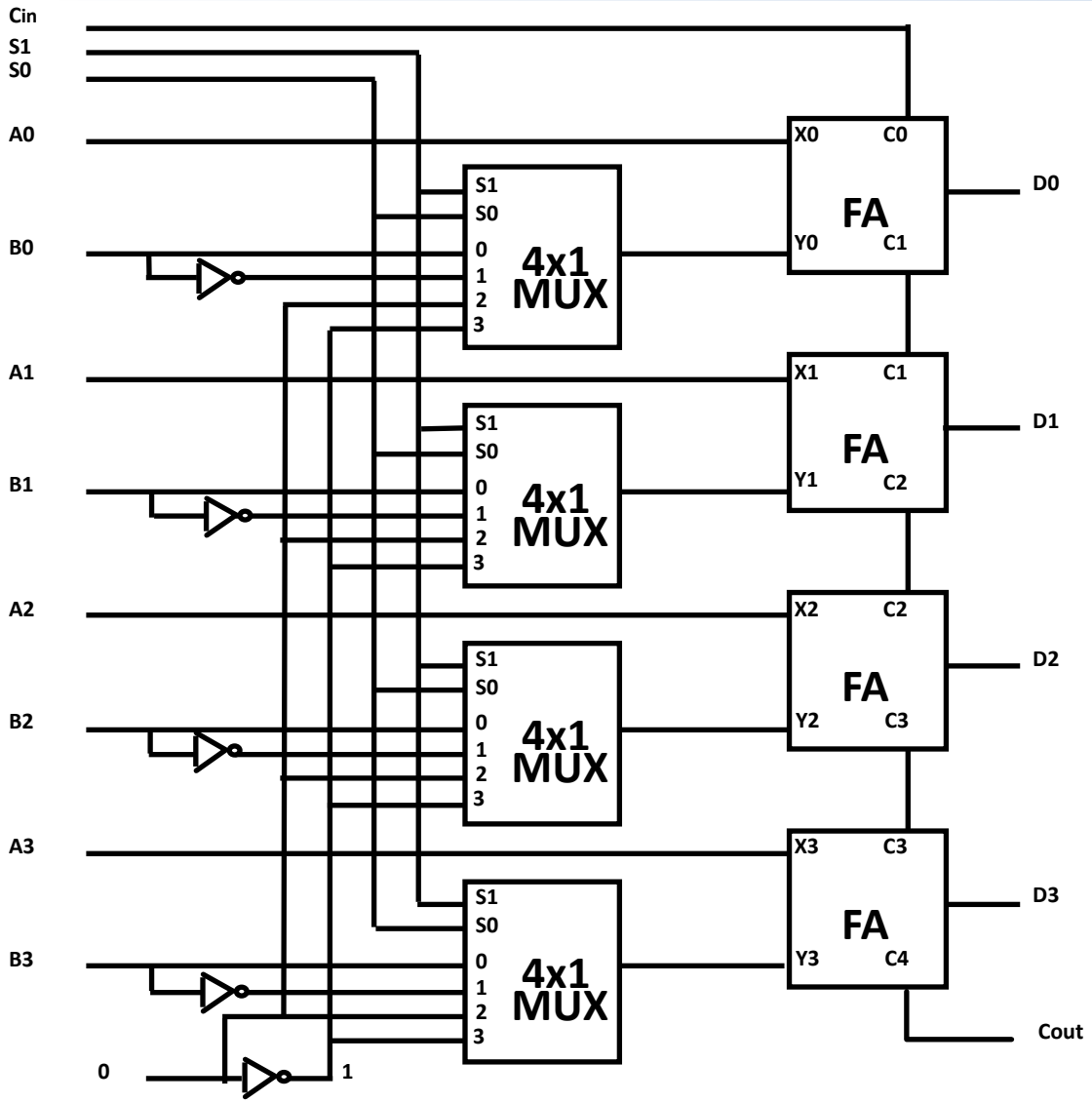
Arithmetic Circuits



Select			Input	Output
S1	S0	C_{in}	Y	$D=A+Y+C_{in}$
0	0	0	B	D=A+B
0	0	1	B	D=A+B+1
0	1	0	B'	D=A+B'
0	1	1	B'	D=A+B'+1
1	0	0	0	D=A
1	0	1	0	D=A+1
1	1	0	1	D=A-1
1	1	1	1	D=A

Overview

- Register Transfer Language
- Register Transfer
- Bus and Memory Transfers
- Arithmetic Micro-operations
- **Logic Micro-operations**
- **Shift Micro-operations**
- **Arithmetic Logic Shift Unit**

Logic Micro operations

- Logic microoperation
  - Logic microoperations consider ***each bit of the register separately*** and treat them as binary variables
    - » *exam)*

$P: R1 \leftarrow R1 \oplus R2$

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  1010  Content of R1
+ 1100  Content of R2
  0110  Content of R1 after P=1
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  - Special Symbols
    - » Special symbols will be adopted for the logic microoperations ***OR(∨), AND(∧),*** and ***complement(a bar on top)***, to distinguish them from the corresponding symbols used to express Boolean functions
    - » *exam)*

$P + Q: R1 \leftarrow R2 + R3,\ R4 \leftarrow R5 \vee R6$

Logic OR

Arithmetic ADD

- List of Logic Microoperation
  - Truth Table for 16 functions for 2 variables : ***Tab. 4-5***
  - 16 Logic Microoperation : ***Tab. 4-6***
- Hardware Implementation
  - 16 microoperation → Use only 4(AND, OR, XOR, Complement)
  - One stage of logic circuit

∵ All other Operation can be derived

- ……. is used to perform the addition of 3 bits.

A) Half adder
B) Full adder
C) Both A and B
D) None of the above

Logic Microoperations

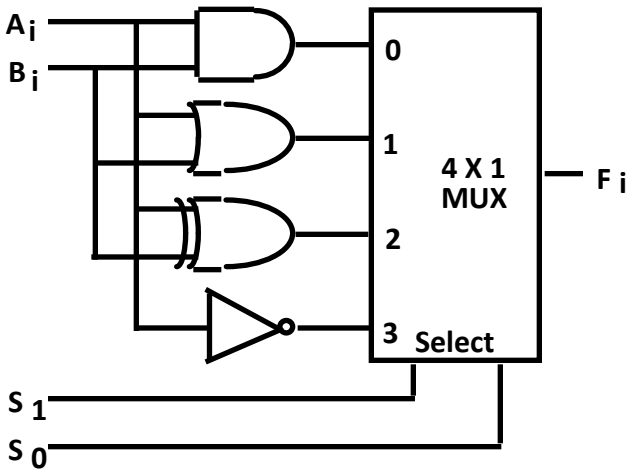
X	Y	F_0	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}	F_{12}	F_{13}	F_{14}	F_{15}
0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
0	1	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1
1	0	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1

TABLE 4-5. Truth Table for 16 Functions of Two Variables

Boolean function	Microoperation	Name
$F_0 = 0$	$F \leftarrow 0$	Clear
$F_1 = xy$	$F \leftarrow A \wedge B$	AND
$F_2 = xy'$	$F \leftarrow A \wedge \overline{B}$	
$F_3 = x$	$F \leftarrow A$	Transfer A
$F_4 = x'y$	$F \leftarrow \overline{A} \wedge B$	
$F_5 = y$	$F \leftarrow B$	Transfer B
$F_6 = x \oplus y$	$F \leftarrow A \oplus B$	Ex-OR
$F_7 = x+y$	$F \leftarrow A \vee B$	OR
$F_8 = (x+y)'$	$F \leftarrow \overline{A \vee B}$	NOR
$F_9 = (x \oplus y)'$	$F \leftarrow \overline{A \oplus B}$	Ex-NOR
$F_{10} = y'$	$F \leftarrow \overline{B}$	Compl-B
$F_{11} = x+y'$	$F \leftarrow A \vee \overline{B}$	
$F_{12} = x'$	$F \leftarrow \overline{A}$	Compl-A
$F_{13} = x'+y$	$F \leftarrow \overline{A} \vee B$	
$F_{14} = (xy)'$	$F \leftarrow \overline{A \wedge B}$	NAND
$F_{15} = 1$	$F \leftarrow$ all 1's	set to all 1's

TABLE 4-6. Sixteen Logic Microoperations

Hardware Implementation



Function table

S_1	S_0	Output	μ-operation
0	0	$F = A \wedge B$	AND
0	1	$F = A \vee B$	OR
1	0	$F = A \oplus B$	XOR
1	1	$F = A'$	Complement

Applications of Logic Microoperations

- **Logic microoperations can be used to manipulate individual bits or a portions of a word in a register**

- **Consider the data in a register A. In another register, B, is bit data that will be used to modify the contents of A**

Selective-set	**$A \leftarrow A + B$**
Selective-complement	**$A \leftarrow A \oplus B$**
Selective-clear	**$A \leftarrow A \bullet B'$**
Mask (Delete)	**$A \leftarrow A \bullet B$**
Clear	**$A \leftarrow A \oplus B$**
Insert	**$A \leftarrow (A \bullet B) + C$**
Compare	**$A \leftarrow A \oplus B$**

- How many Multiplexers and flip flops are required to design a 3-bit Arithmetic circuit?

A) 3 Mux and 2 flip flops
B) 2 Mux and 2 flip flops
C) 3 Mux and 3 flip flops
D) 2 Mux and 3 flip flops

Applications of Logic Microoperations

1. In a selective set operation, the bit pattern in B is used to *set* certain bits in A

1 1 0 0 A_t
1 0 1 0 B
1 1 1 0 A_{t+1} $(A \leftarrow A + B)$

If a bit in B is set to 1, that same position in A gets set to 1, otherwise that bit in A keeps its previous value

2. In a selective complement operation, the bit pattern in B is used to *complement* certain bits in A

1 1 0 0 A_t
1 0 1 0 B

0 1 1 0 A_{t+1} $(A \leftarrow A \oplus B)$

If a bit in B is set to 1, that same position in A gets complemented from its original value, otherwise it is unchanged

Applications of Logic Microoperations

3. In a selective clear operation, the bit pattern in B is used to *clear* certain bits in A

1 1 0 0 A_t

1 0 1 0 B

0 1 0 0 A_{t+1} $(A \leftarrow A \cdot B')$

If a bit in B is set to 1, that same position in A gets set to 0, otherwise it is unchanged

4. In a mask operation, the bit pattern in B is used to *clear* certain bits in A

1 1 0 0 A_t

1 0 1 0 B

1 0 0 0 A_{t+1} $(A \leftarrow A \cdot B)$

If a bit in B is set to 0, that same position in A gets set to 0, otherwise it is unchanged

Applications of Logic Microoperations

5. In a clear operation, if the bits in the same position in A and B are the same, they are cleared in A, otherwise they are set in A

$$\begin{array}{llll} 1\ 1\ 0\ 0 & A_t & & \\ 1\ 0\ 1\ 0 & B & & \\ & & & \\ 0\ 1\ 1\ 0 & A_{t+1} & (A \leftarrow A \oplus B) & \end{array}$$

Applications of Logic Microoperations

6. **An insert operation is used to introduce a specific bit pattern into A register, leaving the other bit positions unchanged**

   This is done as

   - **A mask operation to clear the desired bit positions, followed by**
   - **An OR operation to introduce the new bits into the desired positions**
   - **Example**
     - **Suppose you wanted to introduce 1010 into the low order four bits of A:**
     - **1101 1000 1011 0001 A (Original)**
       1101 1000 1011 1010 A (Desired)

     - `1101 1000 1011 0001  A (Original)`
       `1111 1111 1111 0000  Mask`
       `1101 1000 1011 0000  A (Intermediate)`
       `0000 0000 0000 1010  Added bits`
       `1101 1000 1011 1010  A (Desired)`