

Hello C...TYI!

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Part 1: Input > Process > Output

In this section you will write your first C programs, and learn about the different bits and pieces that are required to compile and run software written in C. By the end of this section you should be able to

- Write a simple, interactive, executable program.
- Understand essential C syntax
- Be aware of different data types in C

Hello World!

“Hello World” is typically the first program that students learn to write, regardless of what language they’re learning. It’s origins are as old as C itself so let’s follow in the footsteps of all the great programmers and write it for ourselves.

```
#include <stdio.h>
#include <stdlib.h>

int main(){
    printf("Hello World");

    return 0;
}
```

Analysis

The first line of our Hello World programs has `#include <stdio.h>` which **includes** commands for inputting and outputting data. We will cover these functions in greater detail in the libraries section. The next line `int main()` creates a function called main that returns a whole number (integer) when it finishes. Again, we will also cover functions in much greater detail but for now

it is sufficient to know that every program that you write must contain a `main()` function. The contents of any function are placed between braces (sometimes called curly braces) like these `{ }`. In the Hello World example, our main function only does two things; firstly it prints the message *Hello World* and then it exits successfully by returning 0. Each of these steps that the program takes is called a **statement**. Note that every statement you write in C (and many other languages) will always end with a semicolon.

Comments

Obviously, as the weeks go on we'll be creating more and more sophisticated programs, and we'll also be collaborating with other programmers. In both of these instances it is useful to have some human-readable text that gives some clue as to what the program or function we are looking at is supposed to do. C has comments for this very purpose. There are two types of comments:

Single line comments that are indicated with two forward slashes `//`

```
//this is a single line comment.
```

Multi line comments, which can span one or more lines. A multi line comment begins with `/*` and ends with `*/`.

```
/*  
This is a  
multiline  
comment  
*/
```

Originally C only supported multi line comments and support for single line comments was introduced after the release of the C++ language. For full backwards compatibility with older compilers it is recommended that you always use multiline comments.

Escape Characters

What if you wanted print the words *Hello* and *World* on separate lines? How would you insert a line break into your text? In the example above, the text you want to display is contained between double quotes, but what if you wanted to display some dialog, like, *Domhnall said “hello world”*, how do you display double quotes without inadvertently closing one string and opening another by accident? Try it if you like.

The solution is to use **escape characters**. This means the symbol you want to display, or keyboard character you want to enter, is escaped by placing a backslash, `\`, in front of it. Try the following example

```
#include <stdio.h>
#include <stdlib.h>

int main(){
    printf("Alice said \"Hello World\" \n");
    printf("Bob said \"Hello World\" too. \n");

    return 0;
}
```

The `printf()` function will print out every character it sees in between the open and closing double quotes. In the example above, to display quotes in the console you have to escape them by preceding the quotes with a backslash. You also have to explicitly tell the compiler when you want to go on to a new line, and this is achieved using the new line escape character, `\n`. A complete list of escape characters is included in the table below.

sequence	output
<code>\a</code>	Alarm (Beep, Bell)
<code>\b</code>	Backspace
<code>\f</code>	Formfeed
<code>\n</code>	Newline (Line Feed);
<code>\r</code>	Carriage Return
<code>\t</code>	Horizontal Tab
<code>\v</code>	Vertical Tab
<code>\\</code>	Backslash
<code>\'</code>	Single quotation mark
<code>\"</code>	Double quotation mark
<code>\?</code>	Question mark
<code>\nnn</code>	A character where nnn interpreted as an octal number
<code>\xhh</code>	The character where hh interpreted as a hexadecimal number

Conversion Characters

Many functions, such as `printf()`, will allow us to substitute information into a `printf()` statement, rather than having to hard code it directly into the output.

```
#include <stdio.h>

int main(){

    printf("Your lucky number is is %d", 42);

    return 0;
}
```

The `printf()` function is now getting two pieces of information, separated by commas. The first piece of information is a string or message to display and the second piece of information is the name of the variable we want to display. At the end of the string there is a new sequence of characters `%d`. This tells the compilers to go and find a variable and substitute in its value in place of the `%d`. There are different **conversion characters** depending on which type of data you want to substitute into your function. In this case, since we are substituting in a whole number we use the integer data type. We'll learn more about data types later in the chapter.

The following table contains a complete list of conversion characters.

Character	Argument to Display
<code>%c</code>	Single character (char)
<code>%d</code>	Signed decimal integer (int)
<code>%e</code>	Signed floating-point value in E notation
<code>%f</code>	Signed floating-point value (float)
<code>%g</code>	Signed value in <code>%e</code> or <code>%f</code> format, whichever is shorter
<code>%i</code>	Signed decimal integer (int)
<code>%o</code>	Unsigned octal (base 8) integer (int)
<code>%s</code>	String of text
<code>%u</code>	Unsigned decimal integer (int)
<code>%x</code>	Unsigned hexadecimal (base 16) integer (int)
<code>%%</code>	(percent character)

Examples

In this first example we see that the integer conversion character can substitute in the result from a mathematical calculation and the substitutions are performed in order. Try this for yourself by changing the digits and the type of calculation.

```
#include <stdio.h>

int main(){

    printf("When you add %d and %d you get %d", 2, 3, 2+3);

    return 0;
}
```

In the next example we see how you can output a specific number of digits from the a **floating point** number. By default a float will display six decimal places but you can add values to the conversion character to change this. `.5` means that five decimal places should be printed, `.4` means display four decimal places, `.3` means 3 and so on. Take a look at the following example, which outputs pi to 6, 4 and 2 decimal places - but with questionable precision!

```
int main(){
    printf("I ate some %f", 3.141592);
    printf("I ate some %.4f", 3.141592);
    printf("I ate some %.2f", 3.141592);

    return 0;
}
```

In the example above there is a (deliberate) rounding error. The first 8 digits of Pi are 3.1415926 so we should have rounded our float up to 3.141593. In order to rectify this mistake we have to make three changes - but in larger programs a small change in specification might require you to make hundreds or thousands of changes. As you can probably imagine, hard-coding values like this directly into `printf()` statements is a bad idea. It makes code harder to maintain and much more error prone. If you continue programming like this you'll end up with slow, inefficient software that is full of tiny mistakes.

As a courtesy to your future self, now is the time to learn as much as you can about variables.

Variables

A variable is simply a placeholder where we are going to store some information in the computer's memory. There are three things you need to do to create a variable in your program. First you need to tell the compiler what **type** of data you'll be working with - i.e. is it a number or letters etc. Then you need to **name** your variable, so that it can refer to it elsewhere in your code. Finally you need to give your variable a **value**. The following code snippet has improved the previous example by creating a **variable** called pi and assigning it a **value** of 3.141593.

```
int main(){

    //declare a floating point variable and name it "pi"
    float pi;

    //assign a value of 3.141593 to the pi variable
    pi = 3.141593;

    printf("I ate some %f", pi);
    printf("I ate some %.4f", pi);
    printf("I ate some %.2f", pi);

    return 0;
}
```

To make your life easier you can **declare** and **initialise** a variable in one line like so:

```
float pi = 3.141593;
```

You can even declare several variable, of the same data type, all at once on the same line. Just use commas to sepearate each varaible name.

```
//some irrational numbers
float e, pi, tau;

//a few floating point inputs
float price, height, temperature;
```

Variable Types

When you started learning maths in secondary school you were probably introduced sets for the first time. You will no doubt remember that there are different *types* of numbers. For example the set \mathbb{Z} is that set which contains all the positive and negative whole number, or integers. Similarly, the set \mathbb{R} contains all the rational and irrational numbers.

In many computer programming languages, including C, you have to specifically declare what type of number you wish to work with.

Integer Types

Integer data types are for storing whole numbers. There are signed and unsigned variants of these, where the allocated size is the same but the range of possible values is changed.

Variable Name	C Identifier	Size	Range
Character	char	8 bit	0 - 255
Integer	int	16 bit	$\pm 32,000$
Short	short	16 bit	$\pm 32,000$
Long	long	32 bit	± 2 billion

Floating Point Types

Floating point data types allow increasing levels of precision for calculations by providing more and more decimal places. For most engineering applications 15 decimal places will usually suffice.

Variable Name	C Identifier	Size	Precision
Float	float	32 bit	6 decimal places
Double	double	64 bit	15 decimal places
Long	long	80 bit	19 decimal places

Arithmetic

You will recall that a computer is defined as a machine that can perform arithmetic and logic operations. So far we've done a little bit of arithmetic, but let's look at how we can use variables to make our calculations more robust.

```
int main(){

    //declare an integer variable
    int a = 7;

    //return the int squared
    printf(a*a);

    return 0;
}
```

Great, let's try one more example. Your code has compiled, it will execute from top to bottom. This means that new values can be assigned “on-the-fly” limiting the need for too many variables. In the following example, the `age` variable is first used to calculate Mark Zuckerberg's age, and then it is reused to calculate how old Bill Gates is.

```
int main(){

    int currentYear = 2017;
    int zuckerBorn = 1984;
    int babyGates = 1955;
    int age;

    //calculates how old Mark Zuckerberg is:
    age = currentYear - zuckerBorn;
    printf("Mark Zuckerberg is %d years old \n", age);

    //here we reuse the age variable to compute how old Bill Gates is.
    age = currentYear - babyGates;
    printf("Bill Gates is %d years old \n", age);

    return 0;
}
```


Input!!

So far we've been manipulating predefined data - this is all well and good but it doesn't make for particularly interactive programs. In this section we will look at the `scanf()` function, which is used for reading (or scanning!) in data from the console.

`scanf()` syntax

Both `scanf()` and `printf()` are part of the `<stdio.h>` library, or header file, so hopefully they will look quite similar to you. As we saw before, when printing data we needed to tell the function both the **type** of data we are working with and a **value** for that data to have. Take a look at the following simple example:

```
int myInt;

scanf("%d", &myInt);
printf("%d", myInt);
```

If you build and run the above example you will just see a console with a blinking cursor - not particularly intuitive for the end user. Typing a number will result in that number being echoed, or repeated back to the console. Notice that in the `scanf()` function that we are looking for an integer input and that the input should be stored in the `myInt` variable. This is specified by using the *address of* operator, in this case `&myInt`. Don't worry about it too much for now, we'll learn more about these operators in the next chapter.

Let's improve the user interface a bit but prompting the user for the type of input we'd like from them. Before scanning for data, let's use a `printf()` function to tell the user what to type:

```
int age;

printf("What year were you born in ? \n");
scanf("%d", &age);
printf("You were born in %d.", age);
```

Challenge

Improve the snippet above so that it asks the user for their year of birth and then returns their (approximate) age to them.

Summary

In this chapter we learned some of the fundamentals of C programming. At this stage in the course you should be able to:

- Use `printf()` and `scanf()` to ask the user for information and return a result to them,
- Include escape characters in your `printf()` statements,
- Recognise conversion characters and know which character correspond to which data type.

Hello C...TYI!

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Part 2: Arithmetic and Logic

Maths Operators

Also known as binary operators, these mathematical operators require two operands to produce an output. For example, $40 + 2 = 42$ requires two inputs to produce an output. As we will see later, programming languages also support unary operators.

Operation	Symbol
addition	+
subtraction	-
multiplication	*
division	/
tabularnewline modulo	%
equivalence	==

A simple incrementer

One of the most common tasks you will encounter in programming (in any language) is incrementing a value i.e. increasing it by a specific amount. Take for example scoring points in a game. Every time you hit a pig in Angry Birds 5000 points are added to your score.

Try the following code snippet:

```
//initialise a variable to store the number of times printf is run
int numPrints = 0;

//increment the variable by one
numPrints = numPrints + 1;
printf("The printf function has run %d times \n", numPrints);
```

```

numPrints = numPrints + 1;
printf("The printf function has run %d times \n", numPrints);

numPrints = numPrints + 1;
printf("The printf function has run %d times \n", numPrints);

```

`i++`

The most common amount to increment a variable by is one, in fact it's so common that there's a shorthand for it. All you have to do is write it in the form `myVariable++`, so the example above becomes:

```

int numPrints = 0;

numPrints++;
printf("The printf function has run %d times \n", numPrints);

numPrints++;
printf("The printf function has run %d times \n", numPrints);

numPrints++;
printf("The printf function has run %d times \n", numPrints);

```

Unary Operators

Unlike binary operators, unary operators only require one operand. They allow you to write your code more concisely. For example, `i++` or `i--` will increment or decrement the integer `i`.

There are several other ways of concisely expressing arithmetic operations, but they are binary rather than unary. For example, if we want to implement the Angry Birds scoring system we could use `myScore+=5000` to increase the score in steps of 5000.

Table of Unary Operators

In the previous chapter we saw the **Address Of** unary operator when we learned about the `scanf()` function. We were able to scan information from the console and store it in a variable called `myInt` using the following line of code:

```
scanf("%d", &myInt);
```

The table below sets out the rest of the unary operators.

Operation	Symbol	Also
Increment	<code>x++</code>	<code>++x</code>
Decrement	<code>x--</code>	<code>--x</code>
Address	<code>&x</code>	
Pointer	<code>*x</code>	
Positive	<code>+x</code>	
Negative	<code>-x</code>	
Ones Complement	<code>~x</code>	
Logical negation	<code>!x</code>	
Variable Size	<code>sizeof x</code>	<code>sizeof(type-name)</code>
Type casting	<code>(type-name)</code>	

Performing Calculations in `printf()`

You can create functions to perform maths operations almost anywhere in your program. It is also worth knowing that you can perform calculations within other functions such as `printf()`. Try the following example:

```
printf("Pi is approximately %f", 22/7);
```

Working with Modulo

You should be familiar with the first four mathematical operations, but modulo may be new to you. Put simply, modulo tells you the remainder of dividing one number by another. For example `7%2` would return 1, since 2 goes into 7 three times with a remainder of 1. Similarly `6%3` would return 0 since 3 divides evenly into six. In general terms, the modulo operator will always return a number between 0 and `d-1`, where `d` is the divisor (or denominator, if you prefer to think in fractions).

Order of Operations

Multiplication is just a concise way of saying that you want to repeatedly add a number to itself, and similarly division is just a simpler way of saying you

want to repeatedly subtract a number. Then when multiplication and division become too cumbersome to work with you can use exponents and radicals (roots) to indicate repeated multiplication and division, respectively. This heirarchy is the reason you had to memorise some acronym for the order of mathematical operations.

PEMDAS	BOMDAS	BIMDAS
Parentheses	Brackets	Brackets
Exponents	Orders	Indices
Multiplication	Multiplication	Multiplication
Division	Division	Division
Addition	Addition	Addition
Subtraction	Subtraction	Subtraction

Order of Operations

Unlike many calculators, C is intelligent enough to understand this order and will apply it when making calculations. This means that if you want some particular step of your calculation to happen in a certain order then you will have to make careful use of brackets.

Try the following snippet as an example and see if you can come up with some others.

```
printf(3 + 5 * 7); //returns 38
printf((3+5) * 7); //returns 56
```

Programming Challenges

Here are a few simple scenarios to challenge your understanding of the programming concepts we've covered so far.

Grade Point Average

Write a simple command line application that accepts 6 integer grades and returns the average of these numbers.

Tip Calculator

Write a command line application that accepts a bill amount and return to the user both the value of a 10% tip and the combined amount of initial bill and tip.

Logic

This section will help you add some “intelligence” or decision making abilities your programs. By the end of this section you will be able to write programs that respond to a variety of different input conditions, and we will conclude this chapter by writing a very simple game.

If Statements

Sometimes referred to as branches, if statements contain code that only executes if a certain condition is met. A nice example of an app that makes decisions based on specific events happening is called “IFTTT” which stands for **If This Then That**. As a more everyday example you can imagine the following scenario: “If it’s raining outside then bring an umbrella”

Syntax

A typical if statement will look like so:

```
if(test if true){
    code to run if test is true;
}
```

Try the following out:

```
int input;

printf("What is the meaning of life, the universe and everything? \n");
scanf("%d", &input);

if (input == 42){
    printf("Such learning. Many wisdom. Wow");
}
```

What ELSE can we do?

In the previous example there was only one “correct” answer. When you run the program you only ever get a response if the number ‘42’ is entered. For every other input the program remains silent.

By adding an else condition we can catch all the other alternatives that our if test misses.

```
if(input == 42){
    printf("Such Learning Many Wisdom. Wow");
}
```

```

} else{
    printf("Try again");
}

```

Else If

Finally, we can run more than two tests by adding in one (or more) `else if` cases. For example:

```

if(input == 42){
    printf("Such Learning Many Wisdom. Wow");
} else if(input == 43){
    printf("Close, but no cigar");
} else if(input == 41){
    printf("Close, but no cigar");
} else{
    printf("Try again");
}

```

Ternary Operator

As with most things in programming, there's a more concise way to write your if statements. We've already seen the a unary operator take one operand, a binary operator takes two and with a ternary operator we can use three operands to handle the "If-Then-Else" elements of an if statement.

```

(test) ? trueCode : falseCode;

```

The ternary operator, just like unary and binary operators, can be used as an argument in other functions such as `printf()`. Try this nice way to print plurals correctly!

```

int numFriends = 2;

printf("You have %d friend%s", numFriends, (numFriends!=1) ? "s." : "." );

```

Coding Challenge!

Sorting...Sort of.

Early entrance is changing - students will now be divided by surname, write a program that checks the first character of a `lastName` string, A-N, M-Z

Truth Tables

Hopefully you will remember truth tables from your electronics studies in EM113. Just in case you've forgotten, here's what the **OR** and **AND** truth tables look like for two inputs.

A OR B

A	B	A+B
0	0	0
1	0	1
0	1	1
1	1	1

A AND B

A	B	A.B
0	0	0
1	0	0
0	1	0
1	1	1

Logic Operators

In your logic tests you can test if more than one condition is met using a logic **AND** operator or you can test to see if either condition is true using the logic **OR** operator.

Here's some pseudo-code to illustrate:

```
//logic and example
if (test 1 && test 2){
    code if both are true;
}
```

Logic and is denoted by **&&** which is Shift + 7 on a UK keyboard. Logic or is denoted by **||** which is Shift + \ on a standard keyboard.

Coding Challenges

Try these two challenges to test your knowledge of what we covered in this chapter:

CAO Points Calculator

Write an application that asks for an integer input (between 0 and 100) and converts it the corresponding Leaving Cert grade.

Fizz Buzz

need to introduce for loops first

Print all the numbers from 0 to 30 inclusive. If the number is evenly divisible by 3 print “FIZZ” instead of the number. If it’s evenly divisible by 5 then print “BUZZ” instead of that number. If the number is divisible by both 3 & 5 then print FIZZBUZZ

Summary

After this second chapter you should now be able to:

- Understand binary operators and use them in your programs,
- Recognise the unary operators, know where to use them and be able to use the Address Of unary operator,
- Write If-ElseIf-Else statements,
- Use ternary operators instead of IF/Else statements,
- Use logic AND in your programs,
- Use logic OR in your programs.

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Hello C...TYI!

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Part 3: Loops

Overview

We've already seen a few instances where we wanted to repeatedly print information to the screen. Performing repetitive tasks is one of the things that computers are exceptionally good at doing. In this chapter we'll introduce a variety of different loops that you can use to write better programs.

Looping

If you've never done any programming before loops can be a challenging topic due to their unfamiliarity. If you think about it in more general terms, how would you give a computer instruction to do something over and over again? How would you avoid getting stuck in an *infinite loop*?

Start, Middle, End

When you creating a loop in any programming language you will have tell it when and where to start. Starting a loop is known as **initialising** the loop.

Next you will have some code to run - for example increment at counter, print some text etc. - while the loop is running.

Finally you need an end condition. Once this condition is met or exceeded then the loop should exit gracefully.

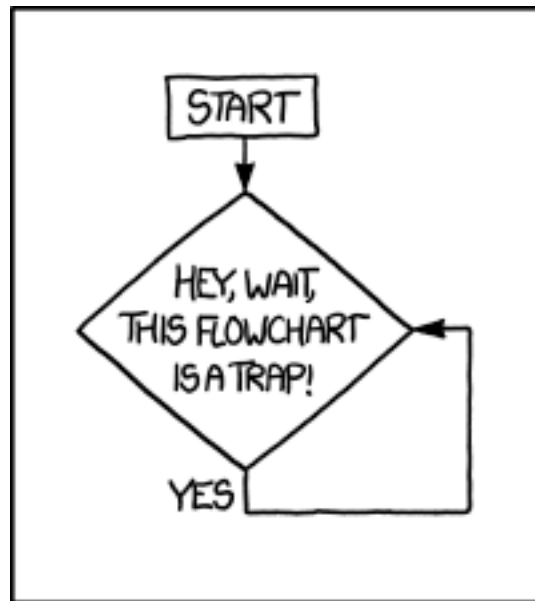


Figure 1: flowchart

While Loops

A **while** loop, as the name implies, executes while a certain condition is true. Once the test condition is no longer true then the loop is broken and code execution moves on to the next line. Try this snippet to get started:

```
int main(){  
  
    int counter = 0;  
  
    while(counter < 10){  
        printf("the value of the counter is: %d \n", counter);  
        counter++  
    }  
  
    printf("successfully exited the while loop! \n");  
  
    return 0;  
}
```

Syntax

A typical `while` loop will begin with a test condition:

```
while(testIfTrue){  
    code to run while true;  
    incrementer;  
}
```

If the test is true then the code inside the loop (i.e between the braces) will run - keep in mind that each line must end with a semi-colon. Finally, you'll need to have some sort of incrementer that gets updated during each pass through the loop. This is essential so that you don't get stuck in an infinte loop.

Example

Try the previous example with different test conditions. For example using `while (counter <= 30)` will cause the loop to run an extra time. Similarly you could continue executing the loop while the counter is *not* equal to a certain value. `while (counter != 30)`

Be careful if you are changing the direction of the inequality!

Visualisation

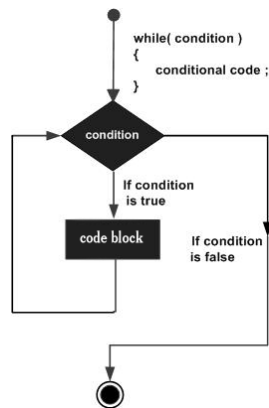


Figure 2: while loop

Programming Challenge

Here's a simple example you can code using `while` loops. Which would you prefer, one million euro today or 1 cent, doubled every day for a month (30

days)?

Your loop should run 30 times, doubling the value of your variable each time.

Do While

With a **while** loop there is always a possibility that the test condition will never be true and that the code within the loop will never run.

A **do while** loop differs from a **while** loop in that it will always run at least once, and the conditional check is performed at the end of the loop, rather than at the beginning.

Do While Syntax

```
int loopCounter = 1;

/* do loop execution */
do
{
    printf("number of times this loop has run: %d\n", loopCounter);
    loopCounter++;
}while( loopCounter < 10 );
```

Visualisation

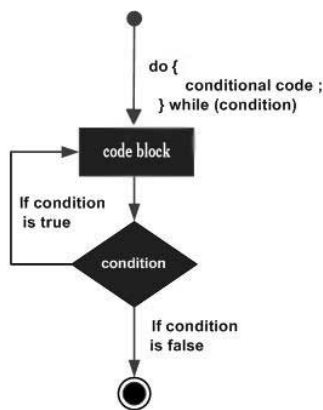


Figure 3: Do While loop

For Loops

The `for` loop contains the starting condition, end condition and incrementer all at the beginning of the loop

Syntax

```
int main(){  
  
    int counter;  
  
    for(counter = 0; counter < 10; counter++){  
        printf("Hello World!");  
    }  
  
    return 0;  
}
```

Visualisation

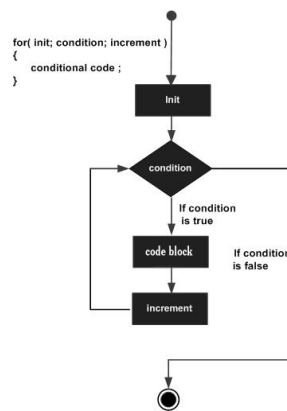


Figure 4: for loop

Example

```
/* Print all the even numbers between 0 and 100 in 3 lines of code */  
int main(){  
  
    int i;
```

```

    for(i = 0; i <=100; i++){
        if(i%2 == 0){
            printf("%d \n", i);
        }
    }

    return 0;
}

```

Nesting For loops

A quick challenge to really test your understanding so far.

Create a program that has variables to represent the number of rows and number of columns that a table should have. Then use nested for loop to print a 3 x 3 table to the console.

Break

Lets say that we have some condition which, if met, should break us out of our loop immediately. In such a scenario we would use a **break**; statement. Here's a simple example that modifies our doWhile application to exit before it has iterated through the loop 10 times.

```

int main(){

    int loopCounter = 1;

    /* do loop execution */
    do
    {
        if(loopCounter == 7){
            break;
        }
        printf("number of times this loop has run: %d\n", loopCounter);
        loopCounter++;
    }while( loopCounter < 10 );

    return 0;
}

```

Continue

Conceptually this is the opposite of a **break** statement. It's behaviour will differ slightly depending on where it is used. In a **for** loop the **continue** statement will cause the conditional test and increment portions of the loop to execute.

When used in a **while** or **do-while** loop, the **continue** statement causes the program control to pass straight to the conditional tests.

Switch

Switch statements are used to test a variable for equivalence against a list of given values. It is conceptually similar to an **if-else if-else** block of code.

Visualisation

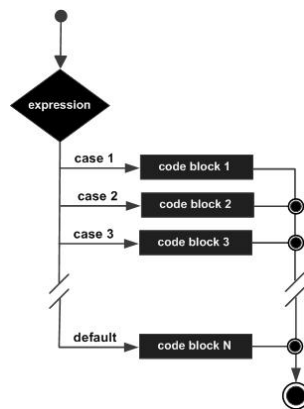


Figure 5: switch

Example 1

```
int main(){
    int input;
    int type;

    printf("Enter a number \n");
    scanf("%d", &input);

    if(input % 2 == 0){
        type = 0;
```

```

    }else{
        type = 1;
    }

    switch(type){
        case(0):
            printf("The number is even\n");
            break;
        case(1):
            printf("The number is odd\n");
            break;
        default:
            printf("Sorry, unknown type of number! \n");
            break;
    }

    return 0;

```

Example 2

```

switch(grade)
{
case 'A' :
    printf("Excellent!\n" );
    break;
case 'B' :
case 'C' :
    printf("Well done\n" );
    break;
case 'D' :
    printf("You passed\n" );
    break;
case 'F' :
    printf("Better try again\n" );
    break;
default :
    printf("Invalid grade\n" );
}

```

Fizz Buzz Revisited

Using a loop of your choosing:

- Print all the numbers from 0 to 30 inclusive.
- If the number is evenly divisible by 3 print “FIZZ” instead of the number

- If it's evenly divisible by 5 then print "BUZZ" instead of that number.
- If the number is divisible by both 3 & 5 the print FIZZBUZZ

Summary

After reading this chapter and completing all the exercises in it you should be able to:

- Create a For loop,
- Understand the differences between a While and Do While loop, and how to use both,
- Use a Switch statement,
- Correctly use the break and continue statements.