**Design of Quaternary ECL Q Gate**

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**Abstract**

A new explanation of quaternary Q gate expression in Post algebra is given in this paper by using transmission function theory proposed in [1] and the quaternary ECL Q gate circuit is designed. The SPICE2 simulation to this circuit has confirmed that it has desired logical function and is totally compatible with various quaternary ECL circuits proposed before.

1. **Introduction**

The multivalued ECL circuit is one of the multivalued logic circuits appeared in recent years. Because of its high operation speed it is prospective in research and indispensable in the multivalued logic circuits family. Various circuits have been proposed such as multivalued ECL inverter, encoder/decoder, full adder, shift register, mode four adder, mode three multiplier, mode four multiplier, 3-2 adder, 7-3 adder and total parallel mixed digital system multiplier[12-14]. The quaternary ECL Q gate which is totally compatible with the ECL circuits proposed in [2-8] is designed on transmission function theory by fully using the wired-operation function of ECL circuit.

Q gate is a kind of universal logic component with powerful function and can be used to construct a full algebra system by itself. In the Post algebra system, its expression is:

\[ Q(s_1, s_2, s_3, s_4, x) = (s_1 \land_0 x^0) \lor (s_2 \land_1 x^1) \lor (s_3 \land_2 x^2) \lor (s_4 \land_3 x^3) \]  

(1)

where \( s_1, s_2, s_3, s_4, x, Q \in \{0, 1, 2, 3\} \), and any \( n \)-variable function can be realized by the tree-like-serial-connection of Q gates. For example, any two-variable function

\[ f(x_1, x_2) = (c_0 \land_0 x_1^0 \land_0 x_2^0) \lor (c_1 \land_0 x_1^0 \land_1 x_2^1) \]

\[ \lor (c_2 \land_0 x_1^0 \land_2 x_2^2) \lor (c_3 \land_0 x_1^0 \land_3 x_2^3) \]

\[ \lor (c_4 \land_1 x_1^1 \land_0 x_2^0) \lor (c_5 \land_1 x_1^1 \land_1 x_2^1) \]

\[ \lor (c_6 \land_1 x_1^1 \land_2 x_2^2) \lor (c_7 \land_1 x_1^1 \land_3 x_2^3) \]

Fig. 1. The realization of two variables function \( f(x, y) \).

Fig. 2. Quaternary total threshold comparison circuit.

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\[ (c_9 \land X_1 \land 0 \land X_2 ) \lor (c_{10} \land 2 \land X_1 \land 2 \land X_2 ) \lor (c_{11} \land 2 \land X_1 \land 3 \land X_2 ) \]
\[ (c_{12} \land 3 \land X_1 \land 0 \land X_2 ) \lor (c_{13} \land 3 \land X_1 \land 1 \land X_2 ) \]
\[ (c_{14} \land 3 \land X_1 \land 2 \land X_2 ) \lor (c_{15} \land 3 \land X_1 \land 3 \land X_2 ) \]

\[ = Q_1 (Q_2 (c_0, c_1, c_2, c_3, c_4), Q_3 (c_4, c_5, c_6, c_7, c_8), Q_4 (c_8, c_9, c_{10}, c_{11}, c_{12}), Q_5 (c_{12}, c_{13}, c_{14}, c_{15}, c_{16}, c_{17}, c_{18}), c_{19}) \]  

(2)

can be realized by the tree-like-serial-connection of Q gate shown in Fig. 1.

2. Transmission Function Theory

The main idea of the transmission function theory is as follows.

In logic algebra, suppose that \( x_1, x_2, \ldots, x_n \) are logic variables and they take two logic values, T (True) and F (False). These two logic values only have inverted relationship, but no comparable relationship in quantity. They describe two inverse states, for example on or off, of a switch. Three basic operations among logic variables are AND (\( \cdot \)), OR (\( + \)) and NOT (\( \sim \)).

In the quaternary Post algebra, the quaternary variables \( x_1, x_2, x_3, \ldots, x_n \) take the values of 3, 2, 1, 0, and form a total ordering relationship: \( 3 > 2 > 1 > 0 \). The basic operations among them are minimum (\( \land \)), maximum (\( \lor \)), literal operations (\( 'x' \)) and complement (\( \sim \)).

If we introduce a detection threshold \( t \), \( t \in \{ 2.5, 1.5, 0.5 \} \), the total ordering relationship is \( 3 > 2.5 > 2 > 1.5 > 1 > 0.5 > 0 \). Physically, the total ordering relationship may describe the relationship of four kinds of quaternary signals and three kinds of circuit detection levels in quantity. Besides, in order to describe the state that the output is opened and insulated with quaternary variable inputs physically, we introduce empty \( \Phi \).

To construct the relation between logic and quaternary variables, we define the following threshold comparison operations.

High-threshold comparison operation

\[ t_x = \begin{cases} 
T, & \text{if } x > t \; \text{ (3) } \\
F, & \text{if } x < t.
\end{cases} \]

Low-threshold comparison operation

\[ x^t = \begin{cases} 
T, & \text{if } x < t \; \text{ (4) } \\
F, & \text{if } x > t.
\end{cases} \]

This is the comparison between the input quaternary signal and detection threshold, and the result is logic variable, which represents the component state, on or off. The following is the logic relationship in various threshold-comparison operation for the same quaternary variable.

1. NOT relationship

\[ \begin{cases} 
\tilde{x}^t = ^t x \\
\tilde{\sim} x = x^t
\end{cases} \]

(5)

2. AND relationship

\[ \begin{cases} 
X^t \land X^t = x_{\min} (t_1, t_2) \\
\max (t_1, t_2, x)
\end{cases} \]

(6)

3. OR relationship

\[ \begin{cases} 
X^t \lor X^t = x_{\max} (t_1, t_2) \\
\min (t_1, t_2, x)
\end{cases} \]

(7)