OrCAD Download

- http://www.cadence.com/products/orcad/pages/downloads.aspx
- OrCAD PCB Designer Lite DVD all products.

Tutoring

- Learning Resources Center (LRC)
  - NC 2006
  - 303-556-2802.
  - Tutorialservices@ucdenver.edu
  - www.ucdenver.edu/lrc.
- Where: LWST 830
  - Tuesdays: 1:10 – 2:50 (Michael D)
  - Wednesdays: 1:10 – 2:50 (Rob F)

Chapter 1 cont

Using Positional Notation

$a_n r^n + a_{n-1} r^{n-1} + \cdots + a_2 r^2 + a_1 r^1 + a_0 r^0 .\ a_{-1} r^{-1} + a_{-2} r^{-2} + \cdots + a_{-m} r^{-m}$

Where r is the radix or base.

Ex. 11_x and let x =8

Then $a_1(8^1)+a_0(8^0) = 1(8)+1(1) = 9_{10}$

Let x =2

Let x =10

Using Positional Notation

Ex: 1011_2

Ex: $A2E_{16}$

Ex : 75_8

Ex : 32.14_8

Using Positional Notation Summary

$$a_n r^n + a_{n-1} r^{n-1} + \cdots + a_2 r^2 + a_1 r^1 + a_0 r^0 .\ a_{-1} r^{-1} + a_{-2} r^{-2} + \cdots + a_{-m} r^{-m}$$

Where r is the radix or base.

Convert a number from any base to decimal.

Base conversion

- Decimal to any base.
- Use division
  - Whole numbers
  - Left of the decimal point
- Use multiplication
  - Fractional part of a number

Decimal to Binary Conversion

- Convert 857_{10} to base 2.

	0	r 1	MSB
	) 1	r 1	
	) 3	r 0	
	) 6	r 1	
	) 13	r 0	
	) 26	r 1	
	) 53	r 1	
	) 107	r 0	
	) 214	r 0	
	) 428	r 1	LSB
2	) 857_{10}		

1101011001_2

Check the result

- Use Positional Notation

2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
512	256	128	64	32	16	8	4	2	1
1	1	0	1	0	1	1	0	0	1

$512 + 256 + 64 + 16 + 8 + 1 = 857_{10}$

Octal

```
         0 r 1
   )     1 r 5
   )    13 r 3
   )   107 r 1
8  )   857
```

$857_{10} = 1531_8$

8^3	8^2	8^1	8^0
512	64	8	1
1	5	3	1

And back again

$1 \times 512 + 5 \times 64 + 3 \times 8 + 1 \times 1 = 857_{10}$

Hexadecimal

0 r 3

) 3 r 5

) 53 r 9

16) 857

$857_{10} = 359_8$

16^2	16^1	16^0
256	16	1
3	5	9

And back

$3 \times 256 + 5 \times 16 + 1 \times 9 = 857_{10}$

Example

324_{10} to base 5

Ex 1.4

0.6875_{10} to binary

$.6875 \times 2 = 1.3750 = \boxed{1} + .3750$

$.3750 \times 2 = 0.7500 = \boxed{0} + .7500$

$.7500 \times 2 = 1.5000 = \boxed{1} + .5000$

$.5000 \times 2 = 1.0000 = \boxed{1} + .0000$

$0.6875_{10} = 0.1011_2$

Ex 1.5

- 0.513_{10} to octal

Powers of 2

- Conversion between binary, octal, and hexadecimal made easy.
- Binary to other powers of two
  - Just regroup and convert
- How to regroup
  - Consider the least number of bits it would take to encode the largest symbol of the new base.

Binary-coded Octal

- 3 bits to encode 7_8
- Why?

Binary	Octal
000	0
001	1
010	2
011	3
100	4
101	5
110	6
111	7

Binary to Octal

110110101010_2

$110 \quad 110 \quad 101 \quad 010_2$ ← Binary Coded Octal

$\quad 6 \quad\quad 6 \quad\quad 5 \quad\quad 2$

6652_8

- To convert from Octal to Binary, do the same thing in reverse

Binary to Hexadecimal

How many bits are needed to represent the largest single cypher in hexadecimal?

110110101010_2

$1101 \quad 1010 \quad 1010_2$

D A A

DAA_{16}

Binary	Hexadecimal
0000	0
0001	1
0010	2
0011	3
0100	4
0101	5
0110	6
0111	7
1000	8
1001	9
1010	A
1011	B
1100	C
1101	D
1110	E
1111	F

Octal to Hexadecimal and vice versa

- Almost the same thing.
- Convert to Binary
- Then regroup as necessary.

Example

237_8 to Hex

Convert to binary

2 3 7

010 011 111

Regroup

0 1001 1111

9 F

Complements of Numbers

- Two basic types
  - Diminished radix complement
    - Defined as: $(r^n - 1) - N$; given a number N in base r having n digits
  - Radix complement
    - Defined as $r^n - N$; given a number $N \neq 0$ in base r having n digits and 0 if $N = 0$.

Diminished Radix Complement

- AKA R-1's complement

$$(r^n - 1) - N$$

Ex. 9's complement of 546700

Ex. 9's complement of 012398

1’s complement

- Binary numbers
  - r = 2
  - r-1 = 1
  - $2^n - 1$ is a binary number represented by n 1’s
- Formed by “flipping the bits”
  - Only 2 cyphers in binary 0 or 1.
  - Change each bit to the opposite possibility.
  - 1’s to 0’s and 0’s to 1’s

(r-1)'s complement

- Octal
  - Subtract each digit from 7

- Hex
  - Subtract each digit from F (15_{10})

Radix Complement

- Defined as $r^n - N$; given a number $N \neq 0$ in base r having n digits and 0 if $N = 0$.
- Is obtained by adding 1 to the (r-1)'s complement

Complements Summary

- The complement of the complement returns the original number
- If there is a radix point
  - Calculate the complement as if the radix point was not there.
- Used in computers to perform subtraction.

Unsigned math

- Procedure for subtraction of 2 ***unsigned*** numbers.
  1. Add M to the r’s complement of N
  2. If $M \geq N$, an end carry is produced which can be discarded.
     - The result is positive as indicated by the carry-out
  3. If $M \leq N$ the result is negative and in r’s complement form

Signed Numbers

- There are three basic ways to designate the sign of a number.
  - Sign and magnitude
  - Radix complement
  - Radix-1'scomplement

Sign and Magnitude

- What is taught in school.
- A value with a sign in front of it
- How does it work in Binary?
- Pretty much the same way as Decimal
- By convention a sign bit is used.
  - 0 → positive
  - 1 → negative

Sign and Magnitude

- Addition of signed numbers
  - May be either positive or negative
  - positive + positive = ? positive
  - negative + negative = ? negative
  - positive + negative = ? it depends

Rules of Addition

- Binary addition

$0_2 + 0_2 = 0_2$

$0_2 + 1_2 = 1_2 + 0_2 = 1_2$

$1_2 + 1_2 = 10_2$

Notice the carry into the next significant bit.

Sign and Magnitude

- Example

$$0100\ 1111_2$$

$$+\ 0010\ 0011_2$$

Sign bit

Carry								
	0	1	0	0	1	1	1	1
	0	0	1	0	0	0	1	1
Result								

Sign and Magnitude

- Example

$$0100\ 1111_2 \qquad\qquad 79$$

$$+\ 0010\ 0011_2 \qquad\qquad \underline{+\ 35}$$

Carry	0	0	0	1	1	1	1	
	0	1	0	0	1	1	1	1
	0	0	1	0	0	0	1	1
Result	0	1	1	1	0	0	1	0

$$=\ 0111\ 0010_2 \qquad\qquad 114$$

Sign and Magnitude

- Another example

$$\ 1\ 1111_2$$

$$+\ 1\ 1011_2$$

Carry					
	1	1	1	1	1
	1	1	0	1	1
Result					

= ?

Sign and Magnitude

- Another example

$1\ 1111_2$ -15

$+\ 1\ 1011_2$ $\underline{+\ (-11)}$

Carry	1	1	1	1	
	1	1	1	1	1
	1	1	0	1	1
Result	1	1	0	1	0

$=\ 1\ 1010_2$ - 26

Sign and Magnitude

- And another example ….

$$0100\ 1111_2$$

$$+\ 0110\ 0011_2$$

Carry								
	0	1	0	0	1	1	1	1
	0	1	1	0	0	0	1	1
Result								

= ?

Sign and Magnitude

- Another example ....

$$0100\ 1111_2 \qquad\qquad 79$$

$$+\ 0110\ 0011_2 \qquad\qquad \underline{+\ 99}$$

$$-50$$

Carry	1	0	0	1	1	1	1	
	0	1	0	0	1	1	1	1
	0	1	1	0	0	0	1	1
Result	1	0	1	1	0	0	1	0

$= \quad 1011\ 0010_2$

What Happened ???

Should be 178

Sign and Magnitude

- The error is due to overflow
- Caused by a carry out of the MSB of the number to the sign bit.
- Signed magnitude works but….
  - Suffers from limitations
  - 2 zeros (positive and negative)
  - Adding positive and negative numbers doesn’t always work.

Complement Arithmetic

- What is a complement?
  - Webster's

    a : something that fills up, completes, or makes perfect.

    b : the quantity, number, or assortment required to make a thing complete
- A way to represent negative numbers.
  - Makes use of the fact that adding a negative number is the same as subtracting a number.
- Two types
  - R-1's Complement (diminished radix complement)
  - R's Complement (radix complement)

R-1's Complement

- $\overline{N} = (r^n - 1) - N$
  - where n is the number of bits per word
  - N is a positive integer
  - $\overline{N}$ is –N in 1's complement notation
  - r is the base
- Word Range:

  $-(r^{n-1}-1)$ to $r^{n-1}-1$

Some Terminology

- Augend, addend, sum

1	Carry
15	Augend
+ 7	Addend
22	Sum

- Minuend, subtrahend, difference

1 15	Carry
~~25~~	Minuend
- 8	Subtrahend
17	Difference

1’s Complement

- Never complement the minuend in a problem.
- Add the 1’s complement of the original subtrahend to the original minuend.
  - This will have the same effect as subtracting the original number.
- If there is a carry-out, end around carry and add back in.

How to use 1's complement.

- Step 1: 1's complement the subtrahend.
- Step 2: Do the math.
- Step 3: If there is a carry out, end around carry and add it back in.
- Note: If there is no carry the answer is in 1's complement form.
  - What does this mean?

Examples

X = 1000   Y = 0101

X – Y

Y - X

Things to notice

- Any negative number will have a leading 1.
- There are 2 representations for 0, 00000 and 11111.
  - Not really a problem, but still have to check for it.
- There is a solution.

r’s Complemet

- $\overline{N} = (r^n) - N$
  - where n is the number of bits per word
  - N is a positive integer
  - $\overline{N}$ is –N in 1’s complement notation
  - r is the base
- Word Range is:

  $-(r^{n-1})$ to $r^{n-1}-1$

How to use 2’s Complement

- Step 1: 2’s complement the subtrahend.
- Step 2: Perform the addition
- Step 3: if there is a carry out, ignore it.

Examples

X = 0111 Y = 0101

X – Y

Y - X