Computer Architecture

Keivan Navi

Cal Poly Pomona University

knavi@cpp.edu

Office hours: Tu/Th 5:25 Pm to 6:55 Pm

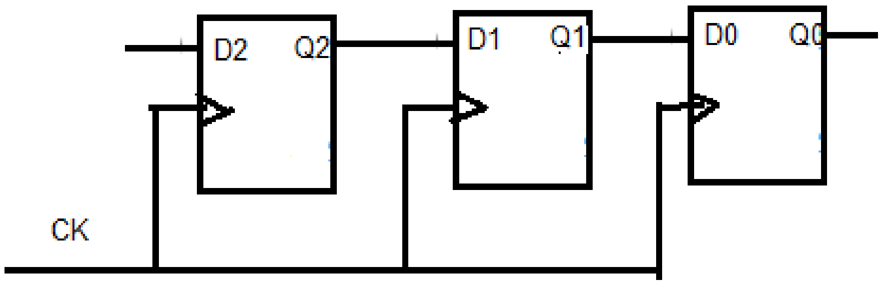
Office: 8-49

Computer Architecture

Shift and Rotate

Shift Right

- The Schema of Shift Right follows:



D3	D2	D1	D0

- One bit Shift Right

0	D3	D2	D1

- 2 bits Shift Right

0	0	D3	D2

- 3 bits Shift Right

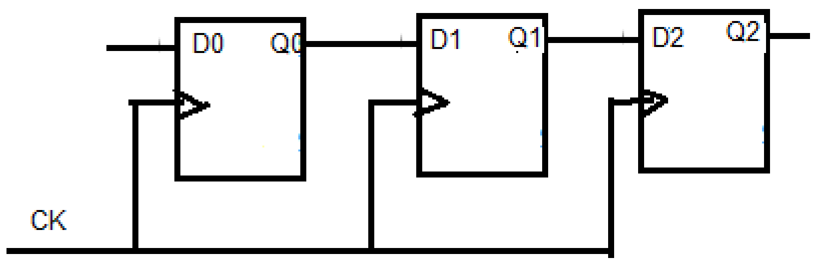
0	0	0	D1

- 4 bits Shift Right

0	0	0	0

Shift Left

- The Schema of Shift Left follows:



D3	D2	D1	D0

- One bit Shift Left

D2	D1	D0	0

- 2 bits Shift Left

D1	D0	0	0

- 3 bits Shift Left

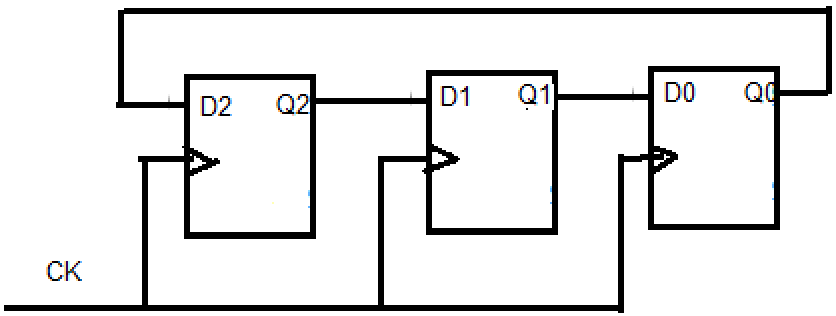
D0	0	0	0

- 4 bits Shift Left

0	0	0	0

Rotate Right

- The Schema of Rotate Right follows:



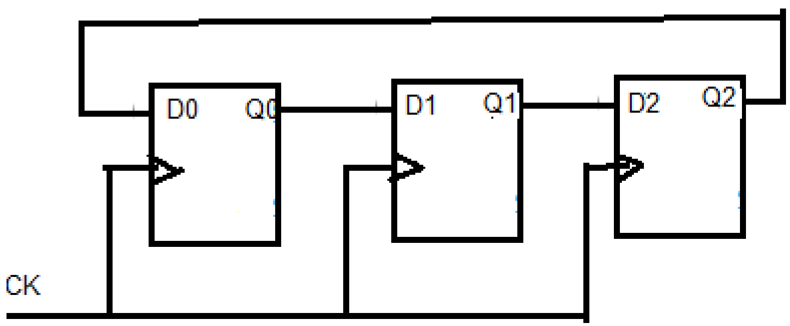
D3	D2	D1	D0

- One bit Rotate Right
- 2 bits Rotate Right
- 3 bits Rotate Right
- 4 bits Rotate Right

D0	D3	D2	D1
D1	D0	D3	D2
D2	D1	D0	D3
D3	D2	D1	D0

Rotate Left

- The Schema of Shift Left follows:



D3	D2	D1	D0

- One bit Shift Left

D2	D1	D0	D3

- 2 bits Shift Left

D1	D0	D3	D2

- 3 bits Shift Left

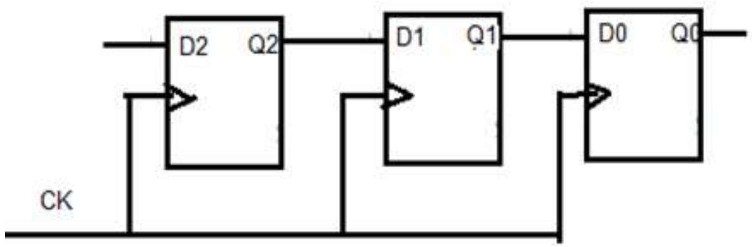
D0	D3	D2	D1

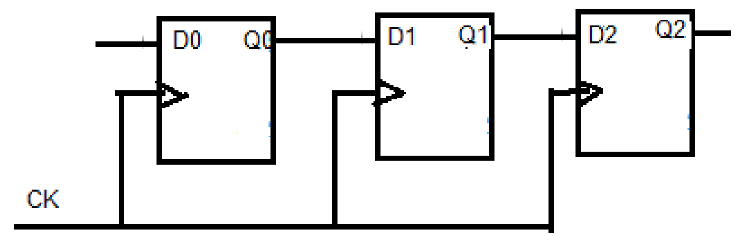
- 4 bits Shift Left

D3	D2	D1	D0

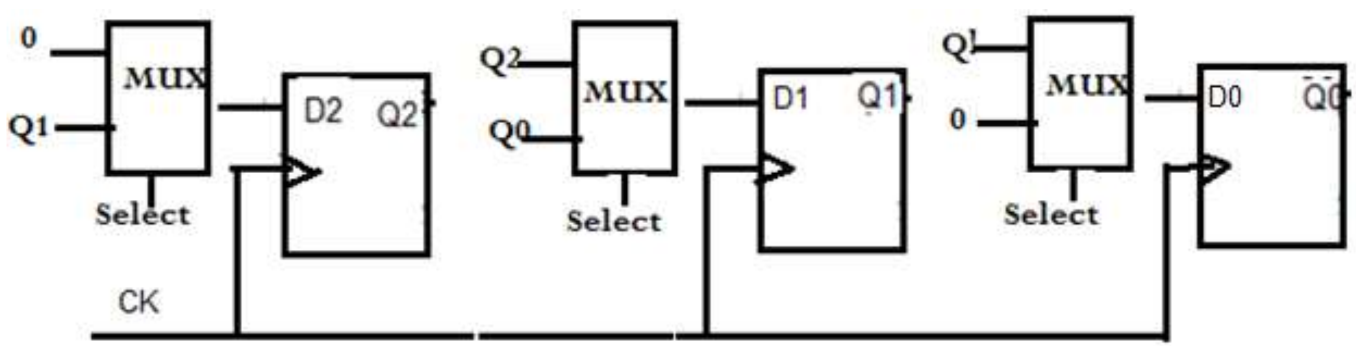
Shift Right/ Shift Left

- How can we combine them together?



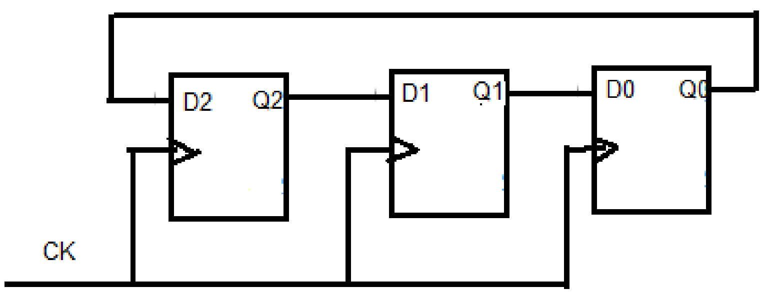


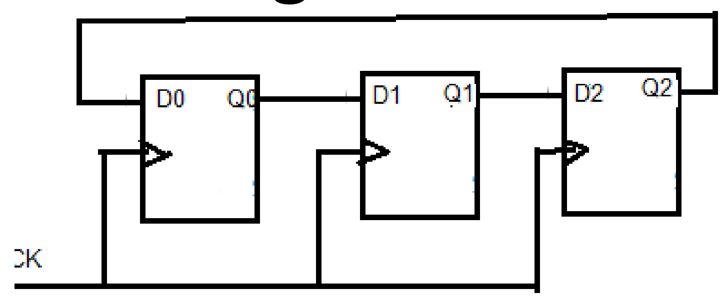
- If Select=0 then Shift Right
- If Select=1 then Shift Left



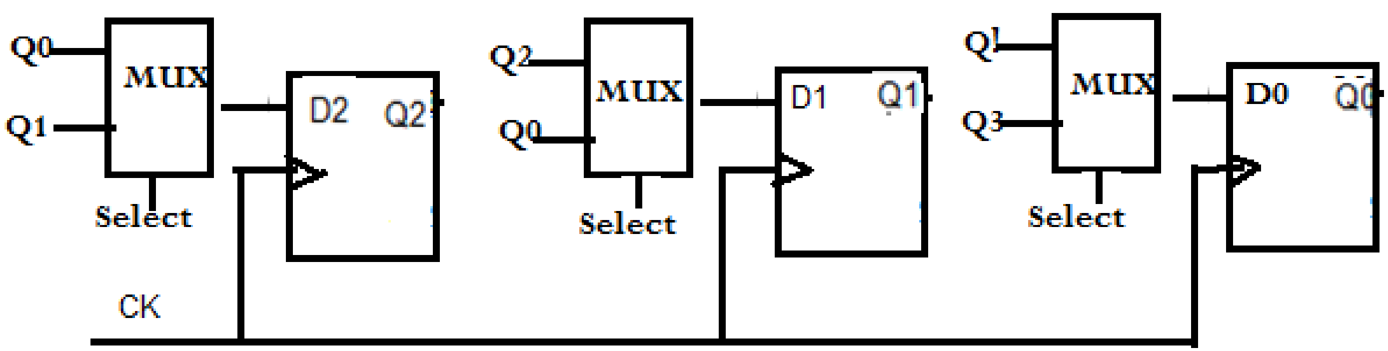
Rotate Right/ Rotate Left

- How can we combine these together?





- If Select=0 then Shift Right
- If Select=1 then Shift Left



Multiplication by 2, 4, 8, …2^n

- In order to multiply a number by 2= 2^1 it is enough to shift left it once.
- In order to multiply a number by 4= 2^2 it is enough to shift left it twice.
- In order to multiply a number by 8= 2^3 it is enough to shift left it 3 times.
- In order to multiply a number by 2^n it is enough to shift left it n times.

Multiplication by 3, 5,7, … 2^n+1

- In order to multiply a number by 3= 2^1 +1:
- The quick way to multiply a binary number by 3 requires **shift left it once, and then adding the original binary number to this**. Effectively we are doing 2x + x where x is the binary number.
- In order to multiply a number by 5= 2^2 +1:
- It is enough to shift left it twice, then adding the original binary number to this. Effectively we are doing 4x + x where x is the binary number.

Multiplication by 3, 5,9, … 2^n+1 (continued)

- In order to multiply a number by 9= 2^3 +1:
- It is enough to shift left it 3 times, then adding the original binary number to this. Effectively we are doing 8x + x where x is the binary number.

- In order to multiply a number by 2^n +1:
- It is enough to shift left it n times, then adding the original binary number to this. Effectively we are doing 2^n x + x where x is the binary number.

Multiplication by 1, 3, 7, 15, 2^n-1

- The simplest multiplication is to multiply any binary number by 1 resulting in the original number!
- In order to multiply a number by 3= 2^2 -1:
- It is enough to shift left it twice, then subtracting the original binary number from this.
- In order to multiply a number by 7= 2^3 -1:
- It is enough to shift left it 3 times, then subtracting the original binary number to this.

Multiplication by 1, 3, 7, 15, 2^{n}-1 (continued)

- In order to multiply a number by 15= 2^{4} -1:
- It is enough to shift left it 4 times, then subtracting the original binary number to this
- .
- In order to multiply a number by 2^{n} -1:
- It is enough to shift left it n times, then subtracting the original binary number to this.

Multiplication by 6, 10, 12,13

- Multiplying a number by 6:
- 6=4+2= $2^{2}+2^{1}$
- Multiplying a number by 10
- 10=8+2= $2^{3}+2^{1}$
- Multiplying a number by 12
- 12=8+4= $2^{3}+2^{2}$
- Multiplying a number by 13
- 13=8+4+1= $2^{3}+2^{2}+2^{0}$
- 13=16-2-1= $2^{4}-2^{1}-2^{0}$
- Which one do you prefer if:
- Each shift operation needs a clock cycle and subtraction is slower than addition?

Multiplication by 60, 120, 144,169

- Multiplying a number by 60:
- $60=(4+2)(8+2)= (2^{2}+2^{1})(2^{3}+2^{1})$
- $60=64-4=2^{6}-2^{2}$
- Multiplying a number by 120:
- $60=(4+2)(8+2)2= (2^{2}+2^{1})(2^{3}+2^{1})\,2^{1}$
- $120=128-8= 2^{7}-2^{3}$
- 144=12*12, can we find another solution?
- 169=13*13, can we find another solution?