The Complete Reference

Chapter 2

Expressions

This chapter examines the most fundamental element of the C (as well as the C++) language: the expression. As you will see, expressions in C/C++ are substantially more general and more powerful than in most other computer languages. Expressions are formed from these atomic elements: data and operators. Data may be represented either by variables or by constants. Like most other computer languages, C/C++ supports a number of different types of data. It also provides a wide variety of operators.

The Five Basic Data Types

There are five atomic data types in the C subset: character, integer, floating-point, double floating-point, and valueless (**char**, **int**, **float**, **double**, and **void**, respectively). As you will see, all other data types in C are based upon one of these types. The size and range of these data types may vary between processor types and compilers. However, in all cases a character is 1 byte. The size of an integer is usually the same as the word length of the execution environment of the program. For most 16-bit environments, such as DOS or Windows 3.1, an integer is 16 bits. For most 32-bit environments, such as Windows 2000, an integer is 32 bits. However, you cannot make assumptions about the size of an integer if you want your programs to be portable to the widest range of environments. It is important to understand that both C and C++ only stipulate the *minimal range* of each data type, not its size in bytes.

Note *To the five basic data types defined by C, C++ adds two more:* ***bool*** *and* ***wchar_t****. These are discussed in Part Two.*

The exact format of floating-point values will depend upon how they are implemented. Integers will generally correspond to the natural size of a word on the host computer. Values of type **char** are generally used to hold values defined by the ASCII character set. Values outside that range may be handled differently by different compilers.

The range of **float** and **double** will depend upon the method used to represent the floating-point numbers. Whatever the method, the range is quite large. Standard C specifies that the minimum range for a floating-point value is 1E–37 to 1E+37. The minimum number of digits of precision for each floating-point type is shown in Table 2-1.

Note *Standard C++ does not specify a minimum size or range for the basic types. Instead, it simply states that they must meet certain requirements. For example, Standard C++ states that an* ***int*** *will "have the natural size suggested by the architecture of the execution environment." In all cases, this will meet or exceed the minimum ranges specified by Standard C. Each C++ compiler specifies the size and range of the basic types in the header* ***<climits>****.*

Type	Typical Size in Bits	Minimal Range
char	8	–127 to 127
unsigned char	8	0 to 255
signed char	8	–127 to 127
int	16 or 32	–32,767 to 32,767
unsigned int	16 or 32	0 to 65,535
signed int	16 or 32	same as **int**
short int	16	–32,767 to 32,767
unsigned short int	16	0 to 65,535
signed short int	16	same as **short int**
long int	32	–2,147,483,647 to 2,147,483,647
signed long int	32	same as **long int**
unsigned long int	32	0 to 4,294,967,295
float	32	Six digits of precision
double	64	Ten digits of precision
long double	80	Ten digits of precision

Table 2-1. *All Data Types Defined by the ANSI/ISO C Standard*

The type **void** either explicitly declares a function as returning no value or creates generic pointers. Both of these uses are discussed in subsequent chapters.

Modifying the Basic Types

Except for type **void**, the basic data types may have various modifiers preceding them. You use a *modifier* to alter the meaning of the base type to fit various situations more precisely. The list of modifiers is shown here:

signed
unsigned
long
short

You can apply the modifiers **signed**, **short**, **long**, and **unsigned** to integer base types. You can apply **unsigned** and **signed** to characters. You may also apply **long** to **double**. Table 2-1 shows all valid data type combinations, along with their minimal ranges and approximate bit widths. (These values also apply to a typical C++ implementation.) Remember, the table shows the *minimum range* that these types will have as specified by Standard C/C++, not their typical range. For example, on computers that use two's complement arithmetic (which is nearly all), an integer will have a range of at least 32,767 to –32,768.

The use of **signed** on integers is allowed, but redundant because the default integer declaration assumes a signed number. The most important use of **signed** is to modify **char** in implementations in which **char** is unsigned by default.

The difference between signed and unsigned integers is in the way that the high-order bit of the integer is interpreted. If you specify a signed integer, the compiler generates code that assumes that the high-order bit of an integer is to be used as a *sign flag*. If the sign flag is 0, the number is positive; if it is 1, the number is negative.

In general, negative numbers are represented using the *two's complement* approach, which reverses all bits in the number (except the sign flag), adds 1 to this number, and sets the sign flag to 1.

Signed integers are important for a great many algorithms, but they only have half the absolute magnitude of their unsigned relatives. For example, here is 32,767:

```
0 1 1 1 1 1 1 1  1 1 1 1 1 1 1 1
```

If the high-order bit were set to 1, the number would be interpreted as –1. However, if you declare this to be an **unsigned int**, the number becomes 65,535 when the high-order bit is set to 1.

When a type modifier is used by itself (that is, when it does not precede a basic type), then **int** is assumed. Thus, the following sets of type specifiers are equivalent:

Specifier	Same As
signed	signed int
unsigned	unsigned int
long	long int
short	short int

Although the **int** is implied, many programmers specify the **int** anyway.

Identifier Names

In C/C++, the names of variables, functions, labels, and various other user-defined objects are called *identifiers*. These identifiers can vary from one to several characters.

The first character must be a letter or an underscore, and subsequent characters must be either letters, digits, or underscores. Here are some correct and incorrect identifier names:

Correct	Incorrect
Count	1count
test23	hi!there
high_balance	high...balance

In C, identifiers may be of any length. However, not all characters will necessarily be significant. If the identifier will be involved in an external link process, then at least the first six characters will be significant. These identifiers, called *external names*, include function names and global variables that are shared between files. If the identifier is not used in an external link process, then at least the first 31 characters will be significant. This type of identifier is called an *internal name* and includes the names of local variables, for example. In C++, there is no limit to the length of an identifier, and at least the first 1,024 characters are significant. This difference may be important if you are converting a program from C to C++.

In an identifier, upper- and lowercase are treated as distinct. Hence, **count**, **Count**, and **COUNT** are three separate identifiers.

An identifier cannot be the same as a C or C++ keyword, and should not have the same name as functions that are in the C or C++ library.

Variables

As you probably know, a *variable* is a named location in memory that is used to hold a value that may be modified by the program. All variables must be declared before they can be used. The general form of a declaration is

type variable_list;

Here, *type* must be a valid data type plus any modifiers, and *variable_list* may consist of one or more identifier names separated by commas. Here are some declarations:

```
int i,j,l;
short int si;
unsigned int ui;
double balance, profit, loss;
```

Remember, in C/C++ the name of a variable has nothing to do with its type.

Where Variables Are Declared

Variables will be declared in three basic places: inside functions, in the definition of function parameters, and outside of all functions. These are local variables, formal parameters, and global variables.

Local Variables

Variables that are declared inside a function are called *local variables*. In some C/C++ literature, these variables are referred to as *automatic* variables. This book uses the more common term, local variable. Local variables may be referenced only by statements that are inside the block in which the variables are declared. In other words, local variables are not known outside their own code block. Remember, a block of code begins with an opening curly brace and terminates with a closing curly brace.

Local variables exist only while the block of code in which they are declared is executing. That is, a local variable is created upon entry into its block and destroyed upon exit.

The most common code block in which local variables are declared is the function. For example, consider the following two functions:

```
void func1(void)
{
  int x;

  x = 10;
}

void func2(void)
{
  int x;

  x = -199;
}
```

The integer variable **x** is declared twice, once in **func1( )** and once in **func2( )**. The **x** in **func1( )** has no bearing on or relationship to the **x** in **func2( )**. This is because each **x** is known only to the code within the block in which it is declared.

The C language contains the keyword **auto**, which you can use to declare local variables. However, since all nonglobal variables are, by default, assumed to be **auto**, this keyword is virtually never used. Hence, the examples in this book will not use it. (It has been said that **auto** was included in C to provide for source-level compatibility with its predecessor B. Further, **auto** is supported in C++ to provide compatibility with C.)

For reasons of convenience and tradition, most programmers declare all the variables used by a function immediately after the function's opening curly braceand before any other statements. However, you may declare local variables within any code block. The block defined by a function is simply a special case. For example,

```
void f(void)
{
  int t;

  scanf("%d%*c", &t);

  if(t==1) {
    char s[80];  /* this is created only upon
                    entry into this block */
    printf("Enter name:");
    gets(s);
    /* do something ... */
  }
}
```

Here, the local variable **s** is created upon entry into the **if** code block and destroyed upon exit. Furthermore, **s** is known only within the **if** block and may not be referenced elsewhere—even in other parts of the function that contains it.

Declaring variables within the block of code that uses them helps prevent unwanted side effects. Since a variable does not exist outside the block in which it is declared, it cannot be accidentally altered.

There is an important difference between C (as defined by C89) and C++ as to where you can declare local variables. In C, you must declare all local variables at the start of a block, prior to any "action" statements. For example, in C89 the following function is in error.

```
/* For C89, this function is in error,
   but it is perfectly acceptable for C++.
*/
void f(void)
{
  int i;

  i = 10;

  int j;  /* this line will cause an error */
```

```
  j = 20;
}
```

However, in C++, this function is perfectly valid because you can declare local variables at any point within a block, prior to their first use. (The topic of C++ variable declaration is discussed in depth in Part Two.) As a point of interest, C99 allows you to define variables at any point within a block.

Because local variables are created and destroyed with each entry and exit from the block in which they are declared, their content is lost once the block is left. This is especially important to remember when calling a function. When a function is called, its local variables are created, and upon its return they are destroyed. This means that local variables cannot retain their values between calls. (However, you can direct the compiler to retain their values by using the **static** modifier.)

Unless otherwise specified, local variables are stored on the stack. The fact that the stack is a dynamic and changing region of memory explains why local variables cannot, in general, hold their values between function calls.

You can initialize a local variable to some known value. This value will be assigned to the variable each time the block of code in which it is declared is entered. For example, the following program prints the number 10 ten times:

```
#include <stdio.h>

void f(void);

int main(void)
{
  int i;

  for(i=0; i<10; i++)  f();

  return 0;
}

void f(void)
{
  int j = 10;

  printf("%d ", j);

  j++;  /* this line has no lasting effect */
}
```

Formal Parameters

If a function is to use arguments, it must declare variables that will accept the values of the arguments. These variables are called the *formal parameters* of the function. They behave like any other local variables inside the function. As shown in the following program fragment, their declarations occur after the function name and inside parentheses:

```
/* Return 1 if c is part of string s; 0 otherwise */
int is_in(char *s, char c)
{
  while(*s)
    if(*s==c) return 1;
    else s++;

  return 0;
}
```

The function **is_in( )** has two parameters: **s** and **c**. This function returns 1 if the character specified in **c** is contained within the string **s**; 0 if it is not.

You must specify the type of the formal parameters by declaring them as just shown. Then you may use them inside the function as normal local variables. Keep in mind that, as local variables, they are also dynamic and are destroyed upon exit from the function.

As with local variables, you may make assignments to a function's formal parameters or use them in any allowable expression. Even though these variables receive the value of the arguments passed to the function, you can use them like any other local variable.

Global Variables

Unlike local variables, *global variables* are known throughout the program and may be used by any piece of code. Also, they will hold their value throughout the program's execution. You create global variables by declaring them outside of any function. Any expression may access them, regardless of what block of code that expression is in.

In the following program, the variable **count** has been declared outside of all functions. Although its declaration occurs before the **main( )** function, you could have placed it anywhere before its first use as long as it was not in a function. However, it is usually best to declare global variables at the top of the program.

```
#include <stdio.h>
int count;  /* count is global */

void func1(void);
```

```
void func2(void);

int main(void)
{
  count = 100;
  func1();

  return 0;
}

void func1(void)
{
  int temp;

  temp = count;
  func2();
  printf("count is %d", count); /* will print 100 */
}

void func2(void)
{
  int count;

  for(count=1; count<10; count++)
    putchar('.');
}
```

Look closely at this program. Notice that although neither **main( )** nor **func1( )** has declared the variable **count**, both may use it. **func2( )**, however, has declared a local variable called **count**. When **func2( )** refers to **count**, it refers to only its local variable, not the global one. If a global variable and a local variable have the same name, all references to that variable name inside the code block in which the local variable is declared will refer to that local variable and have no effect on the global variable. This can be convenient, but forgetting it can cause your program to act strangely, even though it looks correct.

Storage for global variables is in a fixed region of memory set aside for this purpose by the compiler. Global variables are helpful when many functions in your program use the same data. You should avoid using unnecessary global variables, however. They take up memory the entire time your program is executing, not just when they are needed. In addition, using a global where a local variable would do makes a function less general because it relies on something that must be defined outside itself. Finally, using a large number of global variables can lead to program errors because of unknown

and unwanted side effects. A major problem in developing large programs is the accidental changing of a variable's value because it was used elsewhere in the program. This can happen in C/C++ if you use too many global variables in your programs.

The const and volatile Qualifiers

There are two qualifiers that control how variables may be accessed or modified: **const** and **volatile**. They must precede the type modifiers and the type names that they qualify. These qualifiers are formally referred to as the *cv-qualifiers*.

const

Variables of type **const** may not be changed by your program. (A **const** variable can be given an initial value, however.) The compiler is free to place variables of this type into read-only memory (ROM). For example,

```
const int a=10;
```

creates an integer variable called **a** with an initial value of 10 that your program may not modify. However, you can use the variable **a** in other types of expressions. A **const** variable will receive its value either from an explicit initialization or by some hardware-dependent means.

The **const** qualifier can be used to protect the objects pointed to by the arguments to a function from being modified by that function. That is, when a pointer is passed to a function, that function can modify the actual variable pointed to by the pointer. However, if the pointer is specified as **const** in the parameter declaration, the function code won't be able to modify what it points to. For example, the **sp_to_dash( )** function in the following program prints a dash for each space in its string argument. That is, the string "this is a test" will be printed as "this-is-a-test". The use of **const** in the parameter declaration ensures that the code inside the function cannot modify the object pointed to by the parameter.

```
#include <stdio.h>

void sp_to_dash(const char *str);

int main(void)
{
  sp_to_dash("this is a test");

  return 0;
}
```

```
void sp_to_dash(const char *str)
{
  while(*str) {
    if(*str== ' ') printf("%c", '-');
    else printf("%c", *str);
    str++;
  }
}
```

If you had written **sp_to_dash( )** in such a way that the string would be modified, it would not compile. For example, if you had coded **sp_to_dash( )** as follows, you would receive a compile-time error:

```
/* This is wrong. */
void sp_to_dash(const char *str)
{
  while(*str) {
    if(*str==' ' ) *str = '-'; /* can't do this; str is const */
    printf("%c", *str);
    str++;
  }
}
```

Many functions in the standard library use **const** in their parameter declarations. For example, the **strlen( )** function has this prototype:

size_t strlen(const char *_str_);

Specifying *str* as **const** ensures that **strlen( )** will not modify the string pointed to by *str*. In general, when a standard library function has no need to modify an object pointed to by a calling argument, it is declared as **const.**

You can also use **const** to verify that your program does not modify a variable. Remember, a variable of type **const** can be modified by something outside your program. For example, a hardware device may set its value. However, by declaring a variable as **const**, you can prove that any changes to that variable occur because of external events.

volatile

The modifier **volatile** tells the compiler that a variable's value may be changed in ways not explicitly specified by the program. For example, a global variable's address may be passed to the operating system's clock routine and used to hold the real time of the

system. In this situation, the contents of the variable are altered without any explicit assignment statements in the program. This is important because most C/C++ compilers automatically optimize certain expressions by assuming that a variable's content is unchanging if it does not occur on the left side of an assignment statement; thus, it might not be reexamined each time it is referenced. Also, some compilers change the order of evaluation of an expression during the compilation process. The **volatile** modifier prevents these changes.

You can use **const** and **volatile** together. For example, if 0x30 is assumed to be the value of a port that is changed by external conditions only, the following declaration would prevent any possibility of accidental side effects:

```
const volatile char *port = (const volatile char *) 0x30;
```

Storage Class Specifiers

There are four storage class specifiers supported by C:

extern
static
register
auto

These specifiers tell the compiler how to store the subsequent variable. The general form of a declaration that uses one is shown here.

storage_specifier type var_name;

Notice that the storage specifier precedes the rest of the variable declaration.

Note *C++ adds another storage-class specifier called **mutable**, which is described in Part Two.*

extern

Before examining **extern**, a brief description of C/C++ linkage is in order. C and C++ define three categories of linkage: external, internal, and none. In general, functions and global variables have external linkage. This means that they are available to all files that comprise a program. Global objects declared as **static** (described in the next section) have internal linkage. These are known only within the file in which they are declared. Local variables have no linkage and are therefore known only within their own block.

The principal use of **extern** is to specify that an object is declared with external linkage elsewhere in the program. To understand why this is important it is necessary

to understand the difference between a *declaration* and a *definition*. A declaration declares the name and type of an object. A definition causes storage to be allocated for the object. While there can be many declarations of the same object, there can be *only one* definition for the object.

In most cases, variable declarations are also definitions. However, by preceding a variable name with the **extern** specifier, you can declare a variable without defining it. Thus, when you need to refer to a variable that is defined in another part of your program, you can declare that variable using **extern**.

Here is an example that uses **extern**. Notice that the global variables **first** and **last** are declared *after* **main( )**.

```
#include <stdio.h>

int main(void)
{
  extern int first, last; /* use global vars */

  printf("%d %d", first, last);

  return 0;
}

/* global definition of first and last */
int first = 10, last = 20;
```

This programs outputs **10 20** because the global variables **first** and **last** used by the **printf( )** statement are initialized to these values. Because the **extern** declaration in **main( )** tells the compiler that **first** and **last** are declared elsewhere (in this case, later in the same file), the program can be compiled without error even though **first** and **last** are used prior to their definition.

It is important to understand that the **extern** variable declarations as shown in the preceding program are necessary only because **first** and **last** had not yet been declared prior to their use in **main( )**. Had their declarations occurred prior to **main( )**, then there would have been no need for the **extern** statement. Remember, if the compiler finds a variable that has not been declared within the current block, the compiler checks if it matches any of the variables declared within enclosing blocks. If it does not, the compiler then checks the previously declared global variables. If a match is found, the compiler assumes that that is the variable being referenced. The **extern** specifier is needed when you want to use a variable that is declared later in the file.

As mentioned, **extern** allows you to declare a variable without defining it. However, if you give that variable an initialization, then the **extern** declaration becomes a definition. This is important because an object can have multiple declarations, but only one definition.

There is an important use of **extern** that relates to mutiple-file programs. In C/C++, a program can be spread across two or more files, compiled separately, and then linked together. When this is the case, there must be some way of telling all the files about the global variables required by the program. The best (and most portable) way to do this is to declare all of your global variables in one file and use **extern** declarations in the other, as in Figure 2-1.

In File Two, the global variable list was copied from File One and the **extern** specifier was added to the declarations. The **extern** specifier tells the compiler that the variable types and names that follow it have been defined elsewhere. In other words, **extern** lets the compiler know what the types and names are for these global variables without actually creating storage for them again. When the linker links the two modules, all references to the external variables are resolved.

In real world, multi-file programs, **extern** declarations are normally contained in a header file that is simply included with each source code file. This is both easier and less error prone than manually duplicating **extern** declarations in each file.

In C++, the **extern** specifier has another use, which is described in Part Two.

Note ***extern*** *can also be applied to a function declaration, but doing so is redundant.*

File One

```
int x, y;
char ch;
int main(void)
{
 /* ... */
}

void func1(void)
{
 x = 123;
}
```

File Two

```
extern int x, y;
extern char ch;
void func22(void)
{
 x = y / 10;
}

void func23(void)
{
 y = 10;
}
```

Figure 2-1. *Using global variables in separately compiled modules*

static Variables

static variables are permanent variables within their own function or file. Unlike global variables, they are not known outside their function or file, but they maintain their values between calls. This feature makes them useful when you write generalized functions and function libraries that other programmers may use. **static** has different effects upon local variables and global variables.

static Local Variables

When you apply the **static** modifier to a local variable, the compiler creates permanent storage for it, much as it creates storage for a global variable. The key difference between a **static** local variable and a global variable is that the **static** local variable remains known only to the block in which it is declared. In simple terms, a **static** local variable is a local variable that retains its value between function calls.

static local variables are very important to the creation of stand-alone functions because several types of routines must preserve a value between calls. If **static** variables were not allowed, globals would have to be used, opening the door to possible side effects. An example of a function that benefits from a **static** local variable is a number-series generator that produces a new value based on the previous one. You could use a global variable to hold this value. However, each time the function is used in a program, you would have to declare that global variable and make sure that it did not conflict with any other global variables already in place. The better solution is to declare the variable that holds the generated number to be **static**, as in this program fragment:

```
int series(void)
{
  static int series_num;

  series_num = series_num+23;
  return series_num;
}
```

In this example, the variable **series_num** stays in existence between function calls, instead of coming and going the way a normal local variable would. This means that each call to **series( )** can produce a new member in the series based on the preceding number without declaring that variable globally.

You can give a **static** local variable an initialization value. This value is assigned only once, at program start-up—not each time the block of code is entered, as with normal local variables. For example, this version of **series( )** initializes **series_num** to 100:

```
int series(void)
{
```

```
  static int series_num = 100;

  series_num = series_num+23;
  return series_num;
}
```

As the function now stands, the series will always begin with the same value—in this case, 123. While this might be acceptable for some applications, most series generators need to let the user specify the starting point. One way to give **series_num** a user-specified value is to make it a global variable and then let the user set its value. However, not defining **series_num** as global was the point of making it **static**. This leads to the second use of **static.**

static Global Variables

Applying the specifier **static** to a global variable instructs the compiler to create a global variable that is known only to the file in which you declared it. This means that even though the variable is global, routines in other files may have no knowledge of it or alter its contents directly, keeping it free from side effects. For the few situations where a local **static** variable cannot do the job, you can create a small file that contains only the functions that need the global **static** variable, separately compile that file, and use it without fear of side effects.

To illustrate a global **static** variable, the series generator example from the previous section is recoded so that a seed value initializes the series through a call to a second function called **series_start( )**. The entire file containing **series( )**, **series_start( )**, and **series_num** is shown here:

```
/* This must all be in one file - preferably by itself. */

static int series_num;
void series_start(int seed);
int series(void);

int series(void)
{
  series_num = series_num+23;
  return series_num;
}

/* initialize series_num */
void series_start(int seed)
{
  series_num = seed;
}
```

Calling **series_start( )** with some known integer value initializes the series generator. After that, calls to **series( )** generate the next element in the series.

To review: The names of local **static** variables are known only to the block of code in which they are declared; the names of global **static** variables are known only to the file in which they reside. If you place the **series( )** and **series_start( )** functions in a library, you can use the functions but cannot reference the variable **series_num**, which is hidden from the rest of the code in your program. In fact, you can even declare and use another variable called **series_num** in your program (in another file, of course). In essence, the **static** modifier permits variables that are known only to the functions that need them, without unwanted side effects.

static variables enable you to hide portions of your program from other portions. This can be a tremendous advantage when you are trying to manage a very large and complex program.

Note *In C++, the preceding use of **static** is still supported, but deprecated. This means that it is not recommended for new code. Instead, you should use a namespace, which is described in Part Two.*

register Variables

The **register** storage specifier originally applied only to variables of type **int, char**, or pointer types. However, **register**'s definition has been broadened so that it applies to any type of variable.

Originally, the **register** specifier requested that the compiler keep the value of a variable in a register of the CPU rather than in memory, where normal variables are stored. This meant that operations on a **register** variable could occur much faster than on a normal variable because the **register** variable was actually held in the CPU and did not require a memory access to determine or modify its value.

Today, the definition of **register** has been greatly expanded and it now may be applied to any type of variable. Standard C simply states "that access to the object be as fast as possible." (Standard C++ states that **register** is a "hint to the implementation that the object so declared will be heavily used.") In practice, characters and integers are still stored in registers in the CPU. Larger objects like arrays obviously cannot be stored in a register, but they may still receive preferential treatment by the compiler. Depending upon the implementation of the C/C++ compiler and its operating environment, **register** variables may be handled in any way deemed fit by the compiler's implementor. In fact, it is technically permissible for a compiler to ignore the **register** specifier altogether and treat variables modified by it as if they weren't, but this is seldom done in practice.

You can only apply the **register** specifier to local variables and to the formal parameters in a function. Global **register** variables are not allowed. Here is an example that uses **register** variables. This function computes the result of M^e for integers:

```
int int_pwr(register int m,  register int e)
{
  register int temp;

  temp = 1;

  for(; e; e--) temp = temp * m;
  return temp;
}
```

In this example, **e**, **m**, and **temp** are declared as **register** variables because they are all used within the loop. The fact that **register** variables are optimized for speed makes them ideal for control of or use in loops. Generally, **register** variables are used where they will do the most good, which are often places where many references will be made to the same variable. This is important because you can declare any number of variables as being of type **register**, but not all will receive the same access speed optimization.

The number of **register** variables optimized for speed within any one code block is determined by both the environment and the specific implementation of C/C++. You don't have to worry about declaring too many **register** variables because the compiler automatically transforms **register** variables into nonregister variables when the limit is reached. (This ensures portability of code across a broad line of processors.)

Usually at least two **register** variables of type **char** or **int** can actually be held in the registers of the CPU. Because environments vary widely, consult your compiler's documentation to determine if you can apply any other types of optimization options.

In C, you cannot find the address of a **register** variable using the **&** operator (discussed later in this chapter). This makes sense because a **register** variable might be stored in a register of the CPU, which is not usually addressable. But this restriction does not apply to C++. However, taking the address of a **register** variable in C++ may prevent it from being fully optimized.

Although the description of **register** has been broadened beyond its traditional meaning, in practice it still generally has a significant effect only with integer and character types. Thus, you should probably not count on substantial speed improvements for other variable types.

Variable Initializations

You can give variables a value as you declare them by placing an equal sign and a value after the variable name. The general form of initialization is

type variable_name = value;

Some examples are

```
char ch = 'a';
int first = 0;
float balance = 123.23;
```

Global and **static** local variables are initialized only at the start of the program. Local variables (excluding **static** local variables) are initialized each time the block in which they are declared is entered. Local variables that are not initialized have unknown values before the first assignment is made to them. Uninitialized global and **static** local variables are automatically set to zero.

Constants

Constants refer to fixed values that the program cannot alter. Constants can be of any of the basic data types. The way each constant is represented depends upon its type. Constants are also called *literals*.

Character constants are enclosed between single quotes. For example 'a' and '%' are both character constants. Both C and C++ define wide characters (used mostly in non-English language environments), which are 16 bits long. To specify a wide character constant, precede the character with an **L**. For example,

```
wchar_t wc;
wc = L'A';
```

Here, **wc** is assigned the wide-character constant equivalent of A. The type of wide characters is **wchar_t**. In C, this type is defined in a header file and is not a built-in type. In C++, **wchar_t** is built in.

Integer constants are specified as numbers without fractional components. For example, 10 and –100 are integer constants. Floating-point constants require the decimal point followed by the number's fractional component. For example, 11.123 is a floating-point constant. C/C++ also allows you to use scientific notation for floating-point numbers.

There are two floating-point types: **float** and **double**. There are also several variations of the basic types that you can generate using the type modifiers. By default, the compiler fits a numeric constant into the smallest compatible data type that will hold it. Therefore, assuming 16-bit integers, 10 is **int** by default, but 103,000 is a **long**. Even though the value 10 could fit into a character type, the compiler will not cross type boundaries. The only exception to the smallest type rule are floating-point constants, which are assumed to be **double**s.

For most programs you will write, the compiler defaults are adequate. However, you can specify precisely the type of numeric constant you want by using a suffix. For floating-point types, if you follow the number with an F, the number is treated

as a **float**. If you follow it with an L, the number becomes a **long double**. For integer types, the U suffix stands for **unsigned** and the L for **long**. Here are some examples:

Data type	Constant examples
int	1 123 21000 –234
long int	35000L –34L
unsigned int	10000U 987U 40000U
float	123.23F 4.34e–3F
double	123.23 1.0 –0.9876324
long double	1001.2L

Hexadecimal and Octal Constants

It is sometimes easier to use a number system based on 8 or 16 rather than 10 (our standard decimal system). The number system based on 8 is called *octal* and uses the digits 0 through 7. In octal, the number 10 is the same as 8 in decimal. The base 16 number system is called *hexadecimal* and uses the digits 0 through 9 plus the letters A through F, which stand for 10, 11, 12, 13, 14, and 15, respectively. For example, the hexadecimal number 10 is 16 in decimal. Because these two number systems are used frequently, C/C++ allows you to specify integer constants in hexadecimal or octal instead of decimal. A hexadecimal constant must consist of a 0x followed by the constant in hexadecimal form. An octal constant begins with a 0. Here are some examples:

```
int hex = 0x80;   /* 128 in decimal */
int oct = 012;    /* 10 in decimal */
```

String Constants

C/C++ supports one other type of constant: the string. A *string* is a set of characters enclosed in double quotes. For example, "this is a test" is a string. You have seen examples of strings in some of the **printf( )** statements in the sample programs. Although C allows you to define string constants, it does not formally have a string data type. (C++ *does* define a string class, however.)

You must not confuse strings with characters. A single character constant is enclosed in single quotes, as in 'a'. However, "a" is a string containing only one letter.

Backslash Character Constants

Enclosing character constants in single quotes works for most printing characters. A few, however, such as the carriage return, are impossible to enter into a string from the keyboard. For this reason, C/C++ include the special *backslash character constants* shown

in Table 2-2 so that you may easily enter these special characters as constants. These are also referred to as *escape sequences*. You should use the backslash codes instead of their ASCII equivalents to help ensure portability.

For example, the following program outputs a new line and a tab and then prints the string **This is a test**.

```
#include <stdio.h>

int main(void)
{
  printf("\n\tThis is a test.");

  return 0;
}
```

Code	Meaning
\b	Backspace
\f	Form feed
\n	New line
\r	Carriage return
\t	Horizontal tab
\"	Double quote
\'	Single quote
\0	Null
\\	Backslash
\v	Vertical tab
\a	Alert
\?	Question mark
\N	Octal constant (where N is an octal constant)
\xN	Hexadecimal constant (where N is a hexadecimal constant)

Table 2-2. *Backslash Codes*

Operators

C/C++ is rich in built-in operators. In fact, it places more significance on operators than do most other computer languages. There are four main classes of operators: *arithmetic*, *relational*, *logical*, and *bitwise*. In addition, there are some special operators for particular tasks.

The Assignment Operator

You can use the assignment operator within any valid expression. This is not the case with many computer languages (including Pascal, BASIC, and FORTRAN), which treat the assignment operator as a special case statement. The general form of the assignment operator is

variable_name = expression;

where an expression may be as simple as a single constant or as complex as you require. C/C++ uses a single equal sign to indicate assignment (unlike Pascal or Modula-2, which use the := construct). The *target*, or left part, of the assignment must be a variable or a pointer, not a function or a constant.

Frequently in literature on C/C++ and in compiler error messages you will see these two terms: lvalue and rvalue. Simply put, an *lvalue* is any object that can occur on the left side of an assignment statement. For all practical purposes, "lvalue" means "variable." The term *rvalue* refers to expressions on the right side of an assignment and simply means the value of an expression.

Type Conversion in Assignments

When variables of one type are mixed with variables of another type, a *type conversion* will occur. In an assignment statement, the type conversion rule is easy: The value of the right side (expression side) of the assignment is converted to the type of the left side (target variable), as illustrated here:

```
int x;
char ch;
float  f;

void func(void)
{
  ch = x;     /* line 1 */
  x = f;      /* line 2 */
  f = ch;     /* line 3 */
  f = x;      /* line 4 */
}
```

In line 1, the left high-order bits of the integer variable **x** are lopped off, leaving **ch** with the lower 8 bits. If **x** were between 255 and 0, **ch** and **x** would have identical values. Otherwise, the value of **ch** would reflect only the lower-order bits of **x**. In line 2, **x** will receive the nonfractional part of **f**. In line 3, **f** will convert the 8-bit integer value stored in **ch** to the same value in the floating-point format. This also happens in line 4, except that **f** will convert an integer value into floating-point format.

When converting from integers to characters and long integers to integers, the appropriate amount of high-order bits will be removed. In many 16-bit environments, this means that 8 bits will be lost when going from an integer to a character and 16 bits will be lost when going from a long integer to an integer. For 32-bit environments, 24 bits will be lost when converting from an integer to a character and 16 bits will be lost when converting from an integer to a short integer.

Table 2-3 summarizes the assignment type conversions. Remember that the conversion of an **int** to a **float**, or a **float** to a **double**, and so on, does not add any precision or accuracy. These kinds of conversions only change the form in which the value is represented. In addition, some compilers always treat a **char** variable as positive, no matter what value it has, when converting it to an **int** or **float**. Other compilers treat **char** variable values greater than 127 as negative numbers when converting. Generally

Target Type	Expression Type	Possible Info Loss
signed char	char	If value > 127, target is negative
char	short int	High-order 8 bits
char	int (16 bits)	High-order 8 bits
char	int (32 bits)	High-order 24 bits
char	long int	High-order 24 bits
short int	int (16 bits)	None
short int	int (32 bits)	High-order 16 bits
int (16 bits)	long int	High-order 16 bits
int (32 bits)	long int	None
int	float	Fractional part and possibly more
float	double	Precision, result rounded
double	long double	Precision, result rounded

Table 2-3. *The Outcome of Common Type Conversions*

speaking, you should use **char** variables for characters, and use **int**s, **short int**s, or **signed char**s when needed to avoid possible portability problems.

To use Table 2-3 to make a conversion not shown, simply convert one type at a time until you finish. For example, to convert from **double** to **int**, first convert from **double** to **float** and then from **float** to **int**.

Multiple Assignments

C/C++ allows you to assign many variables the same value by using multiple assignments in a single statement. For example, this program fragment assigns **x**, **y**, and **z** the value 0:

```
x = y = z = 0;
```

In professional programs, variables are frequently assigned common values using this method.

Arithmetic Operators

Table 2-4 lists C/C++'s arithmetic operators. The operators **+**, **–**, *****, and **/** work as they do in most other computer languages. You can apply them to almost any built-in data type. When you apply **/** to an integer or character, any remainder will be truncated. For example, 5/2 will equal 2 in integer division.

The modulus operator **%** also works in C/C++ as it does in other languages, yielding the remainder of an integer division. However, you cannot use it on floating-point types. The following code fragment illustrates **%**:

```
int x, y;

x = 5;
y = 2;

printf("%d ", x/y);    /* will display 2 */
printf("%d ", x%y);    /* will display 1, the remainder of
                          the integer division */

x = 1;
y = 2;

printf("%d %d", x/y, x%y); /*  will display 0 1 */
```

The last line prints a 0 and a 1 because 1/2 in integer division is 0 with a remainder of 1.

The unary minus multiplies its operand by –1. That is, any number preceded by a minus sign switches its sign.

Operator	Action
–	Subtraction, also unary minus
+	Addition
*	Multiplication
/	Division
%	Modulus
– –	Decrement
++	Increment

Table 2-4. *Arithmetic Operators*

Increment and Decrement

C/C++ includes two useful operators not found in some other computer languages. These are the increment and decrement operators, **++** and – –. The operator **++** adds 1 to its operand, and – – subtracts 1. In other words:

```
x = x+1;
```

is the same as

```
++x;
```

and

```
x = x-1;
```

is the same as

```
x--;
```

Both the increment and decrement operators may either precede (prefix) or follow (postfix) the operand. For example,

```
x = x+1;
```

can be written

```
++x;
```

or

```
x++;
```

There is, however, a difference between the prefix and postfix forms when you use these operators in an expression. When an increment or decrement operator precedes its operand, the increment or decrement operation is performed before obtaining the value of the operand for use in the expression. If the operator follows its operand, the value of the operand is obtained before incrementing or decrementing it. For instance,

```
x = 10;
y = ++x;
```

sets **y** to 11. However, if you write the code as

```
x = 10;
y = x++;
```

y is set to 10. Either way, **x** is set to 11; the difference is in when it happens.

Most C/C++ compilers produce very fast, efficient object code for increment and decrement operations—code that is better than that generated by using the equivalent assignment statement. For this reason, you should use the increment and decrement operators when you can.

Here is the precedence of the arithmetic operators:

highest	++ −−
	– (unary minus)
	* / %
lowest	+ –

Operators on the same level of precedence are evaluated by the compiler from left to right. Of course, you can use parentheses to alter the order of evaluation. C/C++ treats parentheses in the same way as virtually all other computer languages. Parentheses force an operation, or set of operations, to have a higher level of precedence.

Relational and Logical Operators

In the term *relational operator*, relational refers to the relationships that values canhave with one another. In the term *logical operator*, logical refers to the ways these relationships can be connected. Because the relational and logical operators oftenwork together, they are discussed together here.

The idea of true and false underlies the concepts of relational and logical operators. In C, true is any value other than zero. False is zero. Expressions that use relational or logical operators return 0 for false and 1 for true.

C++ fully supports the zero/non-zero concept of true and false. However, it also defines the **bool** data type and the Boolean constants **true** and **false**. In C++, a 0 value is automatically converted into **false,** and a non-zero value is automatically converted into **true**. The reverse also applies: **true** converts to 1 and **false** converts to 0. In C++, the outcome of a relational or logical operation is **true** or **false**. But since this automatically converts into 1 or 0, the distinction between C and C++ on this issue is mostly academic.

Table 2-5 shows the relational and logical operators. The truth table for the logical operators is shown here using 1's and 0's.

p	q	p && q	p || q	!p
0	0	0	0	1
0	1	0	1	1
1	1	1	1	0
1	0	0	1	0

Both the relational and logical operators are lower in precedence than the arithmetic operators. That is, an expression like 10 > 1+12 is evaluated as if it were written 10 > (1+12). Of course, the result is false.

You can combine several operations together into one expression, as shown here:

```
10>5 && !(10<9) || 3<=4
```

In this case, the result is true.

Although neither C nor C++ contain an exclusive OR (XOR) logical operator, you can easily create a function that performs this task using the other logical operators. The outcome of an XOR operation is true if and only if one operand (but not both) is

Relational Operators

Operator	Action
>	Greater than
>=	Greater than or equal
<	Less than
<=	Less than or equal
= =	Equal
!=	Not equal

Logical Operators

Operator	Action
&&	AND
||	OR
!	NOT

Table 2-5. *Relational and Logical Operators*

true. The following program contains the function **xor( )**, which returns the outcome of an exclusive OR operation performed on its two arguments:

```
#include <stdio.h>

int xor(int a, int b);

int main(void)
{
  printf("%d", xor(1, 0));
  printf("%d", xor(1, 1));
  printf("%d", xor(0, 1));
  printf("%d", xor(0, 0));

  return 0;
}
```

```
/* Perform a logical XOR operation using the
   two arguments. */
int xor(int a, int b)
{
  return (a || b) && !(a && b);
}
```

The following table shows the relative precedence of the relational and logical operators:

Highest	!
	> >= < <=
	== !=
	&&
Lowest	||

As with arithmetic expressions, you can use parentheses to alter the natural order of evaluation in a relational and/or logical expression. For example,

```
!0 && 0 || 0
```

is false. However, when you add parentheses to the same expression, as shown here, the result is true:

```
!(0 && 0) || 0
```

Remember, all relational and logical expressions produce either a true or false result. Therefore, the following program fragment is not only correct, but will print the number 1.

```
int x;

x = 100;
printf("%d", x>10);
```

Bitwise Operators

Unlike many other languages, C/C++ supports a full complement of bitwise operators. Since C was designed to take the place of assembly language for most programming

tasks, it needed to be able to support many operations that can be done in assembler, including operations on bits. *Bitwise operation* refers to testing, setting, or shifting the actual bits in a byte or word, which correspond to the **char** and **int** data types and variants. You cannot use bitwise operations on **float**, **double**, **long double**, **void**, **bool**, or other, more complex types. Table 2-6 lists the operators that apply to bitwise operations. These operations are applied to the individual bits of the operands.

The bitwise AND, OR, and NOT (one's complement) are governed by the same truth table as their logical equivalents, except that they work bit by bit. The exclusive OR has the truth table shown here:

p	q	p ^q
0	0	0
1	0	1
1	1	0
0	1	1

As the table indicates, the outcome of an XOR is true only if exactly one of the operands is true; otherwise, it is false.

Bitwise operations most often find application in device drivers—such as modem programs, disk file routines, and printer routines — because the bitwise operations can be used to mask off certain bits, such as parity. (The parity bit confirms that the rest of the bits in the byte are unchanged. It is usually the high-order bit in each byte.)

Operator	Action
&	AND
|	OR
^	Exclusive OR (XOR)
~	One's complement (NOT)
>>	Shift right
<<	Shift left

Table 2-6. *Bitwise Operators*

Think of the bitwise AND as a way to clear a bit. That is, any bit that is 0 in either operand causes the corresponding bit in the outcome to be set to 0. For example, the following function reads a character from the modem port and resets the parity bit to 0:

```
char get_char_from_modem(void)
{
  char ch;

  ch = read_modem(); /* get a character from the
                        modem port */
  return(ch & 127);
}
```

Parity is often indicated by the eighth bit, which is set to 0 by ANDing it with a byte that has bits 1 through 7 set to 1 and bit 8 set to 0. The expression **ch & 127** means to AND together the bits in **ch** with the bits that make up the number 127. The net result is that the eighth bit of **ch** is set to 0. In the following example, assume that **ch** had received the character "A" and had the parity bit set:

```
Parity bit
    ↓
 1 1 0 0 0 0 0 1    ch containing an "A" with parity set
 0 1 1 1 1 1 1 1    127 in binary
&___________        bitwise AND
 0 1 0 0 0 0 0 1    "A" without parity
```

The bitwise OR, as the reverse of AND, can be used to set a bit. Any bit that is set to 1 in either operand causes the corresponding bit in the outcome to be set to 1. For example, the following is 128 | 3:

```
 1 0 0 0 0 0 0 0    128 in binary
 0 0 0 0 0 0 1 1    3 in binary
¦___________        bitwise OR
 1 0 0 0 0 0 1 1    result
```

An exclusive OR, usually abbreviated XOR, will set a bit on if and only if the bits being compared are different. For example, 127 ^120 is

```
 0 1 1 1 1 1 1 1    127 in binary
 0 1 1 1 1 0 0 0    120 in binary
^___________        bitwise XOR
 0 0 0 0 0 1 1 1    result
```

Remember, relational and logical operators always produce a result that is either true or false, whereas the similar bitwise operations may produce any arbitrary value in accordance with the specific operation. In other words, bitwise operations may produce values other than 0 or 1, while logical operators will always evaluate to 0 or 1.

The bit-shift operators, >> and <<, move all bits in a value to the right or left as specified. The general form of the shift-right statement is

value >> *number of bit positions*

The general form of the shift-left statement is

value << *number of bit positions*

As bits are shifted off one end, 0's are brought in the other end. (In the case of a signed, negative integer, a right shift will cause a 1 to be brought in so that the sign bit is preserved.) Remember, a shift is not a rotate. That is, the bits shifted off one end do not come back around to the other. The bits shifted off are lost.

Bit-shift operations can be very useful when you are decoding input from an external device, like a D/A converter, and reading status information. The bitwise shift operators can also quickly multiply and divide integers. A shift right effectively divides a number by 2 and a shift left multiplies it by 2, as shown in Table 2-7. The following program illustrates the shift operators:

```
/* A bit shift example. */
#include <stdio.h>

int main(void)
{
  unsigned int i;
  int j;

  i = 1;
```

```
  /* left shifts */
  for(j=0; j<4; j++) {
    i = i << 1;  /* left shift i by 1, which
                    is same as a multiply by 2 */
    printf("Left shift %d: %d\n", j, i);
  }

  /* right shifts */
  for(j=0; j<4; j++) {
    i = i >> 1;  /* right shift i by 1, which
                    is same as a division by 2 */
    printf("Right shift %d: %d\n", j, i);
  }

  return 0;
}
```

The one's complement operator, ~, reverses the state of each bit in its operand. That is, all 1's are set to 0, and all 0's are set to 1.

The bitwise operators are often used in cipher routines. If you want to make a disk file appear unreadable, perform some bitwise manipulations on it. One of the simplest

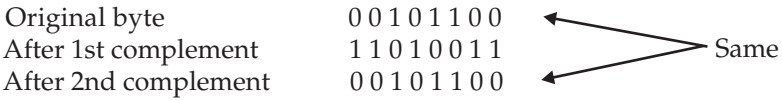
unsigned char x;	x as each statement executes	value of x
x = 7;	0 0 0 0 0 1 1 1	7
x = x<<1;	0 0 0 0 1 1 1 0	14
x = x<<3;	0 1 1 1 0 0 0 0	112
x = x<<2;	1 1 0 0 0 0 0 0	192
x = x>>1;	0 1 1 0 0 0 0 0	96
x = x>>2;	0 0 0 1 1 0 0 0	24

*Each left shift multiplies by 2. Notice that information has been lost after x<<2 because a bit was shifted off the end.

**Each right shift divides by 2. Notice that subsequent divisions do not bring back any lost bits.

Table 2-7. *Multiplication and Division with Shift Operators*

methods is to complement each byte by using the one's complement to reverse each bit in the byte, as is shown here:



Notice that a sequence of two complements in a row always produces the original number. Thus, the first complement represents the coded version of that byte. The second complement decodes the byte to its original value.

You could use the **encode( )** function shown here to encode a character.

```
/* A simple cipher function. */
char encode(char ch)
{
  return(~ch); /* complement it */
}
```

Of course, a file encoded using **encode( )** would be very easy to crack!

The ? Operator

C/C++ contains a very powerful and convenient operator that replaces certain statements of the if-then-else form. The ternary operator **?** takes the general form

Exp1 ? Exp2 : Exp3;

where *Exp1*, *Exp2*, and *Exp3* are expressions. Notice the use and placement of the colon.

The **?** operator works like this: *Exp1* is evaluated. If it is true, *Exp2* is evaluated and becomes the value of the expression. If *Exp1* is false, *Exp3* is evaluated and its value becomes the value of the expression. For example, in

```
x = 10;

y = x>9 ? 100 : 200;
```

y is assigned the value 100. If **x** had been less than 9, **y** would have received the value 200. The same code written using the **if-else** statement is

```
x = 10;
```

```
if(x>9) y = 100;
else y = 200;
```

The **?** operator will be discussed more fully in Chapter 3 in relationship to the other conditional statements.

The & and * Pointer Operators

A *pointer* is the memory address of some object. A *pointer variable* is a variable that is specifically declared to hold a pointer to an object of its specified type. Knowing a variable's address can be of great help in certain types of routines. However, pointers have three main functions in C/C++. They can provide a fast means of referencing array elements. They allow functions to modify their calling parameters. Lastly, they support linked lists and other dynamic data structures. Chapter 5 is devoted exclusively to pointers. However, this chapter briefly covers the two operators that are used to manipulate pointers.

The first pointer operator is **&**, a unary operator that returns the memory address of its operand. (Remember, a unary operator only requires one operand.) For example,

```
m = &count;
```

places into **m** the memory address of the variable **count**. This address is the computer's internal location of the variable. It has nothing to do with the value of **count**. You can think of **&** as meaning "the address of." Therefore, the preceding assignment statement means "**m** receives the address of **count**."

To better understand this assignment, assume that the variable **count** is at memory location 2000. Also assume that **count** has a value of 100. Then, after the previous assignment, **m** will have the value 2000.

The second pointer operator is *, which is the complement of **&**. The * is a unary operator that returns the value of the variable located at the address that follows it. For example, if **m** contains the memory address of the variable **count**,

```
q = *m;
```

places the value of **count** into **q**. Now **q** has the value 100 because 100 is stored at location 2000, the memory address that was stored in **m**. Think of * as meaning "at address." In this case, you could read the statement as "**q** receives the value at address **m**."

Unfortunately, the multiplication symbol and the "at address" symbol are the same, and the symbol for the bitwise AND and the "address of" symbol are the same.

These operators have no relationship to each other. Both **&** and * have a higher precedence than all other arithmetic operators except the unary minus, with which they share equal precedence.

Variables that will hold memory addresses (i.e., pointers), must be declared by putting * in front of the variable name. This indicates to the compiler that it will hold a pointer. For example, to declare **ch** as a pointer to a character, write

```
char *ch;
```

Here, **ch** is not a character but a pointer to a character—there is a big difference. The type of data that a pointer points to, in this case **char**, is called the *base type* of the pointer. However, the pointer variable itself is a variable that holds the address to an object of the base type. Thus, a character pointer (or any pointer) is of sufficient size to hold any address as defined by the architecture of the computer. However, as a rule, a pointer should only point to data that is of that pointer's base type.

You can mix both pointer and nonpointer variables in the same declaration statement. For example,

```
int x, *y, count;
```

declares **x** and **count** as integer types and **y** as a pointer to an integer type.

The following program uses * and **&** operators to put the value 10 into a variable called **target**. As expected, this program displays the value 10 on the screen.

```
#include <stdio.h>

int main(void)
{
  int target, source;
  int *m;

  source = 10;
  m = &source;
  target = *m;

  printf("%d", target);

  return 0;
}
```

The Compile-Time Operator sizeof

sizeof is a unary compile-time operator that returns the length, in bytes, of the variable or parenthesized type-specifier that it precedes. For example, assuming that integers are 4 bytes and **double**s are 8 bytes,

```
double f;

printf("%d ", sizeof f);
printf("%d", sizeof(int));
```

will display **8 4**.

Remember, to compute the size of a type, you must enclose the type name in parentheses. This is not necessary for variable names, although there is no harm done if you do so.

C/C++ defines (using **typedef**) a special type called **size_t**, which corresponds loosely to an unsigned integer. Technically, the value returned by **sizeof** is of type **size_t**. For all practical purposes, however, you can think of it (and use it) as if it were an unsigned integer value.

sizeof primarily helps to generate portable code that depends upon the size of the built-in data types. For example, imagine a database program that needs to store six integer values per record. If you want to port the database program to a variety of computers, you must not assume the size of an integer, but must determine its actual length using **sizeof**. This being the case, you could use the following routine to write a record to a disk file:

```
/* Write 6 integers to a disk file. */
void put_rec(int rec[6], FILE *fp)
{
  int len;

  len = fwrite(rec, sizeof(int)*6, 1, fp);
  if(len != 1) printf("Write Error");
}
```

Coded as shown, **put_rec( )** compiles and runs correctly in any environment, including those that use 16- and 32-bit integers.

One final point: **sizeof** is evaluated at compile time, and the value it produces is treated as a constant within your program.

The Comma Operator

The comma operator strings together several expressions. The left side of the comma operator is always evaluated as **void**. This means that the expression on the right side becomes the value of the total comma-separated expression. For example,

```
x = (y=3, y+1);
```

first assigns **y** the value 3 and then assigns **x** the value 4. The parentheses are necessary because the comma operator has a lower precedence than the assignment operator.

Essentially, the comma causes a sequence of operations. When you use it on the right side of an assignment statement, the value assigned is the value of the last expression of the comma-separated list.

The comma operator has somewhat the same meaning as the word "and" in normal English as used in the phrase "do this and this and this."

The Dot (.) and Arrow (–>) Operators

In C, the **.** (dot) and the –>(arrow) operators access individual elements of structures and unions. *Structures* and *unions* are compound (also called *aggregate*) data types that may be referenced under a single name (see Chapter 7). In C++, the dot and arrow operators are also used to access the members of a class.

The dot operator is used when working with a structure or union directly. The arrow operator is used when a pointer to a structure or union is used. For example, given the fragment

```
struct employee
{
  char name[80];
  int age;
  float wage;
} emp;

struct employee *p = &emp; /* address of emp into p */
```

you would write the following code to assign the value 123.23 to the **wage** member of structure variable **emp**:

```
emp.wage = 123.23;
```

However, the same assignment using a pointer to **emp** would be

```
p->wage = 123.23;
```

The [ ] and ( ) Operators

Parentheses are operators that increase the precedence of the operations inside them. Square brackets perform array indexing (arrays are discussed fully in Chapter 4). Given

an array, the expression within square brackets provides an index into that array. For example,

```
#include <stdio.h>
char s[80];

int main(void)
{
  s[3] = 'X';
  printf("%c", s[3]);

  return 0;
}
```

first assigns the value '**X**' to the fourth element (remember, all arrays begin at 0) of array **s**, and then prints that element.

Precedence Summary

Table 2-8 lists the precedence of all operators defined by C. Note that all operators, except the unary operators and **?**, associate from left to right. The unary operators (*, **&**, –) and **?** associate from right to left.

Note *C++ defines a few additional operators, which are discussed at length in Part Two.*

Expressions

Operators, constants, and variables are the constituents of expressions. An *expression* in C/C++ is any valid combination of these elements. Because most expressions tend to follow the general rules of algebra, they are often taken for granted. However, a few aspects of expressions relate specifically to C and C++.

Order of Evaluation

Neither C nor C++ specifies the order in which the subexpressions of an expression are evaluated. This leaves the compiler free to rearrange an expression to produce more optimal code. However, it also means that your code should never rely upon the order in which subexpressions are evaluated. For example, the expression

```
x = f1() + f2();
```

does not ensure that **f1( )** will be called before **f2( )**.

Highest	( ) [ ] –> .
	! ~ ++ –– (type) * & sizeof
	* / %
	+ –
	<< >>
	< <= > >=
	== !=
	&
	^
	|
	&&
	||
Highest	
	?:
	= += –= *= /= etc.
Lowest	,

Table 2-8. *The Precedence of C Operators*

Type Conversion in Expressions

When constants and variables of different types are mixed in an expression, they are all converted to the same type. The compiler converts all operands up to the type of the largest operand, which is called *type promotion*. First, all **char** and **short int** values are automatically elevated to **int**. (This process is called *integral promotion*.) Once this step has been completed, all other conversions are done operation by operation, as described in the following type conversion algorithm:

IF an operand is a **long double**
THEN the second is converted to **long double**
ELSE IF an operand is a **double**
THEN the second is converted to **double**

ELSE IF an operand is a **float**
THEN the second is converted to **float**
ELSE IF an operand is an **unsigned long**
THEN the second is converted to **unsigned long**
ELSE IF an operand is **long**
THEN the second is converted to **long**
ELSE IF an operand is **unsigned int**
THEN the second is converted to **unsigned int**

There is one additional special case: If one operand is **long** and the other is **unsigned int**, and if the value of the **unsigned int** cannot be represented by a **long**, both operands are converted to **unsigned long**.

Once these conversion rules have been applied, each pair of operands is of the same type and the result of each operation is the same as the type of both operands.

For example, consider the type conversions that occur in Figure 2-2. First, the character **ch** is converted to an integer. Then the outcome of **ch/i** is converted to a **double** because **f*d** is **double**. The outcome of **f+i** is **float**, because **f** is a **float**. The final result is **double**.

Casts

You can force an expression to be of a specific type by using a *cast*. The general form of a cast is

(type) expression

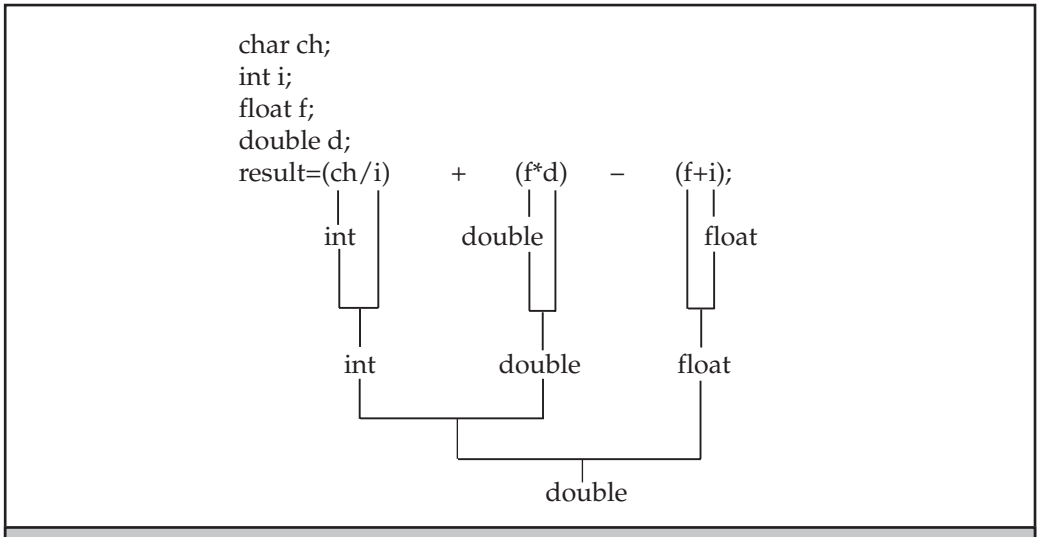


Figure 2-2. *A type conversion example*

where *type* is a valid data type. For example, to make sure that the expression **x/2** evaluates to type **float**, write

```
(float) x/2
```

Casts are technically operators. As an operator, a cast is unary and has the same precedence as any other unary operator.

Although casts are not usually used a great deal in programming, they can be very helpful when needed. For example, suppose you wish to use an integer for loop control, yet to perform computation on it requires a fractional part, as in the following program:

```
#include <stdio.h>

int main(void) /* print i and i/2 with fractions */
{
  int i;

  for(i=1; i<=100; ++i)
    printf("%d / 2 is: %f\n", i, (float) i /2);

  return 0;
}
```

Without the cast **(float)**, only an integer division would have been performed. The cast ensures that the fractional part of the answer is displayed.

Note *C++ adds four more casting operators, such as* ***const_cast*** *and* ***static_cast****. These operators are discussed in Part Two.*

Spacing and Parentheses

You can add tabs and spaces to expressions to make them easier to read. For example, the following two expressions are the same:

```
x=10/y~(127/x);

x = 10 / y ~(127/x);
```

Redundant or additional parentheses do not cause errors or slow down the execution of an expression. You should use parentheses to clarify the exact order of evaluation,

both for yourself and for others. For example, which of the following two expressions is easier to read?

```
x = y/3-34*temp+127;

x = (y/3) - (34*temp) + 127;
```

Compound Assignments

There is a variation on the assignment statement, called *compound assignment*, that simplifies the coding of a certain type of assignment operation. For example,

```
x = x+10;
```

can be written as

```
x += 10;
```

The operator **+=** tells the compiler to assign to **x** the value of **x** plus 10.

Compound assignment operators exist for all the binary operators (those that require two operands). In general, statements like:

var = var operator expression

can be rewritten as

var operator = expression

For another example,

```
x = x-100;
```

is the same as

```
x -= 100;
```

Compound assignment is widely used in professionally written C/C++ programs; you should become familiar with it. Compound assignment is also commonly referred to as *shorthand assignment* because it is more compact.