CSARCH Lecture Series: Binary-Coded Decimal (BCD)

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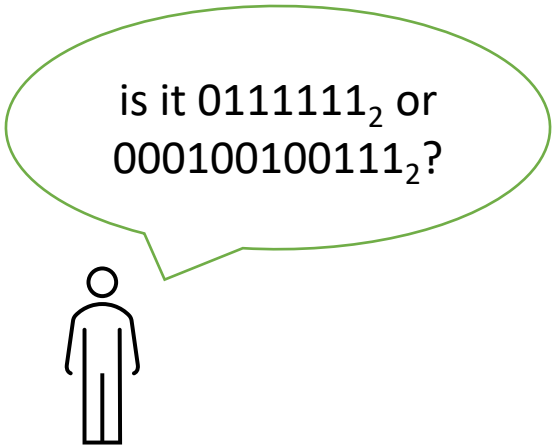
Overview

Reflect on the following question:

- Are there any alternative integer representation for decimal 127?



Overview

- This sub-module introduces the concept of Binary-coded Decimal (BCD)
- The objective is as follows:
  - ✓Describe the process of performing BCD encoding on decimal numbers

Binary-Coded Decimal (BCD)

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

Binary encoding of each decimal digit			
0	0000	8	1000
1	0001	9	1001
2	0010		
3	0011		
4	0100		
5	0101		
6	0110		
7	0111		

Binary-Coded Decimal (BCD)

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

Unpacked BCD

- In unpacked BCD, 1 decimal digit is encoded in 8-bit binary

Decimal	Unpacked BCD	# of bits
7	0000 0111	8
52	00000101 00000010	16
256	00000010 00000101 00000110	24

Packed BCD

- In packed BCD, 1 decimal digit is encoded in 4-bit binary

Decimal	Packed BCD	# of bits
7	0111	4
52	0101 0010	8
256	0010 0101 0110	12

Packed BCD

- Represented in assembly language as 123p or 123_456p
- The value 1100_2 (0xC) is used to denote as positive sign
- The value 1101_2 (0xD) is used to denote negative sign
- Based from accounting terms (Credit and Debit)

Decimal	Packed BCD
-125	0001 0010 0101 1101
+45	0100 0101 1100

Densely Packed BCD

- In Densely packed BCD, 3 decimal digits is encoded in 10-bit binary
- Originally based on Chen-Ho encoding (1975, Tien Chi Chen & Dr. Irving Ho)
- Later, improved by Mike Cowlishaw (2002)

Decimal	Densely packed BCD	# of bits
7	000 000 0 011	10
52	000 101 0 010	10
256	010 101 0 110	10

Densely Packed BCD

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	1	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	1	1	h	1	1	1	m

Densely Packed BCD encoding table

Densely Packed BCD

Example: 489

1.) represent using packed BCD
2.) get the 11th bit (a), 7th bit(e) and the 3rd bit(i)
3.) refer to the table for the equivalent densely packed BCD 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	1	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	1	1	h	1	1	1	m

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

densely packed BCD:	1	0	0	1	0	0	1	1	1	1

Densely Packed BCD

Example: 183

1.) represent using packed BCD
2.) get the 11th bit (a), 7th bit(e) and the 3rd bit(i)
3.) refer to the table for the equivalent densely packed BCD 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	1	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	1	1	h	1	1	1	m

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

densely packed BCD:	0	0	1	0	1	0	1	0	1	1

Try

Decimal	Unpacked BCD	# of bits
2401		
999		

Decimal	Packed BCD	# of bits
2401		
999		

Decimal	Densely Packed BCD	# of bits
2401		
999		

Decimal	Unsigned Integer (minimum # of bits)	# of bits
2401		
999		

Densely Packed BCD

Given: Densely packed BCD

P	Q	R	S	T	U	V	W	X	y
0	0	1	0	1	0	1	0	1	1

packed BCD:

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

Decimal: 183

- Densely Packed BCD 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

To recall …

- What have we learned:
  - ✓Describe the process of performing BCD encoding on decimal numbers