

# Applications of Karnaugh Map and Logic Gates in Minecraft Redstone Circuits

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**Abstract**—This Writing is made to explain the application of Karnaugh Maps in the game Minecraft. Minecraft is a sandbox games that supports making of circuit with the item called redstone. Since redstone circuit takes a lot of space, simplifying logical function is a must in Minecraft

**Keywords**—Circuits, Karnaugh Maps, Logic Gates

## I. INTRODUCTION

Sandbox games are type of games that allow players to create anything that you want. Although it seems that players could create anything they want to, sandbox games are still limited to their implemented features and their uniqueness. Some of those limitations include, the game mode available, and the game's plot. Some examples of sandbox games are Terraria, Minecraft, Subnautica, and The Sandbox.

Minecraft is a sandbox game that features 8-bit styled graphics, and block-based building. Being one of the sandbox games, Minecraft has a lot of features implemented in the game. Features such as building, exploring, battling, and farming are implemented within the game. Aside from those features, Minecraft also has a feature that grants player the ability to create circuits similar to the electronic circuit in real life using redstones that are acquired from mining redstone blocks that are procedurally generated in a specific depth.

Since redstone circuits are one of the crucial features within the game, Minecraft developers implemented more updates allowing player to create circuits using more diverse items, such as buttons, levers, repeaters, and comparators. Thus, allowing players to create various circuits.



Figure 1. Example Redstone Circuit Made Using Minecraft

Through this writing, the author will try to explain the applications of Karnaugh Maps and Logic Gates in term of designing creating circuits using redstone block in Minecraft since in Minecraft, logic gates take a lot of space and space of a circuit is a concern in Minecraft.

## II. THEORIES ON LOGIC GATES AND KARNAUGH MAPS

### A. Logic Gates

Logic gates are devices that performs logical by accepting two inputs, and processes it to return a single output. Logic gates circuit itself is an implementation of boolean algebra, converting the canonic form of boolean algebra into the circuit form of logic gates.

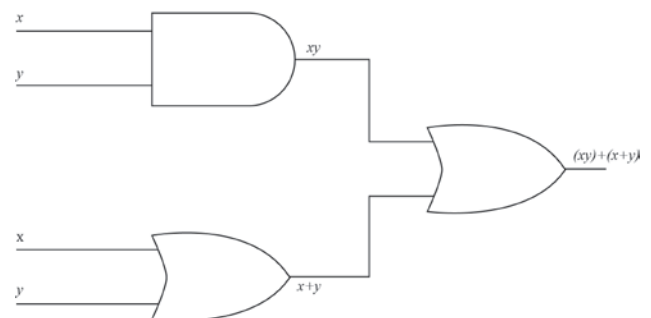


Figure 2. Example of logic gates circuit

Since logic gates implement logical operation, logic gates, have the default operations, such as AND, OR, NOT, XOR, XNOR, NAND, and NOR. These functions will be explained in Table 1.

Operations	Input 1	Input 2	Output
AND	0	0	0
	0	1	0
	1	0	0
	1	1	1
OR	0	0	0
	0	1	1
	1	0	1
	1	1	1
NOT	0		1
	1		0
XOR	0	0	0
	0	1	1
	1	0	1
	1	1	0
XNOR	0	0	1
	0	1	0
	1	0	0
	1	1	1
NAND	0	0	1
	0	1	1
	1	0	1
	1	1	0
NOR	0	0	1
	0	1	0
	1	0	0
	1	1	0

Table 1. Input and Output of Logical Operations

Functions in logic gates circuits are represented by using symbols. Those symbols are given in the picture below.

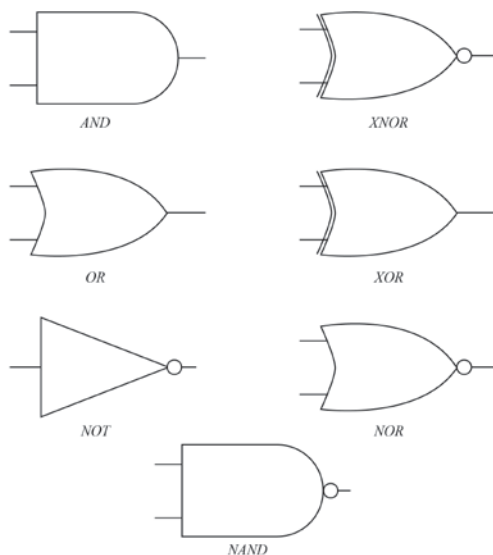


Figure 2. Symbols of Logic Gates

### B. Karnaugh Maps

Karnaugh Maps are graphical method to simplify logical functions / boolean functions. This method simplifies those functions by generalizing the same pattern found in the boolean functions. Karnaugh maps are built by drawing a table consisting of the variables and the possible input, afterwards the content of the table is filled by using the truth table of the given boolean functions.

Karnaugh maps generate simplified boolean functions using the form of conjunctive normal form or disjunctive normal form, depending on the result taken.

### C. Minterm Functions

Minterm functions are functions that are indicated by the form of conjunctive normal form. Each element of the function is connected using the product rule. Furthermore, minterm functions also need to have a complete set of variables. An example of a minterm function is expressed below.

$$f(x, y, z) = (x + y + z)(x' + y' + z') \quad (1)$$

However, if one of the elements above loses one variable, it is considered as not a minterm functions, as minterm functions need to have complete set of variables. An example of this case is represented below.

$$f(x, y, z) = (x + y)(x + y' + z) \quad (2)$$

### D. Maxterm Functions

Minterm functions are functions that are indicated by the form of disjunctive normal form, a form where each element of the function is connected using the sum rule. As in minterm function, maxterm functions also need to have complete set of variables to be considered as a maxterm function. An example of maxterm function is represented below.

$$f(x, y, z) = xy'z + xyz + x'y'z \quad (3)$$

### E. Simplifying Functions using Karnaugh Maps

In simplifying functions, one has to map the function into the Karnaugh map. For example, if given the function below

$$f(x, y, z) = x'yz' + xyz' + xyz \quad (4)$$

The function (4) can be made into a truth table as represented in the table below.

x	y	z	$f(x,y,z) = x'yz' + xyz' + xyz$
0	0	0	0
0	0	1	0
0	1	0	1
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	1
1	1	1	1

Table 2. Truth table representation of function (4)

From the table above, the Karnaugh Maps for function (4) can be mapped by putting zeroes and ones inside the karnaugh maps. If the given function is in the form of a product of sum, zeroes and ones are put inside the maps right away. However, if the given function is in the form of sum of product, zeroes are given in the position of ones, and ones are given in the position of zeroes. Since function (4) is in the form of product of sum, zeroes and ones will be put inside the maps respectively, thus creating the Karnaugh map below.

		yz			
		00	01	11	10
x	0	0	0	0	1
	1	0	0	1	1

Figure 3. Karnaugh map representation of function (4)

Afterwards, the elements are selected base on the similarities in blocks, the elements can be selected in a pair, quads, or octets. From Figure 3, the elements can be selected in pairs creating the function below.

$$f(x, y, z) = xy + yz' \quad (5)$$

### III. MECHANISM OF REDSTONE IN MINECRAFT

#### A. Redstones in General

Redstones are an item in Minecraft that is used as the primary element to make Redstone Circuits. Redstones are used to symbolize wires in Minecraft, moreover, redstones can be crafted into torch as the power source of the circuit.

Redstone component can be classified into 3 categories,

1. Power Components, component that provides power to the circuit (examples : redstone torches, buttons, levers, pressure plates, etc.)
2. Transmission component, component that passes power to the other component (example: redstone dust, redstone repeater, redstone comparator)

3. Mechanism component, component that is affected by the redstone circuit to affect the environment (example: redstone lamp, piston, etc.)

#### B. Power Transmission with Redstone

Redstone component and other block is divided into two states, powered and unpowered. A component can be powered by placing power component on the adjacent block.

An opaque block (e.g. dirt, stone) that is powered by a power component is called strongly-powered block. A strongly powered block, can affect adjacent redstone power block. However, an opaque block powered only by redstone dust is called a weakly-powered block. Such block can't be used to power another redstone dust. Moreover, an opaque block can't be used to power another opaque block. To make such things happen, one must put redstone dust or device in between the blocks. Although there are differences between strongly-powered and weakly-powered block, any powered block, can also affect adjacent redstone components.

#### C. Redstone Torches Behavior

Redstone torches, being one of the redstone power components are a crucial component in process of making redstone circuits. As a power component, redstone torch gives power to the adjacent redstone dust. However, redstone can also be turned off by powering the block it attached to.

Other than that, redstone torches only gives powers to a adjacent redstone component, but only strongly power opaque block above it,

### IV. LOGIC GATES IN MINECRAFT

Utilizing redstone block and redstone component unique behavior, we can manipulate those behavior into creating a logic gate configuration with the symbols listed in the figure below.

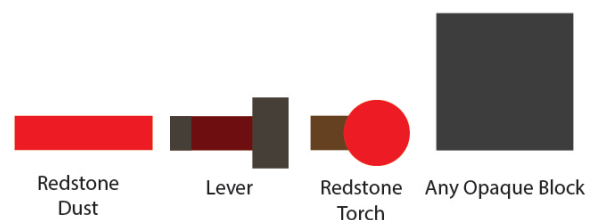


Figure 4. Symbols used in the configuration

**A. NOT Gate**

As we know, the NOT Gate inverts whatever the input given. Thus, by utilizing the redstone torch's behavior of turning off when the block it's attached to powered, we can create a not gate simply by using this configuration.

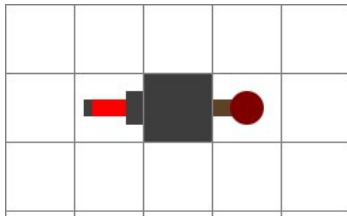


Figure 5. NOT Gate

**B. AND and NAND Gate**

An AND gate requires two input to have the value of TRUE while NAND Gate is the AND gate embedded with a NOT gate. Also utilizing the behavior of redstone torches, an AND gate and a NAND Gate can be made by creating the following structure or a similar structure.

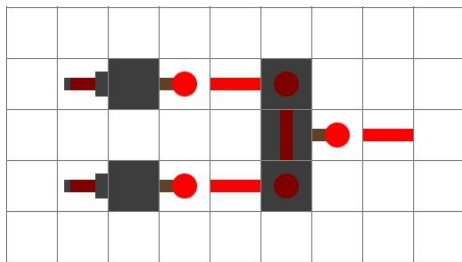


Figure 6. AND Gate

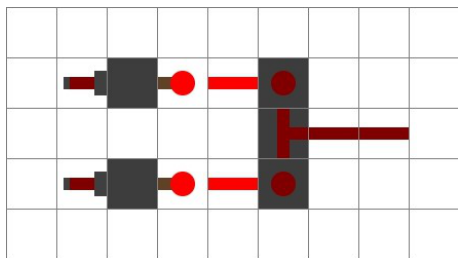


Figure 7. NAND Gate

**C. OR and NOR Gate**

An OR gate requires one of the input to have the value of TRUE while NOR Gate is simply the modified version of the OR gate, just like the AND and NAND gate. The configuration of the OR and NOR gate is listed on the next 2 figure

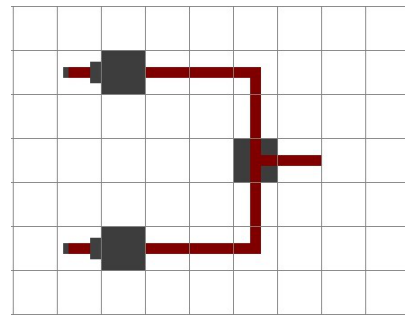


Figure . OR Gate

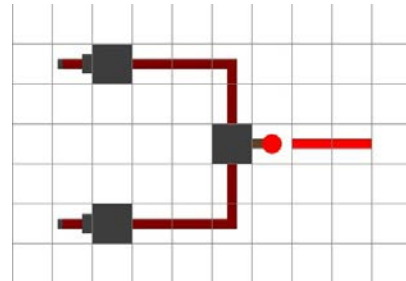


Figure 8. NOR Gate

**D. XOR and XNOR Gate**

An XOR gate only accepts one input, and thus by implementing such structure, the XOR gate can be made. By modifying XOR gate, merging it with a NOT gate, an XNOR gate can be made

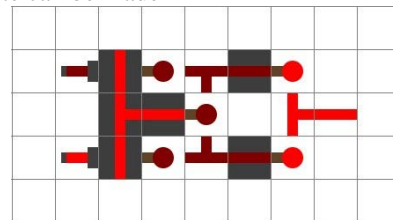


Figure 9. XOR Gate

**VI. KARNAUGH MAP IMPLEMENTATION IN MINECRAFT**

**A. Door Problem**

One of the important feature in Minecraft is building, but after exploring, players are often disturbed by the mechanism of door that needs right clicking before being able to be opened. Thus it's been a problem to create a mechanism that allows player to open door in a specific way. To make such things, player should list what they need, by asking the question "What would this lever do?". For example, to open the fence gate if and only if the door is open from the inside, and to close the fence gate if the door is opened from the outside.

All switch initial position is turned off, if the player flicked the switch inside the house or flicked the switch near the fence gate, both the fence gate and the front door will be opened. If after exiting the front door, or after entering the front gate, the middle switch is flicked, then the fence gate will be closed.

First of all, we need to create the Karnaugh map of the mechanism. With X being the lever inside the house, Y being the lever outside the house, Z being the lever near the gate, A being the front door, and B being the fence gate. The don't care result represents the impossible input.

x	y	z	A	B
0	0	0	0	0
0	0	1	1	1
0	1	0	0	0
0	1	1	1	0
1	0	0	1	1
1	0	1	0	0
1	1	0	1	0
1	1	1	X	X

Table 2. Truth table of the door problem

After finding out the needs using truth table, the truth table should be converted into the Karnaugh Map form. Since there are two components that should be considered, there would be two Karnaugh Maps.

		yz			
		00	01	11	10
x	0	0	1	1	0
	1	1	0	x	1

Figure 10. Karnaugh map for variable A

		yz			
		00	01	11	10
x	0	0	1	0	0
	1	1	0	x	0

Figure 11. Karnaugh map for variable B

By using Karnaugh map, we get the simplified functions below

$$A(x, y, z) = xy'z' + x'z + xy \quad (5)$$

$$B(x, y, z) = xy'z' + x'y'z \quad (6)$$

After finding out the function of the door mechanism, the circuits are then applied to the game, resulting in the following picture

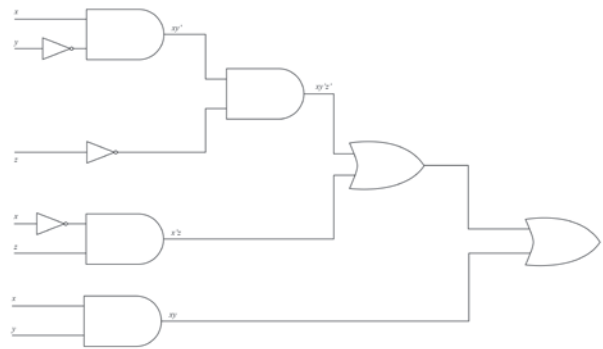


Figure 12. Circuit configuration for Variable A

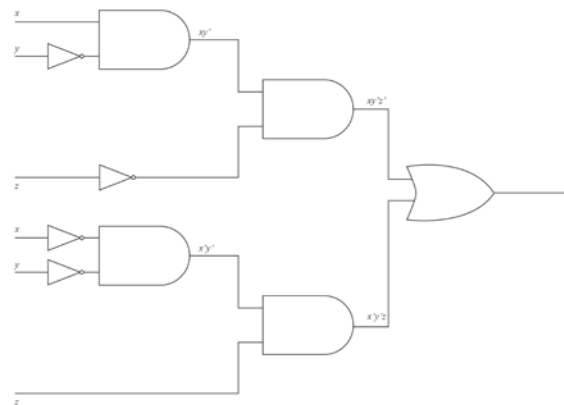


Figure 13. Circuit configuration for Variable B

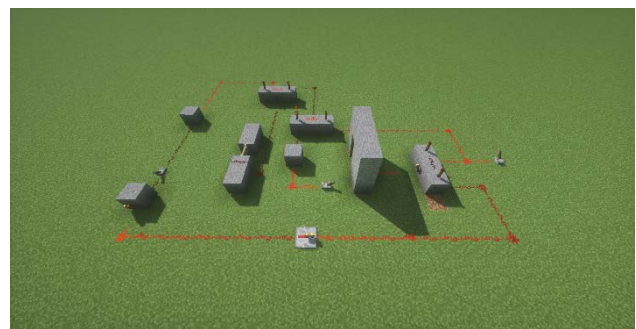


Figure 14. In game configuration for the door problem

There are many variations to this problem and this example door problem is just barely one of the many door problems in Minecraft

### B. Lamp Switch

Another type of redstone circuit that can be implemented in Minecraft is a lamp switch, in which the lamp is shaped like a cross, and the direction of the lamp is determined by the input (binary input) of levers. First of all we need to create the truth table of the given problem, x for the first lever, y for the second lever, A is the lamp on the bottom side, B is the lamp on the left side, C is the lamp on the right side, and D is the lamp on the top side.

x	y	A	B	C	D
0	0	0	0	0	0
0	1	1	0	1	0
1	0	1	1	0	0
1	1	1	0	0	1

Table 3. Truth table of the lamp switch problem

Like usual, after finding the truth table, the truth table is then converted into Karnaugh Map, listed below.

		y	
		0	1
x	0	0	1
	1	1	1

Figure 15. Karnaugh map for variable A

		y	
		0	1
x	0	0	0
	1	1	0

Figure 16. Karnaugh map for variable B

		y	
		0	1
x	0	0	1
	1	0	0

Figure 17. Karnaugh map for variable C

		y	
		0	1
x	0	0	0
	1	0	1

Figure . Karnaugh map for variable D

From the Karnaugh map above, we achieve the simplified function as below. Function B, C, and D can't be simplified because it only consists of only 1 value that is true.

$$A(x, y) = x + x'y \tag{7}$$

$$B(x, y) = xy' \tag{8}$$

$$C(x, y) = x'y \tag{9}$$

$$D(x, y) = xy \tag{10}$$

Thus achieving the configuration of circuits as represented in the next picture



Figure 18. Circuit representation of variable A



Figure 19. Circuit representation of variable B



Figure 20. Circuit representation of variable C

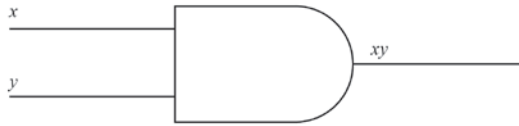


Figure 21. Circuit representation of variable  $D$

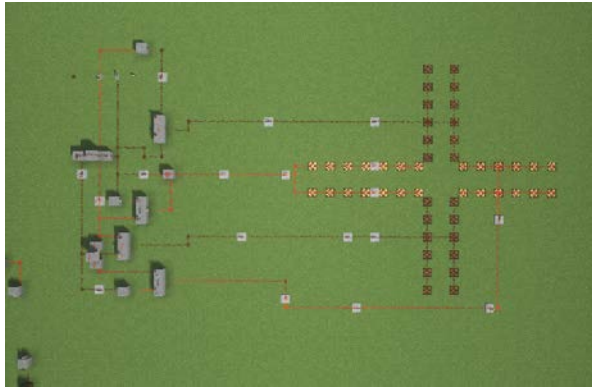


Figure 22. In game representation of the lamp switch circuit

## V. CONCLUSION

Since logic gates in Minecraft takes quite a large space, simplifying boolean functions in Minecraft is very important for saving space and time to create redstone circuits.

## VII. ACKNOWLEDGMENT

The author thanks to God for giving inspirations and time to make this writing, thus the author could finish this writing. Other thanks are given to the author's friend for giving inspiration about what circuits can be created to ease the gameplay of Minecraft.

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## PERNYATAAN

Dengan ini saya menyatakan bahwa makalah yang saya tulis ini adalah tulisan saya sendiri, bukan saduran, atau terjemahan dari makalah orang lain, dan bukan plagiasi.

Bandung, 8 Desember 2016

A handwritten signature in black ink, appearing to read 'Vincent'.

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