Announcements

- Program #1B
  - Due a week from Thursday
- Reading
  - Chapter 5 (today)
  - Chapter 15 (Thursday)

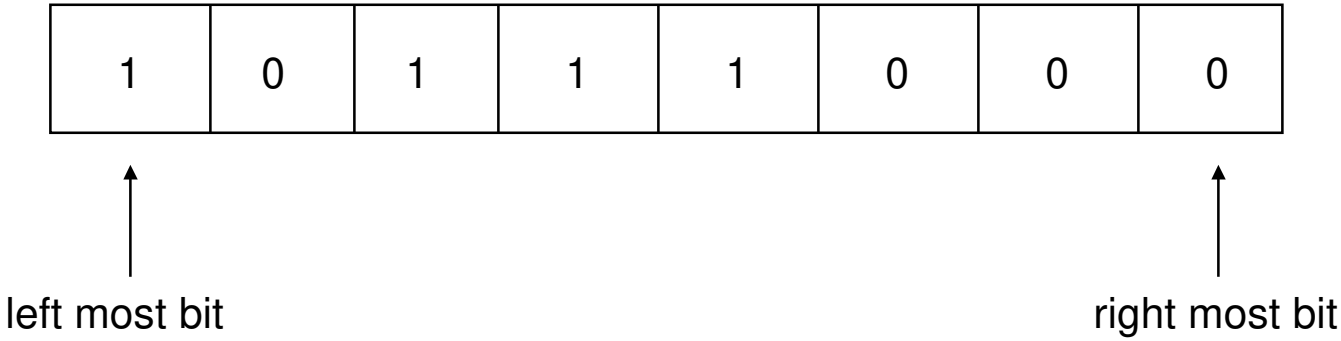
Arithmetic Operators

+ Add two numbers
- Subtract two numbers
* Multiply two numbers
/ Divide two numbers
    For integers, divide truncates to the integer portion
% Remainder of integer divide (also known as mod)

All except % may be used with integers or floats

Bit Operations

- Numbers are represented by a fixed number of bits
  - typically int = 32 bits, char = 8 bits, long = 32 or 64 bits
- C permits direct manipulation of bits within a number
  - This is powerful: can get exactly what you want
  - This can be non-portable: easy to write programs that don't work on different types of computers
- Numbers as a series of bits:



Bit Shift Operator

- C has operators to bit shift numbers
  - number of bits changed depends on size of variable

- Left Shift (number << n)
  - Move each bit of number to the left by n bit positions
  - Leftmost n bits discarded
  - Rightmost n bits gets 0
- Right Shift (number >> n)
  - Move each bit of number to the right by n bit positions
  - Rightmost n bits discarded
  - Leftmost n bits gets 0 (**or can replicate sign bit - so 1 if negative)**
    - for unsigned gets 0
    - for signed, it is **implementation dependent**
  - There is no >>> operator in C.

Examples of Bit Shift

```
unsigned int a, b;
a = 0x0000 0010;
b = a >> 1;          /* b is now 0x0000 0008 */
b = a >> 4;          /* b is now 0x0000 0001 */
b = a >> 5;          /* b is now 0x0000 0000 */

b = a << 1;          /* b is now 0x0000 0020 */
b = a << 4;          /* b is now 0x0000 0100 */
b = a << 5;          /* b is now 0x0000 0200 */
```

Bitwise Operators

- And (&)
  - for each bit in two numbers, "and" the bits together
- Or (|)
  - for each bit in two numbers, "or" the bits together
- Xor (^)
  - for each bit in two numbers, "xor" the bits toegher

And

	0	1
0	0	0
1	0	1

Or

	0	1
0	0	1
1	1	1

Xor

	0	1
0	0	1
1	1	0

Assignment Operator

- Assignment is an operator and the operations specified take place in a sequence:
  - x = y + 3;
  - a = x = y + 3;
  - assignment is right associative, so
    - a = x = y + 3 is the same as a = (x = y + 3)
  - value of assignment operator is result of assignment
    - if truncation is applied, the truncated value is used
    - Consider: (reminder: char is only 8 bits)

```
unsigned char x;
unsigned int a, b;
b = 0xabcd;
a = x = b;
```

at the end, a = 0x00cd;

Compound Assignment

- Shorthand to combine binary operator and assignment
  - += add right operand the left operand and update left
    - a += 3 is equivalent to a = a + 3
  - Also: -=, *=, /=, %=, <<=, >>=, &=, ^=, |=
- Handy for complex expressions in LHS
  - a[i * 2 + j - f(n)] = a[i * 2 + j - f(n)] + 3;
  - a[i * 2 + j - f(n)] += 3;
  - assumes f(n) has no side effects and returns the same value on the two sequential calls to that same function

Unary Operators

- ! logical not operator
  - if the operand is true, result is false
  - if the operand is false, result is true
  - is really an integer operand
    - produces 0 for false
    - produces 1 for true
  - b = !(a == 3); b = (a != 3); b = (a < 3 || a > 3);
- ~ bit-wise negation (ones complement)
  - flip each bit position
  - b = ~a;
- - negation (twos complement)
  - changes sign of a number
  - a = 3;
  - b = -a; /* b is now -3 */

Unary Operators (cont.)

- & Returns the address of a variable
  - int a, *b;
  - a = 3;
  - b = & a; /* b now holds the location (address) of a */
- * Dereferences a pointer
  - int a, *b;
  - a = 3;
  - b = & a; /* b now holds the location (address) of a */
  - printf("%d and %d\n", a, *b); /* 3 printed twice */
- sizeof - return number of bytes in variable or type
  - int a;
  - sizeof int
  - sizeof(int)
  - sizeof(a)
- (<typeName>) - cast to a new type
  - float a; int c,d;
  - a = (float) c / d;

Unary Operators (cont.)

- ++ increment operator
  - can be prefix or postfix

  ++a - add one to a and use new value as result of expression.

  a++ - add one to a and use old value as result of expression.
- -- decrement operator
  - can be prefix or postfix

  --a - subtract one from a and use new value as result of expression

  a-- - subtract one from a and use old value as result of expression.

Examples:

```
a = 10;
c = ++a;
```

```
a = 10;
c = a++;
```

```
b = 2; c = 4;
a = ++b * c++;
```

```
int c=2,a=10,*b;
b = &a;
c = *b++;
```

Relational Operators

- Take two operands, result is integer
  - 0 for false, 1 for true
  - > >= < <= != ==
- != is not equal
- == is equal
- Can use variable in conditional
  - int a;
  - if (a) { … is the same as if (a != 0) { … [note: different if (a==1)]
  - if (!a) { … is the same as if (a == 0) {

Logical Operators

- && - and
  - if both operands are non-zero result is 1
  - else result is 0
  - uses short-circuit evaluation
    - if the first operand is not true, second is not evaluated
    - if ((a++) && (--b)) { .. }
- || or
  - if either operands is non-zero result is 1
  - else result is 1
  - also uses short-circuit evaluation
    - if the first operand is true, second is not evaluated
- Caution: && is not the same as &
  - & performs a bitwise operation
- Caution: || is not the same as |
  - | performs a bitwise operation

Other Operators

- trinary conditional operator
  - expr1 ? expr2 : expr3
  - if expr1 is non-zero, expr2 is evaluated and is the result
  - if expr1 is zero, expr3 is evaluated and is the result
  - a = (2 > 3) ? 65 : 17;
- Comma operator
  - evaluates both operands, rightmost is the result
  - a = (1,3,2); vs. b = 1,3,2;
    - assignment is higher precedence than ,
    - a ends up 2 and b ends up 1

Type Conversion

- Promotion of char and short
  - in expressions, char and short are promoted to int

    char a, b; int c;

    a = b + c;
    - b is converted to int, then the sum is truncated
  - even if a, b and c are all char – b and c are converted to int
- Arithmetic Conversions
  - arithmetic can't be performed on operators of different types
    - converted to "higher" type

      long double ← Highest Type

      double

      float

      unsigned long int

      long int

      unsigned int

      int

Precedence

- There is a set of rules about precedence of operator
  - Most important precedence rule:
    - When in doubt, put in () to ensure correct order
  - Order (highest to lowest):
    - ()
    - Function call, subscript, postfix increment/decrement
    - rest of unary operators
    - type conversion
    - Arithmetic operators
    - Relational operators
    - Bit operators
    - Assignment operators
    - comma operator