Computer Organization & Architecture Cheatsheets

① Base conversions → division - remainder → bigger exponent to smaller exponent

a) 588_{10} = 210210 $_3$

A)

$$
\begin{array}{r|l l}
3 & 588 & 0 \\
3 & 196 & 1 \\
3 & 65 & 2 \\
3 & 21 & 0 \\
3 & 7 & 1 \\
3 & 2 & 2 \\
 & 0 &
\end{array}
$$

210210_3

b) 2254_{10} = 33004 $_5$

B)

$$
\begin{array}{r|l l}
5 & 2254 & 4 \\
5 & 450 & 0 \\
5 & 90 & 0 \\
5 & 18 & 3 \\
5 & 3 & 3 \\
 & 0 &
\end{array}
$$

33004_5

② Base conversions → division - remainder → smaller exponent to bigger exponent

a) 20012_3 = 167 $_{10}$

A) $20012_3 = X_{10}$

$2\times3^4 + 0\times3^3 + 0\times3^2 + 1\times3^1 + 2\times3^0$

$= 2\times81 + 0\times27 + 0\times9 + 1\times3 + 2\times1$

$= 162 + 0 + 0 + 3 + 2$

$= 167_{10}$

b) 4103_5 = 528 $_{10}$

B) $4103_5 = X_{10}$

$4\times5^3 + 1\times5^2 + 0\times5^1 + 3\times5^0$

$= 4\times125 + 1\times25 + 0\times5 + 3\times1$

$= 500 + 25 + 0 + 3$

$= 528_{10}$

$$
\begin{array}{r}
125 \\
\times\ 4 \\
\hline
500
\end{array}
$$

③ decimal fractions to binary

a) 25.84375

· the decimal part

$$
\begin{array}{r|l}
2 & 25 \quad 1 \\
2 & 12 \quad 0 \\
2 & 6 \quad 0 \\
2 & 3 \quad 1 \\
2 & 1 \quad 1 \\
 & 0
\end{array}
$$

bottom to top 11001

· the fraction part

$0.84375 \times 2 = 1.68750$ integer is 1

$0.68750 \times 2 = 1.37500$ integer is 1

$0.37500 \times 2 = 0.75000$ integer is 0

$0.75000 \times 2 = 1.50000$ integer is 1

$0.50000 \times 2 = 1.00000$ integer is 1

$0.00000 \times 2 = 0.00000$ integer is 0

top to bottom 110110

$\boxed{11001.110110}$

d) 84.874023

· the decimal part

$$
\begin{array}{r|l}
2 & 84 \quad 0 \\
2 & 42 \quad 0 \\
2 & 21 \quad 1 \\
2 & 10 \quad 0 \\
2 & 5 \quad 1 \\
2 & 2 \quad 0 \\
2 & 1 \quad 1 \\
 & 0
\end{array}
$$

from bottom to top 1010100

· - on part

$0.874023 \times 2 = 1.748046$ integer is 1

$0.748046 \times 2 = 1.496092$ integer is 1

$0.496092 \times 2 = 0.992184$ integer is 0

$0.992184 \times 2 = 1.984368$ integer is 1

$0.984368 \times 2 = 1.968736$ integer is 1

$0.968736 \times 2 = 1.937472$ integer is 1

from top to bottom 110111

$\boxed{1010100.110111}$

④ convert binary fractions to decimal

a) 10111.1101

10a) 10111.1101

1) write the numbers spaced out
2) write 2^x exponents on top of number
3) multiply top with bottom for each column, add the results of all columns
4) add all numbers

$$
\begin{array}{ccccccccc}
2^4 & 2^3 & 2^2 & 2^1 & 2^0 & 2^{-1} & 2^{-2} & 2^{-3} & 2^{-4} \\
\times 1 & \times 0 & \times 1 & \times 1 & \times 1 & .\times 1 & \times 1 & \times 0 & \times 1
\end{array}
$$

$2^4 + 0 + 2^2 + 2^1 + 1 + \frac{1}{2} + \frac{1}{2^2} + 0 + \frac{1}{2^4}$

$= 16 + 0 + 4 + 2 + 1 + 0.5 + 0.25 + 0.0625$

$= 23.8125$

d) 11000010.111

10d) 11000010.111

$$
\begin{array}{ccccccccccc}
2^7 & 2^6 & 2^5 & 2^4 & 2^3 & 2^2 & 2^1 & 2^0 & 2^{-1} & 2^{-2} & 2^{-3} \\
\times 1 & \times 1 & \times 0 & \times 0 & \times 0 & \times 0 & \times 1 & \times 0 & .\times 1 & \times 1 & \times 1
\end{array}
$$

$2^7 + 2^6 + 0 + 0 + 0 + 0 + 2 + 0 + \frac{1}{2} + \frac{1}{2^2} + \frac{1}{2^3}$

$= 194.875$

⑤ Hexadecimal letters to binary

DEAD BEEF$_{16}$ using the chart

D = 1101
E = 1110
A = 1010
D = 1101
B = 1011
E = 1110
E = 1110
F = 1111

$(DEADBEEF)_{16} = (1101\ 1110\ 1010\ 1101\ 1011\ 1110\ 1110\ 1111)_2$

⑥ decimal to signed-magnitude, one's complement, two's complement representation

a) 60
b) -60
c) 20
d) -20

	signed-magnitude	one's complement	two's complement
60	00111100	00111100	00111100
-60	10111100	11000011	11000100
20	00010100	00010100	00010100
-20	10010100	11101011	11101100

17a) 60

positive number

2	60	0
2	30	0
2	15	1
2	7	1
2	3	1
2	1	1
	0	

bottom to top 111100

so, 60 in binary is 111100

so, 60 in normal binary is 00111100 ← flip backwards???

one's complement : 00111100

two's complement : 00111100

signed-magnitude : 00111100

17b) -60

negative number

2	60	0
2	30	0
2	15	1
2	7	1
2	3	1
2	1	1
	0	

bottom to top 111100

so, 60 in binary is 111100

so, 60 in normal binary is 00111100 ← flip backwards???

signed-magnitude : set 1 as the farthest-left bit, since its a negative number

00111100 becomes 10111100

one's complement : flip 1's to 0's and 0's to 1's

00111100 flips to 11000011

two's complement : add 1 to the above results

11000011 + 1 = 11000100

$$\begin{array}{r} 11000011 \\ +\quad 1 \\ \hline 11000100 \end{array}$$

17c) 20

positive number

2	20	0
2	10	0
2	5	1
2	2	0
2	1	1
	0	

bottom to top 10100

so, 20 in binary is 10100

so, 20 in normal binary is 00101 ← flip backwards???

one's complement : 00010100

two's complement : 00010100

signed-magnitude : 00010100

17D) -20

negative number

2	20	0
2	10	0
2	5	1
2	2	0
2	1	1
	0	

bottom to top 10100

so, 20 in binary is 10100

so, 20 in normal binary is 00010100 ← flip backwards???

signed-magnitude : set 1 as the farthest-left bit, since its a negative number

00010100 becomes 10010100

one's complement : flip 1's to 0's and 0's to 1's

00010100 becomes 11101011

two's complement : add 1 to the above results

11101011 + 1 = 11101100

$$\begin{array}{r} 11101011 \\ +\quad 1 \\ \hline 11101100 \end{array}$$

22. What decimal value does the 8-bit binary number 10110100 have if:

a) it is interpreted as an unsigned number? 180
b) it is on a computer using signed-magnitude representation? -52
c) it is on a computer using one's complement representation? -75
d) it is on a computer using two's complement representation? -76
e) it is on a computer using excess-127 representation? 53

22a) 10110100

$= 1\times2^7 + 0\times2^6 + 1\times2^5 + 1\times2^4 + 0\times2^3 + 1\times2^2 + 0\times2^1 + 0\times2^0$

$= 2^7 + 0 + 2^5 + 2^4 + 0 + 2^2 + 0 + 0$

$= 180$

22b) 10110100

farthest-left bit is 1, so the number is negative

convert the rest of the number to decimal:

0110100

$= 0\times2^6 + 1\times2^5 + 1\times2^4 + 0\times2^3 + 1\times2^2 + 0\times2^1 + 0\times2^0$

$= 0 + 2^5 + 2^4 + 0 + 2^2 + 0 + 0$

$= 52$

So, 10110100 from signed-magnitude to decimal is -52

22c) 10110100

farthest-left bit is 1, so the number is negative

1. flip all bits, 1's to 0's, 0's to 1's, 10110100 becomes 01001011
2. convert result to decimal 1001011

$= 1\times2^6 + 0\times2^5 + 0\times2^4 + 1\times2^3 + 0\times2^2 + 1\times2^1 + 1\times2^0$

$= 2^6 + 0 + 0 + 2^3 + 0 + 2^1 + 1$

$= 75$

Answer: -75

22d) 10110100

farthest-left bit is 1, so the number is negative

1. flip all bits, 1's to 0's, 0's to 1's, 10110100 becomes 01001011
2. Add 1 to the above result: 01001011 + 1 = 1001100

$$\begin{array}{r} 01001011 \\ +\quad\quad 1 \\ \hline 1001100 \end{array}$$

3. convert result to decimal 1001100

$= 1\times2^6 + 0\times2^5 + 0\times2^4 + 1\times2^3 + 1\times2^2 + 0\times2^1 + 0\times2^0$

$= 2^6 + 0 + 0 + 2^3 + 2^2 + 0 + 0$

$= 76$

Answer = -76

Note: each shift to the left multiplies the number by 2
each shift to the right divides the number by 2

44. Using arithmetic shifting, perform the following:

a) double the value 00010101_2 A) shift 1 bit to the left and add 1 zero to the farthest-right: 00010101 → 00101010_2
b) quadruple the value 01110111_2 B) shift 2 bits to the left and add 2 zero to the farthest-right: 01110111 → 11011100
c) divide the value 11001010_2 in half C) shift 1 bit to the right and preserve the sign: 11100101

52. Show how each of the following floating-point values would be stored using IEEE-754 double precision (be sure to indicate the sign bit, the exponent, and the significand fields):

a) 12.5
b) −1.5
c) 0.75
d) 26.625

⊛ values to sign bit, exponent, significant fields

52a) 12.5

- $12.5 = 1100.1 = 1.1001 \times 2^3$
- exponent field (bias + exponent) = 127 + 3 = 130
- convert 130 to binary 130 = 10000010
- positive number, so sign bit = 0

sign	exponent	mantissa
0	10000010	10010000 - - - - - 0

52b) -1.5

- $1.5 = 1.1 = 1.1 \times 2^0$
- exponent field (bias + exponent) = 127 + 0 = 127
- convert 127 to binary 127 = 01111111
- negative number, so sign-bit = 1

sign	exponent	mantissa
1	01111111	10000 - - - - - 0

52c) 0.75

- $0.75 = 0.11 = 1.1 \times 2^{-1}$
- exponent field (bias + exponent) = 127 − 1 = 126
- convert 126 to binary 126 = 01111110
- positive number, so sign bit = 0

sign	exponent	mantissa
0	01111110	10000 - - - - - 0

52d) 26.625

- $26.625 = 11010 = 1.1010 \times 2^4$
- exponent field (bias + exponent) = 127 + 4 = 131
- convert 131 in binary 131 = 10000011
- positive number, so sign bit = 0

sign	exponent	mantissa
0	10000011	1010000 - - - - - 0

⊛ Decode ASCII messages : 1001010 1001111 1001000 1001110 0100000 1000100 1001111 1000101

he following binary ASCII code: 1001010 1101111 1101000

$B_4B_3B_2B_1$ \ $B_7B_6B_5$	000	001	010	011	100	101	110	111
0000	NULL	DLE	SP	0	@	P	`	p
0001	SOH	DC1	!	1	A	Q	a	q
0010	STX	DC2	"	2	B	R	b	r
0011	ETX	DC3	#	3	C	S	c	s
0100	EOT	DC4	$	4	D	T	d	t
0101	ENQ	NAK	%	5	E	U	e	u
0110	ACK	SYN	&	6	F	V	f	v
0111	BEL	ETB	'	7	G	W	g	w
1000	BS	CAN	(	8	H	X	h	x
1001	HT	EM	)	9	I	Y	i	y
1010	LF	SUB	*	:	J	Z	j	z
1011	VT	ESC	+	;	K	[	k	{
1100	FF	FS	,	<	L	\	l	|
1101	CR	GS	-	=	M	]	m	}
1110	SO	RS	.	>	N	^	n	~
1111	SI	US	/	?	O	_	o	D

John Doe

(*) unsigned hexadecimal addition:

```
    1 A=13 F 4
 +  3  3   0 4
 -------------
    4  D   F 8
```

```
    3 D E 7
 +  D 4 9 6
 -----------
   11 2 7 D=13
```

E=14
+9
23

16|23 7
16|1 1
0

17_{16}

16|18 2
16|1 1
0

12_{16}

16|17 1
16|1 1
0

11_{16}

Decimal	4-Bit Binary	Hexadecimal
0	0000	0
1	0001	1
2	0010	2
3	0011	3
4	0100	4
5	0101	5
6	0110	6
7	0111	7
8	1000	8
9	1001	9
10	1010	A
11	1011	B
12	1100	C
13	1101	D
14	1110	E
15	1111	F

(*) unsigned hexadecimal subtraction:

base = 16
borrow = 16

```
   7(6)  B +16 = 27   6
 - 6     C = 12       5
 ----------------------
   0     F            1
```

```
   F(14)  9(8) +16 = 24   2(18)  8 +16 = 24
 - 3      9               5 (18-5=13=D)  D (24-11=11=B)
 -----------------------------------------
   B      F               D      B
```

46. Draw the combinational circuit that directly implements the following Boolean expression:

F(x,y,z) = x + xy + y'z