

Radix 2 Booth

$$X = -113$$

$$X_{C_2} = -128 - 15$$

$$= 10001111$$

$$Y = 79$$

$$Y_{C_2} = 64 + 15$$

$$Y_{C_2} = 01001111$$

$$-Y_{C_2} = 10110001$$

$$\begin{array}{r} -113 \\ +79 \\ \hline 1017 \\ 791 \\ \hline -8927 \end{array}$$

CNT	A	Q	Q-1
000	0000 0000 +10110001 ----- 10110001 11011000 -----	10001111	0-m
001	11101100	01100011	1-sh
010	11110110	00110001	1-sh
011	11111011	00011000	1+m
100	+01001111 ----- 01001010 00100101	00001100	0-sh
101	00010010	10000110	0-sh
110	00001001	01000011	0-m
111	+10110001 ----- 10111010	11011101	00100001
	11011101	00100001	1

Radix 4 Booth

$$X = 11000\ 1111$$

$$Y = 00100\ 1111$$

$$-Y = 11011\ 0001$$

$$2Y = 010011110$$

$$-2Y = 101100010$$

CNT	A	Q	R_{-1}
00	$\begin{array}{r} 0\ 0\ 0\ 0\ 0\ 0\ 0\ 0 \\ + 1\ 1\ 0\ 1\ 1\ 0\ 0\ 1 \\ \hline 1\ 1\ 0\ 1\ 1\ 0\ 0\ 0\ 1 \\ 1\ 1\ 1\ 1\ 0\ 1\ 1\ 0\ 0 \end{array}$	$1\ 0\ 0\ 0\ 1\ 1\ 1\ 1$	0 m
01	$1\ 1\ 1\ 1\ 1\ 1\ 0\ 1\ 1$	$0\ 0\ 0\ 1\ 1\ 0\ 0\ 0$	m
10	$\begin{array}{r} + 0\ 0\ 1\ 0\ 0\ 1\ 1\ 1\ 1 \\ \hline 0\ 0\ 1\ 0\ 0\ 1\ 0\ 1\ 0 \\ 0\ 0\ 0\ 0\ 1\ 0\ 0\ 1\ 0 \end{array}$	$1\ 0\ 0\ 0\ 0\ 1\ 1\ 0$	$-2m$
11	$\begin{array}{r} + 1\ 0\ 1\ 1\ 0\ 0\ 0\ 1\ 0 \\ \hline 1\ 0\ 1\ 1\ 1\ 0\ 1\ 0\ 0 \\ 1\ 1\ 1\ 0\ 1\ 1\ 1\ 0\ 1 \end{array}$	$0\ 0\ 1\ 0\ 0\ 0\ 0\ 1$	✓

Radix 8 Booth

$$X = 11000\ 1111$$

$$Y = 000100\ 1111$$

$$-Y = 111011\ 0001$$

$$2Y = 0010011110$$

$$-2Y = 1101100010$$

$$3Y = 0011101101$$

$$-3Y = 1100010011$$

CNT	A	Q	a_{-1}
00	$ \begin{array}{r} 00\ 0000\ 0\ 0000 \\ +111011\ 0001 \\ \hline 111011\ 0001 \end{array} $ $ \begin{array}{r} 111111\ 0110 \\ +001110001 \\ \hline 001110001 \end{array} $	$ \begin{array}{r} 110001111 \\ \boxed{0} \\ 001110001 \end{array} $	\downarrow
01	$ \begin{array}{r} +001001\ 1110 \\ \hline 001001\ 0100 \end{array} $ $ \begin{array}{r} 000001\ 0010 \\ +100001110 \\ \hline 100001110 \end{array} $	$ \begin{array}{r} 001001000 \\ \boxed{1} \\ 100001110 \end{array} $	\downarrow
10	$ \begin{array}{r} +1101100110 \\ \hline 1101110100 \end{array} $ $ \begin{array}{r} 11111101110 \\ \boxed{1} \\ 100010001 \end{array} $	$ \begin{array}{r} 100010001 \\ \boxed{1} \\ 100010001 \end{array} $	\checkmark

106 / 25

$$X = 108 = 64 + 32 + 8 + 4$$

4; 8



$$= 0000 \ 0000 \ 0110 \ 1100$$

$$Y = 25 = 0001 \ 1001$$

$$-Y = -1110 \ 0111$$

Restoring

CNT	A	Q
000	0000 0000	0110 1100
+	1110 0111	
(G)	1100 1111	
+	0001 1001	
	0000 0000	11011000
	0000 0000	↓
001	1-1 - - - sh	
+	0000 0001	1011 0000
010	0000 0011	
011	0000 0111	0110 0000
100	0000 1110	1100 0000
101	0001 1101	1000 0000
110	+ 1110 0111	
	0000 0010 00	1000 0000 1
	0000 1000 1	0000 0001 0
111	+ 1110 0111	
	1110 1000 0	0000 0100
	+ 0001 1000	0
	0000 1000	4
	0000 1000	8 ✓

Non Restoring

$$M = 0001\ 1001$$

$$-M = 1110\ 0111$$

CNT	S	A	Q
000	0	0 000 0 000	0 110 1100
	+ 1	1 110 0 111	
	(1)	1 110 0 111	
	1	1 100 1 110	11011000
001	+ 0	0 001 1 001	
	(1)	1 110 0 111	
	1	1 100 1 111	10110000
010	+ 0	0 001 1 1001	
	(1)	1 110 1 000	
	1	1 101 0 001	01100000
011	+ 0	0 001 1 001	
	(1)	1 110 1 010	
	1	1 101 0 100	11000000
100	+ 0	0 001 1 001	
	(1)	1 110 1 101	
	1	1 101 1 011	10000000
101	+ 0	0 001 1 001	
	(1)	1 111 1 0100	
	1	1 111 0 1001	00000000
110	+ 0	0 001 1 001	
	(0)	0 000 0 0010	
	0	0 000 0 0100	00000010
111	+ 1	1 111 0 0111	
	(1)	1 111 0 1011	
COR	+ 0	0 001 1 001	
	0	0 000 0 1000	

SRT 2

$$M_F = 011001000$$

$$-M_I = 100111000$$

$$M_F = \begin{array}{r} 00011001 \\ 11001000 \\ \hline 12 \end{array}$$

$k=3$

CNT	A	Q
000	0 0000 0 0000	0 110 1100
	sh <u>0000000</u> $g_0 = 0$ 0011	0 110 0000
000	0 0000 0 0110	1 100 00000
	sh <u>0000000</u> $g_1 = 0$	
001	0 0000 0 1101 1	1 000 00000 00
	sh <u>0000000</u> $g_2 = 0$	
010	0 0000 1 1011 1	0 000 00000 000
	sh <u>0000000</u> $g_3 = 0$	
011	0 00110 110 0	0 0000000000
	sh <u>000110</u> $g_3 = 0$	
100	0 0110 0 1100	0 0000000000
	sh <u>00110</u> $g_4 = 1$	
101	0 11011 0 000	0 0000000001
+ 1001110 0 0	<u>0000000000</u>	0 0000000000
	sh <u>0000000000</u>	
110	0 0010000 0 0	0 000000100
	sh <u>0001000000</u>	
111	0 0100000 0 0	0 000001000
	sh <u>0000001000</u>	
shift	0 000001000 0	4 ✓
	<u>0000001000</u>	
	8 ✓	

SRT 4

$$-M = 100111000$$

$$M = 00011001$$

$$2M = 110010000$$

$$M = \underline{011001} \quad \text{CCG}$$

$$-2M = 001110000$$

$$K=3 \quad 12$$

CNT	A	Q
00	0 0000 0000 <u>2 = 0</u> 0000 2011	0 110 1100 0 110 0000
00	0 0000 1101 <u>0</u>	1 000 0000 0
01	<u>0 0011 0110 1</u>	0 0000 0000 0 0000 0000
10	0 1101 1000 + 10011 1000 <u>0 0001 0000</u>	0 0000 0000 1 0 0 0 0 0 0 0 0
11	0 0100 0000	0 0000 0000 0 P - 0 0 0 0 0 0 0 0
shift	00000 1000 <u>8</u>	00000 0100 <u>4</u> <u>K</u>

(1P OF)

1. Assume a program requires the execution of

3×10^6 FP instructions, 15×10^5 INT instructions, 6×10^6 L/S instructions, and 12×10^5 branch instructions. The CPI for each type of instruction is 1, 2, 2, and 3, respectively.

Assume that the processor has a 2 GHz clock rate.

- a) (1.5P) What is the execution time of the processor? What is the MIPS of the processor?
- b) (1P) By how much must we improve the CPI of INT instructions if we want the program to run 1.5 times faster?
- c) (1.5P) How is the execution time of the program affected if the CPI of INT and LS instructions is reduced by 20%, but the CPI of all other instructions is increased by 10%?

Depth radix 4: $-37 * -115$.

$$CR = 2 \text{ GHz}$$

INSTR	CPI	IC
FP	1	$3 \cdot 10^6$
INT	2	$15 \cdot 10^5$
L/S	2	$6 \cdot 10^6$
Bz	3	$12 \cdot 10^5$

$$\text{Cycles} = 1 \cdot 3 \cdot 10^6 + 2 \cdot 15 \cdot 10^5 + 2 \cdot 6 \cdot 10^6 + 3 \cdot 12 \cdot 10^5$$

$$\text{MIPS} = \frac{\text{IC}}{\text{CPU time} \cdot 10^6} = \frac{3 \cdot 10^5 + 75 \cdot 10^5}{\dots}$$