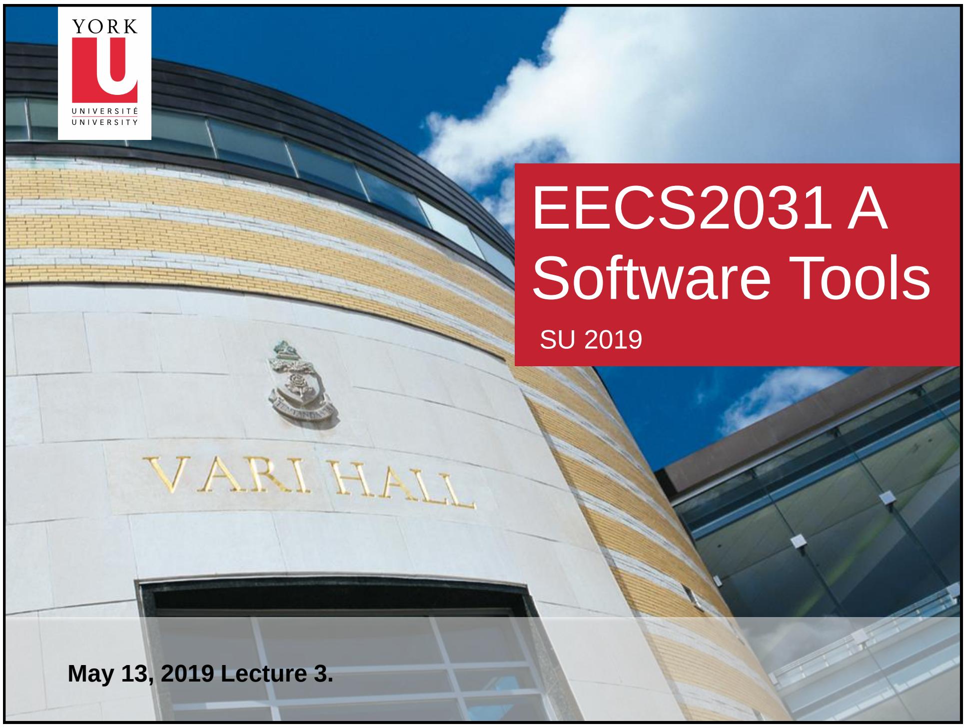

1

Statements

- Program to execute
  - Ended with a ;
- Expression statement (ch2)
  - `i+1;   i++;   x = 4;`
- Function call statement (ch4)
  - `printf("the result is %d");`
- Control flow statement (ch3)
  - `if else, for(), while,  do while, switch`

Same in Java

2

2

Summary and future work

- Type, operators and expressions (Chapter 2) :
  - Types and sizes
    - Basic types, their sizes and constant values (literals)
      - ✓ char: x > 'a' && x < 'z'; x > '0' && x < '9'
      - ✓ int: 122, 0122, 0x12F convert between Decimal, Bin, Oct, Hex
    - Arrays (one dimension) and strings (Ch1.6,1.9)
      - ✓ "hello" has size 6 byte | H | e | l | l | o | \0 |
  - Expressions
    - Basic operators (arithmetic, relational and logical)
      - ✓ y=x++; y=++x;
      - ✓ if (x = 2)
    - Type conversion and promotion
    - Other operators (bitwise, bit shifting , compound assignment, conditional)
      - ✓ Bit: |, &, ~. ^, << >>
      - ✓ Compound: x += 10; x >>= 10; x += y + 3
    - Precedence of operators
- Functions and Program Structure (Chapter 4)

Last week

today

3

3

Expression

- Formed by combining **operands** (variable, constants and function calls) using **operators** (`+ - * % > < == !=`)
- Has return values -- always
  - `x+1`
  - `i < 20` false: 0 true: 1 `printf("%d", i<20);`
  - `sum (i+j)`
  - `x = 5` `= is an operator in C (and Java)! Return value 5`
  - `x = k + sum(i,j)` `printf("%d", x=5);`

"whenever a value is needed, any expression of the same type will do"

- `printf("sum is %d\n", i*y+2)`
- `printf("sum is %d\n", sum(i+j))`

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4

Text book:
4 basic types: char, int, float, double

3 qualifiers: short, long, unsigned

C Types and sizes

- Variables and values have types
- There are two basic types in ANSI-C: integer, and floating point

  - **Integer type**
    - **char** - **character**, single byte (8 bits)
    - **short (int)** - **short integer**, 1 or 2 bytes (8 or 16 bits)
    - **int** - **integer**, usually 2 or 4 bytes (16 or 32 bits)
    - **long (int)** - **long** integer, usually 4 or 8 bytes (32 or 64 bits)
  - **Floating point**
    - **float** - single-precision, usually 4 bytes (32 bits)
    - **double** - double-precision, usually 8 bytes (64 bits)
    - **long double** - extended-precision

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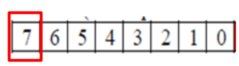
Qualifiers (modifiers) for integer type

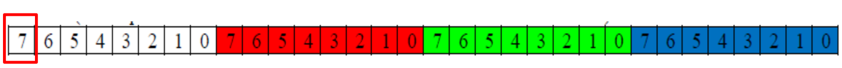
- signed, unsigned qualifiers can be applied to integer types
  - Signed: default. Left most bit signifies sign 0: positive 1: negative
  - Unsigned: positive. Left most bit contributes to magnitude




```
▪ (signed) char
▪ (signed) int
▪ (signed) short int
▪ (signed) long  int

▪ unsigned char
▪ unsigned int
▪ unsigned short int
▪ unsigned long  int
```

Java: no direct support for unsigned int. Always signed



`(signed) int`	$-2^{31} \sim 2^{31}-1$	-2145483648~ 2147483647	2^{32} values
`unsigned int`	$0 \sim 2^{32}-1$	0~ 4294967295	2^{32} values

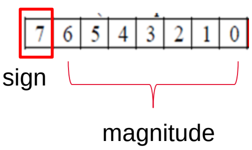
6

Max: signed 0111111….11111 Unsigned: 1111111….11111

6

Qualifiers (modifiers) for integer type

- **signed/unsigned** can be applied to char
  - **signed** char $-2^7 \sim 2^7-1$ /* -128 ~~ 127 */
  - **unsigned** char $0 \sim 2^8-1$ /* 0 ~~ 255 */



Unsigned potentially save bits
E.g., Count # student in our class (about 150)
- If declared `signed short`, max 127, 8 bits not enough
- If declared `unsigned`, then 8 bits are enough.
  `unsigned short counter;`

signed value

Bits	Unsigned value	2's complement value
00000000	0	0
00000001	1	1
00000010	2	2
01111110	126	126
01111111	127	127
10000000	128	−128
10000001	129	−127
10000010	130	−126
11111110	254	−2
11111111	255	−1
	$0 \sim\sim 2^n-1$	$-2^{n-1} \sim\sim 2^{n-1}-1$
	2^n=256 values	2^n=256 values

7

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Summary

- Interger types:
  - `signed char`   `unsigned char`
  - `(signed) short`   `unsigned short`
  - `(signed) int`   `unsigned int`
  - `(signed) long`   `unsigned long`
- There are three types of floating points:
  - `float        /* single-precision */`
  - `double       /* double precision */`
  - `long double  /* extended-precision */`
- C99 added：
  - `(signed) long long int`
  - `unsigned long long intbo`

Java defines

Type
int
short
long
byte
float
double
char
boolean

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8

8

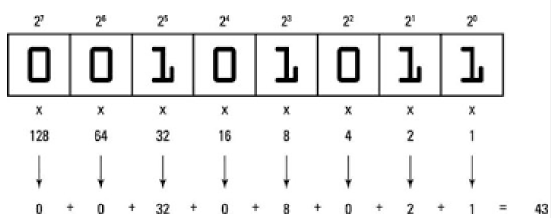
Outline

- Types and sizes
  - Types
  - **Constant values (literals)**
    - **char**
    - int
    - float
- Array and “strings”
- Expressions
  - Basic operators
  - Type promotion and conversion
  - Other operators
  - Precedence of operators

9

9

Internal representation of characters




```
int i =  43;

char a = 'A';
```

How to represent 'A' using 0s and 1s

10

10

01100101 01101100 01101100 01101111 00000000

Internal Representation of Characters

Dec	Hx	Oct	Char
0	0	000	NUL (null)

- '0' - '9' are encoded consecutively (48~57)
- 'A' - 'Z' are encoded consecutively (65~90)
- 'a' - 'z' are encoded consecutively (97~122)
- Upper letters before lower. Index/encoding difference of 'a' and 'A' is 32, so does 'b' and 'B', 'c' and 'C', …
- 8 bits is enough
- Java uses a bigger character set table Unicode, 0~127 are same

Dec	Hx	Oct	Html	Chr	Dec	Hx	Oct	Html	Chr	Dec	Hx	Oct	Html	Chr
32	20	040		Space	64	40	100	@	@	96	60	140	`	`
33	21	041	!	!	65	41	101	A	A	97	61	141	a	a
34	22	042	"	"	66	42	102	B	B	98	62	142	b	b
35	23	043	#	#	67	43	103	C	C	99	63	143	c	c
36	24	044	$	$	68	44	104	D	D	100	64	144	d	d
37	25	045	%	%	69	45	105	E	E	101	65	145	e	e
38	26	046	&	&	70	46	106	F	F	102	66	146	f	f
39	27	047	'	'	71	47	107	G	G	103	67	147	g	g
40	28	050	(	(	72	48	110	H	H	104	68	150	h	h
41	29	051	)	)	73	49	111	I	I	105	69	151	i	i
42	2A	052	*	*	74	4A	112	J	J	106	6A	152	j	j
43	2B	053	+	+	75	4B	113	K	K	107	6B	153	k	k
44	2C	054	,	,	76	4C	114	L	L	108	6C	154	l	l
45	2D	055	-	-	77	4D	115	M	M	109	6D	155	m	m
46	2E	056	.	.	78	4E	116	N	N	110	6E	156	n	n
47	2F	057	/	/	79	4F	117	O	O	111	6F	157	o	o
48	30	060	0	0	80	50	120	P	P	112	70	160	p	p
49	31	061	1	1	81	51	121	Q	Q	113	71	161	q	q
50	32	062	2	2	82	52	122	R	R	114	72	162	r	r
51	33	063	3	3	83	53	123	S	S	115	73	163	s	s
52	34	064	4	4	84	54	124	T	T	116	74	164	t	t
53	35	065	5	5	85	55	125	U	U	117	75	165	u	u
54	36	066	6	6	86	56	126	V	V	118	76	166	v	v
55	37	067	7	7	87	57	127	W	W	119	77	167	w	w
56	38	070	8	8	88	58	130	X	X	120	78	170	x	x
57	39	071	9	9	89	59	131	Y	Y	121	79	171	y	y
58	3A	072	:	:	90	5A	132	Z	Z	122	7A	172	z	z
59	3B	073	;	;	91	5B	133	[	[	123	7B	173	{	{
60	3C	074	<	<	92	5C	134	\	\	124	7C	174			|
61	3D	075	=	=	93	5D	135	]	]	125	7D	175	}	}
62	3E	076	>	>	94	5E	136	^	^	126	7E	176	~	~
63	3F	077	?	?	95	5F	137	_	_	127	7F	177	&#127;	DEL

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Characters

- **chars** are treated in C as small integers, **char** variables and constants are identical to **int** in arithmetic expressions:
  - **char c** is converted to its encoding (index in the character set table)

46	2E	056	.	.
47	2F	057	/	/
48	30	060	0	0
49	31	061	1	1
50	32	062	2	2
51	33	063	3	3
52	34	064	4	4
53	35	065	5	5
54	36	066	6	6
55	37	067	7	7
56	38	070	8	8
57	39	071	9	9
58	3A	072	:	:
59	3B	073	;	;
60	3C	074	<	<
61	3D	075	=	=
62	3E	076	>	>

```
char aChar = '5';    // encoding 53
aChar + 12        // expression with value 53+12 = 65
```

same in Java

- Same for other expressions. In relational expression, characters can be compared directly, comparing their indexes/encodings

```
aChar == 'H'     // index == 72?  ➔ expr with value 0 (false)

aChar == '/n'   // index = 10?  ➔ exp with value 0 (false)

'5' < 'H'   // 53 < 72?  Earlier in table? ➔ expr with 1 (true)
```

12

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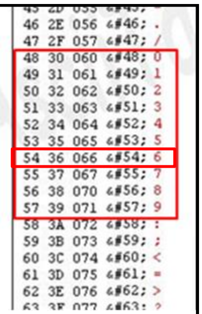
Characters



46	2E	056	.	.
47	2F	057	/	/
48	30	060	0	0
49	31	061	1	1
50	32	062	2	2
51	33	063	3	3
52	34	064	4	4
53	35	065	5	5
54	36	066	6	6
55	37	067	7	7
56	38	070	8	8
57	39	071	9	9
58	3A	072	:	:
59	3B	073	;	;
60	3C	074	<	<
61	3D	075	=	=
62	3E	076	>	>

- Since **chars** are just small integers, **char** variables and constants are identical to **int** in arithmetic expressions:
  - **char c** is converted to its encoding (index in the character set table)

```
char aCh = '6';  // same as   char aCh = 54;
printf("value is %c\n", aCh ); // char 6
printf("value is %d\n", aCh ); // numerical 54
                               // print encoding

printf("value is %d\n", aCh + 2 ); //numerical 56
printf("value is %c\n", aCh + 2 ); // char 8

printf("value is %d\n", aCh-'0' ); // 54-48
                                   //numerical 6
```

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same in Java

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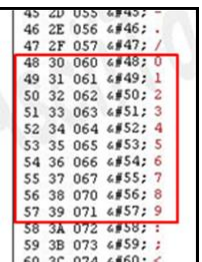
Characters



46	2E	056	.	.
47	2F	057	/	/
48	30	060	0	0
49	31	061	1	1
50	32	062	2	2
51	33	063	3	3
52	34	064	4	4
53	35	065	5	5
54	36	066	6	6
55	37	067	7	7
56	38	070	8	8
57	39	071	9	9
58	3A	072	:	:
59	3B	073	;	;
60	3C	074	<	<

- Since **chars** are just small integers, **char** variables and constants are identical to **int**s in arithmetic expressions: take advantage of this

```
if(c >= '0' && c <= '9') /*index 48~57,is a digit */
                          Located after '0' and before '9'

if(c >='a' && c <= 'z') /* low case letter*/

if(c >='A' && c <= 'Z') /*upper case letter*/


if(c >='0' && c <= '9')  // c<= 48 c>=57  isdigit(c)
  printf("c is a digit\n");
  printf("numerical value is %d\n", c-'0');
```

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same in Java

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Example

- Upper case letters before lower case letters.
- Encoding difference of 'a' and 'A' is 32, so does 'b' and 'B', 'c' and 'C', 'd' and 'D'…

64	40	100	@	@	96	60	140	`	`
65	41	101	A	A	97	61	141	a	a
66	42	102	B	B	98	62	142	b	b
67	43	103	C	C	99	63	143	c	c
68	44	104	D	D	100	64	144	d	d
69	45	105	E	E	101	65	145	e	e
70	46	106	F	F	102	66	146	f	f
71	47	107	G	G	103	67	147	g	g
72	48	110	H	H	104	68	150	h	h
73	49	111	I	I	105	69	151	i	i
74	4A	112	J	J	106	6A	152	j	j
75	4B	113	K	K	107	6B	153	k	k
76	4C	114	L	L	108	6C	154	l	l
77	4D	115	M	M	109	6D	155	m	m
78	4E	116	N	N	110	6E	156	n	n
79	4F	117	O	O	111	6F	157	o	o
80	50	120	P	P	112	70	160	p	p
81	51	121	Q	Q	113	71	161	q	q
82	52	122	R	R	114	72	162	r	r
83	53	123	S	S	115	73	163	s	s
84	54	124	T	T	116	74	164	t	t
85	55	125	U	U	117	75	165	u	u
86	56	126	V	V	118	76	166	v	v
87	57	127	W	W	119	77	167	w	w
88	58	130	X	X	120	78	170	x	x
89	59	131	Y	Y	121	79	171	y	y
90	5A	132	Z	Z	122	7A	172	z	z
91	5B	133	[	[	123	7B	173	{	{
92	5C	134	\	\	124	7C	174			|

```
#include<stdio.h>

/*copying input to output with
converting upper-case to lower-case letters */
main(){
    int c; int lowC;
    c= getchar();
    while (c != EOF)
    {
        if (c >= 'A' && c <= 'Z') /* 65~90 upper case letter*/
            lowC = c + 'a'- 'A';   /* c + 'b' - 'B'   */
                                   /* c + 'c' - 'C'   */
        putchar(lowC);             /* c = tolower(c)   */

        c = getchar(); // read again
    }
    return 0;
}
```

`c + 32` works in the lab but not good for portability. Avoid that!

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Outline

- Types and sizes
  - Types
  - **Constant values (literals)**
    - **char** treated as small int
    - **int** different bases
    - float
- Array and "strings"
- Expressions
  - Basic operators
  - Type promotion and conversion
  - Other operators
  - Precedence of operators

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Integer Constants

0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1

Stored always binary 2^2 2^1 2^0

- Integer constants can be expressed in three different ways:
  1. **Decimal** [base 10]
     - `int x = 31`

     same in Java
  2. **Octal** [base 8]
     - Start with zero **0**
     - `int x = 037` (31 in decimal)

     same in Java
  3. **Hexadecimal** [base 16]
     - Start with **0x** or **0X**
     - `int x = 0x1F` (31 in decimal)

     same in Java

Ways for people to write numbers. No effect on how the numbers are stored –- always binary.

Java also has the 4th: binary
`int x = 0b00011111`

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Others To decimal

- 3 2 8 (10^2 10^1 10^0) ➡ $3*10^2 + 2*10^1 + 8*10^0 =$ 300 + 20 + 8 = 328 — Decimal 328
- 1 0 1 (2^2 2^1 2^0) ➡ $1*2^2 + 0*2^1 + 1*2^0 =$ 4 + 0 + 1 = 5 — 00000000000101 Binary
- 3 4 5 (8^2 8^1 8^0) ➡ $3*8^2 + 4*8^1 + 5*8^0 =$ 192 + 32 + 5 = 229 — Octal 0345
- 3 4 F (16^2 16^1 16^0) ➡ $3*16^2 + 4*16^1 + F*16^0 =$ 3*256 + 4*16 + 15 *1 = 768 + 64 + 15 = 847 — Hex 0x34F 0X34f

You should know these conversions.

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Binary to others -- why Hex and Oct

I know I want an int with representation 01001100, how to code it in C?

In Java, can do binary `int a = 0b01001100`

- 0 1 0 0 1 1 0 0
  2^7 2^6 2^5 2^4 2^3 2^2 2^1 2^0
  → $1*2^6 + 1*2^3 + 1*2^2 =$ 64 + 8 + 4
  Decimal `int a = 76`

- $\underbrace{0\ 1}_{1}\ \underbrace{0\ 0\ 1}_{1}\ \underbrace{1\ 0\ 0}_{4}$ ⇄ `int a = 0114` Octal

- $\underbrace{0\ 1\ 0\ 0}_{4}\ \underbrace{1\ 1\ 0\ 0}_{C}$ ⇄ `int a = 0X4C` `= 0x4c` Hex

19 You should know these conversions (both ways).

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Outline

- Types and sizes
  - Types
  - Constant values (literals)
    - char
    - int
    - float
- **Array and "strings" (Ch1.6,1.9)**
- Expressions
  - Basic operators
  - Type promotion and conversion
  - Other operators
  - Precedence of operators

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Declaring Arrays

- Declare and initialize (how to do in Java?)

```
int k[5];  /* each element get some garble value*/
           -5  122 45623 85 58

int k[5] = {1,5,3,2,25};     1 5 3 2 25

int k[5] = {1,5};            1 5 0 0 0

int k[] = {1,5,3,2,25};      1 5 3 2 25
```

```
sizeof k?   20     // assuming 4 bytes int

sizeof(k)/sizeof(k[0]) = 20/4 = 5
```

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An example involving array and chars

What does this program do?

```
/*counting digits*/
#include <stdio.h>
#define N 10
int main () {
   int c, i;
   int digit[N];

   for (i=0; i< N; i++)
     digit[i]=0;

   c = getchar();
   while (c != EOF)
   {
     if ( c>= '0' && c <= '9' ){
         int pos = c - '0';
         digit[pos] ++;     // digit[c] ++
     }
     c = getchar(); // read again
   }

   for (i=0; i< N; i++)
      printf ("%d: %d ", i, digit[i]);
}
```

45	2D	055	-	-
46	2E	056	.	.
47	2F	057	/	/
48	30	060	0	0
49	31	061	1	1
50	32	062	2	2
51	33	063	3	3
52	34	064	4	4
53	35	065	5	5
54	36	066	6	6
55	37	067	7	7
56	38	070	8	8
57	39	071	9	9
58	3A	072	:	:
59	3B	073	;	;
60	3C	074	<	<

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Strings ⟷ Character Arrays !

```
Dec Hx Oct Char
0   0 000 NUL (null)
1   1 001 SOH (start of heading)
2   2 002 STX (start of text)
```

- There is no separate “string” type in C
- Strings are just arrays of char that end with `'\0'`

```
char s[] = "Hello";
char s[6] = "Hello";
```

'H'	'e'	'l'	'l'	'o'	'\0'
01001000	01100101	01101100	01101100	01101111	00000000

\0 added for you

- What's the size of s in memory? `sizeof (s)?` `6×1 bytes`
  - `char s[5]= "Hello";`
  - `char s[8]= "Hello";` `sizeof s?` `8×1 bytes`

'H'	'e'	'l'	'l'	'o'	'\0'	'\0'	'\0'

- What is the length of s?
  `strlen(s) = 5` later

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Accessing Arrays/Strings

- In C, you can only assign to array members
  - This means you cannot assign to an array:

```
int  i, k[4], j[4];
for (i=0; i<4; i++)
   j[i]= 0;      /* another way? int j[4]={0}   */

k = j;  /* invalid *//* perfectly valid in Java */
```

- **Also cannot compare directly**

```
if (k == j)        /* invalid */
if (k == "quit")   /* invalid, as in Java */

if (c == 'Q')  /* valid, comparing encodings */
while (arr[i] != '\0') /* valid */
```

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An example involving reading char arrays

```
#include<stdio.h>
int length (char []);

main() {
   char my_strg[100];
   int a;

   printf("Enter a word and a int by blank>");
   scanf("%s %d", my_strg,  &a);
   printf("%d", length(my_strg));
}

int length(char arr[]){
    int i = 0;
    while (arr[i] != '\0')
      i++;
    return i;
}
```

No need to give size

No & needed!
A big topic. Talk about that later

No [ ].
Same in Java

No need to give size

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Outline

- Types and sizes
  - Types
  - Constant values (literals)
    - char
    - int
    - float
- Array and “strings” (Ch1.6,1.9)
- **Expressions**
  - **Basic operators (arithmetic, relational and logical)**
  - Type promotion and conversion
  - Other operators (bitwise, bit shifting , compound assignment, conditional)
  - Precedence of operators

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Expressions

- Expressions are made up of *operands* (things we operate upon) and *operators* (things that do the operations: `+ - * % > <`)
  - `x+y/2, i>=0, x==y, i++,…`
- Operands can be constants, variables, array elements, function calls and other expressions
- Every expression has a return value.
  - `x+2` has return value 3 if `x` was 1
  - `i < 20` has return value true or false -- 1 or 0

- In C/Java, `=` is an operator, so assignment is also an expression
  - `variable = expression`
  - `x = 2+3` has return value 5 `printf("%d", x=2+3) // 5`
  - Assignment expression can be an operand in other expressions
    - `y = x = 2;`
    - `while ((c=getchar())!= EOF )`

"whenever a value is needed, any expression of the same type will do" `printf("sum is %d\n", i*y+2);`

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Expressions

- Some of the common operators:
  - `+, -, *, /, %, ++,--` (basic arithmetic)
  - `<, >, <=, >=` (relational operators)
  - `==, !=` (equality operators)
  - `&&, ||, !` (logical operators)
  - `= += -=` (assignment & compound assignment)
- Others: bitwise `& | ~`, bit shifting `<< >>`, conditional `? :`

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Arithmetic (unary) Increment/Decrement Operators

- **++** increment
- **--** decrement

same in Java

- May come before (prefix) or after the operand (postfix)

`++x`	increment x, result of expression is new value	(pre-increment)
`x++`	increment x, result of expression is old value	(post-increment)
`--x`	decrement x, result of expression is new value	(pre-decrement)
`x--`	decrement x, result of expression is old value	(post-decrement)

```
while (x < 10){
  ......
  x++;  // increment later,
        //   before next statement
  ......
}
```

```
while (x < 10){
  ......
  ++x;  // increment immediately
  ......
}
```

Same effects

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Arithmetic (unary) Increment/Decrement Operators

- **++** increment
- **--** decrement

same in Java

- May come before (prefix) or after the operand (postfix)

`++x`	increment x, result of expression is new value	(pre-increment)
`x++`	increment x, result of expression is old value	(post-increment)
`--x`	decrement x, result of expression is new value	(pre-decrement)
`x--`	decrement x, result of expression is old value	(post-decrement)

```
x = 2;
y = x++;  // increment after
          //   assignment
printf("%d %d",x, y);
```

~~x:2 y:3~~ x:3 y:2

```
x = 2;
y = ++x;  // increment before
          //   assignment
printf("%d %d",x, y);
```

x: 3 y:3

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A common use

```
/*initialize to 0 */

#include <stdio.h>
#define N 10

int main () {

   int i=0;
   int digit[N];

   while (i< N)
   {
     digit[i]=0;
     i++;
   }
```

```
// succinct code
while ( i< N)
{
  digit[i++]=0;

}
```

same in Java

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A common use

```
/*copy 4 elements from pos 10 of arrB to arrA */

#include <stdio.h>
#define N 10
int main () {
   int i,j;
   …..

   i=0; j=10;
   while (i<4 && j<14…)
   {
     arrA[i] = arrB[j];
     i++;
     j++;
   }
```

```
// succinct code
while (i<4 && j<14…)
{

  arrA[i++] = arrB[j++];

}
```

same in Java

Stopped here last time

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Summary and future work

- Type, operators and expressions (Chapter 2) :
  - Types and sizes
    - Basic types, their size and constant values (literals)
      - ✓ char: x > 'a' && x < 'z'; x > '0' && x < '9'
      - ✓ int: 122, 0122, 0x12F convert between Decimal, Bin, Oct, Hex
    - Arrays (one dimension) and strings (Ch1.6,1.9)
      - ✓ "hello" has size 6 byte

H	e	l	l	o	\0

  - Expressions
    - Basic operators (arithmetic, relational and logical)
      - ✓ y=x++; y=++x;
      - ✓ if (x = 2)
    - Type conversion and promotion
    - Other operators (bitwise, bit shifting , compound assignment, conditional)
      - ✓ Bit: |, &, ~. ^, << >>
      - ✓ Compound: x += 10; x >>= 10; x += y + 3
    - Precedence of operators
- Functions and Program Structure (Chapter 4)

Last week

today

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Expressions

- Some of the common operators:
  - `+, -, *, /, %, ++,--` (basic arithmetic)
  - `<, >, <=, >=` (relational operators)
  - `==, !=` (equality operators)
  - `&&, ||, !` (logical operators)
  - `= += -=` (assignment & compound assignment)
- Others: bitwise `& | ~`, bit shifting `<< >>`, conditional ? :
  `sizeof`

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Relational and logical Operators

`<, >, <=, >= == !=` (relational and equality operators)
`&&, ||, !` (logical operators)

- Value of a relational or logical expression is `Boolean`
  - 0 when *false*
  - 1 when *true*

In C,
0 means *false*
non-zero means *true*

```
int x = 3;
x > 4      0        printf("%d", x<4);
x == 3     1
x != 4     1

if (x == 5)    not true
while (1)      if (5)
if (x = 5)       ?
```

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Relational and logical Operators

- Not as safe as Java -- probably why Java introduce Boolean

```
int x = 2;
if (x = 1)
  ……
else if (x=2)…
  ……
```

```
int x = 2;
while(x = 3)
  ……
```

```
indigo 311 % javac Hello.java
Hello.java:13: incompatible types
found    : int
required: boolean
              if (x = 1){
                    ^
1 error
```

Relational and **logical** Operators (cont.)

And

p	q	p · q
T	T	T
T	F	F
F	T	F
F	F	F

Or

p	q	p ∨ q
T	T	T
T	F	T
F	T	T
F	F	F

- ! Logical negation

  `!0` returns 1, `!` (any non-zero value) returns 0 `!-4`

Not valid in Java

- || logical or, && logical and
  - `&&` returns 1 if both non-zero. Otherwise 0 `3 && -2`
  - `||` returns 1 if either non-zero. Otherwise 0 `3 || 5`
  - **Short-circuit** (lazy) evaluation stops when we have an answer

```
int  x = 1, y = 1
if (x == 0 && y == 0)….;
```

same in Java

Java example:

```
if ( object != null && object.data  > 9)
  ……
```

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Outline

- Types and sizes
  - Types
  - Constant values (literals)
    - char
    - int
    - float
- Array and “strings” (Ch1.6,1.9)
- Expressions
  - Basic operators (arithmetic, relational and logical)
  - **Type promotion and conversion**
  - Other operators (bitwise, bit shifting , compound assignment, conditional)
  - Precedence of operators

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Type conversion – 4 scenarios

1. Given an expression with operands of mixed types, C converts (promotes) the types of values to do calculations
2. Conversion may happens on assignment
3. May happens on function call arguments
4. May happens on function return type

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Type conversion – scenario 1

```
int x = 5, y = 2;
float f = 2.0
```

- What is the type of expression **x/y** or **y/x**
- What is the result of expression **x/y** or **y/x**

- What is the type of **x/f** or **f/x**?
- What is the result of **x/f** or **f/x**?

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Scenario 1 -- Type conversion (Promotion)

- Given an expression with operands of mixed types, C converts (promotes) the types of values to do calculations
  - Promotes: converts to a more precise type
  - Result is the promoted type.

```
int x = 5, y = 2;
float f = 2.0
```

same in Java

- E.g., for **`x/f`** **`x`** is **`int`**, **`f`** is **`float`**
- **`x`**'s value is read, converted to a float and then used in division (i,e., 5 ⟹ 5.0)
  - 5 / 2.0 = 5.0 / 2.0 = 2.5
  - return type **`float`**

Type Promotion

converts to a more precise type

- Informal rules (from K&R p. 44)
  - **`if either operand is "long double"`**
    - **`convert to "long double"`**
  - **`else if either operand is "double"`**
    - **`convert to "double"`**
  - **`else if either operand is "float"`**
    - **`convert to "float"`**
  - **`else`**
    - **`convert char and short to int`**
    - **`if either operand is long, convert to long`**

short / char ⟹ int ⟹ long ⟹ float ⟹ double ⟹ long double

Examples:

char, int → operator → int

int, double → operator → double

short → int → long → float → double → long double
char

Mixed type arithmetic

- Given an expression with operands of mixed types, C converts (promotes) the types of values to do calculations

- 17 / 5
  - 3
- 'k' + 32
  - 75 + 32 = 107
  - Return type int

same in Java

- 17.0 / 5
  - 17.0 / 5.0 = 3.4
  - Return type double

- 9 / 2 * 3.0 / 4
  - 9/2 = 4 type int
  - 4*3.0 = 4.0*3.0 = 12.0 double
  - 12.0/4 = 12.0/4.0=3.0 double
- 3.0 * 9 / 2 /4
  - 3.0*9 = 3.0*9.0=27.0 double
  - 27.0/2.0 = 13.5 double
  - 13.5/4.0 =3.375 double

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2 conversions

Associativity: left to right

3 conversions

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Scenarion 2: Conversions across assignments

- The value of the right side is converted to the type of the left, which is the type of the result

```
int i = 512
float f;
f = i;  /*value of i is converted to float  512.0 */
        /* return type float, return value 512.0 */
```

same in Java

- If the left side is of smaller range or precision, information may be lost (should avoid)
  - Longer integers converted to shorter ones or chars by dropping the excess high-order bits
  - float/double to int truncates any fractional part.

```
float f = 512.3;
int i = f;  /* f is converted to int 512 */
```

```
.java:10: error: incompatible types: possible lossy conversion from float to int
int i =f;
       ^
```

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Not valid in Java

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Type Conversion - Examples

arithmetic (scenario1) and assignment (scenario2)

same in Java

```
int x=5, y=2;
double q = 2;    // conversion on assignment q=2.0

int w = x/y;        //  no conversions w=2

double z = x/y;  //  z=2.0 conversion on assignment

double z = x/q;   // z=5.0/2=2.5 conversion on /

int w = x/q;
//  conversion on / and then on assignment
//  w = 5.0/2.0 = 2.5 = 2

char x = 'k' + 32; // conversion on + and then on =
                   // x = 75 + 32 = 107 = 'K'
```

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Scenario 3,4 Conversions across function

- arguments
- returns

```
#include <stdio.h>

/* function declaration */
int sum(int, int);

main()
{
  int x = 4; double y= 3.9;
  int su = sum(x,y); // sum receives 4, and 3.9 → 3
  printf( "Sum is %d\n", su); // 7
}

/* function definition */
int sum (int i, int j){
    return i+j;  // 4 + 3
}
```

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Scenario 3,4 Conversions across function

- arguments
- returns

```
#include <stdio.h>

/* function declaration */
double sum(double, double);

main()
{
  int x = 4; double y= 3.9;
  double su = sum(x,y); // sum receives 4 → 4.0 and 3.9
  printf("Sum is %f\n", su); // 7.9
}

/* function definition */
double sum (double i, double j){
   return i+j;    // 4.0 + 3.9
}
```

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Scenario 3,4 Conversions across function

- arguments
- returns

```
type function (){
    return expr;
}
```

- If **expr** is not of type **type**, compiler
  - produces a warning
  - converts **expr** (as if by assignment) to the return **type** of the function
  - should avoid

```
int function (){
   double x;
   return x;   /* return (int)x if you have to
}               tell the complier you know
                what you are doing (losing) */
```

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Scenario 3,4 Conversions across function

- arguments
- returns

```
#include <stdio.h>

/* function declaration */
double aFun();

main()
{
  aFun();  // return type double, value 7.0
}

/* function definition */
double aFun (){
  int i = 3;
  int j = 4;
  return i + j;   /* i+j of type int, converted to double*/
}                  /*  7 → 7.0  */
```

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Scenario 3,4 Conversions across function

- arguments
- returns

```
#include <stdio.h>

/* function declaration */
int aFun();

main()
{
  aFun();  // return type double, value 7.0
}

/* function definition */
int  aFun (){
  double i = 3.6;
  int j = 4;
  return i + j;   /* i+j of type double, converted to int */
}                  /*  7.6 → 7  */
```

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Explicit Conversion (Type Casting)

- We can also explicitly change type
- Type cast operator; **(type-name)operand**

```
int a = 9, b = 2;
float f;

f = a / b;          /* f is 4.0 */
f = a /(float) b    /* f is 4.5 */

f = (float)(a/b)  ?

int d = (int)f
```

Doesn't change the value of b,
Just changes the type to float

Needed in Java

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Outline

- Types and sizes
  - Types
  - Constant values (literals)
    - char
    - int
    - float
- Array and "strings" (Ch1.6,1.9)
- **Expressions**
  - Basic operators (arithmetic, relational and logical)
  - Type promotion and conversion
  - **Other operators (bitwise, bit shifting, compound assignment, conditional)**
  - Precedence of operators

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Bitwise operators

C (and Java) allows us to easily manipulate individual bits in integer types (**char, short, int, long**)

01100101	01101100	01101100	01101111	00000000
01001000	01100101	01101100	01101100	01101111

- bitwise **& | ~ ^**

And

p	q	$p \cdot q$
T	T	T
T	F	F
F	T	F
F	F	F

Or

p	q	$p \vee q$
T	T	T
T	F	T
F	T	T
F	F	F

Not

p	$\sim p$
T	F
F	T

- bit shifting << >>

01001000	01100101	01101100	01101100	01101111	00000000

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Bitwise Operators

Or

p	q	$p \vee q$
T	T	T
T	F	T
F	T	T
F	F	F

Lhs	0	0	1	1
Rhs	0	1	0	1
Result	0	1	1	1

- **|** – bitwise “or”
  - Calculates the “or” of all bits in both operands
  - either bit is 1 ➔ the result is 1 (set) 0: keep whatever other,

- e.g.

```
z= 145 | 41
                  145= 000…10010001
                  41 = 000…00101001
                       000…10111001 = 185 (decimal)
                                      0271 (oct)
                                      0Xb9 (hex)
```

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same in Java

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Bitwise Operators

And

p	q	$p \cdot q$
T	T	T
T	F	F
F	T	F
F	F	F

Lhs	0	0	1	1
Rhs	0	1	0	1
Result	0	0	0	1

- **&** - bitwise "and"
  - Calculates 'and' of all bits in both operands
  - (both bits must be 1 to result in 1)
  - Either is 0: 0 (off) 1: keep whatever the other

- e.g.

```
z= 145 & 41       145= 000…10010001
                   41= 000…00101001
z= 1                   000…00000001   = 1 (decimal)
```

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same in Java

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Bitwise Operators

Exclusive-OR gate

A	B	Output
0	0	0
0	1	1
1	0	1
1	1	0

Lhs	0	0	1	1
Rhs	0	1	0	1
Result	0	1	1	0

- **^** - "xor" ("exclusive-or")
  - like "or" except when both bits are 1, the result is 0)
  - If two bits are different, the result is 1; otherwise 0.

e.g. **z= 145 ^ 41**

```
145 = 000…10010001
 41 = 000…00101001
      000…10111000 = 184  (decimal)
                     0270 (oct)
                     0Xb8 (hex)
```

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same in Java

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Bitwise Operators

Not

p	$\sim p$
T	F
F	T

Rhs	0	1
Result	1	0

- **~**
  - one's complement (bit inversion)
  - flips all bits in its operand

- e.g.(assuming unsigned char)

```
z= ~145        145= 10010001
                ____________
                01101110  = 110 (decimal)
                            0156 (oct)
                            0X6E (hex)
```

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same in Java

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Bit Shifting

01001000	01100101	01101100	01101100	01101111	00000000

- Shifting bits: **<<** (left shift), **>>** (right shift)
  - **x << *n*** means "take *x* and shift it *n* bits to the left"
  - **x >> *n*** means "take *x* and shift it *n* bits to the right"
  - Result is an int value (but does not change **x**)

What goes Out? bits pushed "off the end" on the end

What comes in? >> << different

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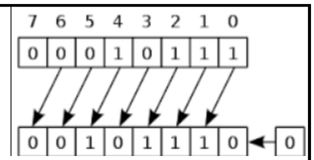
Bit Shifting <<



- Suppose **z** is an int
  - e.g.
    - **z= 26 << 3**
    - **shift left 3 bits**
    - **z= 208**

      0320

      0XD0

26 = 000 000…..11010

000… . 11010000

000

What goes Out? bits pushed "off the end" on the left end

What comes in? we add 0 on the right

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z = x << 3 does not change x

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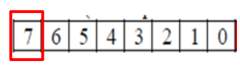
Bit Shifting >>



- What if we shift right? >> complicated.
- For "unsigned" types – <u>all bits are magnitude</u> -- add 0 on left
- e.g. (assume these are all unsigned)

  z = 154 >> 3

  shift left 3 bits

154=…. 10011010

… 00010011 = 19

010

z = x >> 3 does not change x

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Bit Shifting- What Comes In >>

- What about "signed" values?   7 6 5 4 3 2 1 0
  - It's undefined -meaning?
  - On some platforms it's logical (0's –like unsigned values)
  - On others it's arithmetic (whatever the leftmost bit is)
- e.g.(8-bit signed values using 2's complement)
  - -94 >>3   -94= 10010010
  - logical   00010010= 18
  - arithmetic   11110010= -14

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Bit Shifting- What Comes In >>

- What about "signed" values?
  - It's undefined -meaning?
  - On some platforms it's logical (0's –like unsigned values)
  - On others it's arithmetic (whatever the leftmost bit is)

C does not define which method is used
The moral:
Avoid right bit-shifting signed values!

Java address right shift by introducing >>>
>> what ever leftmost is
>>> always 00…

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But What Is It Useful?

- A common use: flags, masks
  - A flag is a boolean value (off=0, on=1) which describes a state, e,g,, switches
  - We could use an "**int**" to describe a flag, but an **int** has a minimum of 16 bits (65536 values) - far more than we need
  - We can use bitwise operators to efficiently represent flags - each bit can be a flag
    - so one **int** can represent at least 16 flags.

00000100 01011000 00001100 11101111

One int -- 32 'Boolean' flags

Masking for bit manipulation

- Masking uses AND and OR operators
- Use OR ('|') to set bits to '1' with 1
- Use AND ('&') to set bits to 0 with 0
- Use XOR(^) to toggle bits (0 -> 1 and 1-> 0)

I 1: turn on (set 1)
& 0: turn off (set 0)
I 0: keep value
& 1: keep value

OR			AND			XOR		
A	B	Output	A	B	Output	A	B	Output
0	0	0	0	0	0	0	0	0
0	1	1	0	1	0	0	1	1
1	0	1	1	0	0	1	0	1
1	1	1	1	1	1	1	1	0

Flags (some idioms)

| 1: turn on
& 0: turn off
| 0: keep value
& 1: keep value

- Unsigned char **`flags`**;
  - **`flags = flags | (1<<5)`**
    - 00100000. Turn 6th bit on (set to 1) (lowest-bit is 1st bit)
  - **`flags = flags & ~(1<< 5)`**
    - 11011111. Turn 6th bit off (set to 0)
  - **`flags = flags & (1<<5)`**
    - 00100000. keep 6th bit only (other off)
  - **`flags = flags & 0177`**
    - …. 001 111 111. Set to zero all but the low-order 7 bits of flag
  - **`flags = flags & ~077`**
    - 000111111->111000000. Set last 6 bits to zero (turn off)

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Practice in the lab. Revisit next time

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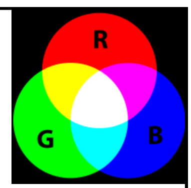
Some examples



- In Java, getRGB() packs 3 +1 values (0~255) into a 32 bit (4 bytes) int

7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0

- 00000000 11111101 01001000 10101011

  ^ Alpha ^Red ^Green ^Blue

java.awt.image

Class BufferedImage

java.lang.Object
java.awt.Image
java.awt.image.BufferedImage

getRGB

```
public int getRGB()
```

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Returns the RGB value representing the color in the default sRGB ColorModel. (Bits 24-31 are alpha, 16-23 are red, 8-15 are green, 0-7 are blue).

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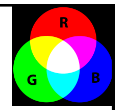
Some examples



- I 1: turn on
- & 0: turn off
- I 0: keep value
- & 1: keep value

- In Java, getRGB() packS 3 +1 values into a 32 bit (4 bytes) int
- How to get blue value?

00001010 11111101 01001000 10101011

^ Alpha ^Red ^Green ^Blue

&

00000000 00000000 00000000 11111111 255 0377 0xFF

Turn off keep value

00000000 00000000 00000000 10101011

- `int blue = (rgb_pack) & 0377;` // rgb_pack not changed */

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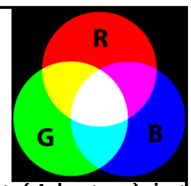
Some examples



- In Java, getRGB() packS 3 +1 values into a 32 bit (4 bytes) int
- 10101100 11111101 01001000 11111111

^ Alpha ^Red ^Green ^Blue

How to get red value?

- First shift to the right end. 00000000 00000000 10101100 11111101
- Then need **000 ….. 11111111** to turn off 9~32 bits -- mask

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Select Command Prompt

```
   Connection-specific DNS Suffix  . :

Wireless LAN adapter Wireless Network Connection:

   Connection-specific DNS Suffix  . :
   Link-local IPv6 Address . . . . . : fe80::81c8:be2f:99d:2c
   IPv4 Address. . . . . . . . . . . : 130.63.199.163
   Subnet Mask . . . . . . . . . . . : 255.255.254.0
   Default Gateway . . . . . . . . . : 130.63.198.1

Ethernet adapter Local Area Connection:

   Media State . . . . . . . . . . . : Media disconnected
   Connection-specific DNS Suffix  . : cs.yorku.ca

Tunnel adapter isatap.{4C22CACA-FD21-424B-91FD-614F471D1709}:
```

Example: ip address 192.168.18.55, subnet mask: 255.255.255.0

11000000 10101000 00010010 00110111

11111111 11111111 11111111 00000000

Address:	11000000 10101000 00010010 00110111
Subnet Mask:	11111111 11111111 11111111 00000000
AND	-------- -------- -------- --------
Network ID:	11000000 10101000 00010010 00000000

NET_ID is 192.168.18

For your information

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Expressions

- Some of the common operators:
  - `+, -, *, /, %, ++,--` (basic arithmetic)
  - `<, >, <=, >=` (relational operators)
  - `==, !=` (equality operators)
  - `&&, ||, !` (logical operators)
  - `= += -=` (assignment & compound assignment)
- Others: bitwise `& | ~`, bit shifting `<< >>`, conditional `? :`

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Somethings to Think About

- | looks similar to || Both do "OR"
- & looks similar to &&   Both do "AND"

- | and & applies to bits, || and && apply to whole values

- Can you substitute | for ||?
- Can you substitute & for &&?

```
int x=1, y=2;
x & y    ?     0
x && y   ?     1

x | y    ?     3
X || y   ?     1
```

And

p	q	$p \cdot q$
T	T	T
T	F	F
F	T	F
F	F	F

Or

p	q	$p \vee q$
T	T	T
T	F	T
F	T	T
F	F	F

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Outline

- Types and sizes
  - Types
  - Constant values (literals)
    - char
    - int
    - float

- Array and "strings" (Ch1.6,1.9)

- **Expressions**
  - Basic operators (arithmetic, relational and logical)
  - Type promotion and conversion
  - **Other operators (bitwise, bit shifting , compound assignment, conditional)**
  - Precedence of operators

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(Compound) Assignment Operators

- C (and Java) provides other "short-hand" assignment operators (we've seen `++` and `--`)
- e.g.
  - `x += 5;      <-->     x = x + 5`
  - `x *= 5;      <-->     x = x * 5`

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Assignment Op. & Expressions

- Assignment operator: "**op=**"
  exp1 op= exp2 is equivalent to
  exp1 =(exp1) op (exp2)
  - exp1 and exp2 are expressions
- **op** can be:
  `+ - * / % << >> & ^ |`
- Thus, we can have
  `+=, -=, *=, /=, %=, <<=, >>=, &=, ^=, |=`

`flags = flags | (1<<5)` ⇔ `flag |= (1 << 5)`

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Assignment Op. -- Examples

- `x *= y + 1` is equivalent to `x = x * (y +1)`
  - Because `*=` has low precedence than `+`

  - `x=2; y=2; x *= y + 1 + 5;`
    `x` has value `2*(2+1+5) = 16`

same in Java

unsigned int x;

- `x =24; x >>=2;` 00011000 24 -> 6
  x is 00000110

- `x =24; x <<=2;` 00011000 24 -> 96
  x is 01100000

- `x =24; x |= 0x02;` 00011000 |
  00000010
  x is 00011010 24->26

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Turn on 2nd bit

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Conditional operator

- `exp1 ? exp 2: exp 3`
- If `exp1` is true, the value of the conditional expression is `exp2`; otherwise, `exp3`

```
z = (a > b) ?  a : b; /* z = max (a,b) */
if (a>b)
   z=a;
else z=b;
```

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Java vs. C, types and operators

	Java	C
Boolean	boolean	int 0/1
Integer types	byte // 8 bits short // 16 bits int // 32 bits long // 64 bits	char unsigned char short unsigned short int unsigned int long unsigned long
String type	String s1 = "Hello"; String s2 = new String("hello");	char s1[] = "Hello"; char s2[6]; strcpy(s2, "hello");

String concatenate	s1 + s2	#include <string.h>
		strcat(s1, s2);

Logical	&&, ||, !	&&, ||, !
Compare	=, !=, >, <, >=, <=	=, !=, >, <, >=, <=
Arithmetic	+, -, *, /, %, unary -	+, -, *, /, %, unary -
Bit-wise ops	>>, <<, >>>, &, |, ^	>>, <<, &, |, ^
Assignments	=, *=, /=, +=, -=, <<=, >>=, >>>=, =, ^=, |=, %=	=, *=, /=, +=, -=, <<=, >>=, =, ^=, |=, %=

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Outline

- Types and sizes
  - Types
  - Constant values (literals)
    - char
    - int
    - float
- Array and "strings" (Ch1.6,1.9)
- **Expressions**
  - Basic operators (arithmetic, relational and logical)
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  - Other operators (bitwise, bit shifting , compound assignment, conditional)
  - **Precedence of operators**

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Precedence

- How do we interpret:
  - `a && b || c && d`
  - `i << 2 +1`   `flag | 1 << 4`
  - `i *= y+1`
  - `(int) f1/f2`

- Rules of precedence tell us what gets evaluated first:
  - `a && b || c && d`
  - `i << 2 + 1`   `flag | 1 << 4`
  - `i *=  y + 1`
  - `(int) f1 / f2`

- Precedence should be familiar from basic math:
  - Given "**x+y*5**", you evaluate "**y*5**" first:
    - **x + (y*5)**

Precedence

```
#include <stdio.h>

main(){
 int c;
 c = getchar();
 while(c != EOF)
 {
   putchar(c);
   c = getchar();/*read next*/
 }
}
```

Succinct code

```
#include <stdio.h>

main(){
 int c;

 while( c = getchar() != EOF )
 {
   putchar(c);

 }
}
```

?

Precedence and Associativity p53

- Observe that:
  - Parentheses first
  - Negation(!,~) next
  - Arithmetic before Relational
  - Arithmetic: /, *, % before +-
  - Relational before Logical
  - Logical: && before ||
  - Bit shift << >> before bitwise & ^ |
  - Assignment = += very low

```
if ( a&&b || c && d)
while((c=getchar()) == EOF)
i << 2 + 1     // i = i << 3
if (a==2 || a<4)
i *= y + 1  // i=i*(y+1)
(*p).data
```

- When in doubt – use parentheses
  - Also for clarity

- Don't need to memorize
  - Will be provided in tests
  - But know how to use them

Similar in Java

Operator Type	Operator	
Primary Expression Operators	() [] . -> expr++ expr--	
Unary Operators	* & + - ! ~ ++expr --expr (typecast) sizeof	
Binary Operators	* / %	arithmetic
	+ -	arithmetic
	>> <<	bit shift
	< > <= >=	relational
	== !=	relational
	&	bitwise
	^	bitwise
	|	bitwise
	&&	logical
	||	logical
Ternary Operator	?:	
Assignment Operators	= += -= *= /= %= >>= <<= &= ^= |=	
Comma	,	

Summary and future work

- Type, operators and expressions (Chapter 2) :
  - Types and sizes
    - Basic types, their size and constant values (literals)
      - ✓ char: x > 'a' && x < 'z'; x > '0' && x < '9'
      - ✓ int: 122, 0122, 0x12F convert between Decimal, Bin, Oct, Hex
    - Arrays (one dimension) and strings (Ch1.6,1.9)
      - ✓ "hello" has size 6 byte | H | e | l | l | o | \0 |
  - Expressions
    - Basic operators (arithmetic, relational and logical)
      - ✓ y=x++; y=++x;
      - ✓ if (x = 2)
    - Type conversion and promotion
    - Other operators (bitwise, bit shifting , compound assignment, conditional)
      - ✓ Bit: |, &, ~. ^, << >>
      - ✓ Compound: x += 10; x >>= 10; x += y + 3
    - Precedence of operators
- Next: Functions and Program Structure (Chapter 4)