Data Representation & Number Systems

Base-X Conversion

Integers (repeated ÷ by 2)

2	x
2	y R 1
2	z R 0
	⋮
2	1 R 0
	0 R 1

LSB ↑ MSB

Fractions (repeated ×1 by 2)

	Carry
2(0.abc) = 0.xyz	0
2(0.xyz) = 1.def	1
2(0.def) = 1.hjk	1
⋮	
2(0.5) = 1.00	1

MSB ↓ LSB

Data

bit (b): 0, 1

byte (B): 8b

word: 32b / 4B

N bits: 2^N values

M values: $\lceil \log_2 M \rceil$ bits

Binary → Octal / Hexadecimal

(from right ←)

$(x)_8$: 010 | 000 | 011 | 000 = 20140_8

$(x)_{16}$: 010 | 0000 | 0110 | 0000 = 2060_{16}

Integers

Rep	+ → −	Range	Zeros
S-M.	Flip MSB	$-(2^{n-1}-1)$, $2^{n-1}-1$	+/−
1s	Flip All	$-(2^{n-1}-1)$, $2^{n-1}-1$	+/−
2s	← till first 1, flip rest	-2^{n-1}, $2^{n-1}-1$	+

Overflow $A+B$: $(MSB_A == MSB_B)\ != MSB_{A+B}$

1s : Add carry to LSB_{A+B}, check for overflow

2s : Ignore carry, check for overflow

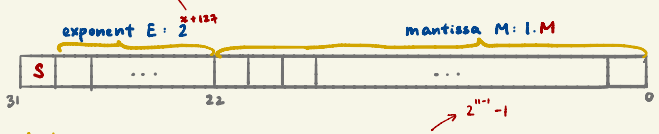
IEEE-754

$(S) \times (1.M) \times 2^{E-127}$

$2^{8-1}-1$

exponent E : 2^{x+127}

mantissa M : 1.M



$2^{11-1}-1$

64b : M : 0 to 51, E : 52 to 62, Bias : 1023

C Programming

Primitives

		Range	
Type	Size (b)	Unsigned	Signed
char	8	[0, 255]	[-128, 127]
short	8	[0, 255]	[-128, 127]
int	32	$[0, 2^{31}-1]$	$[-2^{31}, 2^{31}-1]$
long	64	$[0, 2^{64}-1]$	$[-2^{63}, 2^{63}-1]$
float	32	–	–
double	64	–	–

Casting

(cast_type) var

char → int → float → double

no loss →

← loss

Auto-promotion / demotion

```
2 / 5 == 0;
2.0 / 5 == 0.4;

int x = 0.4; // → 0
double y = 5; // → 5.0
```

Pointers

```
int x = 5;
int *y = &x;
print(x);   // 5
print(*y);  // 5
print(&x);  // addr(x)
print(y);   // addr(x)
```

Pointer declaration ← `int *y = &x;`

Dereference ← `print(*y);`

Go to address of ← `print(&x);`

Parameter-Passing

By-value : primitives (int, char, ...), structures

By-address : arrays (strings) → [ ], " "

scanf

```
int x;
scanf("%d", &x); // address
```

Arrays

```
int arr[5] = {1, 2, 3, 4, 5}
```

i	Value	Address
0	1	0x100
1	2	0x104
2	3	0x108
3	4	0x112
4	5	0x116

```
*(arr+2) == arr[2];
arr+2 == &(arr[2]);
arr == &arr[0];
```

Can be passed as parameter, but not as return type

Strings

"Hello" : `char str[6] = "Hello";` (string terminator)

// {'H', 'e', 'l', 'l', 'o', '\0'}

Structures

Defining a new structure

```
struct struct_name {
    datatype var1;  // one or more fields
    [datatype var2; ]
}
```

Ways to instantiate

```
struct_name str1 = {1};
struct_name str2; str2.var1 = 1;   // ==
```

Ways to reference field

```
struct_name *p = &str1; // pointer of struct_name
(*p).var = 1;
p->var = 1;   // ==
```

MIPS

Key Pitfalls

Load 32b immediate

```
lui $s0, immd[32:16]
ori $s0, immd[15:0]
```

Branch-equal immediate

Immd no. of instructions:
AFTER next instruction

Immd size: 16b → $2^{16}-1$
∴ 2^{16} instructions from beq/bne

J-format immediate

Immd: 26b 'address'

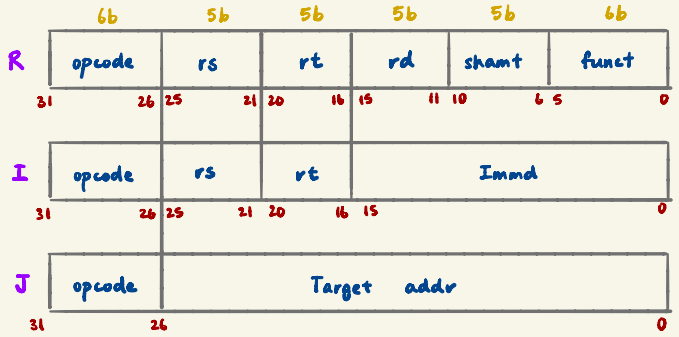
Word-aligned:
- 2 LSB disregarded
- 4 MSB disregarded

∴ Immd: Addr[27:2]

Branching

HLL code				if (x < y) { next; } branch;			if (x ≤ y) { next; } branch;			if (x > y) { next; } branch;			if (x ≥ y) { next; } branch;			if (x == y) { next; } branch;			if (x != y) { next; } branch;		
Possible x and y				x < y	x = y	x > y	x < y	x = y	x > y	x < y	x = y	x > y	x < y	x = y	x > y	x < y	x = y	x > y	x < y	x = y	x > y
Truth values for above				TRUE	FALSE	FALSE	TRUE	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE	TRUE	TRUE	FALSE	TRUE	FALSE	TRUE	FALSE	TRUE
slt	j	x	y	1	0	0	1	0	0	1	0	0	1	0	0						
slt	k	y	x	0	0	1	0	0	1	0	0	1	0	0	1						
beq	j	0	branch	Next	Branch	Branch	Next	Branch	Branch	Next	Branch	Branch	Next	Branch	Branch						
bne	j	0	branch	Branch	Next	Next	Branch	Next	Next	Branch	Next	Next	Branch	Next	Next						
beq	k	0	branch	Branch	Branch	Next	Branch	Branch	Next	Branch	Branch	Next	Branch	Branch	Next						
bne	k	0	branch	Next	Next	Branch	Next	Next	Branch	Next	Next	Branch	Next	Next	Branch						
beq	x	y	branch													Next	Branch	Next	Next	Branch	Next
bne	x	y	branch													Branch	Next	Branch	Branch	Next	Branch

Encoding



Processors

Control Signals

	EX				MEM			WB	
	RegDst	ALUSrc	ALUOp		Mem Read	Mem Write	Branch	MemTo Reg	Reg Write
			op1	op0					
R-type	1	0	1	0	0	0	0	0	1
lw	0	1	0	0	1	0	0	1	1
sw	X	1	0	0	0	1	0	X	0
beq	X	0	0	1	0	0	1	X	0

ALU Control

ALUcontrol	Function
0000	AND
0001	OR
0010	add
0110	subtract
0111	slt
1100	NOR