Types, Operators and Expressions

CSE 2031

Fall 2011

Variable Names (2.1)

- Combinations of letters, numbers, and underscore character (_) that
  - do not start with a number;
  - are not a keyword.
- Upper and lower case letters are distinct (x ≠ X).
- Examples: Identify valid and invalid variable names

```
abc, aBc, abc5,  aA3_ , char, _360degrees,
5sda, my_index, _temp, string, struct,
pointer
```

Variable Names: Recommendations

- Don't begin variable names with underscore _
- Limit the length of a variable name to 31 characters or less.
- Function names, external variables: may be less than 31 characters allowed, depending on systems.
- Lower case for variable names.
- Upper case for symbolic constants
  - `#define MAX_SIZE 100`
- Use short names for local variables and long names for external variables.

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Data Types and Sizes (2.2)

4 basic types in C

- **char** – characters (8 bits)
- **int** — integers (either 16 or 32 bits)
- **float** – single precision floating point numbers (4 bytes)
- **double** – double precision floating point numbers (8 bytes)

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Qualifiers

- `signed char sc;` `/* -127 – +128 */`
- `unsigned char uc;` `/* 0 – +255 */`
- `short s;` `/* 16 bits, -32,768 - +32,767 */`
  - `short int s;`
- `long counter;` `/* 32 bits */`
  - `long int counter;`
  - `int` is either 16 or 32 bits, depending on systems.
  - `signed int sint;` `/* same as int sint; */`
- `unsigned int uint;`
  - 0 – +4,294,967,295, `assuming 4-byte int`
- `long double ld;` `/* 12 bytes */`

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Qualifiers (cont.)

- <limits.h> and <float.h> contain
  - symbolic constants for all of the above sizes,
  - other properties of the machine and compiler.
- To get the size of a type, use `sizeof( )`

```
int_size = sizeof( int );
```

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Characters

- 8 bits
- Included between 2 single quotes
  `char x ='A'`
- Character string: enclosed between 2 double quotes
  `"This is a string"`
- Note: 'A' ≠ "A"

A

A	\0

- **`c ='\012'`** /* 10 decimal; new line character */

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Characters

Dec	Hx	Oct	Char	Dec	Hx	Oct	Html	Chr	Dec	Hx	Oct	Html	Chr	Dec	Hx	Oct	Html	Chr
0	0	000	NUL (null)	32	20	040		Space	64	40	100	@	@	96	60	140	`	`
1	1	001	SOH (start of heading)	33	21	041	!	!	65	41	101	A	A	97	61	141	a	a
2	2	002	STX (start of text)	34	22	042	"	"	66	42	102	B	B	98	62	142	b	b
3	3	003	ETX (end of text)	35	23	043	#	#	67	43	103	C	C	99	63	143	c	c
4	4	004	EOT (end of transmission)	36	24	044	$	$	68	44	104	D	D	100	64	144	d	d
5	5	005	ENQ (enquiry)	37	25	045	%	%	69	45	105	E	E	101	65	145	e	e
6	6	006	ACK (acknowledge)	38	26	046	&	&	70	46	106	F	F	102	66	146	f	f
7	7	007	BEL (bell)	39	27	047	'	'	71	47	107	G	G	103	67	147	g	g
8	8	010	BS (backspace)	40	28	050	(	(	72	48	110	H	H	104	68	150	h	h
9	9	011	TAB (horizontal tab)	41	29	051	)	)	73	49	111	I	I	105	69	151	i	i
10	A	012	LF (NL line feed, new line)	42	2A	052	*	*	74	4A	112	J	J	106	6A	152	j	j
11	B	013	VT (vertical tab)	43	2B	053	+	+	75	4B	113	K	K	107	6B	153	k	k
12	C	014	FF (NP form feed, new page)	44	2C	054	,	,	76	4C	114	L	L	108	6C	154	l	l
13	D	015	CR (carriage return)	45	2D	055	-	-	77	4D	115	M	M	109	6D	155	m	m
14	E	016	SO (shift out)	46	2E	056	.	.	78	4E	116	N	N	110	6E	156	n	n
15	F	017	SI (shift in)	47	2F	057	/	/	79	4F	117	O	O	111	6F	157	o	o
16	10	020	DLE (data link escape)	48	30	060	0	0	80	50	120	P	P	112	70	160	p	p
17	11	021	DC1 (device control 1)	49	31	061	1	1	81	51	121	Q	Q	113	71	161	q	q
18	12	022	DC2 (device control 2)	50	32	062	2	2	82	52	122	R	R	114	72	162	r	r
19	13	023	DC3 (device control 3)	51	33	063	3	3	83	53	123	S	S	115	73	163	s	s
20	14	024	DC4 (device control 4)	52	34	064	4	4	84	54	124	T	T	116	74	164	t	t
21	15	025	NAK (negative acknowledge)	53	35	065	5	5	85	55	125	U	U	117	75	165	u	u
22	16	026	SYN (synchronous idle)	54	36	066	6	6	86	56	126	V	V	118	76	166	v	v
23	17	027	ETB (end of trans. block)	55	37	067	7	7	87	57	127	W	W	119	77	167	w	w
24	18	030	CAN (cancel)	56	38	070	8	8	88	58	130	X	X	120	78	170	x	x
25	19	031	EM (end of medium)	57	39	071	9	9	89	59	131	Y	Y	121	79	171	y	y
26	1A	032	SUB (substitute)	58	3A	072	:	:	90	5A	132	Z	Z	122	7A	172	z	z
27	1B	033	ESC (escape)	59	3B	073	;	;	91	5B	133	[	[	123	7B	173	{	{
28	1C	034	FS (file separator)	60	3C	074	<	<	92	5C	134	\	\	124	7C	174			|
29	1D	035	GS (group separator)	61	3D	075	=	=	93	5D	135	]	]	125	7D	175	}	}
30	1E	036	RS (record separator)	62	3E	076	>	>	94	5E	136	^	^	126	7E	176	~	~
31	1F	037	US (unit separator)	63	3F	077	?	?	95	5F	137	_	_	127	7F	177	&#127;	DEL

Source: www.LookupTables.com

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Constants (2.3)

- Numeric constants
- Character constants
- String constants
- Constant expressions
- Enumeration constants

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Integer Constants

- Decimal numbers
  - `123487`
- Octal: starts with 0 (zero)
  - `0654`
- Hexadecimal: starts with 0x or 0X
  - `0x4Ab2, 0X1234`
- long int: suffixed by L or l
  - `7L, 106l`
- unsigned int: suffixed by U or u
  - `8U, 127u`

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Floating-point Constants

```
15.75
1.575E1        /* = 15.75 */
1575e-2        /* = 15.75 */
-2.5e-3         /* = -0.0025 */
25E-4          /* = 0.0025 */
```

- If there is no suffix, the type is considered **double** (8 bytes).
- To specify **float** (4 bytes), use suffix F or f.
- To specify **long double** (12 bytes), use suffix L or l.

```
100.0L  /* long double */
100.0F  /* float */
```

- You can omit the integer portion of the floating-point constant.

```
.0075e2
0.075e1
.075e1
75e-2
```

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Numeric Constants

- `2010`
- `100000`
- `729L or 729l`
- `2010U or 2010u`
- `20628UL or 20628ul`
- `24.7 or 1e-2`
- `24.7F or 24.7f`
- `24.7L or 24.7l`
- `037`
- `0x1f, 0X1f, 0x1F`
- `0XFUL`

- int
- will be taken as long
- long (int)
- unsigned
- unsigned long
- double
- float
- long double
- octal (= 31 decimal)
- hexadecimal (= 31)
- What is this?

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Character Constants

`'x'`	letter `x`
`'2'`	numeric value 50
`'\0'`	NULL char, value 0
#define NEW_LINE '\012'	octal, 10 in decimal
#define NEW_LINE '\12'	'\ooo' 1 to 3 octal digits
#define SPACE '\x20'	hex, 32 in decimal

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Escape Sequences

\a	alert (bell) character	\\	backslash
\b	backspace	\?	question mark
\f	formfeed	\'	single quote
\n	newline	\"	double quote
\r	carriage return	*ooo*	octal number
\t	horizontal tab	\x*hh*	hexadecimal number
\v	vertical tab		

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String Constants

```
"hello, world\n"

""  /* empty string */

\"  /* double quote character */
```

`"hello," " world"` same as `"hello, world"`

- concatenated at compile time
- useful for splitting up long strings across several source lines.

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Constant Expressions

- Expressions that involve only constants.
- Evaluated during compilation.

```
#define MAXLINE 1000
char line[MAXLINE+1];

#define LEAP 1 /* in leap years */
int days[31+28+LEAP+31+30+31+30+31+31+30+31+30+31];
```

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Enumeration Constants

```
enum boolean { NO, YES };
```

- The first name in an enum has value 0, the next 1, and so on, unless explicit values are specified.

```
enum colours { black, white, red, blue, green };
enum escapes { BELL = '\a', BACKSPACE = '\b', TAB =
  '\t', NEWLINE = '\n', VTAB = '\v', RETURN = '\r'
  };
```

- If not all values are specified, unspecified values continue the progression from the last specified value.

```
enum months { JAN = 1, FEB, MAR, APR, MAY, JUN, JUL,
  AUG, SEP, OCT, NOV, DEC };
  /* FEB = 2, MAR = 3, etc. */
```

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Limits

- File `limits.h` provides several constants
  - char `CHAR_BIT, CHAR_MIN, CHAR_MAX, SCHAR_MIN, …`
  - int `INT_MIN, INT_MAX, UINT_MAX`
  - long `LONG_MIN, …`
- You can find `FLOAT_MIN, DOUBLE_MIN, …` in `<float.h>`

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Declarations (2.4)

- All variables must be declared before use (certain declarations can be made implicitly by content).
- A variable may also be initialized in its declaration.

```
char esc = '\\';
int i = 0;
int limit = MAXLINE+1;
float eps = 1.0e-5;
```

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Qualifier `const`

- Indicates that the value of a variable will not be changed.
- For an array: the elements will not be altered.

```
const double e = 2.71828182845905;
const char msg[] = "warning: ";
```

- Used with array arguments, to indicate that the function does not change that array.

```
int strlen( const char[] );
```

- Note: The result is implementation-defined if an attempt is made to change a const.

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Arithmetic Operators (2.5)

+ — * / %

Examples:

```
abc = x + y * z;
j = a % i;
++x;
x++;
x += 5;    /* x = x + 5; */
y /= z;    /* y = y / z */
```

What is **x *= y + 1 ?**

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Precedence and Associativity

Operators	Associativity
`() [] -> .`	left to right
`! ~ ++ -- + - * (type) sizeof`	right to left
`* / %`	left to right
`+ -`	left to right
`<< >>`	left to right
`< <= > >=`	left to right
`== !=`	left to right
`&`	left to right
`^`	left to right
`|`	left to right
`&&`	left to right
`||`	left to right
`?:`	right to left
`= += -= *= /= %= &= ^= |= <<= >>=`	right to left
`,`	left to right

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Type Conversion (2.7)

- `float f; int i;` What is the type of `f+i` ?
- General rule: convert a “narrower” operand into a “wider” one without losing information.
- So `i` is converted to float before the addition.
- `char` may be freely used in arithmetic expressions.

```
/* lower: convert c to lower case; ASCII only */
int lower(int c)
{
   if (c >= 'A' && c <= 'Z')
      return c - 'A' + 'a';
   else return c;
}
```

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Arithmetic Conversion

- When a binary operator has operands of different types, the “lower” type is *promoted* to the “higher” type before the operation proceeds.
- If either operand is long double, convert the other to long double.
- Otherwise, if either operand is double, convert the other to double.
- Otherwise, if either operand is float, convert the other to float.
- Otherwise, convert char and short to int.
- Then, if either operand is long, convert the other to long.

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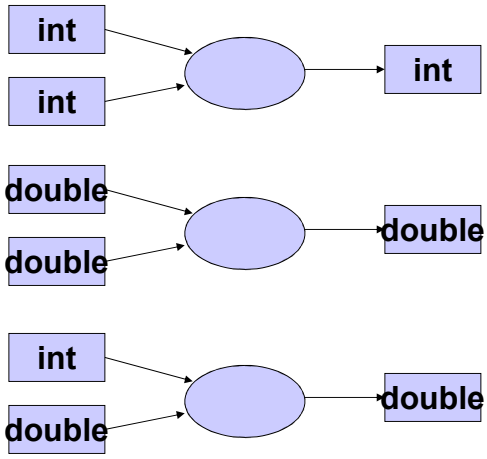
Arithmetic Conversion: Examples




```
int a=5, b=2, c;
double x, y = 2;

x = a/b;
        // x = 2.0
c = a/b;
        // c = 2
x = a/y;
        // x = 2.5
c = a/y;
        // c = 2
```

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More Examples

- 17 / 5
  - 3
- 17.0 / 5
  - 3.4
- 9 / 2 / 3.0 / 4
  - 9 / 2 = 4
  - 4 / 3.0 = 1.333
  - 1.333 / 4 = 0.333

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Type Conversion: More Rules

- Conversions take place across assignments; the value of the right side is converted to the type of the left, which is the type of the result.
- Example:

```
int a;
float x = 7, y = 2;
a = x / y;
```

- `float` to `int` causes truncation of any fractional part.
- Example:

```
float x, y = 2.7;
int i = 5;
x = i;   /* x = 5.0 */
i = y;  /* i = 2 */
```

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Type Conversion: Even More Rules

- Longer integers are converted to shorter ones or to chars by dropping the excess high-order bits.

```
int i;
char c;
i = c;
c = i;
/* c unchanged */
```

```
int i;
char c;
c = i;
i = c;
/* i may be changed */
```

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Casting

```
int A = 9, B = 2;
double  x;
x = A / B;    /* x is 4.0 */
x = A / (double)B; /* C is 4.5 */

int n;
sqrt(double(n))
```

Doesn't change the value of B, just changes the type to double

- The cast operator has the same high precedence as other unary operators.

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Increment and Decrement Operators (2.8)

- ++ or --
- Placing in front: incrementing or decrementing occurs **BEFORE** value assigned

i = 2 and k = 1

k = ++i;

```
i = i + 1; 3
k = i;     3
```

k =--i;

```
i = i - 1; 1
k = i;     1
```

- Placing after: occurs **AFTER** value assigned

i = 2 and k = 1

k = i++;

```
k = i;     2
i = i + 1; 3
```

k = i--;

```
k = i;     2
i = i - 1; 1
```

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Precedence and Associativity

Operators	Associativity
() [] -> .	left to right
! ~ ++ -- + - * (*type*) sizeof	right to left
* / %	left to right
+ -	left to right
<< >>	left to right
< <= > >=	left to right
== !=	left to right
&	left to right
^	left to right
|	left to right
&&	left to right
||	left to right
?:	right to left
= += -= *= /= %= &= ^= |= <<= >>=	right to left
,	left to right

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Examples

int a=2, b=3; c=5, d=7, e=11, f=3;

f += a/b/c; 3

d -= 7+c*--d/e; -3

d = 2*a%b+c+1; 7

a += b +=c += 1+2; 13

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Relational and Logic Operators (2.6)

- Relational operators:

  `>  >=  <  <=`

  `==  !=`
- Logical operators:

  `!  &&  ||`
- Evaluation stops as soon as the truth or falsehood of the result is known.

```
for ( i=0;
   i < lim-1 &&
   (c=getchar()) != '\n' &&
   c != EOF;
   ++i )
     s[i] = c;

if (valid == 0)
/* same as */
if (!valid)
```

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Boolean Expressions

- False is 0; any thing else is 1 (true).
- Write

```
if (!valid)
```

instead of

```
if (valid == 0)
```

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Bitwise Operators (2.9)

- Work on individual bits

  `&  |  ^  ~`

- Examples:

```
short int i=5, j=8;
k=i&j;
k=i|j;
k=~j;
```

```
a =1;
b = 2;
c = a & b; /*c = 0*/
d = a && b; /*d = 1*/
```

- Application: bit masking

```
n = n & 0177;
x = x | SET_ON;
```

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Bit Shifting

- x<<y means shift x to the left y times.
  - equivalent to multiplication by 2^y
- x>>y means shift x to the right y bits.
  - equivalent to division by 2^y
- Left shifting 3 many times:

0 3
1 6
2 12
3 24
4 48
5 ...

13 49512
14 32768

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Right Shifting

- It could be logical (0) or arithmetic (signed)
- If unsigned, 0; if signed undefined in C

```
unsigned int i = 714;
```

357 178 89 44 22 11 5 2 1 0

- What if i = -714 ?

-357 -178 -89 . . . -3 -2 -1 -1 -1 -1

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Bitwise Operators: Examples

```
x = x & ~077;
```

sets the last six bits of x to zero.

```
/* getbits: get n bits from position p */
unsigned getbits(unsigned x, int p, int n)
{
  return (x >> (p+1-n)) & ~(~0 << n);
}
```

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Assignment Operators / Expressions (2.10)

- A *= B; // equivalent to
- A = (A) * (B); // note the parentheses
- Can be used with: `+ – * / % << >> & ^ |`

```
yyval[yypv[p3+p4] + yypv[p1]] += 2

/* bitcount: count 1 bits in x */
int bitcount(unsigned x) {
   int b;
   for ( b = 0; x != 0; x >>= 1 )
       if ( x & 01 )
              b++;
   return b;
}
```

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Conditional Expressions (2.11)

`exp1 ? exp2 : exp3`

- If exp1 is true, the value of the conditional expression is exp2; otherwise, exp3.

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

- If **`expr2`** and **`expr3`** are of different types, the type of the result is determined by the conversion rules discussed earlier.

```
int n; float f;
(n > 0) ? f : n
/* result of type float in either case */
```

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Conditional Expressions: Advantage

- Succinct code

- Example 1:

```
for (i = 0; i < n; i++)
  printf("%6d%c", a[i],
      (i%10==9 || i==n-1) ? '\n' : ' ');
```

- Example 2:

```
printf("You have %d item%s.\n", n,
  n==1 ? "" : "s");
```

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Precedence and Order of Evaluation (2.12)

Operators	Associativity
`() [] -> .`	left to right
`! ~ ++ -- + - * (type) sizeof`	right to left
`* / %`	left to right
`+ -`	left to right
`<< >>`	left to right
`< <= > >=`	left to right
`== !=`	left to right
`&`	left to right
`^`	left to right
`|`	left to right
`&&`	left to right
`||`	left to right
`?:`	right to left
`= += -= *= /= %= &= ^= |= <<= >>=`	right to left
`,`	left to right

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Next time ...

- Control Flow (Chapter 3, C book)
- Functions and program structures (Chapter 4, C book)
- Basic UNIX (Chapter 1, UNIX book)

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