The USAGE clause

Introduction

Aims

The internal representation of data can be an important consideration for program efficiency. Unfortunately the default representation used by COBOL for numeric data items can negatively impact the speed of computations. A more efficient format for numeric data can be specified by using the USAGE clause.

This unit introduces the concept of internal data representations, it discusses the default representation used in COBOL and outlines how that representation, used for numeric data, might cause inefficiencies.

The syntax of the USAGE clause is given and the various options explained.

The SYNCHRONIZED clause is introduced and a generalized example given.

Objectives

By the end of this unit you should -

1. Know that text is stored in a computer using some encoding sequence.
2. Understand the problems caused by storing numeric data as ASCII digits.
3. Be able to use use the USAGE clause to change the way numeric data is stored in the computer.
4. Know when and how to use the SYNCHRONIZED clause.

Prerequisites

Introduction to COBOL
Declaring data in COBOL
Basic Procedure Division commands
Selection in COBOL
Iteration in COBOL
Introduction to Sequential files
Processing Sequential files

Reading Sequential Files
Edited Pictures

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The USAGE clause

Introduction

Computers store their data in the form of binary digits. Apart from cardinal numbers (positive integers) all other data stored in the computer's memory uses some sort of formatting convention.

Text data, for example, is stored using an encoding sequence like ASCII or EBCDIC. An encoding system is simply a convention which specifies that a particular set of bits is to be used to represent a particular character. For instance, the diagram below shows the bit configuration used to represent an upper case "A" in the ASCII and the EBCDIC encoding sequences.

ASCII
American **S**tandard **C**ode for **I**nformation **I**nterchange

EBCDIC
Extended **B**inary **C**oded **D**ecimal **I**nterchange **C**ode

BCD
Binary **C**oded **D**ecimal

SYSTEM	CHAR	HEX	DEC	8	4	2	1	8	4	2	1
ASCII	"A"	41	65	0	1	0	0	0	0	0	1
EBCDIC	"A"	C1	193	1	1	0	0	0	0	0	1

Numeric data can be held as text digits (ASCII digits) or as pure binary numbers (in the case of cardinal values), or as twos complement binary numbers (in the case of integers), or as decimal numbers (using BCD), or as real numbers (using a real number format such as the IEEE specification for floating point numbers).

The USAGE clause is used to specify how a data item is to be stored in the computer's memory. Every variable declared in a COBOL program has a USAGE clause - even when no explicit clause is specified. When there is no explicit USAGE clause, the default - USAGE IS DISPLAY - is applied.

Problems with USAGE IS DISPLAY

For text items, or for numeric items that are not going to be used in a computation (Account Numbers, Phone Numbers etc.), the default of USAGE IS DISPLAY presents no problems; but for numeric items upon which some calculation is to be performed the default usage is not the most efficient way to store the data.

When numeric items (PIC 9 items) have a usage of DISPLAY, they are stored as ASCII digits (see the ASCII digits 0-9 in the ASCII table below).

Consider the following program fragment. What would happen if computations were done directly on numbers stored in this format?

```
   ? ? ? ? ? ? ? ? ? ? ? ?
WORKING-STORAGE SECTION.
01 Num1    PIC 9 VALUE 4.
01 NUM2    PIC 9 VALUE 1.
01 Num3    PIC 9 VALUE ZERO.
   ? ? ? ? ? ? ? ? ? ? ? ?
```

Program Fragment

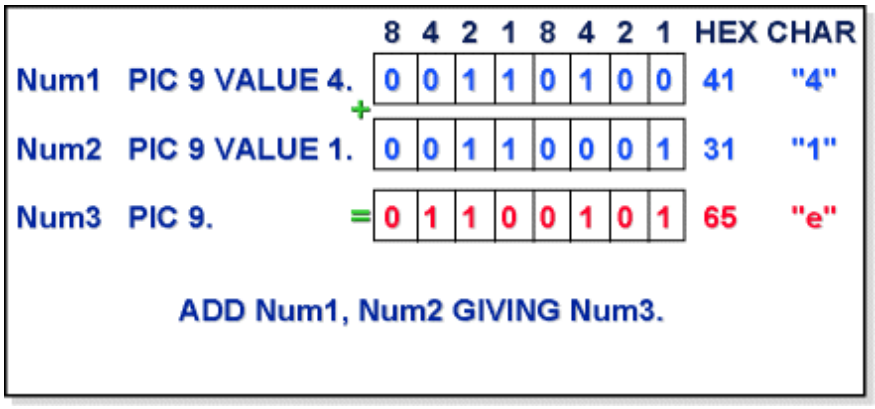
```
PROCEDURE DIVISION.
Begin.
   ? ? ? ? ? ? ? ? ? ? ? ?
   ADD Num1, Num2 GIVING Num3
   ? ? ? ? ? ? ? ? ? ? ? ?
```

Since none of the data items have an explicit USAGE clause they default to - USAGE IS DISPLAY. This means that the values in the variables Num1, Num2 and Num3 are stored as ASCII digits. How does this effect calculations?

If you examine the ASCII table below you will see that the digit 4 (the value in Num1) is encoded as **00110100** and the digit 1 is encoded as **00110001**.

When these these binary numbers are added together the result is **01100101** which is the ASCII code for the lower case letter "e".

The sum **4** + **1** = **e** does not compute.



Tip

When calculations are done with numeric data items whose USAGE IS DISPLAY, the computer has to convert the numeric values to their binary equivalents before the calculation can be done. When the result has been computed the computer has to reconvert it to ASCII digits. Conversion to and from ASCII digits slows down computations.

For this reason, data that is heavily involved in computation is often declared using one of the usages optimized for computation such as USAGE IS COMPUTATIONAL.

The speed of modern computers means that it is hardly worth the effort of using the USAGE clause unless the data item is going to be used in thousands of computations.

For reasons of portability the USAGE clause should never be used in record descriptions. If the file is read on a different make of computer we have no guarantee that the data will be interpreted correctly.

Even on the same make of computer, using the USAGE clause in record descriptions means that the data in the file will probably not be understood by other programming languages or by utility programs or by text editors.

ASCII Table

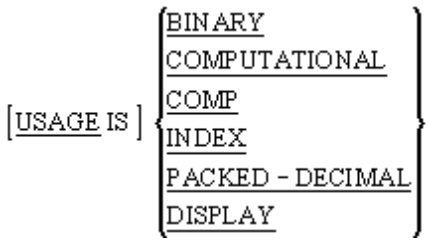
Char	Dec	Hex	Binary
^@ (NUL)	0	00	00000000
^A (SOX)	1	01	00000001
^B (STX)	2	02	00000010
^C (ETX)	3	03	00000011
^D (EOT)	4	04	00000100
^E (ENQ)	5	05	00000101
^F (ACK)	6	06	00000110
^G (BEL)	7	07	00000111
^H (BS)	8	08	00001000

^I (HT)	9	09	00001001
^J (NL)	10	0A	00001010
^K (VT)	11	0B	00001011
^L (NP)	12	0C	00001100
^M (CR)	13	0D	00001101
^N (SO)	14	0E	00001110
^O (SI)	15	0F	00001111
^P (DLE)	16	10	00010000
^Q (DS1)	17	11	00010001
^R (DS2)	18	12	00010010
^S (DS3)	19	13	00010011
^T (DC4)	20	14	00010100
^U (NAK)	21	15	00010101
^V (SYN)	22	16	00010110
^W (ETB)	23	17	00010111
^X (CAN)	24	18	00011000
^Y (EM)	25	19	00011001
^Z (SUB)	26	1A	00011010
^[(ESC)	27	1B	00011011
^\ (FS)	28	1C	00011100
^] (GS)	29	1D	00011101
^^ (RS)	30	1E	00011110
^_ (US)	31	1F	00011111
(SP)	32	20	00100000
!	33	21	00100001
"	34	22	00100010
#	35	23	00100011
$	36	24	00100100
%	37	25	00100101
&	38	26	00100110
'	39	27	00100111
(	40	28	00101000
)	41	29	00101001
*****	42	2A	00101010
+	43	2B	00101011
,	44	2C	00101100
-	45	2D	00101101
.	46	2E	00101110
/	47	2F	00101111
0	48	30	00110000
1	**49**	**31**	**00110001**
2	50	32	00110010
3	51	33	00110011
4	**52**	**34**	**00110100**
5	53	35	00110101
6	54	36	00110110
7	55	37	00110111
8	56	38	00111000
9	57	39	00111001
:	58	3A	00111010
;	59	3B	00111011
<	60	3C	00111100

=	61	3D	00111101
>	62	3E	00111110
?	63	3F	00111111
@	64	40	01000000
A	65	41	01000001
B	66	42	01000010
C	67	43	01000011
D	68	44	01000100
E	69	45	01000101
F	70	46	01000110
G	71	47	01000111
H	72	48	01001000
I	73	49	01001001
J	74	4A	01001010
K	75	4B	01001011
L	76	4C	01001100
M	77	4D	01001101
N	78	4E	01001110
O	79	4F	01001111
P	80	50	01010000
Q	81	51	01010001
R	82	52	01010010
S	83	53	01010011
T	84	54	01010100
U	85	55	01010101
V	86	56	01010110
W	87	57	01010111
X	88	58	01011000
Y	89	59	01011001
Z	90	5A	01011010
[	91	5B	01011011
\	92	5C	01011100
]	93	5D	01011101
^	94	5E	01011110
_	95	5F	01011111
`	96	60	01100000
a	97	61	01100001
b	98	62	01100010
c	99	63	01100011
d	100	64	01100100
e	**101**	**65**	**01100101**
f	102	66	01100110
g	103	67	01100111
h	104	68	01101000
i	105	69	01101001
j	106	6A	01101010
k	107	6B	01101011
l	108	6C	01101100
m	109	6D	01101101
n	110	6E	01101110
o	111	6F	01101111
p	112	70	01110000

q	113	71	01110001
r	114	72	01110010
s	115	73	01110011
t	116	74	01110100
u	117	75	01110101
v	118	76	01110110
w	119	77	01110111
x	120	78	01111000
y	121	79	01111001
z	122	7A	01111010
{	123	7B	01111011
|	124	7C	01111100
}	125	7D	01111101
~	126	7E	01111110
^? (DEL)	127	7F	01111111

USAGE syntax and notes



USAGE notes

- The USAGE clause may be used with any data description entry except those with level numbers of 66 or 88.
- When the USAGE clause is declared for a group item, the usage specified is applied to every item in the group. The group item itself is still treated as an alphanumeric data-item (see example program below).
- USAGE IS COMPUTATIONAL or COMP or BINARY are synonyms of one another.
- The USAGE IS INDEX clause is used to provide an optimized table subscript. When a table is the target of a SEARCH statement it must have an associated index item (see the Search Tutorial).

USAGE rules

1. Any item declared with USAGE IS INDEX can only appear in:
   - A SEARCH or SET statement
   - A relation condition
   - The USING phrase of the PROCEDURE DIVISION
   - The USING phrase of the CALL statement
2. The picture string of a COMP or PACKED-DECIMAL item can contain only the symbols 9, S, V and/or P.
3. The picture clause used for COMP or PACKED-DECIMAL items must be numeric.

Group items are always treated as alphanumeric and this can cause problems when there are subordinate COMP items.

For instance, suppose we had a statement like -
MOVE ZEROS TO GROUP2.
in the program opposite.

On the surface it looks as if this statement is moving the numeric value 0 to NumItem1 and NumItem2 but what is actually moved into these items is the ASCII digit "0".

When an attempt is made to use NumItem1 or NumItem2 in a calculation the program will crash because these data-items contain non-numeric data.

USAGE examples

```
01 Num1 PIC 9(5)V99 USAGE IS COMP.
01 Num2 PIC 99 USAGE IS PACKED-DECIMAL.
01 IdxItem USAGE IS INDEX.

01 GroupItems USAGE IS COMP.
   02 Item1 PIC 999.
   02 Item2 PIC 9(4)V99.
   02 New1 PIC S9(5) COMP SYNC.

01 Group2.
   02 NumItem1 PIC 9(3)V99 USAGE IS COMP.
   02 NumItem2 PIC 99V99   USAGE IS COMP.
```

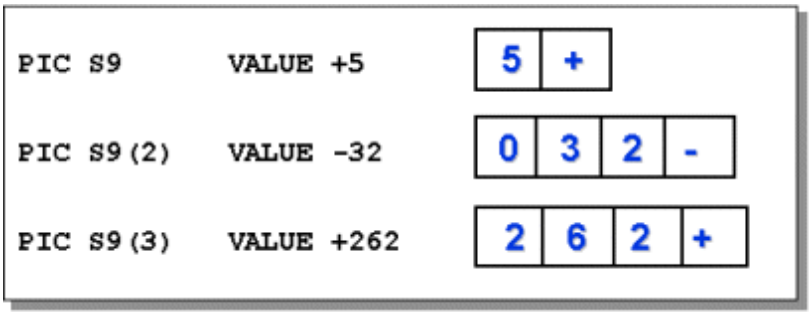
COMP/COMPUTATIONAL/BINARY

COMP items are held in memory as pure binary two's complement numbers. The storage requirements for fields described as COMP are as follows:

Number of Digits	Storage Required.
PIC 9(1 to 4)	1 Word (2 Bytes)
PIC 9(5 to 9)	1 LongWord (4 Bytes)
PIC 9(10 to 18)	1QuadWord (8 Bytes)

PACKED-DECIMAL

Data-items declared as PACKED-DECIMAL are held in binary-coded-decimal (BCD) form.
Instead of representing the value as a single binary number, the binary value of each digit is held in a nibble (half a byte). The sign is held in a separate nibble in the least significant position of the item (see diagram below).



General USAGE notes

The USAGE clause is one of the areas where many vendors have introduced extensions to the COBOL standard. It is not uncommon to see COMP-1, COMP-2, COMP-3, COMP-4, COMP-5 and POINTER usage items in programs written using these extensions.

Even though COMP-1 and COMP-2 are extensions to the COBOL standard, vendors seem to use identical representations for these usages. COMP-1 is usually defined as a single precision, floating point number, adhering to the IEEE specification for such numbers (Real or Float in typed languages) and COMP-2 is

usually defined as a double precision, floating point number (LongReal or Double in typed languages).

The SYNCHRONIZED clause

The SYNCHRONIZED clause is sometimes used with USAGE IS COMP or USAGE IS INDEX items. It is used to optimize speed of processing but it does so at the expense of increased storage requirements.

Many computer memories are organized in such a way that there are natural addressing boundaries - such as word boundaries. If no special action is taken some data items in memory may straddle theses boundaries. This may cause a processing overhead as the CPU may need two fetch cycles to retrieve the data from memory.

The SYNCHRONIZED clause is used to explicitly align COMP and INDEX items along their natural word boundaries. Without the SYNCHRONIZED clause, data-items are aligned on byte boundaries.

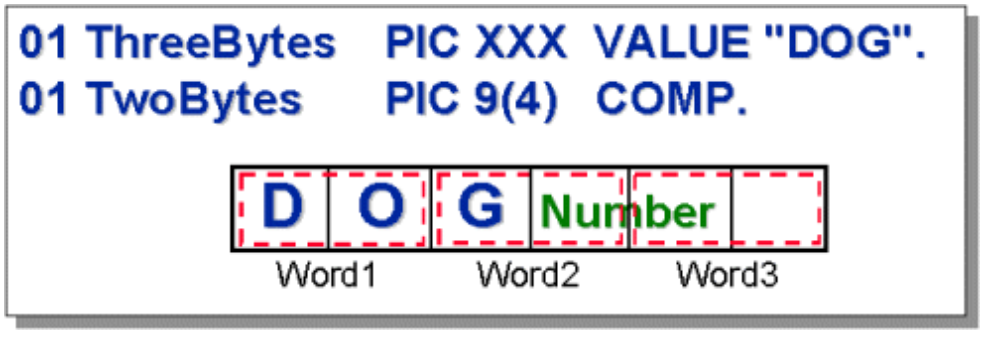
The word SYNC can be used instead of SYNCHRONIZED.

The effect of the synchronized clause is implementation dependant. You will need to read your vendor manual to see how it works on your computer (in some cases it may have no effect).

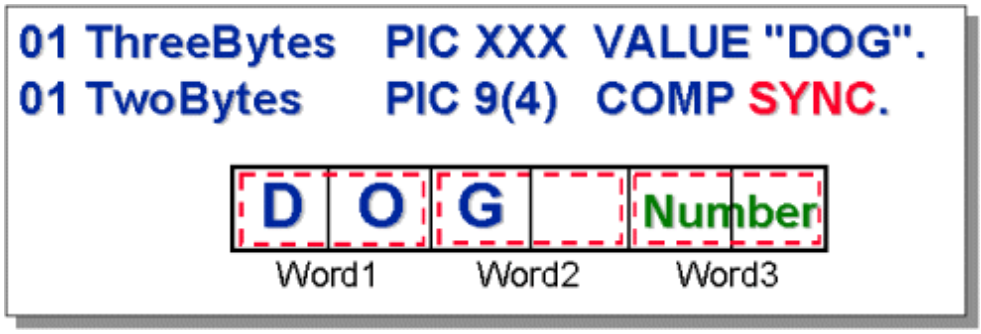
For the purpose of illustrating how the SYNCHRONIZED clause works let us assume that a COBOL program is running on a word-oriented computer where the CPU fetches data from memory a word at a time.

In this program we want to perform a calculation on the number stored in the variable *TwoBytes* (as declared in the diagram below). Because of the way the data items have been declared, the number stored in *TwoBytes* straddles a word boundary.

In order to use the number, the CPU has to execute two fetch cycles - one to get the first part of the number in Word2 and the second to get the second part of the number in Word3. This double fetch slows down calculations.



Now consider the impact of using the SYNCHRONIZED clause. The number in *TwoBytes* is now aligned along the word boundary, so the CPU only has to do one fetch cycle to retrieve the number from memory. This speeds up processing but at the expense of wasting some storage (the second byte of Word2 is no longer used).



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e-mail : CSISwebeditor@ul.ie