Applications of Logic Gates in Whistle Controlled Keychain

Deborah Aprilia Josephine / 13516152
Program Studi Teknik Informatika
Sekolah Teknik Elektro dan Informatika
Institut Teknologi Bandung, Jl. Ganesha 10 Bandung 40132, Indonesia
13516152@std.stei.itb.ac.id

***Abstract*— This writing is made to explain the application of Logic Gates in a Whistle Controlled Keychain ways of working. Whistle controlled keychain is a keychain developed by some industries for commercial use. The keychain have a unique feature that applied the voice frequency-based recognition. The author will model the circuit of the keychain by using Logic Gates.**

***Keywords*— Form, Frequency, Function, Gates.**

I. INTRODUCTION

Figure 1 Whistle Controlled Keychain

People nowadays are very creative and full of idea. A few times ago, the author found a thing called Whistle Controller Keychain in one of the author's friend inventory. The usual keychain we know is only used for ornament to our key, or to make the key easy to hold. We usually forget the last time we hold our key resulting the key lost. But, this Whistle Controller Keychain have a very special feature. It will ring an alarm when someone whistle around it. This special feature allow us to find our lost key although we forget where we put it. This invention is very creative and high-tech that it might be use to learn about electrical circuit. You can see the whistle controlled keychain on the figure above

Whistle is known for their high frequency. The author thought that the inventor might use the voice frequency-based recognition to develop such an invention. The study about voice recognition is handled in Digital Signal Processing.

After we recognize the frequency of the sound, we have to decide whether the alarm of the keychain should be ring or not. Therefore we should know the modelling of logic gates of the keychain.

The author thinks that the idea of the invention is very authentic and very useful. By using a simple voice recognition and a circuit, the developer can make such a great invention. So, through this writing she try to make and explain a model of logic gates of the circuit inside the keychain. To model the circuit, the author use Logic Gates and Karnaugh Method.

II. BOOLEAN ALGEBRA, LOGIC GATES AND KARNAUGH METHOD THEORIES

A. Boolean Algebra

Boolean algebra first studied by George Boole. It is the basic science in switching theories and logic design. A Boolean algebra consists of at least two elements that is 0 and 1, with the operation AND with the symbol of '•', operation OR with the symbol of '+', operation NOT with the symbol '''.

AND operations is used to obtain the Boolean product. The AND operation function is similar to logic operation which means the only "True" goal obtained from both "True" input, wherein Boolean algebra case the input of element 1. To understand the operation, see the following table of operation AND.

AND (•)	0	1
0	0	0
1	0	1

Table 1 AND operation for two elements

Another operation used in Boolean algebra is OR. OR operation is used to obtain the Boolean sum. Similar to OR logic operation, which means we can obtain "True" goal by having at least one "True" input. To understand the operation, see the following table of operation OR.

OR (+)	0	1
0	0	1
1	1	1

Table 2 OR operation for two elements

The last operator used in Boolean algebra is NOT. NOT operation is used to obtain the complement of the element. To understand the operation, see the following table of operation NOT.

NOT (‘)	
0	1
1	0

Table 3 NOT operation for two elements

Boolean algebra hold the following axioms [1]:

1. Idempotent: $x \bullet x = x$ and $x + x = x$
2. Commutative: $x \bullet y = y \bullet x$ and $x + y = y + x$
3. Associative: $x \bullet (y \bullet z) = (x \bullet y) \bullet z$ and $x + (y + z) = (x + y) + z$
4. Absorptive: $x \bullet (x + y) = x$ and $x + (x \bullet y) = x$
5. Distributive: $x \bullet (y + z) = (x \bullet y) + (x \bullet z)$
6. Zero (null, smallest) and one (universal, largest) elements.

Boolean algebra can be expressed in two form, the minterm or canonical product-of-sum form, and the maxterm or canonical sum-of product form. To expressed the Boolean algebra function in this form, we can ignore the dot symbol (•) in the product operation for example when we have $x \bullet y$ we can write *xy*. We also can ignore the parentheses of Boolean products for example we have (*xyz*) we can write *xyz*. To understand the minterm and maxterm function, see this following equation.

$$F(x,y) = x'y + xy'$$

Equation 1 Maxterm form

$$F(x,y) = (x + y')(x' + y)$$

Equation 2 Minterm form

In further explanation, there are a method called Karnaugh Map. In each Karnaugh Map they hold a value of input. In maxterm and minterm form, we usually write the switching function as below.

$$F(x,y) = \sum(value\ of\ input)$$

Equation 3 Maxterm form

$$F(x,y) = \prod(value\ of\ input)$$

Equation 4 Minterm form

B. Logic Gates

Logic gates is a method to draw a Boolean function into some circuit of logic gates. The method help us to understand the way of our devices work and to design how our device works.

Boolean function can be drawn into a form we called Logic Gates. Each operation has a specific shape of the gates. The left side of the gates contains all the input of the operation, and the right side of the gates represent the output of the operation. See the following figure to of the gates for each operation.

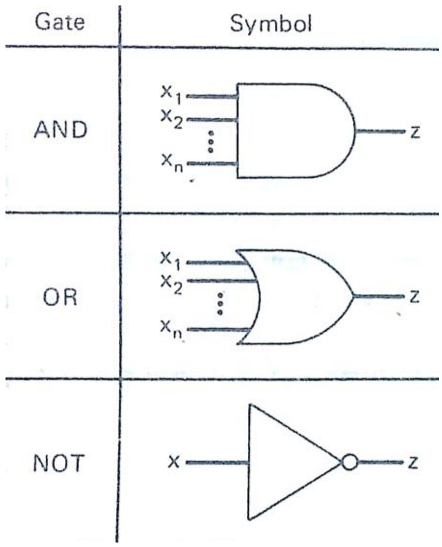

Figure 2 Logic Gates of Basic Operator[1]

In logic gates, there are 3 operator derivate from the basic operator. There are NAND, NOR, and XOR. NAND operator. NAND operator works using AND operator and NOT operator. So we have to operate the elements of 0 and 1 with AND operator, and then we complement the result of the operation. The procedure of the operation NAND also applied in NOR operation. The NOR operation proceed to OR operation then we complement the result with NOT operation.

XOR operation is a little bit different from the other two. The XOR operation works like logic operation that state the input have to be unique or different from one another. To understand the operation, see the following table of operation XOR.

XOR (+)	0	1
0	0	1
1	1	0

Table 4 XOR operation for two elements

The gates of the operation is a little bit different from the basic one. See the following figure to of the gates for each operation.

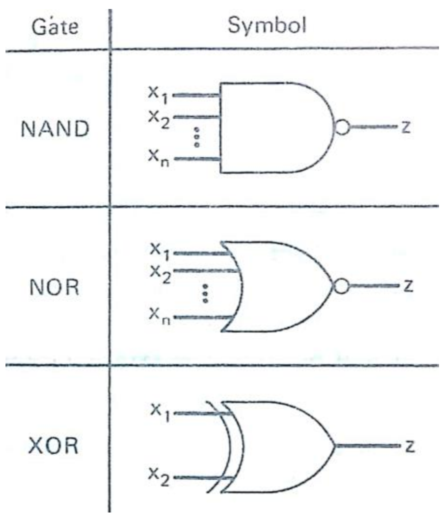

Figure 3 Logic Gates of Derivative Operator[1]

C. Karnaugh Method

Karnaugh method is a method of representing the function of either sum-of-product form or product-of-sum form in a table. The table is called Karnaugh Map. This representative make us easier to minimize or simplify the Boolean function. The Karanaugh Map is constructed from all the possibilities input and the result of the truth table of the problem. After filling the table with the result of the truth table, we can simplify the Boolean function by generalizing the 1's pattern into one function. For example we have the Boolean function of *w'x'yz + w'xyz*. The Karnaugh Map of the Boolean function should be constructed in the following table.

wx/yz	00	01	11	10
00	0	0	1	0
01	0	0	1	0
11	0	0	0	0
10	0	0	0	0

Table 5 Example of Karnaugh Map

Based on the Karnaugh Map, we can see that there are 2 blocks located near from one another in the fourth column. Based on the Karnaugh Method, we can generalize the row 00 and 01 of *wx* into the *w* because when the *x* value 0 or 1, it produce the same result. So, the Boolean function simplified into *w'yz*.

III. Whistle Controlled Keychain Problem

A. Scope of Problem

Whistle controlled keychain is an invention these day that require a voice frequency-based recognition. Explanation about the voice recognition can we get in the study of Digital Signal Processing. The voice that recognized will be converted from analog quantifier to digital quantifier using Voice over IP. This process hold a very important process because the next step which is the executing step is dependent to this phase.

In this writing, the author will try to explain more about the circuit of the keychain, which is the application of Karnaugh Map and Logic Gates. In this writing, the author will represent the modelling of the logic gates of the keychain way of working.

Unfortunately, the lack of knowledge of the author might make this writing is not relatable to the real event. The problem the author tried to explain is in the scope of the application of logic gates in the Whistle Controlled Keychain.

Every electrical devices contains a circuit that define how the device work. In this case, the keychain have a circuit that determine whether the alarm rings or not. The input of the circuit is the digital frequency converted from the analog quantifier of voice. The output of the circuit is the digital signal 0 or 1, where 0 means the alarm isn't ringing, while 1 means the alarm is ringing. The output will change only if the voice is recognized as whistle or the user pressed the button that stop the alarm from ringing. The ringing of the alarm is determined from the output.

B. Whistle Frequency Estimation

Some college student from an institute of technology did a research about the human whistle detection and frequency estimation. Because the human whistles are vary in frequency, they did some research based on 20 sample randomly selected. From their paper, the human whistle is investigated by time-frequency analysis.

Based on their conclusion, human whistle frequency range to be 500-5000 Hz. This range is quite high considering the normal sensitive frequency human can hear is in range 1000-4000Hz. From this conclusion, we can estimate the range of frequency we want to apply in our circuit is in range 0-8000 Hz.

IV. Logic Gates Modelling of Whistle Controlled Keychain

A. Karnaugh Map Implementation

The estimation of the frequency range we got before, we can determine there are 4 input of element 0 or 1 for our logic gates. The range of frequency (0-8000Hz) can be separated into 16 partition. The value of range 0-499 Hz is 0, range 500-1000 H is 1, 1001-1500 Hz is 2, 1501-2000 Hz is 3, 2001-2500 Hz is 4, 2501-3000 Hz is 5, 3001-3500 Hz is 6, 3501-4000 Hz is 7, 4001-4500 Hz is 8, 4501-5000 Hz is 9, 5001-5500 Hz is 10, 5501-6000 Hz is 11, 6001-6500 Hz is 12, 6501-7000 Hz is 13, 7001-7500 Hz is 14, 7501-8000 Hz is 15. This partition is just an example and it might be different in other range of frequency held.

As we know, the whistle's frequency estimated in range 500-5000 Hz. Therefore, we can make a truth table of the frequency range, with the value of 1 until 9 filled with element 1 as the output, and the rest filled with element 0. See the following table to see the result of the truth table.

N	*w*	*x*	*y*	*z*	Alarm
0	0	0	0	0	0
1	0	0	0	1	1
2	0	0	1	0	1
3	0	0	1	1	1
4	0	1	0	0	1
5	0	1	0	1	1
6	0	1	1	0	1
7	0	1	1	1	1
8	1	0	0	0	1
9	1	0	0	1	1
10	1	0	1	0	0
11	1	0	1	1	0
12	1	1	0	0	0
13	1	1	0	1	0
14	1	1	1	0	0
15	1	1	1	1	0

Table 6 Truth Table of Whistle Controlled Keychain

We have 4 input. There are *w*, *x*, *y* and *z* as digital input. From the truth table, we can fill the Karnaugh Map below with the result of the truth table. We divide the input into two part, the *wx* and *yz*. Therefore the column and row valued between 00, 01, 10, and 11. As we can see from the truth table above, the Karnaugh Map constructed can be seen in the following table.

wx/yz	00	01	11	10
00	0	1	1	1
01	1	1	1	1
11	0	0	0	0
10	1	1	0	0

Table 7 Karnaugh Map of Whistle Controlled Keychain

The function formed from the Karnaugh Map is as below.

$$F(w,x,y,z) = w'x'y'z + w'x'yz + w'x'yz' + w'xy'z' + w'xy'z + w'xyz + w'xyz' + wx'y'z' + wx'y'z$$

Equation 5 Boolean Function of Device before Minimization

As we can see, the function is not the simplest form, so we have to minimize the function using Karnaugh Method. See the following table to know the minimize form of the Karnaugh Map.

wx/yz	00	01	11	10
00	0	1	1	1
01	1	1	1	1
11	0	0	0	0
10	1	1	0	0

Table 8 Minimization of the Karnaugh Map

The minimization of the Karnaugh Map is done by generalizing the 1's input into one function. Generalizing the 1's can be done if the number of 1's located near to one another is 2, 4, 8 or 16. As we look in table 8, the 1's grouped or generalized into 4 function. The first one is the four 1's located in column 3 and 4. Because the output is 1 when the *y* valued 0 or 1, and when the *x* valued 0 or 1, we can generalized the function into *w'z*. The next minimization is located in column 4 and 5. Because the output is 1 when the *x* valued 0 or 1, and when the value of *z* is 0 or 1, we can generalized the function into *w'y*. The next minimization is located in row 3, column 2 and 5. Because the output is 1 when the value of *y* is either 0 or 1, we can generalized the function into *w'xz'*. The last minimization is located in the fifth row. Because the output is 1 when the value of *z* is 0 or 1, we can generalized the function into *wx'y'*. Therefore the minimization of the function can be written as below.

$$F(w,x,y,z) = w'z + w'y + w'xz' + wx'y'$$

Equation 6 Boolean Function in The Simplest Form

B. Logic Gates Modelling

As we know, from the previous part, we have determined the Boolean function of Whistle Controlled Keychain. The function formed in the sum-of-product form or the maxterm form. There are 4 products of the variable, and at the end all of them are summed.

Therefore, we draw the 4 product gates or AND gates. After that we draw the input and output line. If the input is complement of a variable, we draw the NOT gates before the AND gates. The first step of the modelling can be seen in the figure below.

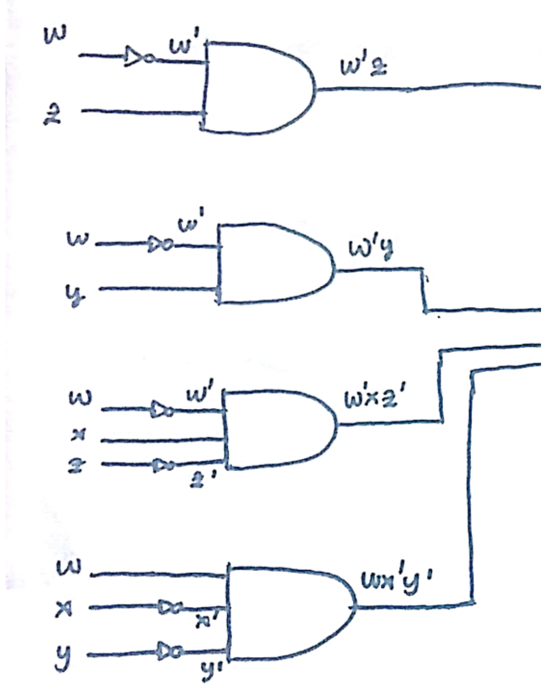

Figure 4 Logic Gates of Whistle Controlled Keychain Part A

In figure 4, the first AND gates is the product of *w'z*. As we can see, input *w* meets the NOT gates, and the product *w'* meet the AND gates. The input *z* meet the AND gates. Therefore the product of the AND gates is *w'z.*

The second AND gates is the product of *w'y*. As we can see, input *w* meets the NOT gates, and the product *y'* meet the AND gates. The input *y* meet the AND gates. Therefore the product of the AND gates is *w'y.*

The third AND gates is the product of *w'xz'*. As we can see, input *w* meets the NOT gates, input *z* meets the NOT gates and the product *w'* and *z'* meet the AND gates. The input *x* meet the AND gates. Therefore the product of the AND gates is *w'xz'*.

The last AND gates is the product of *wx'y'*. As we can see, input *x* meets the NOT gates, input *y* meets the NOT gates and the product *x'* and *y'* meet the AND gates. The input *w* meet the AND gates. Therefore the product of the AND gates is *wx'y'*.

The next step of modelling the logic gates is draw the sum gates or the OR gates. The output of the AND gates is sum in the OR gates. The second step of the modelling of logic gates can be seen in the figure below.

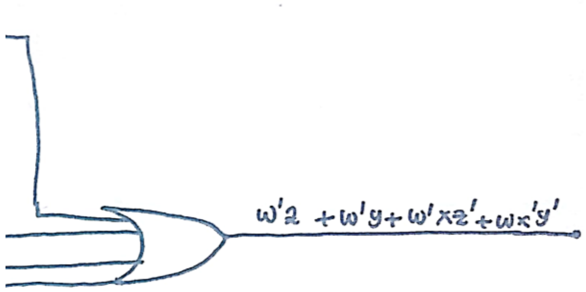

Figure 5 Logic Gates of Whistle Controlled Keychain Part B

In figure 5, the OR gates get input *w'z*, *w'y*, *w'xz'*, *wx'y'*. The input is the product of the previous gates. After meeting the OR gates, the output of the gates are the boolean function of the Whistle Controller Keychain. To see the whole logic gates model, see the figure below.

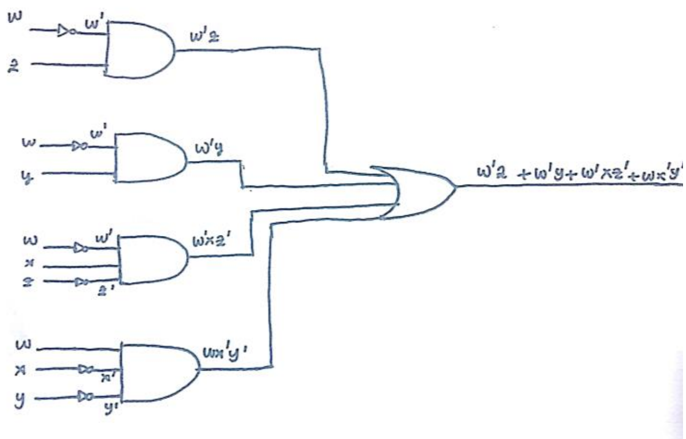

Figure 6 Logic Gates of Whistle Controlled Keychain Whole Part

E. Example of Executing the Logic Gates

For example the Whistle Controlled Keychain recognized a voice in frequency of 1000 Hz. As we know, this frequency should be recognized as whistle. And the keychain should ring the alarm. The voice will be converted to digital quantifier, and as in our modelling, the digital value of the frequency is 0001. The digital value of *w* is 0, *x* is 0, *y* is 0, and *z* is 1.

Now we go through the logic gates with the input. In the first AND gates, we know that *w'* valued 1, and so *w'z* valued 1. In the second AND gates, we know that *w'* valued 1 and so *w'y* values 0. In the third AND gates, we know that *w'* valued 1, *z'* valued 0, and so *w'xz'* valued 0. In the last AND gates, we know that *x'* valued 1, *y'* valued 1, and so *wx'y'* valued 0.

After the AND gates, we got the input 1, 0, 0, 0. Meeting the OR gates, we can determined that the output is 1, because there is at least one 1's. And so the output of the input 0001 is 1 which means the alarm of the Keychain ring.

Another example is the rejected or the output 0 one. For example the Whistle Controlled Keychain recognize a voice of frequency 6000 Hz. Relating to our range, the digital frequency of 6000 Hz is 1011. The digital value of *w* is 1, *x* is 0, *y* is 1, and *z* is 1.

Now we go through the logic gates with the input. In the first AND gates, we know that *w'* valued 0, and so *w'z* valued 0. In the second AND gates, we know that *w'* valued 0 and so *w'y* values 0. In the third AND gates, we know that *w'* valued 1, *z'* valued 0, and so *w'xz'* valued 0. In the last AND gates, we know that *x'* valued 1, *y'* valued 0, and so *wx'y'* valued 0.

After the AND gates, we got the input 0, 0, 0, 0. Meeting the OR gates, we can determined that the output is 0, because there are no 1's. And so the output of the input 1011 is 0 which means the alarm of the Keychain didn't ring.

This modelling help us to understand the inner circuit of the Whistle Controlled Keychain pretty well.

V. Conclusion

In every electrical devices, there are circuit that formed by using the theory of Logic Gates. We can make a model of any devices with any kind of input (analog or digital) by using this theory. This theory help us to understand the way our devices work and design our electrical devices circuit.

To model the logic gates, we have to understand how the devices work, and so we can determined the truth table of the way of the device work. And then we can construct the Karnaugh Map from the truth table and we can get the simplest Boolean function of the Karnaugh Map, and we can draw the model of the Logic Gates.

VI. Acknowledgment

The author give her best gratitude to God for giving the chance and the idea to write this paper. And towards Mrs. Harlili as the most loving lecturer with strong dedication she gives in lectures the author get.

References

[1] Samuel C. Lee, *Digital Circuits And Logic Design*. New Delhi: Prentice Hall, 1981, ch. 1-2.

[2] Kenneth H. Rosen, *Discrete Math and Its Applications 7th Edition*. New York: McGraw-Hill Companies, 2012, ch. 12.

[3] Mikael Nilsson, Josef Strom Bart ¨ un˚ ek, J ˇorgen Nordberg, and Ingvar Claesson, Human Whistle Detection and Frequency Estimation in https://www.diva-portal.org/smash/get/diva2:836227/FULLTEXT01.pdf accessed December 4th, 2017.

[4] Figure Whistle Controlled Keychain was taken from https://www.amazon.com/Finder-Locator-Keychain-Whistle-Control/dp/B00NBTR53W accessed December 4th, 2017.

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, 3 Desember 2017

Deborah Aprilia Josephine - 13516152