Operators

CS 217

Arithmetic Operators

- Binary arithmetic operators: **+ - * /**
- Modulus (remainder) operator: **%**
  - **x%y** is the remainder when **x** is divided by **y**
  - well defined only when **x > 0** and **y > 0**
- Unary operators: **- +**
- Precedence: unary higher than binary
  - **-2*a+b** is parsed as **(((-2)*a)+b**
- Associativity: left to right
  - **a+b+c** is parsed as **((a+b)+c)**

Portability

- Print a number in decimal

```
void putd(int n) {
   if (n < 0) {
      putchar('-');
      n = -n;
   }
   if (n >= 10)
      putd(n/10);
   putchar(n%10 + '0');
}
```

- Can this program print
  INT_MIN == –2147483648

Machine Arithmetic

- Computer values are of fixed-length (32-bits)
- For example, with 6-bits (0..5, right to left)
  - largest number: $111111_2 = 63_{10} = 2^6 - 1$
  - smallest number: $000000_2 = 0$
- What is 50 + 20?

```
  110010
+ 010100
 1000110
```

- Spilling over the lefthand side is overflow

Machine Arithmetic (cont)

- Sign-magnitude notation
  - bit n-1 is the sign; 0 for **+**, 1 for **–**
  - bits n-2 through 0 hold an unsigned number
  - largest number: $01111\ldots111_2 = 2^{n-1} - 1$
  - smallest number: $11111\ldots111_2 = -(2^{n-1} - 1)$
  - addition and subtraction are complicated when signs differ, so sign-magnitude is rarely used

Machine Arithmetic (cont)

- One's-complement notation
  - bit n-1 is the sign; bits n-2..0 hold an unsigned number
  - bits n-2..0 hold the complement of negative numbers
  - $-k = (2^n - 1) - k = 1111\ldots111 - k$
  - largest number: $01111\ldots111_2 = 2^{n-1} - 1$
  - smallest number: $10000\ldots000_2 = -(2^{n-1} - 1)$
  - addition and subtraction are easy, but there are two representations for 0

Machine Arithmetic (cont)

- Two's-complement notation

  bit n-1 is the sign; bits n-2..0 hold an unsigned number

  bits n-2..0 hold the complement of negative numbers +1

  -k = (2^n – k) = (2^n – 1)- k + 1

  largest number: **01111…111$_2$ = 2^{n-1} – 1**

  smallest number: **10000…000$_2$ = -2^{n-1}**

  6-bit examples: "complement and increment" to negate

```
  +6  000110   111001   111010   -6
  -6  111010   000101   000110   +6
  +0  000000   111111   000000   +0
 +31  011111   100000   100001  -31
 -32  100000   011111   100000  -32
```


Machine Arithmetic (cont)

- To add 2's-complement number, ignore signs and add the unsigned bit strings

```
   +20    010100      -20    101100
 + - 7  + 111001    + + 7  + 000111
   +13    001101      -13    110011

   +20    010100      -20    101100
 + + 7  + 000111    + - 7  + 111001
   +27    011011      -27    100101
```

- Signed overflow occurs if the carry into the sign bit differs from the carry out of the sign bit

```
   +20    010100      -20    101100
 + +17  + 010001    + -17  + 101111
   -27    100101      +27    011011
```


Return to `putd` Example

- Convert negative numbers

```
static void putneg(int n) {
   if (n <= -10)
      putneg(n/10);
   putchar("0123456789"[-(n%10)]);
}
void putd(int n) {
   if (n < 0) {
      putchar('-');
      putneg(n);
   } else
   putneg(-n);
}
```

Portability (cont)

- `n/10` and `n%10` are implementation dependent when `n < 0`

```
int a, b, q, r;
q = a/b; r = a%b;
```

ANSI Standard guarantees only that

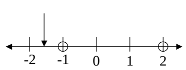
```
q*b + r == a
|r| < |b|
```

`r >= 0` when `a >= 0 && b > 0`

`r` might be negative if `a` is negative

Portability (cont)

`5/(-3) = -1.666…`




```
if 5/(-3) == -2
   5%(-3) = 5 – (-2)(-3) = -1
if 5/(-3) == -1
   5%(-3) = 5 – (-1)(-3) = 2
```


Portability (cont)

- Check for sign of `n%10`; handle both cases

```
static void putneg(int n) {
   int q = n/10, r = n%10;
   if (r > 0) {
      r -= 10;
      q++;
   }
   if (n <= -10)
      putneg(q);
   putchar(“0123456789”[-r]);
}
```

An Easier Way

```
#include <limits.h>
#include <stdio.h>
static void putu(unsigned n) {
   if (n > 10)
      putchar("0123456789"[n%10]);
}
void putd(int n) {
   if (n == INT_MIN) {
      putchar('-');
      putu((unsigned)INT_MAX+1);
   } else if (n < 0) {
      putchar('-');
      putu(-n);
   } else
      putu(n);
}
```


Increment/Decrement

- Prefix ops increment before returning value
  n = 5;
  x = ++n;
  x is **6, n** is **6**
- Postfix ops increment after returning value
  n = 5;
  x = n++;
  x is **5, n** is **6**
- Operands of **++** and **--** must be variables

Relational & Logical Ops

- Logical values are **ints**: **0** is false **!0** is true
- Relational ops: **> >= < <=**
- Equality ops: **== !=**
- Unary logical negation: **!**
- Logical connectives: **&& ||**
- Evaluation is left-to-right as far as needed
  && stops when outcome known to be **0**
  || stops when outcome known to be **!0**

Bit Operations

- Bitwise logical operations apply to all integers

```
&  bitwise AND           1&1=1 0&1=0
|  bitwise inclusive OR  1|0=1 0|0=0
^  bitwise exclusive OR  1^1=0 1^0=1
~  bitwise complement    ~1=0 ~0=1
```

- The **|** operation is used to “turn on” bits

```
#define BIT0 0x1
#define BIT1 0x2
#define BITS (BIT0 | BIT1)
flags = flags | BIT0;
```

- The **&** op is used to “mask off” bits

```
test = flags & BITS;
```


Bit Operations (cont)

- Assuming 16-bit quantities

```
BIT0 =         0000000000000001
BIT1 =         0000000000000010
BITS =         0000000000000011
flags =        0100011100000001
flags | BITS = 0100011100000011
flags & BITS = 0000000000000001
```


Shifting

- Shift operators: `<<` `>>`
  - `x<<y` shifts `x` left `y` bit positions
  - `x>>y` shifts `x` right `y` bit positions
- When shifting right:
  - if `x` is signed, may be logical or arithmetic
  - if `x` is unsigned, shift is always logical
  - arithmetic shift fills with sign bit
  - logical shift fills with `0`
- When shifting left: always fill with `0`

Shifting (cont)

- Assuming 16-bit quantities

```
bits =      1100011100000001
bits << 2 = 0001110000000100
bits >> 2 = 1111000111000000  (arithmetic)
bits >> 2 = 0011000111000000  (logical)
```

- Which do you get?

  implementor's choice (i.e., not portable)

Fall 2001 19

Assignment

- Assignment is an operator, not a statement

```
c = getchar();
if (c == EOF) . . .
```

can be written as

```
if ((c = getchar()) == EOF) . . .
```

- Watch out for typos

```
if (c = EOF) . . .
```

- Combine assignment with other operators

```
i = i + 2;      is the same as  i += 2;
f = f | BITS    is the same as  f |= BITS;
```

Fall 2001 20