



BSI Standards Publication

Nuclear instrumentation – Data format for list mode digital data acquisition used in radiation detection and measurement

National foreword

This British Standard is the UK implementation of EN IEC 63047:2021. It is identical to IEC 63047:2018, incorporating corrigendum April 2020. It supersedes BS IEC 63047:2018, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee NCE/2, Radiation protection and measurement.

A list of organizations represented on this committee can be obtained on request to its committee manager.

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31 May 2020	Implementation of IEC corrigendum April 2020: IEC foreword corrected
28 February 2021	This corrigendum renumbers BS IEC 63047:2018 as BS EN IEC 63047:2021

English Version

**Nuclear instrumentation - Data format for list mode digital data
acquisition used in radiation detection and measurement
(IEC 63047:2018 + COR1:2020)**

Instrumentation nucléaire - Format de données pour
l'acquisition de données numériques en mode liste utilisées
dans la détection et la mesure des rayonnements
(IEC 63047:2018 + COR1:2020)

Nukleare Instrumentierung - Datenformat für digitale
Datenerfassung im List-Mode für Strahlungsnachweis und -
messung
(IEC 63047:2018 + COR1:2020)

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Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

European foreword

This document (EN IEC 63047:2021) consists of the text of IEC 63047:2018¹ prepared by SC 45B "Radiation protection instrumentation" of IEC/TC 45 "Nuclear instrumentation".

The following dates are fixed:

- latest date by which the document has to be implemented at national (dop) 2022-01-25 level by publication of an identical national standard or by endorsement
- latest date by which the national standards conflicting with the (dow) 2024-01-25 document have to be withdrawn

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¹ As impacted by IEC 63047:2018/COR1:2020.

Annex ZA (normative)

Normative references to international publications with their corresponding European publications

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE 1 Where an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu.

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 62755	-	Radiation protection instrumentation - Data - format for radiation instruments used in the detection of illicit trafficking of radioactive materials	-	-
ISO/IEC 8824-1	2015	Information technology - Abstract Syntax - Notation One (ASN.1): Specification of basic notation	-	-
ISO/IEC 8825-7	-	Information technology - ASN.1 encoding - rules - Part 7: Specification of Octet Encoding Rules (OER)	-	-
ISO/IEC 9834	-	Information technology – Procedures for - the operation of object identifier registration authorities: General procedures and top arcs of the international object identifier tree	-	-
ISO/IEC 10646	2017	Information technology - Universal Coded - Character Set (UCS)	-	-
ISO 8601	-	Data elements and interchange formats - - Information interchange - Representation of dates and times	-	-
IEEE 754	-	IEEE Standard for Floating-Point - Arithmetic	-	-

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

NUCLEAR INSTRUMENTATION – DATA FORMAT FOR LIST MODE DIGITAL DATA ACQUISITION USED IN RADIATION DETECTION AND MEASUREMENT

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as “IEC Publication(s)”). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 63047 has been prepared by IEC Technical Committee 45: Nuclear instrumentation.

The text of this International Standard is based on the following documents:

CDV	Report on voting
45/842/CDV	45/848/RVC

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

In this standard, the following print types are used:

- Names of data types, elements and definitions in ASN.1: in `Courier New`

NOTE This publication contains an attached file in the form of an .asn file, whose content is identical to that of Annex A. This file is intended to be used as a complement and does not form an integral part of the publication.

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The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

The contents of the corrigendum of April 2020 have been included in this copy.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

In the context of this document, digital data acquisition devices are high-performance measuring instruments that sample signals from radiation detectors in order to store and process them in a digital manner. They offer advantages over conventional data acquisition systems: they are in general faster and cope better with high count rates, are more compact and less expensive per input channel. They allow easier integration of many radiation detectors in the same system, which results in benefits for nuclear physics. In addition, the real-time processing provided by digital data acquisition systems allows new applications in for example nuclear security and safeguards. They enable off-line processing and re-analysis of acquisition data which may improve the accuracy of radioactivity measurement, and enable computational analysis of individual detector or system response data.

The equipment to which this document applies is commonly known as "digitisers", and may offer signal processing with digital signal processors (DSP) or field-programmable gate arrays (FPGAs). To reduce the amount of data to be stored or transferred, these devices are programmed to extract only the properties of interest, such as the pulse height, pulse area, sub-areas, rise time or pulse shape, and the timestamp of the events associated with the interaction of radiation in a detector. Alternatively, they may also offer the partial or full recording of the digital signal for more advanced processing. This type of time-stamped data is often called "list-mode data" which may be stored for off-line processing and analysis by software.

Typically, digital data acquisition devices are controlled by a computer, which may be embedded in the device, and which runs proprietary or custom-made data acquisition software. Instrument drivers take care of the communication with the data acquisition device. This document specifies the format of the data presented by digital data acquisition devices, primarily used for accurate laboratory measurements, but also for new applications in nuclear safety, security and safeguards. The data may be stored on a local or remote computer, or may be streamed to a remote computer in a network.

This document relies on ASN.1 notation. ASN.1 is an internationally-standardised, vendor-, platform- and language-independent notation to specify data structures at a high level of abstraction. The ASN.1 notation standard is complemented with standardised encoding rules, which are independent of the notation, and again are platform- and language-independent. The encoding rules determine the precise bit-patterns in which values of these data structures are represented, when they are stored in a file or transferred to another computer over a network. Tools are available that facilitate the implementation of this document in software for data acquisition and analysis.

NUCLEAR INSTRUMENTATION – DATA FORMAT FOR LIST MODE DIGITAL DATA ACQUISITION USED IN RADIATION DETECTION AND MEASUREMENT

1 Scope

This international standard specifies the format of binary list-mode data at the output of digital data acquisition devices used for the detection and measurement of radiation. Such data acquisition devices may employ digital signal processors (DSPs) and field-programmable gate arrays (FPGAs) in combination with memory and a communication interface with a computer.

This document is applicable to those data acquisition devices which are able to record and present interaction data of radiation in detectors on an event-per-event basis, with data stored in an output file or streamed to a remote computer. Such list-mode data typically contains timestamp and energy information, but may also contain digital signals or properties like rise time or sub-areas of signals computed by the DSP or FPGA from the signal samples.

It is not the scope of this document to specify the communication protocol between data acquisition hardware and the instrument drivers. Instead, it specifies a standard format for the presentation of data acquired by one or more acquisition devices, to the user or user application.

This document only specifies the binary formatting of data. The formatted data may be sent or stored as specified by other protocols. Also, commands to control data acquisition devices are not included in this document.

This document does not put requirements on encryption or authentication of data. However, data is canonically encoded in the format of this document, which allows the application of data security algorithms.

This document does not replace IEC 62755. This document provides optional mechanisms to include IEC 62755 formatted data into list-mode data.

This document does not apply to data acquisition devices used as instrumentation and control systems in nuclear power plants, nor other safety-critical applications. It is also not intended for medical applications.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 62755, *Radiation protection instrumentation – Data format for radiation instruments used in the detection of illicit trafficking of radioactive materials*

ISO/IEC 8824-1:2015, ITU-T X.680, *Information technology – Abstract Syntax Notation One (ASN.1): Specification of basic notation*

ISO/IEC 8825-7, ITU-T X.696, *Information technology – ASN.1 encoding rules: Specification of Octet Encoding Rules (OER) and Technical Corrigendum 1 and Technical Corrigendum 2*

ISO/IEC 9834, ITU-T X.660, *Information technology – Procedures for the operation of object identifier registration authorities: General procedures and top arcs of the international object identifier tree*

ISO/IEC 10646:2017, *Information technology – Universal Coded Character Set (UCS)*

ISO 8601, *Data elements and interchange formats – Information interchange – Representation of dates and times*

IEEE 754, *IEEE Standard for Floating-Point Arithmetic*

3 Terms and definitions, abbreviated terms and notations

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1 Terms and definitions

3.1.1

ASN.1 specification

collection of one or more ASN.1 modules

Note 1 to entry: In this document, the term refers to the ASN.1 notation of the types defined in Clause 5 and repeated in Annex A (informative).

[SOURCE: ISO/IEC 8824-1:2015, 3.8.5]

3.1.2

ASN.1 module

one or more instances of the use of the ASN.1 notation for type, value, value set, information object class, information object, and information object set (as well as the parameterised variant of those), encapsulated using the ASN.1 notation

Note 1 to entry: The ASN.1 module in this document only uses ASN.1 notation for type and value.

[SOURCE: ISO/IEC 8824-1:2015, 3.8.50]

3.1.3

channel

arrangement of interconnected components within a system that initiates a single output

3.1.4

data acquisition device

measuring instrument that samples the signal generated by one or more sensors

EXAMPLE A digitiser sampling the signal from a radiation detector, or a measuring instrument connected to a temperature sensor.

3.1.5

data stream

sequence of digitally encoded coherent packets of data used to transmit or receive information

3.1.6**dead time**

time that a channel of a data acquisition device is unable to observe or to record properly events from a sensor such as a radiation detector

Note 1 to entry: Dead time may be caused by the detection process, the data acquisition device, or may be imposed on the data after the acquisition.

3.1.7**device**

data acquisition device, as defined in 3.1.4

3.1.8**digital signal**

discretely timed signal in which information is represented by a finite number of well-defined discrete values that one of its characteristic quantities may take in time

[SOURCE: IEC 60050-702:1992, 702-04-05, modified – "discreetly" corrected to "discretely"]

3.1.9**encoding**

bit-pattern resulting from the application of a set of encoding rules to an abstract value

[SOURCE: ISO/IEC 8824-1:2015, 3.8.25]

3.1.10**event**

set of properties (including the timestamp) obtained by measuring the signal from a single sensor, at the time expressed by the timestamp

EXAMPLE 1 The pulse height and timestamp of the detection of a photon in a radiation detector.

EXAMPLE 2 The location and orientation of a radiation detector at a certain time.

EXAMPLE 3 The measurement of the health of a data acquisition device (its power consumption, temperature, etc.) at a certain time.

3.1.11**integer type**

simple type with distinguished values which are the positive and negative whole numbers, including zero (as a single value)

[SOURCE: ISO/IEC 8824-1:2015, 3.8.48]

3.1.12**list-mode**

technique of acquiring and storing data from sensors such as radiation detectors, event by event

Note 1 to entry: Typically, the timestamp and measured properties such as pulse height associated with an event are recorded, but much more information may be added.

3.1.13**live time**

time that a channel of a data acquisition device is able to observe properly events from a sensor such as a radiation detector

Note 1 to entry: Live time is the time between consecutive periods of dead time.

3.1.14

measuring instrument

device intended to be used to make measurements, alone or in conjunction with supplementary devices

[SOURCE: IEC 60050-311:2001, 311-03-01]

3.1.15

object identifier

ordered list of primary integer values from the root of the international object identifier tree to a node, which unambiguously identifies that node

[SOURCE: ISO/IEC 9834-1:2012, ITU-T X.660 (07/2011), 3.5.11]

3.1.16

octet

ordered sequence of eight bits considered as a unit, equivalent to an 8-bit byte

Note 1 to entry: The term is used in preference to "byte" in this document and in the ASN.1 standards to avoid confusion in cases where there is a hardware association e.g. 7-bit byte, 16-bit byte.

3.1.17

radiation detector

sensor component of a radiation measurement instrument designed to produce a quantifiable response to ionising radiation

[SOURCE: IEC 62755:2012, 3.1.26]

3.1.18

randomisation

procedure ensuring that measurements of a random signal with a uniform distribution result in values appearing uniformly distributed, even when the measurement process provides discrete instead of continuous values

3.1.19

real time

sum of the total dead time and total live time of a channel

3.1.20

sampling

process of taking samples of a signal, usually at equal time intervals

[SOURCE: IEC 60050-704:1993, 704-23-02]

3.1.21

sampling frequency

number of samples of a signal taken per unit time

[SOURCE: IEC 60050-704:1993, 704-23-03]

3.1.22

SELECTION types

types defined by reference to a component type of a choice type, and whose values are precisely the values of that component type

[SOURCE: ISO/IEC 8824-1:2015, 3.8.66]

3.1.23**sensor**

part of a measuring instrument, or measuring chain, which is directly affected by the measurand and which generates a signal related to the value of the measurand

[SOURCE: IEC 60050-311:2001, 311-05-01]

3.1.24**SEQUENCE types**

types defined by referencing a fixed, ordered list of types (some of which may be declared to be optional); each value of the **SEQUENCE** type is an ordered list of values, one from each component type

Note 1 to entry: Where a component type is declared to be optional, a value of the sequence type need not contain a value of that component type.

[SOURCE: ISO/IEC 8824-1:2015, 3.8.67]

3.1.25**SEQUENCE OF types**

types defined by referencing a single component type; each value in the **SEQUENCE OF** type is an ordered list of zero, one or more values of the component type

[SOURCE: ISO/IEC 8824-1:2015, 3.8.68]

3.1.26**signal**

analogue electrical output of a sensor that carries information about the value of the measurand

3.1.27**time base**

reference oscillation from which time intervals can be determined in terms of the instants of occurrence of certain parts of the cycles of the oscillation

Note 1 to entry: In this document, time base refers to one cycle of the clock used to increment the timestamp counter of a channel, and is expressed in seconds. Time base is the inverse of the channel element `clockFrequency`, and represented by the symbol *B*.

[SOURCE: IEC 60050-702:1992, 702-04-08]

3.1.28**total dead time**

sum of all individual dead time contributions in a channel since the start of the acquisition

3.1.29**total live time**

sum of all individual live time contributions in a channel since the start of the acquisition

3.1.30**canonical encoding**

encoding producing a unique binary representation for every value

Note 1 to entry: Most of the ASN.1 encoding rules leave some degree of freedom. Encoding rules that leave no degrees of freedom during the encoding are called canonical.

EXAMPLE When a Boolean type is encoded using CANONICAL-OER (C-OER), the value TRUE shall be encoded as 255. This restriction does not apply to BASIC-OER, where FALSE is encoded as 0 while TRUE is encoded as any other value contained in a single octet (1 to 255).

3.2 Abbreviated terms

ADC	Analog to Digital Converter
ASN.1	Abstract Syntax Notation One
DSP	Digital Signal Processor
FPGA	Field Programmable Gate Array
PMT	photomultiplier tube
RMS	root-mean-square[SOURCE: IEC 60050-103:2009, 103-02-02]
RTC	Real-Time Clock
URI	Uniform Resource Identifier[SOURCE: RFC 3986]
UTC	Universal Coordinated Time
XML	Extensible Markup Language

3.3 Notations

3.3.1 Graphical notation

The following graphical notations are used in this document (see also Figure 1):

- channels are represented by thin, straight, black arrows;
- data connections are represented by thick arrows, of which the colour indicates the formatting of the data;
- data acquisition devices, or shortly, devices, are represented by rectangles;
- radiation detectors are represented by the typical shape of a scintillator connected to a photomultiplier tube. That symbol, however, is used to represent any type of radiation detector;
- any other sensor is represented by a square with a diagonal line;
- a storage medium such as a hard drive is represented by a drum;
- when there is no confusion possible, the text in the figures is omitted.

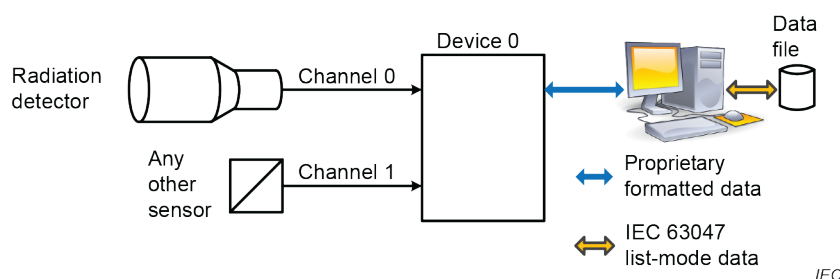


Figure 1 – Graphical notations used in this document.

3.3.2 ASN.1 notation

Names of data types, elements and definitions in ASN.1 are printed in a distinct font Courier New.

The basic notation of ASN.1 is specified in ISO/IEC 8824-1. This subclause briefly summarises the notation for the use in this document:

- ASN.1 type names start with an upper-case letter;
- ASN.1 keywords (including built-in types) are written exclusively in upper case, except some string types which were re-defined using the `OCTET STRING` type;
- each element of a `SEQUENCE` or `CHOICE` type is named by an identifier, which begins with a lower-case letter;
- one-line comments in ASN.1 notation begin with a pair of adjacent hyphens, "--". Even though comments do not have syntactic significance, they do contain normative text related to the application semantics, or constraints on the syntax, when used in Clause 5;

- the three dots "..." indicate places where the ASN.1 definitions are extensible (see 4.2.3).

3.3.3 Decimal separator

The default decimal separator in IEC publications is the comma. This is also the case in this document, except when used in ASN.1 notation, printed in the font `Courier new`, where the point is used as decimal separator.

3.3.4 Hexadecimal and binary numbers

In this document, hexadecimal numbers are represented as 'xx xx xx xx'H, and binary numbers as 'yyyy yyyy'B, where x takes a value from 0 to F and y the value 0 or 1.

4 General requirements

4.1 How to use this document

This document defines the list-mode data format and explains how it shall be used. The document is structured in the following way:

- the list-mode data format is defined by the general requirements in Clause 4 and the data types defined in Clause 5;
- Clause 6 specifies how to use the list-mode data format in different cases, such as the specification of dead time and timestamp counter rollover, and provides examples;
- Annex A (informative) repeats the ASN.1 type definitions from Clause 5 and may be used for copy-paste purposes, which may be helpful when ASN.1 tools are used;
- Annex B (informative) provides an introduction to ASN.1: the annex briefly introduces ASN.1 syntax and the C-OER encoding rule, and explains the ASN.1 workflow.

4.2 The use of Abstract Syntax Notation One (ASN.1)

4.2.1 General

The data format specified in this document is defined using the ASN.1 syntax specified in ISO/IEC 8824. Using available tools such as ASN.1 compilers, source code may be generated from the ASN.1 syntax specification. The generated code provides data structures and encoding and decoding routines that may be used to implement the standard. The use of such tools is not a requirement: the ASN.1 encoding and decoding rules are specified in ISO/IEC 8825, which may be used to develop own code for encoding or decoding. See Annex B (informative) for more information about ASN.1.

4.2.2 Encoding rule

The ASN.1 encoding rule applied to the list-mode data format defined in this document shall be C-OER (Canonical Octet Encoding Rule), as specified in ISO/IEC 8825-7, ITU-T X.696.

4.2.3 Extensibility

The ASN.1 specification in this document provides extensibility. Extensibility ensures backward and forward compatibility between different editions of this document. This means that, when this document is revised in the future (e.g. adding new features) all applications developed for previous editions will continue to work on the data encoded in the revised edition of the standard (but will ignore the new features). Applications developed for the revised standard will be able to read data generated by applications developed for previous editions. In ASN.1 notation, three dots (...) indicate the place where the ASN.1 specification may be extended in a later edition of this document.

4.2.4 Object identifier

In accordance with ISO/IEC 9834, ITU-T X.660, the object identifier which uniquely identifies the ASN.1 specification of this document is defined as `{iso(1) standard(0) listmode-dataformat(63047) 2018}` where 2018 is the year of publication of this document.

NOTE See <http://oid-info.com/get/1.0> for the object identifier tree for International Standards developed by ISO or IEC.

4.2.5 Optional and default elements

Some of the type definitions in this document contain elements which are optional while some other elements are specified with a default value. ASN.1 syntax and encoding rules specify the following:

- when no value is assigned to an optional element, the element will not be encoded. The encoder will use a "presence bitmap" to specify which of the optional elements in a type are assigned with a value. The decoder verifies the presence bitmap to determine which of the elements shall be decoded;
- when no value is assigned to an element with a default value, it will not be encoded. The presence bitmap will indicate that the value was not provided. In that case, the decoder will yield the default value for that element. Also, when the default value is provided, it will not be encoded;
- an element shall not be optional and have a default value at the same time.

EXAMPLE In the following ASN.1 specification, `listModeDataID` is optional, while `listModeDataPart` has a default value of 0. When both elements are not provided with a value, they will not be encoded. Decoding `listModeDataID` will yield an invalid value, while the decoded value of `listModeDataPart` will be 0.

```
listModeDataID    UTF8String OPTIONAL,
listModeDataPart  INTEGER (0..255) DEFAULT 0
```

4.3 The concept of list-mode data acquisition

NOTE In this subclause the terms and definitions defined in Clause 3 are printed in *italic*.

This document specifies the format of the binary data that represents the results of measurements of the *signal* generated by *sensors*. These *sensors* are in the first place *radiation detectors*, but could also be *sensors* that measure environmental conditions, geolocation, etc. In this document, these other *sensors* are treated in the same way as *radiation detectors*. Figure 2 shows a schematic diagram of the acquisition process.

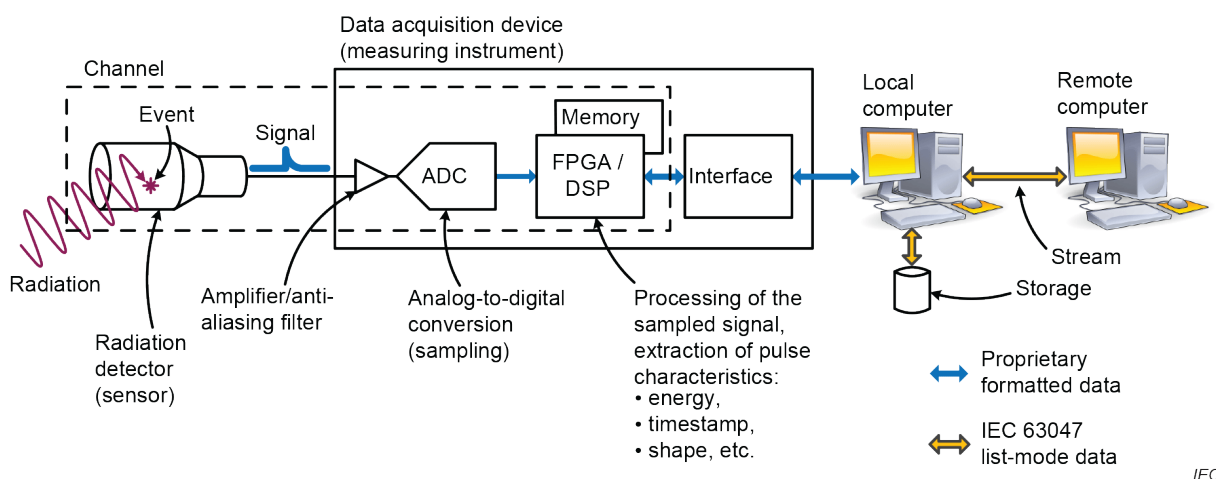


Figure 2 – Typical data acquisition device controlled by a local computer, which stores list-mode data on a local drive and/or sends it to a remote computer

For the application described here, an *event* is a set of properties or parameters of interest associated to an interaction of radiation in the *radiation detector*, recorded by the *measuring instrument* at a certain time. More generally, an *event* associates the result of a measurement performed by any kind of *sensor* with the time at which the measurement was performed.

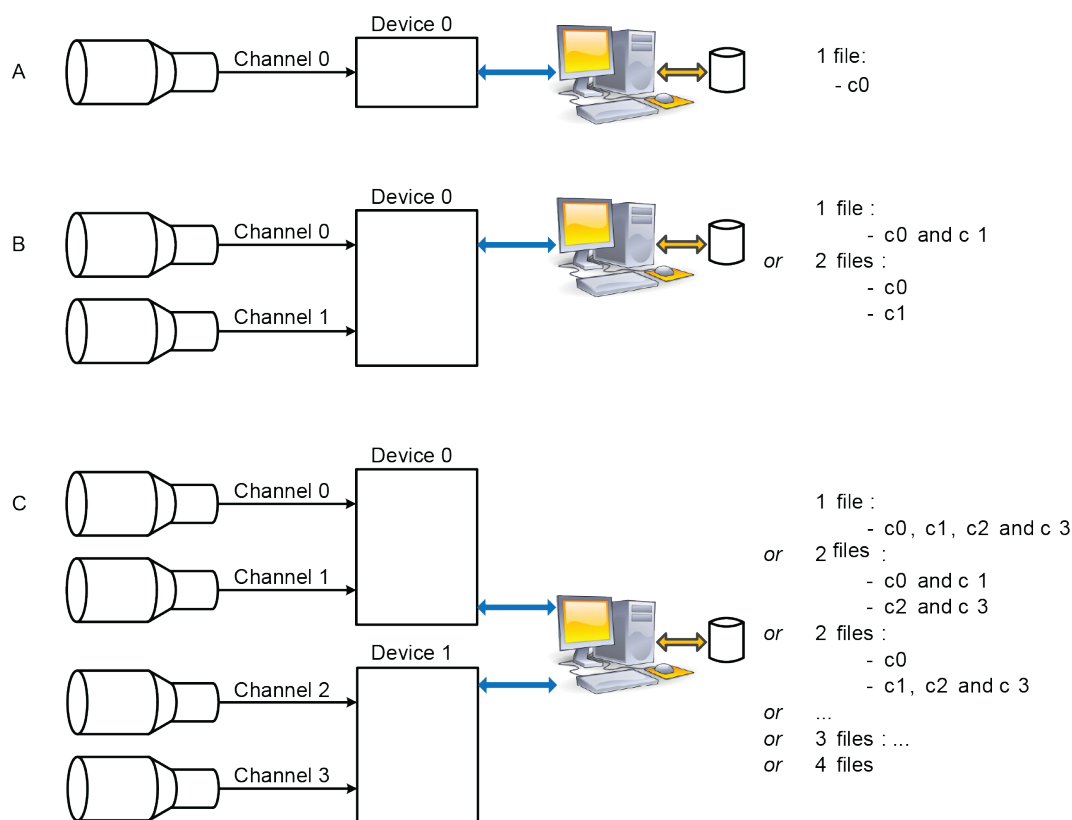
The *signal* generated by a *sensor* is *sampled* by the *measuring instrument* at a certain *sampling frequency*. The *measuring instrument* (or *data acquisition device*) typically contains an amplifier and anti-aliasing filter followed by an analog-to-digital convertor (ADC) and digital electronics (for example embedded in *FPGA* or *DSP*), which processes the *sampled signal* and presents it digitally at the output of the *channel*. The *channel* includes the *sensor* and the part of the *measuring instrument* that *samples* and processes the *signal*.

When measurement results at the output of a *channel* are recorded *event-per-event*, the data is said to be recorded in *list-mode*. This data is stored in *list-mode* data files or transferred using *data streams*.

In *list-mode* data formatted according to this document, *events* may be of different types such as pulses, *digital signals*, etc. A *channel* may produce data of more than one *event* type, and *list-mode* data from more than one *device* and *channel* may be mixed in the same file or *data stream*.

4.4 Channels and devices in a data file or stream

One of the advantages of list-mode data acquisition is the ease at which data acquired with different radiation detectors and other sensors may be combined for processing. This document may be used to specify data acquired in list mode from different channels and from different data acquisition devices into a single data file or stream, or into multiple data files or streams. See Figure 3 for examples. The data acquisition software or hardware that generates list-mode data should allow the same flexibility.



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Figure 3 – Example of combining channels in one or more data files

EXAMPLE Figure 3 shows three different combinations of channels and devices. In A, the data from the single channel in the single device is written to one list-mode data file. In B, device 0 has two channels. List-mode data may be written to a single file combining the two channels, or to two separate files. In C, there are two devices, each having two channels. List-mode data may be written to one or more files, combining the channels in different ways.

4.5 Applicability to data files and streams

This document applies to list-mode data files and data streams. Figure 4 presents the different arrangements in the use of this document. In arrangement A, the computer communicates with the data acquisition device using a proprietary communication format or protocol, but stores list-mode data to a file in the format specified in this document. It is not the intention of this document to impose the standard format on all communication between the data acquisition device and the computer.

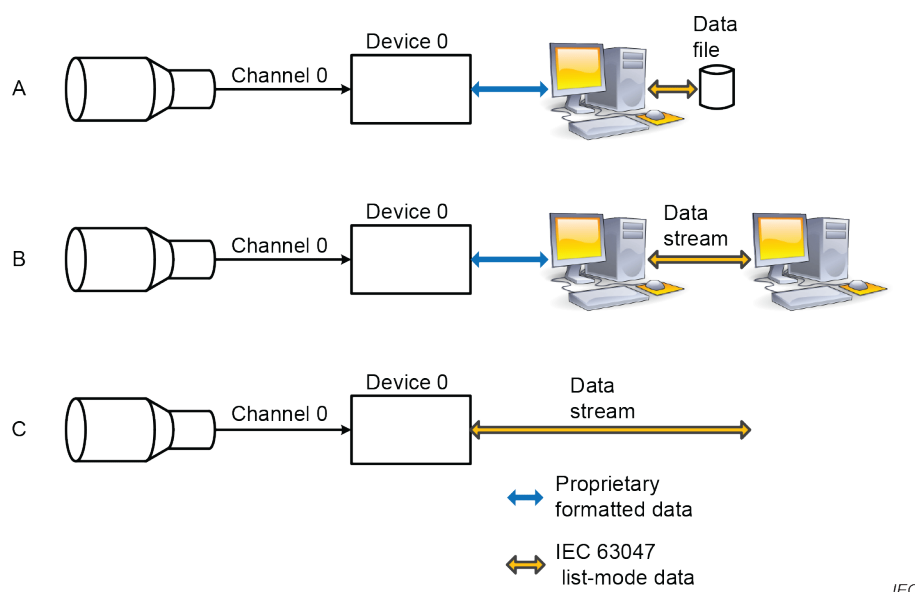


Figure 4 – This document applies to data files and data streams

In arrangement B, the local computer uses the proprietary format to communicate with the data acquisition device, but streams the data to another computer, which may process it, store it, or stream it to yet another computer (not shown).

There is a tendency to embed standard communication protocols into the interface of data acquisition devices. In arrangement C, for example, the data acquisition device acts as a server and accepts network connections, requested by client computers, who store or process the data or send it further.

This topology allows combining data from different detectors and sensors. The data may be processed and stored by computer systems, who share the data with other users. This document applies to list-mode data stored in files or streamed over such connections. Subclause 6.8 describes how this is done.

4.6 Relation with IEC 62755 data format files

IEC 62755 describes the data format of information produced by radiation detectors used for the detection of illicit trafficking of radioactive materials. IEC 62755 uses XML, which is human readable as well as machine readable through defined elements and attributes.

The data format specified in IEC 63047 (this document) addresses digital data acquisition devices that acquire data in list-mode. This way of acquiring data results in data files that may take up to gigabytes of storage space. For performance reasons, the standard requires the data to be stored in binary format. The field of application of the standard is mainly for metrology (the accurate measurement of radiation) and laboratory measurements, but may also be used in nuclear safety, security and safeguards applications (e.g. Compton cameras, active interrogation systems, remote monitoring and waste assay).

IEC 63047 does not replace IEC 62755. Both formats may be used separately. If there is the need for, IEC 63047 provides mechanisms to integrate IEC 62755 formatted data files into IEC 63047 list-mode data, or vice-versa, as schematically represented in Figure 5, and discussed further in 5.14 and 6.15.4.

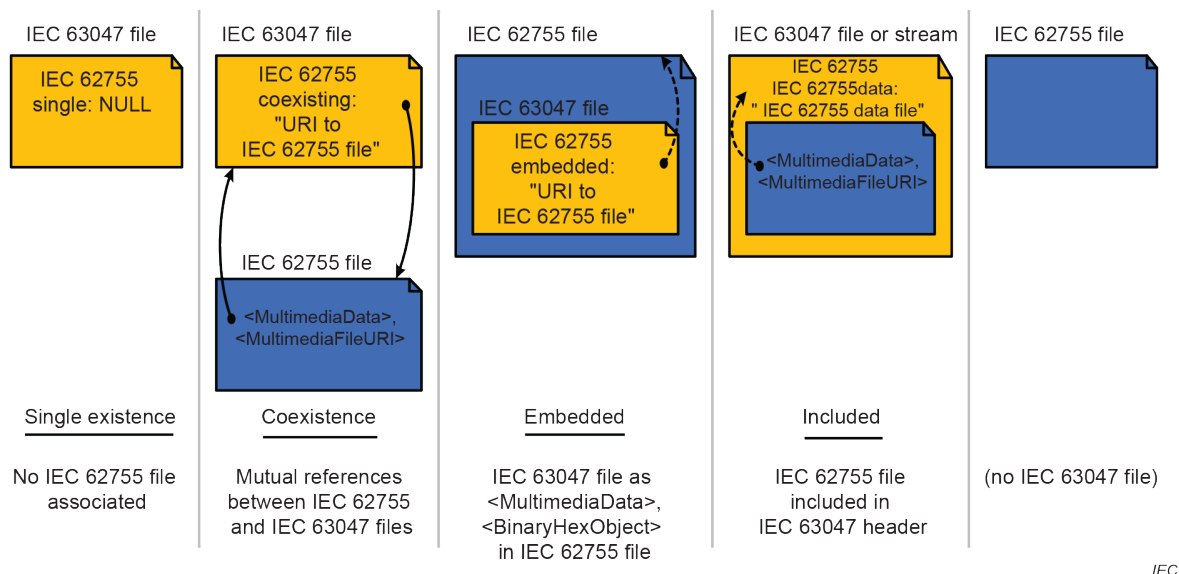


Figure 5 – Relations between IEC 63047 and IEC 62755 data files

The advantage of the integration between both formats is that all the elements in the IEC 62755 format may be used in conjunction with the binary list-mode data, avoiding the need to copy many of the meta-data elements already in IEC 62755. Such elements include the description of the instrument being used for the measurements, the detector configuration, calibration data, radioisotope identification results, etc. The integration is purely optional and depends on the user's needs.

4.7 Data security

To make sure that the encoding was not altered during transfer to a file or over a stream, authentication algorithms may be used to generate a digital signature by the application of a hash function on the octet string generated by the encoder. Then, the encoding and the digital signature may be encrypted with a private key and transferred, depending on the type of algorithm. At the receiver, the data is decrypted and the authenticity is verified. Finally, the decrypted data is decoded.

This document does not put requirements on the authentication or encryption algorithm. However, many authentication algorithms require a canonical encoding rule, which ensures that there is exactly one binary representation for each possible list-mode data value that may occur. The application of the encoding rule specified in 4.2.2 ensures that list-mode data encoded according to this document is canonical. Consequently, this document does not hinder the application of data security algorithms.

Security algorithms may be applied on the list-mode data as a whole (more relevant to files), for all values of the `Listmodedata` type together, or may be applied on individual encoded values (more relevant for streams), or groups of encoded values.

5 ASN.1 type definitions

5.1 Overview

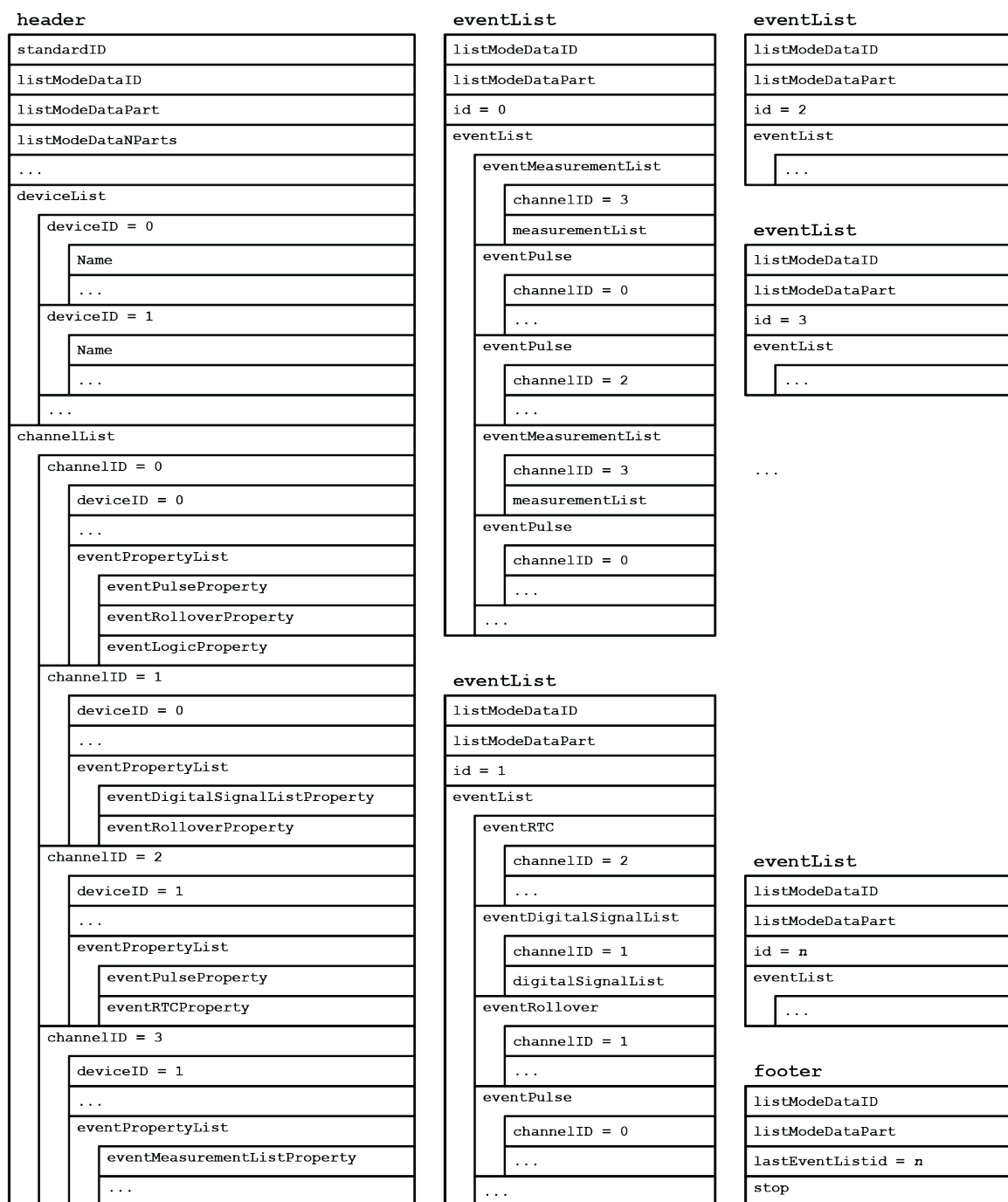
Clause 5 defines the types used in this document and the requirements on their use. Specific cases on the use of this document are described in Clause 6. Annex A (informative) combines all the ASN.1 type definitions from this clause into one piece of text that may be used as an input for ASN.1 tools and compilers.

This overview is essential for proper understanding of this document. The example of Figure 6 may be referred to when reading this overview.

The `Listmodedata` type is the only top-level type; all data packets stored to a file or transferred over a network are encoded values of the `Listmodedata` type.

The `Listmodedata` type is a choice between the `Header`, `EventList` or `Footer` type. The names of the elements used to indicate the choice are `header`, `eventList` or `footer`, respectively:

- the `Header` type (5.13):
 - occurs once in the beginning of the data file or stream;
 - contains general information on the measurement or data acquisition process;
 - contains the list of data acquisition devices (`deviceList`, 5.15);
 - contains the list of channels (`channelList`, 5.16) of the data acquisition devices which write data. For every channel, the `eventPropertyList` contains a list of `EventProperty` values. Every `Event` type that may occur in an `eventList` shall have a corresponding `EventProperty` type in the `eventPropertyList` of the channel. The `EventProperty` value contains general information and default values that apply to all events of the corresponding type;
- the `EventList` type (5.18):
 - occurs at least once in the list-mode data file or stream, after the `header`;
 - groups a number of values of the `Event` type (5.19);
 - the `Event` type is a choice between different types. Depending on the application, a mixture of values of the different `Event` types may be added to the `eventList`:
 - a) `EventPulse`: type of event corresponding to a pulse (5.20);
 - b) `EventDigitalSignalList`: contains one or more digital signals, which are of the `DigitalSignal` type (5.21 and 5.22);
 - c) `EventTime`: specifies total dead time and live time (5.23);
 - d) `EventRollover`: indicates that timestamp counter rollover has occurred (5.24);
 - e) `EventRTC`: specifies synchronisation status, e.g. with a real-time-clock (5.25);
 - f) `EventLogic`: used for logic values (5.26);
 - g) `EventGeo`: used to specify the position, orientation and/or speed of a detector (5.27 to 5.31);
 - h) `EventMeasurementList`: contains one or more measurements of any kind (5.32). The individual measurements are of the `Measurement` type (5.33);
 - i) `EventHistogram1DList`: contains one or more one-dimensional histograms (5.34). The individual histograms are of the `Histogram1D` type (5.35);
 - j) `EventHistogram2DList`: contains one or more two-dimensional histograms (5.36). The individual histograms are of the `Histogram2D` type (5.37);
 - k) `EventMessage`: contains a text message, or a binary piece of information, such as an image (5.38);
- the `Footer` type (5.39):
 - occurs once in the list-mode data file or stream;
 - indicates the end of the list-mode data file or stream.



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Figure 6 – Example with seven values of the Listmodedata type (one value of the Header type, followed by five values of the EventList type and one value of the Footer type)

In Figure 6, the three dots should be considered as a placeholder for other elements, and not as the ASN.1 extension marker.

EXAMPLE In Figure 6, seven values of the Listmodedata type are shown. The seven values are encoded individually and appended to a file, or sent to a client over a network. The first value is of the Header type. The header contains general information (listModeDataID and other elements) and the list of devices and channels. The devices and channels are identified by their position in the list, the first one having ID = 0. Every channel contains general information applicable to the channel (such as the device to which it belongs), and a list of EventProperty types that correspond to the Event types that may occur in an eventList. The channel with channelID = 0

can generate events of the `EventPulse`, `EventRollover` and `EventLogic` type. The `Header`, `EventList` and `Footer` values all contain the element `listModeDataID`, which has identical values. The first `EventList` value has `id = 0`. The first five `Event` values are shown in the `eventList` element. The first event is a list of measurements from `channelID = 3`. The second and third are pulses from `channelID = 0` and `channelID = 2`, respectively. This continues until the last `EventList` value, with `id = n`. Finally, a value of the `Footer` type is added.

5.2 ASN.1 types

The following ASN.1 types are used in this document, and defined in ISO/IEC 8824-1:

- the `BIT STRING` type is a type whose distinguished values are an ordered sequence of zero, one or more bits;
- `ENUMERATED` types are types whose values are given distinct identifiers as part of the type notation;
- the `INTEGER` type is a type with distinguished values which are the positive and negative whole numbers, including zero (as a single value). For practical reasons, when implementing the format described in this document, the values of the `INTEGER` data type shall not occupy more than 8 octets;
- the `OCTET STRING` type is a type whose distinguished values are an ordered sequence of zero, one or more octets, each octet being an ordered sequence of eight bits;
- the `REAL` type is a type whose distinguished values (specified in ISO/IEC 8824-1:2015, Clause 21) include the set of real numbers (numerical real numbers) together with special values such as `NOT-A-NUMBER`;
- the `UTF8String` type is a `RestrictedCharacterStringType`. The characters which may appear in the `UTF8String` type are any of the characters defined in ISO/IEC 10646;
- the `VisibleString` type is a `RestrictedCharacterStringType`. The characters which may appear in a `VisibleString` are any of the characters defined in the ISO International Register of Coded Character Sets to be used with Escape Sequences, Registration Number 6, and the `SPACE` character.

5.3 The `REAL32` and `REAL64` type

5.3.1 Definition

```
REAL32 ::= REAL (0 |
    WITH COMPONENTS {
        mantissa (-16777215..16777215), base (2),
        exponent (-149..104)}) -- IEEE 754 encoding single precision

REAL64 ::= REAL (0 |
    WITH COMPONENTS {
        mantissa (-9007199254740991..9007199254740991), base (2),
        exponent (-1074..971)}) -- IEEE 754 encoding double precision
```

5.3.2 Use

The `REAL32` and `REAL64` types are defined to represent numbers in the IEEE 754 single and double precision floating point format, respectively.

NOTE OER and C-OER are the only currently available encoding rules that employ IEEE 754 representation for 32-bit and 64-bit floating point numbers. The OER or C-OER encoding/decoding of such numbers is very efficient.

5.4 The `REAL32List`, `REAL64List` and `INTEGERList` types

5.4.1 Definition

```
REAL32List ::= SEQUENCE (SIZE(1..MAX)) OF REAL32
REAL64List ::= SEQUENCE (SIZE(1..MAX)) OF REAL64
INTEGERList ::= SEQUENCE (SIZE(1..MAX)) OF INTEGER
```

5.4.2 Use

The `REAL32List`, `REAL64List` and `INTEGERList` types are defined as a sequence of `REAL32`, `REAL64` and `INTEGER` values, respectively. The types are used in the definition of other types when there is a need to specify a list of values.

5.5 The Numeric type

5.5.1 Definition

```
Numeric ::= CHOICE {
    real32  REAL32,
    real64  REAL64,
    int     INTEGER -- Value shall not occupy more than 8 octets
}
```

5.5.2 Use

The `Numeric` type is a choice between the `REAL32`, `REAL64` or `INTEGER` type.

5.6 The UTCDateTime

5.6.1 Definition

```
UTCDateTime ::= SEQUENCE {
    date-time TIME (SETTINGS "Basic=Date-Time Date=YMD Year=Basic Time=HMS Local-or-UTC=Z"),
    fractional-seconds REAL64 -- Expressed in seconds, positive, less than 1
} -- DateTime ISO 8601, UTC
```

5.6.2 Use

The `UTCDateTime` type is defined as a sequence of two elements. The `date-time` element is an ISO 8601 date-time format and shall always be specified in UTC. The `fractional-seconds` element is of the `REAL64` type and is expressed in seconds. The value of `fractional-seconds` shall be positive and less than one.

EXAMPLE "2016-03-28T15:30:41Z" is a valid value of the date-time element.

5.7 The Range type

5.7.1 Definition

```
Range ::= CHOICE {
    rangeOfReals32 SEQUENCE {
        lowerBound REAL32,
        upperBound REAL32
    },
    rangeOfReals64 SEQUENCE {
        lowerBound REAL64,
        upperBound REAL64
    },
    rangeOfInts SEQUENCE {
        lowerBound INTEGER, -- Value shall not occupy more than 8 octets
        upperBound INTEGER -- Value shall not occupy more than 8 octets
    }
}
```

5.7.2 Use

The `Range` type is a choice between `rangeOfReals32`, `rangeOfReals64` or `rangeOfInt`. The `Range` type is used to specify the `lowerBound` and `upperBound` of a range of numeric values. The value of `lowerBound` shall be smaller than the value of `upperBound`.

5.8 The TimeStamp type

5.8.1 Definition

`TimeStamp ::= INTEGER (0..MAX) -- Value shall not occupy more than 8 octets`

5.8.2 Use

The `TimeStamp` type is used to specify timestamps. Timestamps are positive integers less than 2^{64} . All `TimeStamp` values are expressed as integer multiples of time base B , and relative to start, or to the last occurrence in an `eventList` of a value of the `EventRollover` type. The use of the timestamps is defined in 6.2.

NOTE 1 In C-OER encoding, the timestamp is encoded as a length prefix, followed by an unsigned binary integer (big-endian) occupying a variable number of octets; the length prefix contains the number of subsequent octets. The number of octets is the smallest possible, needed to represent the timestamp. This means that the encoding of a timestamp will be 2 to 9 octets long, depending on the value:

- values from 0 to and including $255 = 2^8 - 1$ will be encoded in 2 octets as '01 00'H to '01 FF'H;
- values from $256 = 2^8$ to and including $65\,535 = 2^{16} - 1$ will be encoded in 3 octets as '02 01 00'H to '02 FF FF'H;
- values from $65\,536 = 2^{16}$ to and including $16\,777\,215 = 2^{24} - 1$ will be encoded in 4 octets as '03 01 00 00'H to '03 FF FF FF'H;
- values from $16\,777\,216 = 2^{24}$ to and including $4\,294\,967\,295 = 2^{32} - 1$ will be encoded in 5 octets as '04 01 00 00 00'H to '04 FF FF FF FF'H;
- until finally $18\,446\,744\,073\,709\,551\,615 = 2^{64} - 1$ will be encoded as '08 FF FF FF FF FF FF FF'H.

NOTE 2 The value range constraint is not placed in the ASN.1 type definition itself to limit the size of the encoded values for most applications where 64-bit timestamps are not needed. Were the type defined as `TimeStamp ::= INTEGER (0..18446744073709551615)`, then the C-OER encoding would always be 8 octets long, which takes too much space for most applications where the total acquisition time is limited and the time base is not lower than one nanosecond. For example, with 8 octets and a time base of 1 ns, timestamp counter rollover occurs about every 584 years.

5.9 The SyncStatus type

5.9.1 Definition

```
SyncStatus ::= ENUMERATED {
    synchronised,    -- timestamp counter clock synchronised with a master clock
    unsynchronised  -- timestamp counter clock not synchronised
}
```

5.9.2 Use

The `SyncStatus` type may be employed to specify the status of synchronisation of the clock that is used to increment the timestamp counter with another clock. It is an `ENUMERATED` type which can have the values `synchronised` or `unsynchronised`.

5.10 The FlagKind type

5.10.1 Definition

```
FlagKind ::= ENUMERATED {
    logicstate,
    logictransition -- Transition from 0 to 1 is indicated by flag value 1
}
```

5.10.2 Use

The `FlagKind` type is associated with the `Flags` type. It specifies whether the individual flags relate to a logic state (`logicstate`) or a logic transition (`logictransition`). When the flag relates to a logic transition, it shall contain the new state that applies after the timestamp.

5.11 The AccuracyKind type

5.11.1 Definition

```
AccuracyKind ::= ENUMERATED {
    absolute,
    relative -- A relative accuracy of 1 means 100 %
}
```

5.11.2 Use

The `AccuracyKind` type is used to specify the kind of accuracy for measurement results. It is an `ENUMERATED` type that may have the values `absolute` or `relative`. When `absolute`, the accuracy is expressed in the same unit as the measurement result. When `relative`, an accuracy value of 1 corresponds to 100 %.

5.12 The Listmodedata type

5.12.1 Definition

```
Listmodedata ::= CHOICE {
    header      Header,
    -- First encoding in list-mode data file or stream
    -- Occurs once
    eventList   EventList,
    -- Second and next encoding in list-mode data file or stream
    -- Occurs once or more
    footer      Footer,
    -- Last encoded data in file or stream
    -- Occurs once
    ...
} -- All encoded data in the IEC 63047 format is of the Listmodedata type
```

5.12.2 Use

The `Listmodedata` type is the only top-level type: all encoded data in the format specified in this document shall be of the `Listmodedata` type.

The `Listmodedata` type is a choice between the `Header`, the `EventList` or the `Footer` type.

When encoded list-mode data is written to a file, the first data in the file shall be one encoded value of the `Listmodedata` type where the choice is `Header`, followed by one or more encoded values where the choice is `EventList`, in turn followed by one encoded value where the choice is `Footer` (Figure 7). The same sequence applies when list-mode data is streamed over a network.