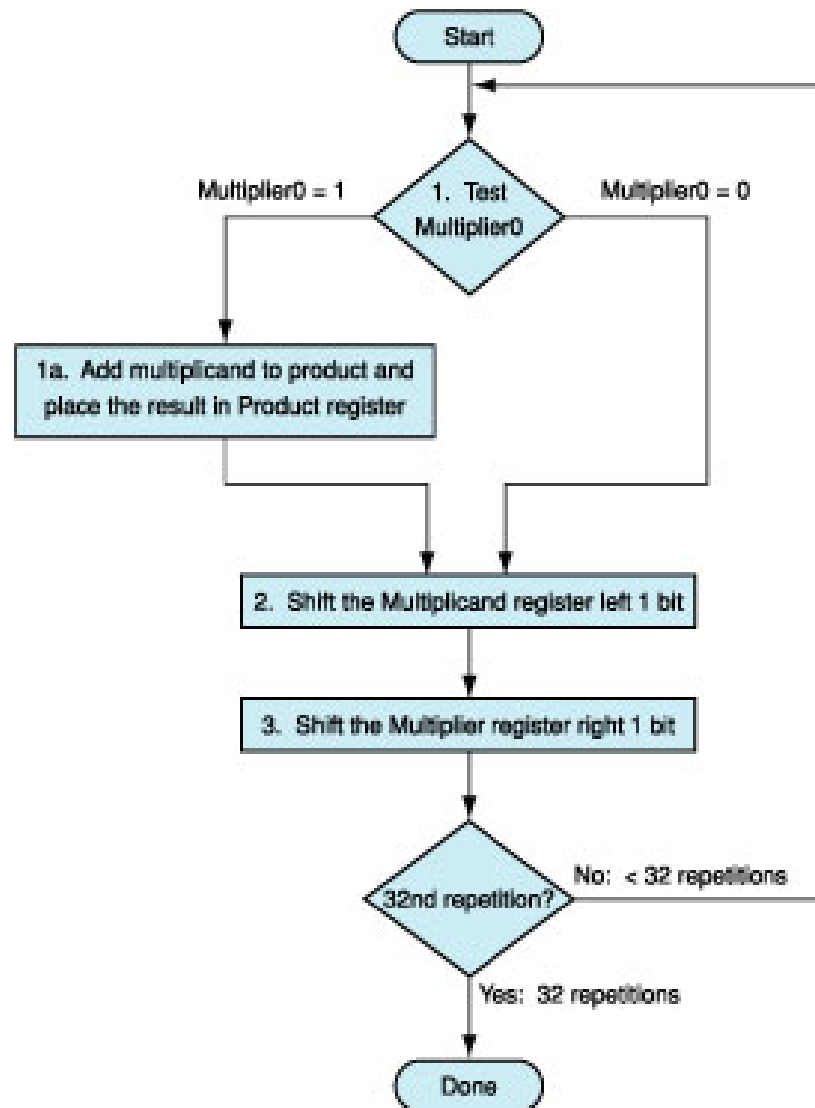


# Module 5 - Additions

# Multiplication - Flowchart



# Multiplication - Flowchart

- Why inefficient in terms of time?

# Multiplication - Flowchart

- Why inefficient?
- Each step is 1 clock cycle! Implies 100 clock cycles for 2 32 bit numbers.
- How to speed things up?

# Multiplication - Flowchart

- Why inefficient?
- Each step is 1 clock cycle! Implies 100 clock cycles for 2 32 bit numbers.
- How to speed things up?
- Do things in parallel!
- Multiplier & multiplicand shift while multiplicand added to product (if multiplier bit = 1)

# Multiplication - Flowchart

- Why inefficient in terms of hardware?

# Multiplication - Flowchart

- Why inefficient in terms of hardware?
- Don't need 64 bit adder, 64 bit multiplicand.
- Can halve width of adder (32 bit) and multiplicand (32 bit) by noticing where there are unused portions!
- Revised hardware...

# Multiplication Example

- $1000 \times 1001 =$

Product

multiplier

--	--	--	--	--	--	--	--



# Multiplication Example

- $1000 \times 1001 =$

Product

multiplier

0	0	0	0	1	0	0	1
---	---	---	---	---	---	---	---

# Multiplication Example

- $1000 \times 1001 =$

Product				multiplier			
0	0	0	0	1	0	0	1

Test? Yes

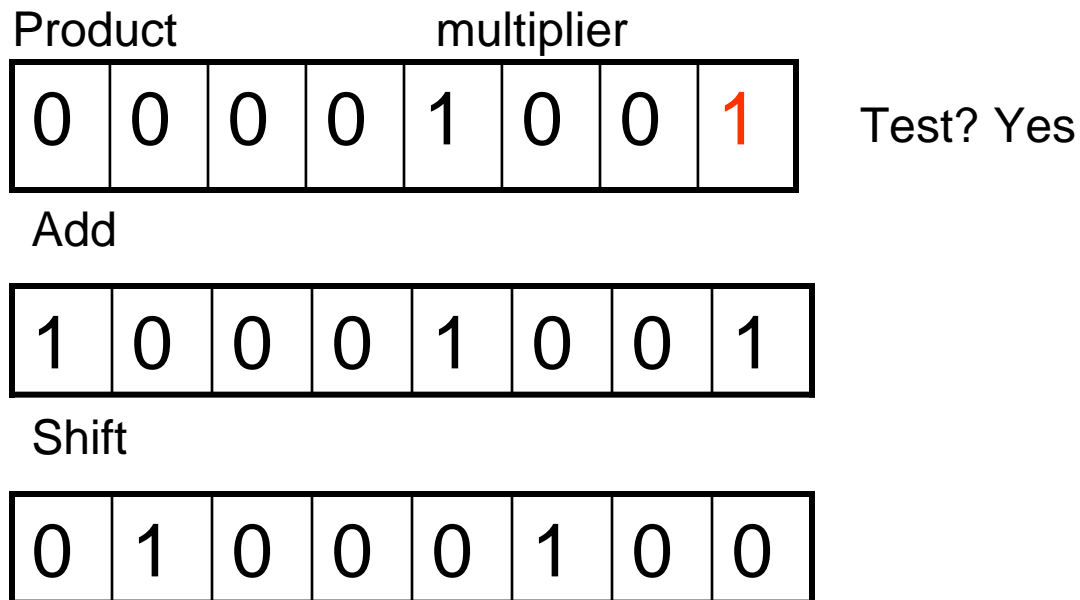
# Multiplication Example

- $1000 \times 1001 =$

Product				multiplier				
0	0	0	0	1	0	0	1	Test? Yes
Add								
1	0	0	0	1	0	0	1	

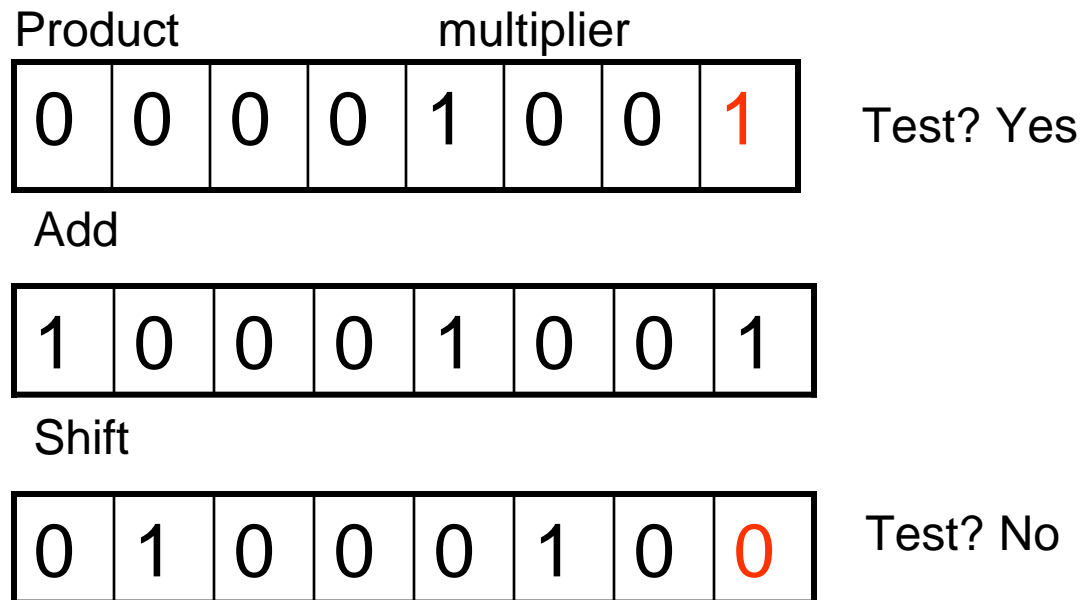
# Multiplication Example

- $1000 \times 1001 =$



# Multiplication Example

- $1000 \times 1001 =$



# Multiplication Example

- $1000 \times 1001 =$

Product				multiplier			
0	0	0	0	1	0	0	1

Test? Yes

Add

1	0	0	0	1	0	0	1
---	---	---	---	---	---	---	---

Shift

0	1	0	0	0	1	0	0
---	---	---	---	---	---	---	---

Test? No

Shift

0	0	1	0	0	0	1	0
---	---	---	---	---	---	---	---

# Multiplication Example

0	0	1	0	0	0	1	0
---	---	---	---	---	---	---	---

Test? No

# Multiplication Example

- $1000 \times 1001 =$

0	0	1	0	0	0	1	0
---	---	---	---	---	---	---	---

Test? No

Shift

0	0	0	1	0	0	0	1
---	---	---	---	---	---	---	---

Test? Yes!

Add

1	0	0	1	0	0	0	1
---	---	---	---	---	---	---	---



# Multiplication Example

- $1000 \times 1001 =$

0	0	1	0	0	0	1	0
---	---	---	---	---	---	---	---

Test? No

Shift

0	0	0	1	0	0	0	1
---	---	---	---	---	---	---	---

Test? Yes!

Add

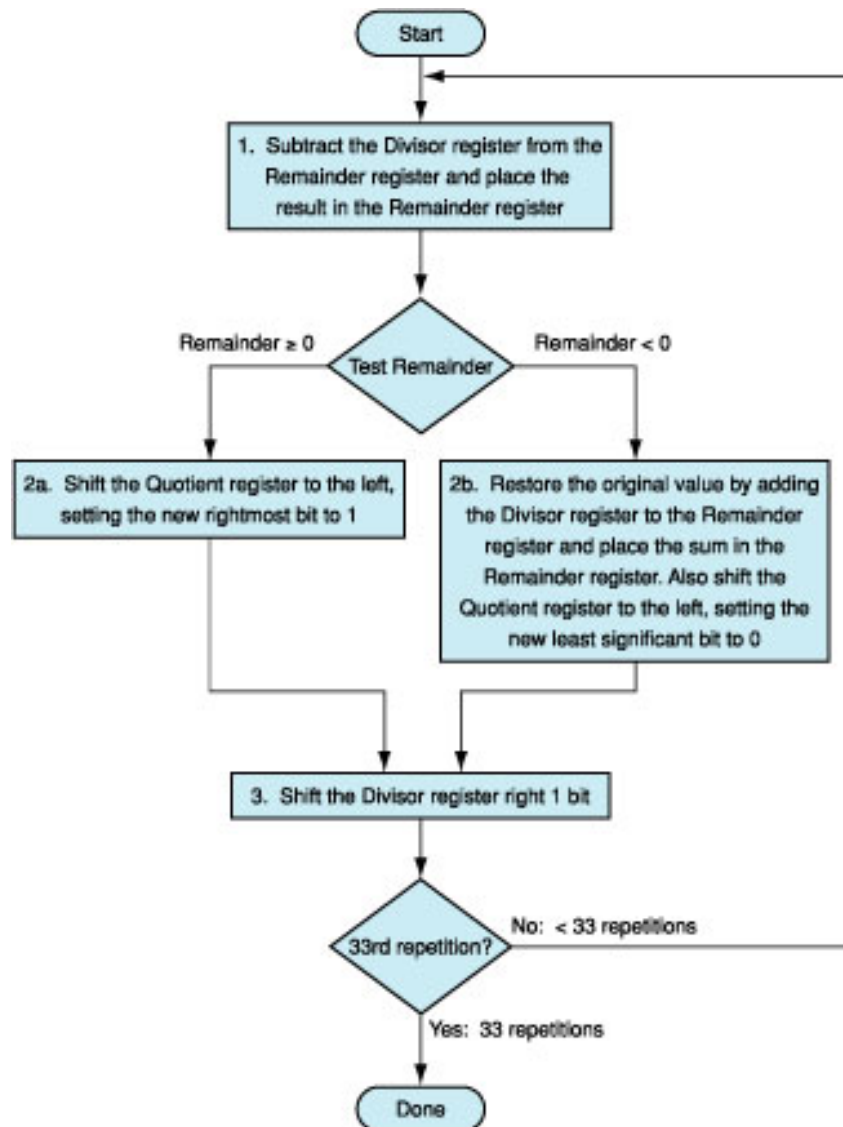
1	0	0	1	0	0	0	1
---	---	---	---	---	---	---	---

Shift

0	1	0	0	1	0	0	0
---	---	---	---	---	---	---	---

N=4. DONE!

# Division - Flowchart



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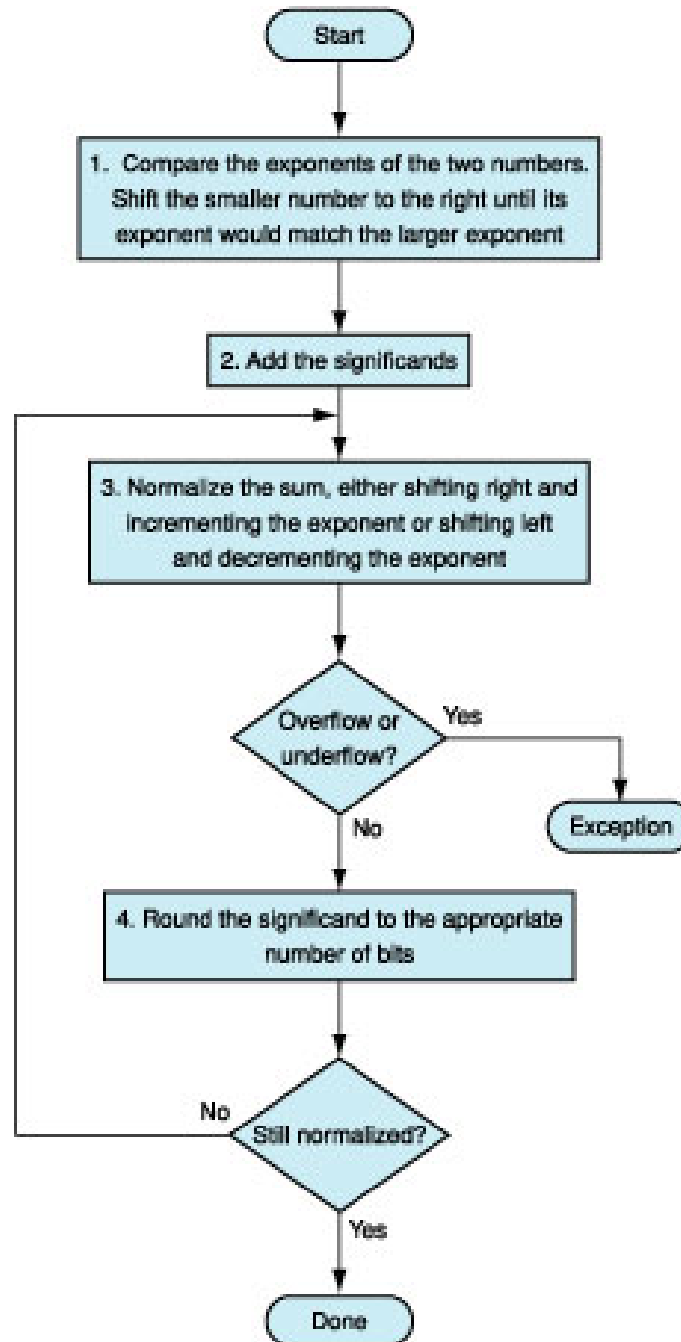
# Division Example – Divide 00000111 by 0010

Iteration	Step	Quotient	Divisor	Remainder
0	Initial Values	0000	0010 0000	0000 0111
1	Rem = Rem – Div	0000	0010 0000	1110 0111
	Rem < 0, +Div, sll Q, Q=0	0000	0010 0000	0000 0111
	Shift Div right	0000	0001 0000	0000 0111
2	Rem = Rem – Div	0000	0001 0000	1111 0111
	Rem < 0, +Div, sll Q, Q=0	0000	0001 0000	0000 0111
	Shift Div right	0000	0000 1000	0000 0111

# Division Example – Divide 00000111 by 0010

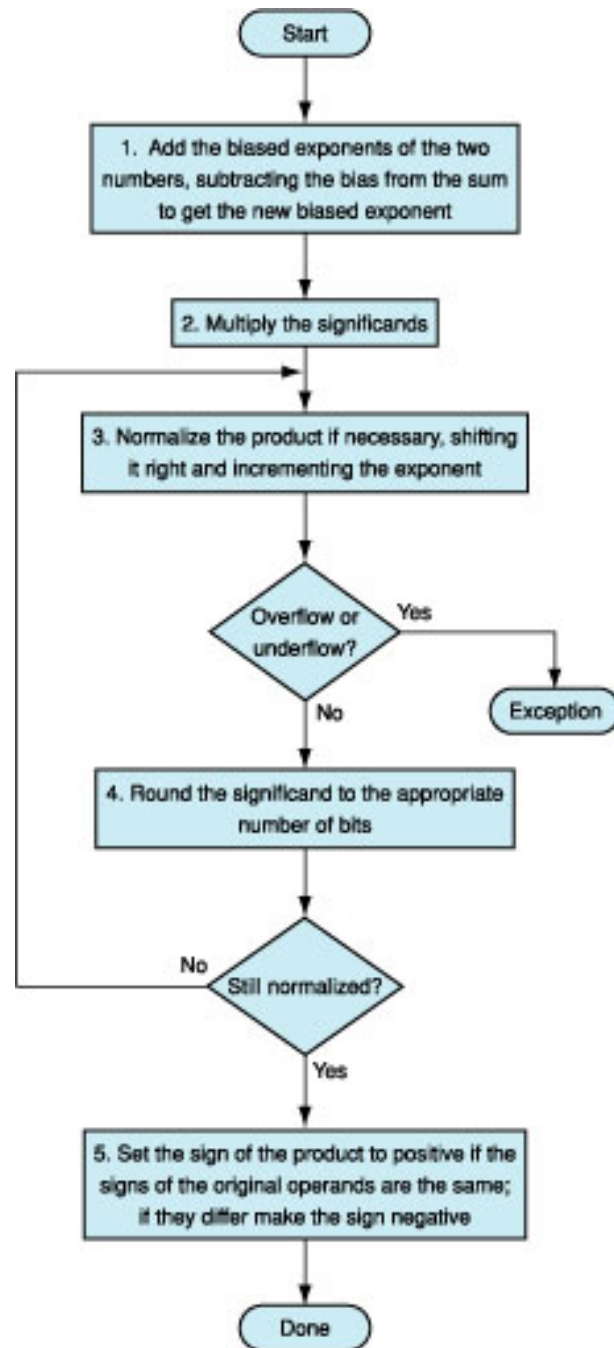
Iteration	Step	Quotient	Divisor	Remainder
3	Rem = Rem – Div Rem < 0, +Div, sll Q, Q=0 Shift Div right	0000 0000 0000	0000 1000 0000 1000 0000 0100	1111 1111 0000 0111 0000 0111
4	Rem = Rem – Div Rem >= 0, sll Q, Q=1 Shift Div right	0000 0001 0001	0000 0100 0000 0100 0000 0010	0000 0011 0000 0011 0000 0011
5	Rem = Rem – Div Rem >= 0, sll Q, Q=1 Shift Div right	0001 0011 0011	0000 0010 0000 0010 0000 0001	0000 0001 0000 0001 0000 0001

# Floating Point Addition



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# Floating Point Multiplication



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