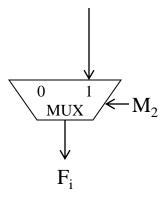
- Design a 4-bit ALU that implements the following set of operations with only the following components (assume 2's complement number representation, no need to implement overflow circuit)
  - 1-bit Full-Adders (FA)
  - 2-input AND/OR/XOR gates
  - Inverters
  - 2:1 MUX

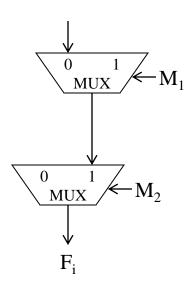
$M_2$	$\mathbf{M}_1$	$M_0$	Function Name	F =
0	0	0	Add	A + B
0	0	1	Subtract	A - B
0	1	0	Increment	A + 1
0	1	1	Decrement	A – 1
1	0	0	Multiply by 2	A * 2
1	0	1	Divide by 2	A/2
1	1	0	Bitwise-AND	A AND B
1	1	1	Bitwise-OR	A OR B

$M_2$	$M_1$	$M_0$	Function Name	F =
0	0	0	Add	A + B
0	0	1	Subtract	A - B
0	1	0	Increment	A + 1
0	1	1	Decrement	A – 1
1	0	0	Multiply by 2	A * 2
1	0	1	Divide by 2	A/2
1	1	0	Bitwise-AND	A AND B
1	1	1	Bitwise-OR	A OR B

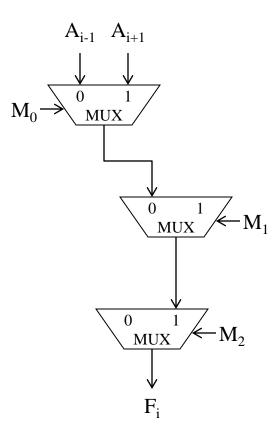
$M_2$	$M_1$	$M_0$	Function Name	F =
0	0	0	Add	A + B
0	0	1	Subtract	A - B
0	1	0	Increment	A + 1
0	1	1	Decrement	A – 1
1	0	0	Multiply by 2	A * 2
1	0	1	Divide by 2	A / 2
1	1	0	Bitwise-AND	A AND B
1	1	1	Bitwise-OR	A OR B



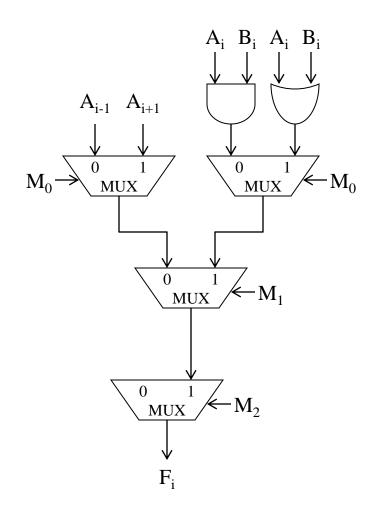
$M_2$	$\mathbf{M}_1$	$\mathbf{M}_0$	Function Name	F =
0	0	0	Add	A + B
0	0	1	Subtract	A - B
0	1	0	Increment	A + 1
0	1	1	Decrement	A-1
1	0	0	Multiply by 2	A * 2
1	0	1	Divide by 2	A / 2
1	1	0	Bitwise-AND	A AND B
1	1	1	Bitwise-OR	A OR B



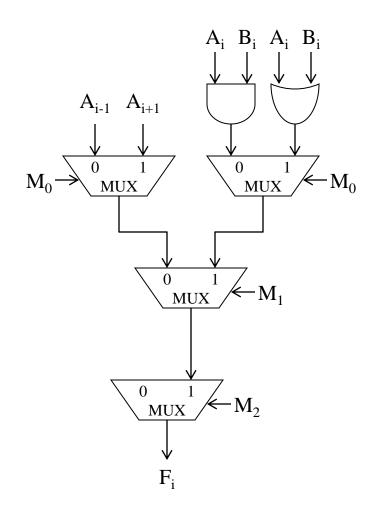
$M_2$	$\mathbf{M}_1$	$\mathbf{M}_0$	Function Name	F =
0	0	0	Add	A + B
0	0	1	Subtract	A - B
0	1	0	Increment	A + 1
0	1	1	Decrement	A – 1
1	0	0	Multiply by 2	A * 2
1	0	1	Divide by 2	A / 2
1	1	0	Bitwise-AND	A AND B
1	1	1	Bitwise-OR	A OR B



$M_2$	$\mathbf{M}_1$	$M_0$	Function Name	F =
0	0	0	Add	A + B
0	0	1	Subtract	A - B
0	1	0	Increment	A + 1
0	1	1	Decrement	A – 1
1	0	0	Multiply by 2	A * 2
1	0	1	Divide by 2	A/2
1	1	0	Bitwise-AND	A AND B
1	1	1	Bitwise-OR	A OR B



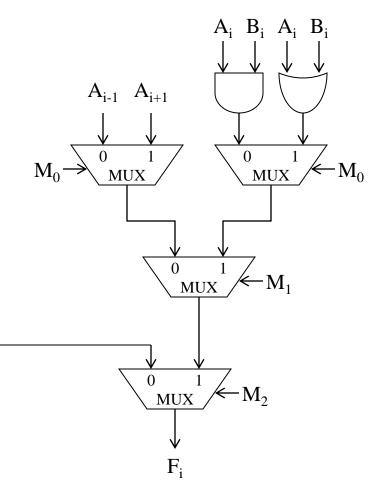
$M_2$	$\mathbf{M}_1$	$M_0$	Function Name	F =
0	0	0	Add	A + B
0	0	1	Subtract	A - B
0	1	0	Increment	A + 1
0	1	1	Decrement	A – 1
1	0	0	Multiply by 2	A * 2
1	0	1	Divide by 2	A/2
1	1	0	Bitwise-AND	A AND B
1	1	1	Bitwise-OR	A OR B



$M_2$	$M_1$	$M_0$	Function Name	F =
0	0	0	Add	A + B
0	0	1	Subtract	A - B
0	1	0	Increment	A + 1
0	1	1	Decrement	A – 1
1	0	0	Multiply by 2	A * 2
1	0	1	Divide by 2	A/2
1	1	0	Bitwise-AND	A AND B
1	1	1	Bitwise-OR	A OR B

 $A_{i}$ 

FA



$M_2$	$M_1$	$\mathbf{M}_0$	Function Name	F =		$C_0$	
0	0	0	Add	A + B	B <sub>i</sub>	0	
0	0	1	Subtract	A-B	NOT(B <sub>i</sub> )	1	
0	1	0	Increment	A + 1	"0"	1	
0	1	1	Decrement	A – 1	"1"	0	
1	0	0	Multiply by 2	A * 2			_
1	0	1	Divide by 2	A/2			$A_i B_i A_i B_i$
1	1	0	Bitwise-AND	A AND B			
1	1	1	Bitwise-OR	A OR B		$A_{i-1}$ $A_{i+1}$	v v v
			$A_{i}$ $C_{i+1} \leftarrow$	$FA$ $\leftarrow C_i$	$M_0$	0 1 MUX O MUX F <sub>i</sub>	$\begin{array}{c} \downarrow \\ \downarrow \\ 0 \\ MUX \end{array} \longrightarrow M_1$ $\begin{array}{c} M_1 \\ M_2 \end{array}$

$M_2$	$M_1$	$\mathbf{M}_0$	Function Name	F =		$C_0$	
0	0	0	Add	A + B	$B_{i}$	0	
0	0	1	Subtract	A – B	NOT(B <sub>i</sub> )	1	
0	1	0	Increment	A + 1	"0"	1	
0	1	1	Decrement	A – 1	"1"	0	
1	0	0	Multiply by 2	A * 2			
1	0	1	Divide by 2	A/2			$A_i B_i A_i B_i$
1	1	0	Bitwise-AND	A AND B			
1	1	1	Bitwise-OR	A OR B		$A_{i-1}$ $A_{i+1}$	
			$B_{i} -$ $A_{i}$ $C_{i+1} \leftarrow$	$\begin{array}{c} M_0 \\ MUX \\ \hline \end{array}$	$M_0$	0 1 MUX O MUX F <sub>i</sub>	$\begin{array}{c} \downarrow \\ \downarrow \\ MUX \\ \hline \\ M_1 \\ \hline \\ M_2 \\ \hline \end{array}$

$M_2$	$\mathbf{M}_1$	$\mathbf{M}_0$	Function Name	F =		$C_0$	
0	0	0	Add	A + B	$B_{i}$	0	
0	0	1	Subtract	A - B	NOT(B <sub>i</sub> )	1	
0	1	0	Increment	A + 1	"0"	1	
0	1	1	Decrement	A – 1	"1"	0	
1	0	0	Multiply by 2	A * 2			
1	0	1	Divide by 2	A/2			$A_i B_i A_i B_i$
1	1	0	Bitwise-AND	A AND B			
1	1	1	Bitwise-OR	A OR B	, A	$\mathbf{A}_{\mathbf{i-1}}$ $\mathbf{A}_{\mathbf{i+1}}$	
			$B_{i} -$ $A_{i}$ $C_{i+1} \leftarrow$	$M_0$ $M_0$ $MUX$ $M_1$ $FA$ $C_i$	$M_0$	0 1 MUX O MUX O MUX	$\begin{array}{c} \downarrow \\ \downarrow \\ MUX \\ \hline \\ M_1 \\ \hline \\ M_2 \\ \end{array}$

 $F_{i}$ 

$M_2$	$M_1$	$M_0$	Function Name	F =		$C_0$	
0	0	0	Add	A + B	$B_{i}$	0	
0	0	1	Subtract	A - B	NOT(B <sub>i</sub> )	1	
0	1	0	Increment	A + 1	"0"	1	
0	1	1	Decrement	A – 1	"1"	0	
1	0	0	Multiply by 2	A * 2			-
1	0	1	Divide by 2	A / 2			$A_i B_i A_i B_i$
1	1	0	Bitwise-AND	A AND B			
1	1	1	Bitwise-OR	A OR B	,	$\mathbf{A}_{i-1}$ $\mathbf{A}_{i+1}$	
			$B_{i} -$ $A_{i}$ $C_{i+1} \leftarrow$	$M_0$ $M_0$ $M_0$ $MUX$ $M_1$ $MUX$ $M_1$	$M_0$	0 1 MUX 0 MUX 0 1 MUX	$M_{0}$ $M_{0}$ $M_{0}$ $M_{0}$ $M_{0}$ $M_{0}$ $M_{0}$ $M_{0}$ $M_{0}$

 $F_{i}$ 

$M_2$	$M_1$	$M_0$	Function Name	F =		$C_0$		
0	0	0	Add	A + B	B <sub>i</sub>	0		
0	0	1	Subtract	A – B	NOT(B <sub>i</sub> )	1		
0	1	0	Increment	A + 1	"0"	1		
0	1	1	Decrement	A – 1	"1"	0		
1	0	0	Multiply by 2	A * 2			1	
1	0	1	Divide by 2	A / 2			$A_i B_i A_i B_i$	
1	1	0	Bitwise-AND	A AND B				
1	1	1	Bitwise-OR	A OR B	,	A A		
			$B_{i} -$ $A_{i}$ $C_{i+1} \leftarrow$	$\begin{array}{c c} B_i & & M_0 \\ A_i & & M_0 \\ \hline \\ MUX & M_1 \\ \hline \end{array}$		$\begin{array}{c} A_{i-1} & A_{i+1} \\ \downarrow & \downarrow \\ M_0 & MUX \\ MUX & MUX \\ MUX & M_1 \\ \hline \\ MUX & M_2 \\ \hline \end{array}$		

 $F_{i}$ 

$M_2$	$M_1$	$M_0$	Function Name	F =		$C_0$	$M_1 M_0$
0	0	0	Add	A + B	B <sub>i</sub>	0	
0	0	1	Subtract	A – B	NOT(B <sub>i</sub> )	1	
0	1	0	Increment	A + 1	"0"	1	
0	1	1	Decrement	A-1	"1"	0	$\bigvee_{\mathbf{C}}$
1	0	0	Multiply by 2	A * 2			$C_0$
1	0	1	Divide by 2	A/2			$A_i B_i A_i B_i$
1	1	0	Bitwise-AND	A AND B			$\downarrow$ $\downarrow$ $\downarrow$ $\downarrow$
1	1	1	Bitwise-OR	A OR B	, A	$\mathbf{A}_{i-1}$ $\mathbf{A}_{i+1}$	
			$B_{i} -$ $A_{i}$ $C_{i+1} \leftarrow$	$M_0$	0 1 MUX 0 MUX 0 MUX F <sub>i</sub>	$\begin{array}{c} \downarrow \\ \downarrow \\ MUX \\ MUX \\ M_1 \\ M_2 \\ M_2 \\ \end{array}$	

