Technical Reports

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Unicode Technical Report #17

UNICODE CHARACTER ENCODING MODEL

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Summary

*This document clarifies a number of the terms used to describe character encodings, and where the different forms of Unicode fit in. It elaborates the Internet Architecture Board (**IAB**) three-layer "text stream" definitions into a four-layer structure.*

Status

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> ***A Unicode Technical Report (UTR)** contains informative material. Conformance to the Unicode Standard does not imply conformance to any UTR. Other specifications, however, are free to make normative references to a UTR.*

Please submit corrigenda and other comments with the online reporting form [Feedback]. Related information that is useful in understanding this document is found in the References. For the latest version of the Unicode Standard see [Unicode]. For a list of current Unicode Technical Reports see [Reports]. For more information about versions of the Unicode Standard, see [Versions].

Contents

1 The Character Encoding Model

This report describes a model for the structure of character encodings. The Unicode Character Encoding Model places the Unicode Standard in the context of other character encodings of all types, as well as existing models such as the character architecture promoted by the Internet Architecture Board (IAB) for use on the internet, or the Character Data Representation Architecture [CDRA] defined by IBM for organizing and cataloging its own vendor-specific array of character encodings. This document focuses on how these models should be extended and clarified to cover all the aspects of the Unicode Standard and ISO/IEC 10646 [10646]. (For a list of common acronyms used in this text, see Section 9 *Definitions and Acronyms*).

The four levels of the Unicode Character Encoding Model can be summarized as:

- ACR: Abstract Character Repertoire

  the set of characters to be encoded, for example, some alphabet or symbol set
- CCS: Coded Character Set

  a mapping from an abstract character repertoire to a set of nonnegative integers
- CEF: Character Encoding Form

  a mapping from a set of nonnegative integers that are elements of a CCS to a set of sequences of particular code units of some specified width, such as 32-bit integers
- CES: Character Encoding Scheme

  a reversible transformation from a set of sequences of code units (from one or more CEFs to a serialized sequence of bytes)

In addition to the four individual levels, there are two other useful concepts:

- **CM**: Character Map

  a mapping from sequences of members of an abstract character repertoire to serialized sequences of bytes bridging all four levels in a single operation~~.~~
- **TES**: Transfer Encoding Syntax

  a reversible transform of encoded data~~. This data~~, which may or may not contain textual data

The IAB model, as defined in [RFC 2130], distinguishes three levels: *Coded Character Set* (**CCS**), *Character Encoding Scheme* (**CES**), and *Transfer Encoding Syntax* (**TES**). However, *four* levels need to be defined to adequately cover the distinctions required for the Unicode character encoding model. One of these, the *Abstract Character Repertoire*, is implicit in the IAB model. The Unicode model also gives the TES a separate status outside the model, while adding an additional level between the CCS and the CES.

The following sections give sample definitions, explanations and examples for each of the four levels, as well as the Character Map, and the Transfer Encoding Syntax. These are followed by a discussion of **API** Binding issues and a ~~complete~~ list of acronyms used in this document.

2 Abstract Character Repertoire

A *character repertoire* is defined as an unordered set of abstract characters to be encoded. The word *abstract* means that these objects are defined by convention. In many cases a repertoire consists of a familiar alphabet or symbol set.

Repertoires come in two types: *fixed* and *open*. ~~For~~In most character encodings, the repertoire is fixed, and often small. Once the repertoire is decided upon, it is never changed. Addition of a new abstract character to a given repertoire creates a new repertoire, which then will be given its own catalogue number, constituting a new object. For the Unicode Standard, on the other hand, the repertoire is inherently open. Because Unicode is intended to be the universal encoding, any abstract character that ever could be encoded is potentially a member of the set to be encoded, whether that character is currently known or not.

Some other character sets use a limited notion of open repertoires. For example, Microsoft has on occasion extended the repertoire of its Windows character sets by adding a handful of characters to an existing repertoire. This occurred when the EURO SIGN was added to the repertoire for a number of Windows character sets, for example. For suggestions on how to map the unassigned characters of open repertoires, see [CharMapML].

Repertoires are the entities that get **CS** (“character set”) values in the IBM **CDRA** architecture.

Examples of Character Repertoires:

- the Japanese syllabaries and ideographs of **JIS** X 0208 (CS 01058) [fixed]

- the Western European alphabets and symbols of Latin-1 (CS 00697) [fixed]
- the POSIX portable character repertoire [fixed]
- the IBM host Japanese repertoire (CS 01001) [fixed]
- the Windows Western European repertoire [open]
- the Unicode/10646 repertoire [open]

2.1 Versioning

The Unicode Standard versions its repertoire by publication of major and minor editions of the standard: 1.0, 1.1, 2.0, 2.1, 3.0,... The repertoire for each version is defined by the enumeration of abstract characters included in that version.

Repertoire extensions for the Unicode Standard are now strictly additive, even though there were several discontinuities to the earliest versions (1.0 and 1.1) ~~and~~ affecting backwards compatibility to them~~. The primary reason for these was~~ , because of the merger of ~~the~~ [Unicode] with [10646]. ~~Starting with version 2.0 and continuing forward indefinitely into future versions, once included, no character is ever removed from the repertoire, as specified in the Unicode Stability Policy [Stability].~~ As of Version 2.0 the Unicode Character Encoding Stability Policy [Stability] guarantees that no character is ever removed from the repertoire.

> **Note**: The Unicode Character Encoding Stability Policy also constrains changes to the standard in other ways. For example, many character properties are subject to consistency constraints, and some properties cannot be changed once they are assigned. Guarantees for the stability of normalization prevent the change or addition of decomposition mappings for existing encoded characters, and also constrain what kinds of characters can be added to the repertoire in future versions.

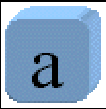
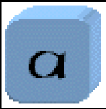
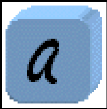
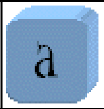
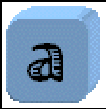
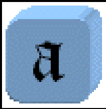
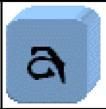
The versioning of the repertoire is different from the versioning of the Unicode Standard as a whole, in particular the Unicode Character Database [UCD], which defines Character Properties (see also [PropModel]). There are *update versions* of the text of the Unicode Standard and of the Unicode Character Database between major and minor versions of the Unicode Standard. While these update versions may amend character properties and descriptions of character behavior, they do not add to the character repertoire. For more information about versions of the Unicode Standard see Versions of the Unicode Standard [Versions].

ISO/IEC 10646 ~~has a different mechanism for extending its repertoire. The 10646 repertoire is extended~~extends its repertoire by a formal amendment process. As each individual amendment containing additional characters is published, it extends the 10646 repertoire. The repertoires of the Unicode Standard and ISO/IEC 10646 are kept in alignment by coordinating the publication of major versions of the Unicode Standard with the publication of a well-defined list of amendments for 10646 or with a major revision and republication of 10646.

2.2 Characters versus Glyphs

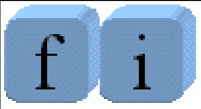
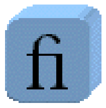
The elements of the character repertoire are abstract *characters*. Characters are different from *glyphs*, which are the particular images representing a character or part of a character. Glyphs for the same character may have very different shapes, as shown in ~~the following examples~~ Figure 1 for the letter ***a***.

Figure 1

Character	Sample Glyphs					
						

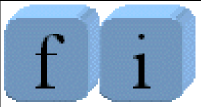
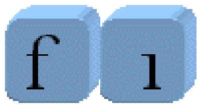
Glyphs do not correspond one-~~for~~to-one with characters. For example, a sequence of *"f"* followed by *"i"* may be ~~represented~~ displayed with a single glyph, called an *fi ligature.* Notice that the shapes are merged together, and the dot is missing from the *"i"* ~~in the following example:~~ as shown in Figure 2.

Figure 2

Character Sequence	Sample Glyph
	

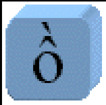
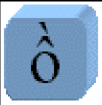
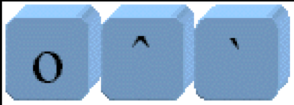
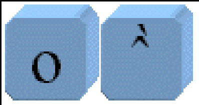
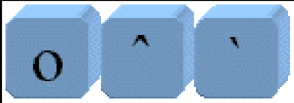
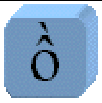
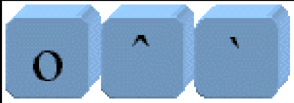
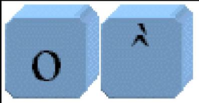
On the other hand, the same image as the *fi ligature* could conceivably ~~also~~ be achieved by a sequence of two glyphs with the right shapes, as in the hypothetical example shown in Figure 3. The choice of whether to use a single glyph or a sequence of two is ~~up to~~ determined by the font ~~containing the glyphs~~ and the rendering software.

Figure 3

Character Sequence	Possible Glyph Sequence
	

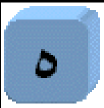
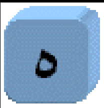
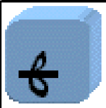
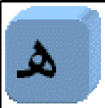
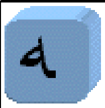
Similarly, an accented character could be represented by a single glyph, or by separate component glyphs positioned appropriately. In addition, any of the accents can also be considered characters in their own right, in which case a sequence of characters can also correspond to different possible glyph representations:

Figure 4

Character Sequence	Possible Glyph Sequences		
			
			

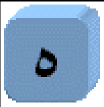
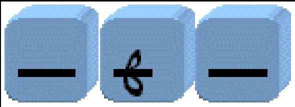
In non-Latin scripts, the connection between glyphs and characters is at times even less direct. Glyphs may be required to change their shape, position and width depending on the surrounding glyphs. Such glyphs are called contextual forms. For example, the Arabic character *heh* has the four contextual glyphs shown in Figure 5.

Figure 5

Character	~~Possible~~ Contextual Glyph~~s, depending on context~~ Shapes			
				

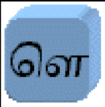
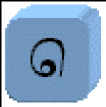
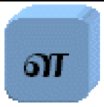
In Arabic and other scripts, ~~justification of~~ text inside fixed margins is ~~not done~~ justified by elongating the horizontal parts of certain glyphs, rather than by expanding the spaces between words. ~~Instead, certain glyphs are stretched by elongating their horizontal parts.~~ Ideally this is implemented by changing the shape of the glyph depending on the desired width. On some systems, this stretching is approximated by inserting extra connecting, dash-shaped glyphs called *kashidas*, as shown in Figure 6. In such a case, a single character may conceivably correspond to a whole sequence of *kashidas + glyphs + kashidas*.

Figure 6

Character	Sequence of glyphs
	

In other cases, a single character must correspond to two glyphs, because those two glyphs are positioned *around* other letters. See the Tamil characters in Figure 7 below. If one of those glyphs forms a ligature with other characters, then ~~there is a situation where what is~~ a conceptual *part* of a character corresponds to visual *part* of a glyph. If a character (or any part of it) corresponds to a glyph (or any part of it), then one says that the character *contributes* to the glyph.

Figure 7

Character	Split Glyphs	
		

~~For the general case,~~ The correspondence between glyphs and characters is generally not one-to-one, and cannot be predicted from the text alone. Whether a particular string of characters is rendered by a particular sequence of glyphs will depend on the sophistication of the host operating system and the font. The ordering of glyphs also does not necessarily correspond to the ordering of the characters. In particular the right-to-left scripts like Arabic and Hebrew give rise to complex reordering. See UAX #9: *~~The~~ Unicode Bidirectional Algorithm* [Bidi].

2.3 Compatibility Characters

For historical reasons, abstract character repertoires may include many entities ~~that normally would~~ not ~~be~~ considered appropriate members of an abstract character repertoire. These so-called compatibility characters may include ligature glyphs, contextual form glyphs, glyphs that vary by width, sequences of characters, and adorned glyphs, such as circled numbers. Figure 8 lists some examples in which these are encoded as single characters in Unicode. As with glyphs, there are not necessarily one-to-one relationships between characters and code points.

What an end-user thinks of as a single character (also called a *grapheme cluster* in the context of Unicode) may in fact be represented by multiple code points; conversely, a single code point may correspond to multiple characters. Here are some examples:

Figure 8

Characters	Code Points	Notes
ه	ﻩ ﻬ ﻫ ﻪ	*Arabic contextual form glyphs* encoded as compatibility characters in Unicode, also known as *presentation forms*.
f i	ﬁ	*Ligature glyph* encoded as compatibility character in Unicode and several character sets
P t s	₧	*A single code point representing a sequence of three characters*~~. (~~encoded as compatibility character in Unicode and several character sets).
क्ष	क ् ष	*The Devanagari syllable* ksha *represented by three code points*.
g̊	g ̊	*G-ring represented by two code points*.

For more information on grapheme cluster boundaries see UAX# 29: *Unicode Text ~~Boundaries~~ Segmentation* [Boundaries].

2.4 Subsets

Unlike most character repertoires, the synchronized repertoire of Unicode and 10646 is intended to be *universal* in coverage. Given the complexity of many writing systems, in practice this implies that nearly all implementations will fully support only some subset of the total repertoire, rather than all the characters.

Formal subset mechanisms are occasionally seen in implementations of some Asian character sets, where for example, the distinction between “Level 1 JIS” and “Level 2 JIS” support refers to particular parts of the repertoire of the JIS X 0208 kanji characters to be included in the implementation.

Subsetting is a major formal aspect of ISO/IEC 10646. The standard includes a set of internal catalog numbers for named subsets, and further makes a distinction between subsets that are *fixed collections* and those that are *open collections*, defined by a range of code positions. Open collections are extended any time an addition to the repertoire gets encoded in a code position between the range limits defining the collection. When the last of its open code positions is filled, an open collection automatically becomes a fixed collection.

The European Committee for Standardization (CEN) has defined several multilingual European subsets of ISO/IEC 10646-1 (called MES-1, MES-2, MES-3A, and MES-3B). MES-1 and MES-2 have been added as named fixed collections in 10646.

The Unicode Standard specifies neither predefined subsets nor a formal syntax for their definition. It is left to each implementation to define and support the subset of the universal repertoire that it wishes to interpret.

3 Coded Character Set (CCS)

A *coded character set* is defined to be a mapping from a set of abstract characters to the set of nonnegative integers. This range of integers need not be contiguous. In the Unicode Standard, the concept of the Unicode scalar value (~~cf.~~ see definition D76, in Chapter 3, "Conformance" of [Unicode]) explicitly defines such a noncontiguous range of integers.

An abstract character is defined to be *in a coded character set* if the coded character set maps from it to an integer. That integer is the *code point* to which the abstract character has been *assigned*. That abstract character is then an *encoded character*.

Coded character sets are the basic object that both ISO and vendor character encoding committees produce. They relate a defined repertoire to nonnegative integers, which then can be used unambiguously to refer to particular abstract characters from the repertoire.

A coded character set may also be known as a *character encoding*, a *coded character repertoire*, a *character set definition*, or a *code page*.

In the IBM CDRA architecture, CP (“code page”) values refer to coded character sets. Note that this use of the term *code page* is quite precise and limited. It should not be—but generally is—confused with the generic use of *code page* to refer to character encoding schemes.

Examples of Coded Character Sets:

Name	Repertoire
JIS X 0208	assigns pairs of integers known as *kuten* points
ISO/IEC 8859-1	ASCII plus Latin-1
ISO/IEC 8859-2	different repertoire than 8859-1, although both use the same code space
Code Page 037	same repertoire as 8859-1; different integers assigned to the same characters
Code Page 500	same repertoire as 8859-1 and Code Page 037; different integers
The Unicode Standard, Version 2.0 ISO/IEC 10646-1:1993 plus amendments 1-7	exactly the same repertoire and mapping
The Unicode Standard, Version 3.0 ISO/IEC 10646-1:2000	exactly the same repertoire and mapping
The Unicode Standard, Version 4.0 ISO/IEC 10646:2003	exactly the same repertoire and mapping

This document does not attempt to list all versions of the Unicode Standard. See

Versions of the Unicode Standard [Versions] for the complete list of versions and for information how they match with particular versions and amendments of 10646.

3.1 Character Naming

SC2, the JTC1 subcommittee responsible for character coding, requires the assignment of a unique character name for each abstract character in the repertoire of its coded character sets. This practice is not generally followed in vendor coded character sets or in the encodings produced by standards committees outside SC2, in which any names provided for characters~~,~~ are often variable and annotative, rather than normative parts of the character encoding.

The main rationale for the SC2 practice of character naming ~~was~~ is to provide a mechanism to unambiguously identify abstract characters across different repertoires given different mappings to integers in different coded character sets. Thus LATIN SMALL LETTER A WITH GRAVE would be the *same* abstract character, even though it occurs in different repertoires and ~~was~~ is assigned different integers in different coded character sets.

The IBM CDRA [CDRA], on the other hand, ensures character identity across different coded character sets (or *code pages*) by assigning a catalogue number known as a **GCGID** (graphic character glyphic identifier), to every abstract character used in any of the repertoires accounted for by the **CDRA**. Abstract characters that have the same GCGID in two different coded character sets are by definition the same character. Other vendors have made use of similar internal identifier systems for abstract characters.

The advent of Unicode/10646 has largely rendered such schemes obsolete. The identity of abstract characters in all other coded character sets is increasingly ~~being~~ defined by reference to Unicode/10646~~ itself~~. Part of the pressure to include every “character” from every existing coded character set into the Unicode Standard results from the desire ~~by many~~ to get rid of subsidiary mechanisms for tracking bits and pieces~~, odds and ends~~ that are not part of Unicode, and instead just use the Unicode Standard as the universal catalog of characters.

3.2 Code Spaces

The range of nonnegative integers used ~~for the~~ to map~~ping of~~ abstract characters defines a related concept of *code space*. Traditional boundaries for types of code spaces are closely tied to the encoding forms (see below), because the mappings of abstract characters to nonnegative integers are done with particular encoding forms in mind. Examples of significant code spaces are 0..7F, 0..FF, 0..FFFF, 0..10FFFF, 0..7FFFFFFF, 0..FFFFFFFF.

Code spaces can also have ~~fairly~~ elaborate structures, depending on whether the range of integers is ~~conceived of as~~ contiguous, or whether particular ranges of values are disallowed. Most complications result from considerations of the encoding form for characters. When an encoding form specifies that the integers ~~that are~~
being encoded are to be serialized as sequences of bytes, there are often constraints placed on the particular values that those bytes may have. Most

commonly such constraints disallow byte values corresponding to control functions. In terms of code space, such constraints on byte values result in multiple non-contiguous ranges of integers that are disallowed for mapping a character repertoire. (See [Lunde] for two-dimensional diagrams of typical code spaces for East Asian coded character sets implementing such constraints.)

> **Note**: In **ISO** standards the term octet is used for an 8-bit byte. In this document, the term byte is used consistently for an 8-bit byte only.

4 Character Encoding Form (CEF)

A *character encoding form* is a mapping from the set of integers used in a **CCS** to the set of sequences of code units. A *code unit* is an integer occupying a specified binary width in a computer architecture, such as an 8-bit byte. The encoding form enables character representation as actual data in a computer. The sequences of code units do not necessarily have the same length.

- A character encoding form whose sequences are all of the same length is known as *fixed width*.
- A character encoding form whose sequences are not all of the same length is known as *variable width*.

A character encoding form *for a coded character set* is defined to be a character encoding form that maps all of the encoded characters for that coded character set.

> **Note**: In many cases, there is only one character encoding form for a given coded character set. In some such cases only the character encoding form has been specified. This leaves the coded character set implicitly defined, based on an implicit relation between the code unit sequences and integers.

When interpreting a sequence of code units, there are three possibilities:

1. The sequence is ~~*illegal*~~*ill-formed*. ~~There are two variants of this: In the first variant,~~ The sequence is *incomplete* or otherwise fails to match the specification of the encoding form. For example,
   - 0xA3 is incomplete in CP950. Unless followed by another byte of the right form, it is ~~illegal~~ill-formed.
   - 0xD800 is incomplete in ~~Unicode~~UTF-16. Unless followed by another 16-bit value of the right form, it is ~~illegal~~ill-formed.
   - 0xC0 is ill-formed in UTF-8. It cannot be the initial byte (or for that matter, any byte) of a well-formed UTF-8 sequence.

   For details on ill-formed sequences for UTF-8 and UTF-16, see Section 3.9, Unicode Encoding Forms, in [Unicode].
   ~~In the second variant, the sequence is complete, but explicitly illegal. For example,~~
   - ~~0xFFFF is illegal in Unicode. This value can never occur in valid Unicode text, and will never be assigned.~~
2. The sequence represents a valid code point, but is *unassigned*. This sequence

may be given an assignment in some future, *evolved* version of the character encoding. For suggestions on how to handle unassigned characters in mapping, see [CharMapML]. For example,

  - 0xA3 0xBF is unassigned in CP950, as of the year 1999.
  - 0x0EDE is unassigned in Unicode~~, V3~~ 5.0

3. The source sequence is *assigned*: it represents a valid encoded character. There are ~~two~~three variants of this:
   First is a ~~standard~~typical assigned character. For example,
   - 0x0EDD is assigned in Unicode~~, V3~~ 5.0

   The second variant is a user-defined character. For example,
   - 0xE000 is an assigned user-defined character whose semantic interpretation is left to agreement between parties outside of the context of the standard.

   The third type is peculiar to the Unicode Standard: the *noncharacter*. This is a kind of internal-use user-defined character, not intended for public interchange. For example,
   - 0xFFFF is an assigned noncharacter in Unicode 5.0

The encoding form for a CCS may result in either fixed-width or variable-width sequences of code units associated with abstract characters. The encoding form may involve an arbitrary reversible mapping of the integers of the CCS to a set of code unit sequences.

Encoding forms come in various types. Some of them are exclusive to the Unicode/10646, whereas others represent general patterns that are repeated over and over for hundreds of coded character sets. Some of the more important examples of encoding forms follow.

Examples of fixed-width encoding forms:

Type	Each character encoded as	Notes
7-bit	a single 7-bit quantity	example: ISO 646
8-bit G0/G1	a single 8-bit quantity	with constraints on use of C0 and C1 spaces
8-bit	a single 8-bit quantity	with no constraints on use of C1 space
8-bit EBCDIC	a single 8-bit quantity	with the EBCDIC conventions rather than ASCII conventions
16-bit (UCS-2)	a single 16-bit quantity	within a code space of 0..FFFF
32-bit (UCS-4)	a single 32-bit quantity	within a code space 0..7FFFFFFF
32-bit (UTF-32)	a single 32-bit quantity	within a code space of 0..10FFFF
16-bit DBCS process code	a single 16-bit quantity	example: UNIX widechar implementations of Asian CCS's

32-bit **DBCS** process code	a single 32-bit quantity	example: UNIX widechar implementations of Asian CCS's
DBCS Host	two 8-bit quantities	following IBM host conventions

Examples of variable-width encoding forms:

Name	Characters are encoded as	Notes
UTF-8	a mix of one to four 8-bit code units in Unicode and one to six code units in 10646	used only with Unicode/10646
UTF-16	a mix of one to two 16 bit code units	used only with Unicode/10646

The encoding form defines one of the fundamental aspects of an encoding: how many *code units* are there for each character. The number of code units per character is important to internationalized software. Formerly this was equivalent to how many *bytes* each character was represented by. With the introduction by Unicode and 10646 of wider code units for **UCS**-2, **UTF**-16, UCS-4, and UTF-32, this is generalized to two pieces of information: a specification of the width of the code unit, and the number of code units used to represent each character. The UCS-2 encoding form, which is associated with ISO/IEC 10646 and can only express characters in the **BMP**, is a fixed-width encoding form. In contrast, UTF-16 uses either one or two code units and is able to cover the entire code space of Unicode.

UTF-8 provides a good example. In UTF-8, the fundamental code unit used for representing character data is 8 bits wide (that is, a byte or octet). The width map for UTF-8 is:

0x00..0x7F	→	1 byte
0x80..0x7FF	→	2 bytes
0x800..0xD7FF, 0xE000..0xFFFF	→	3 bytes
0x10000 .. 0x10FFFF	→	4 bytes

Examples of encoding forms as applied to particular coded character sets:

Name	Encoding forms
JIS X 0208	generally transformed from the *kuten* notation to a 16-bit “JIS code” encoding form, for example "nichi", 38 92 (kuten) → 0x467C JIS code
ISO 8859-1	has the 8-bit G0/G1 encoding form
CP 037	8-bit **EBCDIC** encoding form
CP 500	8-bit **EBCDIC** encoding form
US **ASCII**	7-bit encoding form
ISO 646	7-bit encoding form
Windows CP 1252	8-bit encoding form

Unicode 4.0, 5.0	UTF-16~~ (default)~~, UTF-8, or UTF-32 encoding form
Unicode 3.0	either UTF-16 (default) or UTF-8 encoding form
Unicode 1.1	either UCS-2 (default) or UTF-8 encoding form
ISO/IEC 10646~~,~~:2003	depending on the declared implementation levels, may have UCS-2, UCS-4, UTF-16, or UTF-8.
ISO/IEC 10646:2008	UTF-8, UTF-16, or UTF-32

Note: ~~that~~ Shift-JIS is not an encoding form. It is discussed in the next section.

Note: The pending republication of ISO/IEC 10646 2nd Edition (ISO/IEC 10646:2008) has dropped implementation levels, and its use and discussion of character encoding forms is closely aligned with Unicode 5.0.

5 Character Encoding Scheme (CES)

A *character encoding scheme* (CES) is a reversible transformation of sequences of code units to sequences of bytes in one of three ways:

1. A *simple* CES uses a mapping of each code unit of a CEF into a unique serialized byte sequence in order.

2. A *compound* CES uses two or more simple CESs, plus a mechanism to shift between them. This mechanism includes bytes (for example single shifts, SI/SO, or escape sequences) that are not part of any of the simple CESs, but which are defined by the character encoding architecture and which may require an external registry of particular values (such as for the ISO 2022 escape sequences).

   The nature of a compound CES means there may be different sequences of bytes corresponding to the same sequence of code units. While these sequences are not unique, the original sequence of code units can be recovered unambiguously from any of these.

3. A *compressing* CES maps a code unit sequence to a byte sequence while minimizing the length of the byte sequence. Some compressing CESs are designed to produce a unique sequence of bytes for each sequence of code units, so that the compressed byte sequences can be compared for equality or ordered by binary comparison. Other compressing CESs are merely reversible.

Character encoding schemes are relevant to the issue of cross-platform persistent data involving code units wider than a byte, where byte-swapping may be required to put data into the byte polarity ~~canonical~~ which is used for a particular platform. In particular:

- Most fixed-width byte-oriented encoding forms have a trivial mapping into a CES: each 7-bit or 8-bit quantity maps to a byte of the same value.
- Most mixed-width byte-oriented encoding forms also simply serialize the

sequence of CC-data-elements to bytes.

  - UTF-8 follows this pattern, because it is already a byte-oriented encoding form.
  - UTF-16 must specify byte-order for the byte serialization because it involves 16-bit quantities. Byte order is the sole difference between UTF-16BE, in which the two bytes of the 16-bit quantity are serialized in big-endian order, and UTF-16LE, in which they are serialized in little-endian order.

It is important not to confuse a Character Encoding Form (**CEF**) and a CES.

1. The **CEF** maps code points to code units, while the CES transforms sequences of code units to byte sequences. (For a direct mapping from characters to serialized bytes, see Section 6 *Character Maps*.)
2. The CES must take into account the byte-order serialization of all code units wider than a byte that are used in the CEF.
3. Otherwise identical CESs may differ in other aspects, such as the number of user-defined characters ~~that are~~ allow~~able~~ed. (This applies in particular to the IBM **CDRA** architecture, which may distinguish host **CCSID**s based on whether the set of **UDC**'s is conformably convertible to the corresponding code page or not.)

~~Note that~~ Some of the Unicode encoding schemes have the same labels as the three Unicode encoding forms. When used ~~unqualified~~ without qualification, the terms UTF-8, UTF-16, and UTF-32 are ambiguous between their sense as Unicode encoding forms and as Unicode encoding schemes. ~~For UTF-8,~~ This ambiguity is usually innocuous~~,~~ for UTF-8 because the UTF-8 encoding scheme is trivially derived from the byte sequences defined for the UTF-8 encoding form. However, for UTF-16 and UTF-32, the ambiguity is more problematical. As encoding forms, UTF-16 and UTF-32 refer to code units as they are accessed from memory via 16-bit or 32-bit data types; there is no associated byte orientation, and a BOM is never used. (Viewing memory in a debugger or casting wider data types to byte arrays is a byte serialization.)~~.~~

As encoding *schemes*, UTF-16 and UTF-32 refer to serialized bytes, for example the serialized bytes for streaming data or in files; they may have either byte orientation, and a single BOM may be present at the start of the data. When the usage of the abbreviated designators UTF-16 or UTF-32 might be misinterpreted, and where a distinction between their use as referring to Unicode encoding forms or to Unicode encoding schemes is important, the full terms should be used. For example, use *UTF-16 encoding form* or *UTF-16 encoding scheme*. They may also be abbreviated to UTF-16 CEF or UTF-16 CES, respectively.

Examples of Unicode Character Encoding Schemes:

- The Unicode Standard has seven character encoding schemes: UTF-8, UTF-16, UTF-16BE, UTF-16LE, UTF-32, UTF-32BE, and UTF-32LE.
  - UTF-8, UTF-16BE, UTF-16LE, UTF-32BE and UTF32-LE are simple CESs.
  - UTF-16 and UTF-32 are compound CESs, consisting of an single, optional *byte order mark* at the start of the data followed by a simple

CES.

Name	CEF	CES
UTF-8	+	simple
UTF-16	+	compound
UTF-16BE		simple
UTF-16LE		simple
UTF-32	+	compound
UTF-32BE		simple
UTF-32LE		simple

- Unicode 1.1 had three character encoding schemes: UTF-8, UCS-2BE, and UCS-2LE, although the latter two were not named that way at the time.

Examples of Non-Unicode Character Encoding Schemes:

- ISO 2022-based charsets (ISO-2022-JP, ISO-2022-KR, etc.), which use embedded escape sequences; these are compound CESs.
- **DBCS** Shift (mix of one single-byte CCS, for example **JIS** X 0201 and a DBCS CCS, for example based on JIS X0208, with a numeric shift of the integer values), for example, Code Page 932 on Windows.
- **EUC** (similar to the DBCS Shift encodings, with the application of different numeric shift rules, and the introduction of single-shift bytes: 0x8E and 0x8F, that may introduce 3-byte and 4-byte sequences), for example, EUC-JP or EUC-TW on UNIX.
- IBM host mixed code pages for Asian character sets, which formally mix two distinct CCS's with the SI/SO switching conventions, for example, **CCSID** 5035 on IBM Japanese host machines.

Examples of compressing Character Encoding Schemes:

- **BOCU-1**, see Unicode Technical Note #6: *BOCU-1:* ***MIME****-compatible Unicode Compression*. [BOCU]. BOCU-1 maps each input string to a unique compressed string, but does not map each code unit to a unique series of bytes.
- Punycode, defined in [RFC3492], like BOCU-1, is unique only on a string basis.
- **SCSU** (and **RCSU**): see UTR #6: *A Standard Compression Scheme for Unicode* [SCSU]. The input to SCSU and RCSU ~~are~~ is a stream of code units; the output is a compressed stream of bytes. Because of compression heuristics, the same input string may result in different byte sequences, but the schemes are fully reversible.

5.1 Byte Order

Processor architectures differ in the way that multi-byte machine integers are mapped to storage locations. *Little Endian* architectures put the least significant byte at the lower address, while *Big Endian* architectures start with the most significant byte.

This difference does not matter for operations on code units in memory, but the byte order becomes important when code units are serialized to sequences of bytes using a particular **CES**. In terms of reading a data stream, there are two types of byte order: *Same as* or *Opposite of* the byte order of the processor reading the data. In the former case, no special operation needs to be taken; in the latter case, the data needs to be byte reversed before processing.

In terms of external designation of data streams, three types of byte orders can be distinguished: *Big Endian (**BE**)*, *Little Endian (**LE**)* and *default* or *internally marked*.

In Unicode, the character at code point U+FEFF is defined as the *byte order mark*, while its byte-reversed counterpart, U+FFFE is a noncharacter (U+FFFE) in **UTF-16** , or outside the code space (0xFFFE0000) for UTF-32. At the head of a data stream, the presence of a byte order mark can therefore be used to unambiguously signal the byte order of the code units.

6 Character Maps

The mapping from a sequence of members of an abstract character repertoire to a serialized sequence of bytes is called a *Character Map* (CM). A *simple character map* thus implicitly includes a **CCS**, a **CEF**, and a **CES**, mapping from abstract characters to code units to bytes. A *compound character map* includes a compound CES, and thus includes more than one CCS and CEF. In that case, the abstract character repertoire for the character map is the union of the repertoires covered by the coded character sets involved.

Unicode Technical Report #22: *Character Mapping Markup Language* [CharMapML] defines an XML specification for representing the details of Character Maps. The text also contains a detailed discussion of issues in mapping between character sets.

Character Maps are the entities that get IANA *charset* [Charset] identifiers in the **IAB** architecture. From the **IANA** charset point of view it is important that a sequence of encoded characters be unambiguously mapped onto a sequence of bytes by the charset. The charset must be specified in all instances, as in Internet protocols, where textual content is treated as an ordered sequence of bytes, and where the textual content must be reconstructible from that sequence of bytes.

In the IBM **CDRA** architecture, Character Maps are the entities that get **CCSID** (coded character set identifier) values. A character map may also be known as a *charset*, a *character set*, a *code page* (broadly construed), or a *CHARMAP.*

In many cases, the same name is used for both a character map and for a character encoding scheme, such as UTF-16BE. Typically this is done for simple character mappings when such usage is clear from context.

7 Transfer Encoding Syntax (TES)

A *transfer encoding syntax* is a reversible transform of encoded **data** which may (or may not) include textual data represented in one or more character encoding schemes.

Typically TESs are engineered to transform one byte stream into another, while avoiding particular byte values that would confuse one or more Internet or other transmission/storage protocols. Examples include base64, uuencode, BinHex, and quoted-printable. While data transfer protocols often incorporate data compressions to minimize the number of bits to be passed down a communication channel, compression is usually handled outside the TES, for example by protocols such as pkzip, gzip, or winzip.

The Internet Content-Transfer-Encoding tags "7bit" and "8bit" are special cases. These are data width specifications which are relevant ~~basically~~ to mail protocols and which appear to predate true TESs like quoted-printable. Encountering a "7bit" tag does not imply any actual transform of data; it merely indicates that the charset of the data can be represented in 7 bits, and will pass 7-bit channels—it really indicates the encoding form. In contrast, quoted-printable actually converts various characters (including some ASCII) to forms like "=2D" or "=20", and should be reversed on receipt to regenerate legible text in the designated character encoding scheme.

8 Data Types and API Binding

Programming languages define specific data types for character data, using bytes or multi-byte code units. For example, the char data type in Java or C# always uses 16-bit code units, while the size of the char and wchar_t data types in C and C++ are, within quite flexible constraints, implementation defined. In Java or C#, the 16-bit code units are by definition UTF-16 code units, while in C and C++, the binding to a specific character set is again up to the implementation. In Java, strings are an opaque data type, while in C (and at the lowest level also in C++) they are represented as simple arrays of char or wchar_t.

The Java model supports portable programs, but external data in other encoding forms must first be converted to UTF-16. The C/C++ model is intended to support a byte serialized character set using the char data type, while supporting a character set with a single code unit per character with the wchar_t data type. These two character sets do not have to be the same, but the repertoire of the larger set must include the smaller set to allow mapping from one data type into the other. This allows implementations to support UTF-8 as the char data type and UTF-32 as the wchar_t data type, for example. In such use, the char data type corresponds to data that is serialized for storage and interchange, and the wchar_t data type is used for internal processing. There is no guarantee that wchar_t represent characters of a specific character set. However, a standard macro, __STDC_ISO_10646__ can be used by an environment to designate that it supports a specific version of 10646, indicated by year and month.

However, the definition of the term *character* in the ISO C and C++ standard does not necessarily match the definition of abstract character in this model. Many widely used libraries and operating systems define wchar_t to be UTF-16 code units. Other APIs supporting UTF-16 are often simply defined in terms of arrays of 16-bit unsigned integers, but this makes certain features of the programming language unavailable, such as string literals.

ISO/IEC TR 19769 extends the model used in ISO C and C++ by recommending the use of two typedefs and a minimal extension to the support for character literals and runtime library. The data types char16_t and char32_t are unsigned integers designed to hold one code unit for UTF-16 or UTF-32 respectively. Like wchar_t they can be used generically for any character set, but ~~a~~ predefined macros __STDC_UTF_16__ and __STDC_UTF_32__ can be used to indicate that the data type char16_t or char32_t holds code units that are in the respective Unicode encoding form.

When character data types are passed as arguments in APIs, the byte order of the platform is generally not relevant for code units. The same API can be compiled on platforms with any byte polarity, and will simply expect character data (as for any integral-based data) to be passed to the API in the byte polarity for that platform. However, the size of the data type must correspond to the size of the code unit, or the results can be unpredictable, as when a byte oriented strcpy is used on UTF-16 data which may contain embedded NUL bytes.

While there are many API functions that ~~by design do not need~~ are designed not to care about which character set the code units correspond to (strlen or strcpy for example), many other operations require information about the character and its properties. As a result, portable programs may not be able to use the char or wchar_t data types in C/C++.

8.1 Strings

A string data type is simply a sequence of code units. Thus a Unicode 8-bit string is a sequence of 8-bit Unicode code units; a Unicode 16-bit string is a sequence of 16-bit code units; a Unicode 32-bit string is a sequence of 32-bit code units.

Depending on the programming environment, a Unicode string may or may not also be required to be in the corresponding Unicode encoding form. For example, strings in Java, C#, or ECMAScript are Unicode 16-bit strings, but are not necessarily well-formed UTF-16 sequences. In normal processing, there are many times where a string may be in a transient state that is not well-formed UTF-16. Because strings are such a fundamental component of every program, it can be far more efficient to postpone checking for well formedness.

However, whenever strings are specified to be in a particular Unicode encoding ~~for~~—even one with the same code unit size—the string must not violate the requirements of that encoding form. For example, isolated surrogates in a Unicode 16-bit string are not allowed when that string is specified to be well-formed UTF-16.

9 Definitions and Acronyms

This section briefly defines some of the common acronyms related to character encoding and used in this text. More extensive definitions for some of these terms can be found elsewhere in this document.

ACR	Abstract Character Repertoire
API	Application Programming Interface
ASCII	American Standard Code for Information Interchange

BE	Big-endian (most significant byte first)
BMP	Basic Multilingual Plane, the first 65,536 characters of 10646
BOCU	Byte Ordered Compression for Unicode
CCS	Coded Character Set
CCSID	Code Character Set Identifier
CDRA	Character Data Representation Architecture from IBM
CEF	Character Encoding Form
CEN	European Committee for Standardization
CES	Character Encoding Scheme
CM	Character Map
CP	Code Page
CS	Character Set
DBCS	Double-Byte Character Set
ECMA	European Computer Manufacturers Association
EBCDIC	Extended Binary Coded Decimal Interchange Code
EUC	Extended Unix Code
GCGID	Graphic Character Set Glyphic Identifier
IAB	Internet Architecture Board
IANA	Internet Assigned Numbers Authority
IEC	International Electrotechnical Commission
IETF	Internet Engineering Taskforce
ISO	International Organization for Standardization
JIS	Japanese Industrial Standard
JTC1	Joint Technical Committee 1 (responsible for ISO/IEC IT Standards)
LE	Little-endian (least significant byte first)
MBCS	Multiple-Byte Character Set (1 to n bytes per code point)
MIME	Multipurpose Internet Mail Extensions
RFC	Request For Comments (term used for an Internet standard)
RCSU	Reuters Compression Scheme for Unicode (precursor to SCSU)
SBCS	Single-Byte Character Set
SCSU	Standard Compression Scheme for Unicode
TES	Transfer Encoding Syntax
UCS	Universal Character Set; Universal Multiple-Octet Coded Character Set — the repertoire and encoding represented by ISO/IEC 10646~~-1:1993~~:2003 and its amendments.
UDC	User-defined Character
UTF	Unicode (or UCS) Transformation Format

References

[10646] ISO/IEC 10646 — Universal Multiple-Octet Coded Character Set.
For availability see http://www.iso.org

[Bidi] Unicode Standard Annex #9: ~~*The*~~ *Unicode Bidirectional Algorithm*
http://www.unicode.org/reports/tr9/

[BOCU]	Unicode Technical Note #6: *BOCU-1: MIME-Compatible Unicode Compression*, http://www.unicode.org/notes/tn6/
[Boundaries]	Unicode Standard Annex #29: *Unicode Text ~~Boundaries~~ Segmentation*, http://www.unicode.org/reports/tr29/
[CDRA]	Character Data Representation Architecture Reference and Registry, IBM Corporation~~, Second Edition, December 1995. IBM document SC09-2190-00~~ http://www.ibm.com/software/globalization/cdra/index.jsp
[CharMapML]	Unicode Technical Report #22: *Character Mapping Markup Language* (CharMapML), http://www.unicode.org/reports/tr22/
[Charset]	IANA charset assignments http://www.iana.org/assignments/character-sets
[Charts]	The online code charts can be found at http://www.unicode.org/charts/ An index to characters names with links to the corresponding chart is found at http://www.unicode.org/charts/charindex.html
[FAQ]	Unicode Frequently Asked Questions http://www.unicode.org/faq/ *For answers to common questions on technical issues.*
[Feedback]	Reporting Errors and Requesting Information Online http://www.unicode.org/reporting.html
[Glossary]	Unicode Glossary http://www.unicode.org/glossary/ *For explanations of terminology used in this and other documents.*
[Lunde]	Lunde, Ken, *CJKV Information Processing,* O'Reilley, 1999, ISBN 1-565-92224-7
[PropModel]	Unicode Technical Report #23: *The Unicode Character Property Model*, http://www.unicode.org/reports/tr23/
[Reports]	Unicode Technical Reports http://www.unicode.org/reports/ *For information on the status and development process for technical reports, and for a list of technical reports.*
[RFC2130]	The Report of the IAB Character Set Workshop held 29 February 1 March, 1996. C. Weider, et al., April 1997, http://www.ietf.org/rfc/rfc2130.txt
[RFC2277]	IETF Policy on Character Sets and Languages, H. Alvestrand, January 1998, http://www.ietf.org/rfc/rfc2277.txt (BCP 18)
[RFC3492]	RFC 3492: *Punycode: A Bootstring encoding of Unicode for Internationalized Domain Names in Applications (IDNA)*, A. Costello, March 2003, http://www.ietf.org/rfc/rfc3492.txt

[SCSU] Unicode Technical Standard #6: A Standard Compression Scheme for Unicode,
http://www.unicode.org/reports/tr6/

[Stability] Unicode Character Encoding Stability Polic~~ies~~y,
http://www.unicode.org/policies/stability_policy.html

[UCD] Unicode Character Database.
http://www.unicode.org/ucd/
For an overview of the Unicode Character Database and a list of its associated files

[Unicode] The Unicode Standard
For the latest version see:
http://www.unicode.org/versions/latest/.
For the last major version see: The Unicode Consortium. The Unicode Standard, Version 5.0. ~~(~~Boston, MA, Addison-Wesley, 2007. ISBN 0-321-48091-0.~~)~~ *Or online as:* http://www.unicode.org/versions/Unicode5.0.0/

[Unicode5.0] The Unicode Consortium. The Unicode Standard, Version 5.0. ~~Reading~~Boston, MA, Addison-Wesley, 2007. ISBN 0-321-48091-0.

[Versions] Versions of the Unicode Standard
http://www.unicode.org/standard/versions/
For information on version numbering, and citing and referencing the Unicode Standard, the Unicode Character Database, and Unicode Technical Reports.

[W3CCharMod] *Character Model for the World Wide Web 1.0: Fundamentals*,
http://www.w3.org/TR/charmod

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Modifications

The following summarizes modifications from the previous versions of this document.

Revision 6 [KW]

- Updated title to Unicode Character Encoding Model.
- Updated all references.
- Reorganized Modifications section into bulleted lists, grouped by published revisions, to follow current technical report style.
- Updated for Unicode 5.0 and 5.1.
- Updated numbered bullets 1 and 3 in Section 4 to reflect the updated model regarding ill-formed sequences and the concept of noncharacters.
- Removed claim that UTF-16 is the "default" CEF for Unicode 4.0.
- Updated table of encoding forms to indicate that ISO/IEC 10646:2008 has dropped implementation levels and is now closely aligned with Unicode 5.0.

- Added note about other stability implications in Section 2.1.
- Updated "grapheme" to "grapheme cluster" in Section 2.3.
- Minor editing throughout.

Revision 5 [AF]

- Aligned the discussion of TES to more closely match common practice.
- Improved the discussion of CES. ~~Note: Versions 4 and 3.3 were proposed updates that are superseded.~~
- Edited the text for style and clarity throughout, labeled figures, changed some lists to tables, applied copy edits.
- Improved the discussion of CES.
- Updated for Unicode 4.0.
- Added subsections on Versioning, Byte Order and Strings.
- Expanded the discussion on Data Types and API~~s~~ Binding.
- ~~Edited the text for style and clarity throughout.~~
- Migrated to current TR format.

Revisions 3.3 and 4 being proposed updates, only changes between versions 3.2 and 5 are noted here.