4-bit Arithmetic Logic Unit

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April 24, 2018

1 Designing an ALU

Truth Table : Arithmetic Operations

cs_2	cs_1	cs_0	Arithmetic Operation	x_i	y_i
0	0	0	Transfer A	A_i	0
0	0	1	Increment A	A_i	0
0	1	0	Subtraction with Borrow	A_i	$\overline{B_i}$
0	1	1	Subtraction	A_i	$\overline{B_i}$

Subtract with borrow explanation:
$$= A - B - 1$$
$$= (A + \overline{B} + 1) - 1$$
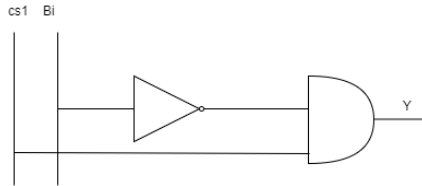$$= A + \overline{B}$$

So, $Y = CS_1\overline{B_i}$

Figure 1: $Y = CS_1\overline{B_i}$

2 Design of Arithmetic Logic Unit

Truth Table : Logical Operations

cs_2	cs_1	cs_0	x_i	y_i	$f_i = X_i \oplus Y_i$	Operation
1	0	0	A_i	0	A_i	OR
1	0	1	A_i	0	$A_i + 1$	OR
1	1	0	A_i	B_i	$A_i - B_i - 1$	AND
1	1	1	A_i	B_i	$A_i - B_i$	AND

Explanation:

we can't modify Y_i because that would change the arithmetic operations and neither can omit A_i in any input, So we change X_i,

Let,

$\qquad X_i = A_i + K_i$

$F_i = X_i \oplus Y_i$

$F_i = X_i \oplus 0$

$F_i = X_i$

$F_i = A_i + K_i$

But the desired output is $A_i + B_i$. So putting $K_i = B_i$

$F_i = X_i \oplus Y_i$

$F_i = (A_i \oplus K_i) \oplus \overline{B_i}$

$F_i = (A_i \oplus K_i)B_i + \overline{(A_i \oplus K_i)}.\overline{B_i}$

$F_i = A_iB_i + K_iB_i + \overline{A_i}.\overline{K_i}.\overline{B_i}$

Here our desired operation is A_iB_i

So, $A_iB_i + K_iB_i + \overline{A_i}.\overline{K_i}.\overline{B_i} = A_iB_i$

if $K_i = \overline{B_i}$ Then $F_i = A_iB_i$

So we need $K_i = B_i$ when we will do OR operation and $K_i = \overline{B_i}$ for AND operation.

cs_2	cs_1	cs_0	B
1	0	0	B_i
1	0	1	B_i
1	1	0	$\overline{B_i}$
1	1	1	$\overline{B_i}$

So from the truth table we can derive,

$X_i = A_i + CS_2(\overline{CS_1}.B(CS_0 + \overline{CS_0} + CS_1.\overline{B_i}))$

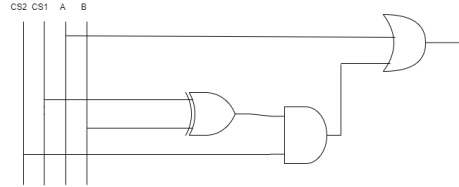Figure 2: $X_i = A_i + CS_2(\overline{CS_1}.B(CS_0 + \overline{CS_0} + CS_1.\overline{B_i}))$

3

3 Final Diagram

$X_i = A_i + CS_2(\overline{CS_1}.B(CS_0 + \overline{CS_0} + CS_1.\overline{B_i}))$

$Y = CS_1\overline{B_i}$

$C_{out} = \overline{CS_2}.C_i$