4-bit Arithmetic Logic Unit

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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, $Y = CS_1\overline{B_i}$

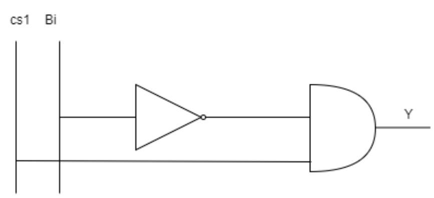

Figure 1: $Y = CS_1\overline{B_i}$

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,

$X_i = A_i + K_i$
$F_i = X_i \oplus Y_i$
$F_i = X_i \oplus 0$
$F_i = X_i$
$F_i = A_i + K_i$

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

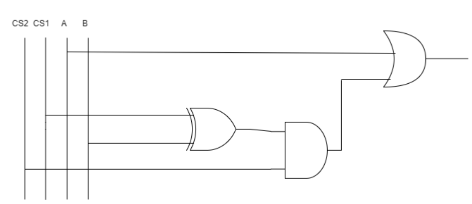

Figure 2: $X_i = A_i + CS_2(CS_1 \oplus B_i)$

3 Final Diagram

$X_i = A_i + CS_2(\overline{CS_1}.B(CS_0 + \overline{CS_0}) + CS_1.\overline{B_i}(CS_0 + \overline{CS_0})))$
$X_i = A_i + CS_2(CS_1 \oplus B_i)$
$Y = CS_1\overline{B_i}$
$C_{out} = \overline{CS_2}.C_i$