Computer Hardware and Software

There are two fundamental concepts to understanding computers: **hardware** and **software**.

Hardware consists of any part of the computer is a physical component. This definition includes any component (or device) that is made from some type of material. The hardware of a computers is any electronic (central processing unit, "memory"), electrical (power supply), electro-mechanical (keyboard, mouse, disk drives, CD-ROM drives, monitor, speakers) and mechanical (case of the computer).

Software is intangible (or not physical) component of the computer. In general, software consists of the instructions that the hardware needs to actually accomplish something useful. The software, also, tells the hardware about structure of various types of information (for example, ASCII is a software specification for assignning binary numbers to particular characters).

The electronic components of the computer are designed around three logic circuits. These circuit are collectively referred as the **Boolean logic circuits**.

The circuits derived their name from an English mathematician, George Boole in the 1880s.

Prior the 1800s, the study of logic was based upon statements written or spoken in a human language such as English. The problem with using human languages is that it is ambiguous. Boole sought to find a way to eliminate the ambiguity of language, and at the same time to preserve the logical structure of the language.

The result of his work is a system of logic know as **Boolean Logic** or **Boolean Algebra** (the two terms are equally correct).

Boolean logic consists of three operations (or operators), namely **AND**, **OR** and **NOT**.

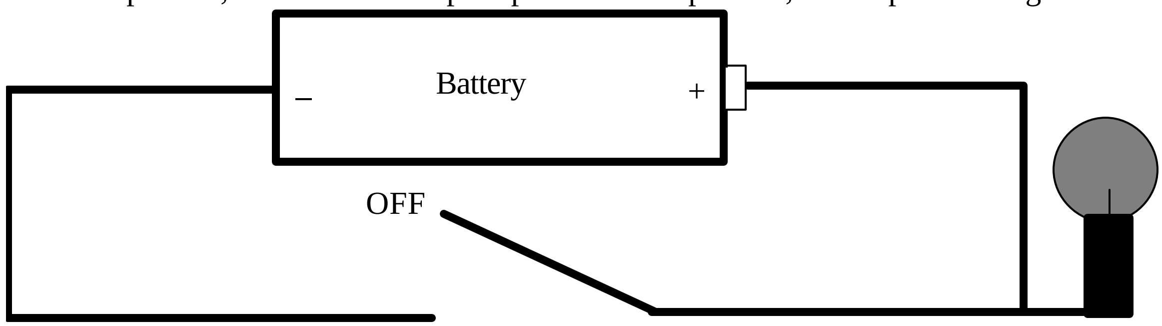
From these three logic functions, one can derive addition.

Mathematicians view addition as the fundamental arithmetic operation,. They take this view because from it one can derive the other arithmetic operations (like subtraction, multiplication and division). Further, addition is derived from the three operations of Boolean logic.

Basic Electricity

Electricity must have a complete path between the negative and positive terminals of a battery in order for it to do any work.

In Figure I, the lamp will not light, because the switch is in the OFF position. When the switch is in the OFF position, there is not a complete path to the lamp. Thus, the lamp will not light.



Key for the Illustration

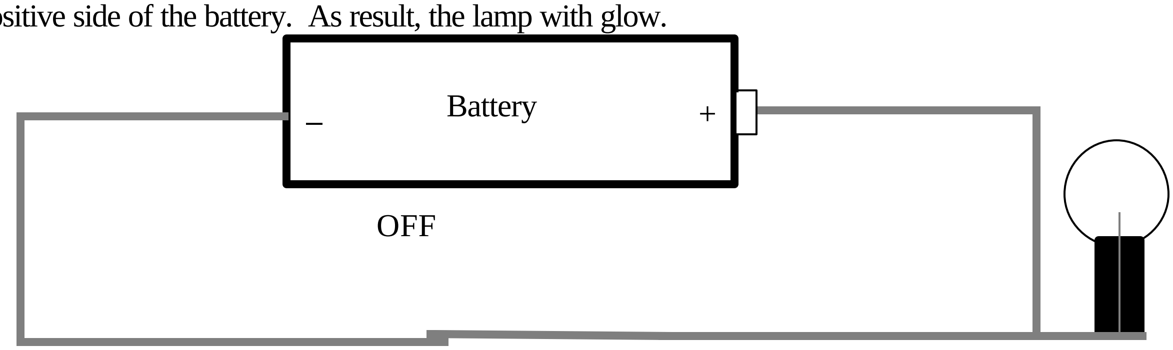
Electricity not flowing

Lamp lit

Electricity flowing

Lamp not lit

In Figure II., the switch is in the ON position. There is a complete path for electricity to follow to the positive side of the battery. As result, the lamp with glow.



Key for the Illustration

Electricity not flowing

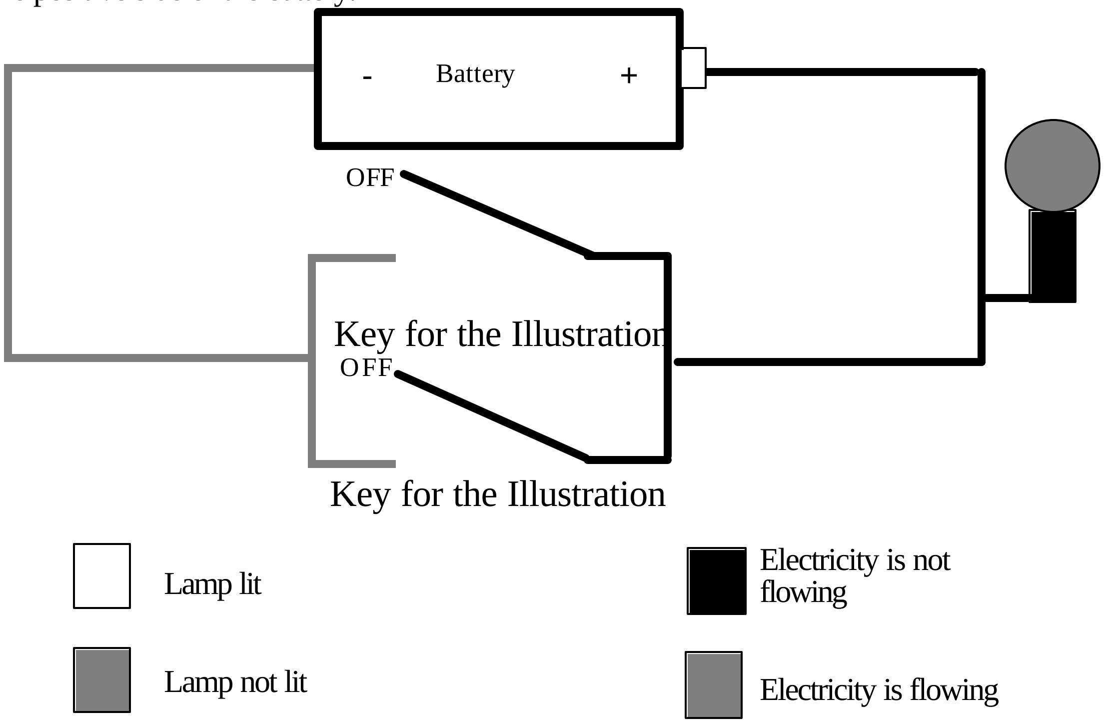
Lamp lit

Electricity flowing

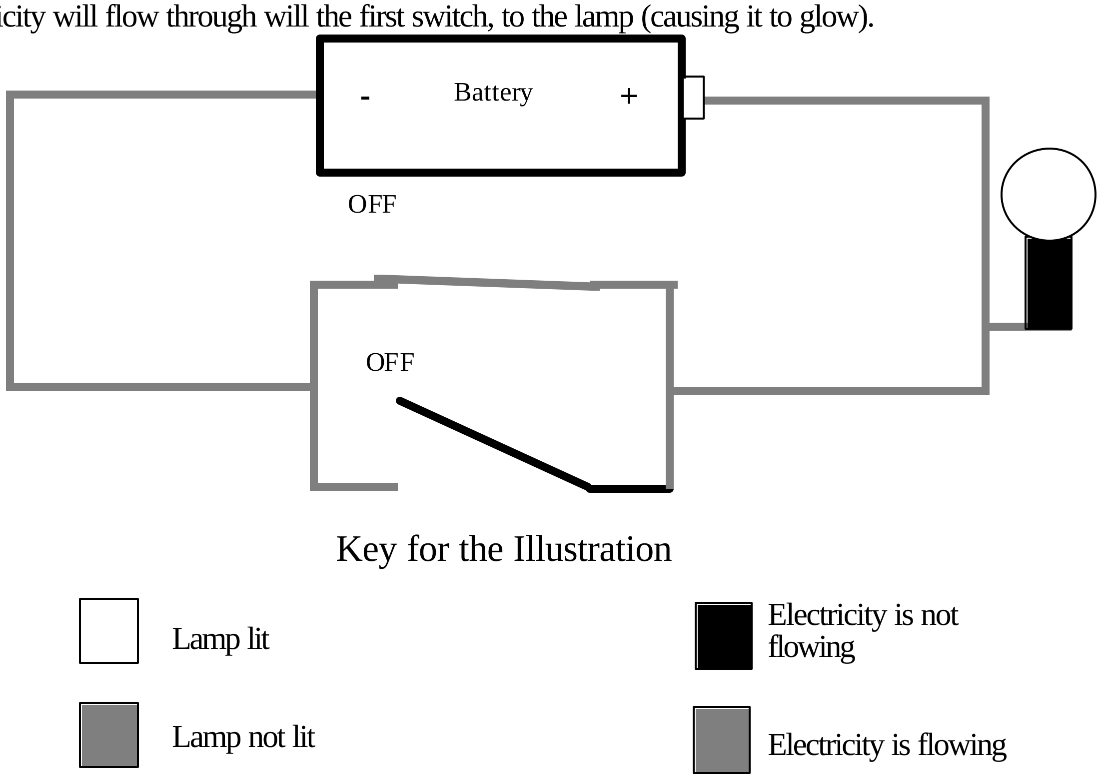
Lamp not lit

Or

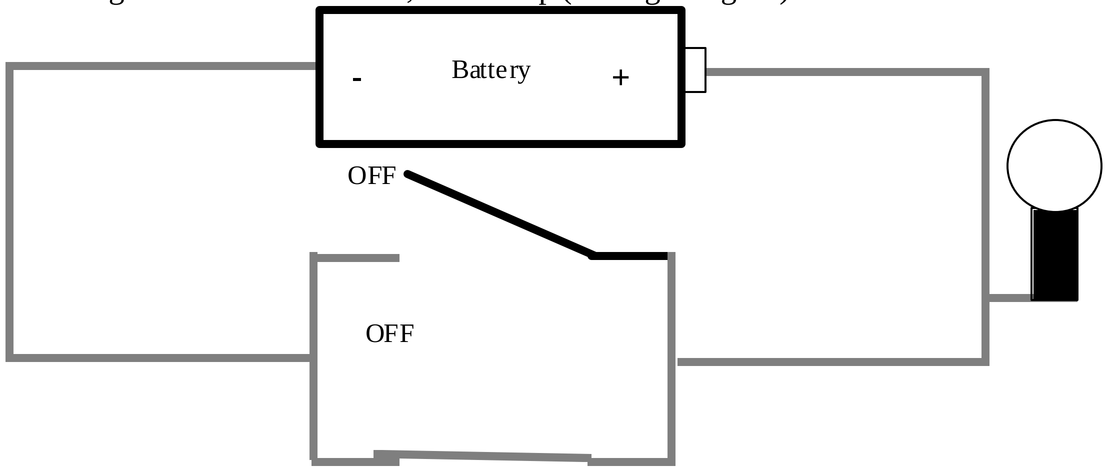
When the two switches are in the OFF position, the electricity cannot pass through to the lamp and the positive side of the battery.



When the first switch is the ON position and the second switch is in the OFF positions, the electricity will flow through will the first switch, to the lamp (causing it to glow).



When the first switch is in the OFF position and the second switch is in the ON position, the electricity will flow through will the second switch, to the lamp (causing it to glow).



Key for the Illustration

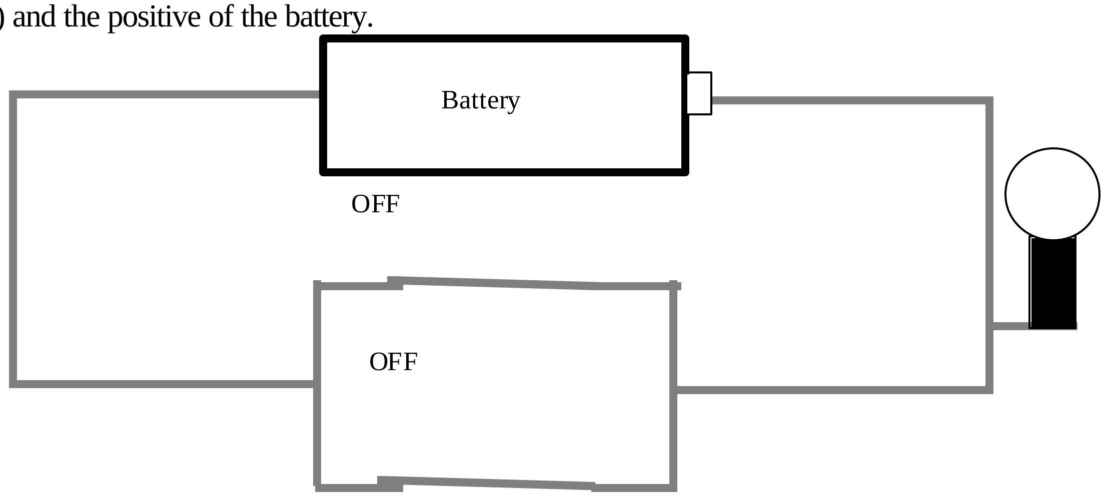
Lamp lit

Electricity is not flowing

Lamp not lit

Electricity is flowing

When the two switches are in the ON position, the electricity can pass through to the lamp (causing it to glow) and the positive of the battery.



Key for the Illustration

Lamp lit

Electricity is not flowing

Lamp not lit

Electricity is flowing

By recording the status of each switch (whether it is on or off) and whether the lamp is lit or not, one could develop a chart that summarizes the results of the experiment.

SW1	SW2	L
OFF	OFF	OFF
ON	OFF	ON
OFF	ON	ON
ON	ON	ON

This chart maybe rewritten with OFF coded as 0 and ON coded as 1. This chart is known as a **truth table**. The truth table below is the defines how the OR operation works.

SW1	SW2	L
0	0	0
1	0	1
0	1	1
1	1	1

Notice that when either switch is in the ON (1) position, the result is that lamp is lit (1).

The OR operation may seen contrainitutive, at first but consider an example in English. Suppose one says to a child:

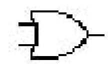
You can go the movies, if you clean your room or wash the dishes.

Now, consider all the combinations of possible actions of the child and the consequences of the child's actions (if a child does a job one can assign 1 to the action; 0, if the child does not do the job):

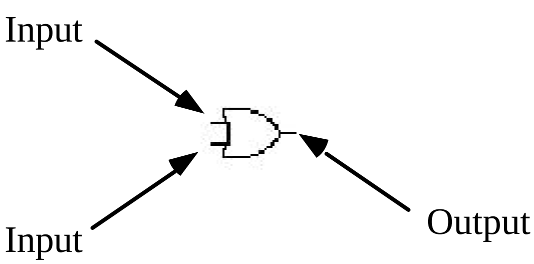
The Child		Conclusion

does not his or her room	does not wash the dishes	does not go to the movies
0	0	0
cleans his or her room	does not wash the dishes	is able to go the movies
1	0	1
does not clean his or her room	washes the dishes	is able to go the movies
0	1	1
cleans his or her room	washes the dishes	is able to go the movies
1	1	1

Electronic engineers use a special symbol to represent the function OR:

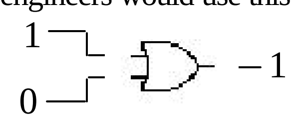


The symbol has several parts. The symbol includes places for inputs and a place for output.



Information enters the OR function through the inputs, the OR function acts upon the information coming into the function and the result leaves through the output.

An example of how electronic engineers would use this symbol is shown below.

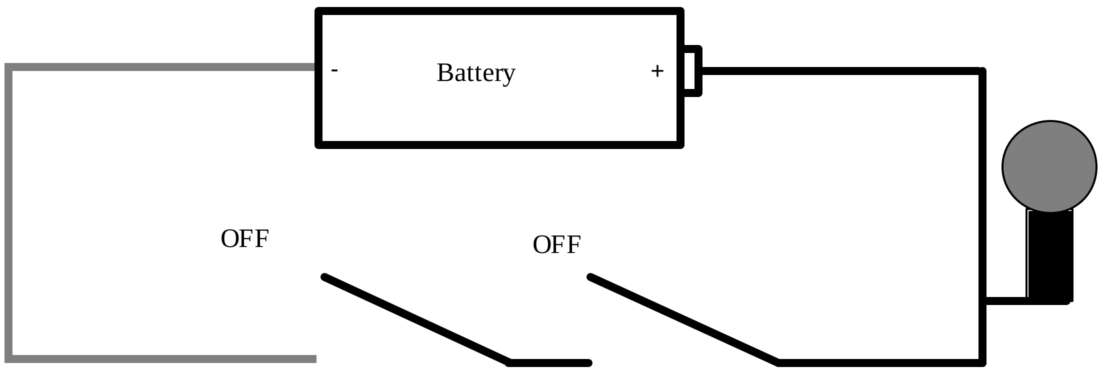


Notice that 1 and 0 enter through the inputs and the result is 1 coming out of the output.

AND

The next operator one needs to understand is the AND operator.

Again, one can run an experiment using a diagram (similar to the one below) to understand how the AND operator works. It is important to see that the diagram for the AND is different from the OR.



Key for the Illustration

Lamp lit

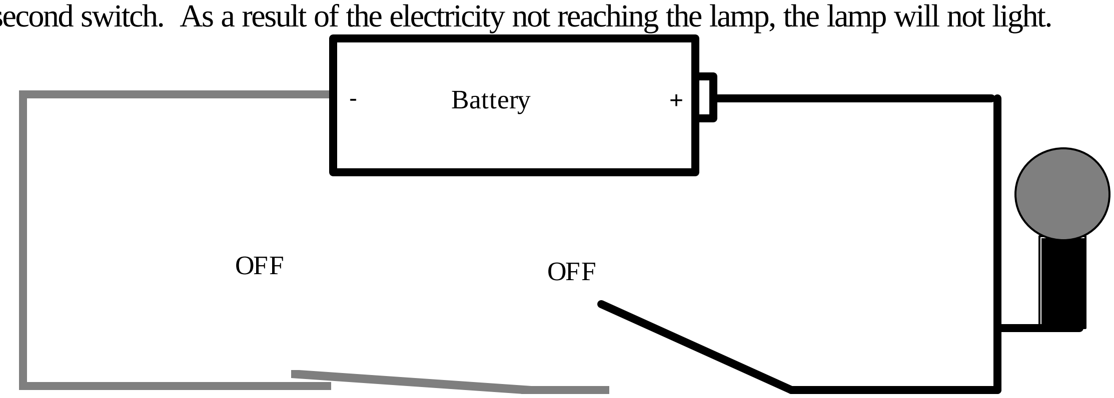
Lamp not lit

Electricity is not flowing

Electricity is flowing

If one puts both switches in the OFF position, the electricity cannot pass through to the lamp and the positive side of the battery.

Now, putting the first switch in the ON position, and keeping the second switch in the OFF position. The electricity will flow through the first switch, but it will not be able to pass through the second switch. As a result of the electricity not reaching the lamp, the lamp will not light.



Key for the Illustration

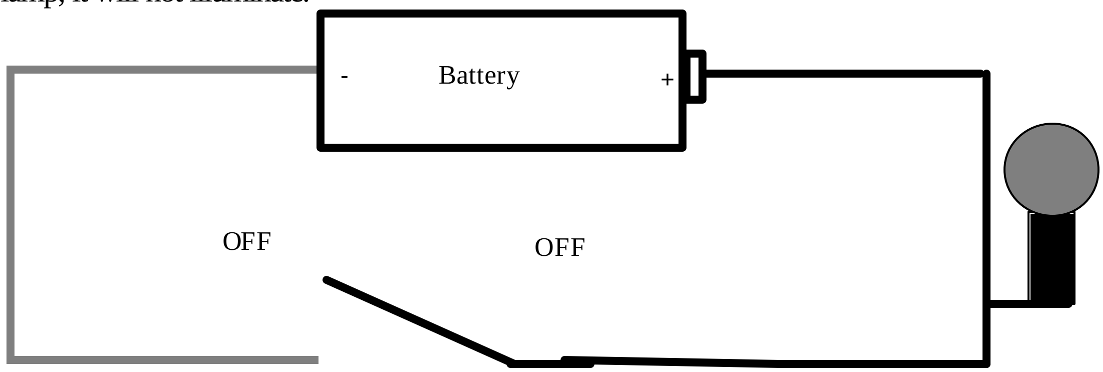
Lamp lit

Lamp not lit

Electricity is not flowing

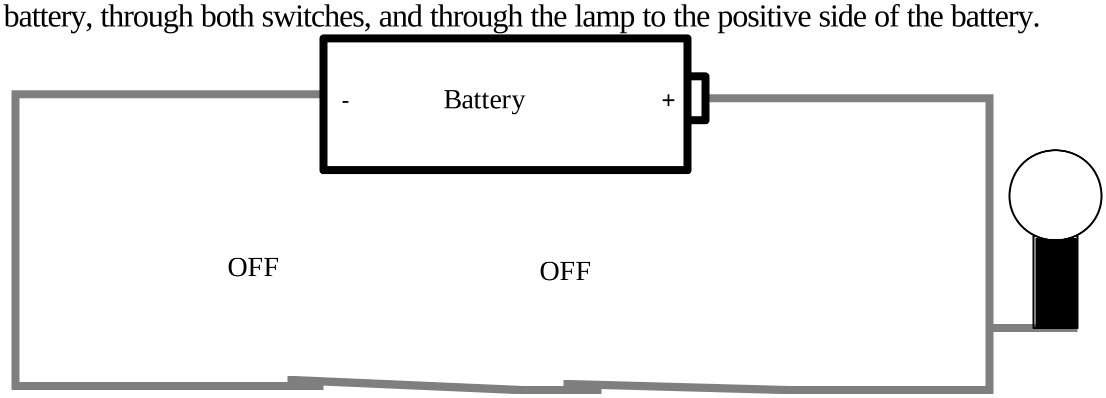
Electricity is flowing

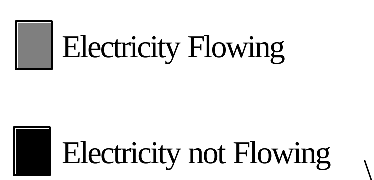
Next, open the first switch and close the second switch. The electricity will pass from the negative side of the battery to the first switch and stop. Since the electricity never passes through the lamp, it will not illuminate.



Key for the Illustration

After putting both switches in the ON position, the electricity will flow from the negative side of the battery, through both switches, and through the lamp to the positive side of the battery.





By recording the status of each switch (whether it is on or off) and whether the lamp is lit or not, one could develop a chart that summarizes the results of the experiment.

SW1	SW2	L
OFF	OFF	OFF
ON	OFF	OFF
OFF	ON	OFF
ON	ON	ON

This chart maybe rewritten with OFF coded as 0 and ON coded as 1. This chart is known as a **truth table**. The truth table is the defines how the AND operation works.

SW1	SW2	L
0	0	0
1	0	0
0	1	0
1	1	1

Notice that when both switches are in the ON (1) position, the result is that lamp is lit (1).

The AND operation may seen contrainitutive, at first but consider an example in English.

Suppose one says to a child:

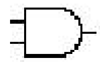
You can go the movies, if you clean your room and wash the dishes.

Now, consider all the combinations of possible actions of the child and the consequences of the child's actions (if a child does a job one can assign 1 to the action; 0, if the child does not do the job):

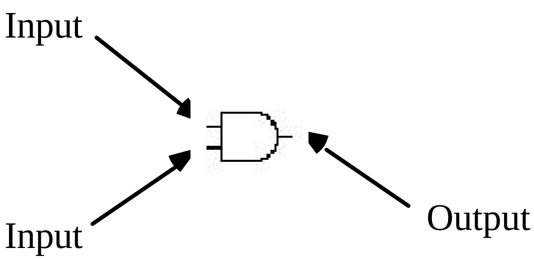
The Child		Conclusion
does not his or her room	does not wash the dishes	does not go to the movies
0	0	0
cleans his or her room	does not wash the dishes	is not able to go the movies
1	0	0

does not clean his or her room	washes the dishes	is not able to go the movies
0	1	0
cleans his or her room	washes the dishes	is not able to go the movies
1	1	1

Electronic engineers use a special symbol to represent the function AND:

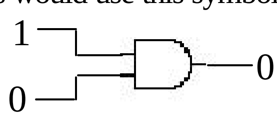


The symbol has several parts. The symbol includes places for inputs and a place for output.



Information enters the AND function through the inputs, the AND function acts upon the information coming into the function and the result leaves through the output.

An example of how electronic engineers would use this symbol is shown below.

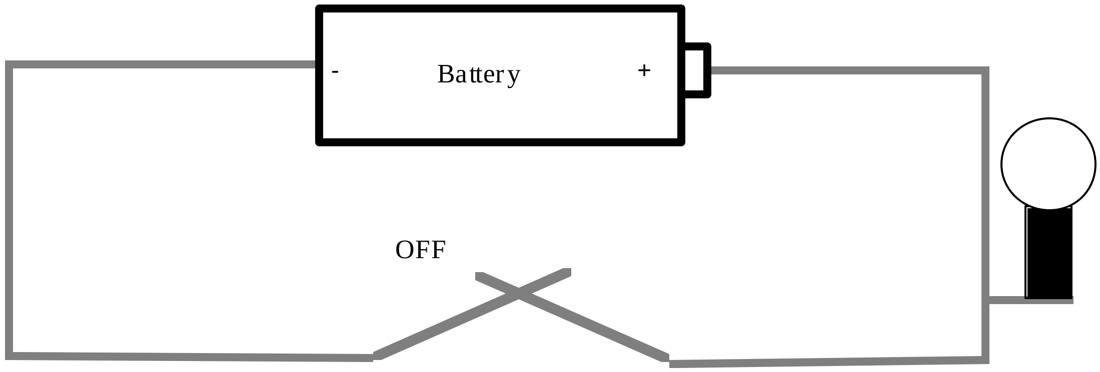


Notice that 1 and 0 enter through the inputs and the result is 0 coming out of the output.

Not

The last operator one needs to understand is the NOT operator.

Again, one can run an experiment using the diagram to understand how the NOT operator works.



Key for the Illustration

Lamp lit

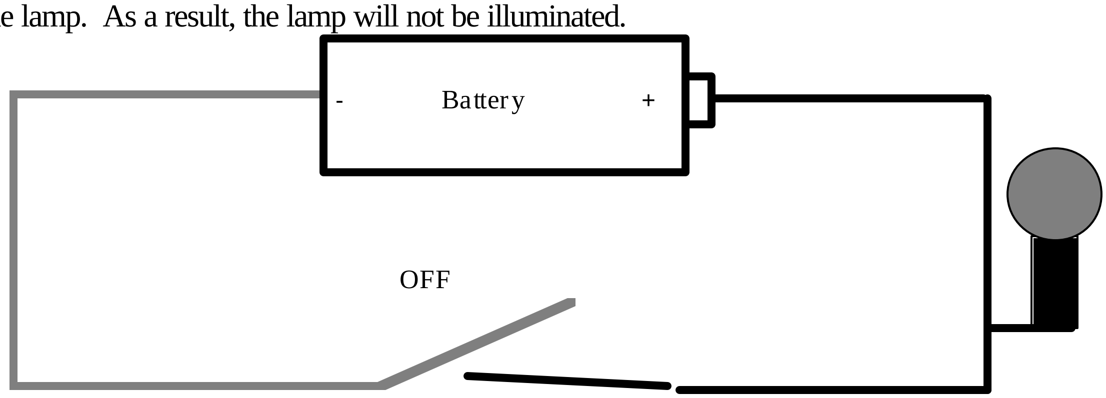
Lamp not lit

Electricity is not flowing

Electricity is flowing

The switch is in the OFF position, electricity will flow from the negative side of the battery, through the switch and the lamp, and to the positive side of the battery. As the electricity passes through the lamp, it will light the lamp.

When the switch is moved into the ON position, the electricity will not pass through the switch or the lamp. As a result, the lamp will not be illuminated.



Key for the Illustration

Lamp lit

Lamp not lit

Electricity is not flowing

Electricity is flowing

By recording the status of each switch (whether it is on or off) and whether the lamp is lit or not, one could develop a chart that summarizes the results of the experiment.

SW	L
OFF	ON
ON	OFF

This chart maybe rewritten with OFF coded as 0 and ON coded as 1. This chart is known as a **truth table**. The truth table below defines how the NOT operation works.

SW	L
0	1
1	0

Notice that when either switch is in the ON (1) position, the result is that lamp is lit (1).

The NOT operation may seen contra-intuitive, at first but consider an example in English.

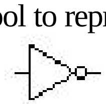
Suppose one says to a child:

You can go the movies, if you clean your room

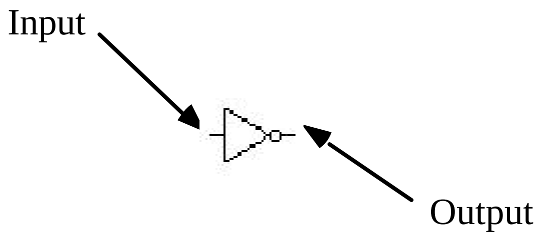
Now, consider all the combinations of possible actions of the child and the consequences of the child's actions (if a child does a job one can assign 1 to the action; 0, if the child does not do the job):

The child	Conclusion
does not clean his or her room	is able to go to the movies
0	1
cleans his or her room	is not able to go to the movies
1	0

Electronic engineers use a special symbol to represent the function AND:

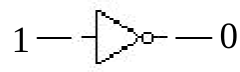


The symbol has several parts. The symbol includes places for inputs and a place for output.



Information enters the NOT function through the inputs, the NOT function acts upon the information coming into the function and the result leaves through the output.

An example of how electronic engineers would use this symbol is shown below.

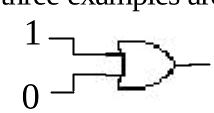


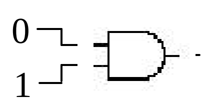
Notice that 1 and 0 enter through the inputs and the result is 0 coming out of the output.

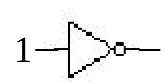
Solving Boolean Logic Problems

Solving Boolean logic problems is a very simple, if you remember three things about each symbol. First, each symbol has at least one input (OR and AND have two inputs). Second, each symbol has an output. Third, that the value of an output can become an input value for another symbol.

The first three examples are very easy.



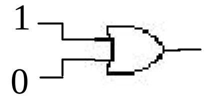




To solve any of these problems, working left to right an top to bottom:

1. Identify the symbol.
2. Identify the inputs.
3. Locate the inputs (or input) on the table.
4. Find the output corresponds to the inputs (or input)

Example I: What is the output value of the OR logic function.



1. Identify the symbol.

    The symbol is the OR symbol.

2. Identify the inputs

    The inputs are 1 and 0.

3. Using the OR truth table, locate input 1 and input 0.

These are the inputs into the OR circuit

SW1	SW2	L
0	0	0
1	0	1
0	1	1
1	1	1

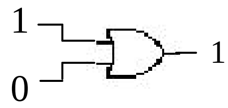
4. Find the output corresponds to the inputs (or input)
   From the truth table for the OR with inputs 1 OR 0 is 1

These are the inputs into the OR circuit

SW1	SW2	L
0	0	0
1	0	1
0	1	1
1	1	1

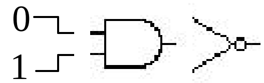
This 1 is the output for this combinations of inputs

Thus, the correct response to the problem is:



The second set of problems are more complex, but the same type of reasoning will solve them.

Example II. What is the output of these Boolean logic operators?



1. Identify the first symbol.

   The first symbol is the AND operator.

2. What are the inputs to the operator?

   The inputs are 0 and 1.

3. Using the AND truth table, locate the input 0 and input 1.

These are the inputs to the AND

SW1	SW2	L
0	0	0
1	0	0
0	1	0
1	1	1

4. Find the output corresponds to the inputs (or input).

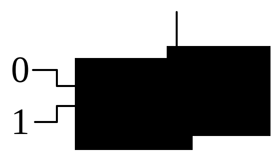
These are the inputs to the AND

SW1	SW2	L
0	0	0
1	0	0
0	1	0
1	1	1

This is the output that corresponds to inputs of 0 and 1.

Now, the output of the AND operator, becomes the input into the NOT (notice that the output of the AND is connected to the input of the NOT).

The output of AND is 0. This becomes the input for the NOT.



5. Identify the next logical operator.

    The next (connected) logical operator is the NOT.

6. Identify the input to the logical operator.

    The input to the NOT is 0.

7. Using the NOT truth table, locate the input 0.

This is the input for the NOT

SW	L
0	1
1	0

8. Find the output corresponds to the inputs (or input).

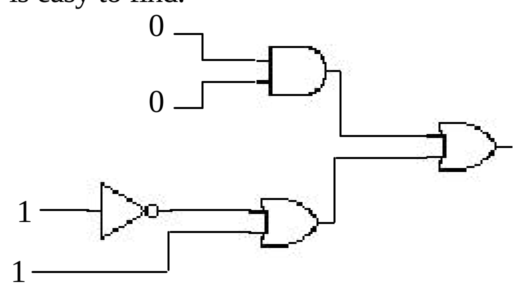
This is the input for the NOT

SW	L
0	1
1	0

This is the output for the NOT operator

The output of the NOT is 1, so that the answer is 1.

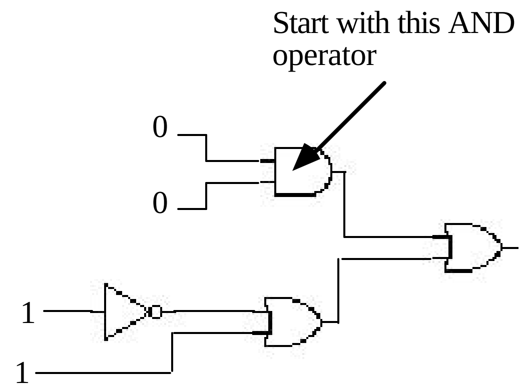
The final example is more complex than the previous example, but if one follows the procedure the answer is easy to find.



Starting in the upper left hand corner:

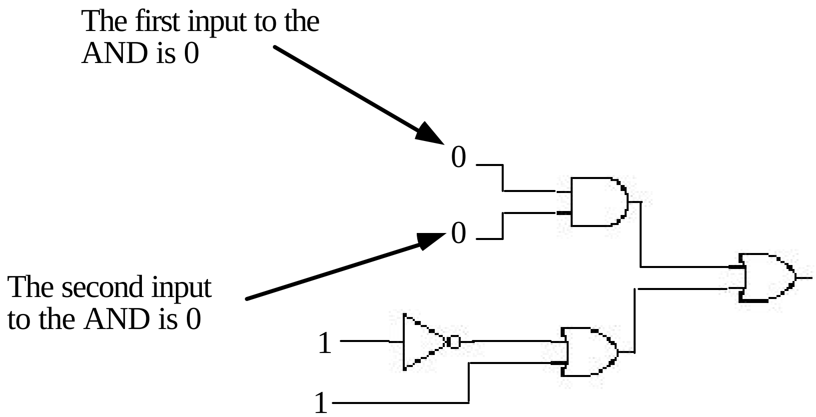
1. Identify the symbol.

   The symbol in the upper left corner is the AND symbol.



2. Identify the inputs.

   The inputs are 0 and 0.



3. Using the AND truth table, locate input 0 and input 0.

Inputs to the AND operator

SW1	SW2	L
0	0	0
1	0	0
0	1	0
1	1	1

4. Find the output that corresponds to the inputs (or input).

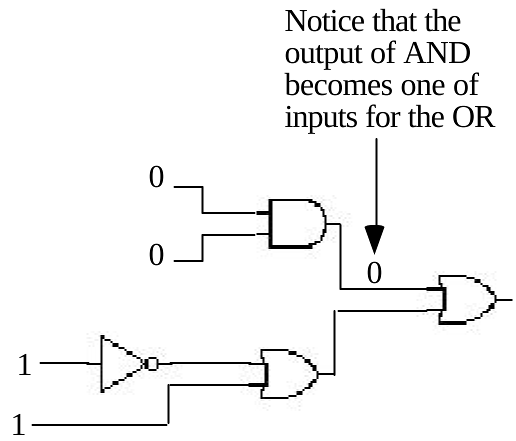
The table shows that the output for 0 AND 0 is 0.

Inputs to the AND operator

This is the output for AND operator

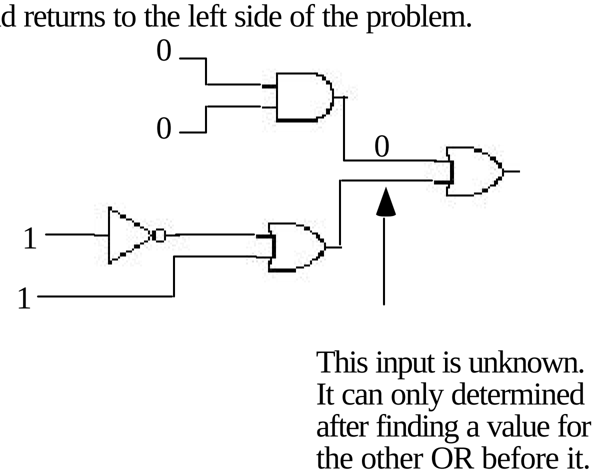
SW1	SW2	L
0	0	0
1	0	0
0	1	0
1	1	1

Now, notice that the output of AND becomes one of the inputs for the OR.

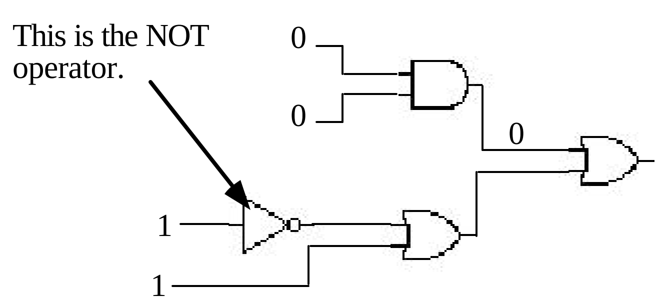


Notice, also, that we don't know the other input for the OR on the right.

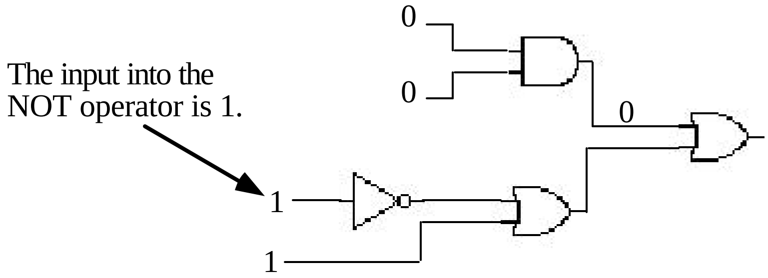
The second input will come from the OR on the left. So, one writes a zero for the OR on the left and returns to the left side of the problem.



5. Next, identify the logical operator on the left.
   The next logical operator is a NOT.



6. What is the input to the NOT?
   A 1 is the input to the NOT.



7. Using the NOT table, locate the input 1.

This the input into NOT operator.

SW	L
0	1
1	0

8. Find the output that corresponds to the input.

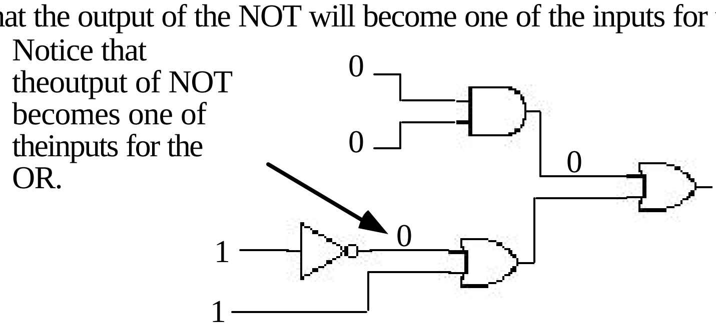
The output that corresponds to the input of 1 is 0.

This the input into NOT operator.

SW	L
0	1
1	0

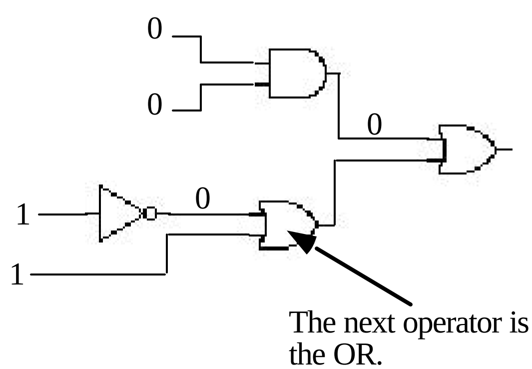
This is the output for NOT operator

Notice that the output of the NOT will become one of the inputs for the OR.



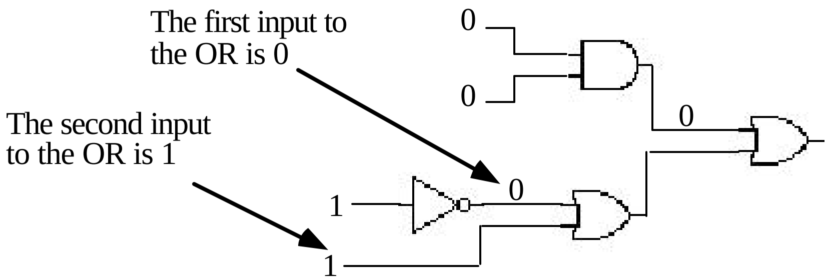
9. Next, identify the next logical operator to the right.

The next logical operator is an OR.



10. What are the inputs to the OR?

One of the input is a 0 and the other is a 1.



11. Using the OR table, locate the input 0 and the input 1.

SW1	SW2	L
0	0	0
1	0	1
0	1	1
1	1	1

Inputs to the OR operator

12. Find the output associated with an input 0 and an input of 1.

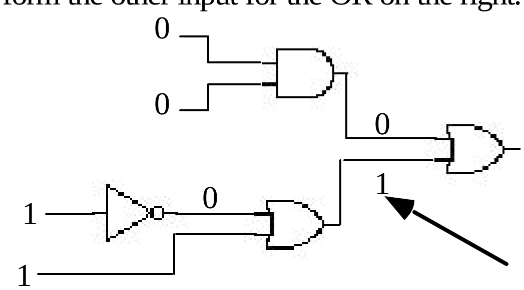
The output of a 0 and a 1 is 1.

SW1	SW2	L
0	0	0
1	0	1
0	1	1
1	1	1

Inputs to the OR operator

This is the output for OR operator.

This will form the other input for the OR on the right.

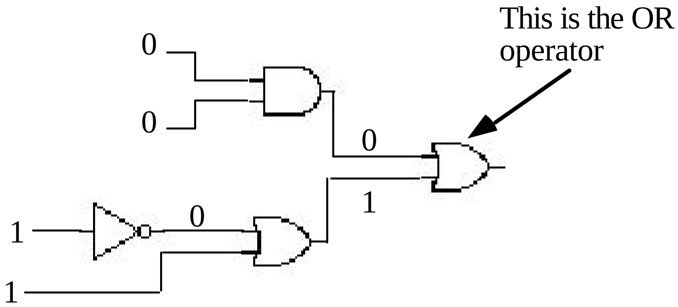


Notice that the output of the OR becomes the input for the other OR

Finally, one can now solve the problem.

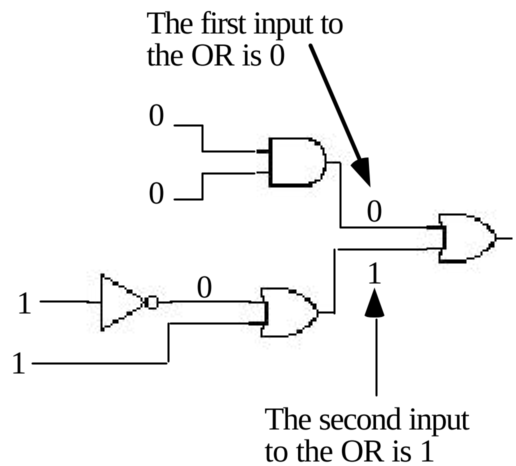
13. Identify the next logical operator to the right.

The next logical operator is an OR.



14. What are the inputs to the OR?

The inputs to the OR are 0 and 1.



15. Using the OR table, locate the input 0 and the input 1.

SW1	SW2	L
0	0	0
1	0	1
0	1	1
1	1	1

Inputs to the OR operator

16. Find the output that corresponds to the inputs

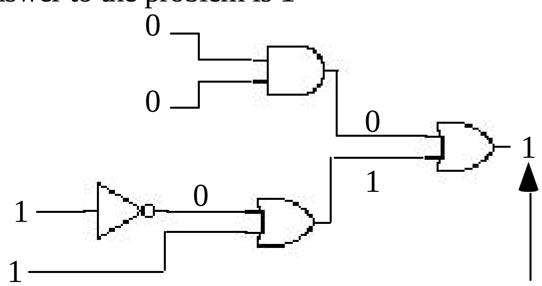
The table shows that the output of O OR 1 is 1.

SW1	SW2	L
0	0	0
1	0	1
0	1	1
1	1	1

Inputs to the OR operator

This is the output for OR operator.

Thus, the answer to the problem is 1



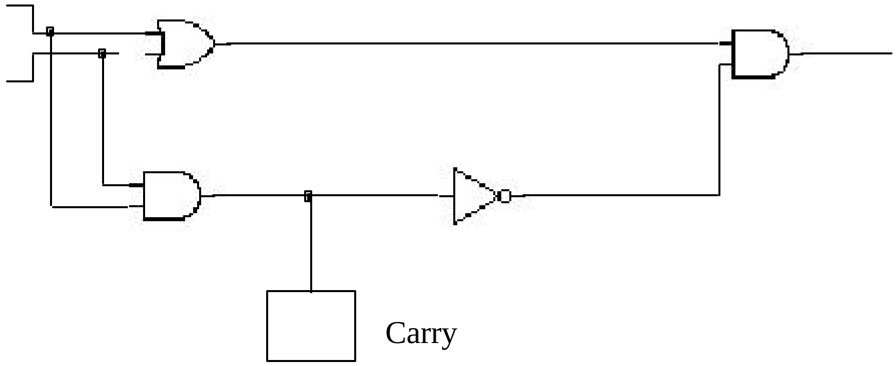
The answer to the problem is 1

Boolean Logic and the Computer

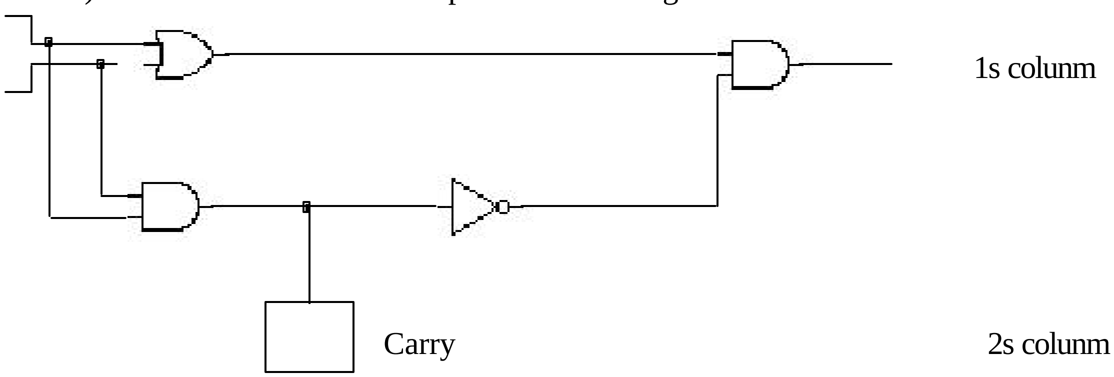
The importance of Boolean logic to the study of computers is that Boolean logic forms the basis of the processing operations of the computer. Everything from the components that process the data entered by an individual to the components that store or hold information are comprised of Boolean logical operators.

For example, if we desire a computer to add two (or more) numbers together, the numbers are added by passing each number through an electronic circut that forms the following logical structure.

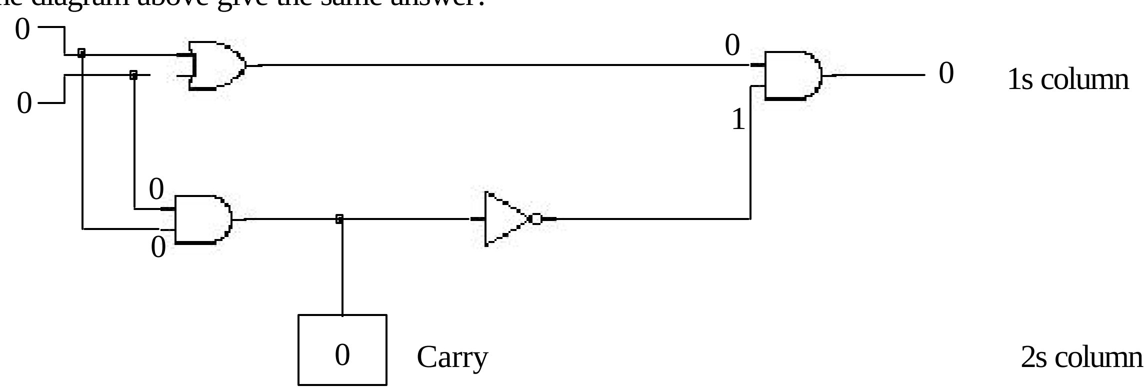
The diagram below is a simplified version of the electronic circuit found in all calculators and computers. It is known as a two-bit adder, because it adds two binary numbers together.



The output of the last OR represents the ones (1s) column (right most digit addition) in the calculations from the section on adding the binary. Also, remember that there is possibilty that there will be a carry from one column to another. As result, the designers of these circuit must somehow account for that carry. The square with the word "Carry" next to it will capture any number into the next column (the 2s column). One can view the circuit as pictured in the diagram below.

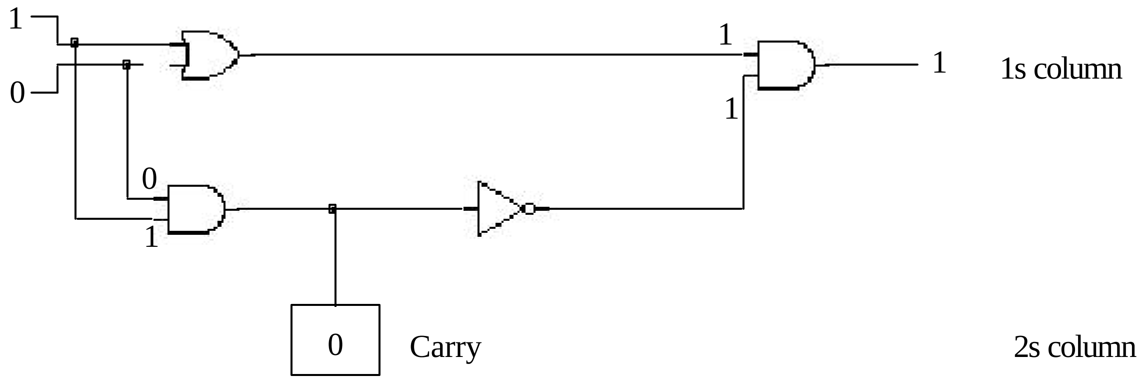


Suppose that one wishes to add binary 0 to binary 0. The result of the calculation is zero. Does the diagram above give the same answer?



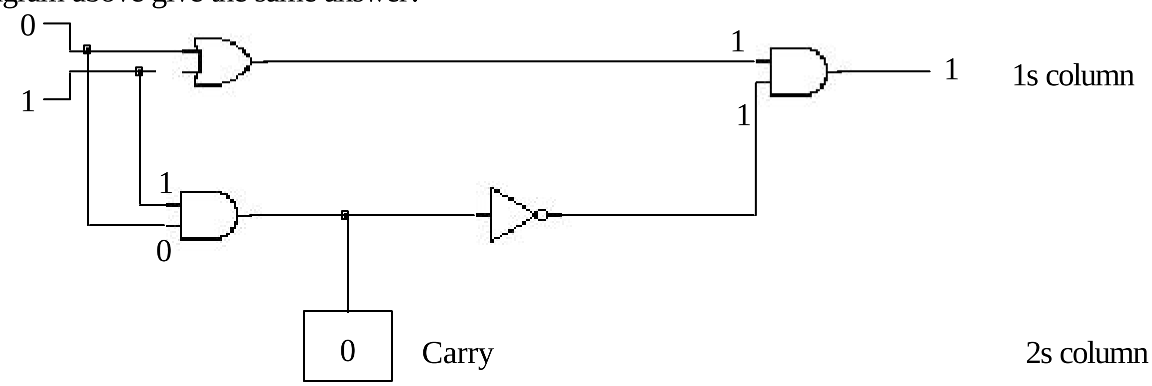
Yes, it does. Notice that the 1s column is 0 and the carry is 0 making the 2s column 0 also.

Suppose that one wishes to add binary 1 to binary 0. The result of the calculation is 1. Does the diagram above give the same answer?



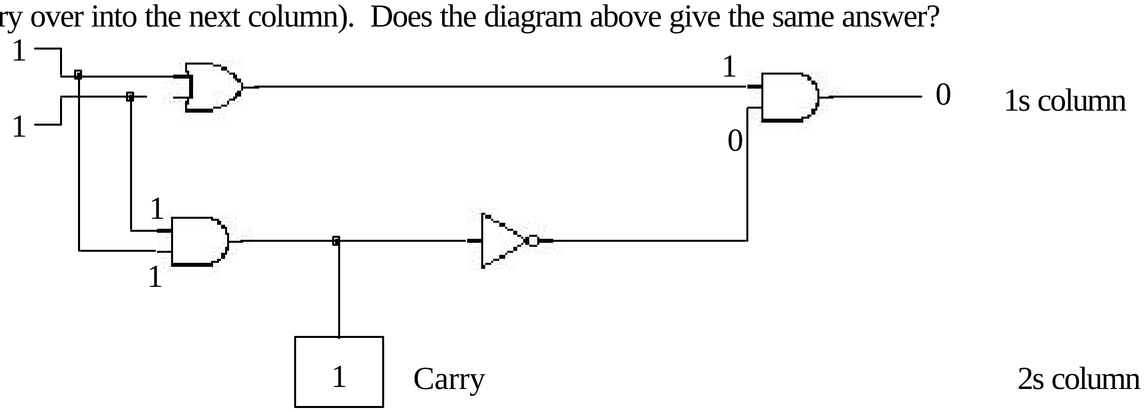
Yes, it does. Notice that the 1s column is 1 and the carry is 0 making the 2s column 0 .

Suppose that one wishes to add binary 0 to binary 1.   The result of the calculation is 1. Does the diagram above give the same answer?



Yes, it does. Notice that the 1s column is 1 and the carry is 0 making the 2s column 0 .

Suppose that one wishes to add binary 1 to binary 1.   The result of the calculation is 10 (there is a carry over into the next column). Does the diagram above give the same answer?



Yes, it does. Notice that the 1s column is 0 and the carry is 1 making the 2s column 1 .

One rarely sees a single two-bit adder, because the sum of two numbers cannot exceed two.

As a result, computer designers will attach multiple copies of the circuit to together as in the diagram below. The diagram represents a 4-bit adder which can handle sums up to 8.