## BCD to 7-Segment Decoder

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Abstract: This paper mainly studies the effect of binary algorithm and truth table on digital circuit, and analyzes its logic circuit (from 0 to 9 ). Binary algorithm is used to make its truth table, draw the circuit diagram and make its PCB template.
Keywords: Circuit Design; Truth Table; 7-Segment Display; K-map; Experiment

## 1. Introduction of this experiment

With the development of science and technology, the application field of diode is more and more extensive. The main advantages of diode are small size, low price, various colors, long service life, easy access, and easy interface with various other digital circuits and electronic components. Due to their small chip size, so many of them can be connected together in a compact and small
package to produce, which is commonly referred to as a 7 -segment display. Therefore, we will study the working principles of decimal numbers displayed in the 7-terminal decoder.

For the first step, we should convert the 4-bit code into 7-bit control signal, so we drew the truth table which is needed for the experiment (we made A the highest position).

Table 1

| A | B | C | D | a | b | c | d | e | f | g |
| ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: |
| 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 |
| 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 |
| 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 |
| 0 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 |
| 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 |

[^0]The ten lines of the capital letter A, B, C, D in the truth table represent Arabic numbers 0 to 9 respectively. The lowercase letters $\mathrm{a}, \mathrm{b}, \mathrm{c}, \mathrm{d}, \mathrm{e}, \mathrm{f}$ and g respectively represent 7 LEDs that can emit light. When A is 1 , it means A is in an open state. When A is 0 , it means A is closed. When the number below the lowercase letter is 1 , the corresponding diode receives the signal, and the diode lights up at this time. When its corresponding number is 0 , the diode does not receive the signal, and the diode turns off the lamp. The lowercase letters $a, b, c, d$,
$\mathrm{e}, \mathrm{f}$ and g represent seven diodes respectively, and the corresponding mode is shown in the following Figure 1. Different codes can make different diodes light up to form the numbers 0 to 9 , thus completing the experiment ${ }^{[1]}$.

We used K-map to simplify the code, and the most simplified formula is the connection mode of the circuit.


Figure 1

## 2. Circuit design

The following formulas are the specific operation results: ("*" is AND; "+" is OR )

Notice that: $(\mathrm{A}+\mathrm{C})!=\mathrm{A}!* \mathrm{C}!$; $(\mathrm{AC})!=\mathrm{A}!+\mathrm{C}!$

$$
\begin{aligned}
& =[(\mathrm{A}+\mathrm{C}+\mathrm{BD}+\mathrm{B}!\mathrm{D}!)!]! \\
& =[\mathrm{A}!* \mathrm{C}!*(\mathrm{BD}+\mathrm{B}!\mathrm{D}!)!]! \\
& =[\mathrm{A}!* \mathrm{C}!*(\mathrm{BD})!*(\mathrm{~B}!\mathrm{D}!)!]!
\end{aligned}
$$

$$
\mathrm{a}=\mathrm{A}+\mathrm{C}+\mathrm{BD}+\mathrm{B}!\mathrm{D}!
$$

## This is my circuit design:

And this circuit can test the state of "a" when we enter any number from zero to nine. If we put 1 into this circuit A is $0, \mathrm{~B}$ is $0, \mathrm{C}$ is 0 and D is 1 . It means $\mathrm{A}, \mathrm{B}$ and

C are off but D is open. At this time, diode " a " isn't bright. When we put 2 in the circuit, it means A is 0 , B is $0, \mathrm{C}$ is 1 and D is 0 . At this time, diode of " a " is bright.


Figure 2


Figure 3

$$
\begin{aligned}
& =[\mathrm{A}!*(\mathrm{~A}!\mathrm{B}!+\mathrm{C}!\mathrm{D}!+\mathrm{CD})!]! \\
& =[\mathrm{A}!*(\mathrm{~A}!\mathrm{B}!)!*(\mathrm{C}!\mathrm{D}!+\mathrm{CD})!]! \\
& =[\mathrm{A}!*(\mathrm{~A}!\mathrm{B}!)!*(\mathrm{C}!\mathrm{D}!)!*(\mathrm{CD})!]!
\end{aligned}
$$

| CD <br> $A B$ | 00 | 01 | 11 | 10 |
| :--- | :--- | :--- | :--- | :--- |
| 00 | 1 | 1 | 1 | 1 |
| 01 | 1 | 0 | 1 | 0 |
| 11 | $x$ | $x$ | $x$ | $x$ |
| 10 | 1 | 1 | $x$ | $x$ |

## This is my circuit design:

When we open B and C , it means we enter the number " 6 " into the circuit. At this time, diode " $b$ " is
not bright. When we open $B$, it means we enter the number " 4 ". At this time, diode " $b$ " is bright.


Figure 5

$$
\begin{aligned}
& =[(\mathrm{B}+\mathrm{A}+\mathrm{D}+\mathrm{C}!)!]! \\
& =(\mathrm{B}!* \mathrm{~A}!* \mathrm{D}!* \mathrm{C})!
\end{aligned}
$$

| CD <br> $A B$ | 00 | 01 | 11 | 10 |
| :--- | :--- | :--- | :--- | :--- |
| 00 | 1 | 1 | 1 | 0 |
| 01 | 1 | 1 | 1 | 1 |
| 11 | $x$ | $x$ | $x$ | $x$ |
| 10 | 1 | 1 | $x$ | $x$ |

This is my circuit design:

When I enter number 3, it shows:


Figure 6
When I enter number 2, it shows:


Figure 7
Notice that NAND=NOT+AND
Then is "d":

$$
\begin{aligned}
& \mathrm{d}=\mathrm{A}+\mathrm{CD}!+\mathrm{B}!\mathrm{D}!+\mathrm{C}!\mathrm{DB}+\mathrm{B}!\mathrm{C} \\
& =[(\mathrm{A}+\mathrm{CD}!+\mathrm{B}!\mathrm{D}!+\mathrm{C}!\mathrm{DB}+\mathrm{B}!\mathrm{C})!]! \\
& =[\mathrm{A}!*(\mathrm{CD}!+\mathrm{B}!\mathrm{D}!+\mathrm{C}!\mathrm{DB}+\mathrm{B}!\mathrm{C})!]! \\
& =[\mathrm{A}!*(\mathrm{CD}!)!*(\mathrm{~B}!\mathrm{D}!+\mathrm{C}!\mathrm{DB}+\mathrm{B}!\mathrm{C})!]! \\
& =\left[\mathrm{A}!*(\mathrm{CD}!)!*(\mathrm{~B}!\mathrm{D}!)^{*}(\mathrm{C}!\mathrm{DB}+\mathrm{B}!\mathrm{C})!\right]! \\
& =\left[\mathrm{A}!*(\mathrm{CD}!)!*(\mathrm{~B}!\mathrm{D}!)^{*}(\mathrm{C}!\mathrm{DB})!*(\mathrm{~B}!\mathrm{C})!\right]!
\end{aligned}
$$

| CD | 00 | 01 | 11 | 10 |
| :--- | :--- | :--- | :--- | :--- |
| 00 | 1 | 0 | 1 | 1 |
| 01 | 0 | 1 | 0 | 1 |
| 11 | $x$ | $x$ | $x$ | $x$ |
| 10 | 1 | 1 | $x$ | $x$ |

This is my circuit design:

When I enter number 7:


Figure 8
When I enter number 3:


Figure 9

Next is "e":
e $=B!D!+C D!+A B+A C$
$=[(\mathrm{B}!\mathrm{D}!+\mathrm{CD}!+\mathrm{AB}+\mathrm{AC})!]!$
$=[(B!\mathrm{D}!)!*(\mathrm{CD}!+\mathrm{AB}+\mathrm{AC})!]!$
$=[(\mathrm{B}!\mathrm{D}!)!*(\mathrm{CD}!)!*(\mathrm{AB}+\mathrm{AC})!]!$
$=[(\mathrm{B}!\mathrm{D}!)!*(\mathrm{CD}!)!*(\mathrm{AB})!*(\mathrm{AC})!]!$

| CD | 00 | 01 | 11 | 10 |
| :--- | :--- | :--- | :--- | :--- |
| 00 | 1 | 0 | 0 | 1 |
| 01 | 0 | 0 | 0 | 1 |
| 11 | $x$ | $x$ | $x$ | $x$ |
| 10 | 1 | 0 | $x$ | $x$ |

This is my circuit design:
e.pdsprj

When I enter number 4:


Figure 10
When I enter number 6:


Figure 11

Next is " f ":
$\mathrm{f}=\mathrm{A}+\mathrm{C}!\mathrm{D}!+\mathrm{BC}!+\mathrm{BD}$ !
$=[(\mathrm{A}+\mathrm{C}!\mathrm{D}!+\mathrm{BC}!+\mathrm{BD}!)!]!$
$=[\mathrm{A}!*(\mathrm{C}!\mathrm{D}!+\mathrm{BC}!+\mathrm{BD}!)!]!$
$\left.=[\mathrm{A}!*(\mathrm{C}!\mathrm{D}!))^{*}(\mathrm{BC}!+\mathrm{BD}!)!\right]!$
$=[\mathrm{A}!*(\mathrm{C}!\mathrm{D}!)!*(\mathrm{BC}!)!*(\mathrm{BD}!)!]!$

| CD | 00 | 01 | 11 | 10 |
| :--- | :--- | :--- | :--- | :--- |
| 00 | 1 | 0 | 0 | 0 |
| 01 | 1 | 1 | 0 | 1 |
| 11 | $x$ | $x$ | $x$ | $x$ |
| 10 | 1 | 1 | $x$ | $x$ |

This is my circuit design:
f.p d sprj

When I enter number 4:


Figure 12

When I enter number 1:


Figure 13
Final is "g":
$\mathrm{g}=\mathrm{A}+\mathrm{BC}!+\mathrm{B}!\mathrm{C}+\mathrm{CD}!$
$=[(\mathrm{A}+\mathrm{BC}!+\mathrm{B}!\mathrm{C}+\mathrm{CD}!)!]!$
$=[\mathrm{A}!*(\mathrm{BC}!+\mathrm{B}!\mathrm{C}+\mathrm{CD}!)!]!$
$=[\mathrm{A}!*(\mathrm{BC}!)!*(\mathrm{~B}!\mathrm{C}+\mathrm{CD}!)!]!$
$=[\mathrm{A}!*(\mathrm{BC}!)!*(\mathrm{~B}!\mathrm{C})!*(\mathrm{CD}!)!]!$

| CD <br> $A B$ | 00 | 01 | 11 | 10 |
| :--- | :--- | :--- | :--- | :--- |
| 00 | 0 | 0 | 1 | 1 |
| 01 | 1 | 1 | 0 | 1 |
| 11 | $x$ | $x$ | $x$ | $x$ |
| 10 | 1 | 1 | $x$ | $x$ |
|  |  |  |  |  |

This is my circuit design:
When I enter number 0:


Figure 14

When I enter number 8:


Figure 15

## 3. The package diagram of the total circuit

Now we have completed the operation of seven di-
odes. When these seven diodes are connected together, the connection of the overall circuit is completed. The specific connection method is shown in the following
Figure 16:
${ }^{8}$


Figure 16

After the previous simplification and connection circuit, we have obtained the connection mode of 7 diodes. We only need to connect these 7 circuits together to obtain a total circuit. This circuit consists of NAND gate, which can encode 4 -bit signal into 7 -bit 2 -signal and output it to the display. Note that the compilation in this experiment uses binary numbers, only 0 and 1 . When the input signal is 1 , the switch representing this position is turned on, and the input terminal will generate an electrical signal and transmit it to the compiling part. After compiling, the compiling result will be output to the corresponding diode, so that the seven diodes will be combined into a digital shape, and the experiment will be
completed ${ }^{[2]}$.
Let's give an example. When the switch A at the signal input is open, B is closed, C is closed, and D is open. The digital Europe that I choose is represented as 0110 in binary, which translates to 6 in decimal, that is, 6 should be A, C, D, E, F and G which are bright, and B is not bright on the diode. In other words, the 0110 I input will be transmitted to the 7 circuits I designed. These 7 circuits are equivalent to 7 decoders, which compile the instruction 0110. The result of A compilation is 1 , so A is bright. The compilation result of bar is 0 , so $b$ is not bright. The compilation results of $\mathrm{c}, \mathrm{d}, \mathrm{e}, \mathrm{f}$ and g are all 1 , so the diodes $\mathrm{c}, \mathrm{d}, \mathrm{e}, \mathrm{f}$ and g are all bright, and the
corresponding signals are finally output to 7 corresponding diodes, forming the number 6 .


Figure 17

Finally, because of the large volume of the main store road, we packaged the circuit, reducing the volume of the circuit and playing the role of protection ${ }^{[3]}$. Since the NAND gate in my software was not packaged, the
package diagrams of 74LS00 and 74LS20 were selected in the circuit diagrams I connected.


Figure 18
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