



# 컴퓨터공학 기초 실험2

Lab #9

Multiplier

# MULTIPLIER

# Multiplier

- Multiplier 는 multiplicand(피승수)와 multiplier(승수)를 곱하여 결과값을 도출하는 hardware이다.
- Features
  - ✓ Multiplicand와 multiplier의 각각의 bit length는 64bits 이며, 곱의 결과값은 128 bits이다.

# Binary Multiplication

➤ Ex) 5 x 3 = 15

A	0101	(5) Multiplicand
X	X 0011	(3) Multiplier
<hr/>		
	0101	} Partial products
	0101	
	0000	
	0000	
<hr/>		
	0001111	(15)

# Binary Multiplication

➤ Ex)  $5 \times -3 = -15$

A	0101	(5) Multiplicand
X	1101	(-3) Multiplier
<hr/>		
	0101	} Partial products
	0000	
	0101	
	0101	
	1011	
<hr/>		
	11110001	(-15)

Multiplier가 음수인 경우 맨 마지막에 multiplicand의 보수 값을 더해준다.

# Booth Multiplication

## ➤ Rule of booth multiplication

$x_i$	$x_{i-1}$	Operation	Description
0	0	Shift only	String of zeros
0	1	Add and shift	End of a string of ones
1	0	Subtract and shift	Beginning of a string of ones
1	1	Shift only	String of ones

# Booth Multiplication

➤ Ex)  $7 \times -7 = -49$

A    0111 ( 7)

X    10010 (-7)

U	V	X	X-1
0000	0000	10010	0
Subtraction			

LSB(least significant bit)의 오른쪽에는 0비트가 있다고 가정하고 Y를 구함

$$\{x_i x_{i-1}\} = 10_{(2)} \rightarrow Y = \bar{1}$$

# Booth Multiplication

➤ Ex)  $7 \times -7 = -49$

A    0111 ( 7)

X    10010 (-7)

$$\begin{array}{r} 0000 \\ +1001 \\ \hline 1001 \end{array}$$

U	V	X	X-1
0000	0000	1001	0
1001			
1001	0000		



# Booth Multiplication

➤ Ex)  $7 \times -7 = -49$

A    0111 (7)

X    10010 (-7)

U	V	X	X-1
0000	0000	1001	0
1001			
1100	1000	1100	1

Arithmetic  
right shift

Circular  
right shift

# Booth Multiplication

➤ Ex)  $7 \times -7 = -49$

A    0111 ( 7)

X    10010 (-7)

$$\begin{array}{r} 1100 \\ +0111 \\ \hline 0011 \end{array}$$

U	V	X	X-1
0000	0000	1001	0
1001			
1100	1000	1100	1
0111		Addition	
0011	1000		

# Booth Multiplication

➤ Ex)  $7 \times -7 = -49$

A    0111 ( 7)

X    10010 (-7)

U	V	X	X-1
0000	0000	1001	0
1001			
1100	1000	1100	1
0111			
0001	1100	0110	0

# Booth Multiplication

➤ Ex)  $7 \times -7 = -49$

A    0111 ( 7)

X    10010 (-7)

U	V	X	X-1
0000	0000	1001	0
1001			
1100	1000	1100	1
0111			
0001	1100	0110	0
Shift			

# Booth Multiplication

➤ Ex)  $7 \times -7 = -49$

A    0111 ( 7)

X    10010 (-7)

U	V	X	X-1
0000	0000	1001	0
1001			
1100	1000	1100	1
0111			
0001	1100	0110	0
0000	1110	0011	0

# Booth Multiplication

➤ Ex)  $7 \times -7 = -49$

A    0111 ( 7)

X    10010 (-7)

U	V	X	X-1
0000	0000	1001	0
1001			
1100	1000	1100	1
0111			
0001	1100	0110	0
0000	1110	0011	0
Subtraction			

# Booth Multiplication

➤ Ex)  $7 \times -7 = -49$

A    0111 ( 7)

X    10010 (-7)

$$\begin{array}{r} 0000 \\ +1001 \\ \hline 1001 \end{array}$$

U	V	X	X-1
0000	0000	1001	0
1001			
1100	1000	1100	1
0111			
0001	1100	0110	0
0000	1110	0011	0
1001			
1001	1110		

# Booth Multiplication

➤ Ex)  $7 \times -7 = -49$

A    0111 ( 7)

X    10010 (-7)

U	V	X	X-1
0000	0000	1001	0
1001			
1100	1000	1100	1
0111			
0001	1100	0110	0
0000	1110	0011	0
1001			
1100	1111	1001	1



# Booth Multiplication

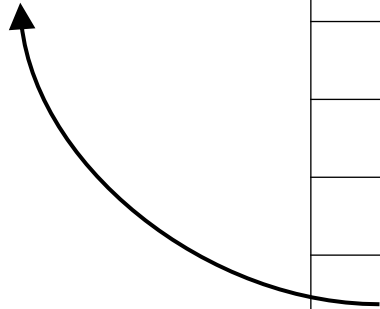
➤ Ex)  $7 \times -7 = -49$

A    0111 ( 7)

X    1001**0** (-7)

---

11001111 (-49)



U	V	X	X-1
0000	0000	1001	0
1001			
1100	1000	1100	1
0111			
0001	1100	0110	0
0000	1110	0011	0
1001			
<b>1100</b>	<b>1111</b>	1001	1

4 clock cycle  
after, STOP

# Radix-4 Booth Multiplication

➤ Rule of radix -4 booth multiplication

$x_i$	$x_{i-1}$	$x_{i-2}$	Operation	$y_i$	$y_{i-1}$	$y$
0	0	0	$0+0=0$	0	0	0
0	0	1	$0+A=A$	0	1	+1
0	1	0	$2A-A=+A$	0	1	+1
0	1	1	$2A+0=2A$	1	0	+2
1	0	0	$-2A+0=-2A$	-1	0	-2
1	0	1	$-2A+A=-A$	0	-1	-1
1	1	0	$0-A=-A$	0	-1	-1
1	1	1	$0+0=0$	0	0	0

# PRACTICE

# Project Properties

## ➤ New Project Wizard

- ✓ Project name : multiplier
- ✓ Family & Device : Cyclone V 5CSXFC6D6F31C6 (밑에서 6번째)

# Pin Description

Direction	Port name	Description
Input	clk	Clock
	reset_n	Active low reset
	multiplier[63:0]	승수
	multiplicand[63:0]	피승수
	op_start	Start operation
	op_clear	Clear operation
Output	op_done	Done operation
	result[127:0]	Multiplier result

# Assignment 9

## ➤ Report

- ✓ 자세한 사항은 homework & practice document 참고

## ➤ Submission

- ✓ Soft copy
  - 강의 후 2주 뒤 제출
  - Delay는 2일까지

Q&A

**THANK YOU**