# DICOM Change Proposal Form - Final Text

| Tracking Information - Administrator Use Only | |
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| Change Proposal Number | CP 14 |
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| Person Assigned | Brian Long, Larry Tarbox, Dwight Simon |

| Log Summary: | |
|---|---|
| Submitter Name<br>Steve Moore | Submission date<br>2/15/94 |
| Type of Modification<br>Ambiguity | |
| Name of Document<br><br>PS 3.5 1994 | Version Number |
| Rationale for change<br><br>Pixel Encoding, especially for 8 bit pixels, was not defined clearly leading to confusion as to when byte swapping was necessary. | |
| Sections of document affected<br><br>Add after Section 3.10.33 two new definitions.<br><br>Change Section 8 to better define Encoding of Pixel Data and to introduce the backward compatible concept of encoding 8 bit pixel data using an explicit OB value representation, in order to totally ignore byte swapping.<br><br>Change A.2 through A.4 to more clearly define Pixel Data encoding in relationship to Transfer Syntax.<br><br>Change by adding to beginning Annex D more examples to better explain how Pixel Data encoding works. | |

Suggested Wording of change

**3.10.34 Pixel Cell:** The container for a Pixel Sample Value that may include unused bits or bits for data other than the Pixel Sample Value (e.g. overlay planes). The size of a Pixel Cell shall be specified by the Bits Allocated (0028, 0100) Data Element.

**3.10.35 Pixel Sample Value:** A value given to an individual pixel. An individual pixel consists of one or more Pixel Sample Values (e.g. color or multi-planar images).

# 8 Encoding of Pixel Data

The Pixel Data Element (7FE0,0010) shall be used for the exchange of encoded graphical image data. This element along with additional Data Elements, specified as Attributes of the Image Information Entities defined in PS 3.3, shall be used to describe the way in which the Pixel Data is encoded and shall be interpreted. Finally, depending on the negotiated Transfer Syntax (see Section 10 and Annex A), Pixel Data may be compressed.

The Pixel Data Element (7FE0,0010) has a VR of OW or OB, depending on the negotiated Transfer Syntax (see Annex A). The only difference between OW and OB being that OB, a string of bytes, shall be unaffected by Byte Ordering (see Section 7.3).

## 8.1 Pixel Data Encoding of Related Data Elements

Encoded Pixel Data of various bit depths shall be accommodated. The following three Data Elements shall define the Pixel Cell structure:

- Bits Allocated (0028,0100)
- Bits Stored (0028,0101)
- High Bit (0028,0102).

Each Pixel Cell shall contain a single Pixel Sample Value. The size of the Pixel Cell shall be specified by Bits Allocated (0028,0100). Bits Stored (0028,0101) defines the total number of these allocated bits that will be used to represent a Pixel Sample Value. Bits Stored (0028,0101) shall never be larger than Bits Allocated (0028,0100). High Bit (0028,0102) specifies where the high order bit of the Bits Stored (0028,0101) is to be placed with respect to the Bits Allocated (0028,0100) specification. Bits not used for Pixel Sample Values can be used for overlay planes described further in PS3.3.

NOTE: For example, in Pixel Data with 16 bits (2 bytes) allocated, 12 bits stored, and bit 15 specified as the high bit, one Pixel Sample is encoded in each 16-bit word, with the 4 least significant bits of each word not containing Pixel Data. See Annex D for other examples of the basic encoding schemes.

Starting with DICOM Version 3.0, restrictions are placed on acceptable Values for Bits Allocated (0028,0100), Bits Stored (0028,0101), and High Bit (0028,0102) and are specified in the Information Object Definitions in PS3.3. Also, the Value Field containing Pixel Data, like all other Value Fields in DICOM, shall be an even number of bytes in length. This means that the Value Field may need to be padded with data that is not part of the image and shall not be considered significant.

The field of bits representing the value of a Pixel Sample shall be a binary 2's complement integer or an unsigned integer, as specified by the Data Element Pixel Representation (0028,0103). The sign bit shall be the High Bit in a Pixel Sample Value that is a 2's complement integer. The minimum actual Pixel Sample Value encountered in the Pixel Data is specified by Smallest Image Pixel Value (0028,0106) while the maximum value is specified by Largest Image Pixel Value (0028,0107).

## 8.2 Native or Encapsulated Format Encoding

Pixel data conveyed in the Pixel Data Element (7FE0,0010).i.(7FE0,0010); may be sent either in a Native (uncompressed) Format or in an Encapsulated Format (e.g. compressed) defined outside the DICOM standard.

If Pixel Data is sent in a Native Format, the Value Representation OW is most often required. The Value Representation OB may also be used for Pixel Data in cases where Bits Allocated has a value less than or equal to 8, but only with Transfer Syntaxes where the Value Representation is explicitly conveyed (see Annex A).

> Note: The DICOM default Transfer Syntax (Implicit VR Little Endian) does not explicitly convey Value Representation and therefore the VR of OB may not be used for Pixel Data when using the default Transfer Syntax.

Native format Pixel Cells are encoded as the direct concatenation of the bits of each Pixel Cell, where the most significant bit of a Pixel Cell is immediately followed by the least significant bit of the next Pixel Cell. The number of bits of each Pixel Cell is defined by the Bits Allocated (0028,0100) Data Element Value. When a Pixel Cell crosses a word boundary in the OW case, or a byte boundary in the OB case, it shall continue to be encoded, least significant bit to most significant bit, in the next word, or byte, respectively (see Annex D). For Pixel Data encoded with the Value Representation OW, the byte ordering of the resulting 2-byte words is defined by the Little Endian or Big Endian Transfer Syntaxes negotiated at the Association Establishment (see Annex A).

> NOTES:
>
> 1. For Pixel Data encoded with the Value Representation OB, the Pixel Data encoding is unaffected by Little Endian or Big Endian byte ordering.
>
> 2. If encoding Pixel Data with a Value for Bits Allocated (0028,0100) not equal to 16 be sure to read and understand Annex D.

If sent in an Encapsulated Format (i.e. other than the Native Format) the Value Representation OB is used. The Pixel Cells are encoded according to the encoding process defined by one of the negotiated Transfer Syntaxes (see Annex A). The encapsulated pixel stream of encoded pixel data is segmented in one or more Fragments which convey their explicit length. The sequence of Fragments of the encapsulated pixel stream is terminated by a delimiter, thus allowing the support of encoding processes where the resulting length of the entire pixel stream is not known until it is entirely encoded. This Encapsulated Format supports both Single-Frame and Multi-Frame images (as defined in PS3.3).

## A.2 DICOM Little Endian Transfer Syntax (explicit VR)

This Transfer Syntax applies to the encoding of the entire DICOM Data Set. This implies that when a DICOM Data Set is being encoded with the DICOM Little Endian Transfer Syntax the following requirements shall be met:

a) The Data Elements contained in the Data Set structure shall be encoded with Explicit VR (with a VR Field) as specified in Section 7.1.2.

b) The encoding of the overall Data Set structure (Data Element Tags, Value Length, and Value) shall be in Little Endian as specified in Section 7.3 of the DICOM Standard.

c) The encoding of the Data Elements of the Data Set shall be as follows according to their Value Representations:

- For all Value Representations defined in this part, except for the Value Representations OB and OW, the encoding shall be in Little Endian as specified in Section 7.3.
- For the Value Representations OB and OW, the encoding shall meet the following specification depending on the Data Element Tag:
    - Data Element (7FE0,0010) Pixel Data
        - where Bits Allocated (0028,0100) has a value greater than 8 shall have Value Representation OW and shall be encoded in Little Endian;
        - where Bits Allocated (0028,0100) has a value less than or equal to 8 shall have the Value Representation OB or OW and shall be encoded in Little Endian.
    - Data Element (60xx,3000) Overlay Data
        - where Bits Allocated (60xx,0100) has a value greater than 8 shall have Value Representation OW and shall be encoded in Little Endian;
        - where Bits Allocated (60xx,0100) has a value less than or equal to 8 shall have the Value Representation OB or OW and shall be encoded in Little Endian.
    - Data Element (50xx,3000) Curve Data has the Value Representation specified in its Explicit VR Field. See the specification of the Curve Data Module in PS 3.3 for the enumerated list of allowable VRs. The component points shall be encoded in Little Endian.

Note: For Data encoded with the Value Representation OB, the Data encoding is unaffected by Little Endian or Big Endian byte ordering.

This DICOM Explicit VR Little Endian Transfer Syntax shall be identified by a UID of Value "1.2.840.10008.1.2.1".

### A.3 DICOM Big Endian Transfer Syntax (explicit VR)

This Transfer Syntax applies to the encoding of the entire DICOM Data Set. This implies that when a DICOM Data Set is being encoded with the DICOM Big Endian Transfer Syntax the following requirements shall be met:

a) The Data Elements contained in the Data Set structure shall be encoded with Explicit VR (with a VR Field) as specified in Section 7.1.2.

b) The encoding of the overall Data Set structure (Data Element Tags, Value Length, and Value) shall be in Big Endian as specified in Section 7.3.

c) The encoding of the Data Elements of the Data Set shall be as follows according to their Value Representations:

- For all Value Representations defined in this part, except for the Value Representations OB and OW, the encoding shall be in Big Endian as specified in Section 7.3.
- For the Value Representations OB and OW, the encoding shall meet the following specification depending on the Data Element Tag:
    - Data Element (7FE0,0010) Pixel Data
        - where Bits Allocated (0028,0100) has a value greater than 8 shall have Value Representation OW and shall be encoded in Big Endian;
        - where Bits Allocated (0028,0100) has a value less than or equal to 8 shall have the Value Representation OB or OW and shall be encoded in Big Endian.
    - Data Element (60xx,3000) Overlay Data
        - where Bits Allocated (60xx,0100) has a value greater than 8 shall have Value Representation OW and shall be encoded in Big Endian;
        - where Bits Allocated (60xx,0100) has a value less than or equal to 8 shall have the Value Representation OB or OW and shall be encoded in Big Endian.
    - Data Element (50xx,3000) Curve Data has the Value Representation specified in its Explicit VR Field. See the specification of the Curve Data Module in PS 3.3 for the enumerated list of allowable VRs. The component points shall be encoded in Big Endian.

Note: For Data encoded with the Value Representation OB, the Data encoding is unaffected by Little Endian or Big Endian byte ordering.

This DICOM Explicit VR Big Endian Transfer Syntax shall be identified by a UID of Value "1.2.840.10008.1.2.2".

## A.4 Transfer Syntaxes for Encapsulation of Encoded Pixel Data

These Transfer Syntaxes apply to the encoding of the entire DICOM Data Set, even though the image Pixel Data (7FE0,0010) portion of the DICOM Data Set is the only portion that is encoded by an encapsulated format. This implies that when a DICOM Message is being encoded according to an encapsulation Transfer Syntax the following requirements shall be met:

a) The Data Elements contained in the Data Set structure shall be encoded with Explicit VR (with a VR Field) as specified in Section 7.1.2.

b) The encoding of the overall Data Set structure (Data Element Tags, Value Length, etc.) shall be in Little Endian as specified in Section 7.3.

c) The encoding of the Data Elements of the Data Set shall be as follows according to their Value Representations:

- For all Value Representations defined in this part, except for the Value Representations OB and OW, the encoding shall be in Little Endian as specified in Section 7.3.

- For the Value Representations OB and OW, the encoding shall meet the following specification depending on the Data Element Tag:

    - Data Element (7FE0,0010) Pixel Data has the Value Representation OB and is a sequence of bytes resulting from one of the encoding processes. It contains the encoded pixel data stream fragmented into one or more Item(s). This Pixel Data Stream may represent a Single or Multi-frame Image. See Figures A.4-1 and A.4-2.

        - The Length of the Data Element (7FE0,0010) shall be set to the Value for Undefined Length (FFFFFFFFH).

        - Each Data Stream Fragment encoded according to the specific encoding process shall be encapsulated as a DICOM Item with a specific Data Element Tag of Value (FFFE,E000). The Item Tag is followed by a 4 byte Item Length field encoding the explicit number of bytes of the Item.

        - All items containing an encoded fragment shall be made of an even number of bytes greater or equal to two. The last fragment of the DICOM message may be padded, if necessary, to meet fragment format requirements of the DICOM Standard.

        - The first Item in the Sequence of Items before the encoded Pixel Data Stream shall be a Basic Offset Table item. The Basic Offset Table Item Value, however, is not required to be present.

            - When the Item Value is not present, the Item Length shall be zero (00000000H) (see Figure A.4-1);

            - When the Item Value is present, the Basic Offset Table Item Value shall contain concatenated 32-bit unsigned integer values that are byte offsets to the first byte of the Item Tag of the first fragment for each frame in the Sequence of Items. These offsets are measured from the first byte of the first Item Tag following the Basic Offset Table item (See Figure A.4-2).

NOTE: For a Multi-Frame Image containing only one frame or a Single Frame Image, the Basic Offset Table Item Value may be present or not. If present it will contain a single 00000000H value.

- This Sequence of Items is terminated by a Sequence Delimiter Item with the Tag (FFFE,E0DD) and an Item Length Field of Value (00000000H) (i.e., no Value Field shall be present).

- Data Element (60xx,3000) Overlay Data
    - where Bits Allocated (60xx,0100) has a value greater than 8 shall have Value Representation OW and shall be encoded in Little Endian;
    - where Bits Allocated (60xx,0100) has a value less than or equal to 8 shall have the Value Representation OB or OW and shall be encoded in Little Endian.

- Data Element (50xx,3000) for Curve Data has the Value Representation specified in its Explicit VR Field. See the specification of the Curve Data Module in PS 3.3 for the enumerated list of allowable VRs. The component points shall be encoded in Little Endian.

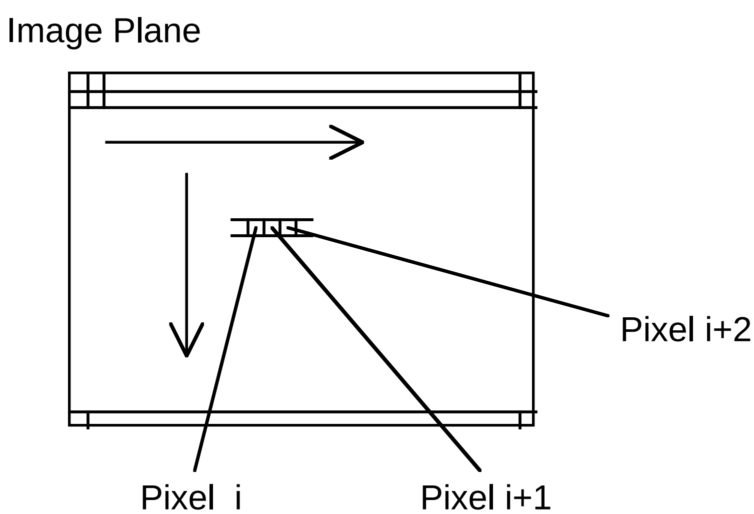
Note: For Data encoded with the Value Representation OB, the Data encoding is unaffected by Little Endian or Big Endian byte ordering.

# Annex D (Informative) Examples of Various Pixel Data and Overlay Encoding Schemes

## D.1 Detailed Example of Pixel Data Encoding

As specified in PS3.3, Image Pixel Data is stored within the Value of the Pixel Data Element (7FE0,0010). The order in which Pixel Data for an image plane is encoded is from left to right and top to bottom, a row at a time (see Figure D-1).

**Figure D-1: An Image Pixel Plane**




An individual pixel may consist of one or more Pixel Sample Values (e.g. color or multi-planar images). Each Pixel Sample Value can be expressed as either a binary 2's complement integer or a binary unsigned integer, as specified by the Pixel Representation Data Element (0028, 0103). The number of bits in each Pixel Sample Value is specified by Bits Stored (0028,0101). For 2's complement integer Pixel Samples the sign bit is the most significant bit of the Pixel Sample Value.

A Pixel Cell is the container for a Pixel Sample Value and optionally additional bits. These additional bits can be used for overlay planes, or to place Pixels on certain boundaries (byte, word, etc.). A Pixel Cell exists for every individual Pixel Sample Value in the Pixel Data. The size of the Pixel Cells is specified by Bits Allocated (0028,0100) and is greater than or equal to the Bits Stored (0028,0101). The placement of the Pixel Sample Values within the Pixel Cells is specified by High Bit (0028,0102)

Any restrictions on the characteristics of a Pixel Cell and the Pixel Sample Value contained therein is specific to the Information Object Definition (e.g. Image Object) containing the Pixel Data Element (see PS3.3).

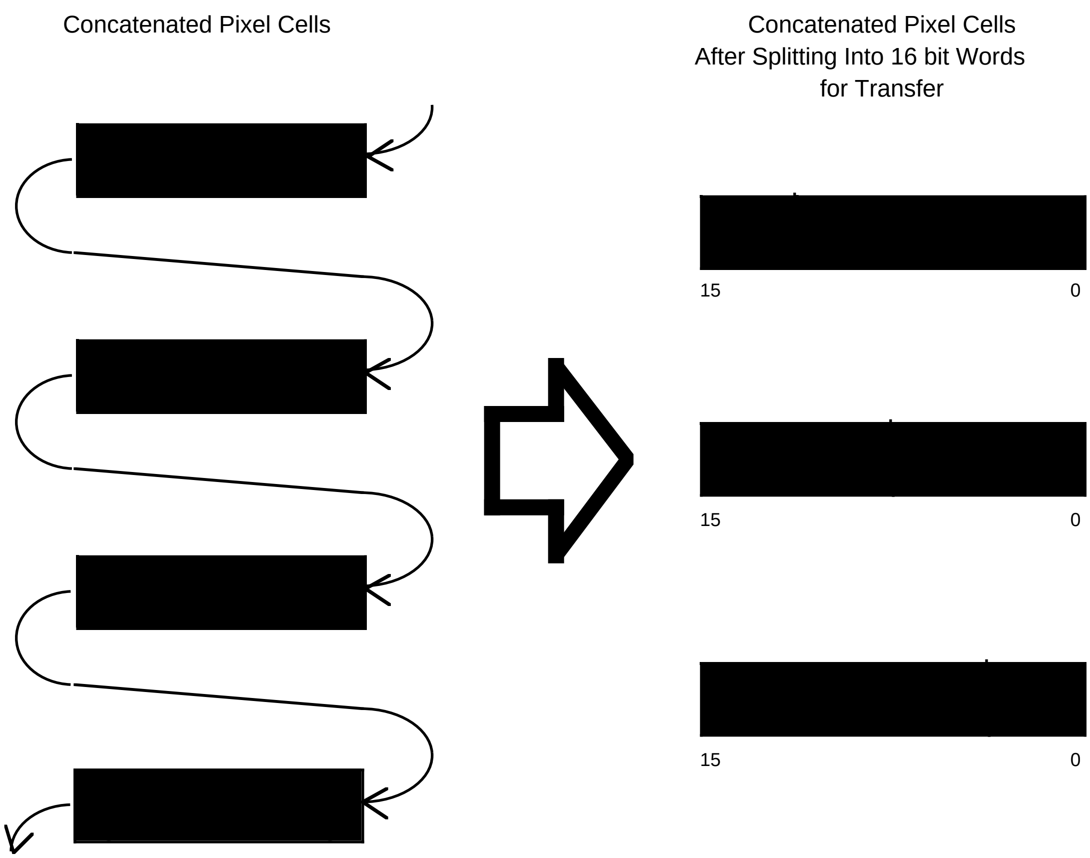
The Pixel Data Element, as specified by the DICOM default Transfer Syntax in PS3.5, has a Value Representation of OW (Other Word String). The Pixel Data in DICOM 3.0, as it was in ACR-NEMA 2.0, is packed (see Figure D-2). One way to visualize this packed encoding is to imagine encoding the Pixel Cells as a concatenated stream of bits from the least significant bit of the first

Pixel Cell up through the most significant bit of the last Pixel Cell. Within this stream, the most significant bit of any Pixel Cell is followed by the least significant bit of the next Pixel Cell. The Pixel Data can then be broken up into a stream of physical 16-bit words, each of which is subject to the byte ordering constraints of the Transfer Syntax.

All other (non-default) DICOM Transfer Syntaxes make use of explicit VR encoding. For these Transfer Syntaxes, all Pixel Data where Bits Allocated is less than or equal to 8 may be encoded with an explicit VR of OB (see Annex A). As in the OW case, Pixel Cells are packed together, but in this case the Pixel Data is broken up into a stream of physical 8-bit words.

NOTE: For Pixel Data encoded with an explicit VR of OB, the encoding of the Pixel Data is unaffected by Little Endian or Big Endian byte ordering.

**Figure D-2: Encoding (Packing) of Arbitrary Pixel Data with a VR of OW**




IODs tend to specify Pixel Cells so that they begin and end on byte or word boundaries and such that the Pixel Sample Value contained within also fits 'neatly' within a cell. However, this does not have to be the case.

We now carry forward two examples of Pixel Data encoding using the Value representation of OW for the purposes of clarification. Example 1 will be a valid example for a CT Image Information Object, while Example 2 will be for a hypothetical information object (see Figure D-3).

**Figure D-3: Example Pixel Cells**

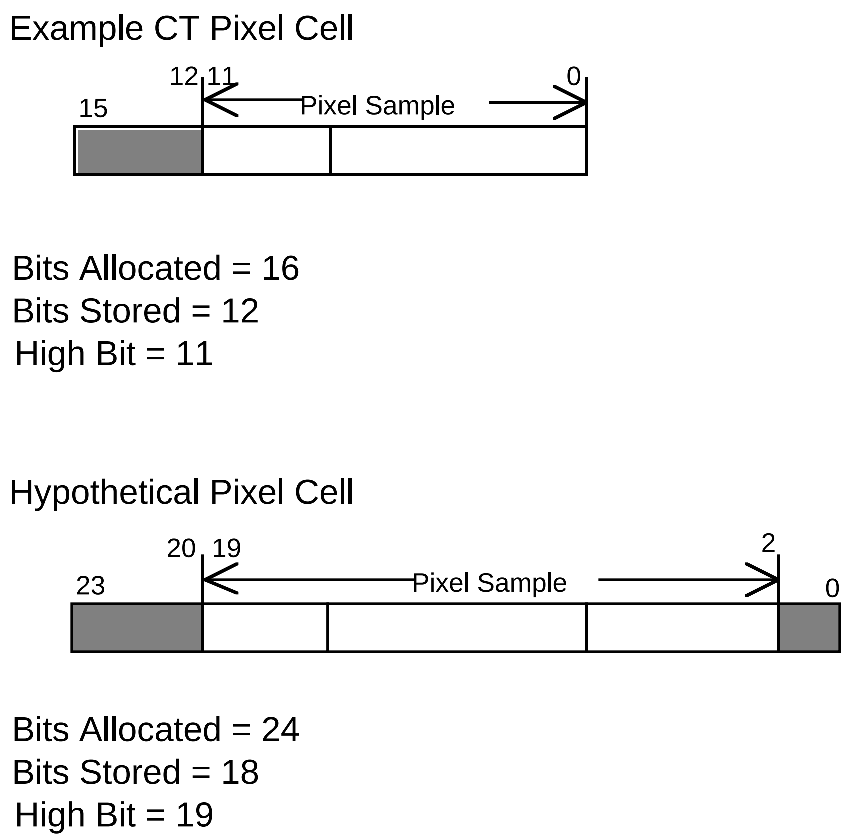
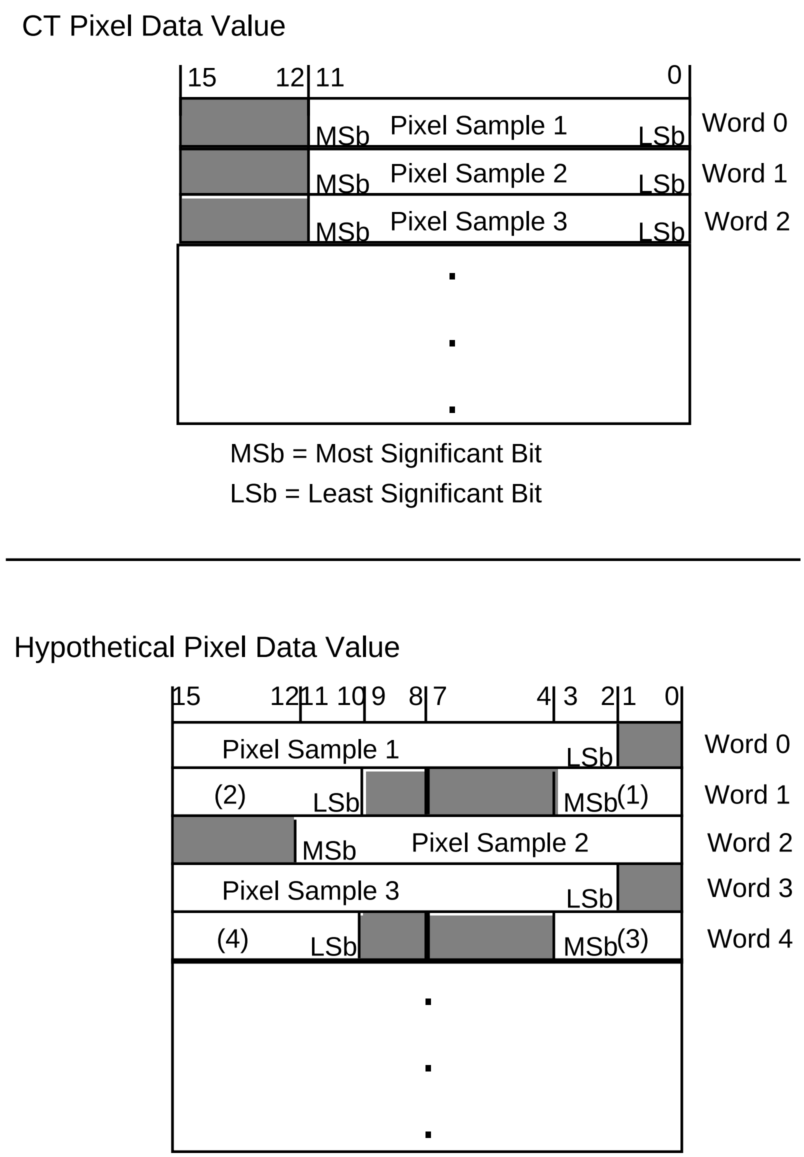


Figure D-4 shows Pixel Data constructed of these example Pixel Cells as they are packed into a stream of 16-bit words.

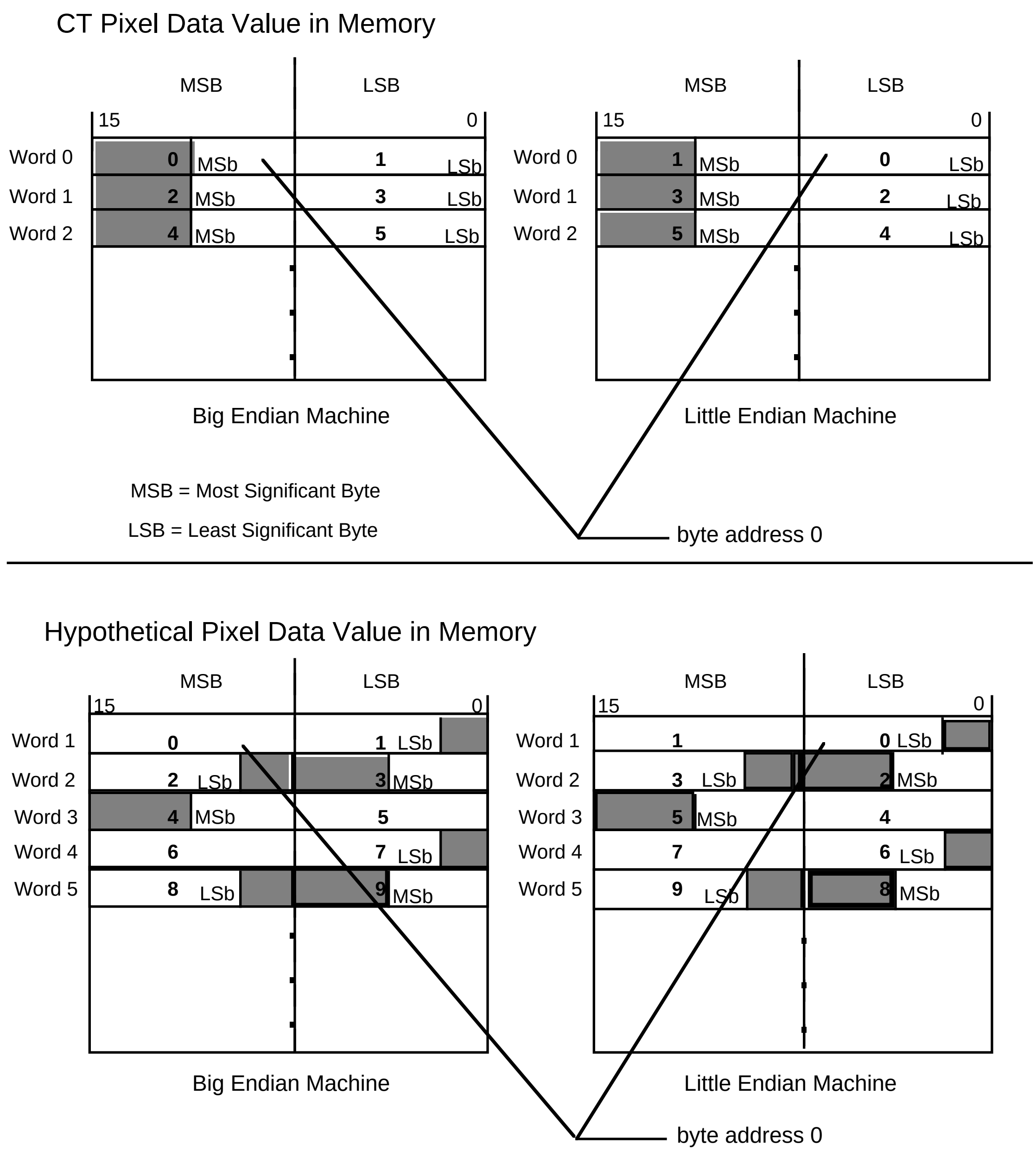
**Figure D-4: Example Pixel Cells Packed into 16-bit Words (VR = OW)**




Byte ordering becomes a consideration when we represent the Pixel Data physically, in memory, a file, or on a network.

In the memory of a byte-addressable Big Endian machine, the highest order byte (bits 8 - 15) in each 16-bit word has a binary address of x...x0. While in a byte-addressable Little Endian machine, the lowest order byte (bits 0 - 7) in each 16-bit word has a binary address of x...x0. Figure D-5 pictures our example Pixel Data streams as they would be addressed in the memory of both a Big Endian and a Little Endian machine.

## Figure D-5: Example Pixel Cells Byte Ordered in Memory (VR = OW)

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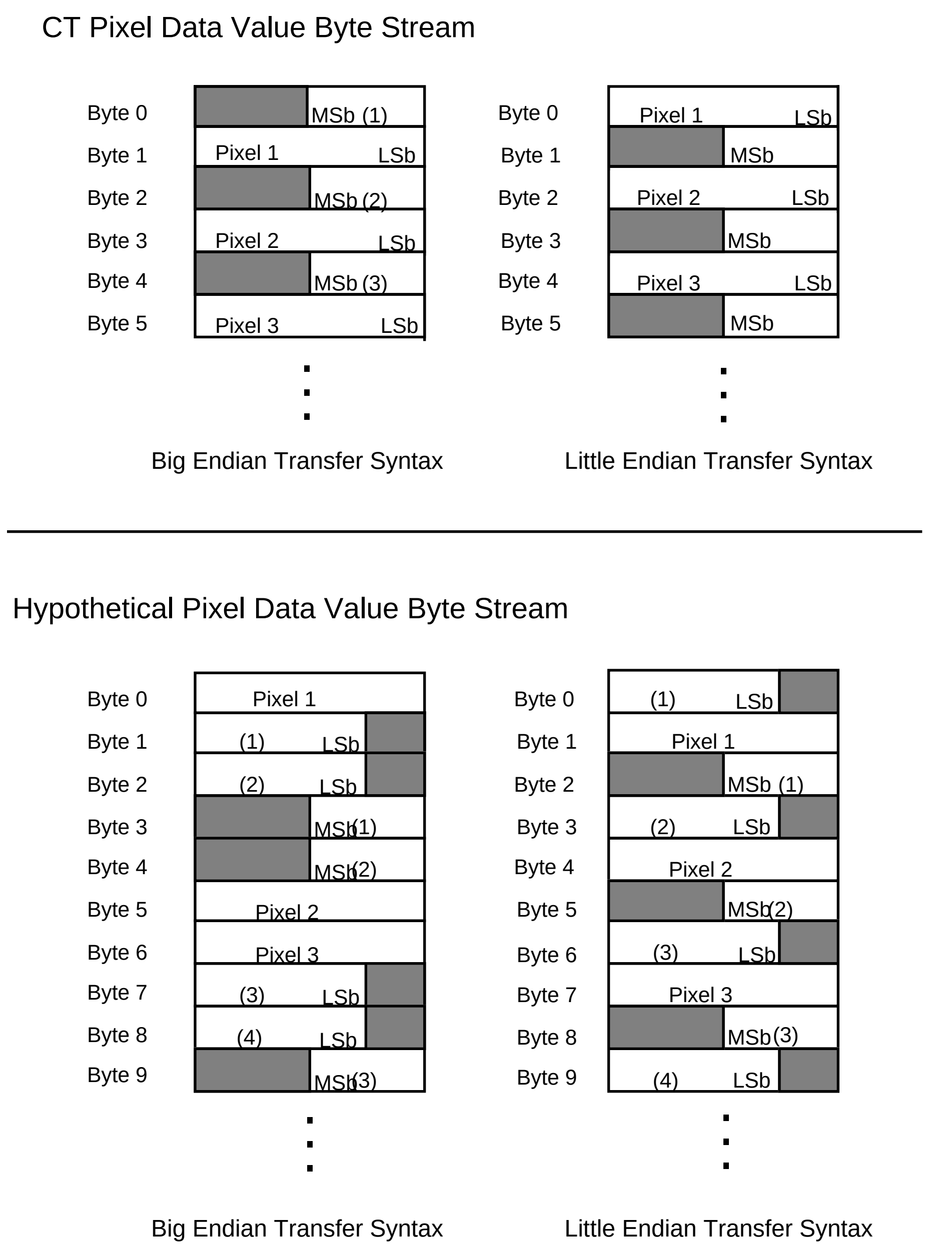
Byte ordering is also specified as part of the negotiated Transfer Syntax used in the exchange of a DICOM message. 16-bit words are transmitted across the network (a byte at a time) least significant byte first in the case of a Little Endian Transfer Syntax and most significant byte first when using a Big Endian Transfer Syntax (see Figure D-6).

**Figure D-6: Sample Pixel Data Byte Streams (VR = OW)**



As a last pair of examples, for Pixel Data having the Value Representation OW and the following attributes: 8 bits allocated, 8 bits stored, and a high bit of 7; the resulting byte streams pictured in Figure D-7 are as they would be transmitted across a network and/or stored on media. For Pixel Data having the same attributes, but having the explicit Value Representation OB; the resulting byte streams are unaffected by byte ordering and are pictured in Figure D-8.

**Figure D-7: Sample Pixel Data Byte Streams for 8-bits Allocated and 8-bits Stored (VR = OW)**

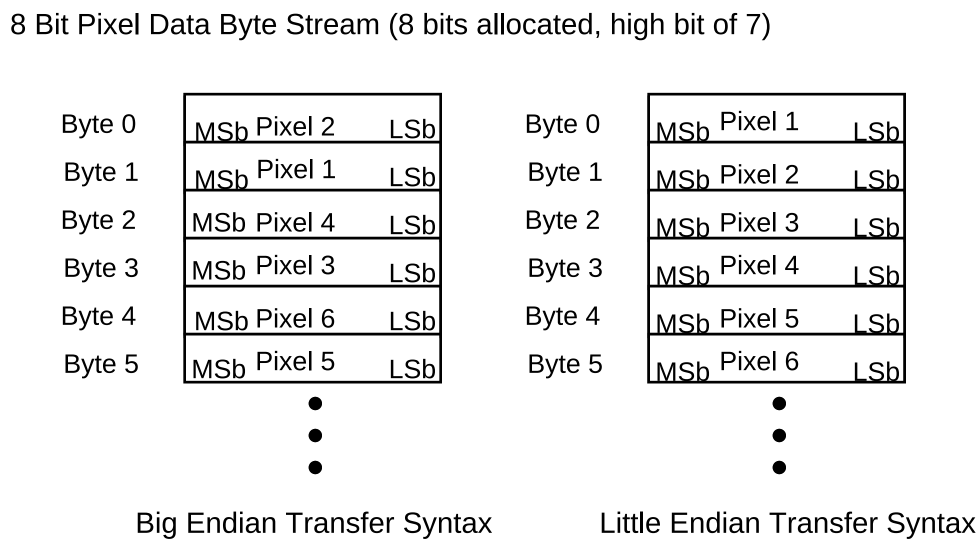
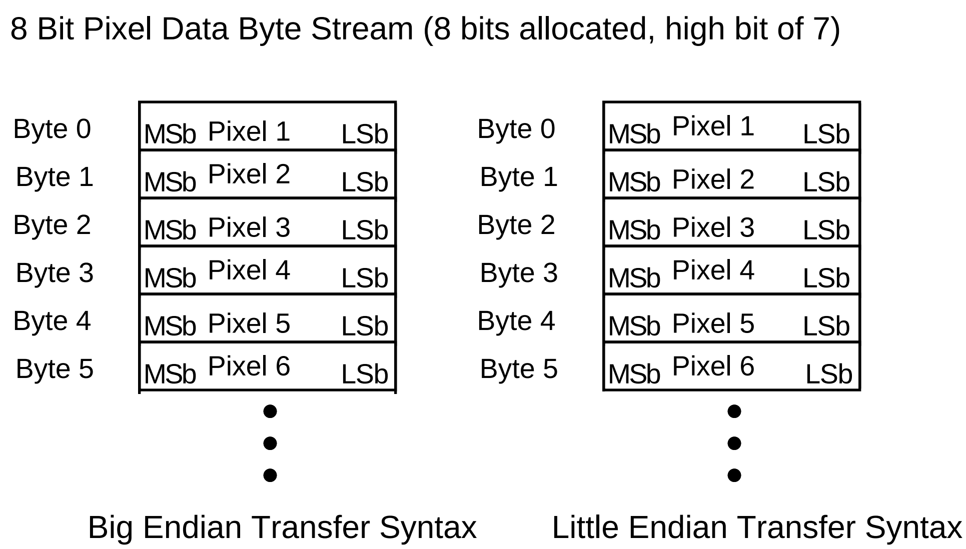
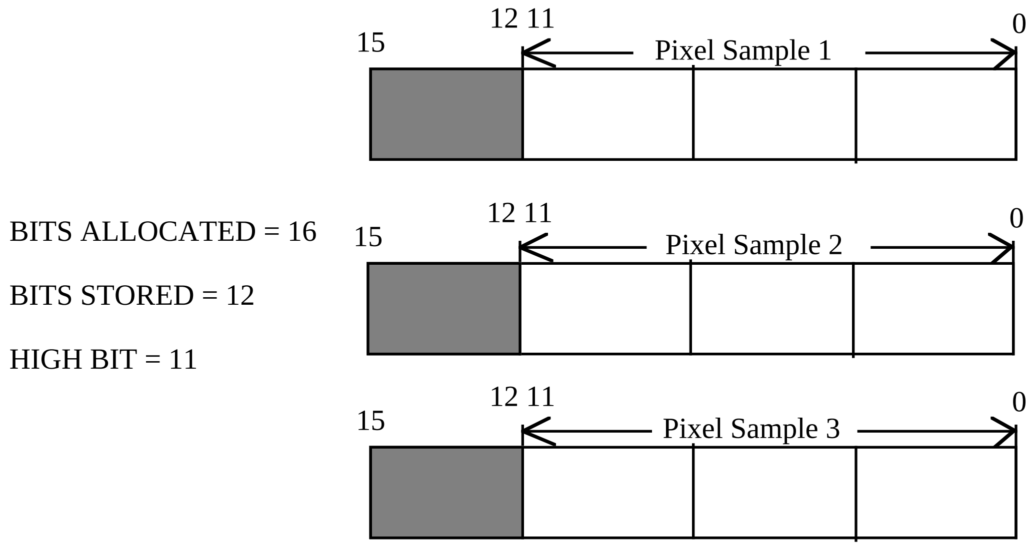


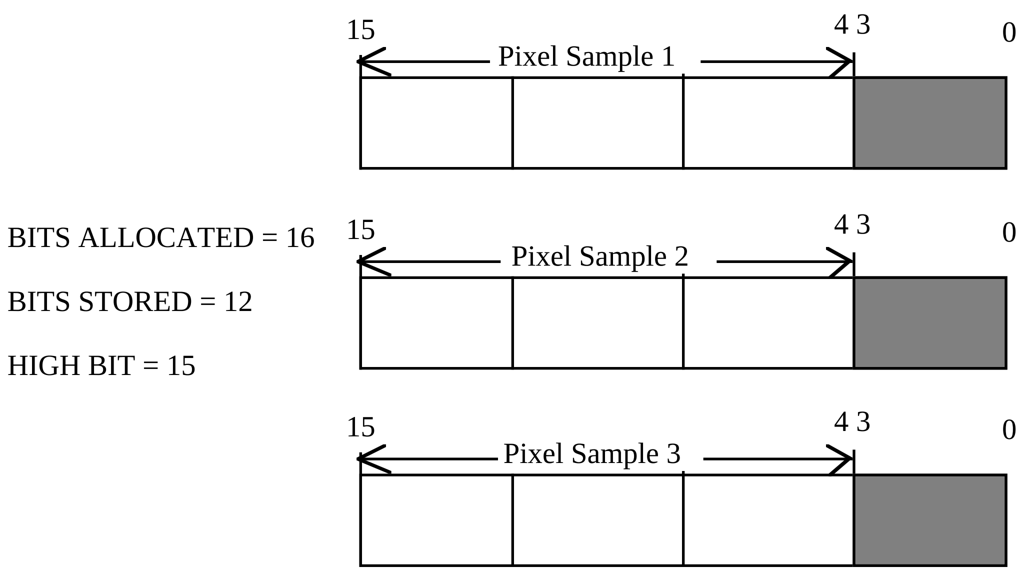

**Figure D-8: Sample Pixel Data Byte Streams for 8-bits Allocated and 8-bits Stored (Explicit VR = OB)**



## D.2 Various Additional Examples of Pixel and Overlay Data Cells

The following examples further illustrate the use of the data elements for Bits Allocated (0028,0100), Bits Stored (0028,0101), and High Bit (0028,0102) in the encoding of Pixel and Overlay Data. All examples show sample Pixel Cells before being encoded in byte streams (and before being affected by a particular Transfer Syntax).

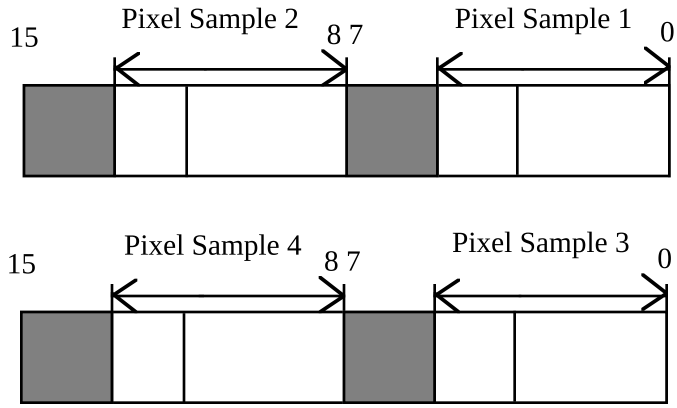


BITS ALLOCATED = 8

BITS STORED = 6

HIGH BIT = 5

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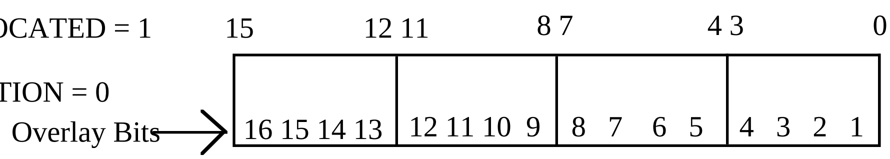
An Example of an encoded Overlay

BITS ALLOCATED = 1

BITS POSITION = 0

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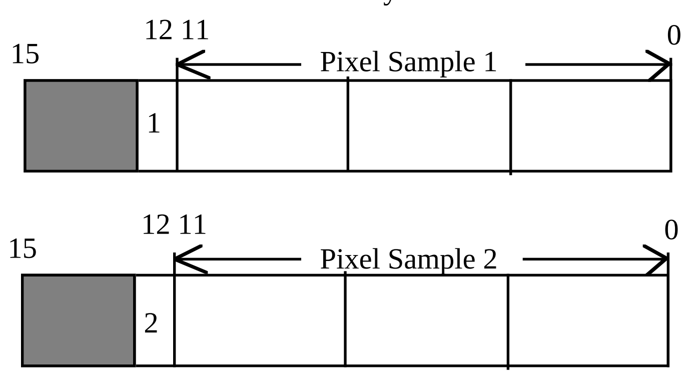
An example of encoded Pixel Data with an embedded Overlay

PIXEL
BITS ALLOCATED = 16
BITS STORED = 12
HIGH BIT = 11

OVERLAY
BITS ALLOCATED = 16
BIT POSITION = 12



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