

A collection of historical artifacts is arranged on a light-colored surface. In the top left, a portion of a wooden chessboard with a checkered pattern and several chess pieces is visible. Below the chessboard, there are two medals: one with a red ribbon and a circular emblem, and another with a blue ribbon and a circular emblem. To the right of these medals is a large, ornate silver cross-shaped medal with a central emblem. In the bottom left corner, there is a round, vintage-style compass with a white face and black markings. A pair of thin, gold-rimmed glasses with round lenses lies diagonally across the lower right portion of the image, overlapping the compass and the text area.

Computer Organization

Concepts of BCD

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BCD – Binary-Coded Decimal

- ◆ Binary-coded Decimal (BCD) is a binary encodings of decimal numbers where each decimal digit is represented by a fixed number of bits.



BCD – Binary Coded Decimal

- ◆ Three types of representation:
 - Unpacked BCD
 - Packed BCD
 - Densely Packed BCD



Unpacked BCD

- ◆ Given an 8-bit binary, only 1 decimal digit can be represented using unpacked BCD
- ◆ $0 = 0000\ 0000$
- ◆ $1 = 0000\ 0001$
- ◆ $5 = 0000\ 0101$
- ◆ $9 = 0000\ 1001$



Packed BCD

- ◆ Given an 8-bit binary, up to 2 decimal digits can be represented using packed BCD
- ◆ $0 = 0000\ 0000$
- ◆ $1 = 0000\ 0001$
- ◆ $55 = 0101\ 0101$
- ◆ $99 = 1001\ 1001$



Packed BCD

- ◆ The value 1100 (0C hex) is used as positive sign and 1101 (0D hex) is used as negative sign.
- ◆ Based from accounting terms (Credit and Debit)
- ◆ Example:
-125: 0001 0010 0101 1101
+45: 0000 0100 0101 1100



Densely Packed Decimal Encoding

- ◆ Based on 3-digit BCD
- ◆ Originally based on Chen-Ho encoding (1975, Tien Chi Chen & Dr. Irving Ho)
- ◆ Later on improved by Mike Cowlshaw (2002)

Example: 555 = 0101 0101 0101

a	b	c	d	e	f	g	h	i	j	k	m
0	1	0	1	0	1	0	1	0	1	0	1



Densely Packed Decimal Encoding

◆ Compression:

aei	pqr stu v wx y	
000	bcd fgh 0 jk m	all digits are small
001	bcd fgh 1 00 m	right digit is large
010	bcd jkh 1 01 m	middle digit is large
011	bcd 10h 1 11 m	left digit is small*
100	jkd fgh 1 10 m	left digit is large
101	fgd 01h 1 11 m	middle digit is small*
110	jkd 00h 1 11m	right digit is small*
111	00d 11h 1 11 m	all digits are large

* The rest of the digit are large



Densely Packed Decimal Encoding

a	e	i		p	q	r	s	t	u	v	w	x	y
0	0	0		b	c	d	f	g	h	0	j	k	m
0	0	1		b	c	d	f	g	h	1	0	0	m
0	1	0		b	c	d	j	k	h	1	0	1	m
0	1	1		b	c	d	l	0	h	1	1	1	m
1	0	0		j	k	d	f	g	h	1	1	0	m
1	0	1		f	g	d	0	1	h	1	1	1	m
1	1	0		j	k	d	0	0	h	1	1	1	m
1	1	1		0	0	d	l	1	h	1	1	1	m



Densely Packed Decimal Encoding

◆ Example:

a	b	c	d	e	f	g	h	i	j	k	m
---	---	---	---	---	---	---	---	---	---	---	---

Decimal	BCD				Densely packed			
555	0101	0101	0101		101	101	0101	
129	0001	0010	1001		001	010	1001	
183	0001	1000	0011		001	010	1011	
489	0100	1000	1001		100	100	1111	



Densely Packed Decimal Encoding

◆ Example:

a	b	c	d	e	f	g	h	i	j	k	m
---	---	---	---	---	---	---	---	---	---	---	---

Decimal	BCD				Densely packed		
967	1000	0110	0111		110	110	1101
928	1001	0010	1000		010	010	1110
987	1001	1000	0111		111	000	1111
999	1001	1001	1001		001	111	1111



Densely Packed Decimal Encoding

◆ Expansion:

vwxst	abcd efgh ijkm
0....	0pqr 0stu 0wxy
100..	0pqr 0stu 100y
101..	0pqr 100u 0sty
110..	100r 0stu 0pqy
11100	100r 100u 0pqy
11101	100r 0pqu 100y
11110	0pqr 100u 100y
11111	100r 100u 100y