Engineering Technology (ENGR 101)

Basic Programming

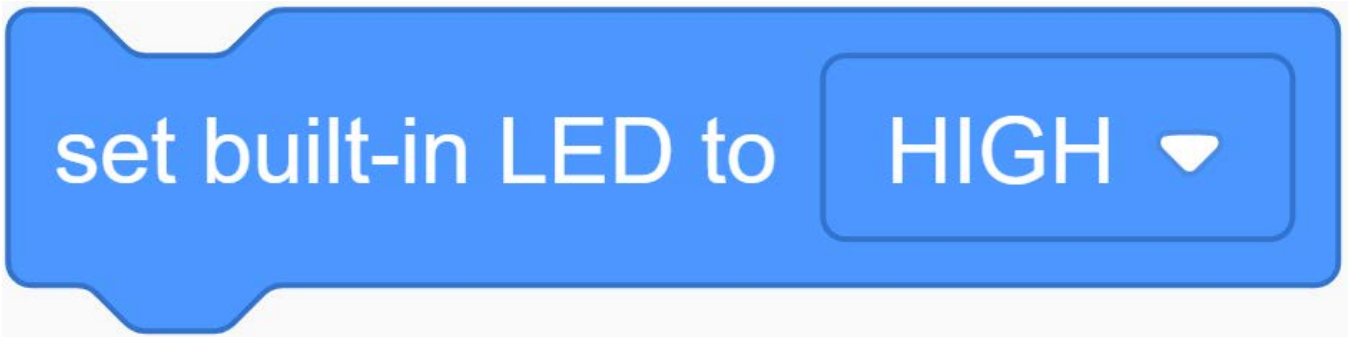
Mohammad Nekooei

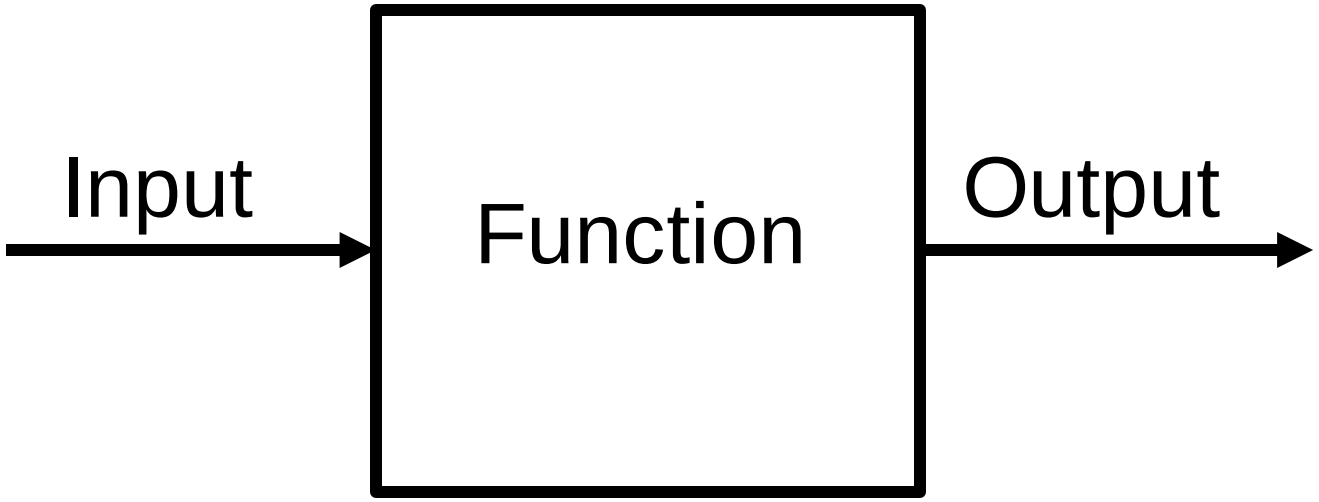
School of Engineering and Computer Science

Victoria University of Wellington

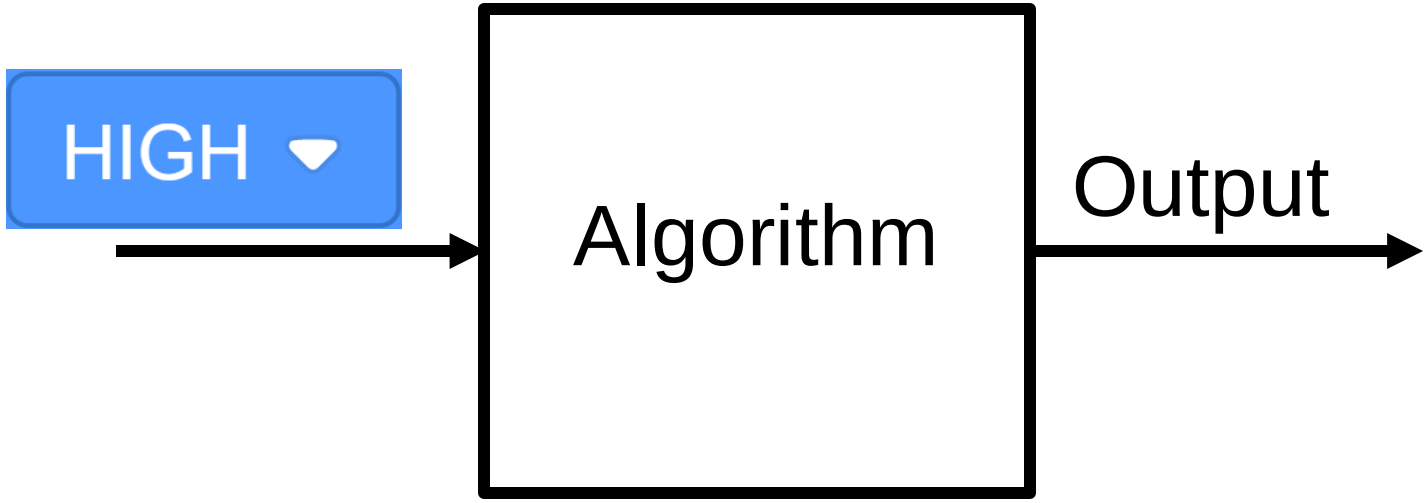
Turn the built in LED on

- This graphical block is a function
  - It takes an input (High voltage to turn the LED on)
  - The function uses instructions to solve the problem or to perform computation
  - The output is the result or side effect of the function

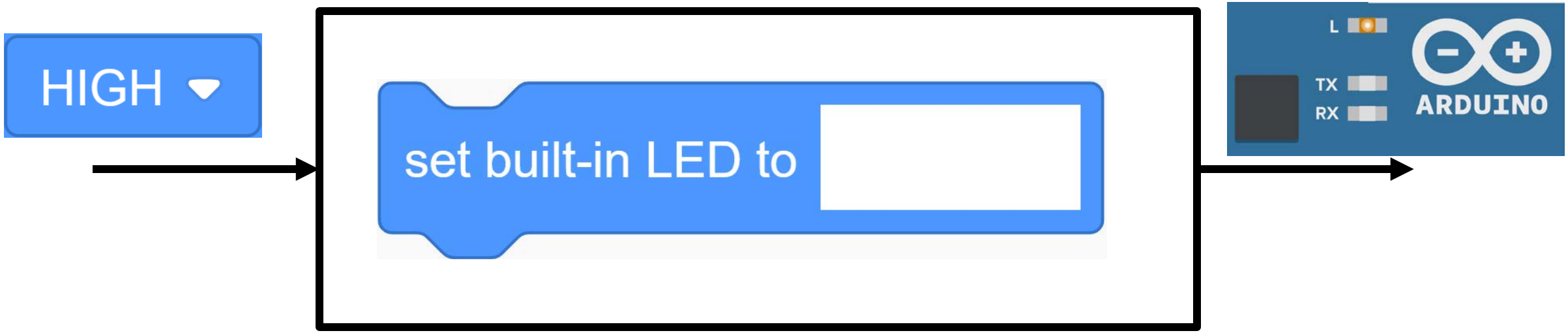




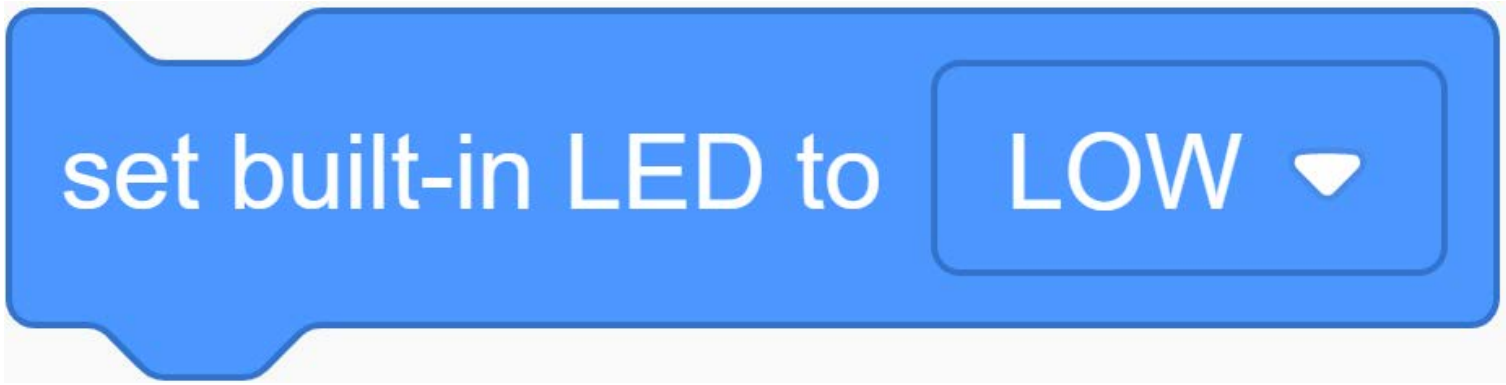
Turn the built in LED on

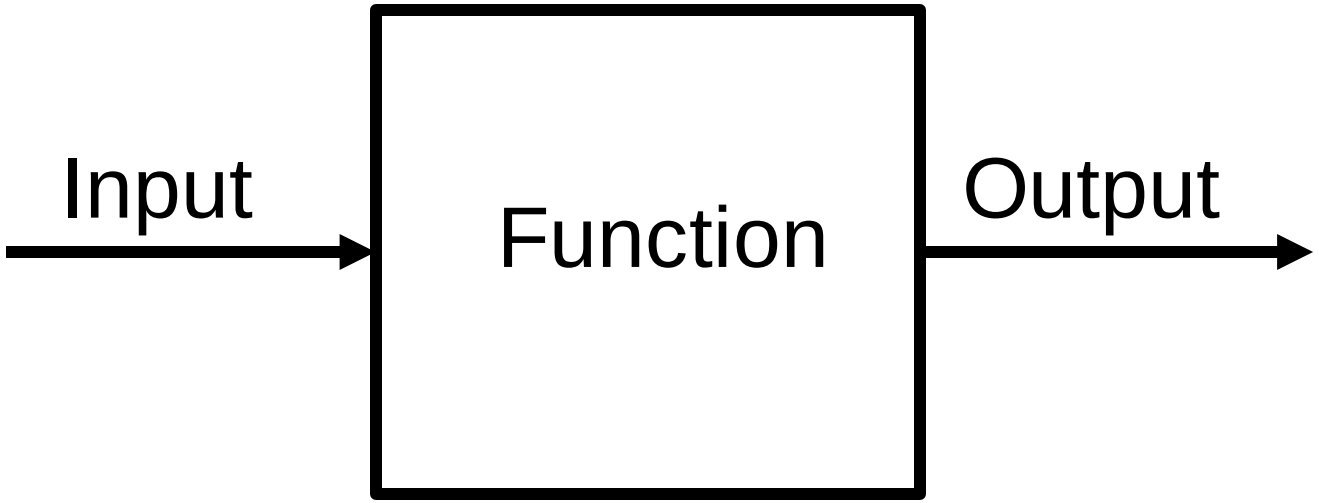


Turn the built in LED on

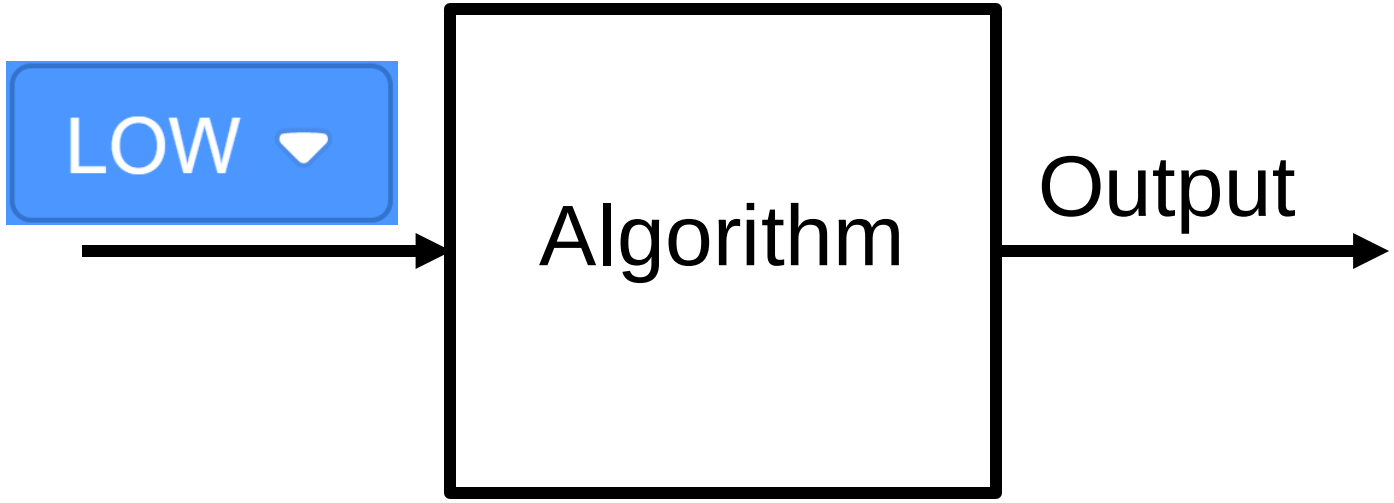


Turn the built in LED off



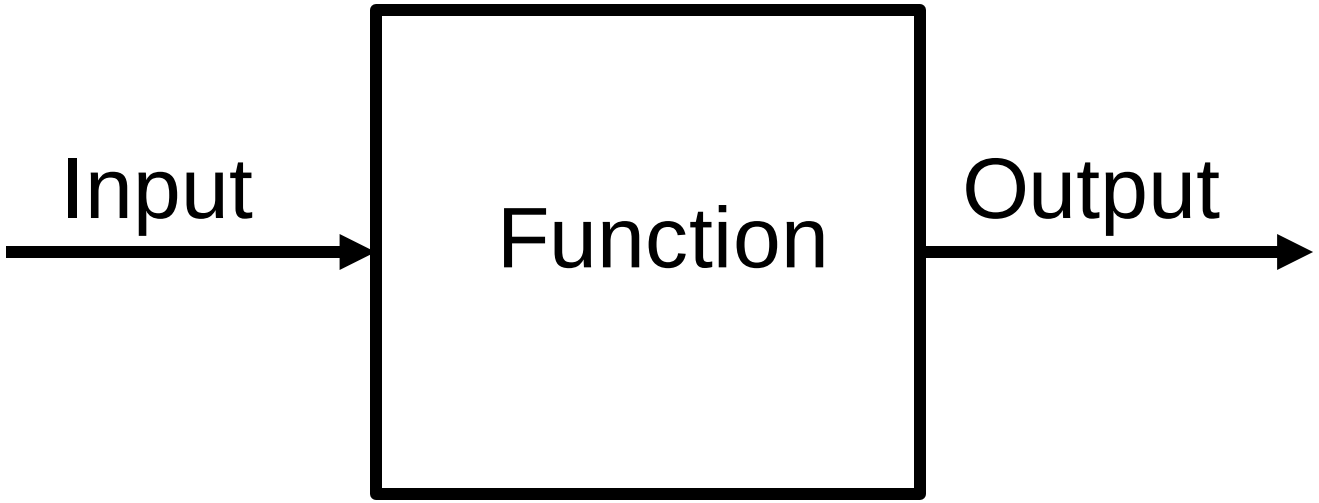


Turn the built in LED off

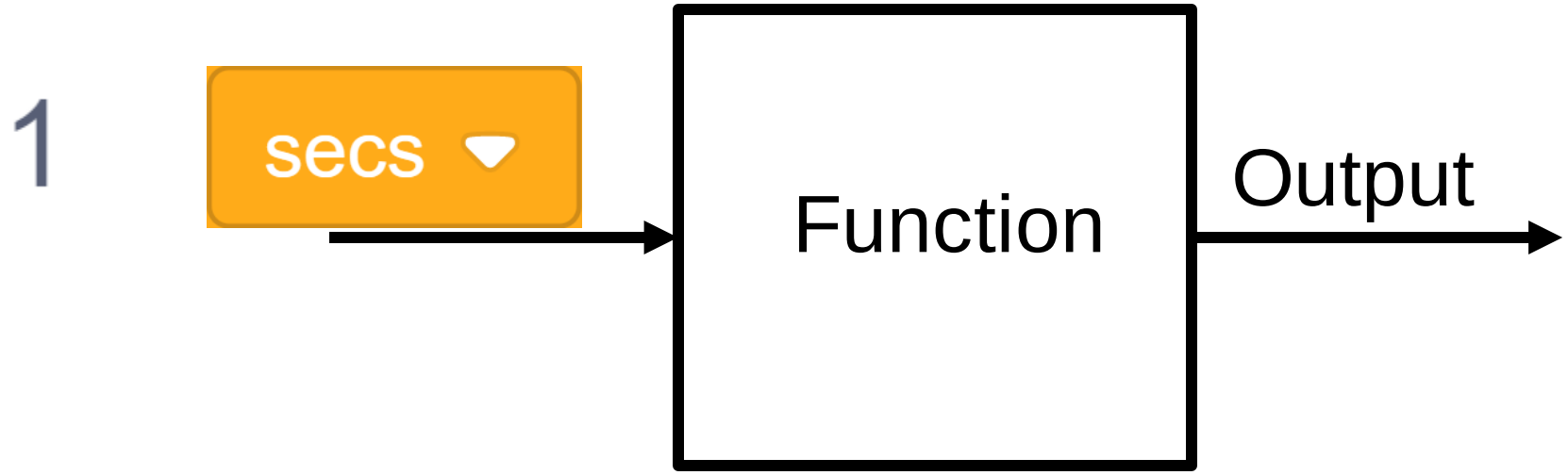


Turn the built in LED off

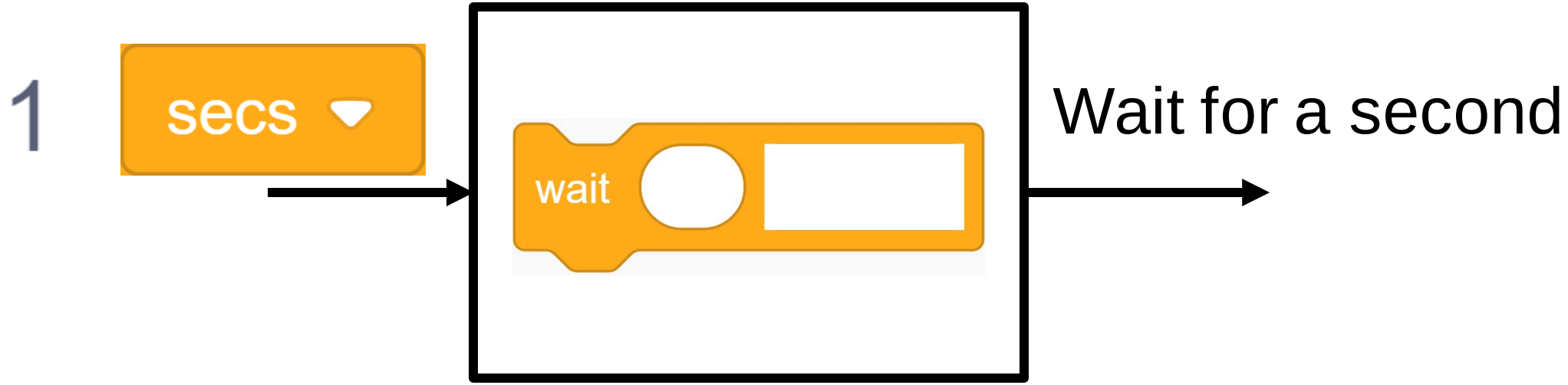
Wait for a second



Wait for a second



Wait for a second

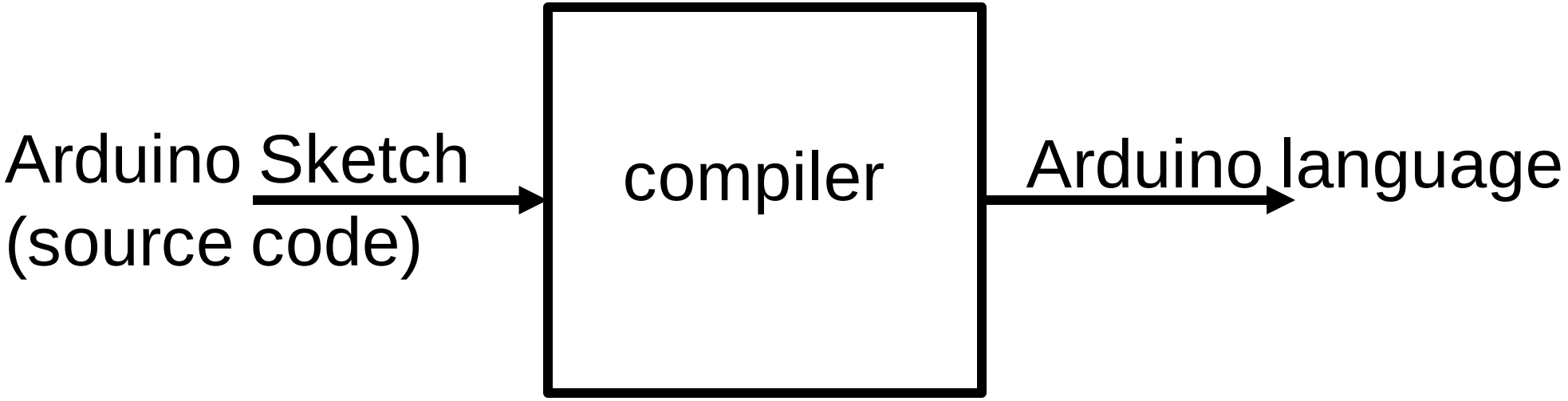


Arduino language

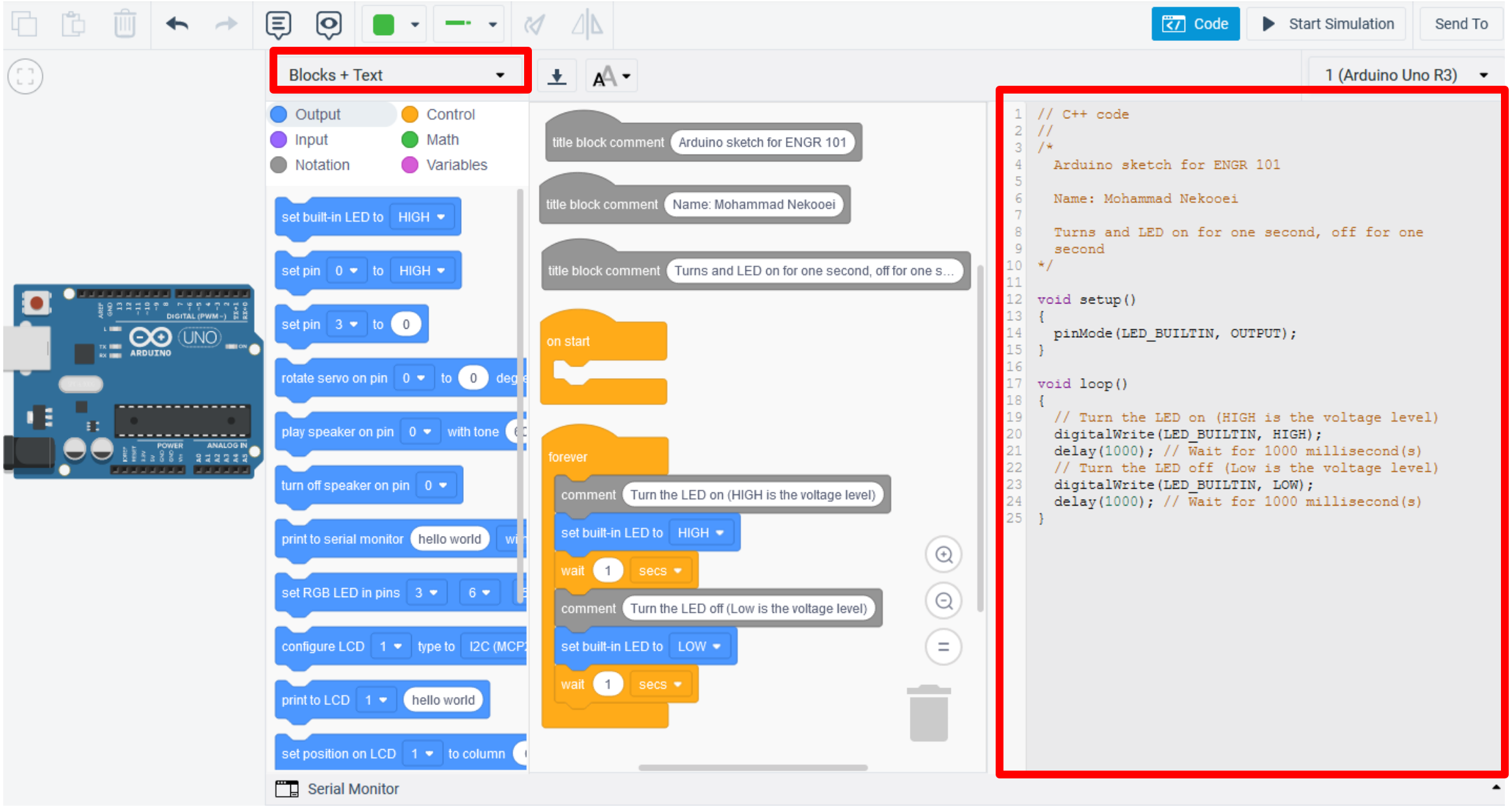
```
01111111 01000101 01001100 01000110 00000010 00000001 00000001 00000000
00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
00000010 00000000 00111110 00000000 00000001 00000000 00000000 00000000
10110000 00000101 01000000 00000000 00000000 00000000 00000000 00000000
01000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
11010000 00010011 00000000 00000000 00000000 00000000 00000000 00000000
00000000 00000000 00000000 00000000 01000000 00000000 00111000 00000000
00001001 00000000 01000000 00000000 00100100 00000000 00100001 00000000
00000110 00000000 00000000 00000000 00000101 00000000 00000000 00000000
01000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
01000000 00000000 01000000 00000000 00000000 00000000 00000000 00000000
01000000 00000000 01000000 00000000 00000000 00000000 00000000 00000000
11111000 00000001 00000000 00000000 00000000 00000000 00000000 00000000
11111000 00000001 00000000 00000000 00000000 00000000 00000000 00000000
00111000 00000010 00000000 00000000 00000000 00000000 00000000 00000000
...
```

Compiler

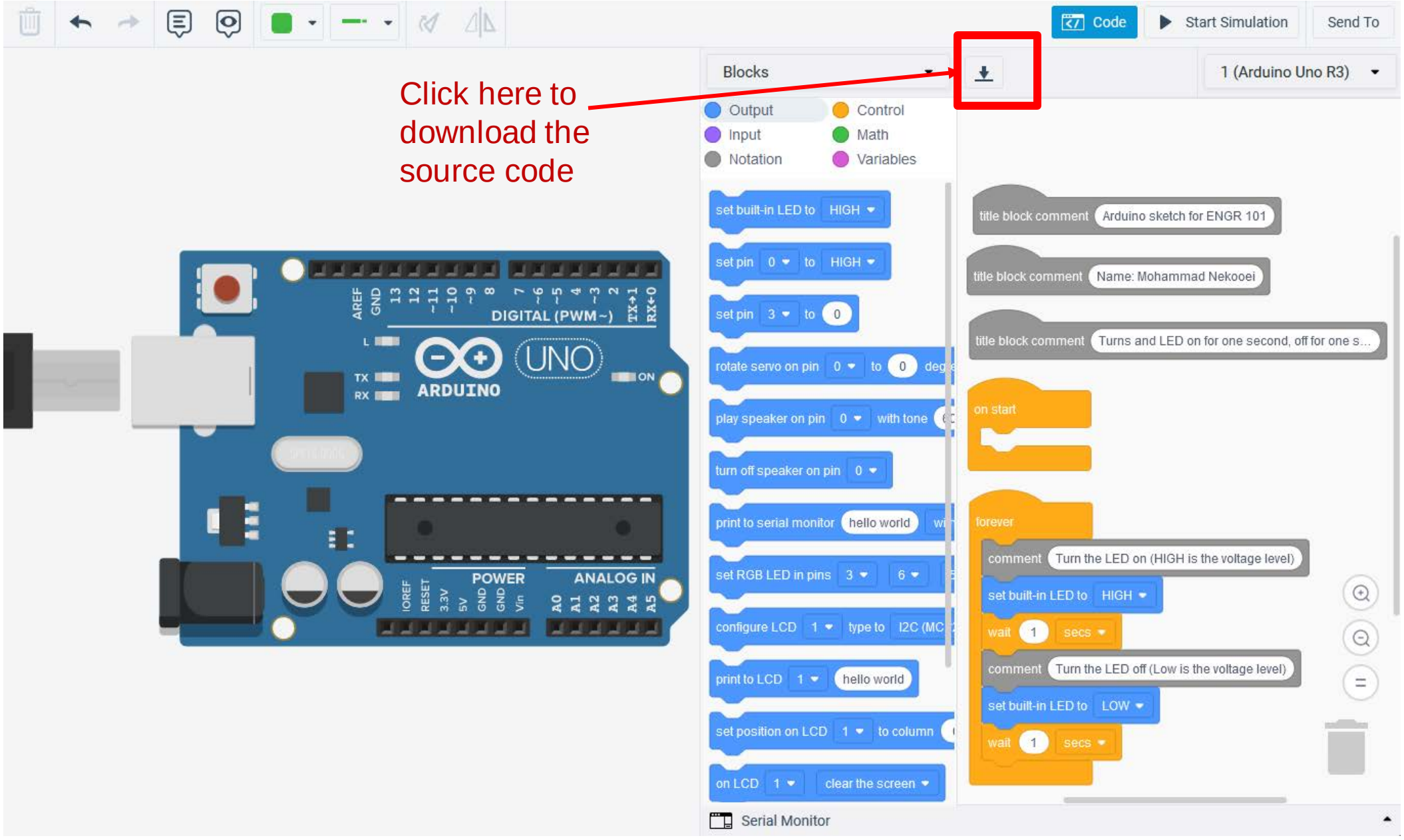
- Translates program to Arduino language



Source code produced by TinkerCad



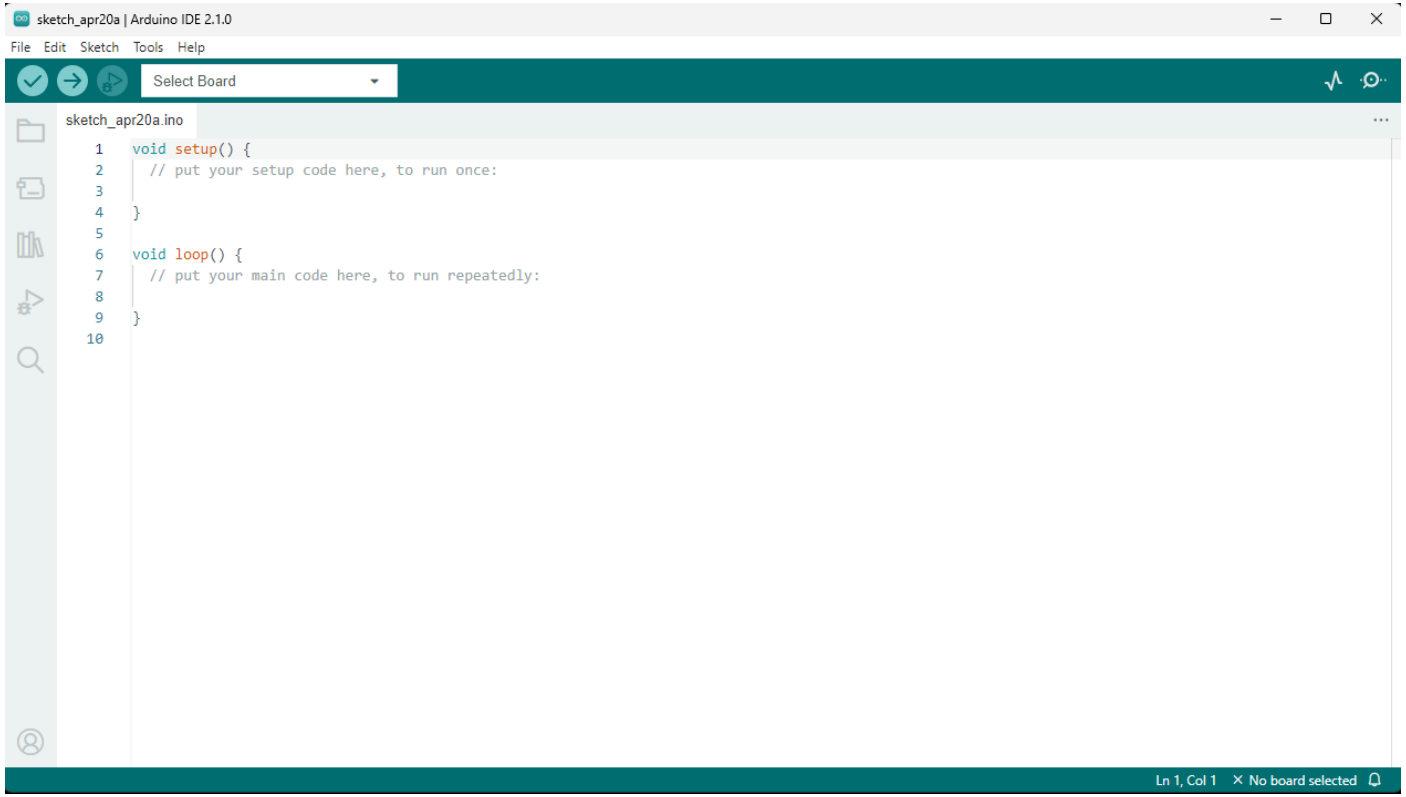
Download source code from TinkerCad



Click here to download the source code

Arduino Programming Environment

- A software environment
  - Program editor
    (Programs written in the C language)
  - Compiler:
    (Translates program to Arduino language)
  - Uploader
    (Sends program to Arduino over USB)
  - Debugger
    (Helps find errors in program)



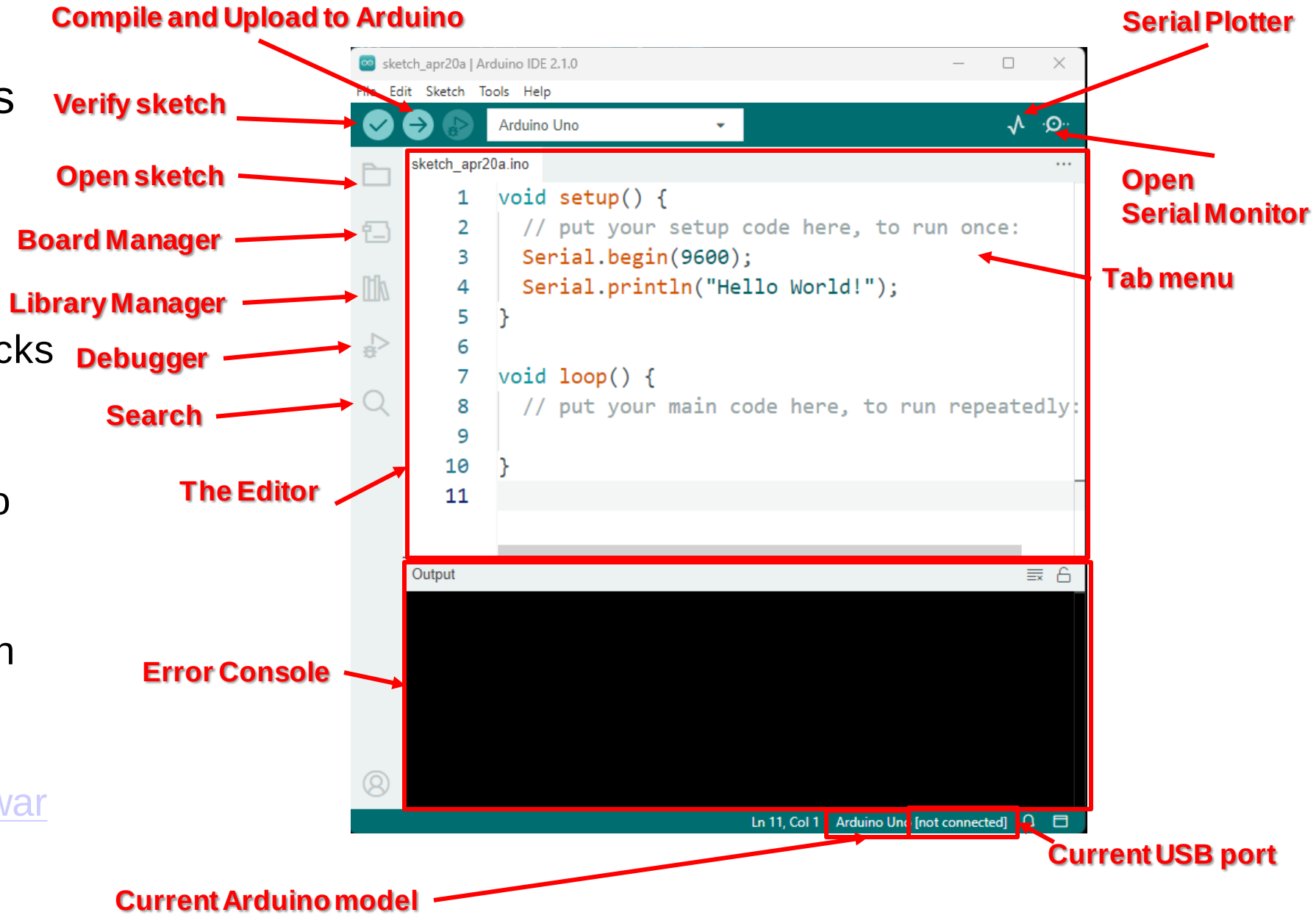
Arduino Terminology

- “sketch” – a program you write to run on an Arduino board
- “pin” – an input or output connected to something. e.g., output to an LED, input from a knob.
- “digital pin” – value is either HIGH or LOW. (aka on/off, one/zero) e.g., switch state
- “analog pin” – value ranges, usually from 0-255. e.g., LED brightness, motor speed, etc.

Arduino Integrated Development Environment (IDE)

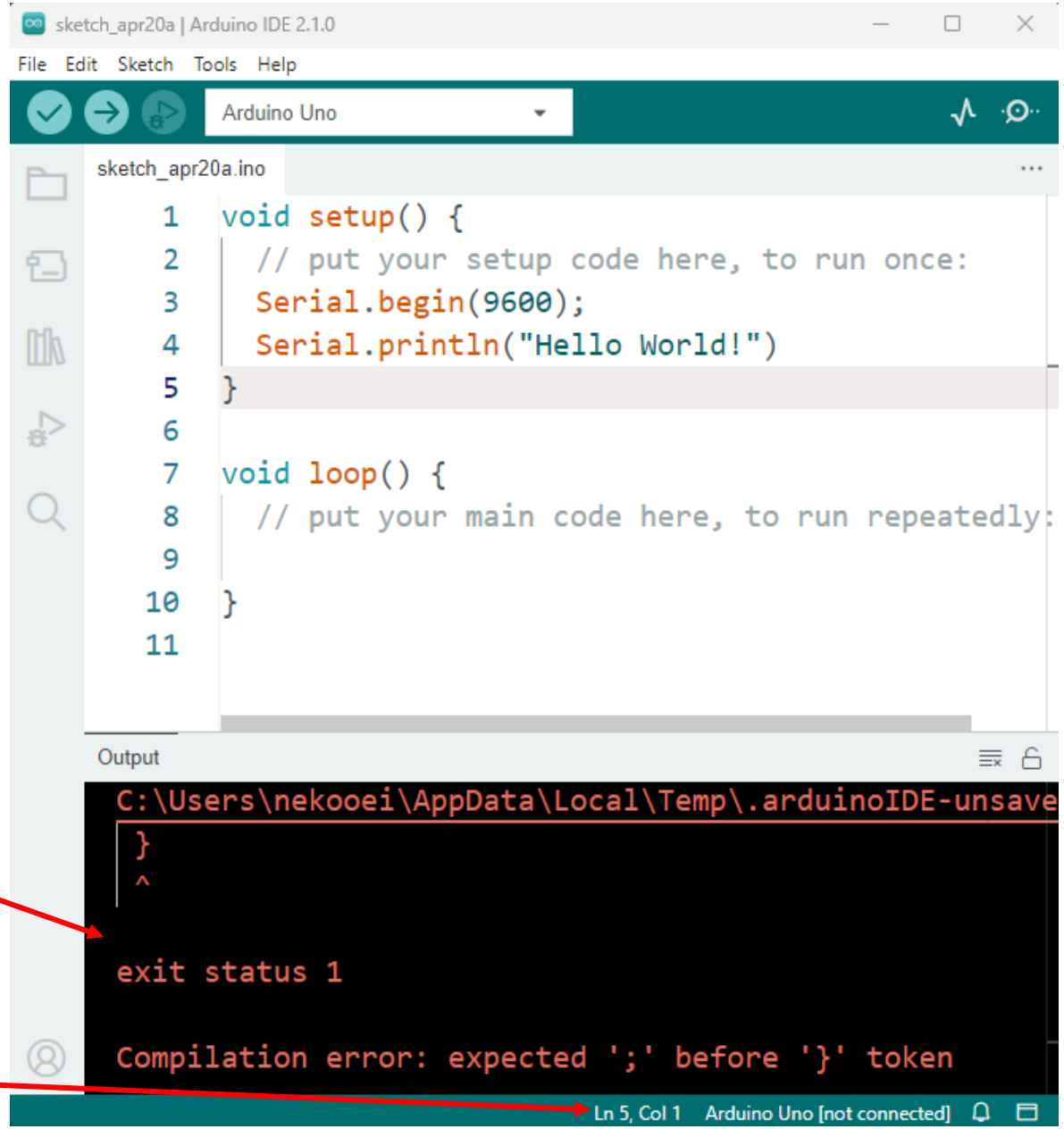
- Like a text editor
- View/write/edit sketches
- But then you program them into hardware

- **Verify:** Compiles code, checks for errors
- **Upload:** Compiles code, checks for errors, uploads to board
- **Serial Monitor:** Opens a window to communicate with the board
- More information: https://docs.arduino.cc/software/ide-v2/tutorials/getting-started-ide-v2



Compile Code

- Verify and Upload both compile
- Message window will show either completion message or error messages
- Error messages will show line numbers

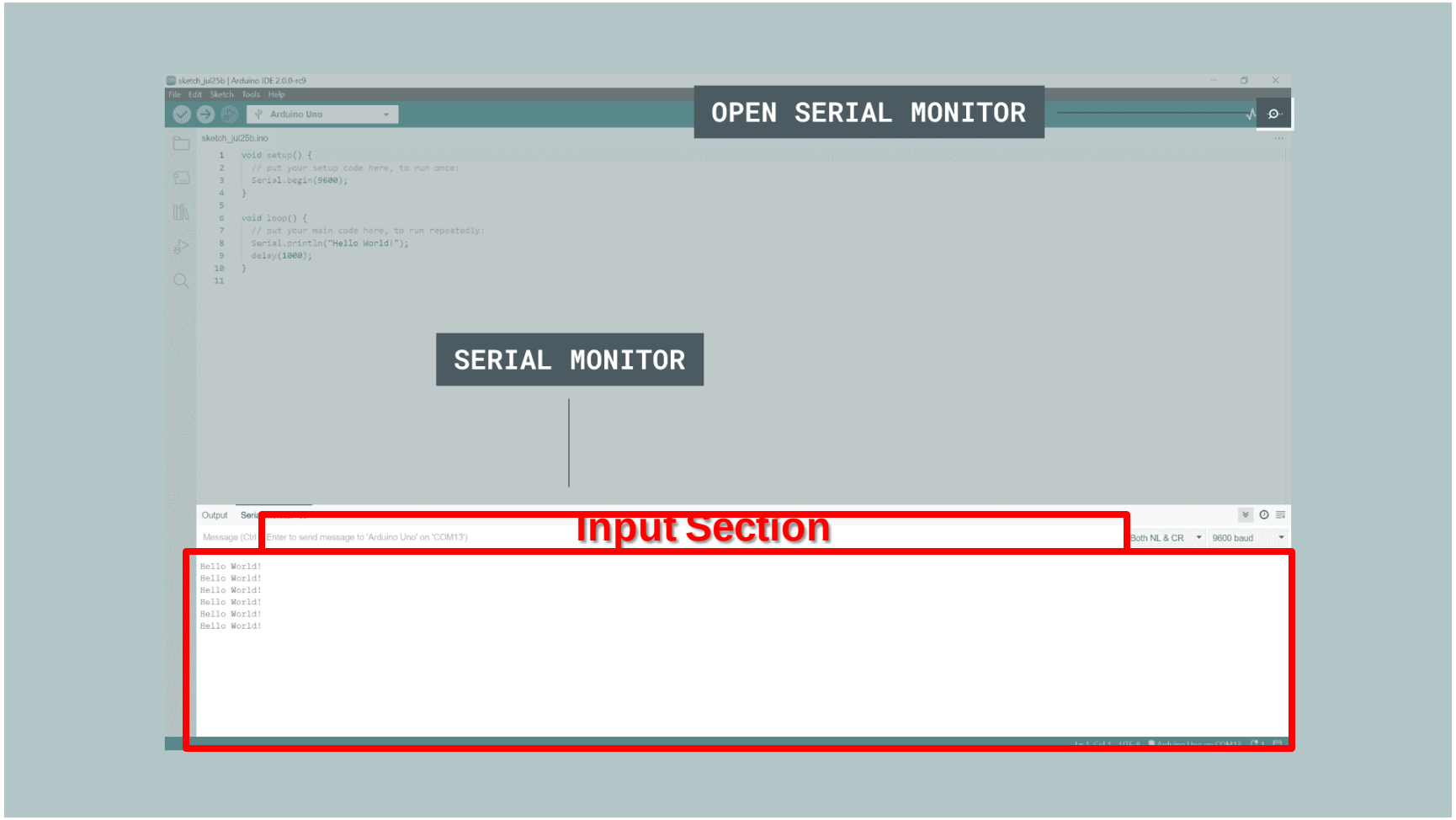


Error Message

Error line number

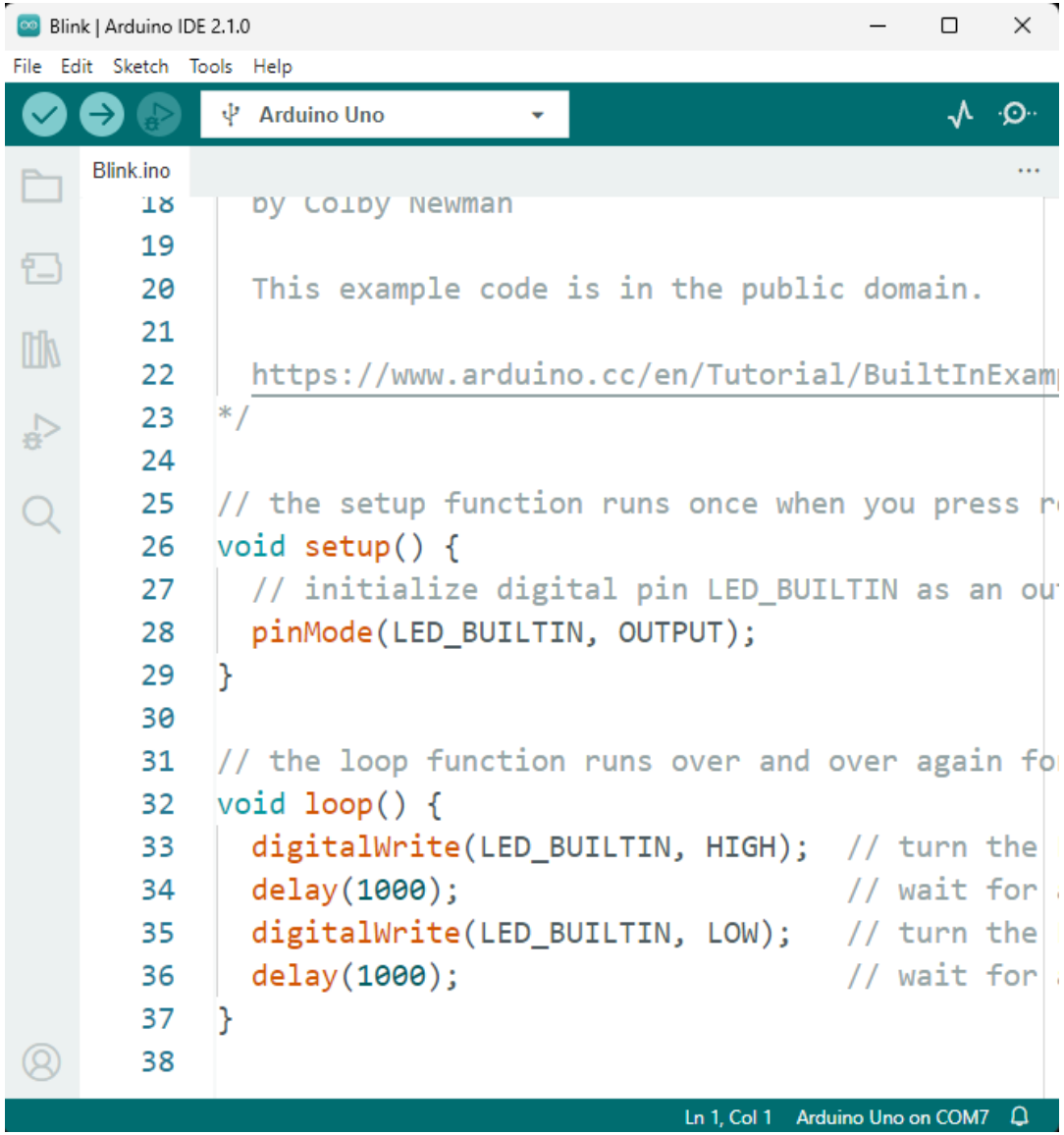
Serial Monitor

- Displays serial data sent from the Arduino
- Allows serial data to be sent to the Arduino from the keyboard
- Library functions in the serial library



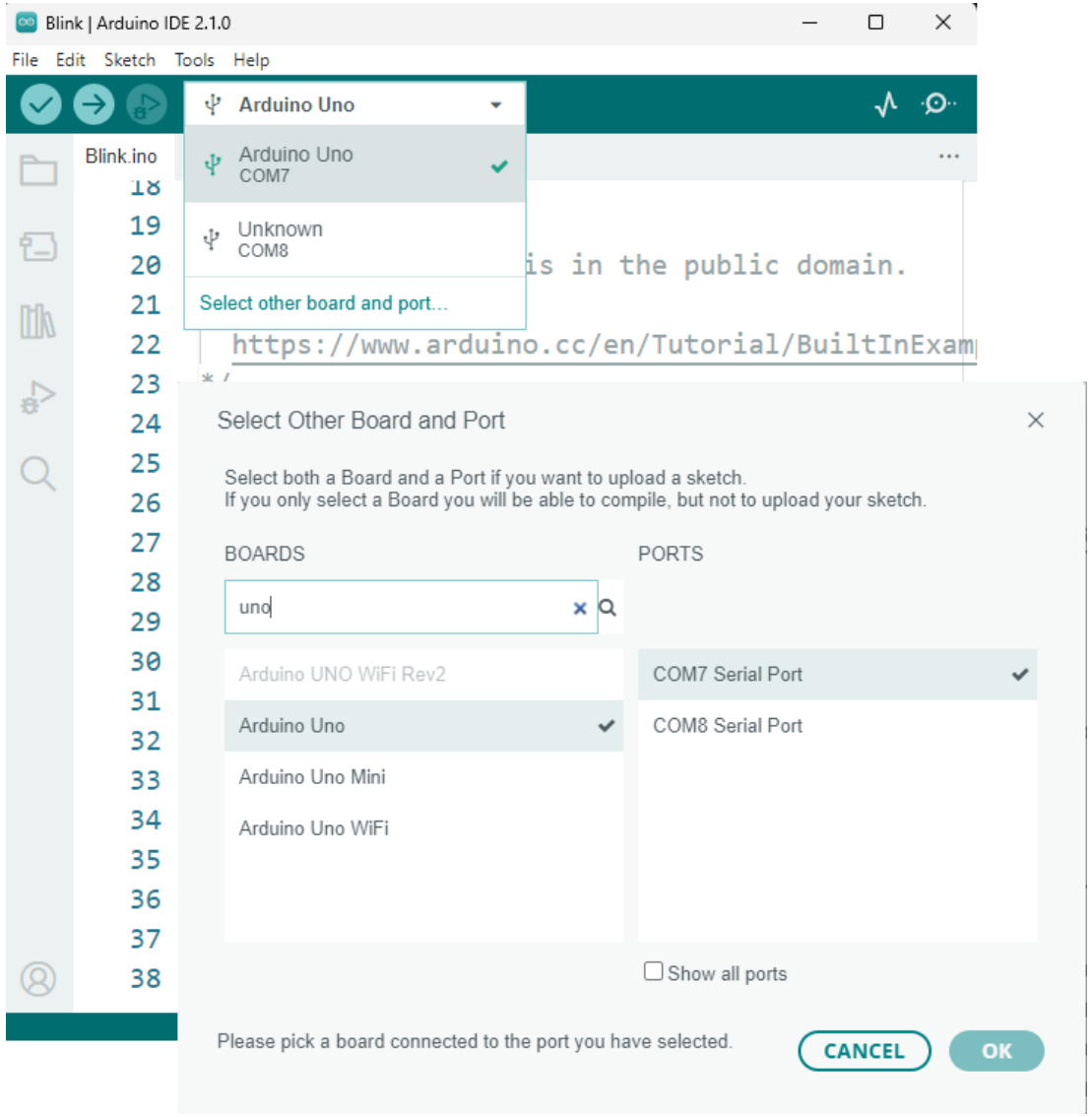
Set Up the Arduino IDE

- Download the IDE
  https://www.arduino.cc/en/Main/Software
  - Easiest to run Windows Installer
  - Also installs USB and other derivers
- Connect the board to your computer
  - Use USB cable
- Run the Arduino application
  - Starts the IDE
- Open the Blink example:
  File>Examples>Basics>Blink



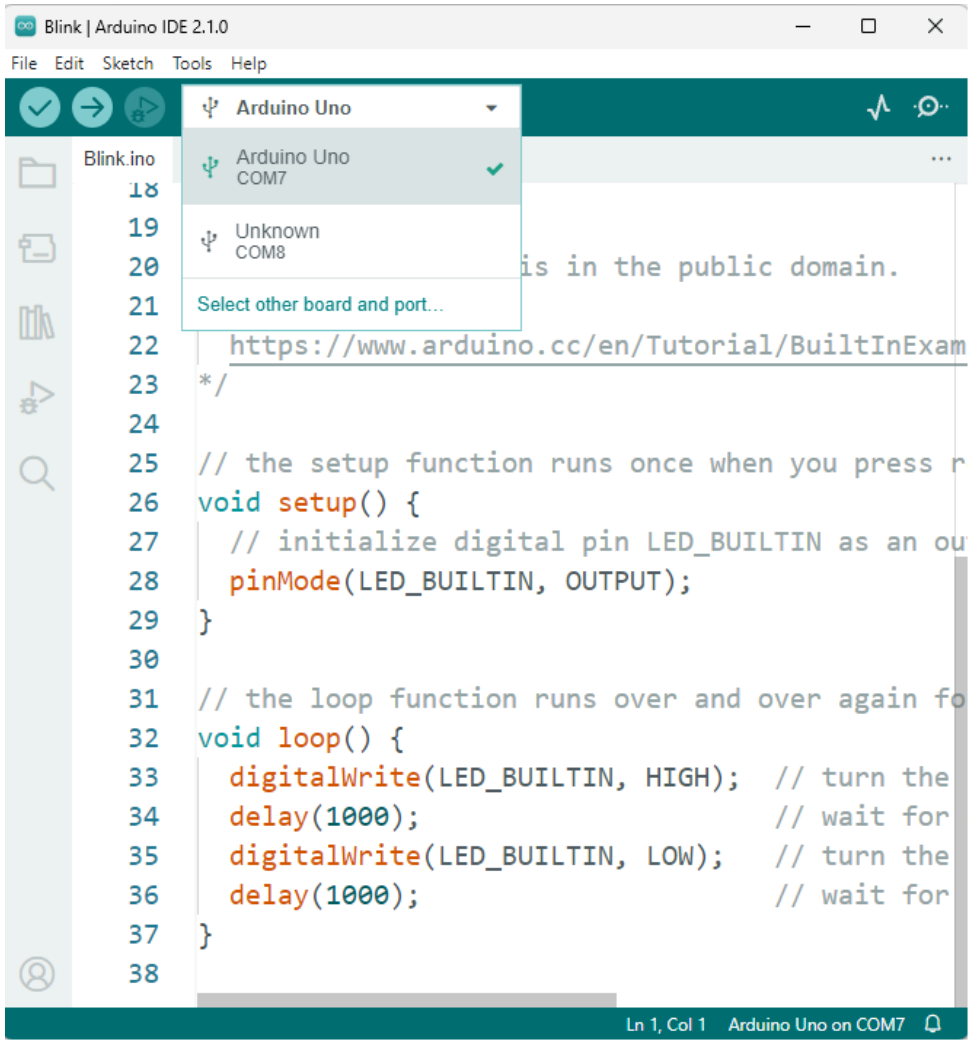
Set Up the Arduino IDE

- Select your Arduino in the tools>Board menu



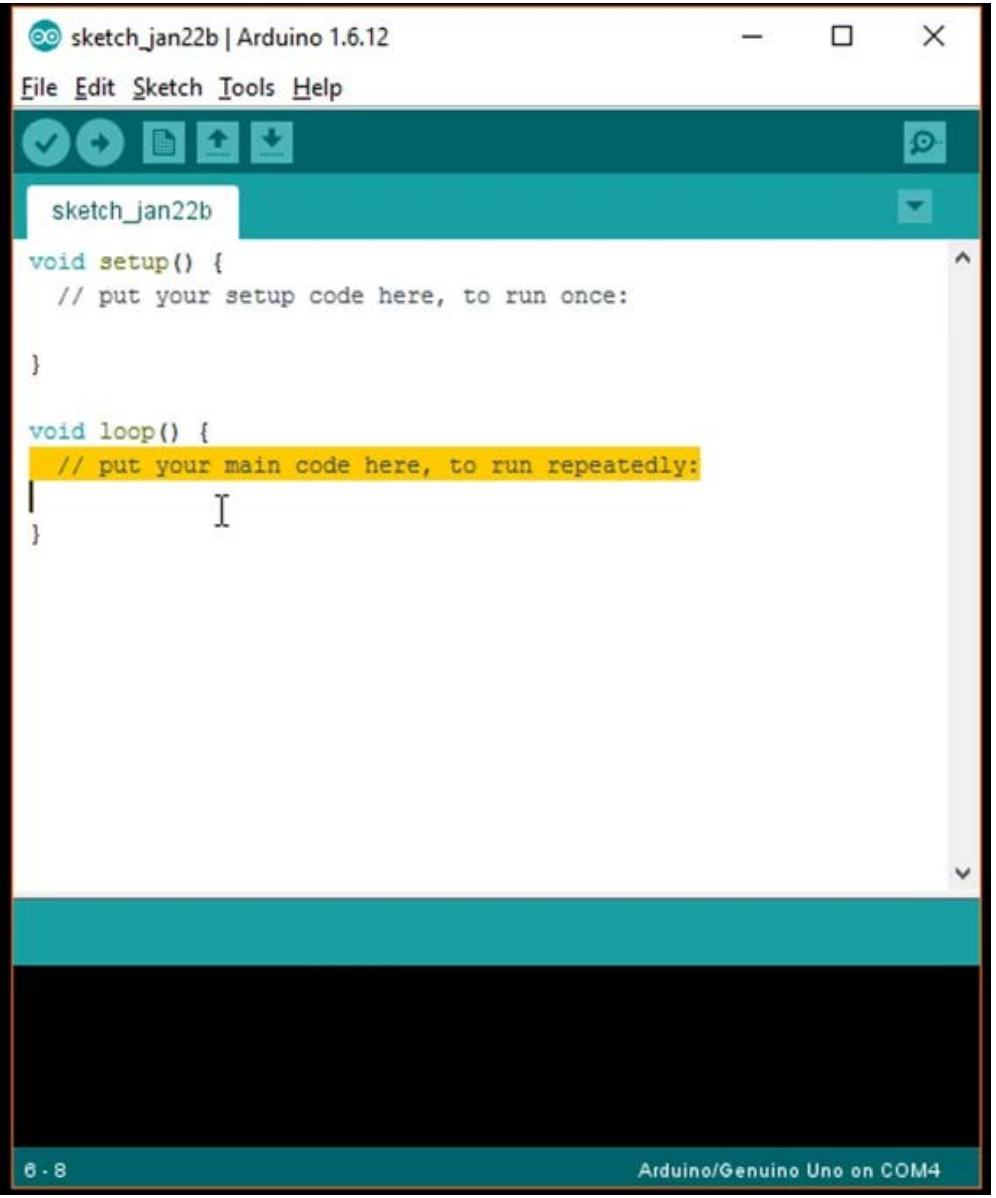
Getting to Blink

- Select your serial port in the tools>Port menu
  - There should be only one selection (COM3 or ..)
  - Check to make sure that the drivers are properly installed.
- Upload the program with the upload button
  - This writes the program onto the Flash of the Arduino
- The LED near pin 13 of the Arduino should blink



Run once ↓

Repeats forever ↻



Arduino IDE

- There are two special functions that are a part of every Arduino sketch
  - **setup()** is called once when the sketch starts. It's a good place to do setup tasks like setting pin modes or initialling libraries.
  - **loop**() function is called over and over and is the heart of most sketches.
- You need to include both functions in your sketch, even if you don't need them for anything.

Arduino IDE

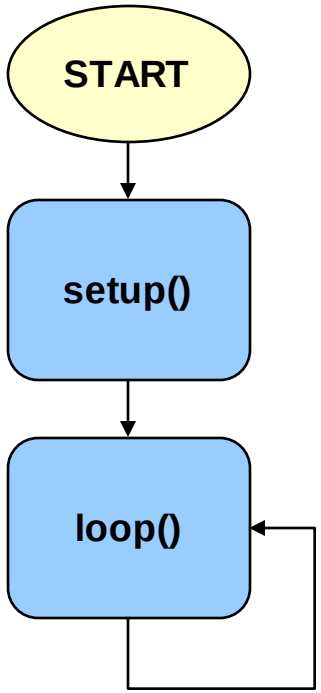
A function is a block of reusable code that is used to perform an action.

Indicates start of compound statement

Indicates end of compound statement

```
void setup(){
    // runs once
}

void loop(){
    // repeats
}
```

Single line comment



Arduino IDE

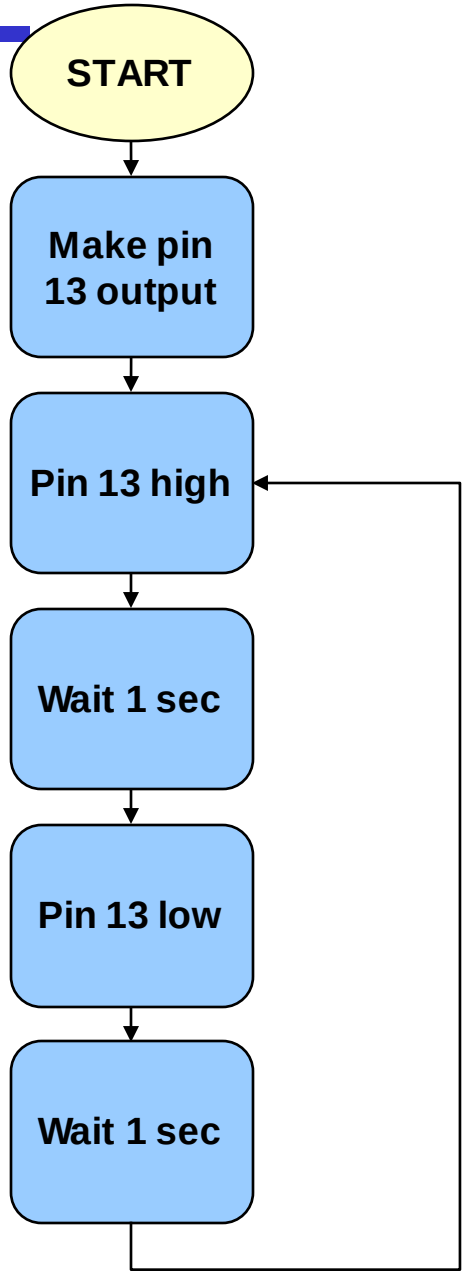
Block Comment or multi-line comment

Indicates start of compound statement

Indicates end of compound statement

```
/* Simple Program
 * structure
*/

void setup() {
   pinMode(13,OUTPUT);
}
void loop() {
   digitalWrite(13, HIGH);
   delay(1000);
   digitalWrite(13, LOW);
   delay(1000);
}
```

Indicates end of statement



C is **case-sensitive**!

Program structure

```
/* Simple Program structure  */
int x;
void setup()
{
  x = 1;
}

void loop()
{
  if(x == 1)
  {
    for( i = 0; i < 10; i++)
    {
      Serial.println(i);
    }
  }
}
```

Comments

```
/* Comment text */
```

- Compiler ignores everything from `/*` to `*/`

```
// Comment text
```

- Compiler ignores everything from `//` to the end of the line
- This commenting style originated from C++ and was adopted by C (C99 standard)

Hello world in Arduino IDE

A function is a block of reusable code that is used to perform an action.

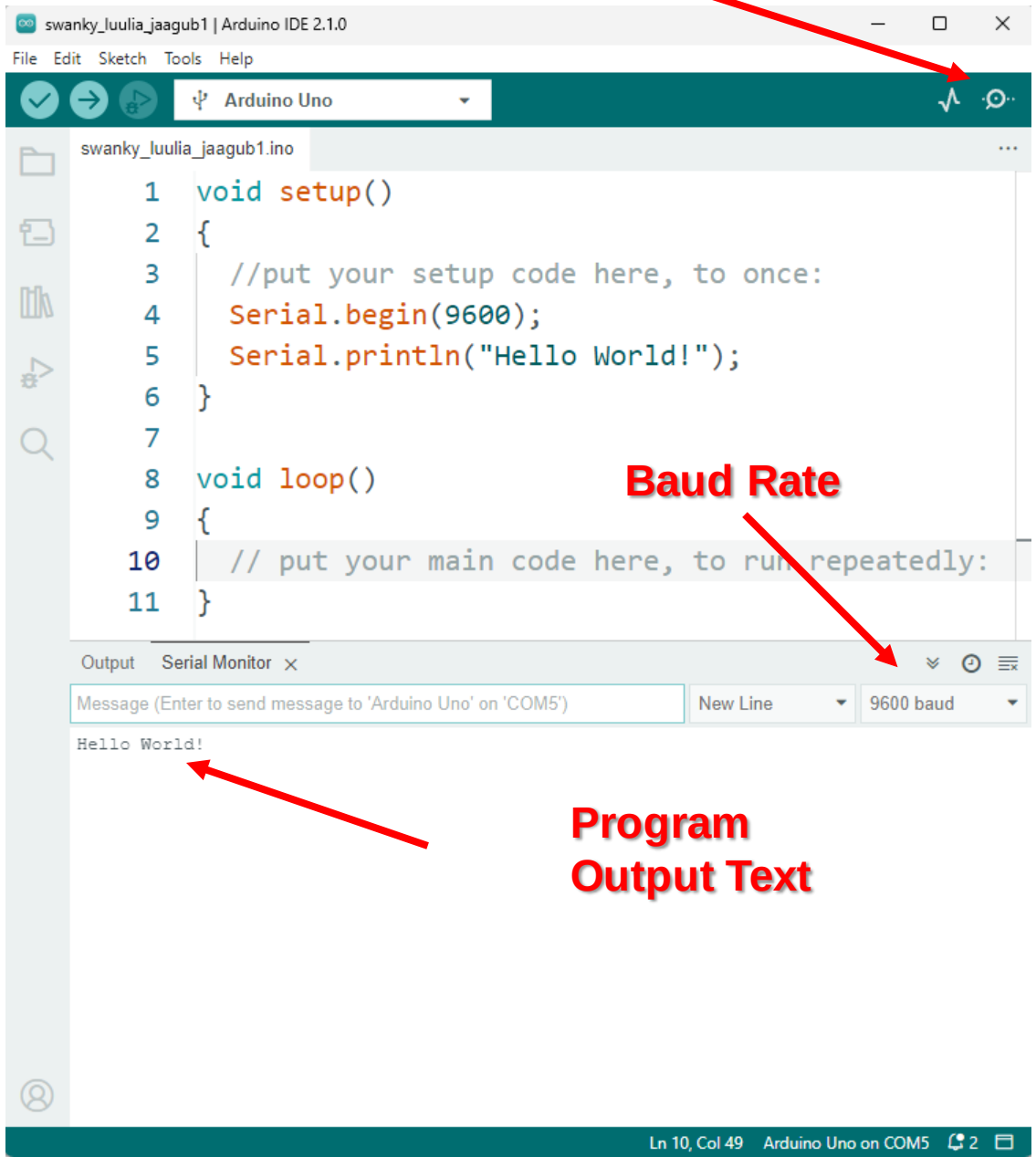
Initializes the speed of the serial port to 9600 baud rate

```
void setup() {
  Serial.begin(9600);
  Serial.println("Hello World!");
}

void loop() {
}
```

prints data to serial bus

- **setup()** function is run first and run only once, every time that the sketch is run.
- **loop()** function will run continuously from top to bottom and then back to the top.

Open Serial Monitor Window



Baud Rate

Program Output Text

Program structure

Block Comment or multi-line comment

Indicates start of compound statement

Indicates end of compound statement

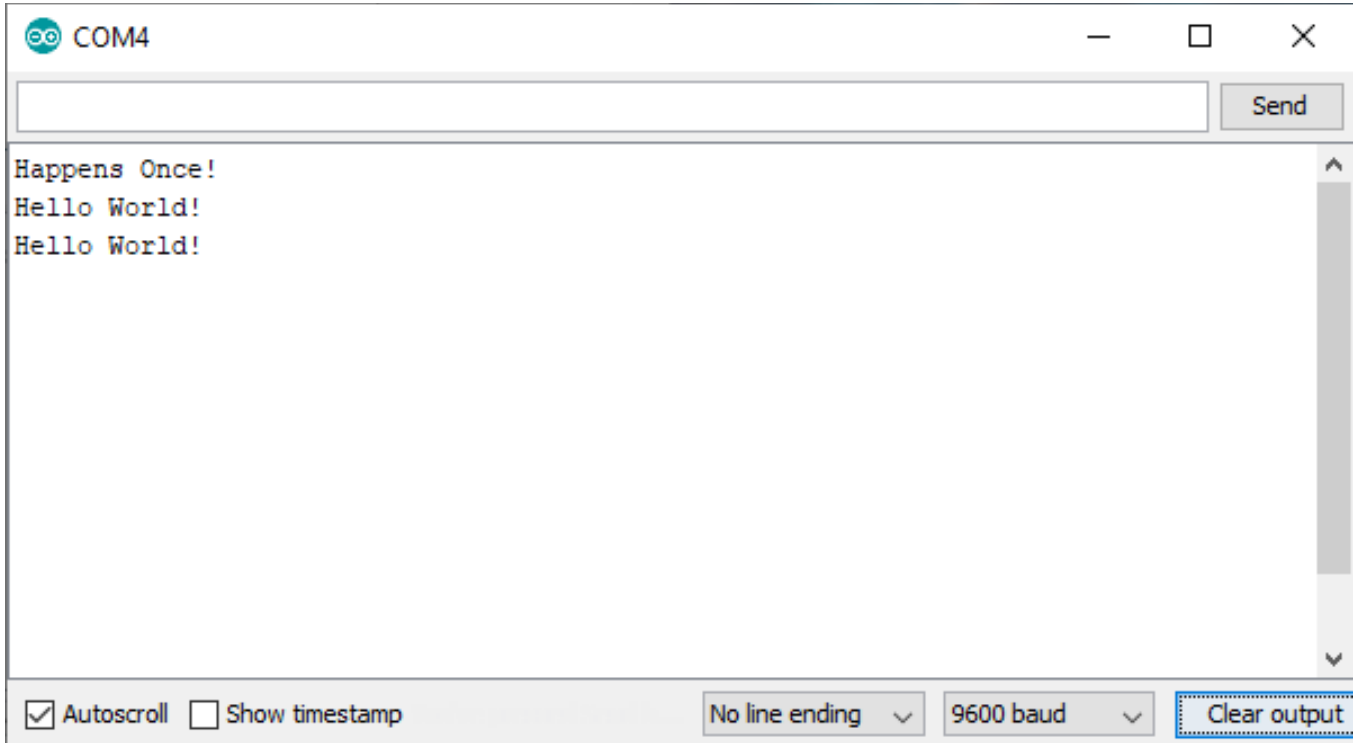
String start and end

```
/* Simple Program
   structure
*/

void setup() {
  Serial.begin(9600);
  Serial.println("Happens Once!");
  delay(2000);
}
void loop() {
  Serial.println("Hello World!");
  delay(2000);
}
```

Indicates end of statement

Hello world in Arduino IDE

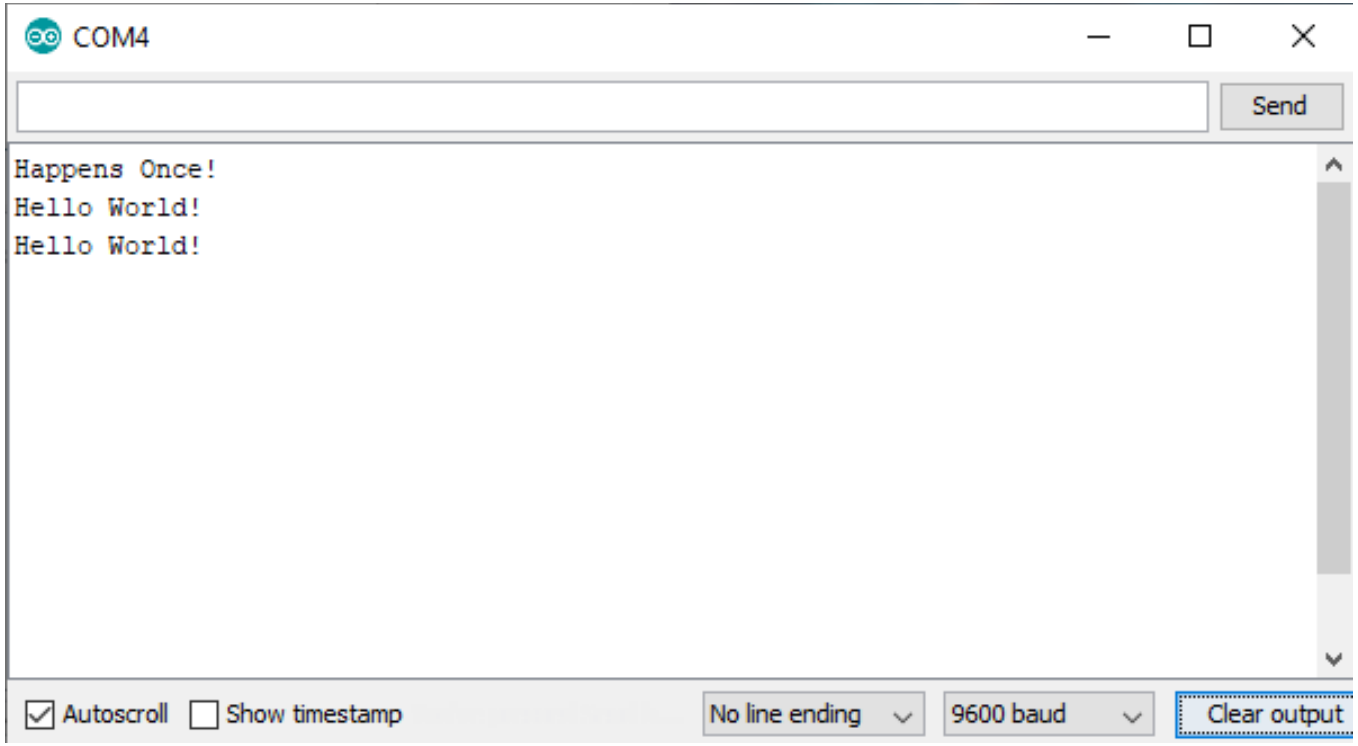
```
void setup() {
  Serial.begin(9600);
  Serial.println("Happens Once!");
  delay(2000);
}
void loop() {
  Serial.println("Hello World!");
  delay(2000);
}
```



- **delay(2000)** function causes a waiting period of 2 seconds (2000 milliseconds

Hello world in Arduino IDE

```
void setup() {
  Serial.begin(9600);
  Serial.println("Happens Once!");
  delay(2000);
}
void loop() {
  Serial.print("Hello ");
  Serial.println("World!");
  delay(2000);
}
```



Writing your own programs

How?

- Use other programs as models, and then modify
  - Very useful strategy
  - Lectures have examples that you can use as models for your assignment programs

A new program

- Change the “Hello world!” program
  - When you upload it to the Arduino, it prints your **name** to the Arduino Serial Monitor once every second.

```
void setup() {
  Serial.begin(9600);
  Serial.println(“Happens Once!");
  delay(2000);
}
void loop() {
  Serial.println(“Hello World!");
  delay(2000);
}
```

```
void setup() {
  Serial.begin(9600);



}
void loop() {



}
```

Writing your own programs

How?

- Use other programs as models, and then modify
  - Very useful strategy

BUT

  - It can be hard to work out how to modify

Need to understand the language

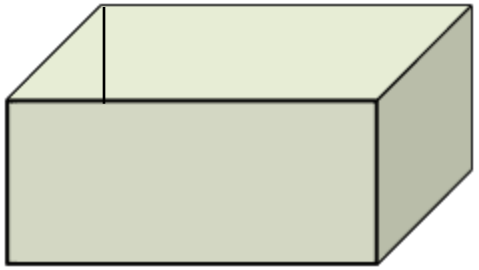
⇒ vocabulary

⇒ syntax rules

⇒ meaning (“semantics”)

Variables and Variable Types

- You can use variables in a similar way as they are used in math or physics
- All variables must be *declared* before they are used, and optionally,
- set an initial value (*initialising the variable*).
- https://www.arduino.cc/reference/en/#variables



- **Variable Types:**
  - **bool**, holds one of two values, *true* or *false*
  - **byte**, holds a number from 0 to 255
  - **char**, holds one character value

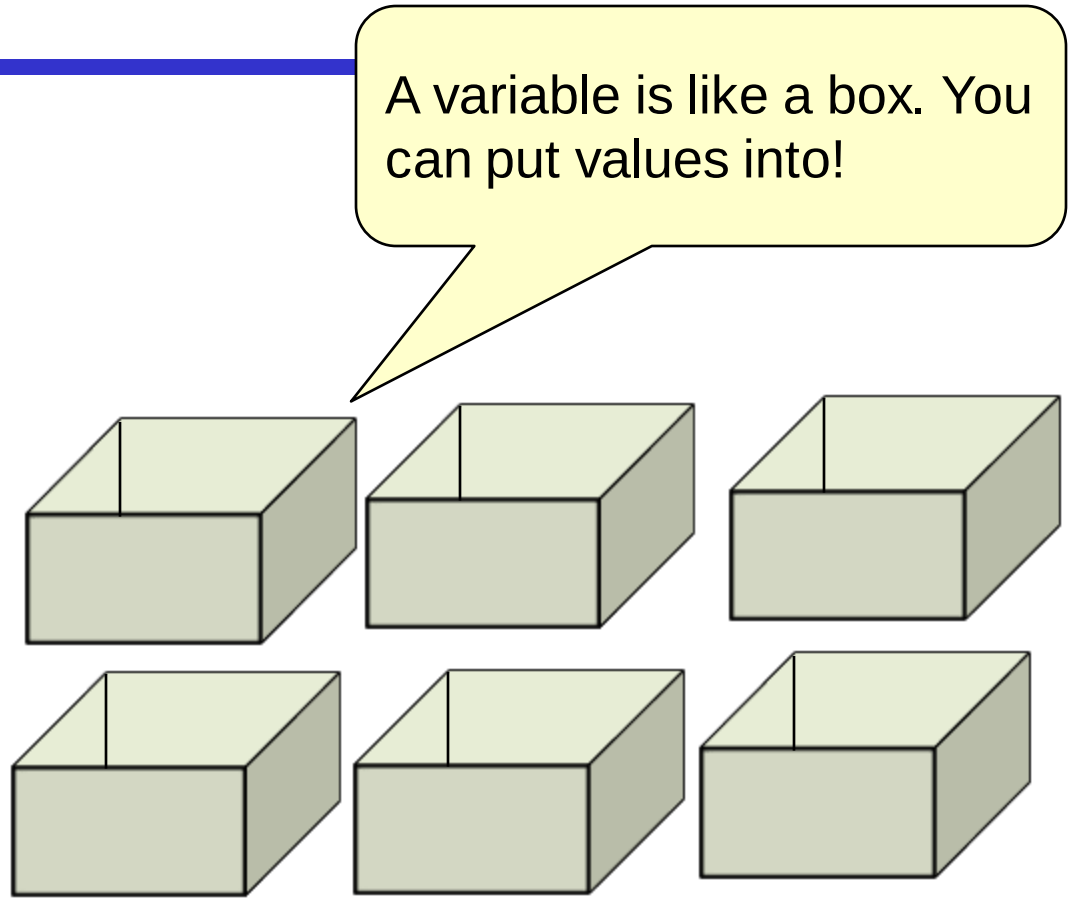
  } 1 byte or 8 bits

  - **int**, in Arduino Uno holds a number from -32,768 to 32,767 → 2 byte or 16 bits
  - **long**, holds a number from -2,147,483,648 to 2,147,483,647
  - **float**, for floating-point numbers. -3.4*10^38 to 3.4*10^38
  - **double**, for floating-point numbers.

  } 4 byte or 32 bits

Variables

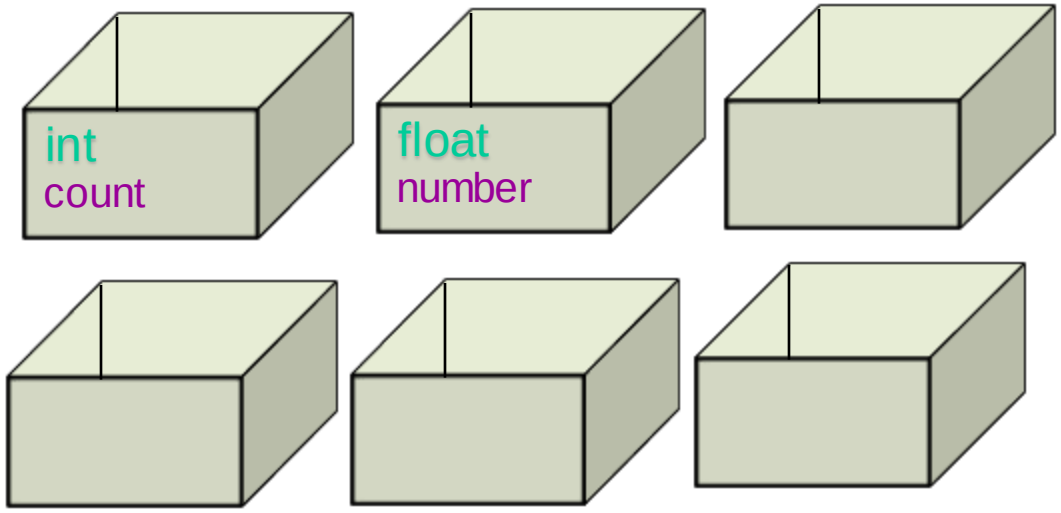
- The power of computer programming
  - Variables
  - Operations with variables
  - Input/output commands
- Variable is not the same as variables in math
- Variable in computer science is like a box that you can put different values into it



Arduino structure

- Processor
  - Central Processing Unit (CPU): It does calculations.
- Memory
  - A place where program and variables live
  - Memory is connected to the CPU

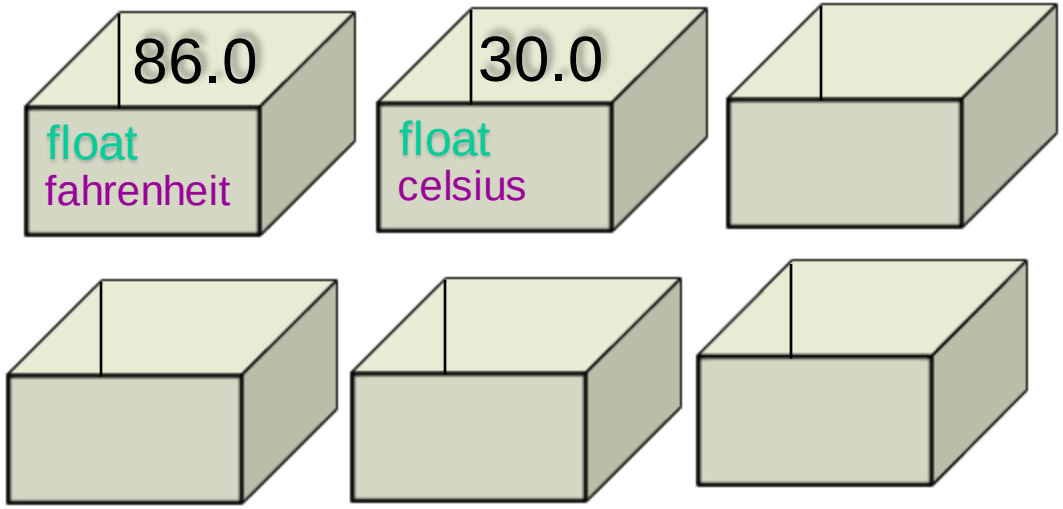
- You can think of memory as an actual physical box
  - Each box can contain a piece of information
  - If you want to use these boxes, we need to be able to refer to them.
    - Every box has a name

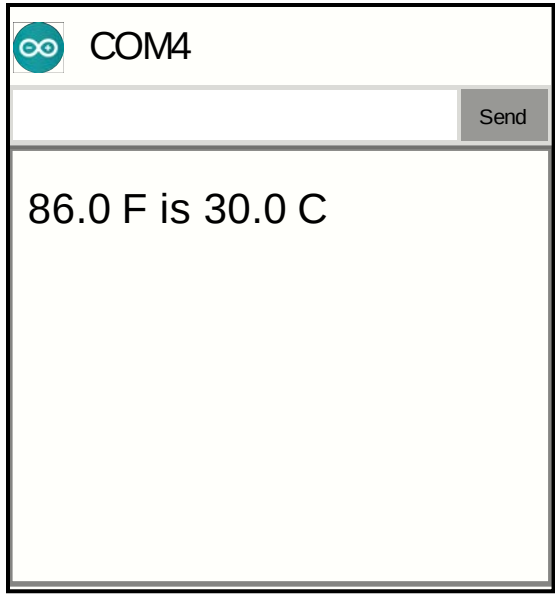


- A variable is a place in memory that can hold a value.
  - It has a name and type
  - It holds a piece of information

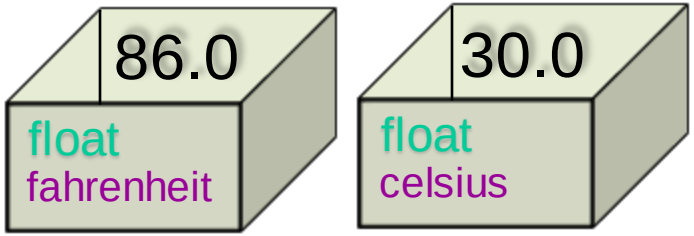
Variables

```
float fahrenheit = 86.0;
float celsius;
void setup() {
  Serial.begin(9600);
  celsius = (fahrenheit – 32.0)*5.0 / 9.0;
  Serial.print(fahrenheit);
  Serial.print(“ F is ”);
  Serial.print(celsius);
  Serial.println(“ C”);
}
void loop() {
}
```





Variables




```
float fahrenheit;
float celsius;
void setup() {
  fahrenheit = 86.0;
  Serial.begin(9600);
  celsius = (fahrenheit - 32.0)*5.0 / 9.0;
  Serial.print(fahrenheit);
  Serial.print(" F is ");
  Serial.println(celsius);
  Serial.println(" C");
}
void loop() {
}
```

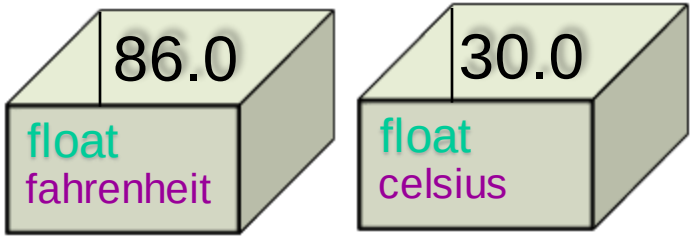
- A variable is a place in memory that can hold a value.
  - Must specify the **type** of value that can be put in the variable
    ⇒ "Declare" the variable first time it is mentioned.

    ⟨type⟩ → ⟨variable⟩
  - Must put a value into a variable before you can use it
    ⇒ "assign" to the variable
  - Can *use* the value by specifying the variable's name
  - Can change the value in a variable (unlike mathematical variable)

Use a variable whenever you need the Arduino to remember something temporarily.

Asking for a place

Assignment Statements




```
float fahrenheit;
float celsius;
void setup() {
  fahrenheit = 86.0;
  Serial.begin(9600);
  celsius = (fahrenheit – 32.0)*5.0 / 9.0;
  Serial.print(fahrenheit);
  Serial.print(“ F is ”);
  Serial.println(celsius);
  Serial.println(“ C”);
}
void loop() {
}
```

- Assignment Statement:

where = *what* ;

⟨variable⟩ → **=** → ⟨expression⟩ → **;**

Putting a value into a variable

name-of-place = *specification-of-value* ;

celsius = (fahrenheit – 32.0)*5.0 / 9.0;

Meaning: Compute the value and put it in the place

Expressions

combining declaration and assignment into a single line

```
float fahrenheit = 86.0;
float celsius;
void setup() {
  Serial.begin(9600);
  celsius = (fahrenheit – 32.0)*5.0 / 9.0;
  Serial.print(fahrenheit);
  Serial.print(“ F is ”);
  Serial.println(celsius);
  Serial.println(“ C”);
}
void loop() {
}
```

- Expressions describe how to compute a value.
- Expressions are constructed from
  - values
  - variables
  - operators (+, -, *, /, etc)
  - functions calls that return a value
  - sub-expressions,
  - …

Using variables

- To change the pin number from 13 to 14
  - Must find all the places where used pin 13 and changed them to 14

```
void setup() {
   pinMode(13,OUTPUT);
}
void loop() {
   digitalWrite(13, HIGH);
   delay(1000);
   digitalWrite(13, LOW);
   delay(1000);
}
```

- To change the pin number from 13 to 14 using variable
  - Only need to change the value of the variable

```
int led = 13;
void setup() {
   pinMode(led,OUTPUT);
}
void loop() {
   digitalWrite(led, HIGH);
   delay(1000);
   digitalWrite(led, LOW);
   delay(1000);
}
```

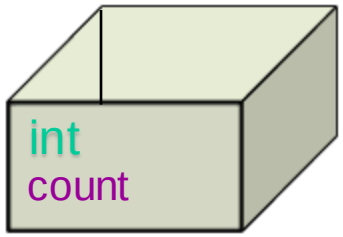
Values / Data

There are lots of different kinds ("Types") of values:

- Numbers
  - Integers **int** (or long) 42 -194573203
  - real numbers **double** (or float) 42.0 16.43
  - …
- Characters char 'X' '4'
- Text **String** " F -> "
- …

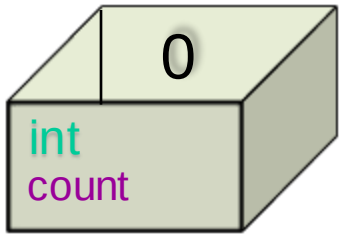
Using a Variable: int

```
int count;
void setup() {
  Serial.begin(9600);





}
void loop() {
}
```



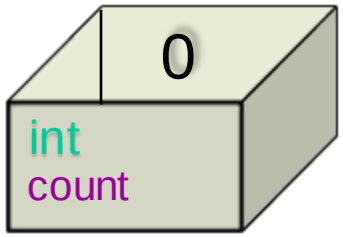
Using a Variable: int

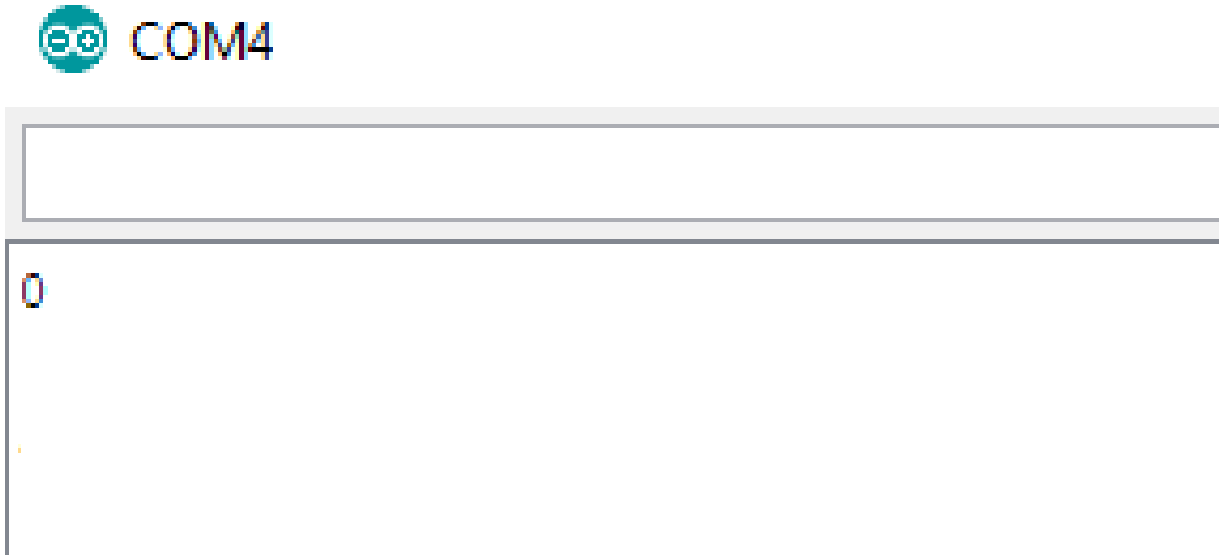
```
int count;
void setup() {
  Serial.begin(9600);
  count = 0;





}
void loop() {
}
```



Using a Variable: int

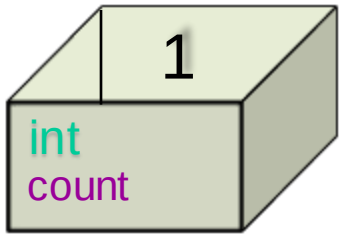
```
int count;
void setup() {
  Serial.begin(9600);
  count = 0;
  Serial.println(count);




}
void loop() {
}
```





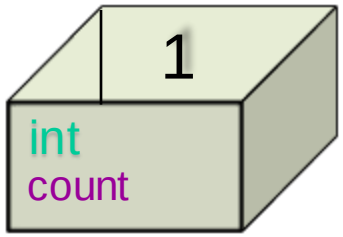
Using a Variable: int

```
int count;
void setup() {
  Serial.begin(9600);
  count = 0;
  Serial.println(count);
  count = 1;




}
void loop() {
}
```



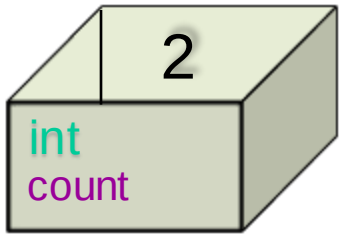
Using a Variable: int

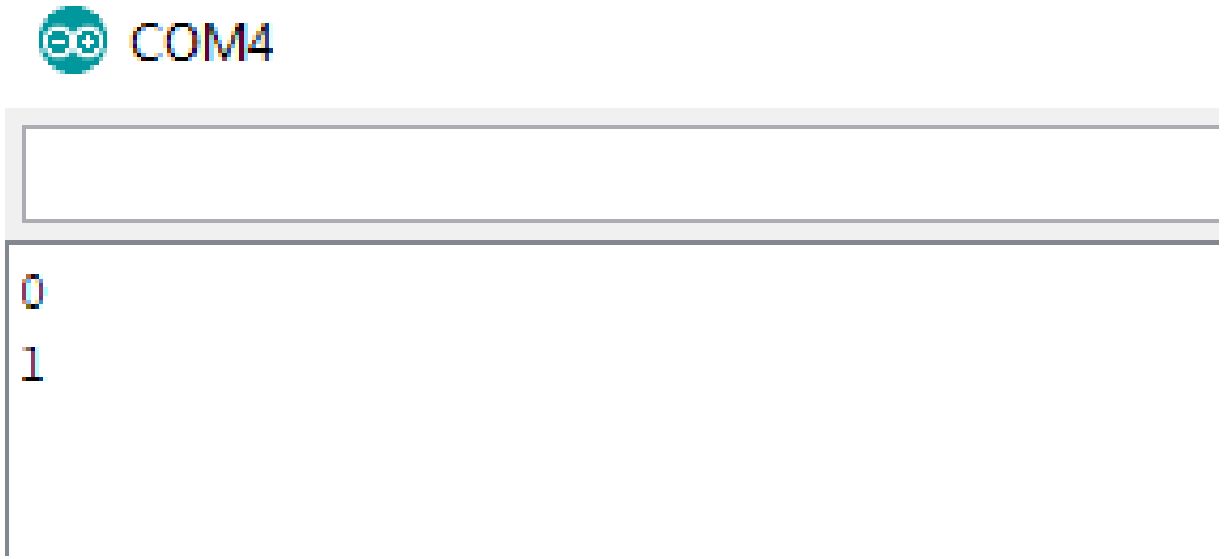
```
int count;
void setup() {
  Serial.begin(9600);
  count = 0;
  Serial.println(count);
  count = 1;
  Serial.println(count);



}
void loop() {
}
```



Using a Variable: int

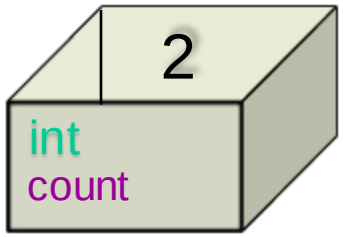
```
int count;
void setup() {
  Serial.begin(9600);
  count = 0;
  Serial.println(count);
  count = 1;
  Serial.println(count);
  count = 2;



}
void loop() {
}
```

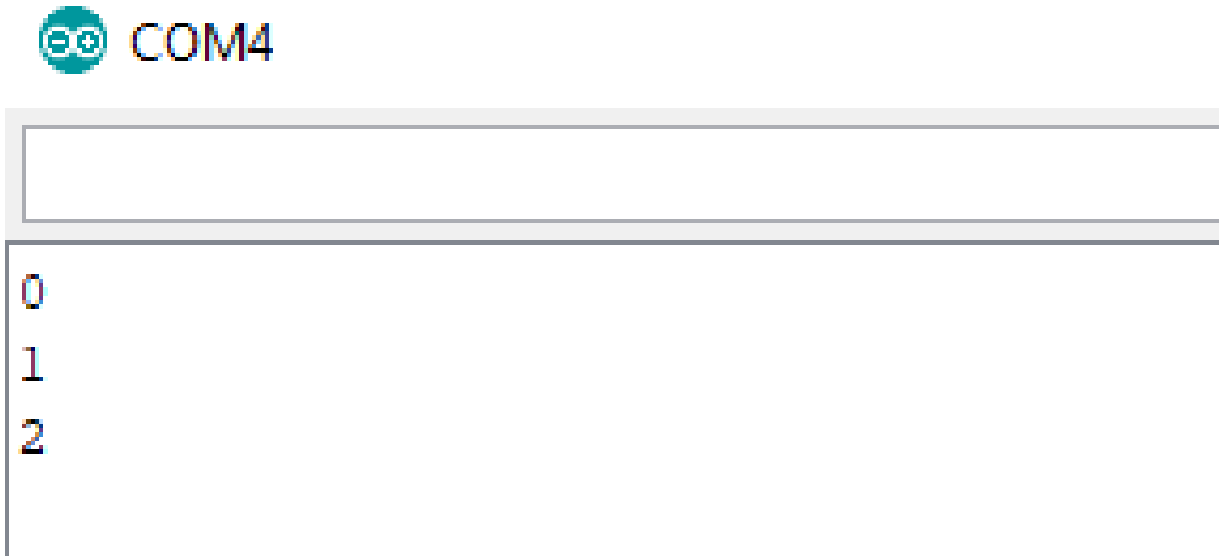




Using a Variable: int

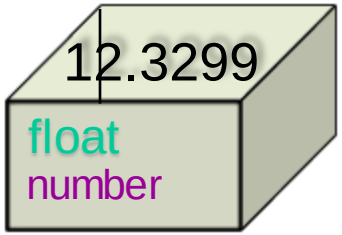
```
int count;
void setup() {
  Serial.begin(9600);
  count = 0;
  Serial.println(count);
  count = 1;
  Serial.println(count);
  count = 2;
  Serial.println(count);

}
void loop() {
}
```



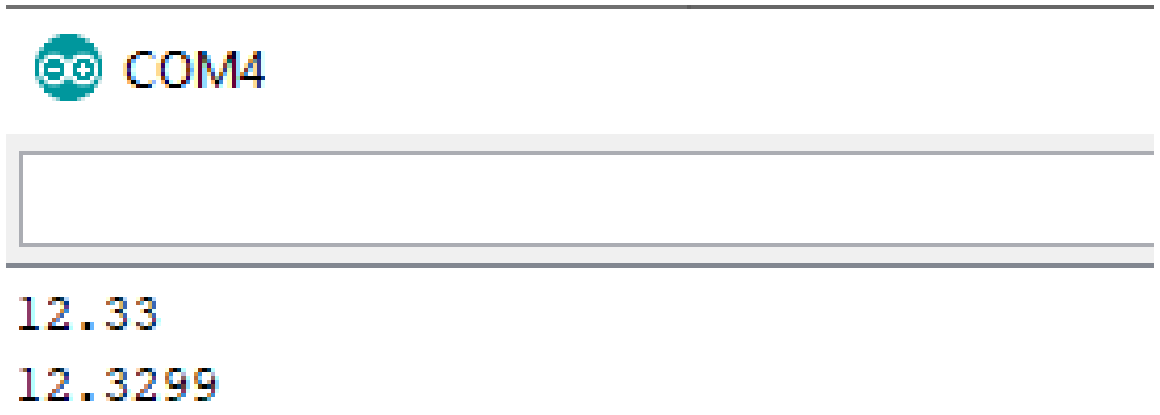


Using a Variable: float

- First println() automatically rounds the number off to two decimal places.
- In the second println(), the number of decimal places is specified as **4** by passing a second parameter value of **4** to the println() function.



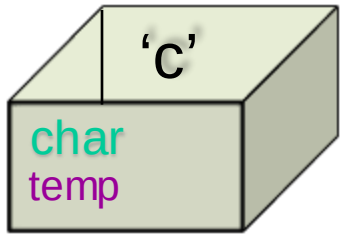

```
float number = 12.3299;
void setup() {
   Serial.begin(9600);
   Serial.println(number);
   Serial.println(number, 4);
}

void loop() {
}
```



char

- char is meant to hold 1 ASCII character
  - see https://www.asciitable.com/

char temp = ‘c’;



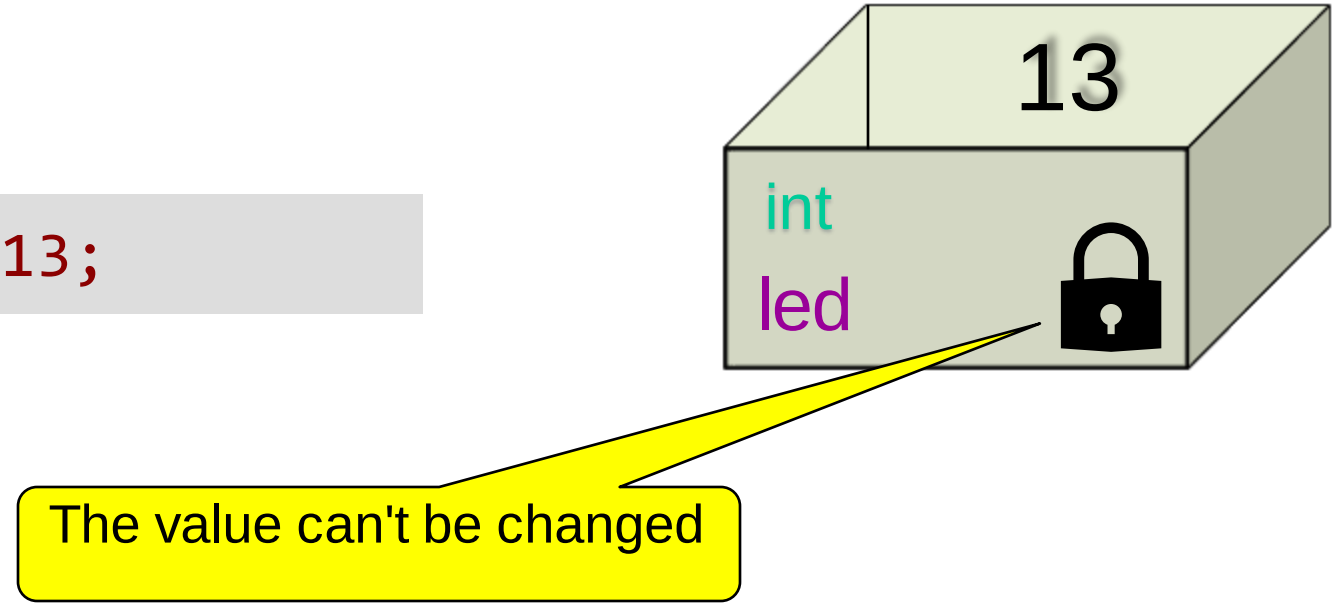
0	NUL	1	SOH	2	STX	3	ETX	4	EOT	5	ENQ	6	ACK	7	BEL
8	BS	9	HT	10	NL	11	VT	12	NP	13	CR	14	SO	15	SI
16	DLE	17	DC1	18	DC2	19	DC3	20	DC4	21	NAK	22	SYN	23	ETB
24	CAN	25	EM	26	SUB	27	ESC	28	FS	29	GS	30	RS	31	US
32	SP	33	!	34	"	35	#	36	$	37	%	38	&	39	'
40	(	41	)	42	*	43	+	44	,	45	-	46	.	47	/
48	0	49	1	50	2	51	3	52	4	53	5	54	6	55	7
56	8	57	9	58	:	59	;	60	<	61	=	62	>	63	?
64	@	65	A	66	B	67	C	68	D	69	E	70	F	71	G
72	H	73	I	74	J	75	K	76	L	77	M	78	N	79	O
80	P	81	Q	82	R	83	S	84	T	85	U	86	V	87	W
88	X	89	Y	90	Z	91	[	92	\	93	]	94	^	95	_
96	`	97	a	98	b	99	c	100	d	101	e	102	f	103	g
104	h	105	i	106	j	107	k	108	l	109	m	110	n	111	o
112	p	113	q	114	r	115	s	116	t	117	u	118	v	119	w
120	x	121	y	122	z	123	{	124	|	125	}	126	~	127	DEL

Constants

- Constants
  - integer constants
  - floating-point constants
  - character constants
  - string constants
  - enumeration constants
- Naming constants
  - Use the const qualifier

Use named constants for values that won't change while the program is running.

```
const int led = 13;
```



Naming Variables

- An identifier is a sequence of letters and digits
  - The first character must be a letter
    - The underscore character _ counts as a letter
    - Upper and lower case letters are different

- C reserved keywords cannot be used as identifiers!

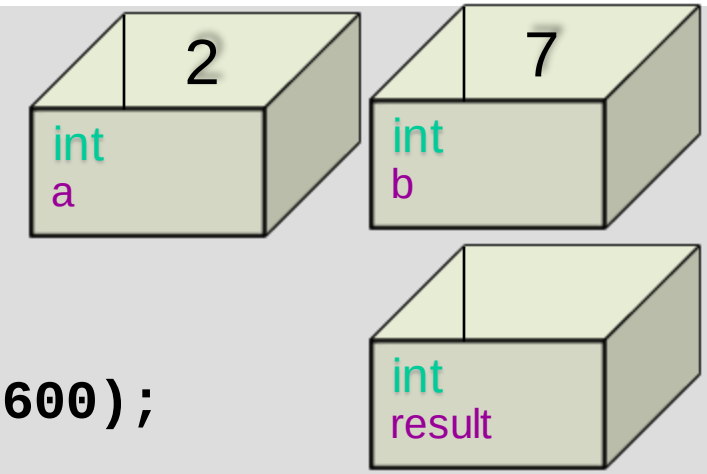
Use meaningful names when naming, *i.e.*, a name that describes the purpose of the entity

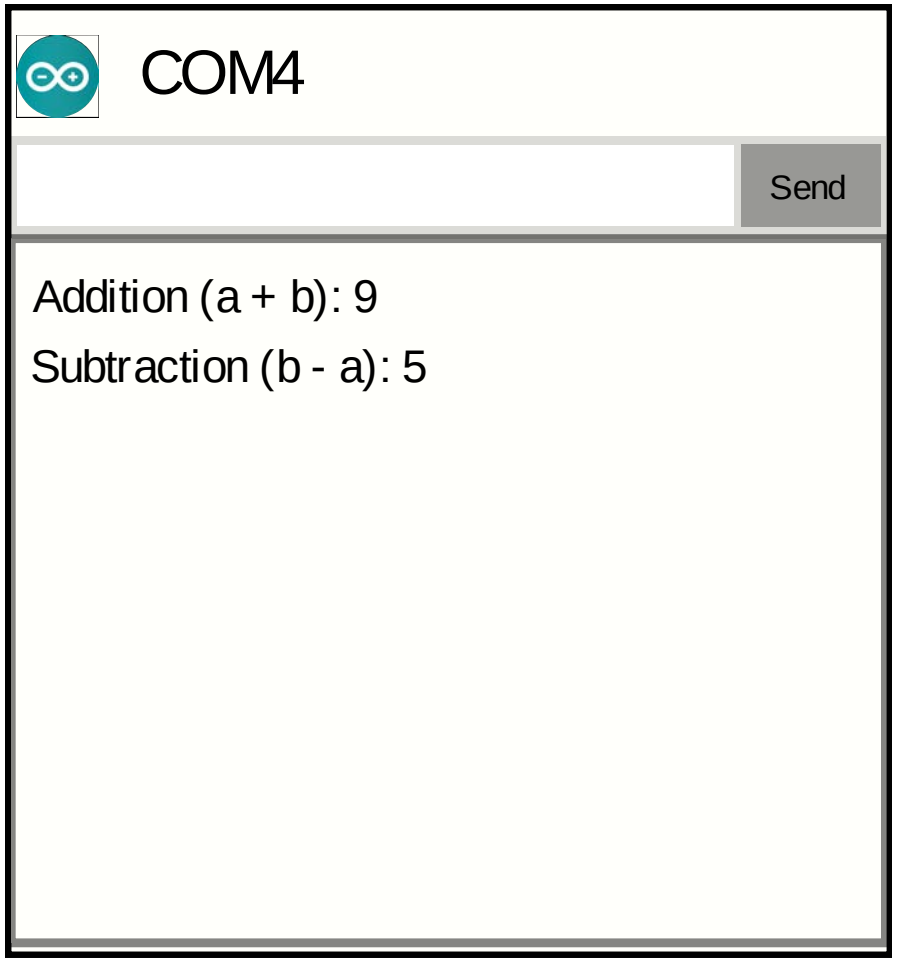
Examples

counter	Valid: consists of letters
_Temp_variable_2	Valid: consists of letters and digits
1myVariable	Invalid: first character is not a letter
steps{2}	Invalid: uses non-letter and non-digit characters
continue	Invalid: reserved word

Arithmetic Operators: + - * / %

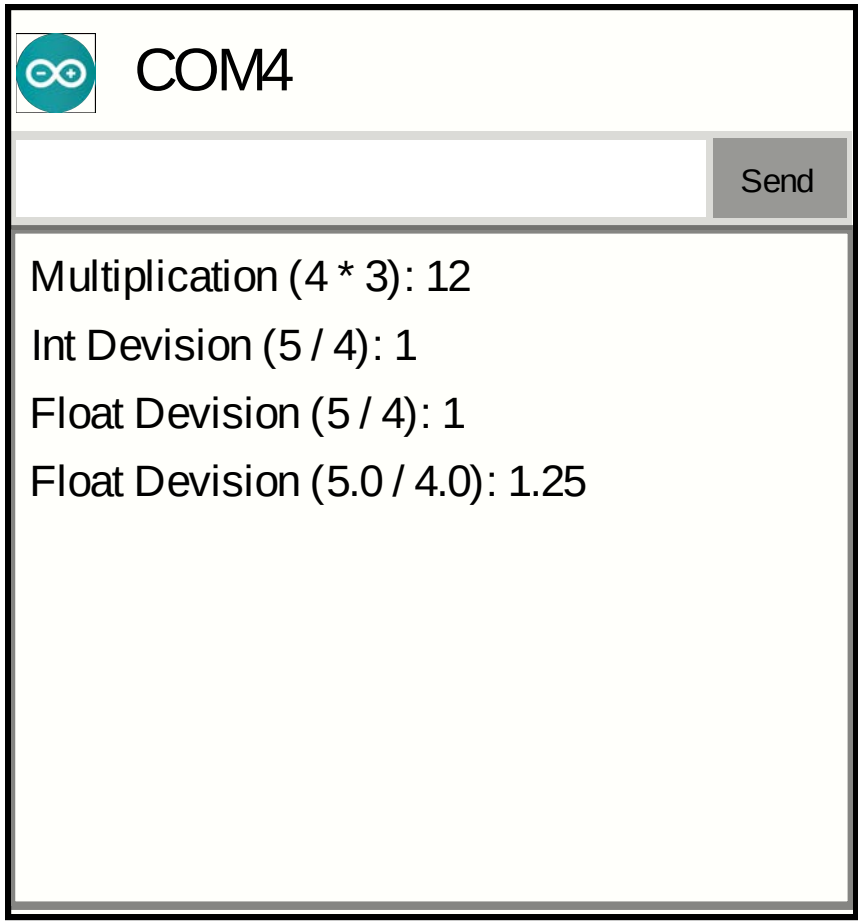
```
int a = 2;
int b = 7;
int result;
void setup() {

   Serial.begin(9600);

   Serial.print("Addition (a + b): ");
   result = a + b;
   Serial.println(result);

   Serial.print("Subtraction (b - a): ");
   result = b - a;
   Serial.println(result);
}
```





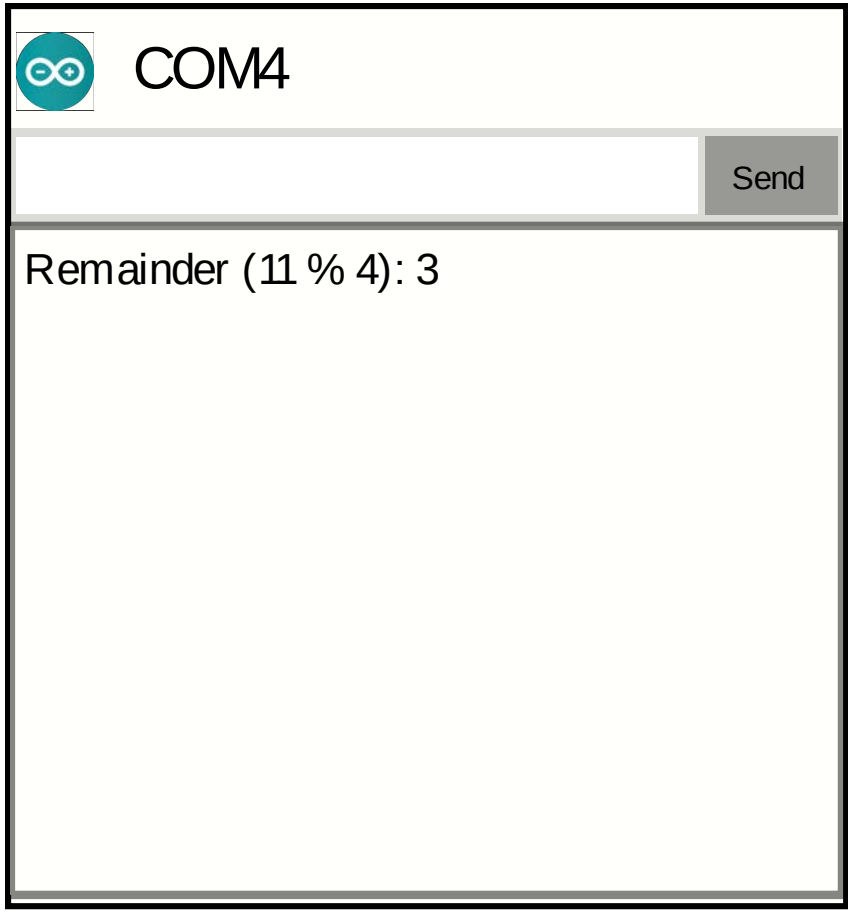
Arithmetic Operators: * /

```
int result;
float result_fl;
void setup() {
   Serial.begin(9600);
   Serial.print("Multiplication (4 * 3): ");
   result = 4 * 3;
   Serial.println(result);

   Serial.print("Int Division (5 / 4): ");
   result = 5 / 4;
   Serial.println(result);

   Serial.print("Float Division (5 / 4): ");
   result_fl = 5 / 4;
   Serial.println(result_fl);

   Serial.print("Float Division (5.0 / 4.0): ");
   result_fl = 5.0 / 4.0;
   Serial.println(result_fl);
}
```



Arithmetic Operators: modulo (%)

```
int result;
void setup() {
   Serial.begin(9600);
   Serial.print("Remainder (11 % 4): ");
   result = 11 % 4;
   Serial.println(result);
}
```

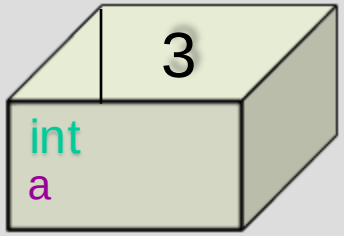


Using the if Statement

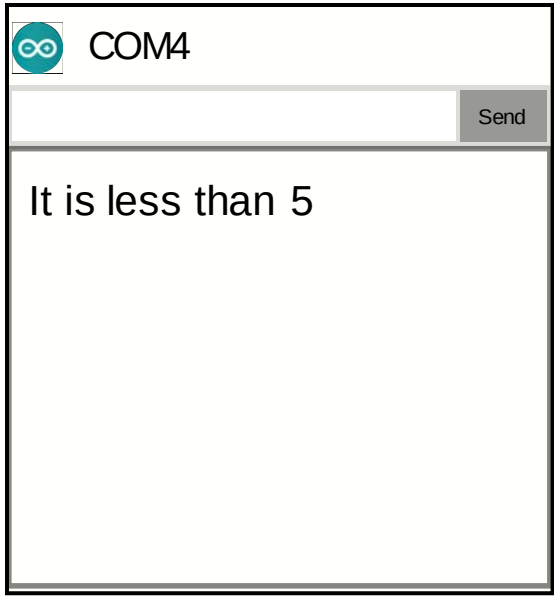
```
if (expression){
        statement
}
```

- If expression evaluates to true, statement is executed

```
int a = 3;
void setup() {
   Serial.begin(9600);
   if( a < 5 ){
      Serial.println("It is less than 5");
   }
}
void loop() {

}
```

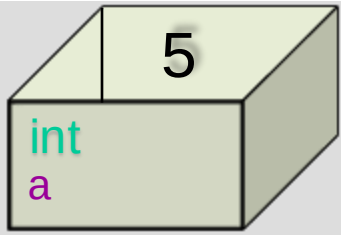


- **Can do an action only in some circumstances**



Using *if-else*

```
int a = 5;
void setup() {
   Serial.begin(9600);
   if( a < 5 ){
      Serial.println("It is less than 5");
   }
   else{
      Serial.print("It is greater than");
      Serial.println("or equal to 5");
   }
}
void loop() {

}
```



Can choose between different actions

```
if (expression){
      statement1
}
else{
      statement2
}
```

- The else part is optional
- If expression evaluates to true, $statement_1$ is executed
- Else, $statement_2$ is executed if the else part is present