Experiment: 1

Aim: Introduction to Arduino.

An Arduino is an open-source microcontroller development board. In plain English, you can use the Arduino to read sensors and control things like motors and lights. This allows you to upload programs to this board which can then interact with things in the real world.

For instance, you can read a humidity sensor connected to a potted plant and turn on an automatic watering system if it gets too dry. Or, you can have it tweet every time your cat passes through a pet door. Or, you can have it start a pot of coffee when your alarm goes off in the morning.

Why arduino?

Inexpensive - Arduino boards are relatively inexpensive compared to other microcontroller platforms.

Cross-platform - The Arduino Software (IDE) runs on Windows, Macintosh OSX, and Linux operating systems. Most microcontroller systems are limited to Windows.

Simple, clear programming environment - The Arduino Software (IDE) is easy-to-use for beginners, yet flexible enough for advanced users to take advantage of as well

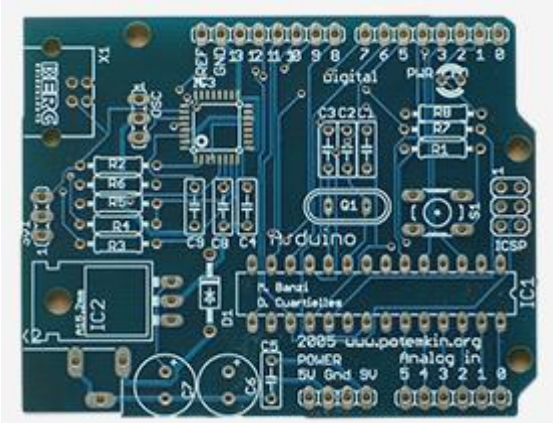
Open source and extensible software - The Arduino software is published as open source tools, available for extension by experienced programmers. The language can be expanded through C++ libraries.

Open source and extensible hardware - The plans of the Arduino boards are published under a Creative Commons license, so experienced circuit designers can make their own version of the module, extending it and improving it. Even relatively inexperienced users can build the breadboard version of the module in order to understand how it works and save money.

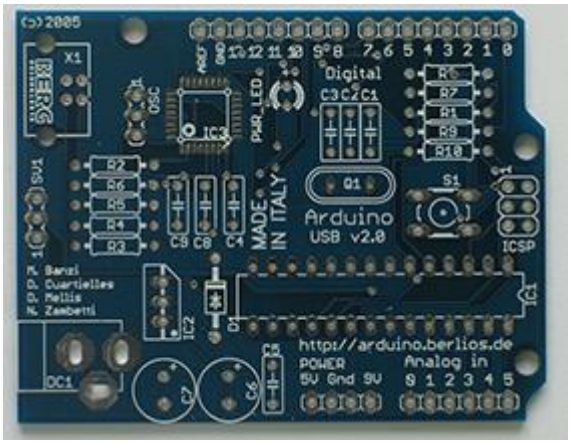
Different Arduino boards:

The Arduino USB:

The Arduino USB was the first board labelled "Arduino". These were mainly sold unassembled as kits. The first version had an incorrect pinout for the USB connector.

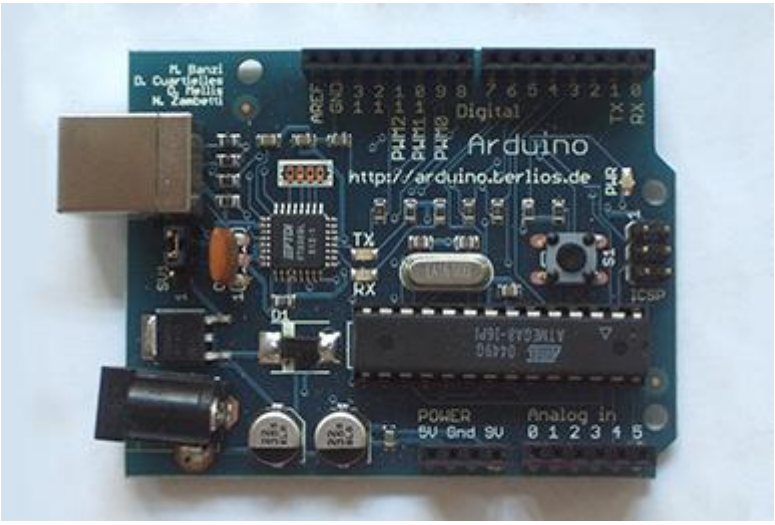


Arduino USB v2.0



The second version of the Arduino USB corrected the USB connector pinout. it was labelled "Arduino USB v2.0"

The Arduino Extreme:



The Arduino Extreme uses many more surface mount components than previous USB Arduino boards and comes with female pin headers. It also has RX and TX LEDs that indicate when data is being sent to or from the board.

Arduino NG, Diecimila, and the Duemilanove (Legacy Versions)

Legacy versions of the Arduino Uno product line consist of the NG, Diecimila, and the Duemilanove. The important thing to note about legacy boards is that they lack particular feature of the Arduino Uno.

- The Diecimila and NG use an ATMEGA168 chips (as opposed to the more powerful ATMEGA328),
- Both the Diecimila and NG have a jumper next to the USB port and require manual selection of either USB or battery power.
- The Arduino NG requires that you hold the rest button on the board for a few seconds prior to uploading a program.

ARDUINO UNO

- This is the latest revision of the basic Arduino USB board. It connects to the computer with a standard USB cable and contains everything else you need to program and use the board. It can be extended with a variety of shields: custom daughter-boards with specific features.
- The most common version of Arduino is the Arduino Uno. This board is what most people are talking about when they refer to an Arduino.

Arduino Mega 2560

- The Arduino Mega 2560 is the second most commonly encountered version of the Arduino family. The Arduino Mega is like the Arduino Uno's beefier older brother. It boasts 256 KB of memory (8 times more than the Uno). It also had 54 input and output pins, 16 of which are analog pins, and 14 of which can do PWM. However, all of the added functionality comes at the cost of a slightly larger circuit board. It may make your project more powerful, but it will also make your project larger.

Arduino Mega ADK

- This specialized version of the Arduino is basically an Arduino Mega that has been specifically designed for interfacing with Android smartphones.

Arduino Yun

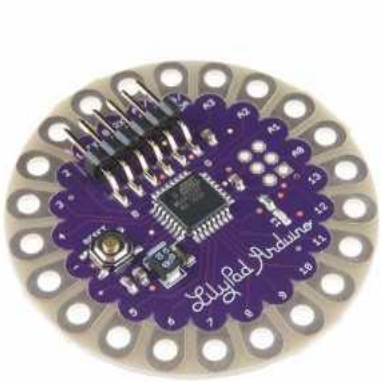
- The Arduino Yun uses a ATMega32U4 chip instead of the ATmega328. However, what really sets it apart is the addition of the Atheros AR9331 microprocessor. This extra chip allows this board to run Linux in addition to the normal Arduino operating system.
- If all of that were not enough, it also has onboard wifi capability and on board Ethernet shield which makes it suitable for IoT applications.

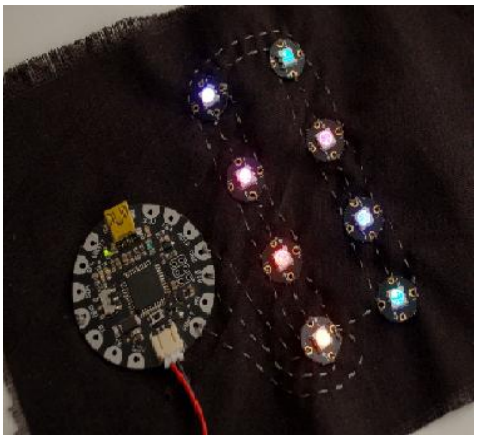
Arduino Nano

If you want to go smaller than the standard Arduino board, the Arduino Nano is for you! Based on a surface mount ATmega328 chip, this version of the Arduino has been shrunk down to a small footprint capable of fitting into tight spaces. It can also be inserted directly into a breadboard, making it easy to prototype with.

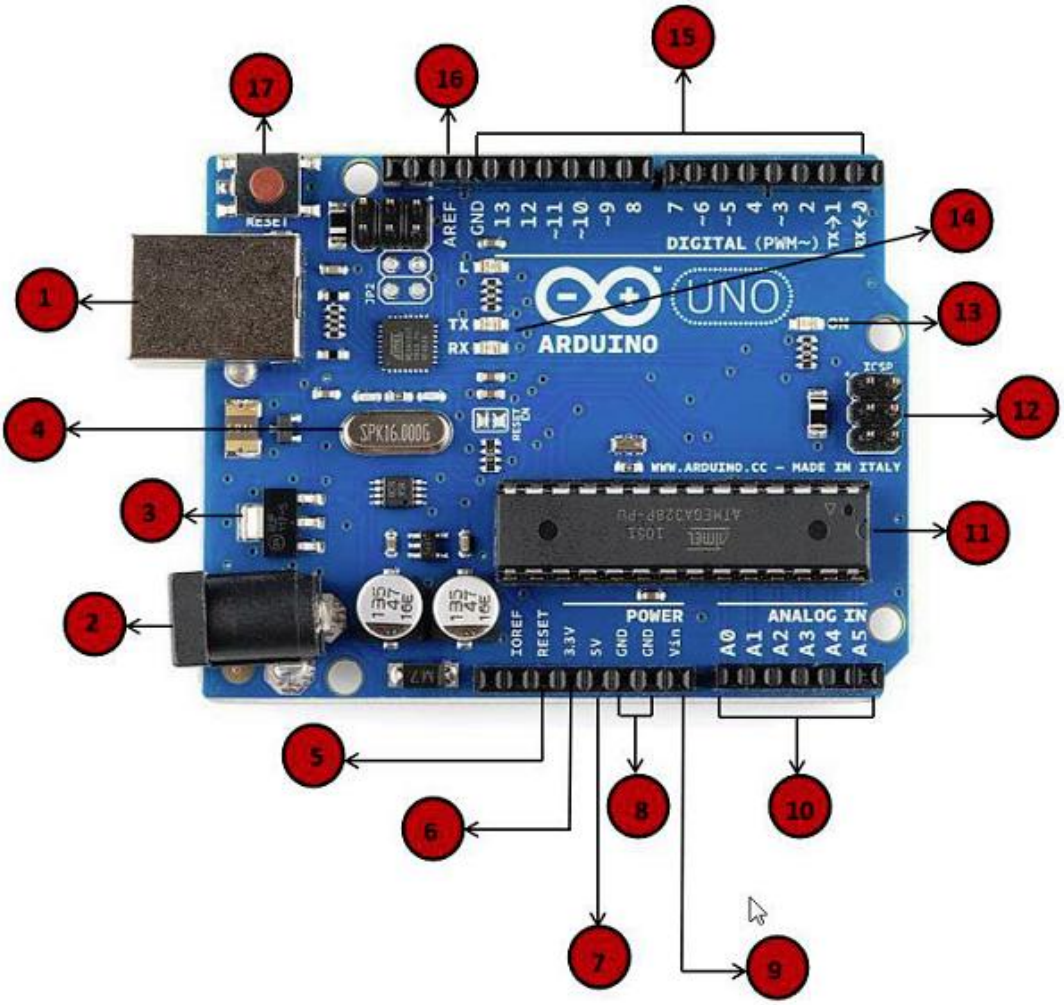
Arduino LilyPad

The LilyPad was designed for wearable and e-textile applications. It is intended to be sewn to fabric and connected to other sewable components using conductive thread.





Introduction to UNO Board:



Power USB

Arduino board can be powered by using the USB cable from your computer. All you need to do is connect the USB cable to the USB connection (1).

Power (Barrel Jack)

Arduino boards can be powered directly from the AC mains power supply by connecting it to the Barrel Jack (2). Adaptor for the same is shown in figure below.

Voltage Regulator

The function of the voltage regulator (3) is to control the voltage given to the Arduino board and stabilize the DC voltages used by the processor and other elements

Crystal Oscillator

The crystal oscillator(4) helps Arduino in dealing with time issues. How does Arduino calculate time? The answer is, by using the crystal oscillator. The number printed on top of the Arduino crystal is 16.000H9H. It tells us that the frequency is 16,000,000 Hertz or 16 MHz.

Arduino Reset

You can reset your Arduino board, i.e., start your program from the beginning. You can reset the UNO board in two ways. First, by using the reset button (17) on the board. Second, you can connect an external reset button to the Arduino pin labelled RESET (5).

Pins (3.3, 5, GND, Vin)

- 3.3V (6) − Supply 3.3 output volt
- 5V (7) − Supply 5 output volt
- Most of the components used with Arduino board works fine with 3.3 volt and 5 volt.
- GND (8)(Ground) − There are several GND pins on the Arduino, any of which can be used to ground your circuit.
- Vin (9) − This pin also can be used to power the Arduino board from an external power source, like AC mains power supply.

Analog pins

- The Arduino UNO board has five analog input pins A0 through A5(10). These pins can read the signal from an analog sensor like the humidity sensor or temperature sensor and convert it into a digital value that can be read by the microprocessor.

Main microcontroller

- Each Arduino board has its own microcontroller (11). You can assume it as the brain of your board.

Power LED indicator

- This LED(13) should light up when you plug your Arduino into a power source to indicate that your board is powered up correctly. If this light does not turn on, then there is something wrong with the connection.

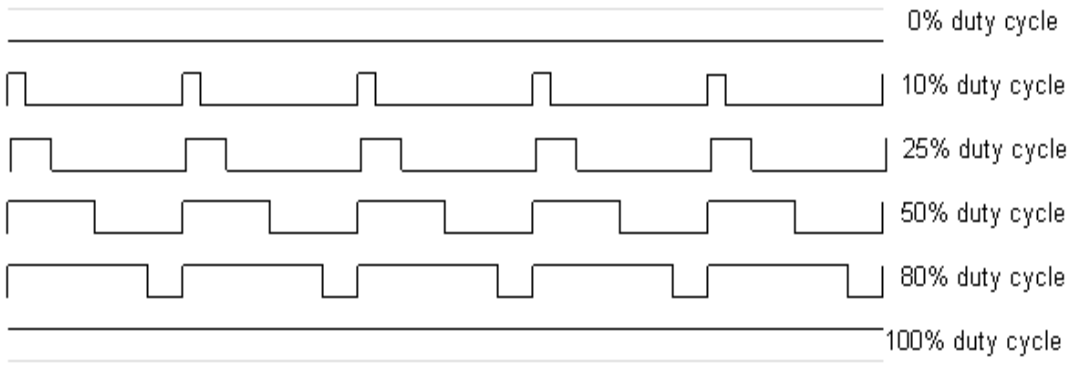
TX and RX LEDs

- On your board, you will find two labels: TX (transmit) and RX (receive). They appear in two places on the Arduino UNO board. First, at the digital pins 0 and 1, to indicate the pins responsible for serial communication. Second, the TX and RX led (14). The

TX led flashes with different speed while sending the serial data. The speed of flashing depends on the baud rate used by the board. RX flashes during the receiving process.

Digital I/O

- The Arduino UNO board has 14 digital I/O pins (15) (of which 6 provide PWM (Pulse Width Modulation) output. These pins can be configured to work as input digital pins to read logic values (0 or 1) or as digital output pins to drive different modules like LEDs, relays, etc. The pins labeled "~" can be used to generate PWM.



- The Arduino's programming language makes PWM easy to use; simply call analogWrite(pin, dutyCycle), where dutyCycle is a value from 0 to 255, and pin is one of the PWM pins (3, 5, 6, 9, 10, or 11).

PWM has several uses:

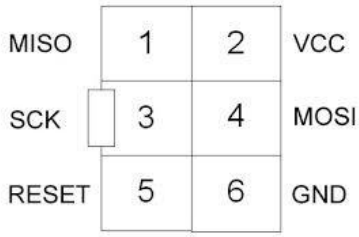
- Dimming an LED
- Providing variable speed control for motors.

ICSP:

The bootloader is the little program that runs when you turn the Arduino on, or press the reset button. Its main function is to wait for the Arduino software on your computer to send it a new program for the Arduino, which it then writes to the memory on the Arduino. This is important, because normally you need a special device to program the Arduino. The bootloader is what enables you to program the Arduino using just the USB cable.

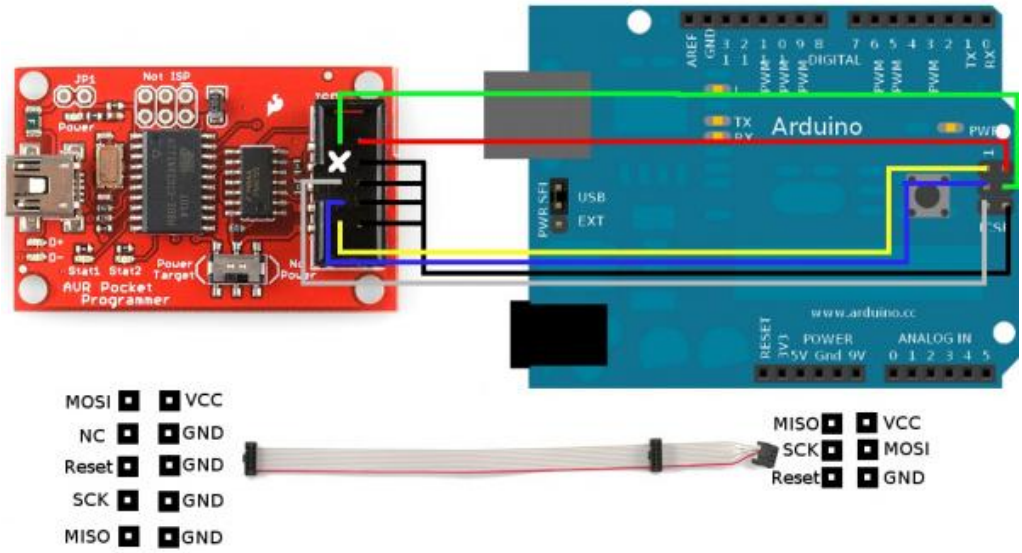
ICSP stands for *In Circuit Serial Programming*, which represents one of the several methods available for programming Arduino boards. Ordinarily, an Arduino bootloader program is used to program an Arduino board, but if the bootloader is missing or damaged, ICSP can be used instead. ICSP can be used to restore a missing or damaged bootloader.

Each ICSP pin usually is cross-connected to another Arduino pin with the same name or function.

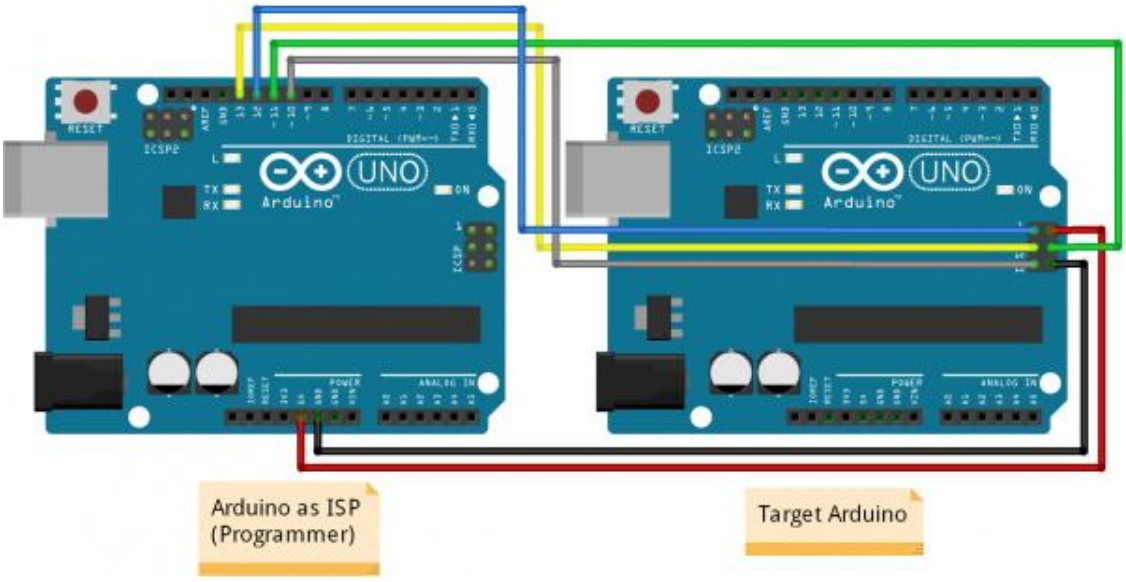


- MISO (Master In Slave Out) - The Slave line for sending data to the master,
- MOSI (Master Out Slave In) - The Master line for sending data to the peripherals,
- SCK (Serial Clock) - The clock pulses which synchronize data transmission generated by the master

Connecting an AVR Programmer to Target



Connecting Arduino as ISP to Target



AREF(16): The Arduino comes with a 10bit ADC (Analog-Digital-Converter), which converts incoming voltages between 0V and 5V to integer values between 0 and 1023. This results in a resolution of roughly 4.8 mV. (This is calculated by dividing 1024 into 5V).

If a sensor only delivers a lower maximum voltage, it is resonable to apply this voltage to the `AREF` pin, just in order to obtain a higher resolution. for example, if we want to measure voltages with a maximum range of 3.3V, we would feed a nice smooth 3.3V into the AREF pin – perhaps from a voltage regulator IC. Then the each step of the ADC would represent around 3.22 millivolts (divide 1024 into 3.3).

Note that in order for this to work, you must run `analogReference(EXTERNAL);` before using `analogRead()`

IORef : Input Output Voltage Reference, It allows shields connected to Arduino board to check whether the board is running at 3.3V or 5V.

structure

The basic structure of the Arduino programming language is fairly simple and runs in at least two parts. These two required parts, or functions, enclose blocks of statements.

```
void setup()
{
  statements;
}

void loop()
{
  statements;
}
```

Where setup() is the preparation, loop() is the execution. Both functions are required for the program to work.

The setup function should follow the declaration of any variables at the very beginning of the program. It is the first function to run in the program, is run only once, and is used to set pinMode or initialize serial communication.

The loop function follows next and includes the code to be executed continuously – reading inputs, triggering outputs, etc. This function is the core of all Arduino programs and does the bulk of the work.

setup()

The setup() function is called once when your program starts. Use it to initialize pin modes, or begin serial. It must be included in a program even if there are no statements to run.

```
void setup()
{
  pinMode(pin, OUTPUT);      // sets the 'pin' as output
}
```

loop()

After calling the setup() function, the loop() function does precisely what its name suggests, and loops consecutively, allowing the program to change, respond, and control the Arduino board.

```
void loop()
{
  digitalWrite(pin, HIGH);   // turns 'pin' on
  delay(1000);               // pauses for one second
  digitalWrite(pin, LOW);    // turns 'pin' off
  delay(1000);               // pauses for one second
}
```

functions

A function is a block of code that has a name and a block of statements that are executed when the function is called. The functions void setup() and void loop() have already been discussed and other built-in functions will be discussed later.

Custom functions can be written to perform repetitive tasks and reduce clutter in a program. Functions are declared by first declaring the function type. This is the type of value to be returned by the function such as 'int' for an integer type function. If no value is to be returned the function type would be void. After type, declare the name given to the function and in parenthesis any parameters being passed to the function.

```
type functionName(parameters)
{
  statements;
}
```

The following integer type function delayVal() is used to set a delay value in a program by reading the value of a potentiometer. It first declares a local variable v, sets v to the value of the potentiometer which gives a number between 0-1023, then divides that value by 4 for a final value between 0-255, and finally returns that value back to the main program.

```
int delayVal()
{
  int v;                  // create temporary variable 'v'
  v  = analogRead(pot);   // read potentiometer value
  v /= 4;                 // converts 0-1023 to 0-255
  return v;               // return final value
}
```

{} curly braces

Curly braces (also referred to as just "braces" or "curly brackets") define the beginning and end of function blocks and statement blocks such as the void loop() function and the for and if statements.

```
type function()
{
  statements;
}
```

An opening curly brace { must always be followed by a closing curly brace }. This is often referred to as the braces being balanced. Unbalanced braces can often lead to cryptic, impenetrable compiler errors that can sometimes be hard to track down in a large program.

The Arduino environment includes a convenient feature to check the balance of curly braces. Just select a brace, or even click the insertion point immediately following a brace, and its logical companion will be highlighted.

; semicolon

A semicolon must be used to end a statement and separate elements of the program. A semicolon is also used to separate elements in a for loop.

```
int x = 13;   // declares variable 'x' as the integer 13
```

Note: Forgetting to end a line in a semicolon will result in a compiler error. The error text may be obvious, and refer to a missing semicolon, or it may not. If an impenetrable or seemingly illogical compiler error comes up, one of the first things to check is a missing semicolon, near the line where the compiler complained.

/*… */ block comments

Block comments, or multi-line comments, are areas of text ignored by the program and are used for large text descriptions of code or comments that help others understand parts of the program. They begin with /* and end with */ and can span multiple lines.

```
/*  this is an enclosed block comment
    don't forget the closing comment -
    they have to be balanced!
*/
```

Because comments are ignored by the program and take no memory space they should be used generously and can also be used to "comment out" blocks of code for debugging purposes.

Note: While it is possible to enclose single line comments within a block comment, enclosing a second block comment is not allowed.

// line comments

Single line comments begin with // and end with the next line of code. Like block comments, they are ignored by the program and take no memory space.

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

Single line comments are often used after a valid statement to provide more information about what the statement accomplishes or to provide a future reminder.

variables

A variable is a way of naming and storing a numerical value for later use by the program. As their namesake suggests, variables are numbers that can be continually changed as opposed to constants whose value never changes. A variable needs to be declared and optionally assigned to the value needing to be stored. The following code declares a variable called inputVariable and then assigns it the value obtained on analog input pin 2:

```
int inputVariable = 0;          // declares a variable and
                                // assigns value of 0
inputVariable = analogRead(2); // set variable to value of
                                // analog pin 2
```

‘inputVariable’ is the variable itself. The first line declares that it will contain an int, short for integer. The second line sets the variable to the value at analog pin 2. This makes the value of pin 2 accessible elsewhere in the code.

Once a variable has been assigned, or re-assigned, you can test its value to see if it meets certain conditions, or you can use its value directly. As an example to illustrate three useful operations with variables, the following code tests whether the inputVariable is less than 100, if true it assigns the value 100 to inputVariable, and then sets a delay based on inputVariable which is now a minimum of 100:

```
if (inputVariable < 100) // tests variable if less than 100
{
  inputVariable = 100;   // if true assigns value of 100
}
delay(inputVariable);    // uses variable as delay
```

Note: Variables should be given descriptive names, to make the code more readable. Variable names like tiltSensor or pushButton help the programmer and anyone else reading the code to understand what the variable represents. Variable names like var or value, on the other hand, do little to make the code readable and are only used here as examples. A variable can be named any word that is not already one of the keywords in the Arduino language.

variable declaration

All variables have to be declared before they can be used. Declaring a variable means defining its value type, as in int, long, float, etc., setting a specified name, and optionally assigning an initial value. This only needs to be done once in a program but the value can be changed at any time using arithmetic and various assignments.

The following example declares that inputVariable is an int, or integer type, and that its initial value equals zero. This is called a simple assignment.

```
int inputVariable = 0;
```

A variable can be declared in a number of locations throughout the program and where this definition takes place determines what parts of the program can use the variable.

variable scope

A variable can be declared at the beginning of the program before void setup(), locally inside of functions, and sometimes within a statement block such as for loops. Where the variable is declared determines the variable scope, or the ability of certain parts of a program to make use of the variable.

A global variable is one that can be seen and used by every function and statement in a program. This variable is declared at the beginning of the program, before the setup() function.

A local variable is one that is defined inside a function or as part of a for loop. It is only visible and can only be used inside the function in which it was declared. It is therefore possible to have two or more variables of the same name in different parts of the same program that contain different values. Ensuring that only one function has access to its variables simplifies the program and reduces the potential for programming errors.

The following example shows how to declare a few different types of variables and demonstrates each variable's visibility:

```
int value;               // 'value' is visible
                         // to any function
void setup()
{
  // no setup needed
}

void loop()
{
  for (int i=0; i<20;)  // 'i' is only visible
  {                     // inside the for-loop
    i++;
  }
  float f;              // 'f' is only visible
}                       // inside loop
```

byte

Byte stores an 8-bit numerical value without decimal points. They have a range of 0-255.

```
byte someVariable = 180;   // declares 'someVariable'
                           // as a byte type
```

int

Integers are the primary datatype for storage of numbers without decimal points and store a 16-bit value with a range of 32,767 to -32,768.

```
int someVariable = 1500;   // declares 'someVariable'
                           // as an integer type
```

Note: Integer variables will roll over if forced past their maximum or minimum values by an assignment or comparison. For example, if `x = 32767` and a subsequent statement adds 1 to x, `x = x + 1 or x++`, x will then rollover and equal -32,768.

long

Extended size datatype for long integers, without decimal points, stored in a 32-bit value with a range of 2,147,483,647 to -2,147,483,648.

```
long someVariable = 90000; // declares 'someVariable'
                           // as a long type
```

float

A datatype for floating-point numbers, or numbers that have a decimal point. Floating-point numbers have greater resolution than integers and are stored as a 32-bit value with a range of 3.4028235E+38 to -3.4028235E+38.

```
float someVariable = 3.14; // declares 'someVariable'
                           // as a floating-point type
```

Note: Floating-point numbers are not exact, and may yield strange results when compared. Floating point math is also much slower than integer math in performing calculations, so should be avoided if possible.

arrays

An array is a collection of values that are accessed with an index number. Any value in the array may be called upon by calling the name of the array and the index number of the value. Arrays are zero indexed, with the first value in the array beginning at index number 0. An array needs to be declared and optionally assigned values before they can be used.

```
int myArray[] = {value0, value1, value2...}
```

Likewise it is possible to declare an array by declaring the array type and size and later assign values to an index position:

```
int myArray[5];    // declares integer array w/ 6 positions
myArray[3] = 10;   // assigns the 4th index the value 10
```

To retrieve a value from an array, assign a variable to the array and index position:

```
x = myArray[3];    // x now equals 10
```

Arrays are often used in for loops, where the increment counter is also used as the index position for each array value. The following example uses an array to flicker an LED. Using a for loop, the counter begins at 0, writes the value contained at index position 0 in the array flicker[], in this case 180, to the PWM pin 10, pauses for 200ms, then moves to the next index position.

```
int ledPin = 10;                      // LED on pin 10
byte flicker[] = {180, 30, 255, 200, 10, 90, 150, 60};
                                      // above array of 8
void setup()                          // different values
{
  pinMode(ledPin, OUTPUT);            // sets OUTPUT pin
}

void loop()
{
  for(int i=0; i<7; i++)              // loop equals number
  {                                   // of values in array
    analogWrite(ledPin, flicker[i]); // write index value
    delay(200);                       // pause 200ms
  }
}
```

arithmetic

Arithmetic operators include addition, subtraction, multiplication, and division. They return the sum, difference, product, or quotient (respectively) of two operands.

```
y = y + 3;
x = x - 7;
i = j * 6;
r = r / 5;
```

The operation is conducted using the data type of the operands, so, for example, 9 / 4 results in 2 instead of 2.25 since 9 and 4 are ints and are incapable of using decimal points. This also means that the operation can overflow if the result is larger than what can be stored in the data type.

If the operands are of different types, the larger type is used for the calculation. For example, if one of the numbers (operands) are of the type float and the other of type integer, floating point math will be used for the calculation.

Choose variable sizes that are large enough to hold the largest results from your calculations. Know at what point your variable will rollover and also what happens in the other direction e.g. (0 - 1) OR (0 - - 32768). For math that requires fractions, use float variables, but be aware of their drawbacks: large size and slow computation speeds.

Note: Use the cast operator e.g. (int)myFloat to convert one variable type to another on the fly. For example, `i = (int)3.6` will set i equal to 3.

compound assignments

Compound assignments combine an arithmetic operation with a variable assignment. These are commonly found in for loops as described later. The most common compound assignments include:

```
x ++      // same as x = x + 1, or increments x by +1
x --      // same as x = x - 1, or decrements x by -1
x += y    // same as x = x + y, or increments x by +y
x -= y    // same as x = x - y, or decrements x by -y
x *= y    // same as x = x * y, or multiplies x by y
x /= y    // same as x = x / y, or divides x by y
```

Note: For example, x *= 3 would triple the old value of x and re-assign the resulting value to x.

comparison operators

Comparisons of one variable or constant against another are often used in if statements to test if a specified condition is true. In the examples found on the following pages, ?? is used to indicate any of the following conditions:

```
x == y    // x is equal to y
x != y    // x is not equal to y
x <  y    // x is less than y
x >  y    // x is greater than y
x <= y    // x is less than or equal to y
x >= y    // x is greater than or equal to y
```

logical operators

Logical operators are usually a way to compare two expressions and return a TRUE or FALSE depending on the operator. There are three logical operators, AND, OR, and NOT, that are often used in if statements:

Logical AND:

```
if (x > 0 && x < 5)    // true only if both
                       // expressions are true
```

Logical OR:

```
if (x > 0 || y > 0)    // true if either
                       // expression is true
```

Logical NOT:

```
if (!x > 0)            // true only if
                       // expression is false
```

constants
The Arduino language has a few predefined values, which are called constants. They are used to make the programs easier to read. Constants are classified in groups.

true/false
These are Boolean constants that define logic levels. FALSE is easily defined as 0 (zero) while TRUE is often defined as 1, but can also be anything else except zero. So in a Boolean sense, -1, 2, and -200 are all also defined as TRUE.

```
if (b == TRUE);
{
  doSomething;
}
```

high/low
These constants define pin levels as HIGH or LOW and are used when reading or writing to digital pins. HIGH is defined as logic level 1, ON, or 5 volts while LOW is logic level 0, OFF, or 0 volts.

```
digitalWrite(13, HIGH);
```

input/output
Constants used with the pinMode() function to define the mode of a digital pin as either INPUT or OUTPUT.

```
pinMode(13, OUTPUT);
```

if

if statements test whether a certain condition has been reached, such as an analog value being above a certain number, and executes any statements inside the brackets if the statement is true. If false the program skips over the statement. The format for an if test is:

```
if (someVariable ?? value)
{
  doSomething;
}
```

The above example compares someVariable to another value, which can be either a variable or constant. If the comparison, or condition in parentheses is true, the statements inside the brackets are run. If not, the program skips over them and continues on after the brackets.

Note: Beware of accidentally using '=', as in `if(x=10)`, while technically valid, defines the variable x to the value of 10 and is as a result always true. Instead use '==', as in `if(x==10)`, which only tests whether x happens to equal the value 10 or not. Think of '=' as *"equals"* opposed to '==' being *"is equal to"*.

if… else

if… else allows for ‘either-or’ decisions to be made. For example, if you wanted to test a digital input, and do one thing if the input went HIGH or instead do another thing if the input was LOW, you would write that this way:

```
if (inputPin == HIGH)
{
  doThingA;
}
else
{
  doThingB;
}
```

else can also precede another if test, so that multiple, mutually exclusive tests can be run at the same time. It is even possible to have an unlimited number of these else branches. Remember though, only one set of statements will be run depending on the condition tests:

```
if (inputPin < 500)
{
  doThingA;
}
else if (inputPin >= 1000)
{
  doThingB;
}
else
{
  doThingC;
}
```

Note: An if statement simply tests whether the condition inside the parenthesis is true or false. This statement can be any valid C statement as in the first example, `if (inputPin == HIGH)`. In this example, the if statement only checks to see if indeed the specified input is at logic level high, or +5v.

for

The for statement is used to repeat a block of statements enclosed in curly braces a specified number of times. An increment counter is often used to increment and terminate the loop. There are three parts, separated by semicolons (;), to the for loop header:

```
for (initialization; condition; expression)
{
  doSomething;
}
```

The initialization of a local variable, or increment counter, happens first and only once. Each time through the loop, the following condition is tested. If the condition remains true, the following statements and expression are executed and the condition is tested again. When the condition becomes false, the loop ends.

The following example starts the integer i at 0, tests to see if i is still less than 20 and if true, increments i by 1 and executes the enclosed statements:

```
for (int i=0; i<20; i++)  // declares i, tests if less
{                         // than 20, increments i by 1
  digitalWrite(13, HIGH); // turns pin 13 on
  delay(250);             // pauses for 1/4 second
  digitalWrite(13, LOW);  // turns pin 13 off
  delay(250);             // pauses for 1/4 second
}
```

Note: The C for loop is much more flexible than for loops found in some other computer languages, including BASIC. Any or all of the three header elements may be omitted, although the semicolons are required. Also the statements for initialization, condition, and expression can be any valid C statements with unrelated variables. These types of unusual for statements may provide solutions to some rare programming problems.

while

while loops will loop continuously, and infinitely, until the expression inside the parenthesis becomes false. Something must change the tested variable, or the while loop will never exit. This could be in your code, such as an incremented variable, or an external condition, such as testing a sensor.

```
while (someVariable ?? value)
{
  doSomething;
}
```

The following example tests whether 'someVariable' is less than 200 and if true executes the statements inside the brackets and will continue looping until 'someVariable' is no longer less than 200.

```
While (someVariable < 200) // tests if less than 200
{
  doSomething;             // executes enclosed statements
  someVariable++;          // increments variable by 1
}
```

do… while

The do loop is a bottom driven loop that works in the same manner as the while loop, with the exception that the condition is tested at the end of the loop, so the do loop will always run at least once.

```
do
{
  doSomething;
} while (someVariable ?? value);
```

The following example assigns readSensors() to the variable 'x', pauses for 50 milliseconds, then loops indefinitely until 'x' is no longer less than 100:

```
do
{
  x = readSensors();    // assigns the value of
                        // readSensors() to x
  delay(50);            // pauses 50 milliseconds
} while (x < 100);      // loops if x is less than 100
```

pinMode(pin, mode)

Used in `void setup()` to configure a specified pin to behave either as an INPUT or an OUTPUT.

```
pinMode(pin, OUTPUT);    // sets ‘pin’ to output
```

Arduino digital pins default to inputs, so they don't need to be explicitly declared as inputs with pinMode(). Pins configured as INPUT are said to be in a high-impedance state.

There are also convenient 20KΩ pullup resistors built into the Atmega chip that can be accessed from software. These built-in pullup resistors are accessed in the following manner:

```
pinMode(pin, INPUT);        // set ‘pin’ to input
digitalWrite(pin, HIGH);    // turn on pullup resistors
```

Pullup resistors would normally be used for connecting inputs like switches. Notice in the above example it does not convert `pin` to an output, it is merely a method for activating the internal pull-ups.

Pins configured as OUTPUT are said to be in a low-impedance state and can provide 40 mA (milliamps) of current to other devices/circuits. This is enough current to brightly light up an LED (don't forget the series resistor), but not enough current to run most relays, solenoids, or motors.

Short circuits on Arduino pins and excessive current can damage or destroy the output pin, or damage the entire Atmega chip. It is often a good idea to connect an OUTPUT pin to an external device in series with a 470Ω or 1KΩ resistor.

digitalRead(pin)

Reads the value from a specified digital pin with the result either HIGH or LOW. The pin can be specified as either a variable or constant (0-13).

```
value = digitalRead(Pin);   // sets 'value' equal to
                            // the input pin
```

digitalWrite(pin, value)

Ouputs either logic level HIGH or LOW at (turns on or off) a specified digital pin. The pin can be specified as either a variable or constant (0-13).

```
digitalWrite(pin, HIGH);   // sets 'pin' to high
```

The following example reads a pushbutton connected to a digital input and turns on an LED connected to a digital output when the button has been pressed:

```
int led   = 13;   // connect LED to pin 13
int pin   =  7;   // connect pushbutton to pin 7
int value =  0;   // variable to store the read value

void setup()
{
  pinMode(led, OUTPUT);    // sets pin 13 as output
  pinMode(pin, INPUT);     // sets pin 7 as input
}

void loop()
{
  value = digitalRead(pin);  // sets 'value' equal to
                             // the input pin
  digitalWrite(led, value);  // sets 'led' to the
}                            // button's value
```

analogRead(pin)

Reads the value from a specified analog pin with a 10-bit resolution. This function only works on the analog in pins (0-5). The resulting integer values range from 0 to 1023.

```
value = analogRead(pin);  // sets 'value' equal to 'pin'
```

Note: Analog pins unlike digital ones, do not need to be first declared as INPUT nor OUTPUT.

analogWrite(pin, value)

Writes a pseudo-analog value using hardware enabled pulse width modulation (PWM) to an output pin marked PWM. On newer Arduinos with the ATmega168 chip, this function works on pins 3, 5, 6, 9, 10, and 11. Older Arduinos with an ATmega8 only support pins 9, 10, and 11. The value can be specified as a variable or constant with a value from 0-255.

```
analogWrite(pin, value);  // writes 'value' to analog 'pin'
```

A value of 0 generates a steady 0 volts output at the specified pin; a value of 255 generates a steady 5 volts output at the specified pin. For values in between 0 and 255, the pin rapidly alternates between 0 and 5 volts - the higher the value, the more often the pin is HIGH (5 volts). For example, a value of 64 will be 0 volts three-quarters of the time, and 5 volts one quarter of the time; a value of 128 will be at 0 half the time and 255 half the time; and a value of 192 will be 0 volts one quarter of the time and 5 volts three-quarters of the time.

Because this is a hardware function, the pin will generate a steady wave after a call to analogWrite in the background until the next call to analogWrite (or a call to digitalRead or digitalWrite on the same pin).

Note: Analog pins unlike digital ones, do not need to be first declared as INPUT nor OUTPUT.

The following example reads an analog value from an analog input pin, converts the value by dividing by 4, and outputs a PWM signal on a PWM pin:

```
int led = 10;    // LED with 220 resistor on pin 10
int pin =  0;    // potentiometer on analog pin 0
int value;       // value for reading

void setup(){}   // no setup needed

void loop()
{
  value =  analogRead(pin);  // sets 'value' equal to 'pin'
  value /= 4;                // converts 0-1023 to 0-255
  analogWrite(led, value);   // outputs PWM signal to led
}
```

delay(ms)

Pauses your program for the amount of time as specified in milliseconds, where 1000 equals 1 second.

```
delay(1000);   // waits for one second
```

millis()

Returns the number of milliseconds since the Arduino board began running the current program as an unsigned long value.

```
value = millis();  // sets ‘value’ equal to millis()
```

Note: This number will overflow (reset back to zero), after approximately 9 hours.

min(x, y)

Calculates the minimum of two numbers of any data type and returns the smaller number.

```
value = min(value, 100); // sets 'value' to the smaller of
                         // 'value' or 100, ensuring that
                         // it never gets above 100.
```

max(x, y)

Calculates the maximum of two numbers of any data type and returns the larger number.

```
value = max(value, 100); // sets 'value' to the larger of
                         // 'value' or 100, ensuring that
                         // it is at least 100.
```

randomSeed(seed)

Sets a value, or seed, as the starting point for the random() function.

```
randomSeed(value);   // sets ‘value’ as the random seed
```

Because the Arduino is unable to create a truly random number, randomSeed allows you to place a variable, constant, or other function into the random function, which helps to generate more random "random” numbers. There are a variety of different seeds, or functions, that can be used in this function including millis() or even analogRead() to read electrical noise through an analog pin.

random(max)
random(min, max)

The random function allows you to return pseudo-random numbers within a range specified by min and max values.

```
value = random(100, 200);  // sets 'value' to a random
                           // number between 100-200
```

Note: Use this after using the randomSeed() function.

The following example creates a random value between 0-255 and outputs a PWM signal on a PWM pin equal to the random value:

```
int randNumber;  // variable to store the random value
int led = 10;    // LED with 220 resistor on pin 10

void setup() {}  // no setup needed

void loop()
{
  randomSeed(millis());         // sets millis() as seed
  randNumber = random(255);     // random number from 0-255
  analogWrite(led, randNumber); // outputs PWM signal
  delay(500);                   // pauses for half a second
}
```