3

Operators and Expressions

3.1 INTRODUCTION

C supports a rich set of built-in operators. We have already used several of them, such as =, +, –, *, & and <. An *operator* is a symbol that tells the computer to perform certain mathematical or logical manipulations. Operators are used in programs to manipulate data and variables. They usually form a part of the mathematical or logical *expressions.*

C operators can be classified into a number of categories. They include:

1. Arithmetic operators
2. Relational operators
3. Logical operators
4. Assignment operators
5. Increment and decrement operators
6. Conditional operators
7. Bitwise operators
8. Special operators

An expression is a sequence of operands and operators that reduces to a single value. For example,

$$10 + 15$$

is an expression whose value is 25. The value can be any type other than ***void***.

3.2 ARITHMETIC OPERATORS

C provides all the basic arithmetic operators. They are listed in Table 3.1. The operators +, –, *, and / all work the same way as they do in other languages. These can operate on any built-in data type allowed in C. The unary minus operator, in effect, multiplies its single operand by –1. Therefore, a number preceded by a minus sign changes its sign.

Table 3.1 *Arithmetic Operators*

Operator	*Meaning*
+	Addition or unary plus
–	Subtraction or unary minus
*	Multiplication
/	Division
%	Modulo division

Integer division truncates any fractional part. The modulo division operation produces the remainder of an integer division. Examples of use of arithmetic operators are:

```
a – b    a + b
a * b    a / b
a % b    –a * b
```

Here **a** and **b** are variables and are known as *operands*. The modulo division operator % cannot be used on floating point data. Note that C does not have an operator for *exponentiation.* Older versions of C does not support unary plus but ANSI C supports it.

Integer Arithmetic

When both the operands in a single arithmetic expression such as a+b are integers, the expression is called an *integer expression*, and the operation is called *integer arithmetic.* Integer arithmetic always yields an integer value. The largest integer value depends on the machine, as pointed out earlier. In the above examples, if **a** and **b** are integers, then for **a** = 14 and **b** = 4 we have the following results:

```
a – b   =   10
a + b   =   18
a * b   =   56
a / b   =   3 (decimal part truncated)
a % b   =   2 (remainder of division)
```

During integer division, if both the operands are of the same sign, the result is truncated towards zero. If one of them is negative, the direction of trunction is implementation dependent. That is,

6/7 = 0 and –6/–7 = 0

but –6/7 may be zero or –1. (Machine dependent)

Similarly, during modulo division, the sign of the result is always the sign of the first operand (the dividend). That is

```
–14 % 3    =   –2
–14 % –3   =   –2
14 % –3    =   2
```

Example 3.1 The program in Fig. 3.1 shows the use of integer arithmetic to convert a given number of days into months and days.

Program
```
main ()
{
  int months, days ;

  printf("Enter days\n") ;
  scanf("%d", &days) ;

  months = days / 30 ;
  days = days % 30 ;
  printf("Months = %d Days = %d", months, days) ;
}
```

Output
```
Enter days
265
Months = 8 Days = 25
Enter days
364
Months = 12 Days = 4
Enter days
45
Months = 1 Days = 15
```

Fig. 3.1 *Illustration of integer arithmetic*

The variables months and days are declared as integers. Therefore, the statement

`months = days/30;`

truncates the decimal part and assigns the integer part to months. Similarly, the statement

`days = days%30;`

assigns the remainder part of the division to days. Thus the given number of days is converted into an equivalent number of months and days and the result is printed as shown in the output.

Real Arithmetic

An arithmetic operation involving only real operands is called *real arithmetic*. A real operand may assume values either in decimal or exponential notation. Since floating point values are rounded to the number of significant digits permissible, the final value is an approximation of the correct result. If **x, y,** and **z** are **floats**, then we will have:

x = 6.0/7.0 = 0.857143
y = 1.0/3.0 = 0.333333
z = –2.0/3.0 = –0.666667

The operator % cannot be used with real operands.

Mixed-mode Arithmetic

When one of the operands is real and the other is integer, the expression is called a *mixed-mode arithmetic* expression. If either operand is of the real type, then only the real operation is performed and the result is always a real number. Thus

15/10.0 = 1.5

whereas

15/10 = 1

More about mixed operations will be discussed later when we deal with the evaluation of expressions.

3.3 RELATIONAL OPERATORS

We often compare two quantities and depending on their relation, take certain decisions. For example, we may compare the age of two persons, or the price of two items, and so on. These comparisons can be done with the help of *relational operators*. We have already used the symbol '<', meaning 'less than'. An expression such as

a < b or 1 < 20

containing a relational operator is termed as a *relational expression*. The value of a relational expression is either *one* or *zero*. It is *one* if the specified relation is *true* and *zero* if the relation is *false*. For example

10 < 20 is true

but

20 < 10 is false

C supports six relational operators in all. These operators and their meanings are shown in Table 3.2.

Table 3.2 *Relational Operators*

Operator	*Meaning*
<	is less than
<=	is less than or equal to
>	is greater than
>=	is greater than or equal to
==	is equal to
!=	is not equal to

A simple relational expression contains only one relational operator and takes the following form:

ae-1 relational operator ae-2

ae-1 and *ae-2* are arithmetic expressions, which may be simple constants, variables or combination of them. Given below are some examples of simple relational expressions and their values:

4.5 <= 10 TRUE	
4.5 < –10 FALSE	
–35 >= 0 FALSE	
10 < 7+5 TRUE	
a+b = c+d TRUE	only if the sum of values of a and b is equal to the sum of values of c and d.

When arithmetic expressions are used on either side of a relational operator, the arithmetic expressions will be evaluated first and then the results compared. That is, arithmetic operators have a higher priority over relational operators.

Relational expressions are used in *decision statements* such as **if** and **while** to decide the course of action of a running program. We have already used the **while** statement in Chapter 1. Decision statements are discussed in detail in Chapters 5 and 6.

Relational Operator Complements

Among the six relational operators, each one is a complement of another operator.

>	is complement of	<=
<	is complement of	>=
==	is complement of	!=

We can simplify an expression involving the *not* and the *less than* operators using the complements as shown below:

Actual one	*Simplified one*
!(x<y)	x >= y
!(x>y)	x <= y
!(x!=y)	x == y
!(x<=y)	x > y
!(x>=y)	x < y
!(x == y)	x != y

3.4 LOGICAL OPERATORS

In addition to the relational operators, C has the following three *logical operators*.

&&	meaning logical	AND
||	meaning logical	OR
!	meaning logical	NOT

The logical operators && and || are used when we want to test more than one condition and make decisions. An example is:

a > b && x == 10

An expression of this kind, which combines two or more relational expressions, is termed as a *logical expression* or a *compound relational expression*. Like the simple relational expressions, a logical expression also yields a value of *one* or *zero*, according to the truth table shown in Table 3.3. The logical expression given above is true only if **a** > **b** is *true* and **x** == 10 is *true*. If either (or both) of them are false, the expression is *false*.

Table 3.3 *Truth Table*

op-1	*op-2*	*Value of the expression*	
		op-1 && op-2	*op-1 || op-2*
Non-zero	Non-zero	1	1
Non-zero	0	0	1
0	Non-zero	0	1
0	0	0	0

Some examples of the usage of logical expressions are:

1. if (age > 55 && salary < 1000)
2. if (number < 0 || number > 100)

We shall see more of them when we discuss decision statements.

NOTE: Relative precedence of the relational and logical operators is as follows:

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

It is important to remember this when we use these operators in compound expressions.

3.5 ASSIGNMENT OPERATORS

Assignment operators are used to assign the result of an expression to a variable. We have seen the usual assignment operator, '='. In addition, C has a set of '*shorthand*' assignment operators of the form

v op= exp;

Where *v* is a variable, *exp* is an expression and *op* is a C binary arithmetic operator. The operator **op**= is known as the shorthand assignment operator.

The assignment statement

```
v op= exp;
```

is equivalent to

```
v = v op (exp);
```

with **v** evaluated only once. Consider an example

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

This is same as the statement

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

The shorthand operator **+=** means 'add y+1 to x' or 'increment x by y+1'. For y = 2, the above statement becomes

```
x += 3;
```

and when this statement is executed, 3 is added to x. If the old value of x is, say 5, then the new value of x is 8. Some of the commonly used shorthand assignment operators are illustrated in Table 3.4.

Table 3.4 *Shorthand Assignment Operators*

Statement with simple assignment operator	*Statement with shorthand operator*
a = a + 1	a += 1
a = a – 1	a –= 1
a = a * (n+1)	a *= n+1
a = a / (n+1)	a /= n+1
a = a % b	a %= b

The use of shorthand assignment operators has three advantages:

1. What appears on the left-hand side need not be repeated and therefore it becomes easier to write.
2. The statement is more concise and easier to read.
3. The statement is more efficient.

These advantages may be appreciated if we consider a slightly more involved statement like

```
value(5*j–2) = value(5*j–2) + delta;
```

With the help of the += operator, this can be written as follows:

```
value(5*j–2) += delta;
```

It is easier to read and understand and is more efficient because the expression 5*j–2 is evaluated only once.

Example 3.2 Program of Fig. 3.2 prints a sequence of squares of numbers. Note the use of the shorthand operator *= .

The program attempts to print a sequence of squares of numbers starting from 2. The statement

```
a *= a;
```

which is identical to

```
a = a*a;
```

replaces the current value of **a** by its square. When the value of **a** becomes equal or greater than **N** (=100) the **while** is terminated. Note that the output contains only three values 2, 4 and 16.

Program

```
#define   N   100
#define   A   2
main()
{
          int a;
          a = A;
          while( a < N )
          {
              printf("%d\n", a);
              a *= a;
          }
 }
```

Output

```
2
4
16
```

Fig. 3.2 *Use of shorthand operator *=*

3.6 INCREMENT AND DECREMENT OPERATORS

C allows two very useful operators not generally found in other languages. These are the increment and decrement operators:

++ and – –

The operator ++ adds 1 to the operand, while – – subtracts 1. Both are unary operators and takes the following form:

```
++m; or m++;
--m; or m--;
```

```
++m; is equivalent to m = m+1; (or m += 1;)
--m; is equivalent to m = m–1; (or m –= 1;)
```

We use the increment and decrement statements in **for** and **while** loops extensively.

While ++m and m++ mean the same thing when they form statements independently, they behave differently when they are used in expressions on the right-hand side of an assignment statement. Consider the following:

```
m = 5;
y = ++m;
```

In this case, the value of y and m would be 6. Suppose, if we rewrite the above statements as

```
m = 5;
y = m++;
```

then, the value of y would be 5 and m would be 6. *A prefix operator first adds 1 to the operand and then the result is assigned to the variable on left. On the other hand, a postfix operator first assigns the value to the variable on left and then increments the operand.*

Similar is the case, when we use ++ (or ––) in subscripted variables. That is, the statement

```
a[i++] = 10;
```

is equivalent to

```
a[i] = 10;
 i = i+1;
```

The increment and decrement operators can be used in complex statements. Example:

```
m = n++ –j+10;
```

Old value of n is used in evaluating the expression. n is incremented after the evaluation. Some compilers require a space on either side of n++ or ++n.

Rules for + + and – – Operators

- Increment and decrement operators are unary operators and they require variable as their operands.
- When postfix + + (or – –) is used with a variable in an expression, the expression is evaluated first using the original value of the variable and then the variable is incremented (or decremented) by one.
- When prefix + +(or – –) is used in an expression, the variable is incremented (or decremented) first and then the expression is evaluated using the new value of the variable.
- The precedence and associatively of + + and – – operators are the same as those of unary + and unary –.

3.7 CONDITIONAL OPERATOR

A ternary operator pair "? :" is available in C to construct conditional expressions of the form

exp1 ? exp2 : exp3

where *exp1, exp2*, and *exp3* are expressions.

The operator ? : works as follows: *exp1* is evaluated first. If it is nonzero (true), then the expression *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. Note that only one of the expressions (either *exp2* or *exp3*) is evaluated. For example, consider the following statements.

```
a = 10;
b = 15;
x = (a > b) ? a : b;
```

In this example, x will be assigned the value of b. This can be achieved using the **if..else** statements as follows:

```
if (a > b)
  x = a;
else
  x = b;
```

3.8 BITWISE OPERATORS

C has a distinction of supporting special operators known as *bitwise operators* for manipulation of data at bit level. These operators are used for testing the bits, or shifting them right or left. Bitwise operators may not be applied to **float** or **double**. Table 3.5 lists the bitwise operators and their meanings. They are discussed in detail in Appendix I.

Table 3.5 *Bitwise Operators*

Operator	*Meaning*
&	bitwise AND
|	bitwise OR
^	bitwise exclusive OR
<<	shift left
>>	shift right

3.9 SPECIAL OPERATORS

C supports some special operators of interest such as comma operator, **sizeof** operator, pointer operators (**&** and *) and member selection operators (. and –>). The comma and **sizeof** operators are discussed in this section while the pointer operators are discussed in