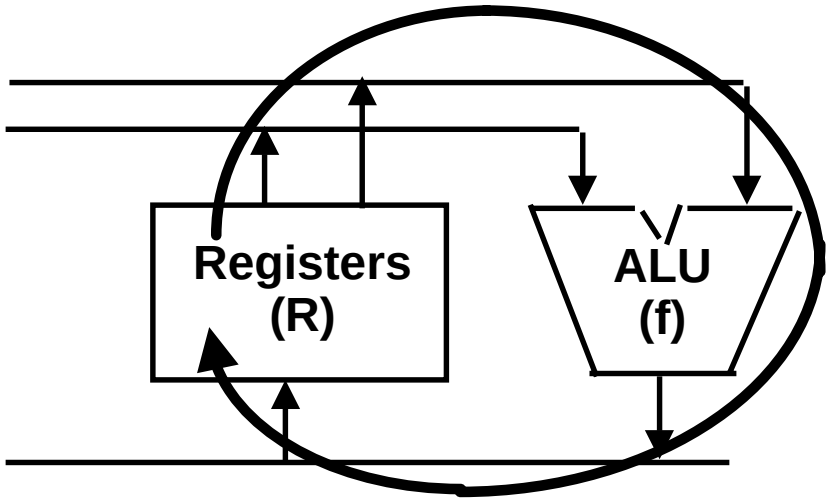
REGISTER TRANSFER AND MICROOPERATIONS

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

Compute

MICROOPERATION

An elementary operation performed during one clock pulse, on the information stored in one or more registers



Compute

1 clock cycle

$R \leftarrow f(R, R)$

f: shift, count, clear, load, add,...

REGISTER TRANSFER LANGUAGE

Definition of the organization of a computer

- **Set of registers and their functions**
- **Microoperations Set**
  Set of allowable microoperations provided by the organization of the computer
- **Control signals that initiate the sequence of microoperations**

For any function of the computer, a sequence of microoperations is used to describe it

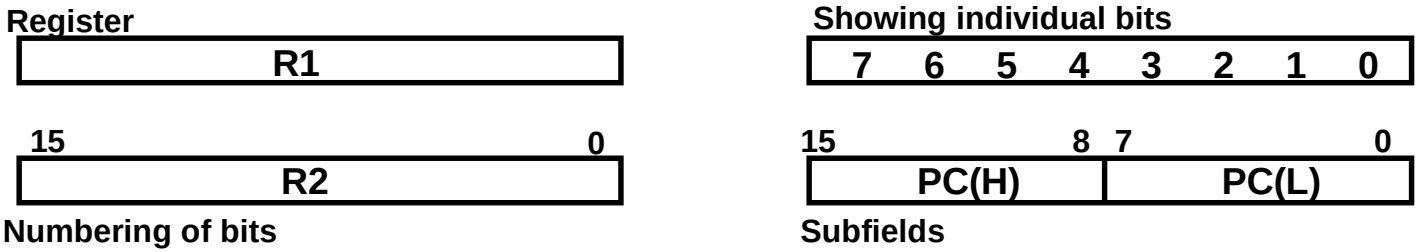
----> *Regi*

- **A symbolic language**
- **A convenient tool for describing the internal organization of digital computers**
- **Can also be used to facilitate the design process of digital systems.**

REGISTER TRANSFER

Designation of a register - a register
- portion of a register
- a bit of a register

Common ways of drawing the block diagram of a register



Representation of a transfer(parallel)

Compute **R2 ← R1**

A simultaneous transfer of all bits from the source to the destination register, during one clock pulse

Representation of a controlled(conditional) transfer

P: R2 ← R1

A binary condition(p=1) which determines when the transfer is to occur

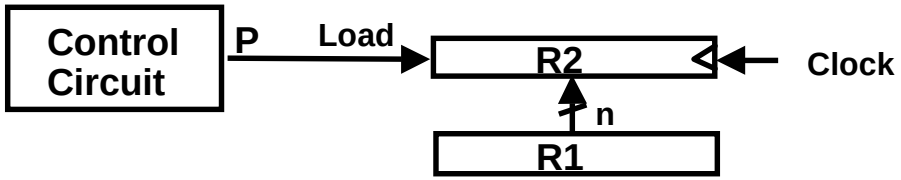
If (p=1) then (R2 ← R1)

HARDWARE IMPLEMENTATION OF CONTROLLED TRANSFERS

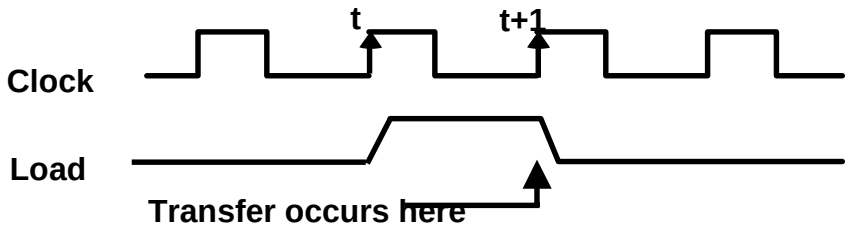
Implementation of controlled transfer

P: R2 ← R1

Block diagram



Timing diagram



Compute

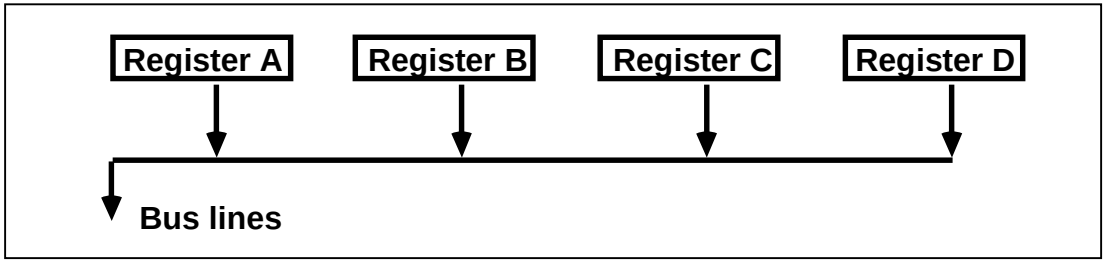
Basic Symbols for Register Transfers

Symbols and numerals	Description	Meaning
Parentheses ( )	Denotes a part of a register	R2(0-7), R2(L)
Arrow ←	Denotes transfer of information	R2 ← R1
Colon :	Denotes termination of control function	P:
Comma ,	Separates two micro-operations	A ← B, B ← A
Capital letters	Denotes a register	MAR, R2

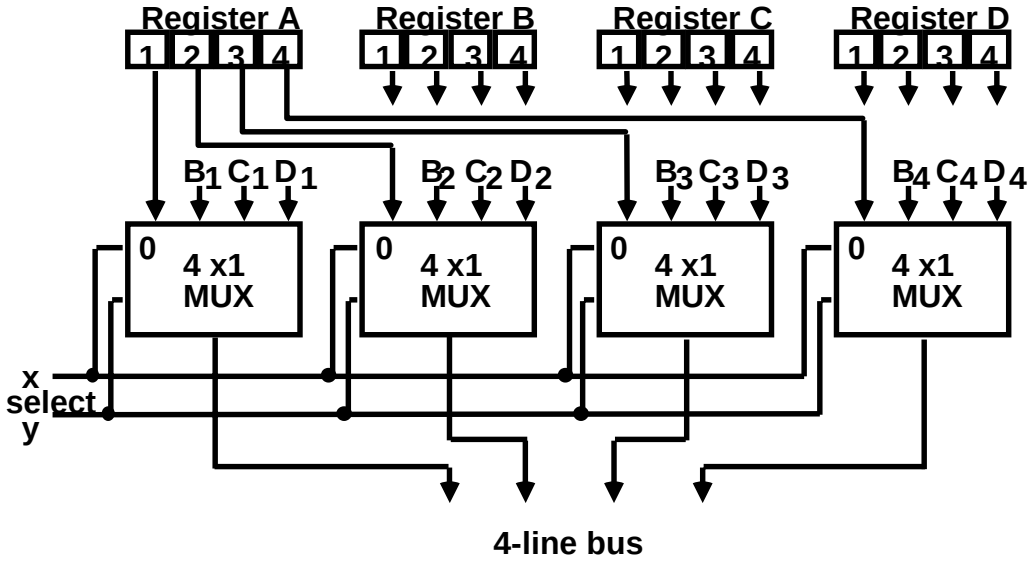
BUS AND MEMORY TRANSFER

Bus is a path(of a group of wires) over which information is transferred, from any of several sources to any of several destinations.

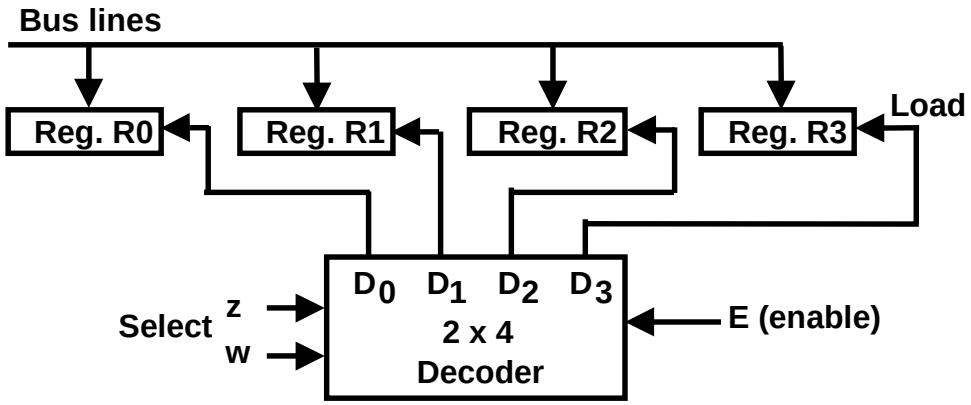
From a register to bus: BUS <- R



Compute



TRANSFER FROM BUS TO A DESTINATION REGISTER



Three-State Bus Buffers

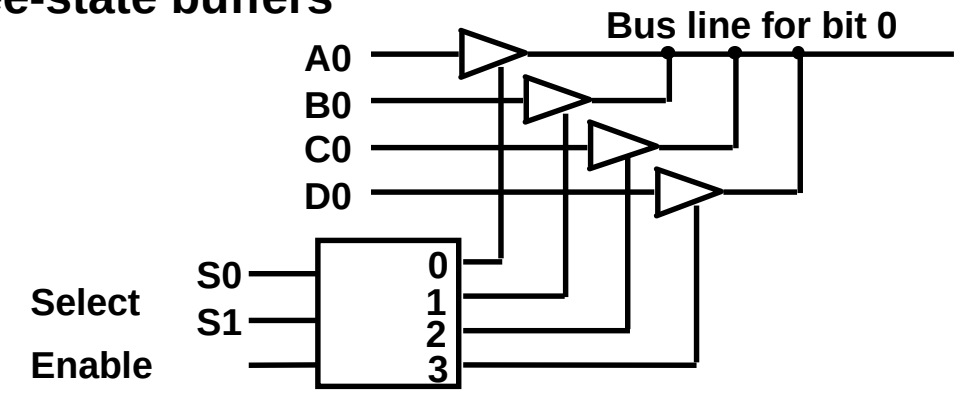
Normal input A

Control input C

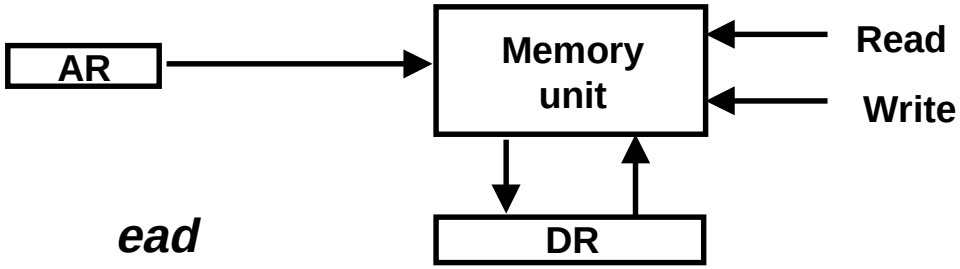
Output Y=A if C=1
High-impedence if C=0

Compute

Bus line with three-state buffers



MEMORY TRANSFERS



ead

Memory *r* micro-op: DR <- M (DR <- M[AR])

Memory *write* micro-op: M <- DR (M[AR] <- DR)

Summary of Register Transfer Microoperations

A ← B	Transfer content of reg. B into reg. A
AR ← DR(AD)	Transfer content of AD portion of reg. DR into reg. AR
A ← constant	Transfer a binary constant into reg. A
ABUS ← R1, R2 ← ABUS	Transfer content of R1 into bus A and, at the same time, transfer content of bus A into R2
AR	Address register
DR	Data register
M[R]	Memory word specified by reg. R
M	Equivalent to M[AR]
DR ← M	Memory *rea* operation: transfers content of memory word specified by AR into DR
M ← DR	Memory *write* operation: transfers content of DR into memory word specified by AR

Compute

d

ARITHMETIC MICROOPERATIONS

Four types of microoperations

- **Register transfer microoperations**
- **Arithmetic microoperations**
- **Logic microoperations**
- **Shift microoperations**

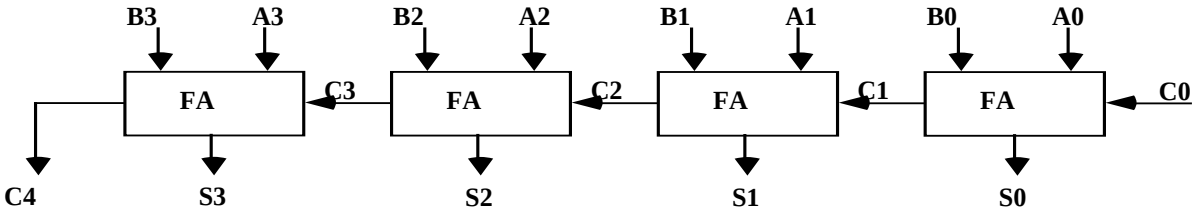
*** Summary of Arithmetic Micro-Operations**

R3 ← R1 + R2	Contents of R1 plus R2 transferred to R3
R3 ← R1 - R2	Contents of R1 minus R2 transferred to R3
R2 ← R2’	Complement the contents of R2
R2 ← R2’+ 1	2's complement the contents of R2 (negate)
R3 ← R1 + R2’+ 1	subtraction
R1 ← R1 + 1	Increment
R1 ← R1 - 1	Decrement

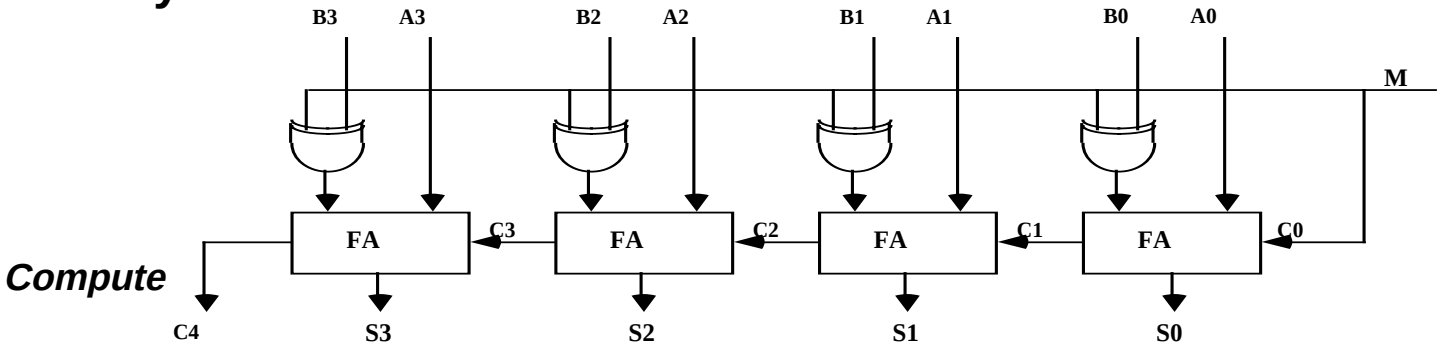
Compute

BINARY ADDER

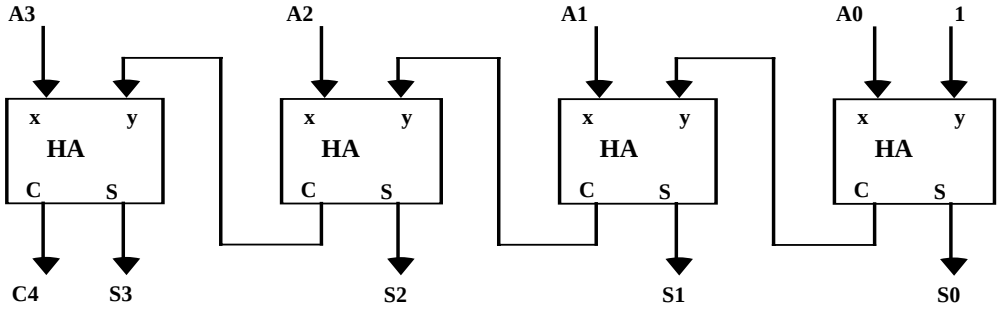
Binary Adder



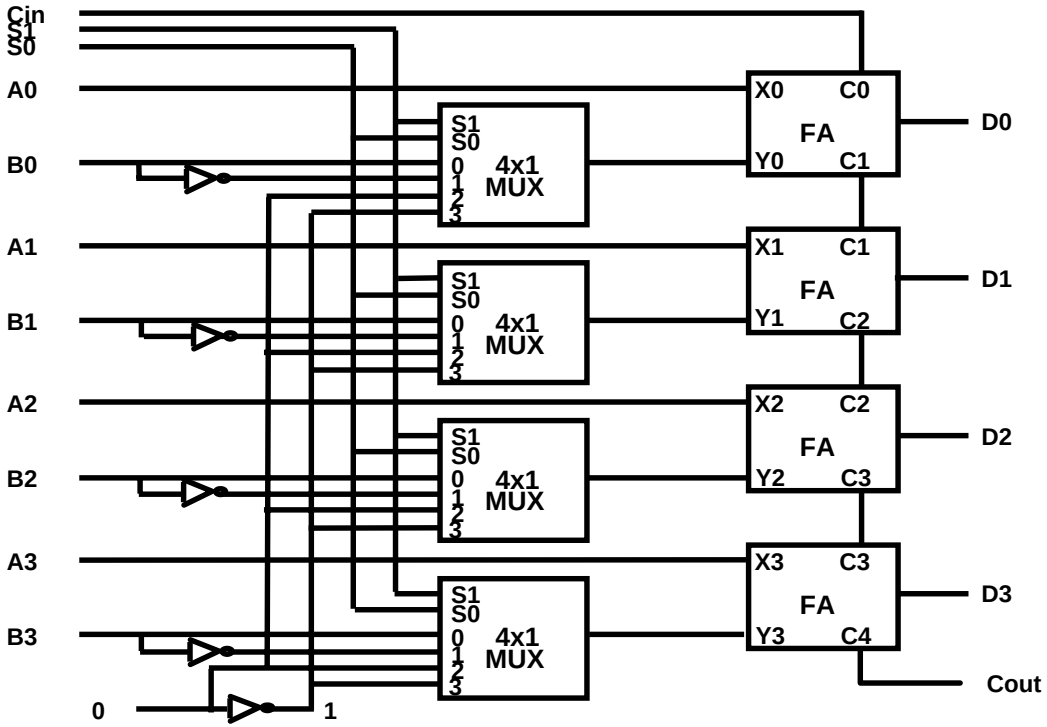
Binary Adder-Subtractor



Binary Incrementer



ARITHMETIC CIRCUIT



Compute

S1	S0	Cin	Y	Output	Microoperation
0	0	0	B	D = A + B	Add
0	0	1	B	D = A + B + 1	Add with carry
0	1	0	B’	D = A + B’	Subtract with borrow
0	1	1	B’	D = A + B’+ 1	Subtract
1	0	0	0	D = A	Transfer A
1	0	1	0	D = A + 1	Increment A
1	1	0	1	D = A - 1	Decrement A
1	1	1	1	D = A	Transfer A

LOGIC MICROOPERATIONS

Specify binary operations on the strings of bits in registers.

- useful for bit manipulations on binary data

AND: Mask out certain group of bits
OR : Merge binary or character data

- useful for making logical decisions based on the bit value

Applications

Manipulating individual bits or a field(portion) of a word in a register

Compute

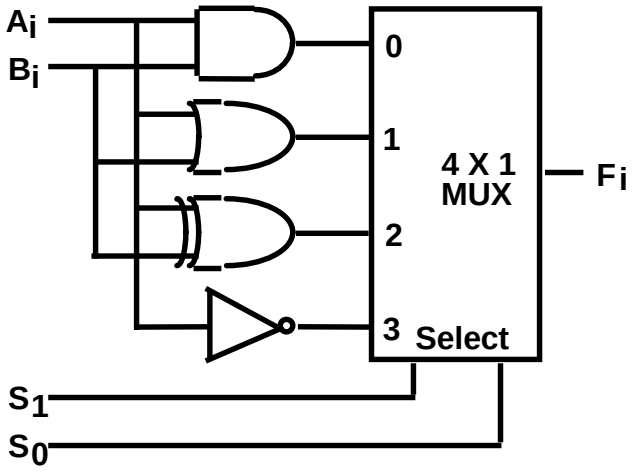
- Selective-set	$A + B$
- Selective-complement	$A \oplus B$
- Selective-clear	$A \cdot \overline{B}$
- Mask (Delete)	$A \cdot B$
- Insert	$(A \cdot B) + C$
- Compare	$A \oplus B$
- Packing	$(A \cdot B) + C$
- Unpacking	$A \cdot B$

LIST OF LOGIC MICROOPERATIONS

- List of Logic Micro-Operations
  - 16 different logic operations with 2 binary vars.
  - n binary vars -> 2^{2^n} functions
- Truth tables for 16 functions of 2 variables and the corresponding 16 logic micro-operations

x	0 0 1 1	*Boolean*	*Micr*	
y	0 1 0 1	*Function*		
Compute	0 0 0 0	F0 = 0	F ← 0	Clear
	0 0 0 1	F1 = xy	F ← A ∧ B	AND
	0 0 1 0	F2 = xy'	F ← A ∧ B'	
	0 0 1 1	F3 = x	F ← A	Transfer A
	0 1 0 0	F4 = x'y	F ← A' ∧ B	
	0 1 0 1	F5 = y	F ← B	Transfer B
	0 1 1 0	F6 = x ⊕ y	F ← A ⊕ B	Exclusive-OR
	0 1 1 1	F7 = x + y	F ← A ∨ B	OR
	1 0 0 0	F8 = (x + y)'	F ← (A ∨ B)'	NOR
	1 0 0 1	F9 = (x ⊕ y)'	F ← (A ⊕ B)'	Exclusive-NOR
	1 0 1 0	F10 = y'	F ← B'	Complement B
	1 0 1 1	F11 = x + y'	F ← A ∨ B	
	1 1 0 0	F12 = x'	F ← A'	Complement A
	1 1 0 1	F13 = x' + y	F ← A' ∨ B	
	1 1 1 0	F14 = (xy)'	F ← (A ∧ B)'	NAND
	1 1 1 1	F15 = 1	F ← all 1's	Set to all 1's

HARDWARE IMPLEMENTATION OF LOGIC MICROOPERATIONS



Compute

Function table

S1	S0	Output	μ-operation
0	0	F = A ∧ B	AND
0	1	F = A ∨ B	OR
1	0	F = A ⊕ B	XOR
1	1	F = A'	Complement

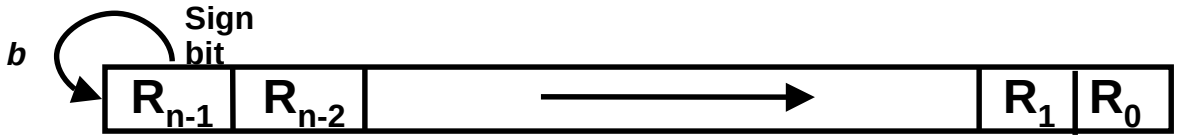
SHIFT MICROOPERATIONS

Shifts

- ***Log*** : shift in a 0 into the extreme flip-flop
- ***Ci*** : circulates the bits of the register around the two ends
- ***Arith*** : shifts a signed number (shift with sign extension)
  Left shift -> multiplied by 2
  Right shift -> divided by 2

Arithmetic shifts for signed binary numbers

- Arithmetic shift-right

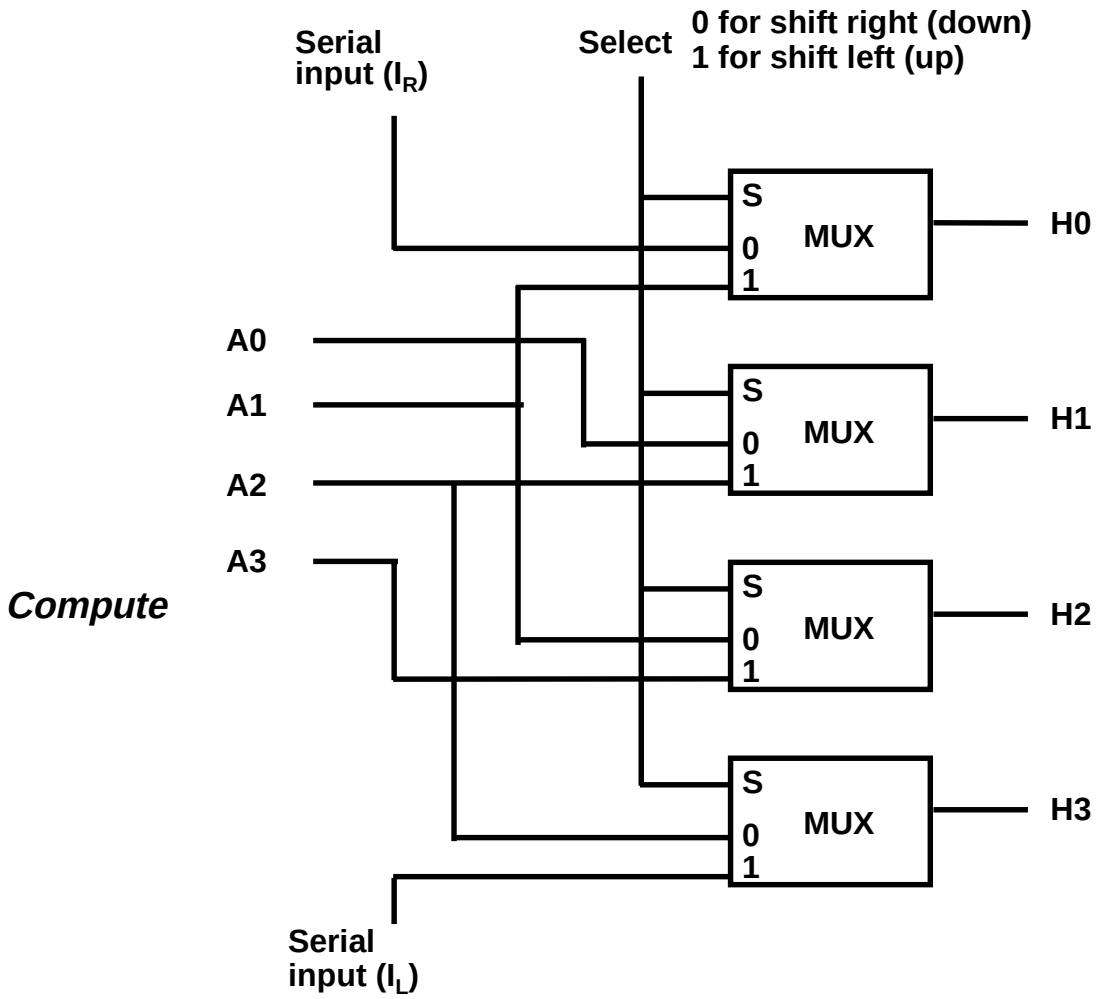


- Arithmetic shift-left Overflow $V = R_{n-1} \neq R_{n-2}$

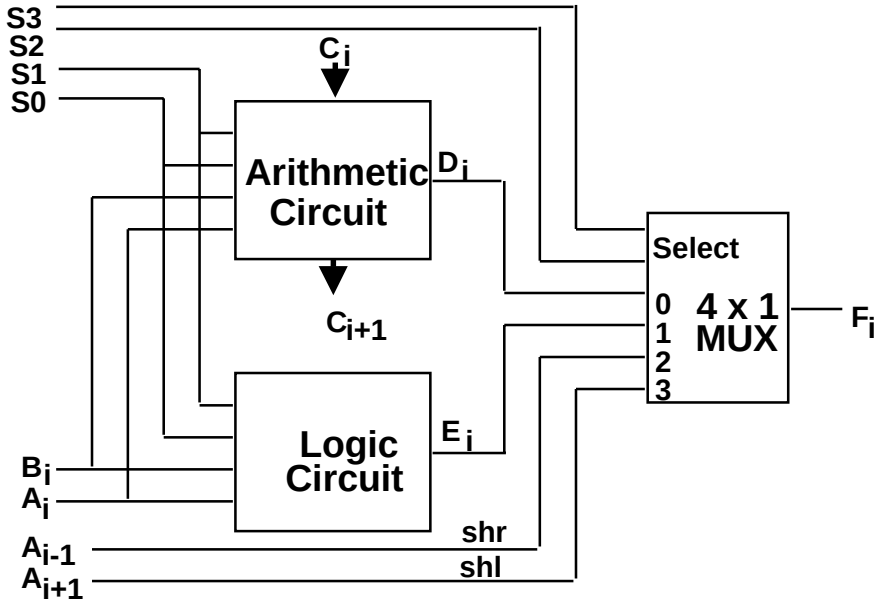
Shift Micro-Operations

Sy	
$R \leftarrow shl\ R$	Shift-left register R
$R \leftarrow shr\ R$	Shift-right register R
$R \leftarrow cil\ R$	Circular shift-left register R
$R \leftarrow cir\ R$	Circular right-shift register R
$R \leftarrow ashl\ R$	Arithmetic shift-left register R
$R \leftarrow ashr\ R$	Arithmetic shift-right register R

HARDWARE IMPLEMENTATION OF SHIFT MICROOPERATIONS



ARITHMETIC LOGIC SHIFT UNIT



Compute

S3	S2	S1	S0	Cin	Operation	Function
0	0	0	0	0	F = A	Transfer A
0	0	0	0	1	F = A + 1	Increment A
0	0	0	1	0	F = A + B	Addition
0	0	0	1	1	F = A + B + 1	Add with carry
0	0	1	0	0	F = A + B’	Subtract with borrow
0	0	1	0	1	F = A + B’+ 1	Subtraction
0	0	1	1	0	F = A - 1	Decrement A
0	0	1	1	1	F = A	TransferA
0	1	0	0	X	F = A ∧ B	AND
0	1	0	1	X	F = A ∨ B	OR
0	1	1	0	X	F = A ⊕ B	XOR
0	1	1	1	X	F = A’	Complement A
1	0	X	X	X	F = shr A	Shift right A into F
1	1	X	X	X	F = shl A	Shift left A into F