Endianness

In computing, the term **endian** or **endianness** refers to the ordering of individually addressable sub-components within the representation of a larger data item as stored in *external memory* (or, sometimes, as sent on a serial connection). Each sub-component in the representation has a unique degree of significance, like the place value of digits in a decimal number. These sub-components are typically 16-, 32- or 64-bit words, 8-bit bytes, or even bits. Endianness is a difference in data representation at the hardware level and may or may not be transparent at higher levels, depending on factors such as the type of high level language used.

The most common cases refer to how bytes are ordered within a single 16-, 32-, or 64-bit word, and *endianness* is then the same as **byte order**.[1] The usual contrast is whether the most significant or least significant byte is ordered first—i.e., at the lowest byte address—within the larger data item. A **big-endian** machine stores the *most* significant byte first, and a **little-endian** machine stores the *least* significant byte first. In these standard forms, the bytes remain ordered by significance. However, mixed forms are also possible where the ordering of bytes within a 16-bit word may differ from the ordering of 16-bit words within a 32-bit word, for instance. Although rare, such cases do exist and may sometimes be referred to as **mixed-endian** or **middle-endian**.

Endianness is important as a low-level attribute of a particular data format. For example, the order in which the two bytes of a UCS-2 character are stored in memory is of considerable importance in network programming where two computers with different byte orders may be communicating with each other. Failure to account for a varying endianness across architectures when writing code for mixed platforms leads to failures and bugs that can be difficult to detect.

Endian	First byte (lowest address)	Middle bytes	Last byte (highest address)	Notes
big	*most* significant	**...**	*least* significant	Similar to a number written on paper (in Arabic numerals as used in most Western scripts)
little	*least* significant	**...**	*most* significant	Arithmetic calculation order (see carry propagation)

The term *endian* as derived from *end* may lead to confusion. Note that it denotes which end (i.e., outermost part) of the number comes first rather than which part comes at the end of the byte sequence (representing the number). See Etymology for an explanation why it refers to the end from which something starts, but not to something coming last.

Endianness and hardware

The full register width among different CPUs and other processor types varies widely (typically between 4 and 64 bits). The internal bit-, byte-, or word-ordering within such a register is normally not considered "endianness", despite the fact that some CPU instructions may address individual bits (or other parts) using various kinds of internal addressing schemes. The "endianness" only describes how the bits are organized as seen from the outside (i.e., when stored in memory). The fact that some assembly languages *label* bits in an unorthodox manner is also largely another matter (a few architectures/assemblers turn the conventional `msb..lsb = D31..D0` the other way round, so that `msb=D0`).

Large integers are usually stored in memory as a sequence of smaller ones and obtained by simple concatenation. The simple forms are:

- increasing numeric significance with increasing memory addresses (or increasing time), known as *little-endian*, and
- decreasing numeric significance with increasing memory addresses (or increasing time), known as *big-endian*[2]

Well-known processor architectures that use the little-endian format include x86 (including x86-64), 6502 (including 65802, 65C816), Z80 (including Z180, eZ80 etc.), MCS-48, 8051, DEC Alpha, Altera Nios, Atmel AVR, SuperH, VAX, and, largely, PDP-11.

Well-known processors that use the big-endian format include Motorola 6800 and 68k, Xilinx Microblaze, IBM POWER, and System/360 and its successors such as System/370, ESA/390, and z/Architecture. The PDP-10 also used big-endian addressing for byte-oriented instructions. SPARC historically used big-endian until version 9, which is bi-endian, similarly the ARM architecture was little-endian before version 3 when it became bi-endian, and the PowerPC and Power Architecture descendants of IBM POWER are also bi-endian (see below).

Serial protocols may also be regarded as either little or big-endian at the bit- and/or byte-levels (which may differ). Many serial interfaces, such as the ubiquitous USB, are little-endian at the bit-level. Physical standards like RS-232, RS-422 and RS-485 are also typically used with UARTs that send the least significant bit first, such as in industrial instrumentation applications, lighting protocols (DMX512), and so on. The same could be said for digital current loop signaling systems such as MIDI. There are also several serial formats where the most significant bit is normally sent first, such as I²C and the related SMBus. However, the bit order may often be reversed (or is "transparent") in the interface between the UART or communication controller and the host CPU or DMA controller (and/or system memory), especially in more complex systems and personal computers. These interfaces may be of any type and are often configurable.

Bi-endian hardware

Some architectures (including ARM versions 3 and above, PowerPC, Alpha, SPARC V9, MIPS, PA-RISC and IA-64) feature a setting which allows for switchable endianness in data segments, code segments or both. This feature can improve performance or simplify the logic of networking devices and software. The word *bi-endian*, when said of hardware, denotes the capability of the machine to compute or pass data in either endian format.

Many of these architectures can be switched via software to default to a specific endian format (usually done when the computer starts up); however, on some systems the default endianness is selected by hardware on the motherboard and cannot be changed via software (e.g., the Alpha, which runs only in big-endian mode on the Cray T3E).

Note that the term "bi-endian" refers primarily to how a processor treats *data* accesses. *Instruction* accesses (fetches of instruction words) on a given processor may still assume a fixed endianness, even if *data* accesses are fully bi-endian, though this is not always the case, such as on Intel's IA-64-based Itanium CPU, which allows both.

Note, too, that some nominally bi-endian CPUs require motherboard help to fully switch endianness. For instance, the 32-bit desktop-oriented PowerPC processors in little-endian mode act as little-endian from the point of view of the executing programs but they require the motherboard to perform a 64-bit swap across all 8 byte lanes to ensure that the little-endian view of things will apply to I/O devices. In the absence of this unusual motherboard hardware, device driver software must write to different addresses to undo the incomplete transformation and also must perform a normal byte swap.

Some CPUs, such as many PowerPC processors intended for embedded use, allow per-page choice of endianness.

Floating-point and endianness

Although the ubiquitous x86 of today use little-endian storage for all types of data (integer, floating point, BCD), there have been a few historical machines where floating point numbers were represented in big-endian form while integers were represented in little-endian form.[3] Because there have been many floating point formats with no "network" standard representation for them, there is no formal standard for transferring floating point values between heterogeneous systems. It may therefore appear strange that the widespread IEEE 754 floating point standard does not specify endianness.[4] Theoretically, this means that even standard IEEE floating point data written by one machine might not be readable by another. However, on modern standard computers (i.e., implementing IEEE 754), one may in practice safely assume that the endianness is the same for floating point numbers as for integers, making the conversion straight forward regardless of data type. (Small embedded systems using special floating point formats may be another matter however.)

Endianness and operating systems on architectures

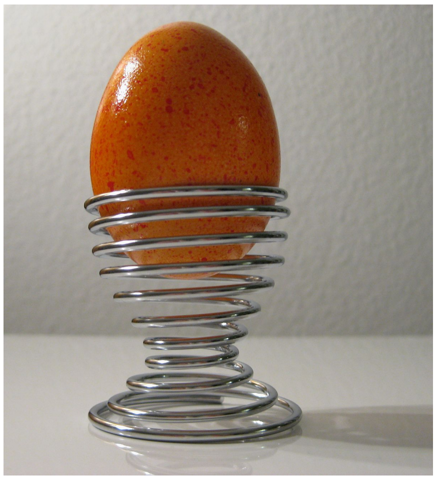
Little-endian (operating systems with architectures on Little Endian):

- DragonFlyBSD on x86, and x86-64
- FreeBSD on x86, x86-64, and Itanium
- Linux on x86, x86-64, MIPS**EL**, Alpha, Itanium, S+core, MN103, CRIS, Blackfin, Microblaze**EL**, ARM, M32R**EL**, TILE, SH, Xtensa**EL** and UniCore32
- Mac OS X on x86, x86-64
- iOS on ARM
- NetBSD on x86, x86-64, Itanium, etc.
- OpenBSD on x86, x86-64, Alpha, VAX, Loongson (MIPS**EL**)
- OpenVMS on VAX, Alpha and Itanium
- Solaris on x86, x86-64, PowerPC
- Tru64 UNIX on Alpha
- ESX on x86, x86-64
- Windows on x86, x86-64, Alpha, PowerPC, MIPS and Itanium

Big-endian (operating systems with architectures on Big Endian):

- AIX on POWER
- AmigaOS on PowerPC and 680x0
- FreeBSD on PowerPC and SPARC
- HP-UX on Itanium and PA-RISC
- Linux on MIPS, SPARC, PA-RISC, POWER, PowerPC, 680x0, ESA/390, z/Architecture, H8, FR-V, AVR32, Microblaze, ARM**EB**, M32R, SH**EB** and Xtensa.
- Mac OS on PowerPC and 680x0
- Mac OS X on PowerPC
- NetBSD on PowerPC, SPARC, etc.
- OpenBSD on PowerPC, SPARC, PA-RISC, SGI (MIPS**EB**), Motorola 68k and 88k, Landisk (SuperH-4)
- MVS and DOS/VSE on ESA/390, and z/VSE and z/OS on z/Architecture
- Solaris on SPARC

Etymology


An egg in an egg cup with the little-endian portion oriented upward.

The term *big-endian* originally comes from Jonathan Swift's satirical novel *Gulliver's Travels* by way of Danny Cohen in 1980.[5] In 1726, Swift described tensions in Lilliput and Blefuscu: whereas royal edict in Lilliput requires cracking open one's soft-boiled egg at the small end, inhabitants of the rival kingdom of Blefuscu crack theirs at the big end (giving them the moniker *Big-endians*).[6] The terms *little-endian* and *endianness* have a similar intent.[7]

"On Holy Wars and a Plea for Peace"[5] by Danny Cohen ends with: "Swift's point is that the difference between breaking the egg at the little-end and breaking it at the big-end is trivial. Therefore, he suggests, that everyone does it in his own preferred way. We agree that the difference between sending eggs with the little- or the big-end first is trivial, but we insist that everyone must do it in the same way, to avoid anarchy. Since the difference is trivial we may choose either way, but a decision must be made."

History

The problem of dealing with data in different representations is sometimes termed the *NUXI problem*.[8] This terminology alludes to the issue that a value represented by the byte-string "UNIX" on a big-endian system may be stored as "NUXI" on a PDP-11 middle-endian system; UNIX was one of the first systems to allow the same code to run on, and transfer data between, platforms with different internal representations.

An often-cited argument in favor of big-endian is that it is consistent with the ordering commonly used in natural languages.[9] Spoken languages have a wide variety of organizations of numbers: the decimal number 92 is spoken in English as *ninety-two*, in German and Dutch as *two and ninety* and in French as *four-twenty-twelve* with a similar system in Danish (*two-and-half-five-times-twenty*). However, numbers are written almost universally in the Hindu-Arabic numeral system, in which the most significant digits are written first in languages written left-to-right, and last in languages written right-to-left.[10]

Optimization

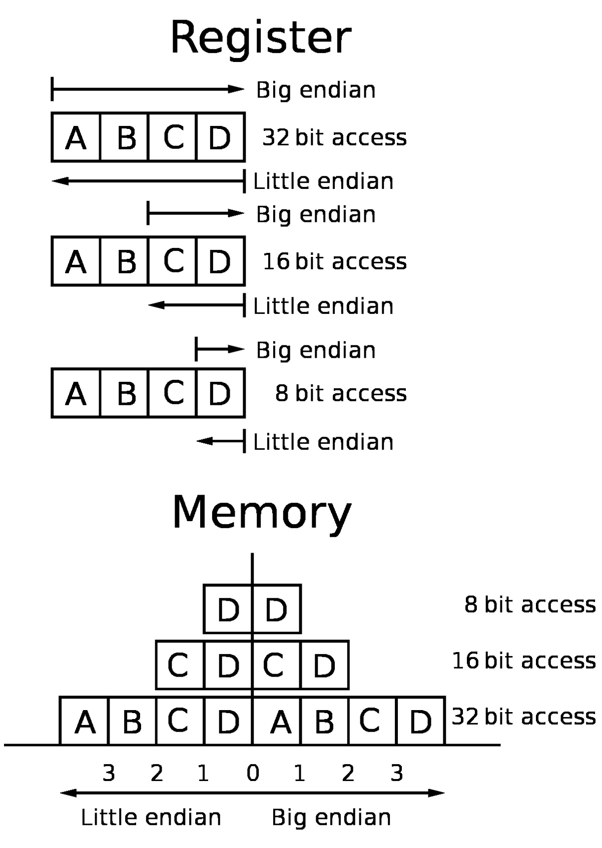
The little-endian system has the property that the same value can be read from memory at different lengths without using different addresses (even when alignment restrictions are imposed). For example, a 32-bit memory location with content 4A 00 00 00 can be read at the same address as either 8-bit (value = 4A), 16-bit (004A), 24-bit (00004A), or 32-bit (0000004A), all of which retain the same numeric value. Although this little-endian property is rarely used directly by high-level programmers, it is often employed by code optimizers as well as by assembly language programmers.

On the other hand, in some situations it may be useful to obtain an approximation of a multi-byte or multi-word value by reading only its most-significant portion instead of the complete representation; a big-endian processor may read such an approximation using the same base-address that would be used for the full value.

Calculation order

Little-endian representation simplifies hardware in processors that add multi-byte integral values a byte at a time, such as small-scale byte-addressable processors and microcontrollers. As carry propagation must start at the least significant bit (and thus byte), multi-byte addition can then be carried out with a monotonic incrementing address sequence, a simple operation already present in hardware. On a big-endian processor, its addressing unit has to be told how big the addition is going to be so that it can hop forward to the least significant byte, then count back down towards the most significant. However, high performance processors usually perform these operations as a single operation, fetching multi-byte operands from memory in a single operation, so that the complexity of the hardware is not affected by the byte ordering.

Diagram for mapping registers to memory locations



Mapping registers to memory locations

Using this chart, one can map an access (or, for a concrete example: "write 32 bit value to address 0") from register to memory or from memory to register. To help in understanding that access, little and big endianness can be seen in the diagram as differing in their coordinate system's orientation. Big endianness's atomic units (in this example the atomic unit is the byte) and memory coordinate system increases in the diagram from left to right, while little endianness's units increase from right to left.

A simple reminder is "In **L**ittle Endian, The **L**east significant byte goes into the **L**owest value slot". So in the above example, D, the least significant byte, goes into slot 0.

If you are writing in a western language the hex value 0x0a0b0c0d you are writing the bytes from *left to right*, you are implicitly writing Big-Endian style. 0x0a at 0, 0x0b at 1, 0x0c at 2, 0x0d at 3. On the other hand the output of memory is normally also printed out bytewise from left to right, first memory address 0, then memory address 1, then memory address 2, then memory address 3. So on a Big-Endian system when you write a 32-bit value (from a register) to an address in memory and after that output the memory, you "see what you have written" (because you are using the left to right coordinate system for the output of values in registers as well as the output of memory). However on a Little-Endian system the logical 0 address of a value in a register (for 8-bit, 16-bit and 32-bit) is the *least significant byte*, the one to the right. 0x0d at 0, 0x0c at 1, 0x0b at 2, 0x0a at 3. If you write a 32 bit register value to a memory location on a Little-Endian system and after that output the memory location (with growing addresses from left to right), then the output of the memory will appear *reversed* (byte-swapped). You have 2 choices now to synchronize the output of what you are seeing as values in registers and what you are seeing as memory: You can swap the output of the register values (0x0a0b0c0d => 0x0d0c0b0a) or you can swap the output of the memory (print from right to left). Because the values of registers are interpreted as numbers, which are, in western languages, written from left to right, it is natural to use the second approach, to display the memory from right to left. The above diagram does exactly that, when visualizing memory (when "thinking memory") on a Little-Endian system the memory should be seen growing to the *left*.

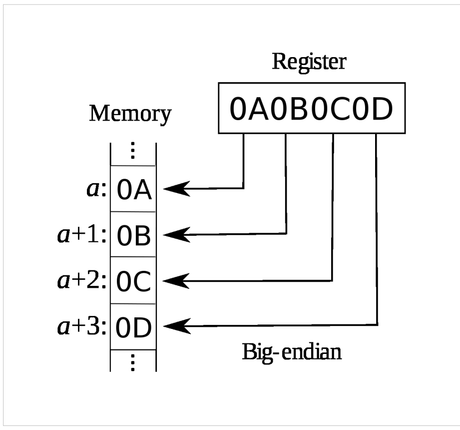
Examples of storing the value `0A0B0C0D`$_h$ in memory

Note that hexadecimal notation is used.

To illustrate the notions this section provides example layouts of the 32-bit number `0A0B0C0D`$_h$ in the most common variants of endianness. There exist several digital processors that use other formats, but these two are the most common in general processors. That is true for typical embedded systems as well as for general computer CPU(s). Most processors used in non CPU roles in typical computers (in storage units, peripherals etc.) also use one of these two basic formats, although not always 32-bit of course.

All the examples refer to the storage in memory of the value.

Big-endian



Atomic element size 8-bit, address increment 1-byte (octet)

increasing addresses →

... `0A`$_h$ `0B`$_h$ `0C`$_h$ `0D`$_h$ ...

The most significant byte (*MSB*) value, which is `0A`$_h$ in our example, is stored at the memory location with the lowest address, the next byte value in significance, `0B`$_h$, is stored at the following memory location and so on. This is akin to Left-to-Right reading in hexadecimal order.

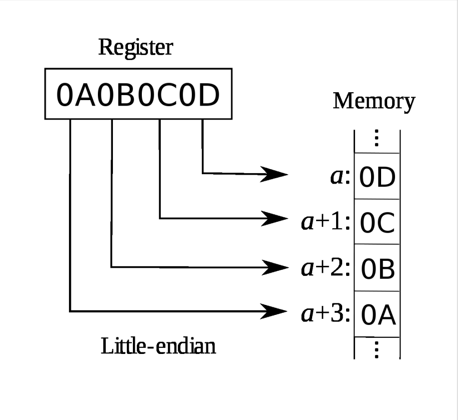
Atomic element size 16-bit

increasing addresses →

... 0A0B$_h$ 0C0D$_h$ ...

The most significant atomic element stores now the value 0A0B$_h$, followed by 0C0D$_h$.

Little-endian



Atomic element size 8-bit, address increment 1-byte (octet)

increasing addresses →

... 0D$_h$ 0C$_h$ 0B$_h$ 0A$_h$ ...

The least significant byte (*LSB*) value, 0D$_h$, is at the lowest address. The other bytes follow in increasing order of significance.

Atomic element size 16-bit

increasing addresses →

... 0C0D$_h$ 0A0B$_h$ ...

The least significant 16-bit unit stores the value 0C0D$_h$, immediately followed by 0A0B$_h$. Note that 0C0D$_h$ and 0A0B$_h$ represent integers, not bit layouts (see bit numbering).

Byte addresses increasing from right to left

Visualising memory addresses from left to right makes little-endian values appear backwards. If the addresses are written increasing *towards* the left instead, each individual little-endian value will appear forwards. However strings of values or characters appear reversed instead.

With 8-bit atomic elements:

← *increasing addresses*

... 0A$_h$ 0B$_h$ 0C$_h$ 0D$_h$ ...

The least significant byte (*LSB*) value, 0D$_h$, is at the lowest address. The other bytes follow in increasing order of significance.

With 16-bit atomic elements:

← *increasing addresses*

`... 0A0B`$_h$ `0C0D`$_h$ `...`

The least significant 16-bit unit stores the value `0C0D`$_h$, immediately followed by `0A0B`$_h$.

The display of text is reversed from the normal display of languages such as English that read from left to right. For example, the word "XRAY" displayed in this manner, with each character stored in an 8-bit atomic element:

← *increasing addresses*

`... "Y" "A" "R" "X" ...`

If pairs of characters are stored in 16-bit atomic elements (using 8 bits per character), it could look even stranger:

← *increasing addresses*

`... "AY" "XR" ...`

This conflict between the memory arrangements of binary data and text is intrinsic to the nature of the little-endian convention, but is a conflict only for languages written left-to-right, such as Indo-European languages including English. For right-to-left languages such as Arabic and Hebrew, there is no conflict of text with binary, and the preferred display in both cases would be with addresses increasing to the left. (On the other hand, right-to-left languages have a complementary intrinsic conflict in the big-endian system.)

Middle-endian

Numerous other orderings, generically called *middle-endian* or *mixed-endian*, are possible. On the PDP-11 (16-bit little-endian) for example, the compiler stored 32-bit values with the 16-bit halves swapped from the expected little-endian order. This ordering is known as *PDP-endian*.

- *storage of a 32-bit word on a PDP-11*

increasing addresses →

`... 0B`$_h$ `0A`$_h$ `0D`$_h$ `0C`$_h$ `...`

The ARM architecture can also produce this format when writing a 32-bit word to an address 2 bytes from a 32-bit word alignment

Segment descriptors on Intel 80386 and compatible processors keep a base 32-bit address of the segment stored in little-endian order, but in four nonconsecutive bytes, at relative positions 2,3,4 and 7 of the descriptor start.

Endianness in networking

Many IETF RFCs use the term *network order*; it simply describes the order of transmission for bits and bytes *over the wire* in network protocols. Among others the historic RFC 1700 (also known as Internet standard STD 2) explains this big endian order.[11]

The telephone network, historically and presently, sends the most significant part first, the area code; doing so allows routing while a telephone number is being composed.

The Internet Protocol defines big-endian as the standard *network byte order* used for all numeric values in the packet headers and by many higher level protocols and file formats that are designed for use over IP. The Berkeley sockets API defines a set of functions to convert 16-bit and 32-bit integers to and from network byte order: the `htonl` (host-to-network-long) and `htons` (host-to-network-short) functions convert 32-bit and 16-bit values respectively from machine (*host*) to network order; the `ntohl` and `ntohs` functions convert from network to host order. These functions may be a no-op on a big-endian system.

In CANopen multi-byte parameters are always sent least significant byte first (little endian).

While the lowest network protocols may deal with sub-byte formatting, all the layers above them usually consider the *byte* (mostly meant as *octet*) as their atomic unit.

Endianness in files and byte swap

Endianness is a problem when a binary file created on a computer is read on another computer with different endianness. Some compilers have built-in facilities to deal with data written in other formats. For example, the Intel Fortran compiler supports the non-standard `CONVERT` specifier, so a file can be opened as

```
OPEN(unit,CONVERT='BIG_ENDIAN',...)
```

or

```
OPEN(unit,CONVERT='LITTLE_ENDIAN',...)
```

Some compilers have options to generate code that globally enables the conversion for all file IO operations. This allows one to reuse code on a system with the opposite endianness without having to modify the code itself. If the compiler does not support such conversion, the programmer needs to swap the bytes via ad hoc code.

Fortran sequential unformatted files created with one endianness usually cannot be read on a system using the other endianness because Fortran usually implements a record (defined as the data written by a single Fortran statement) as data preceded and succeeded by count fields, which are integers equal to the number of bytes in the data. An attempt to read such file on a system of the other endianness then results in a run-time error, because the count fields are incorrect. This problem can be avoided by writing out sequential binary files as opposed to sequential unformatted.

Unicode text can optionally start with a byte order mark (BOM) to signal the endianness of the file or stream. Its code point is U+FEFF. In UTF-32 for example, a big-endian file should start with `00 00 FE FF`. In a little-endian file these bytes are reversed.

Application binary data formats, such as for example MATLAB .mat files, or the .BIL data format, used in topography, are usually endianness-independent. This is achieved by storing the data always in one fixed endianness, or carrying with the data a switch to indicate which endianness the data was written with. When reading the file, the application converts the endianness, transparently to the user.

This is the case of TIFF image files, which instructs in its header about endianness of their internal binary integers. If a file starts with the signature "`MM`" it means that integers are represented as big-endian, while "`II`" means little-endian. Those signatures need a single 16-bit word each, and they are palindromes (that is, they read the same forwards and backwards), so they are endianness independent. "`I`" stands for Intel and "`M`" stands for Motorola, the respective CPU providers of the IBM PC compatibles and Apple Macintosh platforms in the 1980s. Intel CPUs are little-endian, while Motorola 680x0 CPUs are big-endian. This explicit signature allows a TIFF reader program to swap bytes if necessary when a given file was generated by a TIFF writer program running on a computer with a different endianness.

The LabVIEW programming environment, though most commonly installed on Windows machines, was first developed on a Macintosh, and uses Big Endian format for its binary numbers, while most Windows programs use Little Endian format.[12]

Note that since the required byte swap depends on the length of the variables stored in the file (two 2-byte integers require a different swap than one 4-byte integer), a general utility to convert endianness in binary files cannot exist.

"Bit endianness"

The terms *bit endianness* or *bit-level endianness* are seldom used when talking about the representation of a stored value, as they are only meaningful for the rare computer architectures where each individual bit has a unique address. They are used however to refer to the transmission order of bits over a serial medium. Most often that order is transparently managed by the hardware and is the bit-level analogue of little-endian (low-bit first), although protocols exist which require the opposite ordering (e.g. I²C, and SONET and SDH[13]). In networking, the decision about the order of transmission of bits is made in the very bottom of the data link layer of the OSI model. As bit ordering is usually only relevant on a very low level, terming transmissions "LSB first" or "MSB first" is more descriptive than assigning an endianness to bit ordering.

Other meanings

Some authors extend the usage of the word "endianness", and of related terms, to entities such as street addresses, date formats and others. Such usages—basically reducing *endianness* to a mere synonym of *ordering of the parts*—are non-standard usage (e.g., ISO 8601:2004 talks about "descending order year-month-day", not about "big-endian format"), do not have widespread usage, and are generally (other than for date formats) employed in a metaphorical sense.

"Endianness" is sometimes used to describe the order of the components of a domain name, e.g. 'en.wikipedia.org' (the usual modern 'little-endian' form) versus the reverse-DNS 'org.wikipedia.en' ('big-endian', used for naming components, packages, or types in computer systems, for example Java packages, Macintosh ".plist" files, etc.). URLs can be considered 'big-endian', even though the host part could be a 'little-endian' DNS name.

References and notes

[1] For hardware, the Jargon File also reports the less common expression *byte sex* (http://catb.org/jargon/html/B/byte-sex.html). It is unclear whether this terminology is also used when more than two orderings are possible. Similarly, the manual for the ORCA/M assembler refers to a field indicating the order of the bytes in a number field as `NUMSEX`, and the Mac OS X operating system refers to "byte sex" in its compiler tools (http://web.mit.edu/darwin/src/modules/cctools/libstuff/arch.c).

[2] Note that, in these expressions, the term "end" is meant as "extremity", not as "last part"; and that *big* and *little* say which extremity is written *first*.

[3] "Floating point formats" (http://www.quadibloc.com/comp/cp0201.htm). .

[4] "pack - convert a list into a binary representation" (http://www.perl.com/doc/manual/html/pod/perlfunc/pack.html). .

[5] Danny Cohen (1980-04-01). *On Holy Wars and a Plea for Peace* (http://www.ietf.org/rfc/ien/ien137.txt). IEN 137. . "...which bit should travel first, the bit from the little end of the word, or the bit from the big end of the word? The followers of the former approach are called the Little-Endians, and the followers of the latter are called the Big-Endians." Also published at *IEEE Computer*, October 1981 issue (http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=1667115).

[6] Jonathan Swift (1726). *Gulliver's Travels* (http://en.wikisource.org/wiki/Gulliver's_Travels/Part_I/Chapter_IV). . "Which two mighty powers have, as I was going to tell you, been engaged in a most obstinate war for six-and-thirty moons past. (...) the primitive way of breaking eggs, before we eat them, was upon the larger end; (...) the emperor his father published an edict, commanding all his subjects, upon great penalties, to break the smaller end of their eggs. (...) Many hundred large volumes have been published upon this controversy: but the books of the Big-endians have been long forbidden (...)"

[7] David Cary. "Endian FAQ" (http://david.carybros.com/html/endian_faq.html). . Retrieved 2010-10-11.

[8] "NUXI problem" (http://catb.org/jargon/html/N/NUXI-problem.html). *The Jargon File*. . Retrieved 2008-12-20.

[9] *Cf.* entries 539 (http://ling.uni-konstanz.de:591/FMRes/FMPro?-db=universals&number=539&-format=FormVw.htm&-lay=&-max=1&-skip=0&-token=25&-find) and 704 (http://ling.uni-konstanz.de:591/FMRes/FMPro?-db=universals&number=704&-format=FormVw.htm&-lay=&-max=1&-skip=0&-token=25&-find) of the Linguistic Universals Database

[10] "Digression: little/big endian numbers LTR/RTL" (http://lists.w3.org/Archives/Public/www-international/2008AprJun/0104.html). *www-international@w3.org Mail Archives*. 2008-05-02. . Retrieved 2011-07-25.

[11] Reynolds, J.; Postel, J. (October 1994). "Data Notations" (https://tools.ietf.org/html/rfc1700#page-3). *Assigned Numbers* (https://tools.ietf.org/html/rfc1700). IETF. p. 3. STD 2. RFC 1700. . Retrieved 2012-03-02.

[12] read write binary files with LabVIEW (http://digital.ni.com/public.nsf/allkb/97332426D63630EE862565070049FFBB)

[13] Cf. Sec. 2.1 Bit Transmission of http://tools.ietf.org/html/draft-ietf-pppext-sonet-as-00

Further reading

- Danny Cohen (1980-04-01). *On Holy Wars and a Plea for Peace* (http://www.ietf.org/rfc/ien/ien137.txt). IEN 137. Also published at *IEEE Computer*, October 1981 issue (http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=1667115).
- David V. James (June 1990). "Multiplexed buses: the endian wars continue" (http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=56322). *IEEE Micro* **10** (3): 9–21. doi:10.1109/40.56322. ISSN 0272-1732. Retrieved 2008-12-20.
- Bertrand Blanc, Bob Maaraoui (December 2005). *Endianness or Where is Byte 0?* (http://3bc.bertrand-blanc.com/endianness05.pdf). Retrieved 2008-12-21.

External links

- Understanding big and little endian byte order (http://betterexplained.com/articles/understanding-big-and-little-endian-byte-order/)
- Byte Ordering PPC (http://developer.apple.com/documentation/CoreFoundation/Conceptual/CFMemoryMgmt/Concepts/ByteOrdering.html)
- Writing endian-independent code in C (http://www.ibm.com/developerworks/aix/library/au-endianc/index.html?ca=drs-)
- How to convert an integer to little endian or big endian (http://techforb.blogspot.com/2007/10/how-to-convert-integer-to-little-endian.html)
- C-Level Code Illustration (http://sites.google.com/site/insideoscore/endianness)
- xlong/xshort data-types, the Big-Endian, Little-Endian Rosetta stone (http://www.stanford.edu/dept/its/support/uspires/xlong/)

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