO 2022 standard defines the code extension techniques (see diagram below) making it possible to use multiple graphic character sets in a text string thereby achieving a multi-lingual environment. In the ISO 2022 standard, the code extension is realized by mapping the desired graphic character set into the coding space by using the following two steps:

1. The desired graphic character set is designated to one of G0, G1, G2 or G3. This is done by using escape sequences.

2. The designated set (G0, G1, G2 or G3) is invoked to the area in the coding space 02/00 to 07/15 or 10/00 to 15/15. This is done by using shift functions.



A.5.2 Default and initial setting

We shall use only an 8-bit environment, and shall always use G0 for GL and G1 for GR (see figure below). This is done by the announcement of the necessary extension facilities, as described in Chapter 9 of ISO 2022. Under this condition, designation also invokes, so it is not necessary to explicitly invoke.

A 96-character set can only be designated/invoked to GR. This is because 02/00 is SPACE and 07/15 is DELETE so that GL can contain only 94 characters in 02/01 to 07/14. GR can contain 96 characters in 00/00 to 15/15. Hence GR can be invoked by different 94-character sets as well as 96-character sets.

In a 94-character set no characters shall be allocated to the positions 02/00, 07/15, 10/00 and 15/15, while in a 96-character set these positions can contain characters. The three dimensional block in the figure below represents a multi-byte character set. A 94-n character set uses n (n >1) bytes for each character as shown in the Figure of A.5.2.3.

A.5.2.3 The default GL set corresponds to the left half of ISO 8859-1 (Latin 1). This is the same as ASCII (ANSI X3.4-1968).

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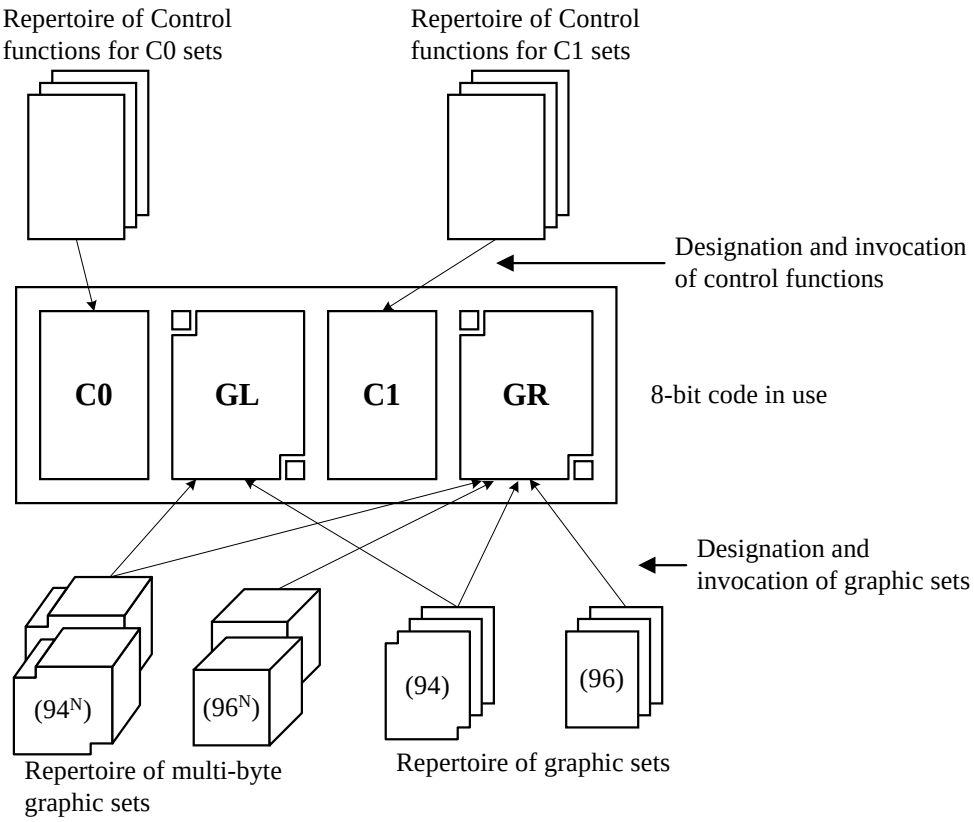
A.5.2.3 The default GR set corresponds to the right half of ISO 8859-1 (Latin 1).

These specifications determine the default character set which can be used without an escape sequence as specified in

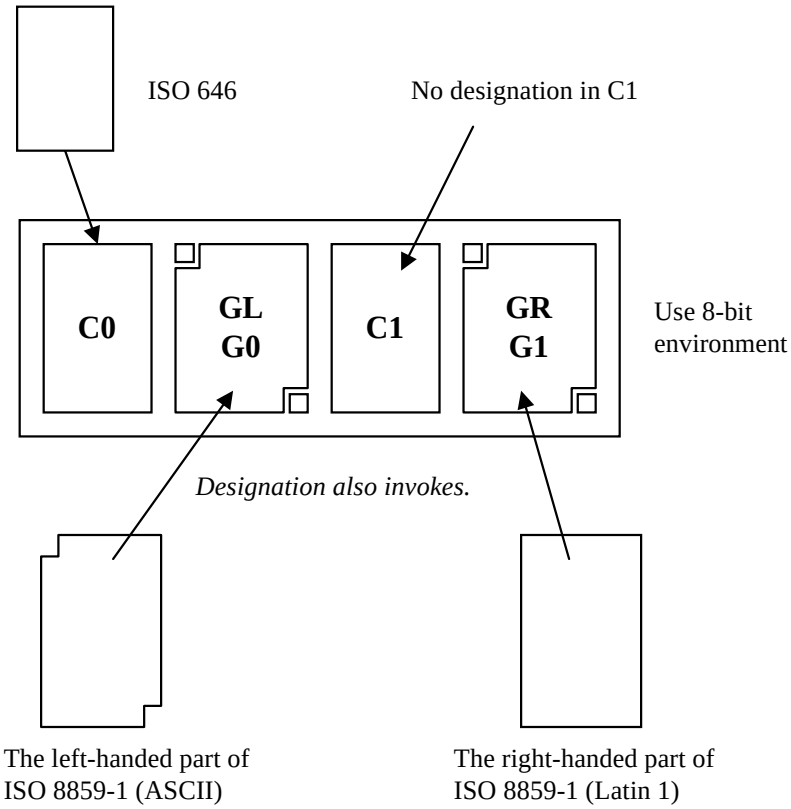


Chapter 6.4 "Initial designation and invocation" of the ISO 2022 Standard. The subset of the ISO 2022 standard for SCP-ECG is shown in the diagram below:

A.5.2.4 The implied initial state in ISO 2022 is defined by the following sequence:

Escape Sequence	Description
ESC 02/00 04/03	GO and G1 in 8-bit environment only. Designation also invokes.
ESC 02/00 04/07	In an 8-bit environment, C1 represented as 8-bits
ESC 02/00 04/09	Graphic character sets can be 94 or 96
ESC 02/00 04/11	8-bit code is used
ESC 02/08 04/02	Designate ASCII into G0
ESC 02/13 04/01	Designate right-handed part of ISO Latin-1 into G1
ESC 02/01 04/00	Designate ISO 646 into C0

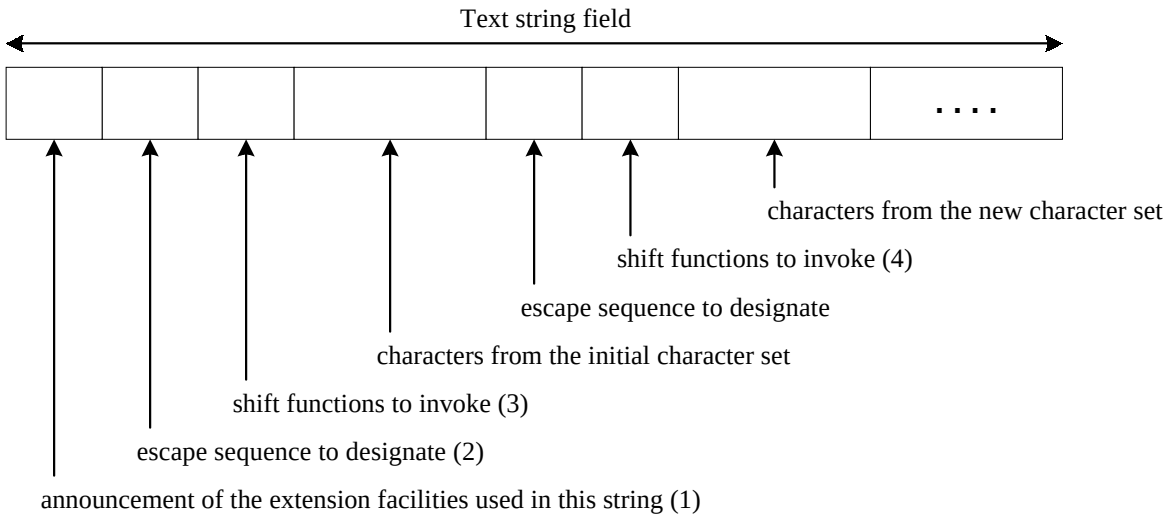
The default character set for SCP-ECG is shown in the following diagram:



A.5.3 Character sets extension

A.5.3.1 General string field encoding structure defined in ISO 2022

The following figure shows the string field structure encoded by the ISO 2022 Standard. The text string with such encoding contains escape sequences or shift function characters, as well as the announcement of extension facilities at the beginning of the string.



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A.5.3.2 Method of text encoding in SCP-ECG

The ISO 2022 method is flexible and powerful, but the full implementation may become too complicated for the SCP-ECG protocol. Some escape sequences, shift functions and announcements can be omitted in accordance with the standard.

The following rules are applied in order to omit some escape sequences and offer a more simple method for multi-lingual encoding .

1. Announcers (1) in the figure above shall be omitted by agreement on extension facilities between interchanging parties. The extension facilities used for SCP-ECG are summarized in the table of A.8.
2. Shift functions (3) and (4) shall be omitted by the escape sequences which designate and also invoke the G0 and G1 into GL and GR respectively, as defined by "ESC 02/00 04/03".
3. The escape sequence (2) is omitted by the following initial default setting:

   - Designate ASCII (left-handed part of ISO 8859) into G0 and also invoke to GL.

   - Designate Latin-1 (right-handed part of ISO 8859) into G1 and also invoke to GR.

   - Designate ISO 646 into C0.

   - No designation to C1.

No escape sequences shall be found in a text string when only ISO 8859-1 is used. This is the normal ASCII 8-bit text string. If another character set is required in a string, an escape sequence for switching the character set is necessary before the characters of the other character set.

The format of a text field with multiple character sets is summarized in the following diagram:

Format of an encoded text string in SCP-ECG

characters from the default character set	escape sequence	characters from the new character set	escape sequence to change to another character set	---

Each string in the transmission shall start with the default character set. A new field or the trailing NULL shall reset to the default character set.

A.5.3.3 The format of an escape sequence for an extension character set is:

ESC {I} F

* "ESC" is the escape character. Its code representation is 01/11.

* "{I}" stands for one or more "intermediate characters", which are in the range 02/00 to 02/15. It shows the function of the escape sequence.

* "F" stands for "Final character", which is always in the range 04/00 to 07/14. These are registered by an International Registration Authority. Some of the final characters are listed in A.5.4.

A.5.3.4 To define another character set encoding to be the GL set, one of the following escape sequences is used:

ESC 02/08 F	94 character set
ESC 02/04 02/08 F	94^N character set
ESC 02/04 F	some special 94^N character set

For the final characters, 04/01 and 04/02 can be used in the form "ESC 02/04 F". This exception comes from ISO 2022 Chapter 6.3.9. The sequence "ESC 02/04 04/02", for the Japanese character set, is commonly used in Japan.

A.5.3.5 A.To define one of the other character set encodings to be the GR set, one of the following control sequences is used:

ESC 02/09 F	94 character set
ESC 02/13 F	96 character set
ESC 02/04 02/09 F	94^N character set

A.5.3.6 The following intermediate characters are allowed: 02/00, 02/01, 02/04, 02/09 and 02/13.The following intermediate characters are not permitted in SCP-ECG:

02/02, 02/03, 02/05, 02/06, 02/07, 02/10, 02/11, 02/12, 02/14 and 02/15.

A.5.3.7 Final characters for private encoding (in the range of 03/00 to 03/15) are not permitted in SCP-ECG.

A.5.3.8 The other escape sequences described in the ISO 2022 document shall not be used for SCP-ECG.

A.5.3.9 A 94^N character set uses N bytes (N>1) for each character. The value of N is derived from the column value of the final character F, specified above:

column 04 2 bytes

column 05 2 bytes

column 06 3 bytes

column 07 4 or more bytes

In a 94^N encoding, the byte values 02/00 and 07/15 (in GL) and 10/00 and 15/15 (in GR) are never used. (The column definitions come from ISO 2022).

A.5.4 Final characters

In SCP-ECG only internationally registered final characters shall be used. The following list shows some of the final characters which may be used.

F	94/96	Description
04/02	94	7-bit ASCII graphics (ANSI X3.4-1968) Left half of ISO 8859 sets
04/09	94	Right half of JIS X0201-1976 (reaffirmed 1984) 8-bit Alphanumeric-Katakana Code
04/10	94	Left half of JIS X0201-1976 (reaffirmed 1984) 8-bit Alphanumeric-Katakana Code
04/01	96	Right half of ISO 8859-1, Latin alphabet No.1
04/02	96	Right half of ISO 8859-2, Latin alphabet No.2
04/03	96	Right half of ISO 8859-3, Latin alphabet No.3
04/04	96	Right half of ISO 8859-4, Latin alphabet No.4
04/06	96	Right half of ISO 8859-7, Latin/Greek alphabet
04/07	96	Right half of ISO 8859-6, Latin/Arabic alphabet
04/08	96	Right half of ISO 8859-8, Latin/Hebrew alphabet
04/12	96	Right half of ISO 8859-5, Latin/Cyrillic alphabet No.1
04/13	96	Right half of ISO 8859-9, Latin alphabet No.5
04/01	94^2	GB2312-1980, China (PRC) Hanzi
04/02	94^2	JIS X0203-1983, Japanese Graphic Character Set
04/03	94^2	KS C5601-1987, Korean Graphic Character Set

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The sets listed as "Left half of ..." shall always be defined as GL. The sets listed as "Right half of ..." shall always be defined as GR. Other sets can be defined either as GL or GR.

If 04/01, 04/02 and 04/03 are used in the form "ESC 02/04 F", they are always defined as GR.

A.6 Language code

The "Language code" field of Section 2 in the SCP-ECG protocol is used to identify the class of character sets used. This field is coded according to the following bit-map:

Value	Description
Bit 0 reset to 0	uses ASCII only
Bit 0 set to 1	uses non-ASCII character set (includes the right half of ISO 8859-1)
Bit 1 reset to 0	uses ISO 8859-1 only
Bit 1 set to 1	uses other than ISO 8859-1
Bit 2 reset to 0	does not use multi-byte character set
Bit 2 set to 1	uses multi-byte character set
Bits 3 to 7	always reset to 0

Note that bit 0 shall be set to be 1, when using the right-handed part of ISO 8859-1. In this case, no escape sequence shall appear in the string.

A.7 Method for handling unsupported character sets

The use of unsupported character sets in the string may cause serious problems in patient identification. The method for handling unsupported character sets is described below. It is assumed that one system can input all characters being displayed/printed.

A.7.1 ISO 8859-1 based machine

Print, display and input all GR and GL characters which cannot be handled in the following manner.

* replace all "\" characters (05/02) with two characters "\\"

* replace the escape character (01/11), which preceeds unknown escape sequences, with four characters "\033". Note that known escape sequences should be processed adequately.

A.7.2 ASCII based machine

* replace all "\" characters (05/02) with two characters "\\"

* replace the escape character (01/11), which preceeds unknown escape sequences, with four characters "\033". (Note that known escape sequences should be processed adequately.)

* replace all GR set characters with four characters "\nnn", where 'nnn' is the 3 column octal representation of each byte.

Checking the language code is helpful for this method. However, parsing of the text string is still required because there might be supported and unsupported character sets in one string.

NOTE: This proposal does not define the actions for over-flowing of display, print or input fields.

A.8 Summary of the escape sequences described in this annex for the encoding of free text in SCP-ECG

At the beginning of an information interchange, it may be required to announce the code extension facilities used in the data which follow. If such an announcement is to be embedded within the character coded information, one or more of the class of three-character escape sequences ESC 02/00 F shall be used. Subject to agreement between the interchanging parties, such an announcement sequence may be omitted.

Escape sequences that are not listed here shall not be used in text fields. "Announcer " shall not appear in the field explicitly.

Escape sequence	Description	Note
ESC 02/00 04/03	G0 and G1 in 8-bit environment only; designation	Announcer[1)]
ESC 02/00 04/07	In an 8-bit environment, C1 represented as 8-bits	Announcer
ESC 02/00 04/09	Graphic character sets can be 94 or 96	Announcer
ESC 02/00 04/11	8-bit code is used	Announcer
ESC 02/08 04/02	Designate ASCII left half of ISO 8895-1 into G0	Default
ESC 02/13 04/01	Designate right half of ISO 8895-1 Latin-1 into G1	Default
ESC 02/01 04/00	Designate ISO 646 into C0	Default
ESC 02/08 F	Designate 94 character set into G0	
ESC 02/04 02/08 F	Designate 94^N character set into G0	
ESC 02/04 F	Designate some special 94^N character set into G0	
ESC 02/09 F	Designate 94 character set into G1	
ESC 02/13 F	Designate 96 character set into G1	
ESC 02/04 02/09 F	Designate 94^N character set into G1	

NOTE:

1) The final characters (04/03, 04/07, 04/09, 04/11) announce the code extensions, which shall actually be used, hence the term "Announcer" and also "announcing sequence". The final character of the announcing sequence indicates the facilities for representing graphic sets and some control sets in the 7-bit or 8-bit environments.

A.9 Examples of encoded text strings

Some examples of encoded strings are shown below. The representation in an unsupported environment is also shown.

EXAMPLE 1: ISO 8859-1 string

text: ä ç å

code representation: 14/04 14/07 14/05

in unsupported environment: \344\347\345

EXAMPLE 2: mixture of ASCII and Japanese Kanji string (JIS X0208)

text: a b c 日本語 1 2 3

code representation: shown in the table below

character encoding	comments
06/01	character "a"
06/02	character "b"
06/03	character "c"
01/11 02/04 04/02	escape sequence to change to Kanji
04/06 07/12	1st character of Kanji string shown above (日)
04/11 05/12	2nd character of Kanji string shown above (本)
03/08 06/12	3rd character of Kanji string shown above (語)
01/11 02/08 04/02	escape sequence to change to ASCII
03/01	character "1"
03/02	character "2"
03/03	character "3"

in unsupported "ASCII only" environment: abc\033$BF|K\\8l\033(B123

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ANNEX B
(Normative)

Definition of compliance with the SCP-ECT standard

B.0 Introduction

The SCP-ECG Standard specifies a means by which ECG devices and systems may exchange information. The Standard adopts an open approach to defining information content while specifying data format, query messaging and data transport. The Data Format Categories defined in this Annex 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. The ways in which ECG data may be encoded are well defined, but are also flexible. In implementing this Standard, a manufacturer may choose to implement only a subset of all possible ways of encoding the ECG data. Therefore, B.2 defines a testing procedure that shall be followed by manufacturers who state SCP-ECG compliance. Because of the flexibility allowed in information content and encoding, the user/purchaser must determine the suitability of a device and/or system for a particular application.

Manufacturers who state SCP-ECG compliance for their devices and/or systems shall follow the specifications and definitions of this Annex. Compliance for data format, query messaging, and data transport are stated independently. Data format includes those items specified in Clauses 5 and 6 (and referenced Annexes) of this Standard. Query messaging includes functions specified in clause 7. Data transport is specified in clause 8.

At this time, there is no recognized tool/method to allow testing compliance with the specifications of this Standard. At best such a tool would be useful to manufacturers in their efforts to assure compatibility of their devices. Because of the flexibility allowed in information content and encoding, compatibility between devices made by different manufacturers must be determined in each case, even if both devices could be shown to be compliant with the Standard. A statement of compliance with the Standard alone would be of little use to a user/purchaser. Therefore, a statement of compliance with the SCP-ECG Standard shall be made with an accompanying statement of compatibility with a device or devices of another manufacturer or manufacturers, uniquely identified by manufacturer trade name, model description and SCP implementation software identifier.

B.1 Compliance specification

B.1.1 Data Format Categories

The following table defines Data Format Categories that shall be used in specifying compliance with the SCP-ECG Standard. The information content provided by each Category is summarized under “Content Description.” Compliance implies that each Data Section shall be encoded as specified in the applicable subclause of Clause 5.

Category	Data Sections Required[1]	Content Description
I	0, 1, 7, 8	Demographics, global measurements and interpretation
II	0, 1, 2, 3, 6, (7), (8)	Demographics and ECG rhythm data [2]
III	0, 1, 2, 3, 5, (7), (8)	Demographics and reference beats [2]
IV	0, 1, 2, 3, 4, 5, 6, (7), (8)	Demographics, ECG rhythm data, and reference beats [2]

1) All devices stating SCP-ECG compliance shall Import data sections 0, 1, 7, and 8. All Categories may have additional sections added (e.g. 9, 10, 11). A device may Export at more than one category. Manufacturer specific data shall be optionally included only in manufacturer specific fields, bytes and data blocks that have been defined in the Standard. Reserved, unspecified and undefined fields, bytes or data blocks shall not be used for manufacturer specific data. "Import" and "Export" are defined in D2.2.

2) (7) and (8) means that these sections are optional for Export.

B.1.2 Data Exchange Functions

B.1.2.1 Export: The ability to make available to a Communications Channel a SCP-ECG record with a specified Data Format Category. The SCP-ECG record is created from raw ECG data as per SCP-ECG specification, with data compression performance specified in 6.5.2.

B.1.2.2 Import: The ability to accept from a Communications Channel, extract and make available to the user information from a SCP-ECG record with a specified Data Format Category. An Importing device shall minimally import a standard 10-second, 12-lead ECG (coded as I, II, V1, V2, V3, V4, V5, V6) (see also requirements in 6.5.2).

B.1.2.3 Transfer: Export of a previously Imported record, at the same Data Format, with or without modification to the individual sections. ECG records stored in formats other than SCP can be converted in compliance with SCP-ECG format. Waveform data imported in a SCP-ECG format shall not be subjected to losses in compression processes for Transfer.

Note: The purpose of the Transfer definition is to preserve components in the record (for example, a manufacturer specific section) that the Importing device is unable to process. The requirement that ECG data shall not be subjected to further losses during Transfer implies that either the original compressed data be sent, or that further compression be without loss. Editing by the user of demographic data, measurements and interpretations, or user chosen data reduction/losses are beyond the scope of this Standard.

B.1.2.4 Communication Channel: Any mechanism capable of making the SCP-ECG record available externally.

Note: The only Communication Channel specified in this Standard is the SCP-ECG Messaging/Transport Protocol defined in B.1.3. This Standard neither restricts nor supports use of any other mechanism.

B.1.3 SCP-ECG Messaging/Transport Protocol

Clause 7 of this Standard specifies query messaging, and Clause 8 specifies data transport. A device shall state one of three options: "Query Messaging and Data Transport not supported", "Query Messaging supported", or "Query Messaging and Data Transport supported".

A statement of "Query Messaging and Data Transport not supported" shall be accompanied by disclosure by the manufacturer of the mechanism(s) by which SCP-ECG data formatted files may be accessed.

"Query Messaging supported" shall imply compliance with Clause 7, but via a transport protocol not specified by this Standard, and which the manufacturer shall disclose.

"Query Messaging and Data Transport supported" shall imply compliance with Clauses 7 and 8.

If a device does not support all functions specified, it shall be considered compliant if it responds to requests in a manner defined in this Standard. For example, if a "Request for patient list" (1.2.2.2) is not supported, the request may be answered with "processing request not supported" (note 11, 1.2.6). A device that fails to respond to an unsupported request, or responds in a manner unspecified in this Standard shall not be considered compliant.

As is the case for overall compatibility specified in B.1, a statement indicating support for SCP-ECG Query Messaging or Data Transport shall require compatibility verified by testing with a device or devices of a different manufacturer or manufacturers. This Standard does not specify the means or methods for such verification.

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It is recognized that other mechanisms for transfer of a SCP-ECG formatted file exist. This Standard neither restricts nor supports use of any mechanism other than SCP-ECG Query Messaging and Data Transport defined in Clauses 7 and 8.

B.1.4 Specification for Statement of Compliance

A statement of SCP-ECG compliance shall have the following form and contents:

The specified device is compliant with SCP-ECG Standard Version x.xx as follows:

Device: Manufacturer's trade name.
Model description.
SCP-ECG implementation software identifier.
Export: Data format category(ies), or "Not supported."
Data sections with content description.
List of Manufacturers (and devices) specifying Categories and optional sections with which Export compatibility has been verified by testing for each device; or the following statement: "A list of Manufacturers (and devices) specifying categories and optional sections with which SCP-ECG Export compatibility has been verified by testing for each device is available on request."

Import: Data format category(ies), or "Not supported."
Data sections with content description.
List of Manufacturers (and devices) specifying Categories and optional sections with which Import compatibility has been verified by testing for each device; or the following statement: "A list of Manufacturers (and devices) specifying categories and optional sections with which SCP-ECG Import compatibility has been verified by testing for each device is available on request."

Transfer: "Supported" or "Not Supported."
SCP-ECG Messaging/Transport:
Transmit: "Query Messaging and Data Transport not supported", or
"Query Messaging supported", or
"Query Messaging and Data Transport supported".
Receive: "Query Messaging and Data Transport not supported", or
"Query Messaging supported", or
"Query Messaging and Data Transport supported".
List of Manufacturers (and devices) with which SCP Messaging/Transport Layer compatibility has been verified by testing; or the following statement: "A list of Manufacturers (and devices) with which SCP-ECG Messaging/Transport Layer compatibility has been verified by testing is available on request."

B.1.5 Hypothetical Examples

B.1.5.1 Cardiograph

SCP-ECG Standard Version 1.1 Statement of Compliance

Device: MyECG Company
Model Top1
SCP-ECG implementation MyECG SCP version 2.
Export: Data Format Category IV.
Data Sections 0, 1, 2, 3, 4, 5, 6, 7, 8, 10, containing demographics, ECG rhythm data, reference beats, global measurements, lead measurements and interpretation.
Export compatibility at Category IV has been verified by testing with:
Xzq Manufacturing, Inc. Models LB1577, LB1755 and ZM922
SCP-ECG implementation software version 6.1
BestECG, LTD. Model PQRST2
SCP-ECG implementation software version 3.0
Import: Data Format Category I:
Data Sections 0, 1, 7, 8, 10, containing demographics, global measurements, lead measurements and interpretation.
Data Format Category II:
Data Sections 0, 1, 2, 3, 6, 7, 8, 10, containing demographics, ECG rhythm data, global measurements, lead measurements and interpretation.
Data Format Category III:
Data Sections 0, 1, 2, 3, 5, 7, 8, 10, containing demographics, reference beats, global measurements, lead measurements and interpretation.
Data Format Category IV:

Data Sections 0, 1, 2, 3, 4, 5, 6, 7, 8, 10, containing demographics, ECG rhythm data, reference beats, global measurements, lead measurements and interpretation.
A list of Manufacturers (and devices) specifying categories and optional sections with which SCP-ECG Import compatibility has been verified by testing for each device is available on request.

Transfer: Not Supported.

SCP-ECG Messaging/Transport:

Transmit: Query Messaging and Data Transport supported.

Receive: Query Messaging and Data Transport supported.

A list of Manufacturers (and devices) with which SCP-ECG Messaging/Transport Layer compatibility has been verified by testing is available on request.

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B.1.5.2 Management System

SCP-ECG Standard Version 1.1 Statement of Compliance:

Device: MyECG Company.
Model Top2.
SCP_ECG implementation version MyECG SCP version 2.

Export: Not Supported.

Import: Data Format Category I:
Data Sections 0, 1, 7, 8, 10, containing demographics, global measurements, lead measurements and interpretation.

Data Format Category II:
Data Sections 0, 1, 2, 3, 6, 7, 8, 10, containing demographics, ECG rhythm data, global measurements, lead measurements and interpretation.

Data Format Category III:
Data Sections 0, 1, 2, 3, 5, 7, 8, 10, containing demographics, reference beats, global measurements, lead measurements and interpretation.

Data Format Category IV:
Data Sections 0, 1, 2, 3, 4, 5, 6, 7, 8, 10, containing demographics, ECG rhythm data, reference beats, global measurements, lead measurements and interpretation.

A list of Manufacturers (and devices) specifying categories and optional sections with which SCP-ECG Import compatibility has been verified by testing for each device is available on request.

Transfer: Supported.

SCP-ECG Messaging/Transport:

Transmit: Query Messaging and Data Transport supported.

Receive : Query Messaging and Data Transport supported.

A list of Manufacturers (and devices) with which SCP-ECG Messaging/Transport Layer compatibility has been verified by testing is available on request.

B.1.5.3 Defibrillator 12-lead ECG

SCP-ECG Standard Version 1.1 Statement of Compliance:

Device: MyECG Company.
Model Top3.
SCP_ECG implementation version MyECG SCP version 2.

Export: Data Format Category II:
Data Sections 0, 1, 2, 3, 6 containing demographics and ECG rhythm data.
Export compatibility at Category IV has been verified by testing with:
- Xzq Manufacturing, Inc. Models LB1577, LB1755 and ZM922 (SCP-ECG implementation software version 6.1
- BestECG, LTD. Model PQRST2 (SCP-ECG implementation software version 3.0)

Import: Not Supported.

Transfer: Not Supported.

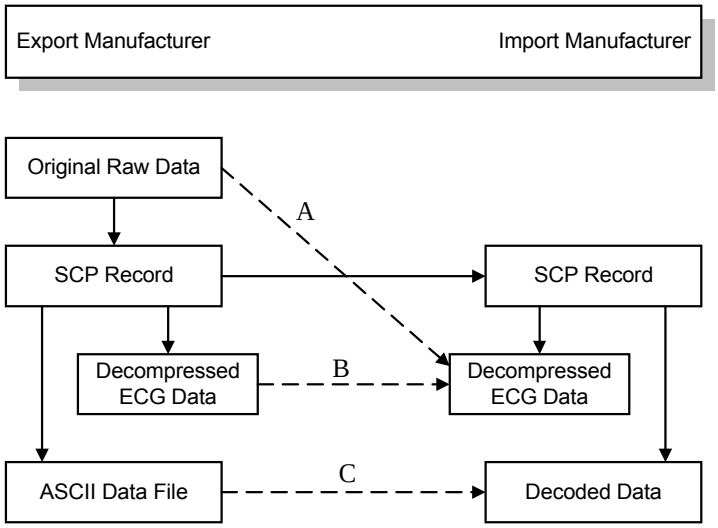
SCP Messaging/Transport:
Query Messaging and Data Transport not supported.

B.2 Testing/validation of SCP-ECG data format compatibility

B.2.1 Overview

Testing/validation of SCP-ECG data format compliance/compatibility may be done by individual manufacturers. The requirements for testing/validation are diagrammed below, and are detailed in B.2.2. In brief, each manufacturer that states Export compliance makes publicly and freely available example SCP-ECG formatted records for each ECG generating device and for each Data Format Level claimed, and additional supporting data files to allow an Importing manufacturer to validate accurate decoding of the SCP-ECG records. By reading Manufacturer A's files, Manufacturer B can validate that A's files could be Imported. If in a SCP-ECG compliance statement, Manufacturer B states validation of Import compatibility with A then Manufacturer A is notified in writing by Manufacturer B. Manufacturer A may then state Export validation with B. Manufacturers therefore "cooperatively self-validate" compatibility with each other.

Import validation may be diagrammed as follows:



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B.2.2 Requirements

An Export Manufacturer shall make five file types publicly and freely available for each test case provided, for each Exporting device type, and for each compliance level:

1) A SCP-ECG formatted binary file. (***.ECG)

2) An original ECG raw data file from which the SCP-ECG file was compiled, and in the binary format defined in B.2.3. (***.EC0)

3) A decompressed ECG data file from the SCP-ECG file using the Export Manufacturer's decompression process, and in the binary format defined in B.2.3. (***.EC1)

4) A text file as defined in B.2.3 specifying the data in the original and the decompressed ECG binary files. (***.EC2)

5) An ASCII data file (for non-waveform data) containing all demographic, measurement and interpretation data. (***.EC3)

An Export manufacturer shall provide test cases consisting of the required five file types for at least those cases specified in C.4 (and its accompanying table). The Export Manufacturer may also provide additional test cases in the required file formats. The set of test cases provided by the Export Manufacturer shall include files with data content at the limits implemented by the Export Manufacturer.

For all test cases provided by the Export manufacturer, the Import Manufacturer shall Import the SCP-ECG records, then decode and decompress them. For each test case, the decompressed ECG data shall be compared to the original ECG data (comparison "A" in the diagram), and the decompressed ECG data shall meet the requirements for quantization and for error limits specified in clause 6.5. Comparison "B" between the Export Manufacturer's decompressed data and the Import Manufacturer's decompressed data is to aid the Import Manufacturer in evaluating differences seen in comparison "A". Comparison "B" is optional.

For each test case, the Import Manufacturer shall compare the decoded demographic, measurement and interpretation data with the data in the ASCII file provided by the Export Manufacturer (comparison "C" in the diagram). This comparison shall be exact for all data fields decoded by the Import Manufacturer.

A Manufacturer may state Import compatibility for each Manufacturer's device and for each data format category that has been validated. If Import compliance is stated for another Manufacturer's Exported files, then the Exporting Manufacturer shall be notified in writing, and the Exporting Manufacturer shall be allowed to state Export compatibility with the Importing Manufacturer.

B.2.3 ECG Binary File Format (***.EC0, ***.EC1)

Each test ECG shall be provided with the following information:

1. A text file (***.EC2) containing:

   a) comma delimited descriptors for each lead of ECG data (which may be more leads or less leads than the typical 8 stored for a resting 12-lead ECG),

   b) the total number of samples for each lead,

   c) the sample rate (per second) or sample interval (microseconds),

   d) and the number of nanoVolts per least significant bit.

2. Binary files (***.EC0, ***.EC1) with ECG data stored as16 bit signed words, stored in Intel format (low-byte, high-byte). The sequence of the samples (S1, S2 … Sn) for leads (L1, L2 … Lm) is:

   $S1_{L1}$, $S1_{L2}$ … $S1_{Lm}$, $S2_{L1}$, $S2_{L2}$ …Sn_{L1}, Sn_{L2} … Sn_{Lm}

Example

The following example is for 8 ECG leads, all identical to each other, with alternating samples of +/- 1.0 mV for each lead. In this case, +/- 1000, hexadecimal values of 03E8 and FC18.

***.EC2 - Text file contains the following:

Leads: I, II, V1, V2, V3, V4, V5, V6

Bytes:	Leads I	II	V1	V2	V3	V4	V5	V6	
00 to 0F	E8 03	E8 03	E8 03	E8 03	E8 03	E8 03	E8 03	E8 03	Sample 1
10 to 1F	18 FC	18 FC	18 FC	18 FC	18 FC	18 FC	18 FC	18 FC	Sample 2
20 to 2F	E8 03	E8 03	E8 03	E8 03	E8 03	E8 03	E8 03	E8 03	Sample 3
30 to 3F	18 FC	18 FC	18 FC	18 FC	18 FC	18 FC	18 FC	18 FC	Sample 4
40 to 4F	E8 03	E8 03	E8 03	E8 03	E8 03	E8 03	E8 03	E8 03	Sample 5
50 to 5F	18 FC	18 FC	18 FC	18 FC	18 FC	18 FC	18 FC	18 FC	Sample 6

5000 samples per lead; 500 samples per second; 1000 nanoVolts per LSB.

***.EC0 or ***.EC1 - Binary file (in Hexadecimal for each byte):

B.3 Coding of SCP-ECG compliance

SCP-ECG compliance is defined separately for Data Format (B.1.1) and the Transport Layer (B.1.3). Clause 5.4.5, Tag 14 (Machine ID Acquiring Device), byte 16 contains the coded compatibility categories. The upper four bits of byte 16 shall be used to characterize the Data Format Category, and the lower 4 bits of the same byte are reserved, as depicted below. Although a particular device may state a variety of Data Format Categories (B.1.4), the upper 4 bits of byte 16 shall indicate the Data Format Category for the record in which the tag is embedded.

Specification of 5.4.5, Tag 14, Byte 16:

	Upper 4 bits: SCP-ECG Data Format Category (I to IV)				Reserved			
bit:	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**

Upper 4 bits: Data Compatibility	**Content**	Category I:	1	0	0	1
		Category II:	1	0	1	0
		Category III:	1	0	1	1
		Category IV:	1	1	0	0

Lower 4 bits: Reserved	0	0	0	0

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ANNEX C
(Informative)

Methodology and conformance testing of the recommended ECG signal compression technique

C.0 Introduction

The methodology of the recommended SCP-ECG signal data compression techniques is explained in this Annex. The principles of the methodology are presented first in general in various diagrams (see C.1). Subsequently, a detailed description is given of the recommended data compression and decompression methodology, with corresponding mathematical definitions (see C.2 and C.3). Finally, a description is given of a test set and criteria for conformance testing (see C.4 and C.5).

A test set ad hoc was created to assess the reconstruction errors of ECG compression methods and to test the absolute accuracy of an ECG compression implementation. This test set is available for public use. The set provides a useful tool for validation and performance testing.

C.1 Principles of "High" SCP-ECG data compresison

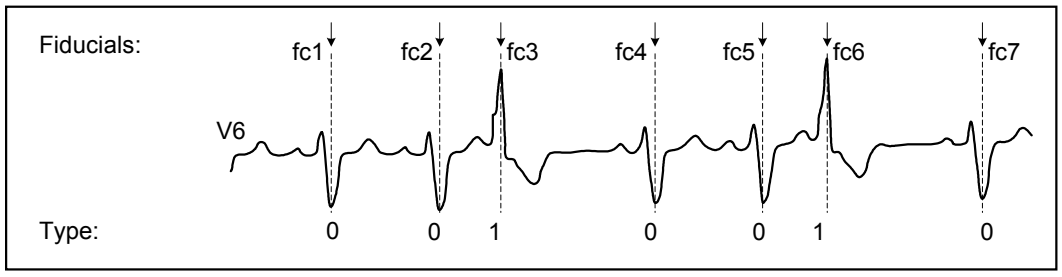
C.1.1 Original ECG - "raw data"

a) Locate a reference point inside all ECG complexes, e.g. the time of QRS_{max} or any other marker

⇒ Fiducials for Reference Beat subtraction (see fc1 to fc7 in figure below)

b) Identify ECG complex types, i.e. normal type, different extrasystoles

⇒ QRS-type 0, 1, etc.



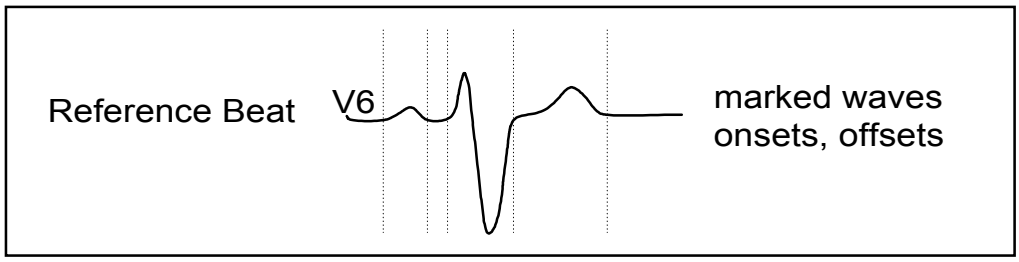
C.1.2 Reference Beat 0

a) Compute the “Reference Beat Type 0”, e.g. representative Average Cycle, Median Cycle, Modal Beat,

b) Identify the wave onsets and offsets of the Reference Beat 0

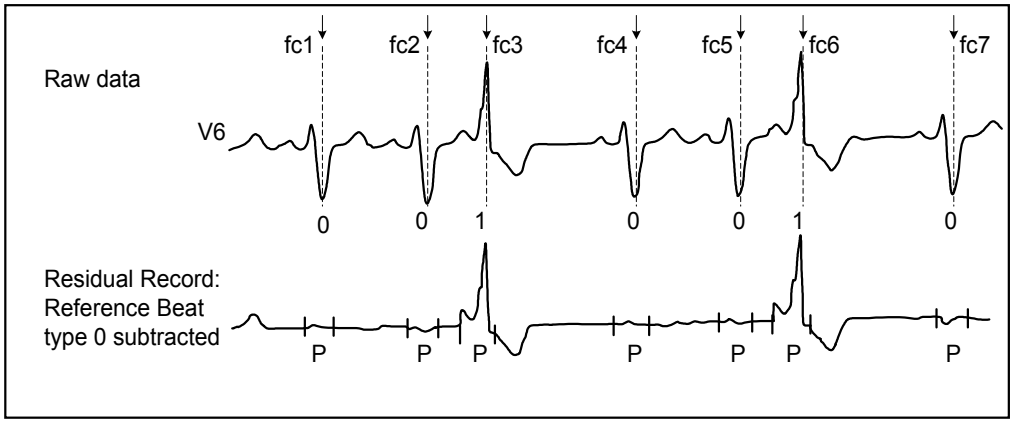
⇒ length of the Reference Beat 0 to be subtracted

⇒ pointers for QRS data segments **p** (see figures in C.1.3 and C.1.4) to be protected from filtering and decimation.



C.1.3 Residual Record

Subtract the Reference Beat Type 0 from all ECG complexes of type 0 using the fiducial locations



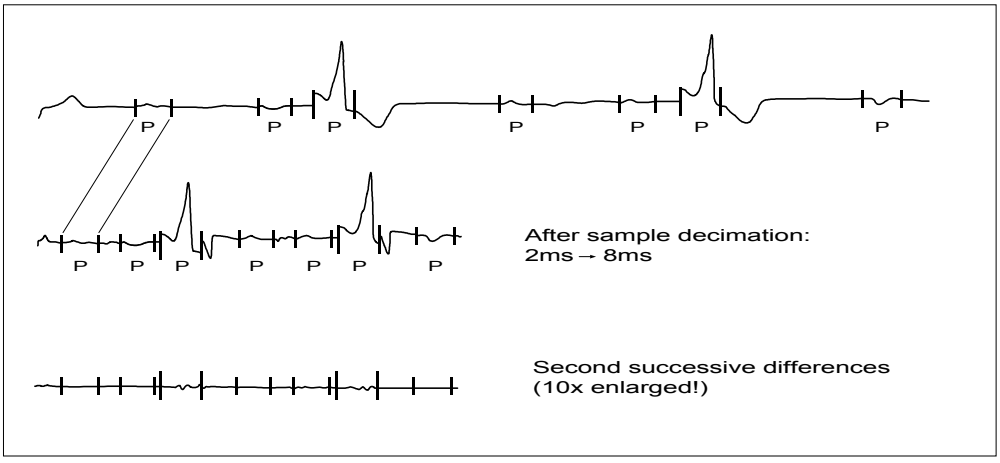
C.1.4 Compressed data

a) Low pass filtering of the residual record (excluding the protected areas **p**)

b) Sample decimation 2 ms -> 8 ms (excluding the protected areas **p**)

c) Compute 2nd successive differences on all the resulting data.

Residual Record



C.1.5 Encoding

The second successive differences are then Huffman encoded, see numerical examples.

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C.1.6 Decompression of SCP-ECG data

For decompression of the ECG data the steps of compression are generally performed backwards. If "high compression" is used, the steps (a) and (b) described below have to be performed on the Residual Record and the Representative Beat. 0. Steps (c) and (d) apply to the Residual Record only, whereas (e) and (f) apply to both the Representative Beat 0 and the Residual Record.

The steps of decompression are:

a. Decoding with Huffman tables

b. Reconstitution of the data from the the first or second differences

c. Reconstitution of decimated samples

d. Low pass filtering of the reconstructed Residual Record outside protected areas

e. Multiplication with AVM (the amplitude value modifier)

f. In case of high compression: addition of the Representative Beat 0 to the Residual Record at all complex type 0 locations. For this the stored pointers fc(k), SB(k) and SE(k) of the Residual Record and fcM of the Reference Beat 0 shall be used.

Steps C.1.1 to C.1.6 are explained in detail in C.2 and C.3 in the following pages of this Annex.

C.2 Equations for SCP-ECG data compression

C.2.1 Definitions

C.2.1.1 Raw data

Elements of raw data : $X_r(m,n)$

subscript *r* : raw data

lead : $m;\ 1 \leq m \leq M$

sample : $n;\ 1 \leq n \leq N$

Amplitude quantization: $LSB\ [\mu V] = AVM * 10^{-3}$

(AVM, the amplitude value multiplier specified in Section 6, Header bytes 1-2)

Sampling interval: $SI\ [ms] = STM * 10^{-3}$

(STM, the sampling time multiplier specified in Section 6, Header bytes 3-4)

C.2.1.2 Sample number and time relationship

a) By definition: the first sample, n=1, is at time t=0.

b) A sampling interval (SI) of 2 ms is specified as minimum requirement for SCP-ECG compatible data.

c) With SI = 2 ms, then the relationship between sample n and time t within the record is:

t = (n-1)*SI[ms]=2*(n-1)[ms].

C.2.1.3 Examples of Denomination and indexing of ECG data

Raw data

Leads I, II,V1,..., V6 $\Rightarrow$ M = 8

Record length 10 seconds, 2 ms sampling interval

Number of samples $\Rightarrow$ N = 5000

Lead I: $X_r(1,1), X_r(1,2), \ldots X_r(1,n), \ldots X_r(1,5000)$

Lead II: $X_r(2,1), X_r(2,2), \ldots X_r(2,n), \ldots X_r(2,5000)$

Lead VI: $X_r(3,1), X_r(3,2), \ldots X_r(3,n), \ldots X_r(3,5000)$

Lead V6: $X_r(8,1), X_r(8,2), \ldots X_r(8,n), \ldots X_r(8,5000)$

Reference Beat

Leads I, II,V1,..., V6 $\Rightarrow$ M = 8

Record length 1 second, 2 ms sampling interval

Number of samples $\Rightarrow$ P = 500

Lead I: $Y_r(1,1), Y_r(1,2), \ldots Y_r(1,p), \ldots Y_r(1,500)$

Lead II: $Y_r(2,1), Y_r(2,2), \ldots Y_r(2,P), \ldots Y_r(2,500)$

Lead VI: $Y_r(3,1), Y_r(3,2), \ldots Y_r(3,p), \ldots Y_r(3,500)$

Lead V6: $Y_r(8,1), Y_r(8,2), \ldots Y_r(8,p), \ldots Y_r(8,500)$

NOTE: The data (potentials V) for leads III, aVR, aVL and aVF may be computed according to the formula of Einthoven and Goldberger, whereby:

$$III = II - I = V_F - V_L \qquad V_{aVR} = \frac{-(I+II)}{2} = \frac{2V_R - V_L - V_F}{2}$$

$$V_{aVL} = I - \frac{II}{2} = \frac{2V_L - V_R - V_F}{2} \qquad V_{aVF} = II - \frac{I}{2} = \frac{2V_F - V_L - V_R}{2}$$

C.2.1.4 Pointers

Raw data:

Pointer to the fiducial point of cycle k in the raw data (number of QRS complexes in raw data: K): fc(k)

Reference beat:

Pointer to the fiducial point in the reference beat data (the fiducial point may be the spatial maximum, QRS-onset or any other point of the QRS complex.): fcM

Pointer to the beginning of P in the reference beat data: PBM

Pointer to P end in the reference beat data: PEM

Pointer to QRS beginning in the reference beat data: QBM

Pointer to QRS end in the reference beat data: QEM

Pointer to T end in the reference beat data: TEM

Residual record:

Pointer to the beginning of subtraction of Reference Beat 0 for cycle k in the raw data: SB(k)

Pointer to the end of subtraction of Reference Beat 0 for cycle k in the raw data: SE(k)

Pointer to the beginning of the protected area for complex k in the raw data and in the residual data: QB(k)

Pointer to end of the protected area for complex k in the raw data and in the residual data: QE(k)

NOTE: The pointers QB(k), QE(k) are explicitly stored in SCP-ECG section 4 (see 5.7.4). The protected area includes the interval from QRSonset until QRSoffset, but it may be larger (e.g. because of N-sample boundaries for decimated samples => see C.2.4.2).

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QRSonset(k) and QRSoffset(k) can be calculated from the fiducial fcM of Reference Beat 0, its QRS duration and the intervals bM and eM (see C.2.3.1) and from the fiducials fc(k) for each beat.

QRSonset(k) = fc(k)-bM

QRSoffset(k)= fc(k)-eM

C.2.2 Truncation of all values to 5 µV resolution

The amplitude quantization (resolution, precision) of the raw data and the reference beat data should be LSB $\leq$ 5 µV. The following equations describe the truncation of the data to 5 µV/LSB based upon the assumption that the original data are recorded with 1 µV/LSB resolution.

NOTES:

1) Rounding and truncation are not handled by all compilers in the same way. During design of a compression program it should be made sure that rounding of positive and negative numbers is correct. For example, in Intel processors, truncation is always towards zero, i.e., -9/5 = -1.8 truncates to –1. In contrast, for calculations done in offset binary, the answer would truncate to a value equivalent to –2.

2) Index t: truncated data

C.2.2.1 Raw data

$$X_t(m,n) = \frac{X_r(m,n)+2}{5} \quad for\ X_r(m,n) \geq 0$$

$$X_t(m,n) = \frac{X_r(m,n)-2}{5} \quad for\ X_r(m,n) < 0$$

C.2.2.2 Reference Beat data

$$Y_t(m,p) = \frac{Y_r(m,p)+2}{5} \quad for\ Y_r(m,p) \geq 0$$

$$Y_t(m,p) = \frac{Y_r(m,p)-2}{5} \quad for\ Y_r(m,p) < 0$$

C.2.3 Subtraction of the Reference Beat from the raw signal data

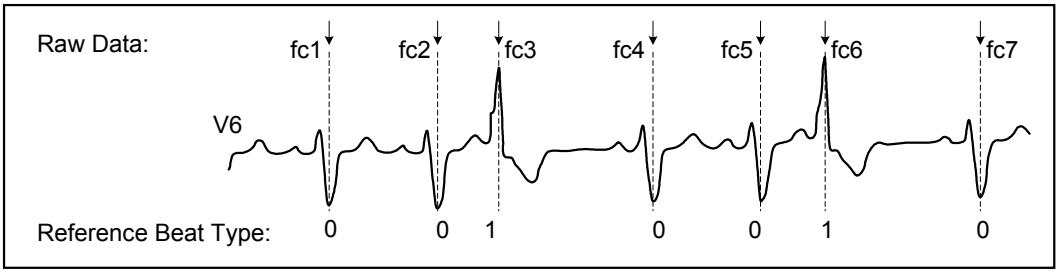
The SCP-ECG Protocol was designed to handle ECG signal data which may be compressed and encoded by different methods:

a) pure redundancy reduction.

b) "high compression" by using a "Reference Beat 0" which is encoded separately. It may be subtracted from the raw data and the residual data may be filtered, sample decimated, etc.

The following text and equations describe in detail the computation and specification of the Residual Record for a compression according to b), described above as "high compression" scheme.

C.2.3.1 Given truncated raw data of lead V6 with located ECG complexes (fiducial points fck) as indicated in the figure below.

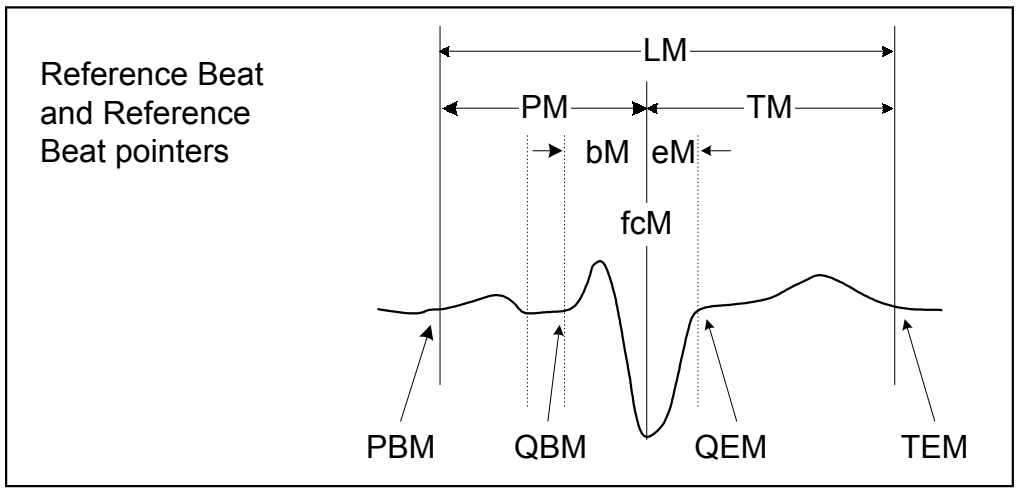


The table gives the locations and types of the QRS complexes located in the raw data depicted in this figure from t = 0 to t= 5 seconds (samples 1-2500).

sample	pointer	QRS type	data
1			$X_f(m,1)$
2			$X_f(m,2)$
333	fc1	0	$X_f(m,333)$
675	fc2	0	$X_f(m,675)$
840	fc3	1	$X_f(m,840)$
1357	fc4	0	$X_f(m,1357)$
1702	fc5	0	$X_f(m,1702)$
1869	fc6	1	$X_f(m,1869)$
2373	fc7	0	$X_f(m,2373)$
5000			$X_f(m,5000)$

C.2.3.2 Computation of the Residual Data

C.2.3.2.1 Align ("synchronize") the fiducial point fcM of reference beat 0 data with each of the fiducial points fc1, fc2, ...fc(k) for beat type 0 complexes of the raw data.



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The following table presents the direct storage location of the pointers and the formula to calculate them from the data in the SCP-ECG record.

Pointer	Chapter	Section	Byte	Direct	Calculation
LM	5.10.2	7		no	TEM-PBM
PM	5.7.1/5.10.2	4,7		no	fcM-PBM
TM	5.7.1/5.10.2	4,7		no	TEM-fcM
bM	5.7.1/5.10.2	4,7		no	fcM-QBM
eM	5.7.1/5.10.2	4,7		no	QEM-fcM
fcM	5.7.1	4	3-4	yes	
PBM	5.10.2	7	1-2	yes	
PEM	5.10.2	7	3-4	yes	
QBM	5.10.2	7	5-6	yes	
QEM	5.10.2	7	7-8	yes	
TEM	5.10.2	7	9-10	yes	

C.2.3.2.2 Subtract sample by sample the Reference Beat data from the raw data at the respective cycle location fc(k).

NOTE: The length of the data segment to be subtracted is not necessarily the total length LM of the Reference Beat. In addition it may vary from cycle to cycle within the raw data. To accommodate this, within Section 4 of the SCP-ECG Protocol under 5.7.3, bytes 3-6 are reserved to store pointers for the beginning of Reference Beat data subtraction. Bytes 11-14 are reserved to store the end of Reference Beat data subtraction for each cycle respectively.

For practical reasons it is most convenient to subtract constantly the "complete" Reference Beat data from PBM to TEM (this segment has the length LM). The pointers for the beginning and end of the subtraction of the Reference Beat data for cycle k are then found by

$$SB(k) = fc(k) - PM$$

$$SE(k) = fc(k) + TM$$

These pointers are to be used during the subtraction procedure and they have to be stored within the QRS field data of Section 4.

NOTE: Subtraction of the Reference Beat ("normal" Type 0) is not effective if the raw data cycle is not of the same type, e.g. an extrasystole (Type 1). However, the QRS data segments of the extrasystoles should be protected from low pass filtering and sample decimation as well.

C.2.3.2.4 The data remaining after subtraction of the Reference Beat at all suitable complex locations fc(k) are called **"Residual Record"**.

C.2.4 Low Pass Filtering

C.2.4.1 Low pass filtering of the residual record improves effectively the compression ratio. Since high frequency components are usually found only within the QRS, all data segments except those where QRS complexes were located, can be filtered and sample decimated.

C.2.4.2 Pointers to the protected data segment of cycle k are computed as follows:

$$QB(k) = QRSonset(k) - e1$$

$$QE(k) = QRSoffset(k) + e2$$

If reference beat global measurements (clause 5.10.3) are present for the beat type of beat k, pointers to the QRSonset and QRSoffset are computed as follows:

$$QRSonset(k) = fc(k) - bM$$

$$QRSoffset(k) = fc(k) + eM$$

where bM denotes the interval from fiducial point fcM to QRS begin of the Reference Beat and eM is the interval from fcM to QRS-end of the Reference beat. The values bM, eM can be calculated from the location of the fiducial point of the Reference Beat (stored in bytes 3-4 of Section 4, see 5.7.2) and the QRS onset and offset pointers (stored in bytes 5-6 and 7-8 of Section 7, see 5.10.3).

The values e1 and e2 in the equations are adjustments to the protected data segment to avoid problems with sample decimation/reconstruction. A practical solution is to set boundaries for QB and QE so that the interval for sample decimation between beat k-1 and beat k (= QB(k)-QE(k-1) - 1) is a multiple of the sample interval of the residual record. The values e1 and e2 may also include a "safety margin" for possible errors in locating the QRS onset and offset.

C.2.4.3 A simple non-recursive moving average filter has given sufficient results for low pass filtering of the Residual Record. The filter length (L) is 9 samples.

Filter values for an odd filter length L are calculated as follows[1)]:

$$F(m,a) = X(m,a)$$

$$F(m,a+1) = \frac{X(m,a) + X(m,a+1) + X(m,a+2) + 1}{3}$$

$$F(m,a+2) = \frac{X(m,a) + X(m,a+1) + X(m,a+2) + X(m,a+3) + X(m,a+4) + 2}{5}$$

$$F(m,a+3) = \cdots$$

$$F(m,n) = \frac{X(m,n-((L-1)/2)) + \ldots + X(m,n) + \ldots + X(m,n+((L-1)/2)) + (L-1)/2}{L}$$

$$F(m,b-3) = \cdots$$

$$F(m,b-2) = \frac{X(m,b-4) + X(m,b-3) + X(m,b-2) + X(m,b-1) + X(m,b) + 2}{5}$$

$$F(m,b-1) = \frac{X(m,b-2) + X(m,b-1) + X(m,b) + 1}{3}$$

$$F(m,b) = X(m,b)$$

After subtraction of reference beat type 0, there can be steps in the residual data at the boundaries of the subtraction zones, SB(k) and SE(k). These steps must not be filtered, so that it is possible to reproduce them in the reconstituted residual data.

There are 3 filter intervals [a,b] for each complex k, and an additional one from the end of complex K to the end of the data stream:

1) From the end of the reference beat type 0 subtraction of the preceding complex (k-1) to the beginning of subtraction of the current complex (k).

   a = SE(k-1)+1 SE(0)= 0

   b = SB(k)-1

2) From the beginning of the reference beat type 0 subtraction of the current complex (k) to the QRS onset of the current complex (k).

   a = SB(k)

   b = QB(k)-1

3) From the QRS offset of the current complex (k) to the end of the reference beat type 0 subtraction of the current complex (k).

   a = QE(k)+1

   b = SE(k)

4) The filter interval for the remaining samples until the end of the data is:

   a = SE(K)+1

   b = N

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NOTATIONS:

m = lead number

n = sample number

K = number of QRS complexes

N = number of the last sample

k = QRS complex number

Pointer to begin subtraction of reference beat type 0 for cycle (k) in raw data: SB(k)

Pointer to end subtraction of reference beat type 0 data for cycle (k) in raw data: SE(k)

Pointer to beginning of protected area for complex (k) in raw data and in residual data: QB(k)

Pointer to end of protected area for complex (k) in raw data and in residual data: QE(k)

NOTE:

1) The methods for rounding are defined in C.2.2.1 and C.2.2.2. The rounding constants 1, 2, .. (L-1)/2 in the previous filter equations should be negated in case the filtered values are negative.

C.2.5 Sample Decimation

Besides low pass filtering sample decimation can be applied to "slowly changing" data. The SCP-ECG Protocol specifies as a minimum sampling rate of 125 samples/s for the Residual Record, which is equivalent to an 8 ms sampling interval.

Decimation of sampling is permitted only outside the protected QRS data segments. In SCP, sample decimation is called “bimodal compression”.

For sample decimation an averaging algorithm is applied. This is different from sample decimation with subsequent four sample averaging.

For the implementation of SCP-ECG, manufacturers may choose the method with which they want to perform sample decimation, by averaging or sample skipping. It should be noted that the best results are obtained if compression and decompression algorithms are adjusted to each other.

Although no particular method of decimation and reconstruction are required, transients can be created at the subtraction zone boundaries by the reconstruction process unless certain conditions are met. Therefore SCP-ECG recommends the following boundaries for reference beat type 0 subtraction:

- Place SB(k) at the beginning of a decimated sample interval (e.g. sample 1,5,9,13,17,21..)
- SE(k) is at the end of a decimated sample interval (e.g. sample 4,8,12,16,20,..)

If these conditions are met, then it is not necessary to know which decimating algorithm is used to avoid transients at the subtraction zone boundaries during reconstruction.

A sampling interval of 8 ms is the maximum which is allowed for the residual record in SCP-ECG. So 125 samples/s is the lowest effective sampling rate within the residual record. Bimodal compression is indicated by 5.9.2 byte 6.

To avoid problems with sample decimation/reconstruction a practical solution is to set boundaries for QB and QE so that the interval for sample decimation between beat k-1 and beat k (= QB(k)-QE(k-1)-1) is a multiple of the sample interval of the residual record.

It is not necessary to update the pointers for begin and end of the protected area after sample decimation, because they are pointers within the residual record and not within the sample decimated residual record (see specifications for Section 4, clause 5.7).

There is no universal algorithm for the reconstruction of the decimated samples. It is left to the manufacturers in which way they do the reconstruction (interpolation or repeating of samples). However, the reconstruction RMS error and the absolute errors between the original and decompressed ECG shall be verifiable on the SCP-ECG test set. This test set is described in C.4.

EXAMPLE for filtering and decimation of the Residual Record resulting from ECG data depicted in C.2.3.

Sample Number	Pointer	Protected Segment	Data Filtered	Data Decimated	Comment
1		no	yes	yes	
2		no	yes	yes	
3		no	yes	yes	
⋮					
178	SB1	no	yes	yes	P1 onset
⋮					
264		no	yes	yes	
265	QB1	yes	no	no	Begin protected area 1st QRS
⋮					
267	QRSonset1	yes	no	no	QRS begin 1st QRS
⋮					
333	fc1	yes	no	no	fiducial 1st QRS
⋮					
361	QE1=QRSoffset1	yes	no	no	End protected area and QRS end 1st QRS
362		no	yes	yes	
⋮					
495	SE1	no	yes	yes	T1 end
⋮					
520	SB2	no	yes	yes	P2 onset
⋮					
605		no	yes	yes	
606	QB2	yes	no	no	Begin protected area 2nd QRS
⋮					
609	QRSonset2	yes	no	no	QRS begin 2nd QRS
⋮					
675	fc2	yes	no	no	fiducial 2nd QRS

NOTE: QB2 is not equal to QRSonset2 because in this case the difference for sample decimation (= QB2-QE1-1) would be 609-361-1= 247 samples, which is not a multiple of the 4 sample decimation. The sample 606 for QB2 is suitable, because 606-361-1= 244 samples, which is a multiple of the 4 sample decimation.

C.2.6 Computation and Storage of the Difference Data

To take advantage of inter-sample correlation, first or second successive differences of the respective data can be stored and encoded instead of the "original" values of the Reference Beat and of the Residual Record data. Usually the word length (in bits) of an original sample is much larger than that of the first or second successive differences.

The SCP-ECG Protocol leaves it to the user, whether first or second differences (or even original data) are stored/transmitted. This has to be specified in byte 5 of the header of Section 5 (for Reference Beat data) and of Section 6 (for residual data), respectively.

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C.2.6.1 Computation of First and Second Successive Differences

It is assumed that of the Residual Record, resulting from the raw data recording of N samples, Q samples remain in the decimated record.

We denote these samples for lead m:

$$Z(m,1),\ Z(m,2),\ \ldots\ Z(m,q),\ \ldots\ Z(m,Q)$$

The differences are then calculated in the following way:

First differences:

$$\Delta 1(m,q) = Z(m,q+1) - Z(m,q); q = 1 \ldots\ (Q-1)$$

(Note: $\Delta 1(m,1) \equiv Z(m,1)$, where $\equiv$ means, "is defined as")

Second differences:

$$\Delta 2(m,q) = Z(m,q+2) - 2 * Z(m,q+1) + Z(m,q);\ q = 1 \ldots\ (Q-2)$$

(Note: $\Delta 2(m,1) \equiv Z(m,1)$, $\Delta 2(m,2) \equiv Z(m,2)$)

Equivalently the first and/or second differences for the Reference Beat can be calculated from the Reference Beat data Yt(m,p).

C.2.6.2 Reconstitution of the Data from the Differences

Reconstitution of the data from the first differences requires storage/transmission of one (the first) original value because:

$$Z(m,q+1) = Z(m,q) + \Delta 1(m,q);\ q = 1 \ldots\ (Q-1)$$

where Z(m,l) is the necessary value to restore Z(m,2),

$$Z(m,2) = Z(m,1) + \Delta 1(m,1)$$

(Note: $Z(m,1) = \Delta 1(m,1)$)

Reconstitution of the data from the second differences requires storage and transmission of two original values:

$$Z(m,q+2) = 2 * Z(m,q+1) - Z(m,q) + \Delta 2(m,q);\ q = 1 \ldots\ (Q-2)$$

where Z(m,1) and Z(m,2) are the necessary values to restore Z(m,3),

$$Z(m,3) = 2 * Z(m,2) - Z(m,1) + \Delta 2(m,1)$$

(Note: $Z(m,1) = \Delta 2(m,1)$, $Z(m,2) = \Delta 2(m,2)$)

The respective original values should be stored at the beginning of the encoded data (see 5.8.2).

C.2.7 Huffman Encoding within SCP-ECG

C.2.7.1 Introduction

Huffman encoding provides a minimum redundancy encoding for data with non-uniform probability of occurrence. An encoding scheme is applied where the most frequently occurring values are assigned the shortest bit code length, the most seldomly occurring data shall be given the longest bit code length. Huffman encoding changes word oriented data into a bit-oriented data stream.

With the Huffman tables provided in the SCP-ECG protocol pure Huffman encoding and initial encoding are possible. It is possible to use more than one Huffman table and to switch between different tables during the encoding for a better compression efficiency if the distribution of the data word lengths changes.

C.2.7.1.1 Pure Huffman Encoding:

In pure Huffman encoding one data word is represented in the Huffman table with the "entire code", which is stored as the "base code" or the "prefix". For encoding the prefix shall be used and for the decoding the base value from the table. The length of the entire code in bits after encoding is equal to the length of the prefix.

EXAMPLE:

In the Huffman Table 1 presented below, the code for "0" shall be 0_b in the prefix. The entire code length is 1 bit which is equal to the length of the prefix. For the value "1" the prefix is 100_b and the bit code length shall be 3, i.e. the length of the prefix .

C.2.7.1.2 Initial Encoding:

If the data value is not contained in the Huffman table the value shall be initially encoded. The base value contains in this case no reasonable and useful value (should be "0"). But the table contains an information about the number of bits of a "remainder" in the bit stream which follows the prefix. From this remainder the reconstructed data word shall be calculated. The number of these bits is equal to the difference between the number of bits of the entire case and the prefix.

EXAMPLE:

Bit stream: 1110000000101_b

1) The comparison of the bit stream to the Huffman Table 1 presented in C.2.7.2.1 provides structure 6 for decoding. Therefore the first 4 bits are used.

2) For decoding, the method of initial encoding has to be used, because the number of bits of the prefix is less than that of the entire code. (9 bit - 1 bit = 8 bit > 0)

3) The length of the remainder is equal to the difference between the number of bits of the entire code and the prefix. In this case these are 8 bits (00000101_b), used for reconstruction of the data word.

4) To complete the data word (2 bytes), the missing bits shall be filled with the most significant bit of the remainder.

Reconstructed data word: $0000000000000101_b = 5_h$

C.2.7.2 Huffman Tables Used in SCP-ECG

The following Huffman tables are used in the examples for encoding of the ECG data.

C.2.7.2.1 Structure of the Huffman Tables

Huffman Table 1, presented below, contains 7 structures, 5 structures for pure Huffman encoding, 1 for 8-bit initial encoding and 1 for changing to Table 2. Data values less or equal 2 are pure Huffman encoded. Data values greater than 2 are initial encoded. In this case the first 4 bits of 12 bits entire code are the prefix (1111_b). The following 8 bits are the remainder.

If the third byte (**table mode switch**) of a structure (in this case no. 6) is reset to 0 this indicates that the actual Huffman table should change to the Huffman table with the number entered in the base value. In this case the prefix for changing is 1110_b and the number of the new table is 2.

Huffman Table 1

No. of code structures	number of bits		table mode	base value	prefix code (in bits)
	entire code	prefix			
1	1	1	1	0	0
2	3	3	1	1	100
3	3	3	1	-1	101
4	4	4	1	2	1100
5	4	4	1	-2	1101
6	4	4	0	2 (switch to Table 2)	1110
7	12	4	1	no entry (0), 8-bit original	1111

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Huffman Table 2 contains 5 structures, 3 structures for pure Huffman encoding, 1 for 8-bit initial encoding and 1 for changing to Table 1. Data values less or equal 1 are pure Huffman encoded. Data values greater than 1 are initial encoded. The first bit of the nine bit code is the prefix.

If the third byte (**table mode switch**) of the structure (in this case no. 5) is reset to 0 this indicates that the actual Huffman table should change to the Huffman table with the number entered in the base value. In this case the prefix for changing is 111_b and the number of the new table is 1.

Huffman Table 2

No. of code structures	number of bits		table mode	base value	prefix code (in bits)
	entire code	prefix			
1	9	1	1	no entry (0), 8-bit original	0
2	3	3	1	0	100
3	3	3	1	1	101
4	3	3	1	-1	110
5	3	3	0	1 (switch to Table 1)	111

C.2.7.2.2 Huffman Tables without Table Mode Switch

Let's consider an example of the following succession of byte-oriented data values:

1, 2, -1, 0, 3, 0, 4, 1, 0, -2,

0, 15, -1, 0, 13, 0,1, -2, -1, l

These data shall be encoded with the Huffman Table 1 from C.2.7.2.1. For each data value the corresponding bit code from the Huffman table is picked up and connected to the bit stream. If a value is not found in the table it shall be encoded with the initial encoding as described above.

Alignment of byte oriented data values and Huffman code bits:

No.	Value	Entire code	Comments
1	1	100	3 bit prefix, no remainder
2	2	1100	4 bit prefix, no remainder
3	-1	101	3 bit prefix, no remainder
4	0	0	1 bit prefix, no remainder
5	3	111100000011	4 bit prefix, 8 bit remainder
6	0	0	1 bit prefix, no remainder
7	4	111100000100	4 bit prefix, 8 bit remainder
8	1	100	3 bit prefix, no remainder
9	0	0	1 bit prefix, no remainder
10	-2	1101	4 bit prefix, no remainder
11	0	0	1 bit prefix, no remainder
12	15	111100001111	4 bit prefix, 8 bit remainder
13	-1	101	3 bit prefix, no remainder
14	0	0	1 bit prefix, no remainder
15	13	111100001101	4 bit prefix, 8 bit remainder
16	0	0	1 bit prefix, no remainder
17	1	100	3 bit prefix, no remainder
18	-2	1101	4 bit prefix, no remainder
19	-1	101	3 bit prefix, no remainder
20	1	100	3 bit prefix, no remainder

Resulting bit stream:

100110010101111000000110111100000100100011101

011110000111110101111000011010100110110110 0

C.2.7.2.3 Huffman Tables with Table Mode Switch

To get a better compression efficiency it is possible to encode data with more than one Huffman table. For example it is reasonable to encode the Reference Beat and the Residual Record with different tables. Or to switch to another Huffman table within the encoding exercise because the probability of occurrences has changed with time.

For example, should the following succession of byte oriented data values be picked up (including the switch statements):

1, 2, -1, 0, 3, 0, 4, 1, 0, -2, switch to table 2

0, 15, -1, 0, 13, switch to table 1, 0, 1, -2, -1, 1

The encoding begins with Huffman Table 1 from C.2.7.2.1. After the 10th value, the encoding changes to Huffman Table 2, and after the encoding of the 16th value, it changes back to Table 1.

Alignment of byte oriented data values and Huffman bit codes:

No.	Value	Entire code	Table	TMS	Comments
1	1	100	1	1	3 bit prf., no rem.
2	2	1100	1	1	4 bit prf., no rem.
3	-1	101	1	1	3 bit prf., no rem.
4	0	0	1	1	1 bit prf., no rem.
5	3	111100000011	1	1	4 bit prf., 8 bit rem.
6	0	0	1	1	1 bit prf., no rem.
7	4	111100000100	1	1	4 bit prf., 8 bit rem.
8	1	100	1	1	3 bit prf., no rem.
9	0	0	1	1	1 bit prf., no rem.
10	-2	1101	1	1	4 bit prf., no rem.
11	(2)	1110	1	0	4 bit prf.,->table 2
12	0	100	2	1	3 bit prf., no rem.
13	15	000001111	2	1	1 bit prf., 8 bit rem.
14	-1	110	2	1	3 bit prf., no rem.
15	0	100	2	1	3 bit prf., no rem.
16	13	000001101	2	1	1 bit prf., 8 bit rem.
17	(1)	111	2	0	3 bit prf. -> table 1
18	0	0	1	1	1 bit prf., no rem.
19	1	100	1	1	3 bit prf., no rem.
20	-2	1101	1	1	4 bit prf., no rem.
21	-1	101	1	1	3 bit prf., no rem.
22	1	100	1	1	3 bit prf., no rem.

NOTATIONS:

TMS	table mode switch,
prf.	prefix
rem.	remainder,
" -> table #"	switch to table #
(#)	# shall not be transferred from the base value to the reconstituted data field;
#	is the number of the new Huffman table

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Resulting bit stream:

10011001010111100000011011110000010010001101111 0

10000000111111010000000110111101001101101100

C.2.7.3 Definition and Storage of the Huffman Tables in Section 2

To explain how Huffman tables (for base code/prefix see Note 1) have to be stored in Section 2 the tables used within the examples C.2.7.2.2 and C.2.7.2.3 are presented like the layout overview in the SCP-ECG protocol in the main document .

Section header:	CRC	ID	length	reserved
	2[2)]	*2*	*4*	*8*

Number of tables:	2
	2

Number of structures:	7 (number for the first Table)
	2

Structure 1	1	1	1	0	0
Structure 2	3	3	1	1	1
Structure 3	3	3	1	-1	5
Structure 4	4	4	1	2	3
Structure 5	4	4	1	-2	11
Structure 6	4	4	0	2	7
Structure 7	4	12	1	0	15
for each structure[2)]	*1*	*1*	*1*	*2*	*4*

Number of structures:	5 (number for the second Table)
	2

Structure 1	1	9	1	0	0
Structure 2	3	3	1	0	1
Structure 3	3	3	1	1	5
Structure 4	3	3	1	-1	3
Structure 5	3	3	0	1	7
for each structure[2)]	*1*	*1*	*1*	*2*	*4*

NOTES:

1) Base code/prefix- 1st bit in code represented by the least significant bit of the 4 byte area. It means that the code is stored in the 4-byte field in its bit-reversed format. Thus, store code 100b (decimal 4) as 1b (decimal 1), code 1100b (decimal 12) as 0011b (decimal 3) and so on. Compare for this the last two columns in the default Huffman Table (C.2.7.4).

2) The numbers in italic indicate the length in bytes of the corresponding fields.

C.2.7.4 Definition of the Default SCP-ECG Huffman Table

Theoretically, different ECG data sets may require different Huffman code tables. However, through extended experiments with different data sets it was found that the following Huffman table can be used for practically all types of ECG data without much loss in data compression efficiency.

If, on the other hand, a manufacturer wants to apply different tables to different ECGs (ECG data sets) he can do so by specifying these tables in Section 2 of the SCP-ECG protocol.

The table below is the **Default SCP-ECG Huffman Table** referred to in the main document under 5.5.5, bytes 1-2. The table has been used for the encoding of the data depicted in the EXAMPLES 1 and 2 in C.3.1 and C.3.2, respectively.

No.	number of bits		table mode	base value	prefix code (in bits)	store binary as
	entire code	prefix				
1	1	1	1	0	0	0d
2	3	3	1	1	100	1d
3	3	3	1	-1	101	5d
4	4	4	1	2	1100	3d
5	4	4	1	-2	1101	11d
6	5	5	1	3	11100	7d
7	5	5	1	-3	11101	23d
8	6	6	1	4	111100	15d
9	6	6	1	-4	111101	47d
10	7	7	1	5	1111100	31d
11	7	7	1	-5	1111101	95d
12	8	8	1	6	11111100	63d
13	8	8	1	-6	11111101	191d
14	9	9	1	7	111111100	127d
15	9	9	1	-7	111111101	383d
16	10	10	1	8	1111111100	255d
17	10	10	1	-8	1111111101	767d
18	18	10	1	8 bit orig.	1111111110	511d
19	26	10	1	16 bit orig.	1111111111	1023d

In order to identify a switch to another Huffman Table a Table Mode Switch shall be used (see 5.5.5, byte 7 in the main document). This switch shall be inserted in the Huffman encoded data stream. It identifies the change of the Huffman Table. The new Huffman Table which shall be used to decode the data is identified in the structure (see 5.5.5, bytes 8+9 in the main document).

C.2.8 Decoding of Compressed ECG Data

To make the explanation of the compression and decompression logic consistent, the same notation has been used for variables and indices. The variables and indices used in the decompression algorithms get an apostrophe (').

Examples: Compression : X(m,n), Z(m,q), Δ1(m,q), etc.

Decompression : X'(m,n), Z'(m,q), Δ1'(m,q), etc.

C.2.8.1 Decoding with Huffman Tables

The method of decoding Huffman encoded data is as follows:

The first bit from the bit stream of every encoded lead is picked up and compared with the first (or default) Huffman table. If an equal prefix is found, the corresponding value shall be entered in the field for the decoded data. This value is in case of pure Huffman coding the corresponding base value or in case of initial encoding from the remainder reconstructed data value. The length of the remainder is equal to the difference length of entire code and prefix. If there is no equal prefix code found, the first two bits are picked up and compared, if necessary the first three and so on. Is the code found and the data value entered in the field, the comparison continues with the next bit.

If a prefix of a structure for changing to another Huffman table is found, the actual table shall be quit. This is indicated by the table mode switch of this structure. It is reset to 0. The number of the new table is read from the base value of this structure. Inside the new table the decoding can continue as described.

C.2.8.2 Reconstitution of the First and Second Differences

In the SCP-ECG protocol it is left to the user, whether first or second differences are stored/transmitted (or even original data). The kind of data is specified in the headers of Section 5 (for the Reference Beat) and Section 6 (for the Residual Record) in byte 5, respectively. It is assumed that the Residual Record, resulting from Huffman decoding, contains a total of Q values.

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C.2.8.2.1 First differences:

We denote the Huffman decoded samples for lead m:

$\Delta 1'(m,l), \Delta 1'(m,2),...\Delta 1'(m,q),...\Delta 1'(m,Q)$

The "original" data Z'(m,n) can be calculated in the following way:

$Z'(m,q) = Z'(m,q-1) + \Delta 1'(m,q); \quad q = 2..Q$

Reconstitution of the "original" data from first differences requires storage/transmission of one (the first) original data value

$Z'(m,1) = \Delta 1'(m,1)$

$Z'(m,2) = Z'(m,1) + \Delta 1'(m,2)$

where $\Delta 1'(m,1)$ is the necessary "original" value.

C.2.8.2.2 Second differences:

We denote the Huffman decoded samples for lead m:

$\Delta 2'(m,1), \Delta 2'(m,2),...\Delta 2'(m,q),...\Delta 2'(m,Q)$

The "original" data Z'(m,n) can be calculated in the following way:

$Z'(m,q) = 2*Z'(m,q-1) - Z'(m,q-2) + \Delta 2'(m,q); \quad q = 3..Q$

Reconstitution of the "original" data from second differences requires storage and transmission of two original values:

$Z'(m,1) = \Delta 2'(m,1)$

$Z'(m,2) = \Delta 2'(m,2)$

$Z'(m,3) = 2*Z'(m,2) - Z'(m,1) + \Delta 2'(m,3)$

where $\Delta 2'(m,1)$ and $\Delta 2'(m,2)$ are the necessary "original" values.

Equivalently the Reference Beat data Y'(m,p) can be calculated from the first and/or second differences of the Reference Beat .

The respective original values should be stored at the beginning of the encoded data (see 5.8.2).

C.2.8.3 Reconstitution of Decimated Samples

For "slowly changing" data a sample decimation (up to a maximum sample interval of 8ms which is equivalent to 125 samples/s) can be applied. The use of sample decimation is called bimodal compression, and is indicated by 5.9.2, byte 6.

C.2.8.3.1 There is no exact algorithm for reconstitution of the decimated samples. The best results of sample decimation are obtained if compression and decompression algorithms are adjusted to each other.

An averaging algorithm with sufficient results for compression is:

First average value:

$$Z_{av}(m,1) = \frac{X(m,1) + X(m,2) + X(m,3) + X(m,4)}{4}$$

Second average value:

$$Z_{av}(m,2) = \frac{X(m,5) + X(m,6) + X(m,7) + X(m,8)}{4}$$

…

and for decompression:

$$X'(m,i) = \frac{Z'_{av}(m,2) - Z'_{av}(m,1)}{4} * (i-1) + Z'_{av}(m,1)$$

with $1 \le i \le 4$.

$Z'_{av}(m,l)$ is the left-sided average value (equal to X'(m,1)) and $Z'_{av}(m,2)$ is the right-sided average value of the four recalculated values of the interval. This reconstruction moves over the complete non-protected area [a,b] (b-a is the number of the non-decimated samples). The first two reconstructed samples of this area are set equal to the first average value and the last two samples equal to the last average value .

Interval [a,b]:

X'(m,a) = $Z'_{av}(m,a)$,

X'(m,a+1) = $Z'_{av}(m,a)$,

Interpolation over (b-a-1)/4 intervals.

X'(m, b-1) = $Z'_{av}(m,(b-a)/4)$,

X'(m,b) = $Z'_{av}(m,(b-a)/4)$

C.2.8.3.2 EXAMPLE

The table gives an example of decimation and reconstitution of 100 samples. For easier presentation the steps with difference data and Huffman encoding are omitted. The values of Z_{av} are calculated as described above.

No.	Original	Decimated	Reconstructed
1	X'(m,1)	$Z'_{av}(m,1)$	$Z'_{av}(m,1)$
2	X'(m,2)		$Z'_{av}(m,1)$
3	X'(m,3)		$Z'_{av}(m,1)$
4	X'(m,4)		$Z'_{av}(m,1)+1*(Z'_{av}(m,2)-Z'_{av}(m,1))/4$
5	X'(m,5)	$Z'_{av}(m,2)$	$Z'_{av}(m,1)+2*(Z'_{av}(m,2)-Z'_{av}(m,1))/4$
6	X'(m,6)		$Z'_{av}(m,1)+3*(Z'_{av}(m,2)-Z'_{av}(m,1))/4$
7	X'(m,7)		$Z'_{av}(m,2)$
8	X'(m,8)		$Z'_{av}(m,2)+1*(Z'_{av}(m,3)-Z'_{av}(m,2))/4$
9	X'(m,9)	$Z'_{av}(m,3)$	$Z'_{av}(m,2)+2*(Z'_{av}(m,3)-Z'_{av}(m,2))/4$
10	X'(m,10)		$Z'_{av}(m,2)+3*(Z'_{av}(m,3)-Z'_{av}(m,2))/4$
11	X'(m,11)		$Z'_{av}(m,3)$
12	X'(m,12)		$Z'_{av}(m,3)+1*(Z'_{av}(m,4)-Z'_{av}(m,3))/4$
⋮	⋮	⋮	⋮
93	X'(m,93)	$Z'_{av}(m,24)$	Z'av(m,23)+2*(Z'av(m,24)-Z'av(m,24))/4
94	X'(m,94)		$Z'_{av}(m,23)+3*(Z'_{av}(m,24)-Z'_{av}(m,24))/4$
95	X'(m,95)		$Z'_{av}(m,24)$
96	X'(m,96)		$Z'_{av}(m,24)+1*(Z'_{av}(m,25)-Z'_{av}(m,24))/4$
97	X'(m,97)	$Z'_{av}(m,25)$	$Z'_{av}(m,24)+2*(Z'_{av}(m,25)-Z'_{av}(m,24))/4$
98	X'(m,98)		$Z'_{av}(m,24)+3*(Z'_{av}(m,25)-Z'_{av}(m,24))/4$
99	X'(m,99)		$Z'_{av}(m,25)$
100	X'(m,100)		$Z'_{av}(m,25)$

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C.2.8.4 Low Pass Filtering of Reconstructed Residual Record

Low pass filtering of the Residual Record outside the protected areas after reconstruction of the decimated samples smoothes noise which has risen during reconstitution. A simple non-recursive moving average filter has given sufficient results for low pass filtering of the Residual Record.

The filter length is 3 samples. The filter values are calculated as follows:

$$F'(m,a) = X'(m,a)$$

$$F'(m,a+1) = \frac{X'(m,a) + X'(m,a+1) + X'(m,a+2) + 1}{3}$$

$$F'(m,a+2) = \frac{X'(m,a+1) + X'(m,a+2) + X'(m,a+3) + 1}{3}$$

$$\vdots$$

$$F'(m,n) = \frac{X'(m,n-1) + X'(m,n) + X'(m,n+1) + 1}{3}$$

$$\vdots$$

$$F(m,b-1) = \frac{X'(m,b-2) + X'(m,b-1) + X'(m,b) + 1}{3}$$

$$F'(m,b) = X'(m,b)$$

for k= 0 to K
a = QE(k)+I, QE(0) = 0
b = QB(k+1)-I, QB(K+1) = 1
$a+1 \le n \le b-1$

NOTE:

1) The methods for rounding are defined in C.2.2.1and C.2.2.2. The rounding constant “1” in the previous equation should be negated in case the filtered values are negative.

C.2.8.5 Multiplication of Raw Data with AVM

This step means calibration. For this purpose the data are multiplied by the AVM to get the raw data, and in case of high compression the Residual Record and the Reference Beat in equal resolution for addition.

Raw data:

$X'_r(m,n) = X'(m,n) * AVM,$ for $1 \le n \le N$, $1 \le m \le M$

Reference Beat data:

$Y'_r(m,n) = Y'(m,p) * AVM,$ for $1 \le p \le P$, $1 \le m \le M$

C.2.8.6 Addition of the Reference Beat to the Residual Record

The SCP-ECG protocol was designed to handle data which may be compressed and encoded by differrent methods:

a) pure redundancy reduction.

b) “high SCP-ECG compression”.

In case of "high" compression it is necessary to add the Reference Beat again to the Residual Record at all locations were it was subtracted during compression. Therefore the Reference Beat shall be synchronized to the Residual Record

with the fiducial pointers stored in the SCP-ECG record as fc(k) and fc(M). Pointers to the QRS protected zones are calculated from the stored pointers. The area for addition of Reference Beat to cycle k is known through the pointers SB(k) (addition begin) and SE(k) (addition end).

NOTES:

1) Within Section 4 of the SCP-ECG protocol under 5.7.3, bytes 3-6 are reserved to store pointers for the beginning of Reference Beat data addition (SB(k)). Bytes 7-10 are reserved to store the fiducial pointer of cycle k (fc(k)) and bytes 11-14 are reserved to store the end of Reference Beat data addition (SE(k)) for each cycle, respectively. Addition on a sample by sample basis of the Reference Beat data to the Residual Record at the respective cycle location fc(k) shall get the original sample data back.

2) If the QRS type is non-zero (bytes 1-2, under 5.7.3) then Reference Beat 0 has not been substracted from this cycle. (See Note 2 under 5.7.5.)

C.2.8.7 Default SCP-ECG Decompression Parameters

- Reference Beat subtraction used (Section 3, byte 2, bit 0 = 1)
- AVM for reference beat data = 5 µV (Section 5, bytes 1+2 = 5000)
- Sample time interval for reference beat data = 2 ms (Section 5, bytes 3+4 = 2000)
- Second difference data used for reference beat data (Section 5, byte 5 = 2)
- AVM for residual record = 20 µV (Section 6, bytes 1+2 = 20000)
- Sample time interval for residual record outside protected areas (QRS) = 8 ms (Section 6, bytes 3+4 = 8000)
- Second difference data used for residual record (Section 6, byte 5 = 2)
- Sample interpolation to 2 ms sampling interval (for algorithm see C.2.8.8)
- Low pass filtering after sample interpolation with filter length of 3 samples (for algorithm see C.2.8.9)
- Huffman table for decoding of reference beat data and residual record (see default Table in C.2.7.4)

C.2.8.8 Default Method for Interpolation of Decimated Samples

In compressed data only the protected areas have the original sampling interval. The areas between the protected areas and the parts before the first and after the last protected area have to be expanded by an interpolation algorithm to get the original sampling interval.

An algorithm which gives sufficient results for sample interpolation in the interval [a,b] is as follows:

```
Z'(m,a')  = decimated samples
X'(m,a)           = interpolated samples
m                 = lead number

        X'(m,a)         = Z'(m,a')
        X'(m,a+1)       = Z'(m,a')
        X'(m,a+2)       = Z'(m,a')              Δ = (Z'(m,a'+1)-Z'(m,a')) / 4
        X'(m,a+3)       = Z'(m,a') + 1*Δ
        X'(m,a+4)       = Z'(m,a') + 2*Δ
        X'(m,a+5)       = Z'(m,a') + 3*Δ
        X'(m,a+6)       = Z'(m,a'+1)            Δ = (Z'(m,a'+2)-Z'(m,a'+1)) / 4
        .                 .
        X'(m,a+9)       = Z'(m,a'+1) + 3*Δ
        .                   .
        .                   .
        .                   .
        X'(m,b-1)       = Z'(m,b')
        X'(m,b)         = Z'(m,b')
```

These computations are performed for all K+1 data segments outside the protected areas:

```
for k = 0 to K
        a = QE(k)+I             QE(0) = 0
        b = QB(k+1)-1           QB(K+1) = N+1
```

C.2.8.9 Default Method for Three Sample Point Moving Average

Low pass filtering of the reconstituted residual record is done for smoothing of the truncation steps. Low pass filtering can only be done outside the protected areas, because inside the QRS the reconstruction error is strictly limited to 15 µV. Special care has to be taken to the boundaries of the subtraction areas. After the subtraction of the reference beat data there can be steps at these boundaries and those steps shall be present again after the addition of the reference

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beat data. Therefore they cannot be eliminated by filtering. A simple non-recursive moving averaging filter has given sufficient results for low pass filtering of the reconstituted residual record

The filter length (L) shall be 3 samples. The filter values for an odd filter length L are calculated as follows:

$$F'(m,a) = X'(m,a)$$

$$F'(m,a+1) = \frac{X'(m,a) + X'(m,a+1) + X'(m,a+2) + 1}{3}$$

$$\vdots$$

$$F'(m,n) = \frac{X'(m,n-(L-1)/2) + \ldots + X'(m,n) + \ldots + X'(m,n+(L-1)/2) + (L-1)/2}{L}$$

$$\vdots$$

$$F'(m,b-1) = \frac{X'(m,b-2) + X'(m,b-1) + X'(m,b) + 1}{3}$$

$$F'(m,b) = X'(m,b)$$

There are 3 filter intervals [a,b] for each complex k, and an additional one from the end of complex K to the end of the data stream:

1) From the end of the reference beat subtraction of the preceding complex (k-l) to the beginning of subtraction of the current complex (k).

   a = SE(k-1)+l SE(0)= 0

   b = SB(k)-1

2) From the beginning of the reference beat subtraction of the current complex (k) to the QRS onset of the current complex (k).

   a = SB(k)

   b = QB(k)-1

3) From the QRS offset of the current complex (k) to the end of the reference beat subtraction of the current complex (k).

   a = QE(k)+1

   b = SE(k)

4) The filter interval for the remaining samples until the end of the data is:

   a = SE(K)+1

   b = N

NOTATIONS:

m = lead number

n = sample number

K= number of QRS complexes

N = number of the last sample

k = QRS complex number

Pointer to begin subtraction of Reference Beat for cycle (k) in raw data: SB(k)
Pointer to end subtraction of Reference Beat data for cycle (k) in raw data: SE(k)

Pointer to the beginning of the protected area for complex k in the raw data and in the residual data: QB(k)
Pointer to end of the protected area for complex k in the raw data and in the residual data: QE(k)

NOTE:

1) The methods for rounding are defined in C.2.2.1 and C.2.2.2. The rounding constants 1,... (L-1)/2 in the previous equation should be negated in case the filtered values are negative.

C.3 Numerical examples for SCP-ECG data compression

C.3.1 EXAMPLE 1

This example shows the different data obtained during SCP-ECG high compression for the first 28 samples of an ECG record.

RAW: raw data with 1 µV/LSB, sampling interval 2 ms (500 samples/s)

TRU: truncated raw data l µV/LSB -> 5 µV/LSB

RES: Residual Record, after subtraction of the Reference Beat

FIL: non-recursive moving average filter over 9 samples

DEC: sampling rate decimation to 8 ms with averaging (125 samples/s)

2D: second differences, first two original values

HUF: Huffman encoding (default code table see C.2.7.4)

Sample Number	RAW	TRU	RES	FIL	DEC	2D	HUF
1	63	13	13	13	14	14	111111111000001110
2	70	14	14	14			
3	74	15	15	14			
4	71	14	14	15			
5	79	16	16	16	18	18	111111111000010010
6	89	18	18	17			
7	96	19	19	19			
8	102	20	20	20			
9	108	22	22	21	22	0	0
10	112	22	22	22			
11	114	23	23	22			
12	116	23	23	23			
13	116	23	23	23	22	-4	111101
14	112	22	22	22			
15	110	22	22	21			
16	100	20	20	19			
17	87	17	17	18	13	-9	111111111011110111
18	74	15	15	14			
19	59	12	12	12			
20	42	8	8	9			

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Sample Number	RAW	TRU	RES	FIL	DEC	2D	HUF
21	28	6	6	6	3	-1	101
22	13	3	3	4			
23	5	1	1	2			
24	-1	0	0	0			
25	-8	-2	-2	-1	-2	5	1111100
26	-11	-2	-2	-2			
27	-13	-3	-3	-3			
28	-17	-3	-3	-3			
...	...	...	...	...	...	...	...

56 bytes = 448 bits -> reduced to 71 bits

The first 28 samples of the raw data lead are compressed to this bit stream:

11111111100000111011111111110000100100

11110111111111101111011111011111100...

which is hexadecimal represented by these bytes:

FF 83 BF E1 27 BF F7 BD ...

C.3.2 EXAMPLE 2

This example shows the different data obtained during SCP-ECG pure redundancy reduction for the first 28 samples of an ECG record.

RAW: raw data with 1 µV/LSB, sampling interval 2 ms (500 samples/s)

TRU: truncated raw data 1 µV/LSB -> 5 µV/LSB

RES: Residual Record, after subtraction of the Reference Beat

2D: second differences, first two data are original values

HUF: Huffman encoding with default Huffman table (see C.2.7.4)

Sample Number	RAW	TRU	RES	2D	HUF
1	63	13	13	13	111111111000001101
2	70	14	14	14	111111111000001110
3	74	15	15	0	0
4	71	14	14	-2	1101
5	79	16	16	3	11100
6	89	18	18	0	0
7	96	19	19	-1	101
8	102	20	20	0	0
9	108	22	22	1	100
10	112	22	22	-2	1101
11	114	23	23	1	100

Sample Number	RAW	TRU	RES	2D	HUF
12	116	23	23	-1	101
13	116	23	23	0	0
14	112	22	22	-1	101
15	110	22	22	1	100
16	100	20	20	-2	1101
17	87	17	17	-1	101
18	74	15	15	1	100
19	59	12	12	-1	101
20	42	8	8	-1	101
21	28	6	6	2	1100
22	13	3	3	-1	101
23	5	1	1	1	100
24	-1	0	0	1	100
25	-8	-2	-2	-1	101
26	-11	-2	-2	2	1100
27	-13	-3	-3	-1	101
28	-17	-3	-3	1	100
...	...	...	...		

56 bytes = 448 bits -> reduced to 113 bits

The first 28 samples of the lead are compressed to this bit stream:

11111111100000110111111111110000011100110111101010101001101100 1

0101011001101101100101101110010110010010111001011 00...

which is hexadecimal represented by these bytes:

FF 83 7F E0 E6 F5 53 65 59 B6 5B 96 4B 96..

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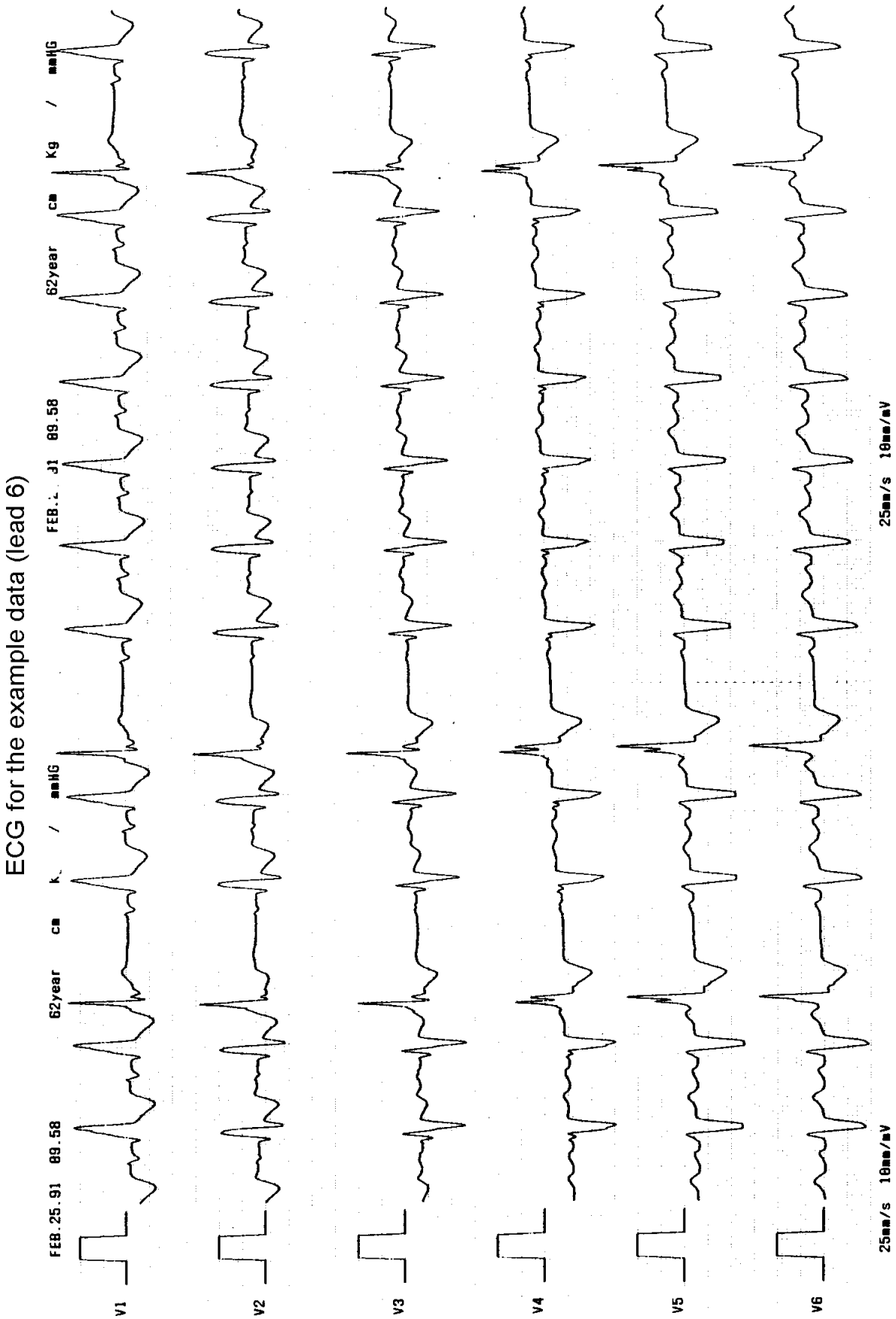
ECG for the example data (lead 6)



C.4 Test set of ECGs for conformance testing

The Table on the following page lists the ECGs selected for testing SCP-ECG compression and decompression errors. The data are provided as 10 seconds digital records with 500 samples/s and 5 µV LSB quantization level. There are ECGs with sinus rhythm, with atrial fibrillation and atrial flutter, with polyform and monoform ventricular extrasystoles, with bigeminy and a supraventricular extrasystole. Two cases with major intraventricular conduction defects are included. To verify the absolute calibration, an artificial ECG with low noise and a heart rate of 120/minute and sinus rhythm has also been included.

These data are selected from the CSE multilead reference database for wave recognition testing and from the CSE diagnostic reference database. A few data have been slightly smoothed to remove some noise. All these ECG recordings have been compressed and decompressed within the standards proposed by the SCP-ECG Working Group. The RMS error figures and the absolute maximum errors found after reconstitution of the original signals are listed in the following table.

TEST SET FOR ERROR VERIFICATION OF SCP-ECG COMPRESSION REQUIREMENTS

Patient	Rhythm, QRS Morphology	Noise
PD2-003	Sinus rhythm, anterior infarction, QRS with notch	5 µV
Decompressed	Abs. max. error: 64 µV; RMS: 7.9 µV	
PD2-010	Sinus tachycardia;	6 µV
Decompressed	Abs. max. error: 67µV; RMS: 8.1 µV	
PD2-051	Sinus rhythm, infarction	3 µV
Decompressed	Abs. max. error: 44 µV; RMS: 7.6 µV	
PD2-078	Atrial flutter, muscle tremor in leads I, and II, large amplitudes (prefiltered)	16 µV
PF2-078	Abs. max. error: 43 µV; RMS: 8.8 µV	10 µV
Decompressed		
PD2-217	Sinus rhythm, intraventr. conduction defect, anterior infarction	3 µV
Decompressed	Abs. max. error: 39 µV; RMS: 7.5 µV	
PD2-313	Atrial flutter/fibrillation	8 µV
Decompressed	Abs. max. error: 62 µV; RMS: 8.8 µV	
PD3-145	Polymorphic ventricular extrasystoles (prefiltered)	18 µV
PF3-145	Abs. max. error: 77 µV; RMS: 8.6 µV	8 µV
Decompressed		
PD3-167	Bigeminy (prefiltered)	15 µV
PF3-167	Abs. max. error: 41 µV; RMS: 9.8 µV	9 µV
Decompressed		
PD3-471	Atrial flutter	4 µV
Decompressed	Abs. max. error: 52 µV; RMS: 8.1 µV	
PD3-1207	Supraventricular extrasystoles (prefiltered)	6 µV
PF3-1207	Abs. max. error: 89 µV; RMS: 7.7 µV	4 µV
Decompressed		
PWE-103	Polymorphic ventricular extrasystoles (prefiltered)	26 µV
PFE-103	Abs. max. error: 41 µV; RMS: 8.6 µV	8 µV
Decompressed		
PWE-105	Ventricular extrasystoles, complete right bundle branch block (prefiltered)	19 µV

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Patient	Rhythm, QRS Morphology	Noise
PFE-105 Decompressed	Abs. max. error: 54 µV; RMS: 7.7 µV	12 µV
P120-N00 Decompressed	Sinus tachycardia, normal QRS complex-mathematically constructed Abs. max. error: 16 µV; RMS: 5.0 µV	0 µV 3 µV

ANNEX D
(Informative)

Universal electrocardiographic interpretation statement codes

D.0 Introduction

Universal ECG interpretive statement codes may be used, in addition to free text, to transfer interpretive statements between various ECG analysis systems, but also between such systems and clinical workstations and hospital information systems.

A common set of statement codes is of utmost importance in order to exchange interpretive ECG messages in a multilingual environment, and is also an important asset for data compression.

These codes can also be used for storage of the overreading trail. Storage of overreading results is necessary for legal reasons. Changes made to the computer interpretation by a cardiologist need to be stored, and should be retrievable for transfer to general practitioners or other specialists, and to other third parties.

D.1 Constraints

The coding scheme presented below provides a "pragmatic" approach to the problem of mapping computer statements onto a common and understandable lexicon. Simple, basic mnemonics, modifiers and conjunctives are proposed which can be used to compose and reflect simple but also rather complex ECG interpretive statements.

It should clearly be understood that it is not assumed that ECG computer programs should attempt to make all the statements listed in this Annex. This is beyond the reach of current technology and even the desire of cardiologists. Indeed, based on the ECG alone several statements listed in this Annex are hard to make on an objective basis. The present Standard does not want to provide a value judgment on the usefullness or limitations of standard electrocardiography. However, this Annex attempts to provide a fair representation of the electrocardiographic terminology and ECG reporting used in current practice.

D.2 Composition of the code and general syntax rules

D.2.1 General principle

Mnemonics which are as far as possible widely used in the literature, and which can possibly be remembered by physicians overreading ECGs, have been used. These mnemonics can be converted into numeric codes for "internal" program use. The electrocardiographer who only occasionally reviews computerized ECG interpretations cannot be expected to familiarize himself with a set of code numbers or the sometimes rather complex mnemonics used in the programs of different manufacturers.

Through the use of a flexible, but unique code structure, the computer can be made to gain at least a general understanding about the changes made by readers without forcing them into a strict use of numbers. Vice versa, rather complex statements hidden in the free text of computer interpretive reports can by means of acronyms and simple syntax rules be converted into universal understandable statement codes.

Future updates of the statement codes shall be done in the CSE Coordinating Center in Leuven, Belgium and released with future versions of the SCP-ECG Protocol.

D.2.2 Basic composition of the code

The universal SCP-ECG interpretation code consists of one or more fields. In principle there is no limit to the number of different fields, except that the parsing and phrasing of the interpretive statement may become too long.

- The **first field** (5 bytes long) defines the basic diagnostic interpretation or descriptive statement.
- The **second field** (one or two bytes) is primarly used to indicate an estimated probability that a statement is correct or to define the certainty degree of the corresponding statement.
  e.g. A or DE = definite D or CE = rule out/cannot exclude

  B or PR = probable SS = strongly suggestive

  C or PS = possible CO = consider

  U or UN = unknown CW = consistent with

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The second field can also be used for other purposes (see below).

- The **third and other field**s (two bytes) are used for other modifiers

D.2.3 Modifiers

The following modifiers can be used:

1) to indicate the age of an infarction or ischemic ST-T changes

   OL = old EV = evolving

   RE = recent XO = probably old

   AC = acute XA = probably acute (recent)

   SU = subacute YO = possibly old

   AI = age indeterminate YA = possibly acute (recent)

   AU= age undetermined

2) to indicate the location of ST-T and other abnormalities

   AN = anterior BA = basal

   AS = anteroseptal AF = antero-inferior

   AL = anterolateral SE = septal

   IN = inferior PL = posterolateral

   IL = inferolateral SN = subendocardial

   PO = posterior SP = subepicardial

   LA = lateral EX = extensive

   HL = high lateral WI = widespread

   IP = inferoposterior DI = diffuse

3) to indicate the severity of the abnormality e.g. hypertrophy, conduction defect or ST-depression

   - MA = major, MO = moderate and MI = minor

   - Another coding scheme e.g. S1 to S5, may be used, where grade S1 is used to define light and grade S5 represents very prominent

4) to indicate the evolving nature or time course of some abnormalities, where:

   - SE: serial changes consistent with...

   - CC: continuing changes of...

   - OC: occasional TR: transient UF: unifocal

   - IM: intermittent FR: frequent MF: multifocal

   - TE: temporary

   - EV: evolving

   - NE: new- MU: multiple

5) to indicate the physiopathological nature of ST-T changes

   - LV: compatible with left ventricular strain

   - MD: compatible with myocardial ischemic damage

- PE: compatible with pericarditis

- EL: compatible with electrolyte abnormalities

6) to indicate the normality or abnormality of a finding

- NO: within normal limits

- NX: may be normal variant

- BO: borderline

- AB: abnormal

- BN: borderline normal

- BA: borderline abnormal

7) rhythm modifiers / anatomic locations

- SI: sinus

- AT: atrial

- SV: supraventricular

- ND: nodal

- VE: ventricular

8) miscellaneous

- IC: incomplete

- CP: complete

- TY: typical

- YT: atypical (Note: AT means "atrial"; see above in (7))

D.2.4 Separation delimiters

1) The different fields within a statement code shall be separated by an underscore, e.g. LVH_PR.

2) The main diagnostic code shall be put first. The modifier indicating the certainty or probablity of a code shall be put as second (as shown in (1) LVH_PR). In case the program or the reader is uncertain about a modifier such as the phase of an infarction or of ischemic ST-T changes, then a certainty modifier should be added to this modifier, as demonstrated in the following examples:

   AMI_PR_AC: means Probable acute anterior infarction

   AMI_AC_PR: means Anterior infarction, probably acute

   AMI_PR_AC_PR: means Probable anterior infarction, probably acute.

   In the second case there is assumed (definite) certainty about the infarction, but uncertainty about its phase.

3) Various statement codes shall be separated from each other by semicolons. Statements shall be preceeded by sequence numbers during the transmission of the data (see SCP-ECG Protocol). These sequence numbers can be used to link various statements, but also conjunctive terms can be used to this end.

D.2.5 Conjunctive terms

Conjunctive terms may be used to link statements or to create composite statements.

1) The classical Boolean operators can be used as conjunctives, i.e.: AND, OR, NOT, XOR, EOR.

The conjunctive NOT can be used to indicate that the leading statement is true "in absence of" or "without" the subsequent statement.

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2) The following arithmetic and relational operators can be used as conjunctives:

- ADD: add (+)
- SUB: subtract (-)
- MPY: multiply (*)
- DIV: divide (/)
- EXP: exponent
- SQR: square root of
- ABS: absolute value of
- MAX: maximum value of
- MIN: minimum value of
- EQU: equals
- ILT: is less than
- IGT: is greater than
- INE: is not equal to
- IGE: is greater than or equal to
- ILE: is less than or equal to

3) Conjunctive terms with respect to serial comparison, such as:

- SER: serial changes of
- DEC: decreased (in comparison to the previous recording)
- INC: increased (in comparison to the previous recording)
- UNC: unchanged/has not changed (in comparison to the previous recording)
- CHG: changed/has changed (in comparison to the previous recording)
- DIS: (now) disappeared (in comparison to the previous recording)
- REP: (now) replaced ((statement) reported previously)
- IMP: improved (compared to)
- WRS: worse (compared to)

4) Other conjunctive terms can also be used, such as:

- RES: to indicate that the leading statement "results" in (or "causes") the next statement.
- SEC: to indicate that the leading statment is "secondary to" the subsequent statement
- ASS: is associated with
- EXC: exclude, rule out, or consider also the next statement.
- WTH: with
- ALT: alternating with.

The conjunctive terms can be max. 3 bytes long and shall be given between two semicolons to link separate statements.

Linkage of the conjunctive terms within a composite statement shall be performed with the underscore (_) sign.

D.3 Acronyms for ECG interpretive statements

D.3.1 References used for the elaboration of this proposal

Lists with interpretive statements of different ECG computer programs have been consulted to elaborate the current proposal. These lists can be found in the 5th to 8th CSE Progress Reports, as well as in the Physicians Handbook of several manufacturers.

In addition, two reports on "Standardization of terminology and interpretation" and on "Definitions and classification of cardiac arrhythmias" have largely been used. These reports have been published respectively in the Amer. J. Cardiology (1978;41:130-145), and in the Amer. Heart J. (1978;95:796-806).

D.3.2 Acronyms

D.3.2.1 Normal/Abnormal

NORM	normal ECG
NLECG	normal ECG
NLQRS	normal QRS
NLP	normal P wave
NLSTT	normal ST-T
WHNOR	ECG within normal limits for age and sex
POSNL	possibly normal ECG
BOECG	borderline ECG
ABECG	abnormal ECG
POSAB	possibly abnormal ECG
ABQRS	abnormal QRS
ABSTT	abnormal ST-T
NFA	normal for age
NFB	normal for build
ABFA	abnormal for age
ABFB	abnormal for build
UFB	unusual for build

D.3.2.2 Ventricular Hypertrophy

LVH	left ventricular hypertrophy
VCLVH	voltage criteria (QRS) for left ventricular hypertrophy
RVH	right ventricular hypertrophy
VCRVH	voltage criteria (QRS) for right ventricular hypertrophy
BVH	biventricular hypertrophy
SEHYP	septal hypertrophy
PRANT	prominent anterior forces

D.3.2.3 Myocardial Infarction

(The infarct location shall preferentially be defined within the basic acronym, but can also be defined with a location modifier)

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MI	myocardial infarction
AMI	anterior myocardial infarction
ASMI	anteroseptal myocardial infarction
ALMI	anterolateral myocardial infarction
LMI	lateral myocardial infarction
HLMI	high-lateral myocardial infarction
APMI	apical myocardial infarction
IMI	inferior myocardial infarction
ILMI	inferolateral myocardial infarction
IPMI	inferoposterior myocardial infarction
IPLMI	inferoposterolateral myocardial infarction
PMI	posterior myocardial infarction

D.3.2.4 Conduction disturbances

(for definitions J. Amer. Coll. Cardiol. 5:1261-75, 1985.)

BBB	unspecified bundle branch block
CLBBB	complete left bundle branch block
ILBBB	incomplete left bundle branch block
ALBBB	atypical left bundle branch block
CRBBB	complete right bundle branch block
IRBBB	incomplete right bundle branch block
IVCD	non-specific intraventricular conduction disturbance (block)
IVCD>	intraventricular conduction disturbance (QRS>120 ms)
IVCD<	minor intraventricular conduction disturbance (QRS<120 ms)
WPW	Wolf-Parkinson-White syndrome
WPWA	Wolf-Parkinson type A
WPWB	Wolf-Parkinson type B
PREEX	pre-excitation
LAFB	left anterior fascicular block
LPFB	left posterior fascicular block
BIFAS	bifascicular block (its two components shall always be listed separately)
TRFAS	trifascicular block

D.3.2.5 Other QRS morphology or general descriptive statements

COPD	ECG consistent with chronic obstructive pulmonary disease
PE	pulmonary emphysema
QWAVE	Q waves present
POORR	poor R-wave progression in precordial leads

ABRPR	abnormal R-wave progression
PROMR	prominent R waves in right precordial leads
DXTRO	dextrocardia
LVOLT	low QRS voltages in the frontal and horizontal leads
HVOLT	high QRS voltage
LVOLF	low voltage in frontal leads
LVOLH	low QRS voltages in the horizontal leads
HVOLF	high QRS voltages in the frontal leads
HVOLH	high QRS voltage in the horizontal leads
S1S23	S1 S2 S3 type QRS pattern
RSR1	rSr' type in V1 or V2
TRNZL	Transition zone in precordial leads displaced to the left
TRNZR	Transition zone in precordial leads displaced to the right
MYOPA	compatible with cardiomyopathy
MYOCA	compatible with myocarditis
CRIMA	criteria for
CRIMO	moderate criteria for
CRIMI	minimal criteria for

D.3.2.6 Rhythm Statements

(for definitions of rhythm statements see Amer. Heart J. 95:796-806, 1978)

Statements related to impulse formation (abnormalities)

SR	sinus rhythm
NSR	normal sinus rhythm
SARRH	sinus arrhythmia
MSAR	marked sinus arrhythmia
SVARR	supraventricular arrhythmia
STACH	sinus tachycardia
ETACH	extreme tachycardia
SBRAD	sinus bradycardia
EBRAD	extreme bradycardia
JTACH	junctional tachycardia
SVTAC	supraventricular tachycardia
JBRAD	junctional bradycardia
SVBRA	supraventricular bradycardia
WQTAC	wide QRS tachycardia
NQTAC	narrow QRS tachycardia

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TACHO	tachycardia, origin unknown or not specified
BRADO	bradycardia, origin unknown or not specified
ARRHY	arrhythmia, origin unknown
IRREG	irregular rhythm
REGRH	regular rhythm
JESCR	junctional escape rhythm
VESCR	ventricular escape rhythm
ACAR	accelerated atrial rhythm
ACVR	accelerated ventricular rhythm
ACJR	accelerated junctional rhythm
AVJR	AV-junctional rhythm
ARHYT	atrial rhythm
SVRHY	supraventricular rhythm
JRHYT	junctional rhythm
VRHYT	ventricular rhythm
UNRHY	undetermined rhythm
EAR	ectopic atrial rhythm
LAR	left atrial rhythm
MAR	multifocal atrial rhythm
NODRH	nodal rhythm
RAR	low right atrial rhythm
LGL	Lown-Ganong-Levine syndrome
SHTPR	Short PR-interval
AFIB	atrial fibrillation
AFLT	atrial flutter
ATACH	atrial tachycardia
PSVT	paroxysmal supraventricular tachycardia
PAT	paroxysmal atrial tachycardia
MFAT	multifocal atrial tachycardia
RATAC	run of atrial tachycardia
RJTAC	run of junctional tachycardia
AVNRT	atrioventricular nodal re-entrant tachycardia
AVRT	atrioventricular reciprocating tachycardia
IDIOR	idioventricular rhythm
VFIB	ventricular fibrillation
VTACH	ventricular tachycardia

RVTAC	run of ventricular tachycardia
SVT	sustained ventricular tachycardia
NSVT	non-sustained ventricular tachycardia
TORSA	torsade des pointes ventricular tachycardia
MTACH	multifocal tachycardia (multiform), supraventr. or ventricular
VFLT	ventricular flutter
ASYST	asystole

Sinus node dysfunction, atrial and AV-conduction defects

1AVB	first degree AV block
2AVB	second degree AV block
3AVB	third degree AV block
I2AVB	intermittent second degree AV block
A2AVB	alternating second degree AV block
AVDIS	AV-dissociation
WENCK	Wenckebach phenomenon
MOBI2	Mobitz type 2 second degree AV block
SAR	sinus arrest
SARA	sinus arrest with atrial escape
SARSV	sinus arrest with supraventricular escape
SARJ	sinus arrest with junctional escape
SARV	sinus arrest with ventricular escape
SABLK	sino-atrial block
SPAUS	sinus pause
WANDP	wandering pacemaker
LRR	long R-R interval measured
OCAP	occasional capture

Statements related to ectopic rhythm abnormalities

PRC(S)	premature complex(es)
PAC or APC (APB)	atrial premature complex (beat) (use of APB is not recommended)
BPAC	blocked premature atrial contraction
MAPCS	multiple atrial premature complexes
PVC or VPC (VPB)	ventricular premature complex (beat) (use of VPB is not recommended)
MVPCS	multiple premature ventricular complexes
RVPCS or RPVCS	run of ventricular premature complexes

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RAPCS	run of atrial premature complexes
RJPCS	run of junctional premature complexes
VIC	ventricular interpolated complexes
MVICS	multiple ventricular interpolated complexes
MICS	multiple interpolated complexes
SVPC	supraventricular premature complex
SVPCS	(multiple) supraventricular premature complexes
SVIC(S)	supraventricular interpolated complex(es)
ABER(S)	aberrantly conducted complex(es)
ABPCS	aberrant premature complexes, origin unknown
ABSVC	aberrant complex, possibly supraventricular origin
ABSVS	aberrant complexes, possibly supraventricular origin
ABASH	aberrant supraventricular complexes of the Ashman type
JPC(S)	junctional premature complex(es)
MJPCS	multiple junctional premature complexes
PVPCS or PPVCS	paired ventricular premature complexes
PAPCS	paired atrial premature complexes
PJPCS	paired junctional premature complexes
OVPAC	occasional ventricular paced complexes
ONPAC	occasional non-paced complexes
VBIG	ventricular bigeminy
ABIG	atrial bigeminy
SVBIG	supraventricular bigeminy
BIGU	bigeminal pattern (unknown origin, SV or Ventricular)
FUSC(S)	fusion complex(es)
CAPT(S)	capture complex(es)
VEC(S)	ventricular escape complex(es)
AEC(S)	atrial escape complex(es)
SVEC(S)	supraventricular escape complex(es)
JEC(S)	junctional escape complex(es)
ESCUN	escape complex, origin unknown
VPARA	ventricular parasystole
APARA	atrial parasystole
VTRIG	ventricular trigeminy
ATRIG	atrial trigeminy

SVTRI	supraventricular trigeminy
TRIGU	trigeminal pattern (unknown origin, SV or Ventricular)
VQUAG	ventricular quadrigeminy
RECIP	reciprocal or re-entrant impulse

Statements related to (predominant) conduction and block

B2T1	(predominant) 2:1 block
B3T1	(predominant) 3:1 block
B4T1	(predominant) 4:1 block
B5T1	(predominant) 5:1 block
VARBL	variable block
EXIBL	exit block
ENTBL	entrance block
VABL	ventriculo-atrial block
BLOCK	unspecified delay or failure of impulse propagation
C2T1	(predominant) 2:1 conduction
C3T1	(predominant) 3:1 conduction
C4T1	(predominant) 4:1 conduction
C5T1	(predominant) 5:1 conduction
VARCO	variable conduction
SVR	slow ventricular response
IVR	irregular ventricular response
RVR	rapid ventricular response
WRV	wide rate variation
AAVCO	accelerated AV conduction
RETCO	retrograde conduction
ANTCO	anterograde conduction
ORTCO	orthograde conduction
ABBCO	aberrant conduction
CONCO	concealed conduction
AVREN	AV nodal re-entry
CONRE	concealed re-entry
RENTR	re-entry phenomenon
AECHO	return of impulse to its chamber of origin: the atrium
VECHO	return of impulse to its chamber of origin: the ventricle
FCOUP	fixed coupling interval
VCOUP	variable coupling interval

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Pacemaker types and pacemaker function

PACE	normal functioning artificial pacemaker
PACEA	artificial pacemaker rhythm with 100% capture
PACEP	artificial pacemaker rhythm with partial capture
PACEF	artificial pacemaker rhythm with underlying atrial fib or flutter
PACED	demand pacemaker rhythm
PACEM	malfunctioning artificial pacemaker
EPAVS	electronic pacemaker AV sequential, normal capture
EPVC	electronic pacemaker, ventricular capture
EPDM	electronic pacemaker, demand mode
EPFC	electronic pacemaker, failure to capture
EPFS	electronic pacemaker, failure to sense
EPARV	bipolar electronic pacemaker at the apex of the right ventricle
EPU	unipolar electronic pacemaker
EPURV	unipolar electronic pacemaker at the apex of the right ventricle
PAA	electronic atrial pacing
PAD	dual chamber electronic pacing
PAVA	electronic ventricular pacing with atrial sensing
PADEM	demand pacing, analysis based upon intrinsic complexes
OVPAC	occasional ventricular paced complexes
ONPAC	occasional non-paced complexes

- international classification of pacemaker types

PAVVI	- 3rd byte = the chamber paced:
PAAAI	V: ventricle; A: atrium; D: both
PAVAT	- 4th byte = the chamber sensed:
PAVDD	V, A, D: same as above; O: no sensing
PADVI	- 5th byte = the response of the pacemaker to a sensed beat:
PADDD	T: triggered;
	I: inhibited;
	D:double (atrial triggered + ventricular inhibited or atrial triggered/inhibited + ventric. inhibited)

-other rhythm related statements

ARATE	atrial rate
VRATE	ventricular rate
RATE	rate, not specified ventricular or atrial (but mostly ventricular)
RHY(T)	rhythm

D.3.2.7 Descriptive axis statements

LAD	left axis deviation of QRS in frontal plane (< -30)
RAD	right axis deviation of QRS in frontal plane (> +90)
AXL	leftward axis (i.e. not severe enough to be called LAD)
AXR	rightward axis (i.e. not severe enough to be called RAD)
AXIND	QRS axis indeterminate
AXSUP	axis shifted superiorly
AXPOS	axis shifted posteriorly
AXVER	axis vertical in frontal plane
AXHOR	horizontal axis in frontal plane
TRSLT	transition in horizontal leads shifted leftward
TRSRT	transition in horizontal leads shifted rightward
CCWRT	counterclockwise rotation
CWRT	clockwise rotation

D.3.2.8 ST-T descriptive statements

The following basic roots are proposed:

ISC_	ischemic
INJ_	subendocardial injury
EPI_	epicardial injury
STT_	ST-T change
NST_	non-specific ST changes
STE_	non-specific ST elevation
STD_	non-specific ST depression
RST_	reciprocal ST-T changes
TAB_	T-wave abnormality
NT_	non-specific T-wave changes

Two solutions can be used to define the location of the ST-T changes - either by using a location modifier - or by extending the root with 2 more characters to define the region, as follows:

ischemic ST-T changes

ISCAN	- in anterior leads
ISCAL	- in anterolateral leads
ISCIN	- in inferior leads
ISCAS	- in anteroseptal leads
ISCLA	- in lateral leads
ISCPO	- in posterior region
ISCIP	- in inferoposterior region

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ISCIL	- in inferolateral leads	
ISCAF	- in antero-inferior leads	
ISCWI	widespread ischemic ST-T changes	
ISCDI	diffuse ischemic ST-T changes	
ischemic ST-T changes compatible with subendocardial injury		
INJAN	- in anterior leads	
INJAL	- in anterolateral leads	
INJIN	- in inferior leads	
INJAS	- in anteroseptal leads	
INJLA	- in lateral leads	
INJPO	- in posterior region	
INJIP	- in inferoposterior region	
INJIL	- in inferolateral leads	
INJAF	- in antero-inferior leads	
INJWI	widespread subendocardial injury	
INJDI	diffuse subendocardial injury	
ST-T changes compatible with subepicardial injury		
EPIAN	- in anterior leads	
EPIAL	- in anterolateral leads	
IPIIN	- in inferior leads	
EPIAS	- in anteroseptal leads	
EPILA	- in lateral leads	
EPIPO	- in posterior region	
EPIIP	- in inferoposterior region	
EPIIL	- in inferolateral leads	
EPIAF	- in antero-inferior leads	
EPIWI	widespread subepicardial injury	
EPIDI	diffuse subepicardial injury	
non-specific ST-T changes		alternative
NSTAN	- in anterior leads	STNAN
NSTAL	- in anterolateral leads	STNAL
NSTIN	- in inferior leads	STNIN
NSTAS	- in anteroseptal leads	STNAS
NSTLA	- in lateral leads	STNLA
NSTPO	- in posterior region	STNPO
NSTIL	- in inferolateral leads	STNIL

NSTAF	- in antero-inferior leads	STNAF
NSTWI	widespread non-specific ST-T changes	STNWI
NSTDI	diffuse non-specific ST-T changes	STNDI

non-specific ST elevation

STExx and replace xx by the corresponding lead or location, e.g. AN

non-specific ST depression

STDxx and replace xx by the corresponding lead or location, e.g. AL

other ST-T descriptive statements

NDT	non-diagnostic T abnormalities
TNOR	normal T-wave variations
DIG	digitalis-effect
HTVOL	high T-voltages
QUIN	ST-T changes due to quinidine-effect
PERIC	ST-T changes compatible with pericarditis
STVAG	ST-elevation V1-V3 possibly due to enhanced vagal tone
LNGQT	long QT-interval
SHTQT	short QT-interval
HIGHT	high amplitude T-waves
LOWT	low amplitude T-waves
INVT	inverted T-waves
HPOCA	consider hypocalcemia
HPOK	consider hypokalemia
HPRCA	consider hypercalcemia
HPRK	consider hyperkalemia
STDJ	junctional ST depression
REPOL	ST-T changes compatible with early repolarization
ANEUR	ST-T changes compatible with ventricular aneurysm
POSTO	post-operative changes
PULM	compatible with pulmonary embolism
ACET	related to pacemaker activity
NDOC	compatible with endocrine disease
METAB	possibly due to metabolic changes
IBP	compatible with hypertension
CONG	secondary to congenital heart disease
VALV	secondary to valvular heart disease
RESP	secondary to respiratory disease

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JUV	juvenile T waves
CLIN	interpret with clinical data
MYOIN	suggests myocardial infarction (no location specified)
ISDIG	compatible with ischemia / digitalis effect
STNOR	normal variant
STPAC	review ST-T analysis for the effects of pacing
STPVC	post-extrasystolic T-wave changes

D.3.2.9 Atrial statements

LAO/LAE	left atrial overload/enlargement
RAO/RAE	right atrial overload/enlargement
BAO/BAE	bi-atrial overload/enlargement
IACD	intra-atrial conduction delay
HPVOL	high P-voltages
NSPEP	non-specific P wave abnormalities
ABPAX	abnormal P-axis
UNPAX	unusual P-axis

D.3.2.10 Statements related to pediatric ECG analysis

PED	pediatric interpretation
RVD	right ventricular dominance
ASD	changes compatible with atrial septal defect (ostium secundum)
ECD	compatible endocardial cushion defect (ASD ostium primum)
EBSTA	compatible with Ebstein's anomaly
TCA	compatible with tricuspid atresia
ACA	compatible with anomalous location of the coronary artery

D.3.2.11 Statements related to the ECG calibration

HSCAL	all leads half standard calibration (i.e. 5 mm/mV)
HSPRE	precordial leads half standard calibration
HSLIM	limb leads half standard calibration
DSCAL	all leads double standard calibration (i.e. 20 mm/mV)
DSPRE	precordial leads double standard calibration
DSLIM	limb leads double standard calibration
NSCAL	non-standard calibration

D.3.2.12 Technical problems

ARMRE	suspect arm leads reversed
LMISP	lead misplacement
QCERR	poor data quality, interpretation may be adversely affected

AHERR	acquisition/hardware error
MEASE	possibly measurement error
NOISE	noisy recording
WANDR	baseline wander
FAULT	faulty lead
ARTEF	artifacts
SIMUL	input is from simulator or test pattern
PINFO	inconsistent or erroneous patient demographic data
INCAN	incomplete or no analysis (by the program)
NODAT	missing or no data

D.3.3 Examples

D.3.3.1 The statements “Probable old anterior infarction and atrial fibrillation” shall be coded as follows: AMI_OL_PR; AFIB. The statement AFIB has no direct relation to AMI , therefore the AND conjunction is not used . There are in fact 2 independent statements, one on QRS contour and one on cardiac rhythm.

D.3.3.2 The statement “Probable left ventricular hypertrophy with ST-T changes compatible with left ventricular strain” shall be coded as follows: LVH_PR_AND_STT_LV. The underscore signs before and after the AND indicates that the conjunction is made within a single statement.

If the same statement had been made on 2 separate lines, and one wants to link them logically, i.e.,

Probable left ventricular hypertrophy

ST-T changes compatible with left ventricular hypertrophy

then coding shall be done as follows: LVH_PR;AND;STT_LV

D.4 Overreading of measurement results

D.4.1 Waveform and interval designations

P	P-wave
P+	P-wave, positive component
P-	P-wave, negative component
PA	the atrial repolarization wave
Q	Q-wave, i.e. the first negative deflection of QRS
R	R-wave, i.e. the first positive deflection of QRS
S	S-wave, i.e. first negative deflection after first positive deflection in QRS
R2	second R-wave, i.e. the first positive deflection in QRS after the S-wave
S2	second S-wave
R3	third R-wave in QRS
S3	third S-wave in QRS
J	the J-point
ST	the ST-interval
ST20	the amplitude of ST 20 ms after the J-point
ST60	the amplitude of ST 60 ms after the J-point

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ST80	the amplitude of ST 80 ms after the J-point
STO	the amplitude of ST at the onset of ST, i.e. the J-point
STM	the amplitude of ST at the middle of ST
STE	the amplitude of ST at the end of ST, i.e. the beginning of the T-wave
T	the T-wave
T+	the (maximal) positive component of the T-wave
T-	the (maximal) negative component of the T-wave
U	the U-wave
QRS	the QRS complex
QR	QR type of QRS complex
QS	QS type of QRS comple
RS	RS type of QRS complex
RSR	RSR2 type of QRS complex
PR	the PR-interval
PP	the P-P interval
RR	the R-R interval
QT	the QT-interval
JT	the interval between the J-point and the end of the T-wave
TP	the interval between the end of the T-wave and the succeeding P-wave
ARP	absolute refractory period
ERP	effective refractory period
RRP	relative refractory period
FRP	functional refractory period

D.4.2 Lead denominators

a) For the abbreviations of the leads, see “Specification of the ECG Lead Definition – Section 3” portion of this document.

b) The following conventional lead-labels shall most often be used:

D1	aVR	V1	V4	X
D2	aVL	V2	V5	Y
D3	aVLF	V3	V6	Z

c) Further abbreviations:

LEAD	lead
INN	indication of location, for example in lead D3: translated as INN_D3
AXIS	axis

NOTE: INN used instead of IN which has been reserved for "Inferior"

D.4.3 Units of measurement

DUR	duration
MSEC	milliseconds
SEC	second(s)
AMP	amplitude
MVOLT	millivolt
MUVLT	microvolt
DEGR	degrees
RATIO	ratio of e.g. Q/R amplitude
UNIT	*unsigned units*

D.4.4 Examples

Most of the time rather simple single or composite ECG interpretive statements, such as listed in D.3.3 will be generated, but more complex statements can also be created such as listed in the examples shown below. It should be noted that these abbreviations and conventions for creating statements are to be used for communication between heterogeneous systems and that each system manufacturer can continue to use its own abbreviations for internal use.

P_AMP_INN_LEAD_V1_EQU_120_MVOLT
The P-amplitude in lead V1 equals 120 millivolts.

Q_DUR_INN_LEAD_D3_EQU_40_MSEC
The Q-wave in lead D3 equals 40 milliseconds

RATIO_Q_AMP_DIV_R_AMP_INN_D2_IGT_0.5
The Q/R ratio in lead D2 is greater than 0.5

(S_AMP_INN_V1_ADD_R_AMP_INN_V5)_IGT_3.5_MVOLT
The sum of the S amplitude in V1 and the R amplitude in V5 is greater than 3.5 millivolt (i.e. the Sokolov index is positive)

(MAX_R_AMP_ADD_MAX_S_AMP)_INN_V_LEADS_IGT_4.5_MVOLT
The maximal R amplitude and the maximal S amplitude in the V-leads is greater than 4.5 millivolt

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ANNEX E
(Informative)

Glossary

A basic background in Electrocardiography and in Computer Science are prerequisites for the reader to understand this Standard Communications Protocol for Computer-Assisted Electrocardiography. For this reason, only terms that are beyond the knowledge of basic names and definitions in these fields are presented in the following glossary .

Analog to digital conversion
The approximating process by which a continuous signal is converted to a digital representation. The degree of approximation has to safeguard all useful information in the original signal .

Time sampling
The first of the three steps of analog to digital conversion, i.e. taking discrete samples from a continuous signal in the time domain.

Amplitude quantization
The second of the three steps of analog to digital conversion. The amplitude of each sample is truncated to an integer multiple of a fixed value, which is chosen to be "small" in comparison to the detail in the original signal.

Amplitude coding
The third of the three steps of analog to digital conversion. The sequence of integers produced by the quantization step may be encoded (e.g., Huffman, first difference) to reduce memory requirements.

Artifact filter
A filter that removes artifacts from the ECG signal.

Baseline filter
A baseline filter removes low frequency drift or oscillations from the ECG signal.

Beat data
Data related to the morphological characteristics of single ECG cycles.

Compression ratio
The ratio of the memory occupancy before compression to that after.

Data compression
Any method that satisfies the general aim of reducing the size of a given set of data . Algorithms usually take advantage of characteristics of the signal to be compressed, such as alphanumeric data, digitized signals or digitized image data.

Decimation
The process of choosing a lower quantity of samples among an ordered set (see ANNEX C).

Fiducial point
A reference point within the ECG signal.

Huffman method of coding
An encoding method where variable length codes are used in such a way that the shortest codes are used to encode the most frequently occurring data.

Irreversible data compression
Data compression becomes irreversible when the possibility of reconstructing the original signal, as it was before compression, is lost.

Low-level transport protocol
A detailed procedure to be used in the absence of other methods to ensure data and data communication link integrity during communications between two digital machines.

Low pass filter
A low pass filter removes components of the input signal above a given frequency.

Notch filter

A filter that should remove a particular frequency component of the input signal, commonly at 50 or 60 Hz, i.e. the mains power distribution frequency.

Pacemaker spikes
The pacemaker impulses as they appear superimposed on the ECG.

Tag
A number used to identify a particular data item.

Transform/inverse transform
A signal can be expressed as a weighted sum of orthogonal functions. This set of weights, or coefficients, is known as the transform of the signal in the given domain. The weighted sum of these signals is known as the inverse transform. Often signals can be expressed, processed, or compressed more simply in the transform domain.

See also Definitions (Clause 3) for other specific terms related to this Standard.

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ANNEX F
(Informative)

Additional references

F.0 National standards

ANSI-AAMI EC18-1982 American National Standard for Diagnostic Electrocardiographic Devices, American Association for the Advancement of Medical Instrumentation: Arlington, Virginia, 1983

ANSI-AAMI EC12-1983 American National Standard for Pregelled Disposable Electrodes, American Association for the Advancement of Medical Instrumentation: Arlington, Virginia, 1983

ANSI-AAMI SCL12-78 American National Standard for Safe Current Limits for Electromedical Apparatus,American Association for the Advancement of Medical Instrumentation: Arlington, Virginia, 1978

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JIS X0202 Code Extension Techniques for Use with the Code for Information Interchange

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ANNEX G
(Informative)

Changes from CEN prENV 1064 to AAMI Draft Revision 1.3

This document contains a summary of all substantive changes to the CEN prENV 1064 SCP document that have been made by the AAMI SCP-ECG working group, along with rationales. Minor editorial changes (e.g., spelling) are not included. The purpose of this "Changes" document is to facilitate the review of the changes, and to help future implementers of SCP-ECG to identify changes and clarifications of the original standard. The intention is for this list to be complete, however individual implementers remain responsible for confirming compliance with the standard.

Note: References to clauses in the "Change and Rationale" column refers to the new AAMI numbering unless otherwise indicated. Most changes in numbering (from the CEN version to the AAMI version) were to establish consistent sub-clause number sequencing in all clauses. Some new sub-clauses were also added.

CEN clause	AAMI clause	Change and Rationale
Global	Global	Change: Throughout the entire document, the term “median” is replaced with “reference.” Also use of the term “QRS type” is replaced with “reference beat type”. Rationale: Clarification. As changes were considered to sections 5.7, 5.8, 5.9 and 5.10, it became increasingly difficult to state precisely what was meant as long as the term “median beat” was used instead of a more neutral term. See also 5.1.10
Global	Global	Change: The term “section” is used only when referring to the data sections that are defined in a SCP-ECG record. When referring to a part of the document itself, the term “clause” is used. Rationale: Clarification.
0	0	Change: The 5th paragraph ("To enable…") has been clarified. A new 6th paragraph has been added cautioning the user in the application of the SCP standard. Rationale: SCP allows a variety of implementations, so that the ability of machines of different manufacturers to communicate is not assured without verification. Therefore the users of equipment in which SCP is implemented need this explicit advice to help prevent inappropriate expectations.
1	1	Change: In paragraph 2, the sentence “The clinical need for transmission of these specialized recordings is indeed very low and has therefore not been considered in this Standard” has been deleted. Rationale: This statement is not needed to define the scope of this document. Change: Paragraph 5 beginning "Reference databases…" has been deleted. Rationale: The reference is incomplete and doesn’t seem necessary. Change: The sentence "A minimum set of control…" and the paragraph beginning "A low-level transport…" have been deleted and replaced with text that outlines the new Data Format Categories and the new statements of compliance (see Annex B for details). Rationale: A discussion of compliance was identified as needed near the beginning of the document at the April 1997 meeting so that users could easily identify and understand the meaning of the compliance categories. This replacement text provides an overview of SCP compliance.
2	2	Change: The IEC 62D(C06) reference has been moved to Annex F.1 Rationale: This standard is still under development. A draft version is available as an informative reference and contains useful definitions for the purposes of the SCP standard.
	3.1.2	Change: A definition of bimodal compression has been added. Rationale: clarification.
3.1.4	3.1.9	Change: The definition of Median Beat was replaced with Reference Beat.

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CEN clause	AAMI clause	Change and Rationale
		Rationale: See 5.1.10
3.1.6	3.1.3 and 3.1.7	Change: The definition of Overreading has been changed and a new definition of Confirming has been added. Rationale: Precise definitions of these terms are needed to support sections 5.11.2 and 5.14.2.1.
5.1.10	5.1.10	Change: This clause has been changed to reflect the use of the term "reference beat" in preference to "median beat," and several other clarifications. Rationale: These changes were added as a clarification. Our consensus was to change to "reference" for the following reasons. The term "reference beat" is more methodologically neutral than the term "median beat". In addition, we use the term "reference beat" to refer to any class of reference beat, not just type 0. The former term "median beat" becomes "reference beat type 0". This distinction allows greater ease in defining the various data sections, for example, in data section 7 (5.10). That section contains global measurements for the various reference beat types, where it is necessary to make the distinction between reference beat type 0 and the other reference beat types. This distinction would be problematical without using the term reference beat type - "beat type" for example refers to the type of an individual beat, and "median beat type" is of course not appropriate. This change to "reference" from "median" was the consensus result of a lengthy discussion at the June 1997 and April 1998 meetings of the WG. Although the term “reference beat type 0” reads more awkwardly than “median beat”, we felt that the increased ability to say exactly what we wanted justified the change.
5.2.1	5.2.1	Change: The following explanatory sentence was added: “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.” Rationale: Clarification.
5.2.7	5.2.7	Change: Byte 10 was changed from “Reserved” to “Version number of the protocol (refer to 5.4.5 tag 14, byte 15)". Change: Added the following reference to Byte 11 - 16 Contents: "Reserved (for data section 0 see 5.3.1)" Change: Edited the last sentence to read as follows, and added the subsequent sentences: “Each section shall have Section and Protocol Version Numbers (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 - 11, Section Version Numbers (byte 9) shall be the Protocol Version under which the section was approved. For data sections 12 - 1023, Section Version shall refer to the manufacturer's version for that section, independent of protocol version.” Rationale: Having the version number in the header assures that the version number can be located irrespective of the version. The other changes are to clearly define the intended use of Section and Protocol Version Numbers.
5.2.9	5.2.9	Change: Section lay-out reconciled with changes to 5.2.7
5.2.12	5.2.12	Change: Item (4). Changed from “…signal contained in Section 5 below…” to “…signal contained in Section 6 below…” Rationale: correct error. Change: Item (8) Deleted the words "for the legal document". Rationale: Consistency with prior change to 5.11. Change: Item (9) Changed to “This section contains the manufacturer specific diagnostic statements of the analyzing device and overreading trails of the interpretations. The source of the analyzing device and the name of the latest confirming physician (or device) are defined in the "Header section" (Section 1). This section is optional.”

CEN clause	AAMI clause	Change and Rationale
		Rationale: Consistency with prior changes to 5.4.3.5 tag 21, and eliminating an unnecessary “should” in relation to a manufacturer specific section.
5.3.0	5.3.1	Change: Added the following sentence to clause 5.3.1: "Bytes 11-16 shall contain the following ASCII character string: "SCPECG" ". Rationale: SCP-ECG files are increasingly being exchanged via E-mail or other EDI interchange protocols. In case of lost extensions, this would help any recipient in identifying very quickly (e.g., by using Notepad or Wordpad) the type of the file without requiring any SCP-ECG compatible plugins or Viewers. The WG noted that this mechanism is not a "fool proof" method of identifying a SCP record, but it is much better than having nothing embedded within a SCP file to identify it as such. These bytes of ASCII characters would occur once, very near the beginning of a SCP file.
5.3.1	5.3.2	Change: The first two bullets in 5.3.2 of the AAMI Draft SCP were edited to read as follows: One pointer field for each section 0 - 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 a SCP-ECG data record, the special codes defined in 5.3.2.2 and 5.3.2.3 for the pointer field shall be used. Manufacturer specific sections, if present, shall have a pointer field in section 0. Rationale: Clarification.
5.3.1.2	5.3.2.2	Change: The original last sentence read “If a section is not included in the SCP-ECG record the length shall be set to 0.” It was replace with the following: “For data Sections 2 - 11 a pointer field must be included. If no data is transmitted for any of these sections, set the section length to 0.” Rationale: Clarification.
5.4.2.1	5.4.3.1	Change: Edited as follows the sentence "In addition, the SCP-ECG Working Group highly recommends the following parameters for ~~unique patient identification~~ uniquely identifying the patient and time of acquisition." Change: Add the new tag 34 to the "highly recommended" list as follows: (10) 34 Date Time Zone Rationale: Time of acquisition is needed to uniquely determine a record. Inclusion of the Date Time Zone removes ambiguity in the time of acquisition.
5.4.2.2 b)	5.4.3.2 b)	Change: Added a sentence that states that “A tag may have a length field of 0.” Rationale: Clarification
5.4.2.3	5.4.3.3	Change: Changed name of tag 32 to Medical History Codes and added new tag 35. Rationale: clarification and updating.
5.4.2.5	5.4.3.5	Change: Corrected Section number in table from 2 to 1. Rationale: Correct error. Change: Deleted the last 3 sentences of the opening paragraph, and added a reference to tag 35. The paragraph reads as below. “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 the table below.” Rationale: The new Annex B requires devices that claim Import and Export compatibility to validate that all non-waveform data is reproduced exactly. Therefore the sentences in prENV 1064 that mention “dissenting implementors” and allowing receivers to ignore characters are no longer appropriate.

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CEN clause	AAMI clause	Change and Rationale
		Change: Renamed Tag 21 to “Latest confirming physician.” Rationale: In case of multiple overreads, the latest confirming physician is the responsible party. Change: Deleted the listing of tag 32 from the table. Rationale: Tag 32 is a binary tag, not free text. Change: Added tag 35 to the table. Rationale: the Medical History Codes of tag 32 are inadequate to meet the needs of all manufacturers and users. A free text medical history tag allows transmission of medical history that is not manufacturer specific.
5.4.4 tag 10	5.4.5 tag 10	Change: In notes (1) and (2), the reference to bytes "3 - ***" was changed to "4 - ***". Rationale: Correct error.
5.4.4 tag 14	5.4.5 tag 14	Change: Byte 8: set the Manufacturer Code to be 255, and added a string at the end of the tag for Manufacturer. Rationale: Recognizing that SCP-ECG will in the future probably be used by more than resting ECG carts, we considered that one byte may not be sufficient to code all possible manufacturers. We therefore decided to use code 255 to indicate that information identifying the manufacturer is in a character string. Change: Clarified bytes 9-14 of tag 14 to read “Text characters: Text model description. Up to 5 characters and NULL terminator.” Change: Deleted the last sentence of the Contents for byte 15. Rationale: the location and control of future revisions is not yet determined, and need not be mentioned in the definition of this byte. Change: Byte 17: Choice of language code sets has been expanded. Rationale: The new table replaces the set of 8-bit codes alluded to by the original “8-bit sets only” table entry with a number of popular codes specified in ISO-8859. The uncommon or unused alternate Latin sets 3, 9, 10, and 12-14 are omitted. Multi-byte code sets for Western languages are largely being subsumed into Unicode (ISO-60646). However, there are still a number of 16-bit codes for the Eastern ideographic languages, the most popular of which are listed in the table. Future revisions of Unicode will probably incorporate a standard set of ideographs. Both sets of the table require bits 6 and 7 are set to zero, so there is substantial expansion capability remaining. Change: bytes 20 - 35 (Internet address). Changed these bytes to “Reserved for future use”. Rationale: The Internet address cannot be defined right now. Reserve the bytes to maintain spacing. Change: Added a note to the contents of byte 36 to clarify the use of NULLs in the character strings. Change: At the end of tag 14, after “**-** Character string: Serial number of Acquisition Device…” added a character string for Manufacturer of the Acquisition Device. Rationale: Changing from a manufacturer’s code to the manufacturer’s registered trade name eliminates the necessity of maintaining a separate list for SCP, and addresses the potential need for an increased number of codes. Change: Also added two new identifier strings for system software and SCP implementation software to the strings at the end of tag 14. Rationale: These strings will allow devices to identify not only the manufacturer, but also which manufacturer’s version of system software and which manufacturer’s version of SCP software has been implemented in the acquiring device.
5.4.4 Tag	5.4.5 Tag	Change: Renamed Tag 21 to “Latest confirming physician.” Edited the text of 5.4.4 Tag 21 as

CEN clause	AAMI clause	Change and Rationale
21	21	follows: “This field provides a text description of the latest confirming physician.” Rationale: In case of multiple overreads, the latest confirming physician is the responsible party.
5.4.4 Tag 26	5.4.5 Tag26	Change: Replaced “, unless otherwise indicated under Tag 34” with “in the Time Zone of acquisition. The Time Zone is represented in field (tag) 34.” Rationale: Clarification of relationship between tag 26 and the new tag 34.
5.4.4 Tag 32	5.4.5 Tag 32	Changed title to “Medical History Codes”, and changed the paragraph beginning “Byte 0 is used to designate the Diagnostic Code Table…” to “Byte 0 is used to designate the Medical History Code Table…” Rationale: To establish consistent use of the term “Medical History Code.”
	5.4.5 Tag 33	Change: Added new tag - Electrode Configuration Code. Rationale: This tag allows recording of electrode configuration for 12-lead and for orthogonal lead ECGs.
	5.4.5 Tag 34	Change: Added new tag - Date Time Zone. Rationale: this tag was added to allow precise description of the date and time of acquisition of the ECG. Elapsed time since an ECG was taken is sometimes an important parameter. Identification of the time zone removes the uncertainty. Offset is in minutes because some time zones have 30 minute offsets. The index is provided to allow space for future definition of a table of time zone text descriptions. The text string is provided to allow designation of time zone prior to the definition of a standard table.
	5.4.5 Tag 35	Change: Added new tag - Free Text Medical History Rationale: the Medical History Codes of tag 32 are inadequate to meet the needs of all manufacturers and users. A free text medical history tag allows transmission of medical history that is not manufacturer specific.
5.5.4	5.5.5	Change: In Contents of Byte 1-2, changed “C.2.7” to “C.2.7.4”. Rationale: Correction. Change: Byte 5-??? Correction of error for Value 1 ("=" instead of ">="). Rationale: The number of bits in the prefix can't be greater than the number of bits in the entire code.
5.6.1	5.6.2	Change: Edited Byte 2, Bit 0 to read “Set = Reference beat subtraction used for compression” and “Reset = Reference beat subtraction not used for compression” Rationale: Clarification.
5.6.2	5.6.3	Change: Added new leads 66 through 85 Rationale: A more complete list of lead identification labels enables use of SCP for a wider range of conditions.
5.6.4	5.6.5	Change: Note 3: added a reference to tag 33. Change: Note 4: Removed reference to a coordinating center and changed an inappropriate “shall” to “may”. Rationale: Clarification.
5.7	5.7	Change: Title changed to more completely represent the contents. Rationale: Clarification.
5.7.1	5.7.2	Changed "median" to "reference" and added an equation for calculating the number of samples from the length. Rationale: Clarification.

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CEN clause	AAMI clause	Change and Rationale
5.7.2	5.7.3	Change: Set the start/end of subtraction/addition to zero for beats that are not of type 0. Rationale: supports the new clause 5.7.4 that specifies protected zones explicitly.
	5.7.4	Change: New clause to add data on location of protected areas for each QRS. Rationale: These changes add explicit storage of the protected zones and clarify the beat subtraction process. These changes add flexibility in specifying the beginning and end of the QRS protected zone independent of the QRS type and independent of the QRS onset/offset in 5.10. Note: The block of data in 5.7.4 has been introduced with SCP-ECG version V1.1 (an addition after prENV 1064: 1993). Therefore records stored with legacy equipment implementing SCP-ECG versions prior to V1.1 will not have this block of data to explicitly store the protected zone for each QRS. In reconstructing legacy records, calculate the beginning and end of the protected zones for beats of type 0 from fc(k) (the fiducial point for each QRS, 5.7.3 bytes 7-10), fcM (the fiducial point for the reference beat, 5.7.2 bytes 3-4), and bM and eM (beginning and end of QRS in the reference beat, stored in 5.10.3 bytes 5-6 and 7-8). The clauses (from the AAMI Draft SCP 5.7 and Annex C) which have changed due to explicitly storing the protected zone are 5.7.3, the addition of clause 5.7.4, and in 5.7.5, C.2.1.4, C.2.4.2, C.2.5, and C.2.8.9.
5.7.3	5.7.5	Change: Diagram and notes updated to reflect changes in 5.7. Change: Added a note clarifying the use of sections 5.7.3 and 5.74 if bimodal compression is used, but not reference beat subtraction. Rationale: Clarification.
5.8	5.8	Change: Title changed Rationale: Clarification.
5.8.1	5.8.2	Change: Changed the table in Note 1 to correct an error for the second “second difference” table entry. Also see related change at C.2.6.1 and C.2.6.2. Rationale: correct error
5.8.2	5.8.3	Change: Clarification of data formatting if Huffman encoding is not used, with an informative note added regarding using a "dummy" Huffman table. Rationale: Clarification.
5.9.1	5.9.2	Change: Byte 6 has been defined to indicate explicitly if bimodal data compression is used. Rationale: The WG designated Byte 6 to indicate whether downsampling outside of the protected zone is used, independent of reference beat type 0 subtraction. The Note to Byte 6 explains the proper method of determining if the Amplitude Value Multiplier is different for the two regions. “Bimodal compression” is the term used to designate using two different sample rates.
5.9.3	5.9.4	Change: Clarification of data formatting if Huffman encoding is not used, with an informative note added regarding using a "dummy" Huffman table. (Same change as in 5.8.3.) Rationale: Clarification.
5.9.4	5.9.5	Change: Diagram updated to reflect 5.9.2 byte 6. Rationale: Correct an error
5.10	5.10	Change: Clarification of the meaning of "global." Rationale: Clarification.
5.10.1	5.10.2	Change: Definition of 19999 edited to use P instead of Q-wave as example. Rationale: None of the measurements in the measurement block relate to the existence of a Q wave (the example in the CEN version). QRS onset is a global onset and is not related to whether there is a Q wave in any particular lead. Changing the example to a P wave also

CEN clause	AAMI clause	Change and Rationale
		addresses a concern about deleting note 3 from prEVN 1064 clause 5.10.2.
5.10.1.1	5.10.2.1	Change: The definition of byte 1 has been changed to eliminate reference to whether "median beats are used." Rationale: The change to this definition was to allow programs that do not create a median beat to provide global measurements for the reference beat types that may be found in an ECG. Section 5.10.2.4 was added as a new clause to identify the reference beat type of each specific beat of the record, so that the measurements for each reference beat type could be correlated with each specific beat. Change: The definition of bytes 23-38 was clarified. Rationale: Clarification.
5.10.1.2	5.10.2.2	Change: Changed the amplitude bytes (3-4, 7-8, etc. and Note 1) from “Unsigned integer” to “Signed integer.” Rationale: Signed integers allow more information to be passed. The special codes in 5.10.2 are not allowed because a pacemaker spike will not be reported if it is not found or measured.
	5.10.2.3	Change: Added a new clause to specify pacemaker spike information. Rationale: This new section is needed to provide information about the source and type of pacemaker spikes.
	5.10.2.4	Change: Added a new clause to specify QRS type information for each QRS. Rationale: This data provides a link between each QRS and the measurements given in the measurement blocks. There has been a question regarding why 2 bytes are used for the number of QRSs, but only one for Reference beat type. The number of QRSs is also specified in 5.7.2 bytes 5-6, so using 2 bytes in 5.10.2.4 is consistent with 5.7.2. The number of reference beat types is stored in one byte in 5.10.2.1 byte 1, so using 1 byte in 5.10.2.4 is consistent with 5.10.2.1. A comment noted that 2 bytes are used to specify the reference beat type in 5.7.3 (data section 4), and that there may be more reference beat types than the number for which measurement blocks have been reported, i.e. the number indicated in 5.10.2.1 byte 1. The purpose of the “QRS type information” clause in 5.10 is to identify the beats in an ECG record which correspond to the measurements in the measurement blocks, especially when data section 4 is not provided. Therefore the fact that data section 4 (5.7.3) allows two bytes for beat type is not relevant to 5.10. It has also been suggested that this block is redundant with 5.7.3. The WG did not accept this comment because data section 4 (5.7) may not be included if reference beat subtraction or bimodal compression is not used for compression. Without clause 5.10.2.4 there would be no way to indicate which beats in the ECG record correspond to the reference beat types for which global measurements are included.
	5.10.2.5	Change: Added a new clause for Additional global measurements. Rationale: This clause contains additional global measurements for the ECG. Ventricular rate was added to avoid round off errors in converting RR interval (5.10.1.1 bytes 3-4) to ventricular rate. For a similar reason, atrial rate was also added. QT corrected was added because it is a common feature of programs. It has been suggested that ventricular and atrial rates are not needed because they are calculable from the intervals stored in 5.10.2.1. However these rates are included because the WG was unable to define a process that would assure that the HR calculated from an interval measurement would always yield exactly the same HR that was used in the derivation of ECG interpretive statements. For example, a HR of 272 yields an interval of 221 ms., whereas an interval of 221 ms yields a HR of 271, given the usual rules regarding rounding. The addition of a number of parameters for QT dispersion indicated that a fixed byte length field for additional global measurements might soon be exhausted. Using tagged fields allows the future addition of a total of 255 measurements of variable length without burdening each record to transmit default values if a measurement is not provided.
5.10.2	5.10.3	Change: The heading was changed so that the block could be either reference beat data or

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CEN clause	AAMI clause	Change and Rationale
		data for each QRS. Rationale: consistency with other changes Change: References to frontal plane angle measurement ranges were deleted Rationale: original ranges were too restrictive and unnecessary. Change: A new note 1 was written and the descriptions were cleaned up accordingly. Rationale: Clarification. Change: The diagram in Note 2 was modified to show only zero and positive and negative angle directions to provide only necessary information. Rationale: Consistency with other changes Change: Note 3 was deleted Rationale: Note 3 had no referent and was not necessary.
5.10.3	5.10.4	Change: This clause was updated to reflect changes in 5.10. Rationale: Consistency.
5.10.4	5.10.5	Change: This clause was updated to reflect changes in 5.10. Rationale: Consistency.
5.11	5.11	Change: References to the "legal document" and "all overreading" were removed. Rationale: The term “legal document” is not necessary and may not be true in all cases, and a particular ECG may not include all overreadings.
5.11.2	5.11.3	Change: Byte 1: Value 0 "Type" was changed to be consistent with new definitions in 3.1 Rationale: Consistency.
5.11.3	5.11.4	Change: Byte 1 definition clarified. Rationale: Clarification.
5.13.1	5.13.2	Change: in item a), the definition was clarified. Rationale: clarification Change: in item b), byte number reference corrected. Rationale: correct error Change: in item d), byte number reference corrected. Rationale: correct error
5.13.3	5.13.4	Change: Changed from "length of this block" to 2 manufacturer specific bytes. Rationale: The length of the block is not needed because the length for each lead is given in 5.13.5 Bytes 3-4, and the total length of the Section is in the Section ID Header.
5.13.4	5.13.5	Change: Added 2 ST measurement points in bytes 63-66. Rationale: Add commonly used heart rate adjusted measures of ST amplitude.
5.13.5	5.13.6	Change: Updated figure to reflect changes to 5.13. Rationale: Consistency.
5.14.2.1	5.14.3.1	Change: Byte 1: Value 0 "Type" was changed to be consistent with new definitions in 3.1 Rationale: Consistency.
6.4.2.1	6.5.2.1	Change: Replaced this sentence with “If reference beat subtraction is used for data compression, all leads of an ECG record shall be recorded simultaneously.”

CEN clause	AAMI clause	Change and Rationale
		Rationale: To make explicit the requirement for simultaneous recording for whatever lead set is used when reference beat subtraction is used for compression.
6.4.2 Notes	6.5.2 Notes	Change: The Notes following this clause have been combined into one note and clarified. The following sentence was added: "Calculate error measures from the beginning of the first subtraction to the end of the last subtraction." Rationale: The existing two notes have the same references, so they should be combined. The added sentence is to prevent erroneously high error readings for the cases in which a portion of a QRS is at the beginning or end of the record, and is not included in the reference type 0 subtraction.
7.2	7.2	Change: Added sentence to clarify reference to notes. Rationale: clarification
7.2.1	7.2.1	Change: Updated descriptions for bytes 10-15, 21-128, 129-153, 154-178, 179-256 to agree with modified 5.4.5 tag 14, and added some explicitly reserved bytes. Rationale: Reserved bytes were added because SPARE bytes are made manufacturer specific in Note 12.
7.2.2	7.2.2	Change: Added left column heading, edited definition of bytes 15-256, removed numbering of notes, added clarifying sentences for Request Sequence Numbers and Request messages. Rationale: Clarification. All numbered notes for 7.2 are collected in 7.2.6, so numbering these paragraphs confused what was being referenced. Also, the words "Request Mask/Spare" were considered confusing, especially when used with the definition of note 12 in 7.2.6.
Notes to 7.2.2.1 and 7.2.2.2	7.2.2.4	Change: Added new clause to contain these rules and added a third rule. Rationale: These "notes" are not actually referenced in sections 7.2.2.1 and 7.2.2.2, but do apply to those sections, and they do not apply to section 7.2.2.3 where they are presently located. The new note 3 is needed to establish the end of the TAG data.
7.2.2.3	7.2.2.3	Change: Clarified explanatory sentence below the table. Rationale: clarification
7.2.3	7.2.3	Change: Added explanatory sentences to the Status message description. Rationale: clarification
7.2.4	7.2.4	Change: Added 2 reserved bytes. Rationale: consistency with other messages
7.2.5	7.2.5	Change: Added 2 reserved bytes Rationale: consistency with other messages Change: added explanatory notes regarding use of the Done message. Rationale: clarification
	7.2.7	Change: Added a new section specifying Minimum Functionality. Rationale: necessary to complete definition of Compliance (Annex B)
7.3	7.2.6	Change: all notes were originally under section 7.3 were moved to 7.2.6 Rationale: Notes applied only to 7.2, and so did not warrant an independent sub-clause. Change: In note 6, clarified description for value 0 and value 16. Rationale: Clarification Change: In note 10, clarified Status Flag description. Rationale: Clarification

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CEN clause	AAMI clause	Change and Rationale
		Change: In note 11, added error status codes 7 and 44. Rationale: These error codes are not covered by other codes. Change: New note 12 added to explicitly open SPARE message data blocks for manufacturer specific use. In the individual clauses where needed, some bytes have been specifically reserved for future use. Rationale: Correct a deficiency
	7.3	Change: New clause added to illustrate state machines for Establishment of Session and Query Messaging. Rationale: clarification
7.4 and 7.5	7.4 and 7.5	Change: In the text and “comments” of the examples in 7.4 and 7.5, “cart” has been changed to “initiator,” and “host system” or “system” has been changed to “responder”. Rationale: This change allows more intelligent and capable cart devices to perform data management functions. Note: The definition of “initiator” as “the device that send the first "ID" message”, leaves open the question of how to determine which device sends the initial “ID” message of a session. This may be link-layer dependent.
7.4.4	7.4.4	Change: Corrected message sequence order (“h”) and corrected a typographical error (“i”). Rationale: correct errors
8.0	8.1	Change: Paragraph 3 “Error-correcting modems.....in this section” was deleted. Rationale: The issue of what is allowed under SCP for low-level transport is handled more fully in the new Annex B.
8.3.2.3.3	8.4.2.4.3	Change: A limit was added for the number of consecutive NAKs. Rationale: This change will allow graceful termination when the transmitter is locked up sending NAKs.
8.3.2.3.4	8.4.2.4.4	Change: Changed action in case of a time-out. See also 8.4.3.4.2 and figure in 8.4.6.2.2. Rationale: By re-sending the last packet instead of the SYN, communication loss from cable breaks is diminished. This change from prENV 1064 avoids a metastable error state associated with un-“ACK”ed retransmitted packets. This condition occurs in association with high latency channels such as satellite transmission, TC/IP, and certain modem protocols.
	8.4.3.4.2	Change: New clause related to time-out change in 8.4.2.4.4. Rationale: consistency with other changes
8.3.6.2.3	8.4.6.2.2	Change: 'Bubble' 2.3.4 updated to agree with 8.4.2.4.4 Rationale: consistency with other changes
8.3.3.3	8.4.3.4	Change: A new sentence was added after the last sentence: “Non-valid inputs are discarded.” Rationale: Clarification.
8.3.3.4	8.4.3.5	Change: ENQ was added to BAD DATA valid inputs. Rationale: This change adds additional ability to recover from BAD DATA state.
	8.4.3.5.4	Change: New clause added Rationale: improve ability to recover from BAD DATA state.
8.3.4.1	8.4.4.1	Change: The last sentence was clarified, the range of errors was corrected, and a clause governing normal termination was added. Rationale: Clarification.

CEN clause	AAMI clause	Change and Rationale
8.3.4.2	8.4.4.2	Change: A new note was added for clarification. Rationale: Clarification.
8.3.5	8.4.5	Change: Added a sentence to the first paragraph clarifying the calculation of the CRC. The last sentence was corrected to refer to the CRC, not a checksum. Rationale: Clarification.
8.3.7	8.4.7	Change: Item z) was clarified. Rationale: Clarification.
Annex A.1.1	Annex A.1.1	Change: In table, reference to Section 2 was corrected to Section 1, and the table was updated to include the new tags. Rationale: Correct errors and provide consistency with other changes.
Annex B	Annex D	Change: Exchanged positions of annexes B and D in order to place all normative annexes before any informative annexes. Rationale: CEN requirement.
B.0	D.0	Change: Changed the opening sentence to "Universal ECG interpretive statement codes ~~shall~~ may be used, ..." Rationale: This section is optional.
C.0	C.0	Change: Deleted the last sentence of C.0. Rationale: The WG recommends that the test set be made available as part of the SCP standard, not obtained separately.
C.1.1, C.1.3, and C.2.3.1	C.1.1, C.1.3, and C.2.3.1	Change: The figures were changed to correct the beat typing to show type 0 as "normal." Rationale: correct error. Note: Although the figures do not demonstrate it, the numbering of beat types is not sequential in order of occurrence. For example, the first beat could be type 1 followed by a type 0 beat (i.e. the beat type chosen for measurements and on which diagnostic statements are based, and the beat type that is used for compression).
C.2.1.3 Note	C.2.1.3 Note	Change: Equations were added for aVR, aVL, and aVF based on leads I and II. Rationale: clarification
C.2.1.4	C.2.1.4	Change: This section was updated to be consistent with explicitly storing QB(k) and QE(k) in 5.7. Rationale: consistency with other changes
C.2.2	C.2.2	Change: An example of truncation/rounding error was added. Rationale: clarification
C.2.4.2	C.2.4.2	Change: This section has been completely reworked to include changes needed with explicitly storing QB(k) and QE(k) in 5.7. Rationale: consistency with other changes
C.2.4.3	C.2.4.3	Change: The last paragraph, including equations, has been replaced. The new text defines the proper use of the low pass filter at subtraction zone boundaries. Rationale: Subtraction of reference beat type 0 can result in a step at the subtraction zone boundaries. Low pass filtering this step would result in a ramp in the residual data, and when the reference beat type 0 is added back to the residual, a biphasic transient would result with amplitude about half of the step size, and duration about equal to the width of the low pass filter. A number of manufacturers have noted this transient, and found it unacceptable. This method provides a solution that is backwards compatible.

CEN clause	AAMI clause	Change and Rationale
C.2.5	C.2.5	Change: Added a sentence to the second paragraph defining bimodal compression. Removed the text describing how to determine sample decimation, and replaced it with a reference to 5.9.2 byte 6. Rationale: clarification, and updating to include the new use of 5.9.2 byte 6. Change: Replaced paragraphs 6 and 7 (of CEN version) with text that clarifies the decimation process and that is consistent with changes in 5.7 which explicitly store the protected zone pointers. Change: A new paragraph was added providing a recommended process for reconstruction of decimated data. Rationale: Several manufacturers noted that interpolation across subtraction zone boundaries sometimes resulted in narrow transients being added to the reconstructed data. This change provides a method to avoid generating transients at subtraction zone boundaries during reconstruction of decimated data.
C.2.5 Example	C.2.5 Example	Change: Updated the example to include the changes in 5.7 that explicitly store the protected zone pointers and added an explanatory note. Rationale: clarification
C.2.6.1	C.2.6.1	Change: Added explanatory notes after equations for first and second differences for consistency with changes to the Table in 5.8.2 Rationale: clarification
C.2.6.2	C.2.6.2	Change: Added explanatory notes after equations for reconstituting first and second differences for consistency with changes to the Table in 5.8.2 Rationale: clarification
C.2.7.4	C.2.7.4	Change: Item 15 in table – “store binary as” was corrected from 513d to 383d. Rationale: correct error
C.2.8.3	C.2.8.3	Change: Removed the text describing how to determine sample decimation, and replaced it with a reference to 5.9.2 byte 6. Rationale: clarification, and updating to include the new use of 5.9.2 byte 6.
C.2.8.6	C.2.8.6	Change: Note 2 was clarified. Rationale: clarification
C.2.8.9	C.2.8.9	Change: Modified text describing QB(k) and QE(k) to be consistent with changes in 5.7 which explicitly store the protected zone pointers. Rationale: consistency with other changes
C.4 and Table	C.4 and Table	Change: The Table listing the Test Set is now in C.4 so the reference to it was deleted. Rationale: consistency with other changes
C.5		Change: Clause C.5 was deleted. Rationale: This clause is redundant with document clause 6.5, and is less completely specified. Annex C is "informative" and should not state a requirement. In addition, the last clause states a requirement for being "SCP compatible." SCP compatibility requirements are defined in Annex B, so requirements should not be addressed in this clause.
Annex D	Annex B	Change: Exchanged positions of annexes B and D in order to place all normative annexes before any informative annexes. Rationale: CEN requirement.
Annex D	Annex B	Change: Annex B (Annex D in the original CEN document), which specifies compliance with the SCP-ECG standard, has been completely replaced.

CEN clause	AAMI clause	Change and Rationale
		Rationale: In an early meeting of the WG we agreed that the prENV 1064 Annex B (then Annex D) statements of compliance levels were not adequate. For example, a device that provided a full 12-lead ECG record, but without measurements and interpretation did not fit any compliance category. An open communication among WG participants generated a variety of issues and approaches to specifying compatibility. At a subsequent WG meeting a consensus approach emerged, and has evolved to the proposed new Annex B. Details of this process can be reviewed in WG minutes and materials. Highlights of the new Annex B include definition of Data Format Categories, separate specification of Data Format and Messaging/Transport Protocol, and a manufacturer based testing plan.

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