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Health informatics — Medical waveform format —

Part 2: Electrocardiography

Informatique de santé — Forme d'onde médicale —

Partie 2: Electrocardiographie

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Foreword

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The committee responsible for this document is ISO/TC 215, *Health informatics*.

ISO/TS 22077 consists of the following parts, under the general title *Health informatics — Medical waveform format*:

— *Part 1: Encoding rules*

— *Part 2: Electrocardiography*

— *Part 3: Long term electrocardiography*

Introduction

The standard 12-lead electrocardiogram (ECG) is one of the most widely used medical waveforms in clinical sites. In particular, the increased usage of electronic medical records provides the environment in which these ECGs can be accurately utilized; however, it is essential that to address the therapeutic requirements, ECG use is not constrained to specific machine types and manufacturers. Furthermore, there is great interest in the various kinds of patient information contained in ECGs that are extensively studied and shared between health care providers.

This Technical Specification defines the detailed rules for electrocardiogram waveform format that is encoded according to the medical waveform format encoding rules (MFER). In addition to electrocardiogram waveform format encoding, there are rules for other waveforms such as long-term ECG (Holter ECG), stress ECG, etc. that are contained in other MFER technical specifications. Please refer to those specifications for additional information.

About MFER

Medical waveforms such as electrocardiogram, electroencephalogram, and blood pressure waveforms are widely utilized in clinical areas such as physiological examinations, electronic medical records, medical investigations, research, education, etc. Medical waveforms are used in various combinations and document types according to the intended diagnostic purpose. For example, ECG waveforms are utilized extensively in the clinical arena, with resting 12-lead ECG being used the most. A cardiologist makes diagnoses using 10 s to 15 s ECG waveform measurements; however, longer periods are sometimes required to recognize patient heart conditions such as arrhythmia. Also, there are many other methods using ECG such as Holter ECG, physiologic monitoring ECG, stress ECG, intracardiac ECG, VCG, EEG with ECG, blood pressure with ECG, PSG, etc. MFER can describe not only ECG for physiological examinations conducted in ICU and operating room acute care contexts, but also EEG, respiration waveform, and pulse.

Simple and easy

MFER is a specialized representation for medical waveforms that removes unnecessary coded elements ("tags") for waveform description. For example, a standard 12-lead ECG can be described simply only using a common sampling condition and the lead condition, making waveform synchronization and correct lead calculation much easier.

Using with other appropriate standards

It is recommended that MFER only describes medical waveforms. Other information can be described using appropriate standards such as HL7, DICOM, IEEE, etc. For example, clinical reports that include patient demographics, order information, medication, etc. are supported in other standards such as HL7 Clinical Document Architecture (CDA); by including references to MFER information in these documents, implementation for message exchange, networking, database management that includes waveform information becomes simple and easy.

Separation between supplier and consumer of medical waveforms

The MFER specification concentrates on data format instead of paper-based recording. For example, recorded ECG is processed by filter, data alignment, and other parameters, so that the ECG waveform can be easily displayed using an application viewer. However, it is not as useful for other purposes such as data processing for research investigations. A design goal of MFER is that a waveform is described in raw format with as complete as possible recording detail. When the waveform is used, appropriate processing of the data are supported like filtering, view alignment and so on. In this way, the medical waveform described in MFER can be used for multiple purposes.

Product capabilities are not limited

Standards often support only a minimum set of requirements, so the expansion of product features can be greatly limited. MFER can describe medical waveform information without constraining the potential features of a product. Also, medical waveform display must be very flexible, and thus MFER has mechanisms supporting not only a machine-readable coded system for abstract data, but also human-readable representation.

The MFER specification can support both present and future product implementations. MFER supports the translation of stored waveform data that was encoded using other standards, enabling harmonization and interoperability. This capability supports not only existing waveform format standards, but can be extended to support future formats as well.

Health informatics — Medical waveform format —

Part 2: Electrocardiography

1 Scope

This Technical Specification defines the application of medical waveform format encoding rules (MFER) to describe standard electrocardiogram waveforms measured in physiological laboratories, hospital wards, clinics, and primary care medical checkups. It covers electrocardiograms such as 12-lead, 15-lead, 18-lead, Cabrera lead, Nehb lead, Frank lead, XYZ lead, and exercise tests that are measured by inspection equipment such as electrocardiographs and patient monitors that are compatible with MFER.

Medical waveforms that are not in the scope of this Technical Specification include Holter ECG, exercise stress ECG, and real-time ECG waveform encoding used for physiological monitors.

2 Normative references

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

ISO 22077-1, *Health informatics — Medical waveform format — Part 1: Encoding rules*

3 Terms and definitions

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

3.1
dominant beat
typical heart beat used for measurement and analysis in standard 12-lead ECG

Note 1 to entry: In general, it is the primary heart beat excepting extrasystole or drifts of baseline.

3.2
average beat
typical heart beat used for measurement and analysis in standard 12-lead ECG

Note 1 to entry: This is averaged for waveforms excluding abnormal beats for each lead.

3.3
median beat
typical heart beat used for measurement and analysis in standard 12-lead ECG

Note 1 to entry: This is a waveform with the median value of waveforms excluding the abnormal beats for each lead.

3.4
tag
identifier code for a semantic concept

4 Symbols and abbreviated terms

CEN Comité Européen de Normalization/European Committee for Standardization

DBMS Data Base Management system

DICOM Digital Imaging and Communications in Medicine

ECG Electrocardiogram

EEG Electroencephalogram

EHR Electronic Health Record

GPS Global Positioning System

HL7 Health Level Seven

IEC International Electrotechnical Commission

IEEE Institute of Electrical and Electronic Engineers

JIS Japanese Industrial Standard

LSB Least significant bit

MFER Medical waveform Format Encoding Rules

MSB Most significant bit

OID Reference to the ISO standard

SAS Sleep Apnea Syndrome

SCP-ECG Standard Communications Protocol for Computerized Electrocardiography (ISO IS 11073-91064)

SpO2 Saturation of Peripheral Oxygen

UID Reference to the ISO standard

UUID Reference to the ISO standard

VCG Vectorcardiogram

XML Extensible Markup Language

5 Encoding format

5.1 Primary description

MFER provides encoding of Long-term ECG waveforms but since MFER is used mutatis mutandis for encoding of ECG waveforms such as ambulatory ECG, patient monitor system, etc., In addition, together with encoding of ECG waveforms, encoding of information of recognition for waveform, measurement information, interpretation information, etc. is provided, but these are all optional functions and are dependent on each implementation concept. For instance, interpretation code or measurement value might be described by other standard such as HL7, XML, DBMS, etc. with waveforms decoding MFER. However, in all instances, when implementing a device, apply the requirements as listed in ISO 22077-1.

5.1.1 Sampling attributes

Sampling attributes including sampling rate and resolution are given in Tables 1 to 4.

5.1.1.1 MWF_IVL (0Bh): Sampling rate

This tag indicates the frequency or sampling interval for the medical waveform is sampled (Table 1).

Table 1 — Sampling rate

MWF_IVL			Data length	Default	Encoding range/remarks	Duplicated definitions
11	0Bh	Unit	1	1 000 Hz	—	Override
		Exponent (10th power)	1		$10^{-128\sim+127}$	
		Mantissa	≤4		e.g. unsigned 16-bit integer	

The unit may be frequency in hertz, time in seconds, or distance in meters (Table 2).

Table 2 — Sampling rate unit

Unit		Value	Remarks
Frequency	Hz	0	Including power
Time interval	s	1	—

5.1.1.2 MWF_SEN (0Ch): Sampling resolution

This tag indicates the resolution, minimum bits, the medical waveform sampled (generally, digitized) (Table 3).

Table 3 — Sampling resolution

MWF_SEN			Data length	Default	Encoding range/remarks	Duplicated definitions
12	0Ch	Unit	1	See Table 4	—	Override
		Exponent (10th power)	1		$10^{-128\sim+127}$	
		Mantissa	≤4		e.g. unsigned 16-bit integer	

Table 4 — Sampling units

Unit		Value	Default	Remarks
Voltage	Volt	0	0,000 001 V	—

5.1.2 Frame attributes

A frame is composed of data blocks, channels and sequences.

5.1.2.1 MWF_BLK (04h): Data block length

This tag indicates the number of data sampled in a block (Table 5).

Table 5 — Data block length

MWF_BLK		Data length	Default	Remarks	Duplicated definitions
04	04h	≤4	1	—	Override

5.1.2.2 MWF_CHN (05h): Number of channels

This tag indicates the number of ECG channels (Table 6). If a previously specified channel attribute is reset to the root definition including Default, the number of channels should be specified before each definition of the channel attribute. The number of channels cannot be specified within the definition of a channel attribute.

Table 6 — Number of channels

MWF_CHN		Data length	Default	Remarks	Duplicated definitions
05	05h	≤4	1	—	Override

5.1.2.3 MWF_SEQ (06h): Number of sequences

This tag indicates the number of sequences (Table 7). If the number of sequences is not designated, it depends on the data block length, the number of channels and the number of waveform data values that are defined for the specified frame.

Table 7 — Number if sequences

MWF_SEQ		Data length	Default	Remarks	Duplicated definitions
06	06h	≤4	Depends on waveform data length	—	Override

5.1.3 Waveform

The waveform class and type, waveform attributes and waveform data are encoded as follows.

5.1.3.1 MWF_WFM (08h): Waveform class

Waveforms such as standard 12-lead ECG and monitoring ECG are grouped based on instruments and purpose, as shown in Table 8.

Table 8 — Waveform class

MWF_WFM		Data length	Default	Remarks	Duplicated definitions
08	08h	2	Non-specific waveform	—	Override
		Str ≤ 32	Waveform description	—	

As a general rule, each type of waveform is described in a separate specification.

For types of waveforms (Table 9), numbers 1 to 49151 (BFFFh) are reserved. Numbers 49152 to 65535 can be used privately, but it is recommended to add these to the MFER specification rather than rely on private extensions.

Table 9 — Standard 12-lead ECG waveforms

Waveform kind	Type	Value	Waveform description	Remarks
Electrocardiogram	ECG_STD12	1	Standard 12-lead ECG	Standard 12-lead ECG including general ECG in short-term recording.
	ECG_BEAT	9	QRS beat	In general, one heart beat waveform extracted from standard 12-lead ECG recording. Write comment Average, Median, Dominant
	ECG_DRV	12	Derived lead	Derived ECG from Frank vector leads, EASI lead, etc.

5.1.3.2 MWF_LDN (09h): Waveform attributes (lead name, etc.)

This is the waveform code used in 12-lead ECGs and vector lead ECGs. Because the lead code is encoded by 0 to 127, care should be taken when other standards such as SCP-ECG, etc. are followed. Since part of these code spaces overlap, the present table shall be followed in all MFER applications.

Since in this specification, the code for the lead name is encoded by 127 or less, the codes specified in systems such as SCP-ECG shall require conversion. However, in the present lead code table, leads which are not used in standard 12-lead ECG are defined and, in general, will not need to be replaced.

Table 10 — Definition of waveform attributes

MWF_LDN			Data length	Default	Description range, remarks	Duplicated definition
09	09h	Waveform code	2	Undefined	Data length = 2, if waveform information is encoded	Override
		Waveform information	Str ≤ 32		—	

The present code supports 12-lead electronic cardiogram waveforms. In this Technical Specification, it is recommended to encode leads using MFER waveform information, rather than those specified in other standards.

In addition, this Technical Specification extends the 12-lead names for humans to include ECG lead names for animals. When other leads for animals are used, such as CV5RL, CV6LL, CV6LU, and V10, they should be specified by waveform information.

Table 11 — Lead name

Code	Lead	Code	Lead
1	I	—	—
2	II	—	—
3	V1	—	—
4	V2	—	—
5	V3	—	—
6	V4	—	—
7	V5	—	—
8	V6	—	—
9	V7	—	—

Table 11 *(continued)*

Code	Lead	Code	Lead
10	b	—	—
11	V3R	61	III
12	V4R	62	aVR
13	V5R	63	aVL
14	V6R	64	aVF
15	V7R	65	-aVR[a]
16	X	66	V8
17	Y	67	V9
18	Z	68	V8R
19	CC5	69	V9R
20	CM5	70	D(Nehb Dosal)
—	—	71	A(Nehb Anterior)
31	NASA	72	J(Nehb Inferior)
32	CB4	—	—
33	CB5	—	—
34	CB6	—	—

[a] aVR lead shall not be encoded according to MFER. The users (viewer) should mke a calculation to derive −aVR when required.

[b] Although V2R (10) is defined in other rules such as SCP-ECG, the definition shall not be used in MFER.

Code and information can be added to the type of waveform. If a waveform is required to be reconfigured, as in the case of deriving leads III and aVF from leads I and II, the codes should always be specified. The codes should be taken into special consideration as they have a function to specify some processing, as in the case of deriving other limb leads from leads I and II or deriving a waveform based on the lead name. See Annex D for the definition of waveform attributes.

As the lead names are defined depending on the class of waveform, the lead subsets are not called out for each class of waveform in MFER. Thus, caution should be taken in encoding lead names.

For waveform codes, numbers 1 to 49151 (BFFFh) are already reserved. Numbers 49152 to 65535 can be used privately but it is recommended to add these to the MFER specification rather than rely on private extensions.

5.1.3.3 MWF_WAV (1Eh): Waveform data

The entire set of waveform data should be strictly aligned as defined in Frame attributes. If the waveform data are compressed, the data alignment may depend on the compression method, but the waveform data after un-compressing should be aligned according to the definition. Refer to Annex B.

If waveform data are different from what is defined in frame information, they may be discarded depending on application processing. MFER behaviour is undefined in this case.

5.1.4 Channel

5.1.4.1 MWF_ATT (3Fh): Channel attributes (channel definition)

This tag defines the attributes for each channel (see Table 12). Before this definition, the channel number shall be specified using the values in Table 6.

Table 12 — Channel attributes

MWF_ATT		Data length	Default	Remarks	Duplicated definitions
63	3Fh	Depends on definition	—	—	Override

NOTE Channel definition for each channel is encoded with a special context tag of P/C = 1 and tag number of 1Fh. That is, the type number is P/C + tag number encoded with 3Fh and identifies the attribute of the relevant channel.

For the tag of the channel attribute definition, context mode is selected with P/C (bit 6 = 1).

<table>
<tr><td>8</td><td>7</td><td>6</td><td>5 4 3 2 1</td><td></td><td></td></tr>
<tr><td rowspan="2">0</td><td rowspan="2">0</td><td>1</td><td>31(1Fh)</td><td rowspan="2">0</td><td rowspan="2">Channel number</td></tr>
<tr><td colspan="2">63(3Fh)</td></tr>
</table>

Figure 1 — Number of channel

The data length includes all the range of the channel attribute definition (Figure 2).

<table>
<tr><td colspan="2">Tag</td><td>Data length</td><td colspan="10">Group of definition</td></tr>
<tr><td rowspan="2">3Fh</td><td rowspan="2">Channel number</td><td rowspan="2">All definition</td><td colspan="3">Channel attribute</td><td colspan="3">Channel attribute</td><td>—</td><td colspan="3">Channel attribute</td></tr>
<tr><td>T</td><td>L</td><td>V</td><td>T</td><td>L</td><td>V</td><td>—</td><td>T</td><td>L</td><td>V</td></tr>
</table>

Figure 2 — Definition of channel attributes

<table>
<tr><td colspan="2">Tag</td><td>Data length</td><td colspan="9">Group of definition</td></tr>
<tr><td rowspan="2">3Fh</td><td rowspan="2">Channel number</td><td rowspan="2">80h</td><td colspan="3">Channel attribute</td><td colspan="3">Channel attribute</td><td>—</td><td colspan="2">End-of-contents</td></tr>
<tr><td>T</td><td>L</td><td>V</td><td>T</td><td>L</td><td>V</td><td>—</td><td>00</td><td>00</td></tr>
</table>

Figure 3 — Definition of channel attributes with indefinite length

5.2 Data alignment

This Technical Specification supports many ECG alignment styles according to Annex B, allowing for complicated alignment formats that could result in processing issues. It is recommended that formats be simplified as much as possible in order to maximize interoperability.

5.3 Abstract waveform

This example is in principle the same as the 12-lead ECG, but one heartbeat of P-QRS-T is extracted and expressed. The abstract waveform is processed in three ways: extraction as dominant beat, averaged beat and median beat. These depend on the system concept and measurement method. The abstract waveform should be clearly stipulated in implementation specifications, but all leads may be encoded by abstract waveform of MFER.

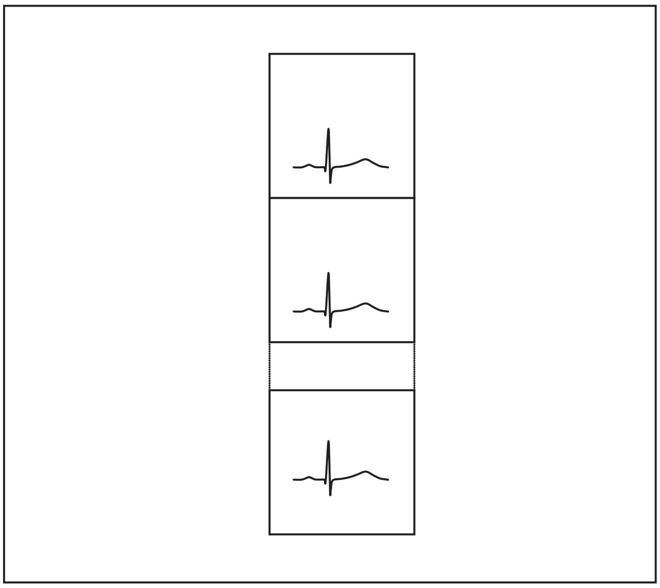

Figure 4 — Abstract waveform

5.4 Lead calculation

Recent electrocardiographs frequently adopt systems to record limb leads by Leads I and II only. In such event, Leads III, aVR, aVL, and aVF shall be found by calculation. Derivation shall be performed by the following operation:

> In implementing lead calculation, thorough consideration shall be given to aspects such as A/D conversion method, phase deviation or electrode disconnection, and care must be practiced to prevent occurrence of arithmetic waveform distortion.

Table 13 — Lead calculation operation table (calculation from leads I and II)

Lead name	Calculation operation	Computation (right arm potential R; left arm potential L, left foot potential F)
III	II – I	III = F–L = (F–R)– (L–R) where, II = F - R and I = L - R
aVR	– (I + II)/2	aVR = R–(L+F)/2 = {(R–L)+(R–F)}/2
aVL	I – II/2	aVL = L–(R+F)/2 = {(L–R)+(L–F)}/2 = (I–III)/2 = I–II/2
aVF	II – I/2	aVL = F–(R+L)/2 = {(F–R)+(F–L)}/2 = (II+III)/2 = II–I/2
-aVR	Negative number of aVR	

Table 14 — Lead calculation operation table (calculation from leads I and III)

Lead name	Calculation operation	Computation (right arm potential R; left arm potential L, left foot potential F)
II	III+ I	II = F–R = (F–L)+ (L–R) where, III = F - L and I = L - R
aVR	– I – III/2	aVR = R–(L+F)/2 = {(R–L)+(R–F)}/2 = {–I–(III+I)}/2 = –I–III/2
aVL	(I – III)/2	aVL = L–(R+F)/2 = {(L–R)+(L–F)}/2 = (I–III)/2
aVF	III + I/2	aVL = F–(R+L)/2 = {(F–R)+(F–L)}/2 = {(III+I)+III}/2 = III+I/2
-aVR	Negative number of aVR	

Table 15 — Lead calculation operation table (calculation from leads II and III)

Lead name	calculation operation	Computation (right arm potential R; left arm potential L, left foot potential F)
I	II – III	I = L–R = (F–R)– (F–L) where, II = F - R and III = F - L
aVR	– II + III/2	aVR = R–(L+F)/2 = {(R–L)+(R–F)}/2 = {– (II–III) –II }/2 = –II+III/2
aVL	–III + II/2	aVL = L–(R+F)/2 = {(L–R)+(L–F)}/2 = {(II–III) –III}/2 = –III+II/2
aVF	(II +III)/2	aVL = F–(R+L)/2 = {(F–R)+(F–L)}/2 = (II+III)/2
-aVR	Negative number of aVR	

Sampled ECG data for all leads shall be completely synchronized.

5.5 Filter information

When filter information is described in MFER, it is classified in two cases: filter-processed data and non-filtered use information.

5.5.1 Description of filter-processed data

Description is made on the filter information processed for the data described by MFER.

Table 16 — Filter information

MWF_FLT		Data length	Duplicated definitions
17	11h	Str < 256	Possible

Table 17 — Filter description example

Filter function	Abbreviation	Example	Meaning
Filter information only	None	Hum filter ON	Hum filter (characteristics, etc. not specified) used.
High-frequency pass filter	HPF	HPF = 0,05	Indefinite characteristics 0,05 Hz low frequency cutoff (high-pass) filter used.
Low-frequency pas filter	LPF	LPF = 150^secondary Butterworth filter	Butterworth secondary characteristics 150 Hz high frequency cutoff (low-pass) filter used.
Band elimination filter	BEF	BEF = 50^Hum filter	50 Hz Hum filter used. Cutoff characteristics not known.

In ECG, high-pass (low frequency cutoff) filter is frequently described by the time constant, but in MFER, it is recommended to describe it by frequency. For example, the low frequency cutoff filter, which has the primary Butterworth characteristics shown by frequently used CR, is described by the following:

By High-Pass Filter = $1/\omega T$, the lower cutoff frequency of time constant of 3 s is described by $1/(2\pi \times 3\ s) \approx 0{,}05$ Hz.

5.5.2 Description of filter use information

In this case, MFER ECG data has not been subject to filter processing, and the fact that a specific filter is used is stipulated only. For example, this information may be used to indicate that the ECG was measured by an electrocardiograph, printed on recording paper underwent the relevant filter processing and may be utilized for diagnosis.

5.6 Unique identifier

This tag indicates UID (Unique Identifier).

Table 18 — Unique identifier

MWF_UID		Length	Default value	Remarks	Override
135	87h	Str ≤ 64	No		No

Definition of the Object Identifier is not in the scope of MFER. This is designated with OID, UUID.

6 Measurement information

Of information generated during measuring ECG, information that would exert effect on the authenticity of ECG and validity of waveforms is encoded. For example, it is possible to encode waveform display information and power supply frequency that do not exert effect on generation of ECG waveform measurement but that are required to reproduce the condition at the time of measurement. The descriptions in this chapter are recommended to be implemented in accordance to local conventions whenever possible.

Refer to Annex C.

6.1 Measurement date/time

This tag encodes the examination/measurement date/time or the data acquisition date/time (Table 19).

The date/time is an important object stored using MFER. Care should be taken to ensure it is accurate.

Table 19 — Measurement time

MWF_TIM			Data length	Default	Remarks	Duplicated definitions
133	85 h	Year	2	None	1900 – 2100	Override
		Month	1		1 – 12	
		Day	1		1 – 31(1 – 30, 1–28, 29)	
		Hour	1		0 – 23	
		Minute	1		0 – 59	
		Second	1		0 – 59	
		Millisecond	2		0 – 999	
		Microsecond	2		0 – 999	

6.2 Measurement time (classification point)

The measurement time (classification point) is encoded by MWF_EVT format.

Table 20 — Event

MWF_EVT			Data length	Encoding range/remarks	Duplicated definition
65	41h	Event code	2		Possible
		Starting time (point)	4	Number of samples acquired at the sampling interval defined in the root definition	
		Duration	4		
		Event information	Str < 256		

When the recognition point of ECG waveform is shown (Figure C.1), it is encoded by the event code. When the recognition point in an ECG waveform is encoded by the root definition, it applies to all leads. When it is in a channel definition (each channel), the recognition point shall only apply to that channel.

By specifying the lead inside the channel definition, the recognition point of each lead may be encoded. If the waveform is not encoded using MFER, then the lead should be specified in the channel definition.

6.3 Measurement value

The measurement value is encoded by MWF_VAL.

Table 21 — Measurement value

MWF_VAL			Data length	Encoding range/remarks	Duplicated definition
66	42h	Value code	2		Multiple definitions available
		Time point	4	Number of data values sampled is encoded.	
		Value	Str ≤ 32	Value is encoded with a character string with unit (“^”).	

6.4 Measurement information classification

6.4.1 Observation event

Events that have actually occurred, such as clinical observations, can be encoded by the use of MWF_EVT.

Table 22 — Event information

MWF_EVT			Data length	Encoding range/remarks	Duplicated definition
65	41h	Event code	2		Possible
		Starting time (point)	4	Number of data values acquired at the sampling interval defined in the root definition.	
		Duration	4		
		Event information	Str < 256		

6.4.2 Waveform ancillary information

Information that may possibly exert an effect on the waveform, such as power supply frequency, shall be encoded using MWF_INF.

Table 23 — Waveform ancillary information

MWF_INF			Data length	Encoding range/remarks	Duplicated definition
21	15h	Ancillary information code	2		Possible
		Starting time (point)	4	Number of data values acquired at the sampling interval defined in the root definition.	
		Duration	4		
		Waveform information	Str < 256		

6.4.3 Recording/display condition

Though no influence is exerted on the waveform encoded in MFER, MWF_CND shall be used to encode information on lead combinations used when the ECG was measured. This encoding is used when recording and display conditions should be reproduced, for example, in electronic medical records, in order to improve, authenticity.

Table 24 — Recording/display, etc. information

MWF_CND			Data length	Remarks	Duplicated definition
68	44h	Recording/display condition	2		Possible
		Description code 1	2		
		Description code 2	2		
		Starting point	4		
		Duration	4		
		Descriptive information	Str < 256		

6.4.3.1 Waveform display example

Recording lead combinations used when ECG is measured are encoded by MWF_CND.

Tag: MWF_CND

Recording/display condition: MWF_ECG_LEADS (65030)

Description code 1: channel No. 1 -

Description code 2: lead name

Starting point: record starting point

Duration: Relevant recording time

6.4.3.2 Recording sensitivity display example

The recording sensitivity used at the time of recording is encoded.

6.5 Power supply frequency

The power supply frequency may be encoded. In general, the electrocardiograph has an AC interference elimination filter, but recording without filter processing and adding encoding of power supply frequency can eliminate AC interference by secondary processing.

6.6 Electrode condition

This may be specified when electrodes are disconnected. In particular, in the event that lead composition is performed, the derivation operation will not be performed accurately, a possible situation that should be thoroughly taken into account in implementation.

6.7 Calibration waveform

Encoding can be performed when calibrated waveform is implemented.

6.8 Artefact contamination

This code can be used to indicate that artefact and noise get mixed at the time of measuring ECG.

6.9 Automatic interpretation code, etc.

The Interpretation code is used for an automatic analysis system, but in the event that this function may be represented using another protocol such as HL7, it that protocol should be used.

6.9.1 MFER interpretation code and heart beat code encoding rules

Interpretation statements code and beat annotation can be encoded using the event tag.

Table 25 — Automatic interpretation code

MWF_EVT			Data length	Encoding range/remarks	Duplicated definitions
65	41h	Interpretation statements code	2		Possible
		Starting time (point)	4	Number of data values acquired at the sampling interval defined in the root definition.	
		Duration	4		
		Interpretation statements descriptive information	Str < 256		

16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
0	0	0	Interpretations statements code											Question	

Figure 5 — Composition of interpretation statements code

The interpretation statements code is composed with 128 - 8191.

The question bit code means:

0: Undesignated (finalization or designation is not particularly needed)

1: In the event that there is little possibility of rendering an opinion

2: When there is any question

3: When there is strong question,

and is able to designate the following supplementation:

a) Interpretation code

When the applicable opinion is encoded throughout the whole frame, definition shall be made in the root definition region. In the event that no event information is used, both starting time and duration are not used. In the case that event information is used, “zero” shall be employed for both starting time and duration.

b) Waveform classification for each heart beat

The time of the position of the applicable heart beat shall be designated as the starting time and no duration time is used. When the event information is used, the duration shall be set to “zero” and the event information is used.

c) Waveform classification within the period

For example, transient bundle branch block, etc. are encoded, using the starting time and duration, the relevant regional time shall be specified.

d) When waveform classification is encoded simultaneously with event information, event code and event information can be specified at the same time, or the event code = 0 and the event information may be encoded.

6.10 Patient information

6.10.1 Patient name

Patient name should be as follows.

Family name^first name^middle name

Table 26 — Patient name

MWF_PNM		Data length	Default	Remarks	Duplicated definition
129	81h	Str ≤ 128	None		Override

6.10.2 Patient ID

The patient identifier may be encoded. Management of patient identifiers is outside the scope of the MFER specification. It is recommended to encode a patient ID as follows:

Patient ID^Local ID^Temporary ID.

If the above format is not provided, then the available identifier shall be used for all applications.

Table 27 — Patient ID

MWF_PID		Data length	Default	Remarks	Duplicated definition
130	82h	Str ≤ 64	None		Override

6.10.3 Age and date of birth

Age of the patient and date of birth may be encoded. The patient age is based on the date of examination or waveform acquisition.

Table 28 — Age and date of birth

MWF_AGE				Data length	Default	Remarks	Duplicated definition
131	83h	Age	Years	1	None		Override
			days	2			
		Date of birth	Year	2			
			Month	1			
			Day	1			

6.10.4 Gender

The gender of the patient may be encoded.

Table 29 — Gender

MWF_SEX		Data length	Default	Remarks	Duplicated definition
132	84h	1	Unclear		Override

Table 30 — Gender code

Gender	Code
Unclear	0
Male	1
Female	2
Unspecified	3

6.11 Comment

Memos and comments may be encoded. Information that does not exert a direct effect on waveform may be encoded (e.g. patient movement).

[Reference] Information that exerts effect on waveform may be encoded by ancillary information (MWF_INF).

Table 31 — Comment

MWF_NTE		Data length	Default	Remarks	Duplicated definitions
22	16h	Str < 256			Possible

Only one comment shall be encoded within 255 characters; however, multiple comments may be included as required. Each comment may be read by a viewer, whether or not the comment has any user specified meaning.. By using multiple instances of comments, longer comments may be accommodated.

Annex A
(informative)

MFER Conformance statement

A.1 Conformance statement

Each implementer should provide a specification sheet of their MFER waveform format using the conformance statement below (Table A.1). Use of non-default values should be identified clearly. If the extension capabilities of the MFER description are used, an additional sheet with these optional extensions should also be provided.

Table A.1 — Conformance statement template

MFER specification			**Frame**		/	**Ver.**	
Producer	Manufacturer		Date			Model	
	Author		Edited date				
Waveform title			Specification				
Preamble			Endianity	•Default(big endian) •Big endian •Little endian			
Version	..	Character					
Sampling attributes	Sampling rate	Unit		Exponent		Mantissa	
	Sampling resolution	Unit		Exponent		Mantissa	
Data type	•Default •( )	NULL	•Not used •( )	Offset value	•Not used •( )		
Frame number		Block		Channel		Sequence	
Channel No.	**Lead or Waveform**	**Condition**				**Remarks**	
Note							

Annex B
(informative)

Waveform alignment

NOTE In this section, the term "channel" is used differently from the "channel attributes" of the frame referred to in MFER Part 1 according to traditional electrocardiography. Care must be taken to avoid any misunderstanding in its interpretation. For example, a 3-channel ECG has a different meaning from the channel attributes of the MFER frame.

B.1 1-channel ECG

This model describes the oldest type of 1-channel electrocardiograph, where an ECG is recorded by measuring over one lead. For each lead, the frame is encoded and the waveform length is variable. Waveforms may be viewed in chronological order, but the format should be properly changed for display or recording as is the case with the realignment to 3x4 leads of Figure B.2. This encoding is old-fashioned as an electrocardiograph but is still popularly used for a biological information monitor, for example.

B.1.1 1-channel ECG recording

ECG is recorded frame by frame and relevant lead waveform is not ensured of temporal continuation. Consequently, time-phase that bestrides leads, for example, RR interval, has no meaning.

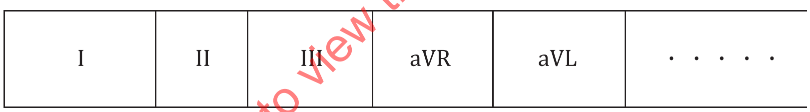

Figure B.1 — 1-channel ECG

B.1.2 3-channel realignment of waveforms recorded in 1-channel ECG

In this case, 1-lead ECGs that are shown in 1-channel ECG of Figure B.1 are realigned into 3x4 leads. In such events, the waveform phase between channels is not compensated and there is no synchronism in each heartbeat.

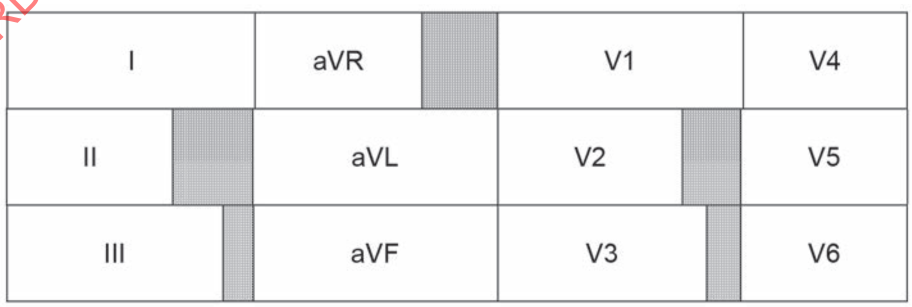

Figure B.2 — Realignment to 3x4 leads

B.1.3 6-channel realignment of waveforms recorded in 1-channel ECG

This is a case in which 1-lead ECG shown in 1-channel ECG of Figure B.1 is realigned into 6x2 leads. In such event, the waveform phase between channels is not compensated and there is no synchronism in each heartbeat.

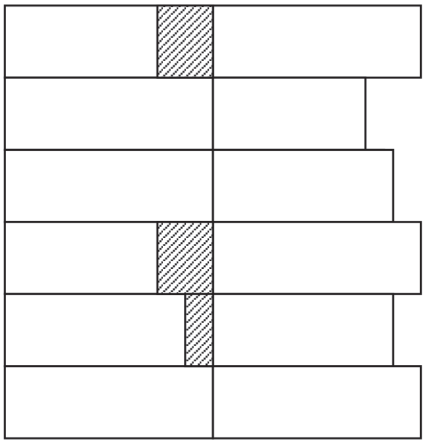

Figure B.3 — Realignment to 6x2 leads

B.2 Multichannel ECG

This is a model to represent 2-channel, 3-channel, and other ECGs. No synchronism is achieved in waveform phases between groups.

This information does not indicate the actual recording image such as multiplex mode recording, alternate mode recording, as prescribed in ISO 22077-1.

B.2.1 3-channel ECG

In this model, there is no time synchronism between groups, for example, I, II, and III and aVR, aVL, and aVF groups.

I	aVR	V1	V4
II	aVL	V2	V5
III	aVF	V3	V6

Figure B.4 — 3-channel ECG

B.2.2 Realignment of 3-channel ECG to 6x2 lead ECG

In this case, too, there is no time synchronism between groups, either, same as B.2.1.

I	V1
II	V2
III	V3
aVR	V4
aVL	V5
aVF	V6

Figure B.5 — 6x2 lead realignment

B.2.3 In case where calculating leads are used

It is possible to calculate from Limb Lead I and Lead II by other limb lead composition.

I	V1
II	V2
III or calculated III	V3
calculated aVR	V4
calculated aVL	V5
calculated aVF	V6

Figure B.6 — Realignment of calculated 6x2 leads

B.3 Multichannel simultaneous recording ECG

In general, 8 leads of I, II, V1, V2, V3, V4, V5, and V6 are encoded by MFER to exchange and retain messages, and when they are used for display or recording, other limb leads are found by derivation (see 5.4). In this format, a method of simultaneously recording 9 leads (I, II, III, V1, V2, V3, V4, V5, and V6 are simultaneously recorded and aVR, aVL, and aVF are arithmetically found) and 12 leads (I, II, III, aVR, aVL, aVF, V1, V2, V3, V4, V5, and V6) is used. This information does not indicate actual recording images such as multiplex recording, alternate mode recording, etc. prescribed in ISO 22077-1.

NOTE Besides deriving other leads found from two leads of I and II, other leads can be derived from Leads I and III or Leads II and III (see Table 13).

B.3.1 8-lead ECG

The ECG consists of 2 channels limb leads (in general, Leads I and II) and 6 channels chest leads from V1 through V6. The remaining limb leads (III, aVR, aVL, and aVF) can be found by lead composition (refer to Table 13). However, limb leads are able to be used in other combinations, for example, combinations of Leads II and III and Leads III and I [see Table 13)].

I
II
V1
V2
V3
V4
V5
V6

Figure B.7 — 8-lead ECG

B.3.2 9-lead ECG

I
II
III
V1
V2
V3
V4
V5
V6

Figure B.8 — 9-lead ECG

B.3.3 12-lead simultaneous ECG

All 12-lead ECGs are simultaneously recorded.

I
II
III
aVR
aVL
aVF
V1
V2
V3
V4
V5
V6

Figure B.9 — 12-lead ECG

B.3.4 12-lead full synchronizing ECG at the time of use

In ECGs encoded in B.1 and B.2, remaining Leads III, aVR, aVL, and aVF are found by calculation (refer to Table 13).

I
II
Lead III
Lead aVR
Lead aVL
Lead aVF
V1
V2
V3
V4
V5
V6

Figure B.10 — Calculated 12-lead synchronization display

B.3.5 6x2 lead composition synchronization ECG

In this display, there is a method to display all leads fully synchronized and a method to display temporal misalignment, that is, to display Lead I (group) followed by Lead V1 (group) (from II and III, other leads can be found or from Leads I and III, other waveforms can be found by calculations).

I	V1
II	V2
Lead III	V3
Lead aVR	V4
Lead aVL	V5
Lead aVF	V6

Figure B.11 — Calculation type 6x2 leads

B.3.6 3x4+1 leads are displayed by calculated leads

I	Lead aVR	V1	V4
II	Lead aVL	V2	V5
Lead III	Lead aVF	V3	V6
II			

Figure B.12 — Figure 13 3x4+1 leads

B.3.7 Lead-reassigned 12-lead ECG display 1

This is to reassign 12-lead ECG waveforms in the order of vector with directions taken into account.

Lead aVL
I
Lead (- aVR)
II
Lead aVF
Lead III
V1
V2
V3
V4
V5
V6

Figure B.13 — Reassigned 12-lead ECG

B.3.8 6x2 lead composition synchronization ECG

In this display, there is a method to display all leads fully synchronized and a method to display temporal misalignment, that is, to display Lead I (group) followed by Lead V1 (group) (from II and III, other leads may be found or from Leads I and III, other waveforms may be found by calculations).

Lead aVL	V1
I	V2
Lead -aVR	V3
II	V4
Lead aVF	V5
Lead III	V6

Figure B.14 — Lead-reassigned 12-lead ECG display 6x2 display

B.3.9 Free format

In addition, this format describes an optional time with optional lead combinations. In this example, optional combinations of a total of 3 leads of Lead II, Lead V1, and Lead aVF are recorded for an optional time.

II
V1
aVF

Figure B.15 — Free format

B.3.10 Extended lead

When extended lead is lead-designated, extended display is enabled by the above display and the display that conforms to multichannel ECG (possibility of failure of time-phase coincidence).

I	V1	V2(V1R)
II	V2	V1(V2R)
Lead III	V3	V3R
Lead aVR	V4	V4R
Lead aVL	V5	V5R
Lead aVF	V6	V6R

Figure B.16 — Extended lead example

I	V1	—
II	V2	—
Lead III	V3	—
Lead aVR	V4	V7
Lead aVL	V5	V8
Lead aVF	V6	V9

Figure B.17 — Extended lead 1

I	V1	—
II	V2	—
Lead III	V3	—
Lead aVR	V4	V3R
Lead aVL	V5	V4R
Lead aVF	V6	V5R

Figure B.18 — Extended lead 2

Annex C
(informative)

Encoding of waveform recognition point and measurement values

C.1 General

Waveform recognition points (classification point) may be encoded with event tag (MWF_EVT), which is categorized as Level 2 as defined in ISO 22077-1.

C.1.1 Waveform recognition point

The ECG waveform recognition points are shown in Figure C.1, and each point is encoded with the event tag of MFER coding. In the case that the recognition point is encoded in the root definition, the recognition points affect all leads of the beat. On the other hand, if the recognition points are in the channel definition, they only apply to beats in that channel.

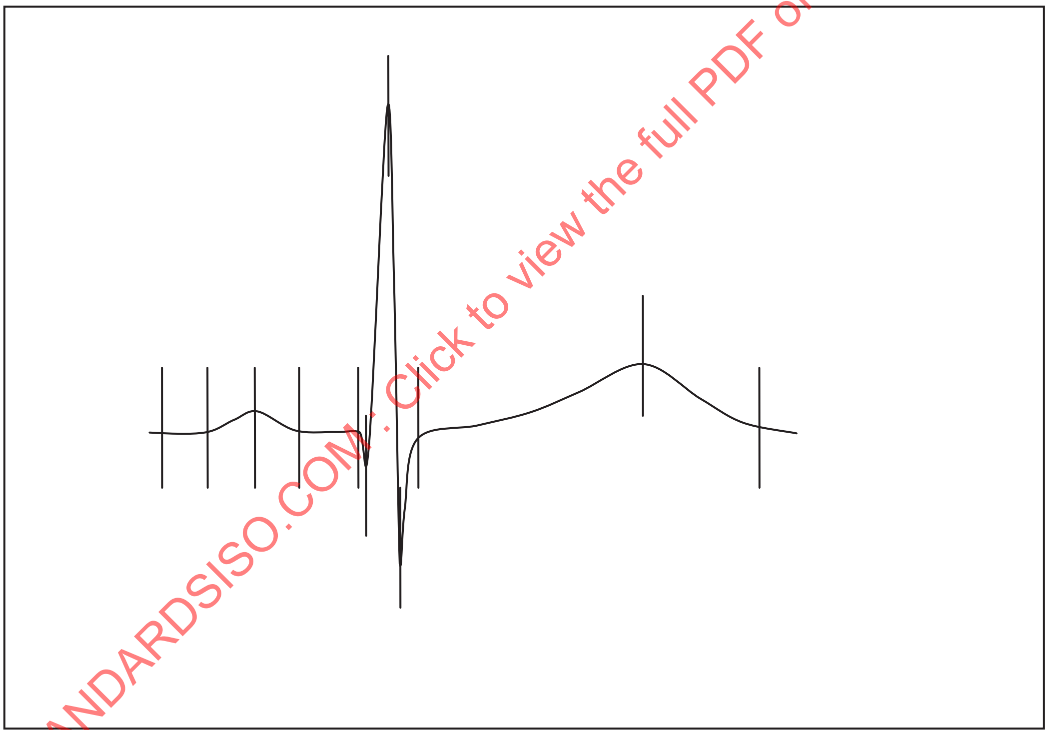

Figure C.1 — Waveform recognition point

C.1.2 Encoding for recognition point

The waveform identification point is encoded with an event tag (MWF_EVT). The episode code such as P wave, QRS, etc. is represented on the waveform recognition code of the MWF_EVT.

The start point of the episode such as P onset, QRS onset, etc. is described on the starting time position of the MWF_EVT, In the case of single point representation such as peak point, only the staring time position is used. If this is the case and supplement information is used, the duration shall be zero.

The end point is described by start point and duration, namely the end point is presented by start point + duration period. If there is specific information for the recognition point, the information can be described on the supplementary part in a text string.

Table C.1 — Event

MWF_EVT			Data length	Encoding range/remarks	Duplicated definitions
65	41h	Event code	2	Waveform recognition point code	Possible
		Starting time (point)	4	Number of data values acquired at the sampling interval defined in the root definition	
		Duration	4		
		Interpretation statements descriptive information	Str < 256		

16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
Waveform recognition point code							0	0	Lead code						

Figure C.2 — Waveform recognition point code bit

Lead code designation can be encoded as channel information when the channel coincides with the entity but in the 12-lead ECG, it is encoded by Figure C.2.

C.1.3 Group definition

When the waveform recognition points are identified as the same heart beat such as a P-QRST-T, the beat is indicated using bracketing by group definition (MWF_SET). Since this tag is P/C = 1(bit 6), the group definition implies the context mode.

Table C.2 — Group definition

MWF_SET		Data length	Default	Remarks	Duplicated definitions
103	67h	Depends on definition			Not possible within scope

The group definition means that all recognition points are related to each other. For example, a P wave activity generates the following QRS contraction, and QRS and T wave are same beat phenomenon. Therefore, when some events should be described at same time, these events can be grouped as same beat.

MWF_SET			
	P wave	QRS	T wave

Figure C.3 — Example of P-QRS-T Group

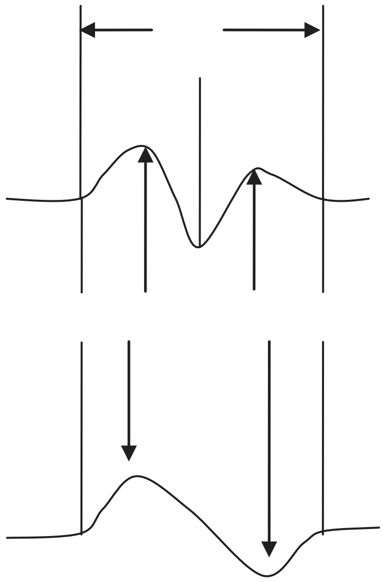

Figure C.4 — P wave

C.1.4 Classification code

Each classified point is represented in Table C.3 on the first element of MWF_EVN.

Table C.3 — Classification code

Reference ID	CODE		English name
	DEC	HEX	
MWF_ECG_DOMT	55808	DA00	Dominant beat
MWF_ECG_AVBEAT	56320	DC00	Averaging beat
MWF_ECG_P_WAVE	35328	8A00	P wave
MWF_ECG_P2_WAVE	35840	8C00	P2 wave
MWF_ECG_P1_PEAK	36352	8E00	P wave first peak
MWF_ECG_P2_PEAK	36864	9000	P wave second peak
MWF_ECG_PP_WAVE	37376	9200	P' wave (Retrograde)
MWF_ECG_PP2_WAVE	37888	9400	P'2 wave
MWF_ECG_PP1_PEAK	38400	9600	P' wave first peak
MWF_ECG_PP2_PEAK	38912	9800	P' wave second peak
MWF_ECG_QRS_COMPLEX	41472	A200	QRS complex
MWF_ECG_QRS_PEAK	41984	A400	QRS peak
MWF_ECG_Q_WAVE	43008	A800	Q wave
MWF_ECG_Q_PEAK	43520	AA00	Q wave peak
MWF_ECG_R_WAVE	44032	AC00	R wave
MWF_ECG_R_PEAK	44544	AE00	R wave peak
MWF_ECG_R2_WAVE	45056	B000	R' wave
MWF_ECG_R2_PEAK	45568	B200	R' wave peak
MWF_ECG_R3_WAVE	46080	B400	R" wave
MWF_ECG_R3_PEAK	46592	B600	R" wave peak

Table C.3 *(continued)*

Reference ID	CODE		English name
	DEC	HEX	
MWF_ECG_S_WAVE	47104	B800	S wave
MWF_ECG_S_PEAK	47616	BA00	S wave peak
MWF_ECG_S2_WAVE	48128	BC00	S' wave
MWF_ECG_S2_PEAK	48640	BE00	S' wave peak
MWF_ECG_S3_WAVE	49152	C000	S" wave
MWF_ECG_S3_PEAK	49664	C200	S" wave peak
MWF_ECG_QRS_NOTCH	50176	C400	Notch
MWF_ECG_DELTA	42496	A600	Delta
MWF_ECG_T_END	51712	CA00	T wave end
MWF_ECG_T_PEAK	52224	CC00	T wave peak
MWF_ECG_T2_END	52736	CE00	T' wave end
MWF_ECG_T2_PEAK	53248	D000	T' wave peak
MWF_ECG_U_END	53760	D200	U wave end
MWF_ECG_U_PEAK	54272	D400	U wave peak
MWF_ECG_STJ	50688	C600	ST-j
MWF_ECG_ST	51200	C800	ST
WMF_ECG_J_WAVE	39424	9A00	J wave
MWF_ECG_H_WAVE	40448	9E00	His bundle wave
MWF_ECG_FIDUCIAL	33792	8400	Fiducial point
MWF_ECG_ISOELECTRIC	33280	8200	Isoelectric point
MWF_ECG_UN_PACING	34048	8500	Pacing pulse (unknown)
MWF_ECG_A_PACING	34304	8600	Atrial pacing pulse
MWF_ECG_V_PACING	34816	8800	Ventricular pacing pulse
MWF_ECG_CAL	55296	D800	Calibration

C.1.5 Measurement value (measurement value with no lead designation)

Table C.4 shows the values measured by total leads.

Table C.4 — Measurement value (no lead designation) code table

Reference ID	CODE		English name
	DEC	HEX	
MWF_ECG_HEART_RATE	32769	8001	Heart rate
MWF_ECG_VPC_MIN	32778	800A	VPC rate per min
MWF_ECG_VPC_HOUR	32780	800C	VPC rate per hour
MWF_ECG_TIME_PD_RR	32770	8002	RR interval
MWF_ECG_ANGLE_P_FRONT	32772	8004	P wave axis
MWF_ECG_ANGLE_QRS_FRONT	32774	8006	QRS axis
MWF_ECG_ANGLE_T_FRONT	32776	8008	T wave axis
MWF_ECG_ANGLE_T_PP	32782	800E	PP interval

C.1.6 Measurement value (allowed to designate for each lead)

In the event that the measurement value differs for each lead and all leads are standardized, the measurement value shall be specified. In the event that Leads III and aVL are values found from lead composition, the measurement value can be described by designating the virtual channel, but to be simple, it can be encoded by the present rules (lead name designation). In the case of lead code 0, it is interpreted to be no lead designation. Where still more detailed description is required, it is found by operation from the waveform classification point and sampling information.

16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
Measurement value code									Lead code						

Figure C.5 — Measurement value code composition

Table C.5 — Measurement value table for each lead

Reference ID	CODE		English name
	DEC	HEX	
MWF_ECG_TIME_PD_P	57472	E080	P width
MWF_ECG_AMPL_P1	57600	E100	P1 amplitude
MWF_ECG_AMPL_P2	57728	E180	P2 amplitude
MWF_ECG_TIME_PD_PQ	57856	E200	PQ interval
MWF_ECG_AREA_P_WAV	59776	E980	P Area
MWF_ECG_TIME_PD_Q	57984	E280	Q duration
MWF_ECG_AMPL_Q	58112	E300	Q amplitude
MWF_ECG_TIME_PD_QRS	58240	E380	QRS duration
MWF_ECG_TIME_PD_R	59904	EA00	R duration
MWF_ECG_AMPL_R	58368	E400	R amplitude
MWF_ECG_TIME_PD_R2	60032	EA80	R2 duration
MWF_ECG_AMPL_R2	59392	E800	R2 amplitude
MWF_ECG_TIME_PD_S	60160	EB00	S duration
MWF_ECG_AMPL_S	58496	E480	S amplitude
MWF_ECG_TIME_PD_S2	60288	EB80	S2 duration
MWF_ECG_AMPL_S2	59520	E880	S2 amplitude
MWF_ECG_AMPL_STJ	58624	E500	STj
MWF_ECG_AMPL_ST	58752	E580	ST
MWF_ECG_ST_MIN	60416	EC00	STmin
MWF_ECG_AMPL_T	58880	E600	T amplitude
MWF_ECG_AMPL_T2	60544	EC80	T2 amplitude
MWF_ECG_TIME_PD_QT	59008	E680	QT interval
MWF_ECG_TIME_PD_QT_CORR	59136	E700	QTc interval
MWF_ECG_TIME_PD_VAT	59264	E780	Ventricular activation time
MWF_ECG_AMPL_ST_SLOPE	59648	E900	ST-slope
MWF_ECG_AMPL_ST1	60672	ED00	ST-amplitude at the J-point plus 20 ms (μV)
MWF_ECG_AMPL_ST2	60800	ED80	ST-amplitude at the J-point plus 40 ms (μV)