2001년도 대한전기학회/대한전자공학회 시스템및제어분야 합동 추계학술대회 논문집 (2001.11.24)

74LS381 ALU의 분석 및 등가회로의 설계

이 재 석*, 정 태 상**
*중앙대학교 제어계측학과, **중앙대학교 전자전기공학부

Analysis of the 74LS381 ALU and Design of an Equivalent Circuit to the 74L

Jae-Seok Lee*, Tae-Sang Chung**
*Dept. of Control and Instrumentation Eng., **School of Electrical and Electronics Eng., Chung-A

Abstract - This paper analyzes the 74LS381 ALU and designs its equivalent circuit. The 74LS381 ALU is arithmetic logic units(ALUs)/function generators that perform eight binary arithmetic/logic operations on two 4-bit words. However there are only little information to understand and design this circuit. Thus, we not only analyzed it but also designed an equivalent circuit to the 74LS381.

1. 서 론

74LS381은 그림 1에서 볼 수 있는 것과 같이 2개의 -bit 입력을 받아 selector 3-bit에 의해 8가지의 2진 산술/논리 연산을 수행하는 회로이다.

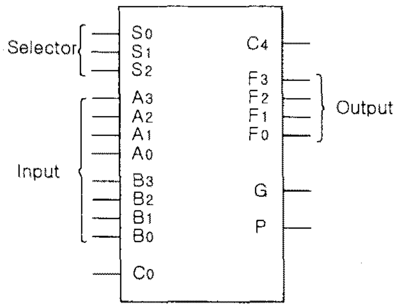


그림 1

또한 표 1은 74LS381의 function table이다.

S_2	S_1	S_0	Function		
0	0	0	CLEAR	0	
0	0	1	B−A	$\overline{A_i \oplus B_i} \oplus \bar{c_i}$	Arithmetic
0	1	0	A−B	$\overline{A_i \oplus B_i} \oplus \bar{c_i}$	
0	1	1	A+B	$A_i \oplus B_i \oplus c_i$	
1	0	0	A⊕B	$A_i \oplus B_i$	Logic
1	0	1	A∨B	$A_i \vee B_i$	
1	1	0	A·B	$A_i \cdot B_i$	
1	1	1	PRESET	1	

표 1

2. 본 론

2.1 Logic Expressions for Arithmetic Ope

등가의(equivalent) 74LS381을 설계하기 위한 논리식을 구하면 다음과 같다. s_i 는 1-bit 전가산기(full adder) / 전감산기(full subtracter)의 sum bit, c_{i+1} 는 carry-out / borrow-out bit 이다.

2.1.1 Addition : A + B

$$s_i = A_i \bar{B_i} \bar{c_i} + \bar{A_i} B_i \bar{c_i} + \bar{A_i} \bar{B_i} c_i + A_i B_i c_i$$
$$= A_i \oplus B_i \oplus c_i = (A_i \oplus B_i) \oplus c_i = p_i \oplus cc_i$$

$$c_{i+1} = \bar{A_i} B_i c_i + A_i \bar{B_i} c_i + A_i B_i \bar{c_i} + A_i B_i c_i$$
$$= A_i B_i + (\bar{A_i} B_i + A_i \bar{B_i}) c_i$$
$$= A_i B_i + (A_i \oplus B_i) c_i$$
$$= g_i + p_i c_i = g_i + p_i cc_i$$

$$\begin{cases} g_i = A_i \cdot B_i = (A_i + B_i)(A_i + \bar{B_i})(\bar{A_i} + B_i) \\ p_i = A_i \oplus B_i = (A_i + B_i)(\bar{A_i} + \bar{B_i}) \\ cc_i = c_i \end{cases}$$

$$c_1 = g_0 + p_0 c_0$$
$$c_2 = g_1 + p_1 c_1 = g_1 + p_1 (g_0 + p_0 c_0)$$
$$= g_1 + p_1 g_0 + p_1 p_0 c_0$$
$$c_3 = g_2 + p_2 c_2$$
$$= g_2 + p_2 g_1 + p_2 p_1 g_0 + p_2 p_1 p_0 c_0$$
$$c_4 = g_3 + p_3 c_3$$
$$= g_3 + p_3 g_2 + p_3 p_2 g_1 + p_3 p_2 p_1 g_0 + p_3 p_2 p_1 p_0 c_0$$

2.1.2 Subtraction : A - B

$$s_i = \bar{A_i} \bar{B_i} c_i + \bar{A_i} B_i \bar{c_i} + A_i \bar{B_i} \bar{c_i} + A_i B_i c_i$$
$$= A_i \oplus B_i \oplus c_i = \overline{(A_i \oplus B_i)} \oplus \bar{c_i} = p_i \oplus cc_i$$

$$\overline{c}_{i+1} = \overline{A}_i\,\overline{B}_i\,\overline{c}_i + A_i\,\overline{B}_i\,\overline{c}_i + A_i\,\overline{B}_i c_i + A_i B_i\,\overline{c}_i$$
$$= A_i\,\overline{B}_i + (\,\overline{A}_i\,\overline{B}_i + A_i B_i\,)\,\overline{c}_i$$
$$= A_i\,\overline{B}_i + \overline{A_i \oplus B_i}\;\overline{c}_i$$
$$= g_i + p_i\,\overline{c}_i = g_i + p_i\,cc_i$$

$$\begin{cases} g_i = A_i \cdot \overline{B}_i = (A_i+B_i)(A_i+\overline{B}_i)(\overline{A}_i+\overline{B}_i) \\ p_i = \overline{A_i \oplus B_i} = (A_i+\overline{B}_i)(\overline{A}_i+B_i) \\ cc_i = \overline{c}_i \end{cases}$$

$$\begin{cases} \overline{c}_1 = g_0 + p_0\,\overline{c}_0 \\ \overline{c}_2 = g_1 + p_1 g_0 + p_1 p_0\,\overline{c}_0 \\ \overline{c}_3 = g_2 + p_2 g_1 + p_2 p_1 g_0 + p_2 p_1 p_0\,\overline{c}_0 \\ \overline{c}_4 = g_3 + p_3 g_2 + p_3 p_2 g_1 \\ \qquad + p_3 p_2 p_1 g_0 + p_3 p_2 p_1 p_0\,\overline{c}_0 \end{cases}$$

2.1.3 Subtraction : B - A

$$s_i = \overline{A}_i\,\overline{B}_i c_i + \overline{A}_i B_i\,\overline{c}_i + A_i\,\overline{B}_i\,\overline{c}_i + A_i B_i c_i$$
$$= A_i \oplus B_i \oplus c_i = \overline{(A_i \oplus B_i)} \oplus \overline{c}_i = p_i \oplus cc_i$$

$$\overline{c}_{i+1} = \overline{A}_i\,\overline{B}_i\,\overline{c}_i + \overline{A}_i B_i\,\overline{c}_i + \overline{A}_i B_i c_i + A_i B_i\,\overline{c}_i$$
$$= \overline{A}_i B_i + (\,\overline{A}_i\,\overline{B}_i + A_i B_i\,)\,\overline{c}_i$$
$$= \overline{A}_i B_i + \overline{A_i \oplus B_i}\;\overline{c}_i$$
$$= g_i + p_i\,\overline{c}_i = g_i + p_i\,cc_i$$

$$\begin{cases} g_i = \overline{A}_i \cdot B_i = (A_i+B_i)(\overline{A}_i+B_i)(\overline{A}_i+\overline{B}_i) \\ p_i = \overline{A_i \oplus B_i} = (A_i+\overline{B}_i)(\overline{A}_i+B_i) \\ cc_i = \overline{c}_i \end{cases}$$

$$\begin{cases} \overline{c}_1 = g_0 + p_0\,\overline{c}_0 \\ \overline{c}_2 = g_1 + p_1 g_0 + p_1 p_0\,\overline{c}_0 \\ \overline{c}_3 = g_2 + p_2 g_1 + p_2 p_1 g_0 + p_2 p_1 p_0\,\overline{c}_0 \\ \overline{c}_4 = g_3 + p_3 g_2 + p_3 p_2 g_1 \\ \qquad + p_3 p_2 p_1 g_0 + p_3 p_2 p_1 p_0\,\overline{c}_0 \end{cases}$$

2.2 Propagator Control

$$p_i = (M_0 + A_i + B_i)(M_1 + A_i + \overline{B}_i)$$
$$(M_2 + \overline{A}_i + B_i)(M_3 + \overline{A}_i + \overline{B}_i)$$

S_2	S_1	S_0	M_0	M_1	M_2	M_3	p_i	Function
0	0	0	0	0	0	0	0	CLEAR
0	0	1	1	0	0	1	$\overline{A_i \oplus B_i}$	B−A
0	1	0	1	0	0	1	$\overline{A_i \oplus B_i}$	A−B
0	1	1	0	1	1	0	$A_i \oplus B_i$	A+B
1	0	0	0	1	1	0	$A_i \oplus B_i$	A⊕B
1	0	1	0	1	1	1	$A_i \vee B_i$	A∨B
1	1	0	0	0	0	1	$A_i \cdot B_i$	A·B
1	1	1	1	1	1	1	1	PRESET

M_0, M_1, M_2, M_3 을 Karnaugh map을 이용해 구하면 다음과 같다.

$$M_0 = \overline{S_2}\,\overline{S_1}\,S_0 + S_2 S_1 S_0 + \overline{S_2}\,S_1\,\overline{S_0}$$
$$M_1 = S_2\,\overline{S_1} + S_1 S_0$$
$$M_2 = S_2\,\overline{S_1} + S_1 S_0 = M_1$$
$$M_3 = \overline{S_1}\,S_0 + S_2 S_0 + S_1\,\overline{S_0}$$

2.3 Generate Control for the Case of Borrow Input

$$g_i = (N_0 + A_i + B_i)(N_1 + A_i + \overline{B}_i)$$
$$(N_2 + \overline{A}_i + B_i)(N_3 + \overline{A}_i + \overline{B}_i)$$

S_2	S_1	S_0	N_0	N_1	N_2	N_3	g_i	Function
0	0	0	×	×	×	×	×	CLEAR
0	0	1	0	1	0	0	$\overline{A_i} B_i$	B−A
0	1	0	0	0	1	0	$A_i \overline{B_i}$	A−B
0	1	1	0	0	0	1	$A_i B_i$	A+B
1	0	0	×	×	×	×	×	A⊕B
1	0	1	×	×	×	×	×	A∨B
1	1	0	×	×	×	×	×	A·B
1	1	1	×	×	×	×	×	PRESET

$N_0 = 0$ $\qquad N_1 = \overline{S_1}$

$N_2 = \overline{S_0}$ $\qquad N_3 = S_1 S_0$

2.4 Carry Control for the Case of Inverted Borrow Input ($\overline{c_0}$: inverted incoming carry (borrow) for subtraction)

S_2 S_1 S_0	carry_in x	cc_i	p_i	$F_i = p_i \oplus cc_i$
0 0 0	-	0	0	$0 \oplus 0 = 0$
0 0 1	$\overline{c_0}$	$\overline{c_i}$	$\overline{A_i \oplus B_i}$	$\overline{A_i \oplus B_i} \oplus \overline{c_i} = A_i \oplus B_i \oplus c_i$
0 1 0	$\overline{c_0}$	$\overline{c_i}$	$\overline{A_i \oplus B_i}$	$\overline{A_i \oplus B_i} \oplus \overline{c_i} = A_i \oplus B_i \oplus c_i$
0 1 1	c_0	c_i	$A_i \oplus B_i$	$A_i \oplus B_i \oplus c_i$
1 0 0	-	0	$A_i \oplus B_i$	$A_i \oplus B_i$
1 0 1	-	0	$A_i \vee B_i$	$A_i \vee B_i$
1 1 0	-	0	$A_i \cdot B_i$	$A_i \cdot B_i$
1 1 1	-	0	1	$1 \oplus 0 = 1$

그러므로,

$\overline{S_2}\,\overline{S_1} S_0$: B−A 일 때,

$p_i = \overline{A_i \oplus B_i}$, $g_i = \overline{A_i} B_i$, $x_0 = \overline{c_0}$ 이고,

$\overline{S_2} S_1 \overline{S_0}$: A−B 일 때,

$p_i = \overline{A_i \oplus B_i}$, $g_i = A_i \overline{B_i}$, $x_0 = \overline{c_0}$ 이고.

$x_i = \overline{c_i}$ 라고 하면 다음과 같다.

$$\begin{cases} x_1 = \overline{c_1} = g_0 + p_0 \overline{c_0} = g_0 + p_0 x_0 \\ x_2 = \overline{c_2} = g_1 + p_1 \overline{c_1} = g_1 + p_1 g_0 + p_1 p_0 x_0 \\ x_3 = \overline{c_3} = g_2 + p_2 g_1 + p_2 p_1 g_0 + p_2 p_1 p_0 x_0 \\ x_4 = \overline{c_4} = g_3 + p_3 g_2 + p_3 p_2 g_1 \\ \qquad + p_3 p_2 p_1 g_0 + p_3 p_2 p_1 p_0 x_0 \end{cases}$$

마찬가지로,

$\overline{S_2} S_1 S_0$: A+B 일 때,

$p_i = A_i \oplus B_i$, $g_i = A_i B_i$, $x_0 = c_0$ 이고,

$x_i = c_i$ 라고 하면 다음과 같다.

$$\begin{cases} x_1 = c_1 = g_0 + p_0 c_0 = g_0 + p_0 x_0 \\ x_2 = c_2 = g_1 + p_1 c_1 = g_1 + p_1 g_0 + p_1 p_0 x_0 \\ x_3 = c_3 = g_2 + p_2 g_1 + p_2 p_1 g_0 + p_2 p_1 p_0 x_0 \\ x_4 = c_4 = g_3 + p_3 g_2 + p_3 p_2 g_1 \\ \qquad + p_3 p_2 p_1 g_0 + p_3 p_2 p_1 p_0 x_0 \end{cases}$$

따라서,

$$cc_i = \overline{S_2}\,\overline{S_1} S_0 \overline{c_i} + \overline{S_2} S_1 \overline{S_0}\,\overline{c_i} + \overline{S_2} S_1 S_0 c_i$$

$$= (\overline{S_2}\,\overline{S_1} S_0 + \overline{S_2} S_1 \overline{S_0} + \overline{S_2} S_1 S_0) x_i$$

$$= (\overline{S_2} S_0 + \overline{S_2} S_1) x_i$$

로 표현할 수 있으며, 4-bit block에 들어오는 carry-in(borrow-in)이 덧셈에서는 $x_0 = c_0$, 뺄셈에서는 $x_0 = \overline{c_0}$ 이면, 4-bit block의 carry-out(borrow-out)은 덧셈일 때는 c_4, 뺄셈일 때는 $\overline{c_4}$가 된다.

2.5 Generate Control for the Case of Non Borrow Input

non-inverted borrow input의 경우를 살펴보면 다음과 같다.

$$g_i = (N_0 + A_i + B_i)(N_1 + A_i + \overline{B_i})$$
$$(N_2 + \overline{A_i} + B_i)(N_3 + \overline{A_i} + \overline{B_i})$$

S_2 S_1 S_0	N_0 N_1 N_2 N_3	g_i	Function
0 0 0	× × × ×	×	CLEAR
0 0 1	0 1 0 0	$A_i \overline{B_i}$	B−A
0 1 0	0 0 1 0	$\overline{A_i} B_i$	A−B
0 1 1	0 0 0 1	$A_i B_i$	A+B
1 0 0	× × × ×	×	A⊕B
1 0 1	× × × ×	×	A∨B
1 1 0	× × × ×	×	A·B
1 1 1	× × × ×	×	PRESET

$N_0 = 0$ $\qquad$ $N_1 = \overline{S_0}$

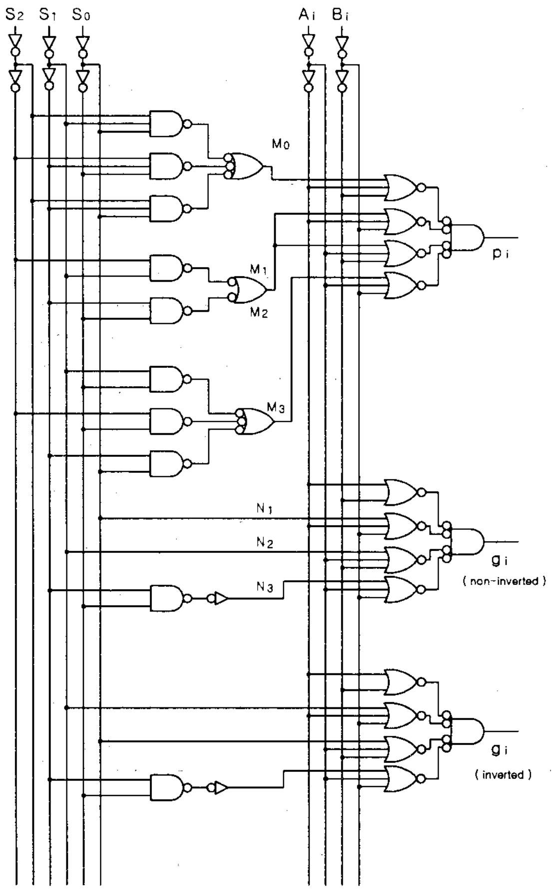
$N_2 = \overline{S_1}$ $\qquad$ $N_3 = S_1 S_0$

2.6 Carry Control for the Case of Non-Borrow Input (c_0 : non-inverted incomi (borrow) for subtraction)

S_2 S_1 S_0	carry_in x	cc_i	p_i	$F_i = p_i \oplus cc_i$
0 0 0	-	0	0	$0 \oplus 0 = 0$
0 0 1	c_0	c_i	$\overline{A_i \oplus B_i}$	$\overline{A_i \oplus B_i} \oplus c_i$
0 1 0	c_0	c_i	$\overline{A_i \oplus B_i}$	$\overline{A_i \oplus B_i} \oplus c_i$
0 1 1	$\overline{c_0}$	$\overline{c_i}$	$A_i \oplus B_i$	$A_i \oplus B_i \oplus \overline{c_i} = \overline{A_i \oplus B_i \oplus c_i}$
1 0 0	-	0	$A_i \oplus B_i$	$A_i \oplus B_i$
1 0 1	-	0	$A_i \vee B_i$	$A_i \vee B_i$
1 1 0	-	0	$A_i \cdot B_i$	$A_i \cdot B_i$
1 1 1	-	0	1	$1 \oplus 0 = 1$

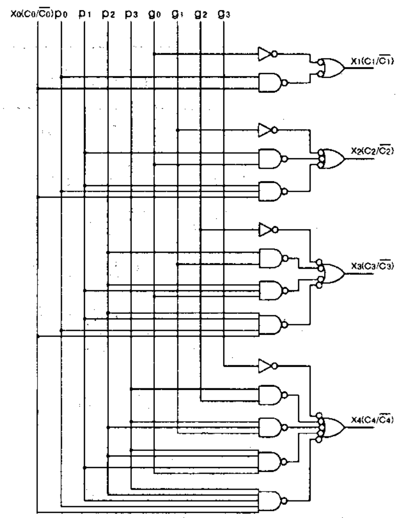
2.7 Circuits for the Propagators and Generators

2.2에서 구한 propagator control p_i와 2.3, 2.5에 한 generator control g_i를 위한 circuit은 다음과 같다

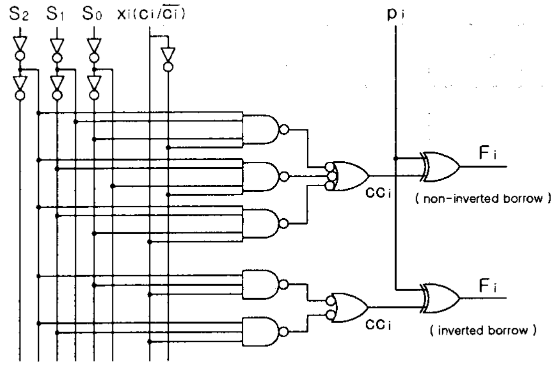


2.8 Look-Ahead Carry Circuits

2.4에서 구한 look-ahead carry x_1, x_2, x_3, x_4을 위한 circuit은 다음과 같다.



2.9 Carry Control and Function Output Circuits



2.4에서 구한 것처럼 cc_i는 다음과 같고,

$$cc_i = (\overline{S}_2 S_0 + \overline{S}_2 S_1) x_i = \overline{S}_2 S_0 x_i + \overline{S}_2 S_1 x_i$$

최종 $F_i = p_i \oplus cc_i$ 이다.

3. 결 론

이 논문에서는 74LS381을 새롭게 해석하여 등가의 새로운 회로를 설계하였다. 이 논문에서 설계한 등가회로는 내부 논리식을 직관적으로 보여주므로 이해하기가 쉽고 다른 회로의 설계에 쉽게 이용할 수 있는 장점이 있다.

[참 고 문 헌]

[1] "Data sheet of 74LS381 ALU", Texas Instruments.
[2] John F. Wakerly, "Digital Design: Principle & Practices", Prentice-Hall International Editions, pp.439-440, 2000