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## COMPUTER ARCHITECTURE & ORGANIZATION

DA-1

1.

$R8 \leftarrow \text{count}$

$R1 \leftarrow x$

$R2 \leftarrow y$

$R3 \leftarrow z$

set R4 R2 R1 // set R4 if  $R2 < R1$  ( $y < x$ )

beq R4 \$zero endit // if R4 is not set branch to endit

set R4 R3 R1 // set R4 if  $R3 < R1$  ( $z < x$ )

beq R4 \$zero endit // if R4 is not set branch to endit

addi R8 R8 #1 //  $R8 = R8 + 1$

endit

2.

i)  $(-16) + (-17)$

$-16 \rightarrow 2$ 's complement  $q_0$  (010000)

$\rightarrow 110000$

$-17 \rightarrow 2$ 's complement  $q_0$  (010001)

$\rightarrow 101111$

Addition

110000
101111
101111

carry and overflow

\*  $2$ 's complement  $q_0$  (011111)

$\rightarrow -(100001)$

$\rightarrow -33$

11) 117 + 112

17  $\rightarrow$  010001

112  $\rightarrow$  001100

010001

001100

011101

no carry and no overflow

Ans (011101)  $\rightarrow$  +29

3. We have instruction count :  $10^9$  instructions

The clock time can be computed quickly from the clock rate to be  $0.5 \times 10^{-9}$  seconds. so we only need to compute clocks per instruction as an effective value

Value	Frequency	Product
3	0.5	1.5
4	0.3	1.2
5	0.2	1.0
	CPI	3.7

$\Rightarrow$

Execution time =  $1 \times 10^9 \times 3.7 \times 0.5 \times 10^{-9}$

= 1.85 sec

4

$$1) 20 \times -13$$

$$M = 20$$

$$Q = -13$$

$$M = 010100$$

$$-M = 101011$$

$$\begin{array}{r} 1 \\ 101100 \end{array}$$

$$Q = -13$$

$$= 011011$$

$$110011$$

Count

A

Q

Q<sub>0</sub>

Action

6  $\begin{array}{r} 000000 \\ 101100 \\ \hline 101100 \end{array}$   $110011$  0 Initialization

$$101100$$

$$A \leftarrow A - M$$

$$110110$$

$$011001$$

1

Arithmetic  
Right Shift

5  $\begin{array}{r} 110110 \\ 111011 \\ \hline \end{array}$   $011001$  1  
 $001100$  1 Arithmetic  
Right Shift

4  $\begin{array}{r} 111011 \\ 010100 \\ \hline 100111 \end{array}$   $001100$  1  $A \leftarrow A + M$

$$100111$$

$$000111$$

$$100110$$

0

Arithmetic  
Right Shift

3  $\begin{array}{r} 000111 \\ 000011 \\ \hline \end{array}$   $100110$  0  
 $110011$  0 Arithmetic  
Right Shift

$$000011$$

$$110011$$

0

2  $\begin{array}{r} 000011 \\ 101100 \\ \hline 101111 \end{array}$   $1100$   $A \leftarrow A - M$

$$101111$$

$$101111$$

$$110111$$

$$111001$$

1

Arithmetic  
Right Shift

1  $\begin{array}{r} 110111 \\ 111011 \\ \hline \end{array}$   $111001$  1  
 $111001$  1 Arithmetic  
Right Shift

$$\begin{array}{r} 100000011 \\ 1 \\ \hline 100000100 \end{array}$$

$$100000100 \quad x = 260$$

11)  $-12 \times -11$

$M = -12 = 10100$

$Q = -11 = 10101$

$-M = 12 = 01100$

Count	A	Q	Q <sub>0</sub>	Action
5	$\begin{array}{r} 00000 \\ 01100 \\ \hline 01100 \\ 00110 \end{array}$	$\begin{array}{r} 10101 \\ 10101 \\ 01010 \end{array}$	$\begin{array}{r} 0 \\ 1 \end{array}$	<p>Initialization</p> <p><math>A = A - M</math></p> <p>right shift</p>
4	$\begin{array}{r} 00110 \\ 10100 \\ \hline 11010 \\ 11101 \end{array}$	$\begin{array}{r} 01010 \\ 01010 \\ 00101 \end{array}$	$\begin{array}{r} 1 \\ 1 \\ 0 \end{array}$	<p><math>A = A + M</math></p> <p>right shift</p>
3	$\begin{array}{r} 11101 \\ 01100 \\ \hline 101001 \end{array}$	$\begin{array}{r} 00101 \\ 00101 \end{array}$	$\begin{array}{r} 0 \\ 0 \end{array}$	<p><math>A = A - M</math></p> <p>right shift</p>
2	$\begin{array}{r} 00100 \\ 10100 \\ \hline 11000 \\ 11100 \end{array}$	$\begin{array}{r} 10010 \\ 10010 \\ 01001 \end{array}$	$\begin{array}{r} 1 \\ 1 \\ 0 \end{array}$	<p><math>A = A + M</math></p> <p>right shift</p>
1	$\begin{array}{r} 11100 \\ 01100 \\ \hline 101000 \end{array}$	$\begin{array}{r} 01001 \\ 01001 \end{array}$	$\begin{array}{r} 0 \\ 0 \end{array}$	<p><math>A = A - M</math></p> <p>shift right</p>

$$\begin{array}{c} 00 \\ \text{sign} \end{array} \overbrace{10000100}^x$$

$$x = 10000100$$

$$= 132$$

5.

i)  $A = 010111$        $B = 110110$

$M = 010111$   
 $M' = 101001$

$2 \times M = 101110$   
 $-2 \times M = 010010$

A	Q	Q <sub>0</sub>	SC	Action
$\begin{array}{r} 000000 \\ 010010 \\ \hline 010010 \end{array}$	110110	0	3	$-2 \times M$
$\begin{array}{r} 000100 \\ 101110 \\ \hline 110010 \end{array}$	101101	1	2	<del>ASR</del> Shift Right $+2M$
$\begin{array}{r} 111100 \\ 101001 \\ \hline 100101 \end{array}$	101011	0	1	AShift Right $-1 \times M$
111001	011010	1	0	
111001011010				

ii)  $A = 27$        $B = -11$

$M = 27 \rightarrow 011011$

$Q = -11 \rightarrow 110101$

$-1 \times M = 100101$   
 $2 \times M = 110110$   
 $-2 \times M = 001010$

A	Q	Q <sub>0</sub>	SC	Action
$\begin{array}{r} 000000 \\ 011011 \\ \hline 011011 \end{array}$	110101	0	3	$1 \times M$
$\begin{array}{r} 000110 \\ 011011 \\ \hline 100001 \end{array}$	111101	0	2	Shift Right $-1 \times M$
$\begin{array}{r} 111000 \\ 100101 \\ \hline 011101 \end{array}$	011111	0	1	Shift Right $-1 \times M$

Ans    000111    010111    1    0

ii)  $A = 20$        $B = -13$

$M = 010100$        $-1 \times M = 101100$   
 $Q = 110011$        $2 \times M = 101000$   
                           $-2 \times M = 011000$

A	Q	Q <sub>0</sub>	SC	Action
000000 <u>101100</u> 101100	110011	0	3	-1xM
111011 <u>010100</u> 001111	001100	1	2	shift Right 1xM
000011 <u>101100</u> 101111	110011	0	1	shift Right -1xM
111011	111100	1	0	shift Right

$2^1$ 's complement of 11101111100  
 $\Rightarrow -(100000100) = -260$

6. #

1)  $A = 22$      $B = 4$

$Q = 22 = 10110$      $M = 000100$      $-M = 111100$

n	A	Q	Action
5	$\begin{array}{r} 000000 \\ 000001 \\ 111100 \\ \hline 111101 \end{array}$	$\begin{array}{r} 10110 \\ 0110- \\ \hline 01100 \end{array}$	Shift left $A = A - M$ $Q[0] = 0$ Restore A
4	$\begin{array}{r} 000001 \\ 000010 \\ 111100 \\ \hline 111110 \end{array}$	$\begin{array}{r} 01100 \\ 1100- \\ \hline 11000 \end{array}$	Shift left $A = A - M$ $Q[0] = 0$ Restore A
3	$\begin{array}{r} 000010 \\ 000101 \\ 111100 \\ \hline 10000001 \end{array}$	$\begin{array}{r} 11000 \\ 1000- \\ \hline 100001 \end{array}$	Shift left $A = A - M$ $Q[0] = 01$
2	$\begin{array}{r} 000001 \\ 000011 \\ 111100 \\ \hline 111111 \end{array}$	$\begin{array}{r} 10001 \\ 0001- \\ \hline 00010 \end{array}$	Shift Left $A = A - M$ $Q[0] = 0$ Restore A
1	$\begin{array}{r} 000011 \\ 000110 \\ 111100 \\ \hline 1000010 \end{array}$	$\begin{array}{r} 00010 \\ 0010- \\ \hline 00101 \end{array}$	Shift left $A = A - M$ $Q[0] = 1$
0	$000010$	$00101$	

2

5

Quotient = 5

Remainder = 2

ii)

$$A = 46 \quad B = 11$$

$$-M = 1110101 \quad Q = 101110$$

h	A	Q	Action
6	$\begin{array}{r} 0000000 \\ 0000001 \\ 1110101 \\ \hline 1110110 \end{array}$	$\begin{array}{r} 101110 \\ 01110- \\ \hline 011100 \end{array}$	Shift left $A = A - M$ $Q[0] = 0$ , Restore A
5	$\begin{array}{r} 0000001 \\ 0000010 \\ 1110101 \\ \hline 1110111 \end{array}$	$\begin{array}{r} 011100 \\ 11100- \\ \hline 111000 \end{array}$	Shift left $A = A - M$ $Q[0] = 0$ , Restore A
4	$\begin{array}{r} 0000010 \\ 0000101 \\ 1110101 \\ \hline 1110101 \\ \hline 1110101 \end{array}$	$\begin{array}{r} 111000 \\ 11000- \\ \hline 110000 \end{array}$	Shift left $A = A - M$ $Q[0] = 0$ , Restore A
3	$\begin{array}{r} 0000101 \\ 0001011 \\ 1110101 \\ \hline 0000000 \end{array}$	$\begin{array}{r} 110000 \\ 10000- \\ \hline 10001 \end{array}$	Shift left $A = A - M$ $Q[0] = 1$
2	$\begin{array}{r} 0000000 \\ 0000001 \\ 1110101 \\ \hline 1110110 \end{array}$	$\begin{array}{r} 10001 \\ 0001- \\ \hline 00010 \end{array}$	Shift left $A = A - M$ $Q[0] = 0$ , Restore A
1	$\begin{array}{r} 0000001 \\ 0000010 \\ 1110101 \\ \hline 1110111 \end{array}$	$\begin{array}{r} 000010 \\ 00010- \\ \hline 000100 \end{array}$	Shift left $A = A - M$ $Q[0] = 0$ , Restore A
0	$0000010$	$000100$	

$$\text{Quotient} = 4$$

$$\text{Remainder} = 2$$



iii)  $A \oplus Q = \text{Dividend} = 12$   
 $B = \text{Divisor} = 3$   
 $Q = 1100$   
 $M = 00011$   
 $-M = 11100$

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11101

n	A	Q	Action
4	$\begin{array}{r} 00000 \\ 00001 \\ 11101 \\ \hline 11110 \end{array}$	$\begin{array}{r} 1100 \\ 100- \\ \hline 1000 \end{array}$	Initialization left shift $A \leftarrow A - M$ $q_0 \leftarrow 0$ Restore A
3	$\begin{array}{r} 00001 \\ 00011 \\ 11101 \\ \hline 1)00000 \end{array}$	$\begin{array}{r} 1000 \\ 000- \\ \hline 0001 \end{array}$	left shift $A \leftarrow A - M$ $q_0 \leftarrow 1$
2	$\begin{array}{r} 00000 \\ 00000 \\ 11101 \\ \hline 11101 \end{array}$	$\begin{array}{r} 00001 \\ 001- \\ \hline 0010 \end{array}$	left shift $A \leftarrow A - B$ $q_0 \leftarrow 0$ Restore A
1	$\begin{array}{r} 00000 \\ 00000 \\ 11101 \\ \hline 11101 \end{array}$ $\underline{00000}$ Remainder = 0	$\begin{array}{r} 0010 \\ 010- \\ \hline 0100 \end{array}$ $\underline{0100}$ Quotient = 4	left shift $A \leftarrow A - M$ <del><math>A \leftarrow A</math></del> $q_0 \leftarrow 0$ , Restore A

7  $A = 22 \quad B = 4$

i)

$n$	$M$	$A$	$Q$	Action
5	000100	000000 000001 111101	10110 0110_ 01100	Initialization shift left $A = A - M$ $q_0 \leftarrow 0$
4		111101 111010 111110	01100 1100_ 11000	shift left $A = A + M$ $q_0 \leftarrow 0$
3		111110 111101 000001	11000 1000_ 10001	shift left $A = A + M$ $q_0 \leftarrow 1$
2		000001 000011 111111	10001 0001_ 00010	shift left $A = A - M$ $q_0 \leftarrow 0$
1		111111 111110 000010	00010 0010_ 00101	shift left $A = A + M$ $q_0 \leftarrow 1$
0		000010 <u>          </u> Remainder	00101 <u>          </u> Quotient	

Remainder = 2

Quotient = 5

i)  $A = 46$   $B = 11$

$Q = 101110$   $M = 1011$

n	M	A	Q	Action
6	0001011	0000000 0000001 1110110 1110110 1101100	101110 01110- 011100 011100 11100-	Initialization shift left $A = A - M$ $q_0 \leftarrow 0$
5		1110110 1101100 1110111	011100 11100- 111000	shift left $A = A + M$ $q_0 \leftarrow 0$
4		1110111 1101111 1111010	111000 11000- 110000	shift left $A = A + M$ $q_0 \leftarrow 0$
3		1111010 1110101 0000000	110000 10000- 100001	shift left $A = A + M$ $q_0 \leftarrow 1$
2		0000000 0000001 1110110	100001 00001- 000010	shift left $A = A - M$ $q_0 \leftarrow 0$
1		1110110 1101100 1110111	000010 00010- 000100	shift left $A = A + M$ $q_0 \leftarrow 0$
		0000010	000100	
		2 (Remainder)	4 (Quotient)	

ii)  $A = 3$      $\beta = 7$

$n$	$M$	$A$	$Q$	Action
5	000111	000000 000001 111010	11111 1111- 11110	Initialization Shift left $A = A - M$
4		111010 1101010 111100	11110 1110- 11100	Shift left $A = A + M$ $q_0 \leftarrow 0$
3		111100 111001 000000	11100 1100- 11001	Shift left $A = A + M$ $q_0 \leftarrow 1$
2		000000 000001 111011	11001 1001- 10010	Shift left $A = A - M$ $q_0 \leftarrow 0$
1		111011 110111 111110	10010 0010- 00100	Shift left $q_0 \leftarrow 0$
0		$\underbrace{000011}_\text{Remainder} = 3$ $\underbrace{00100}_\text{Quotient} = 4$		