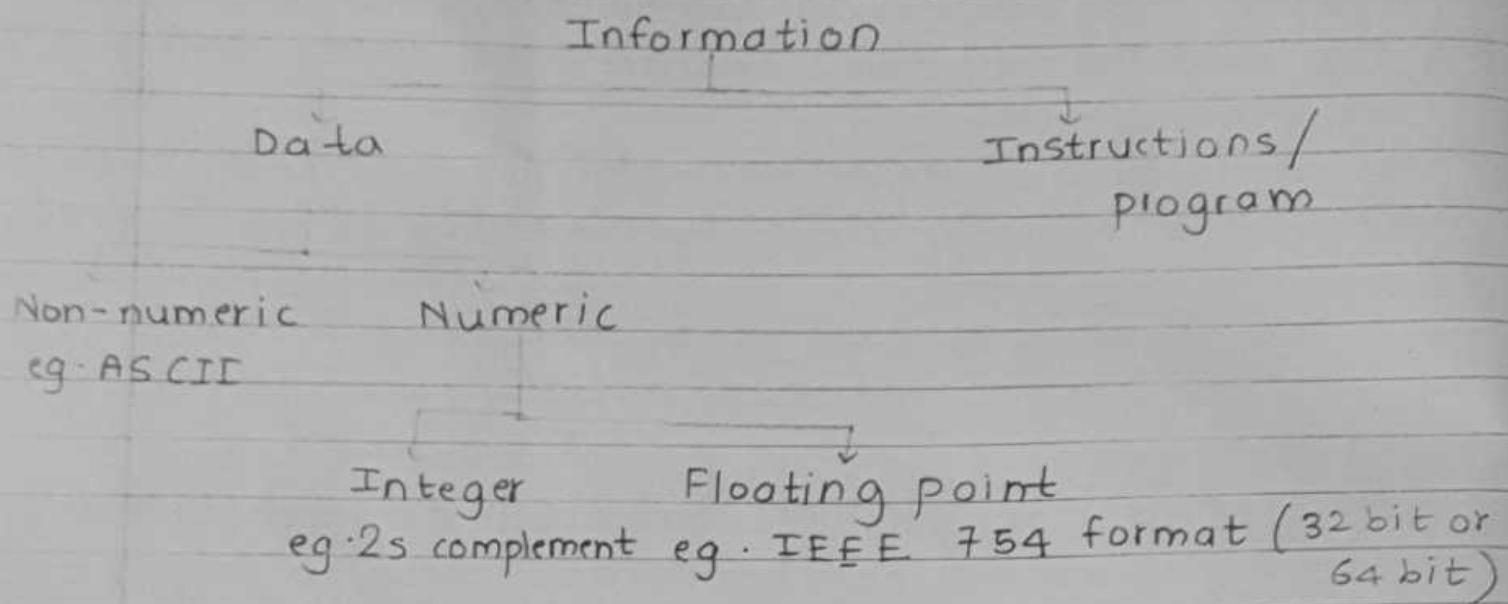


Data Representation inside the computer system:-



Floating point representation:-

Normalization :-

e.g.

$(0.01011)_2$

$(110.11)_2$

$(0.01001)_2$

$$(-1)^s \times 2^E \times 1.m$$

$s \rightarrow$ sign

$E \rightarrow$ exponent

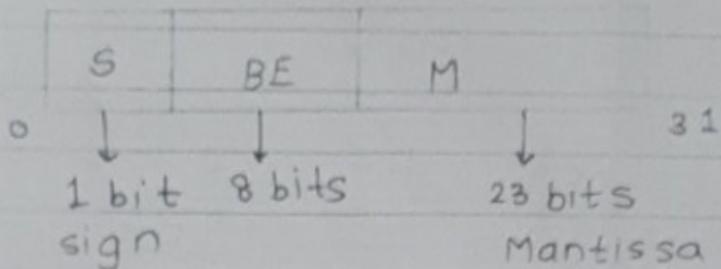
$m \rightarrow$ mantissa

Bias value = $2^{e-1} - 1$

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IEEE 754 32 bit format

-128 to +127



Biased

Exponent

$$BE = TE + 127$$

1 to 254 is only reserved for use.

0 and 255 are reserved for showing error

very

very high

1) $(9)_{10}$

Step 1:- $(1001 \cdot 0)_2$

Step 2:- Normalization

$$(-1)^5 \times 2^E \times 1 \cdot M$$

$$(-1)^0 + 2^3 + 1 \cdot 0010$$

Step 3:-

5	BE	M
---	----	---

$$M \rightarrow 0010$$

$$S \rightarrow 0$$

$$BE = TE + 127$$

$$= 3 + 127$$

$$= (130)_{10}$$

$$\Rightarrow (10000010 \cdot 0010)$$

Q E

0	10000010	0010
---	----------	------

$$\begin{array}{r}
 0.4 \\
 \times 2 \\
 \hline
 0.8
 \end{array}
 \quad
 \begin{array}{r}
 0.8 \\
 \times 2 \\
 \hline
 0.16
 \end{array}
 \quad
 \begin{array}{r}
 0.16 \\
 \times 2 \\
 \hline
 0.32
 \end{array}$$

2) $(15.4)_{10}$

Step 1:- $(1111.0110)_2$

$$\begin{array}{r}
 0.4 \\
 \times 2 \\
 \hline
 0.8
 \end{array}
 \quad
 \begin{array}{r}
 0.8 \\
 \times 2 \\
 \hline
 0.16
 \end{array}
 \quad
 \begin{array}{r}
 0.6 \\
 \times 2 \\
 \hline
 0.12
 \end{array}
 \quad
 \begin{array}{r}
 0.2 \\
 \times 2 \\
 \hline
 0.4
 \end{array}$$

→

Step 2:-

$$(-1)^S \times 2^E \times 1.M$$

$$(-1)^0 \times 2^3 \times 1 \cdot 1110110$$

$B.E. = T.E. + 127 = 3 + 127 = 130 = (130)_{10}$

0	10000010	1110110
---	----------	---------

3) $(-8.08)_{10}$

Step 1:- $(1000.0001)_2$

$$\begin{array}{r}
 0.08 \\
 \times 2 \\
 \hline
 0.16
 \end{array}
 \quad
 \begin{array}{r}
 0.16 \\
 \times 2 \\
 \hline
 0.32
 \end{array}
 \quad
 \begin{array}{r}
 0.32 \\
 \times 2 \\
 \hline
 0.64
 \end{array}
 \quad
 \begin{array}{r}
 0.64 \\
 \times 2 \\
 \hline
 1.28
 \end{array}$$

→

Step 2:-

$$(-1)^S \times 2^E \times 1.M$$

$$(-1)^1 \times 2^3 \times 1 \cdot 10000001$$

$$B.E. = T.E. + 127 = 130$$

1	10000010	10000001
---	----------	----------

3.) $(BFCOO)_{16}$ Step 1 :- $(1011\ 1111\ 1100\ 0000\ 0000)_2$

Step 2:-

$$(-1)^S + 2^E + 1 \cdot M$$

$$E = 19$$

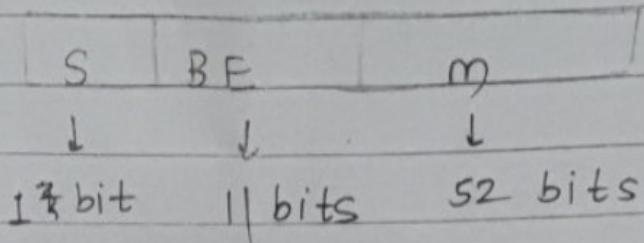
$$(-1)^S + 2^{19} + 1 \cdot 011\ 1111\ 1100\ 0000\ 0000$$

$$B \cdot E \cdot = T \cdot E \cdot + 127 = 19 + 127 = 146$$

$$= (10010010)_2$$

0	10010010	0111111100000000
---	----------	------------------

IEEE 754 (64 bit) Format



$$B.E. = T.E. + 1023$$

$$\begin{aligned} \text{Bias Value} &= 2^{E-1} - 1 \\ &= 2^{11-1} - 1 \\ &= 1023 \end{aligned}$$

Error / Exceptions in IEEE 754 floating point representation:- (For 32 bit)

i) overflow error -

- When the exponent is too large to be stored the condition is called as overflow.
- It occurs when the magnitude of the number becomes very large and it goes out of range.

This error is represented by showing the B.E. 255
(All 8 bits = 1)

(Not a number) (NAN)

$$\text{eg. } T.E. = 130 \text{ (left shift)}$$

$$B.E. = 130 + 127$$

$$= 257$$

257 cannot be represented by 8 bits of exponent.

2.) Underflow error -

- When the exponent is too small to be stored the conditⁿ is called as underflow error.
- It occurs when the no. becomes too small and cannot be normalised.
- The error is represented by making B·E = 0
- Such no. is called de-normalised number.

e.g. T·E = -129 (right shift)

$$\begin{aligned} B \cdot E &= -129 + 127 \\ &= -2 \end{aligned}$$

The aim to make B·E always +ve is not achieved. Hence all B·E bits are made 0.

Summary:- (For 32 bit)

	Exponent	Mantissa	Condition
Normal (valid no.)	$0 < E < 255$	$m = x$	Normal
Not a number (NAN)	$E = 255$	$m = x$	overflow
Infinite	$E = 255$	$m = \infty$	overflow
Denormalize no.	$E = 0$	$m = x$	Underflow
Zero.	$E = 0$	$m = 0$	Underflow

Half Adder

A	B	Sum	Carry
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

$$\text{sum} = \sum m(1, 2)$$

	\bar{B}	B	
A	\bar{B}	B	
\bar{A}	0	1	1
A	1	0	1
	2	3	

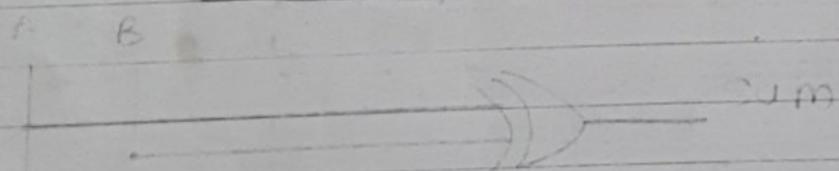
$$\text{Sum} = A\bar{B} + B\bar{A}$$

$$\text{Sum} = A \oplus B$$

$$\text{carry} = \sum m(3)$$

	\bar{B}	B	
\bar{A}	0	0	1
A	0	1	3
	2	3	

$$\text{carry} = AB$$



D carry

Full Adder

A	B	C	Sum	Carry
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
0	1	1	0	1
1	0	0	1	0
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

$$\text{Sum} = \sum m(1, 2, 4, 7)$$

	$\bar{B}\bar{C}$	$\bar{B}C$	$\bar{B}\bar{C}$	BC	$B\bar{C}$
\bar{A}	0	1	0	1	0
A	1	0	1	0	1
	4	5	6	7	2

$$\text{Sum} = A\bar{B}\bar{C} + \bar{A}\bar{B}C + A BC + \bar{A}B\bar{C}$$

$$= A(\bar{B}\bar{C} + BC) + \bar{A}(\bar{B}C + B\bar{C})$$

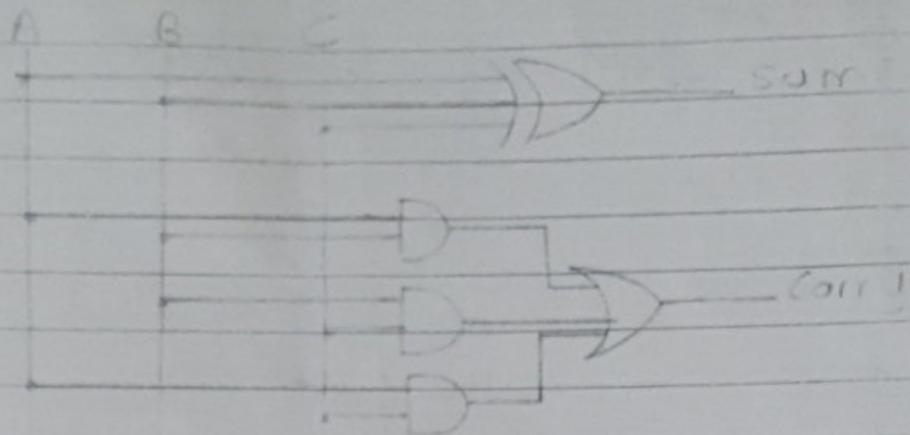
$$= A(\bar{B} \oplus C) + \bar{A}(B \oplus C)$$

$$= A \oplus B \oplus C$$

$$\text{Carry} = \sum m(3, 5, 6, 7)$$

	$\bar{B}\bar{C}$	$\bar{B}C$	BC	$B\bar{C}$
\bar{A}	0	1	1	2
A	1	0	1	0
	4	5	7	6

$$\text{Carry} = AC + BC + BA$$



carry look ahead adder:-

$$A \rightarrow A_3 A_2 A_1 A_0$$

$$B \rightarrow B_3 B_2 B_1 B_0$$

$$\text{sum} \rightarrow A \oplus B \oplus C_{in}$$

$$\text{carry} \rightarrow AB + BC_{in} + AC_{in}$$

$$C_i \rightarrow A_i B_i + B_i C_{in} + A_i C_{in}$$

$$\rightarrow A_i B_i + (A_i + B_i) C_{in}$$

$$\rightarrow g_i + p_i C_{in}$$

\downarrow
carry to be
generated by
current addition

\downarrow
carry to be
propogated

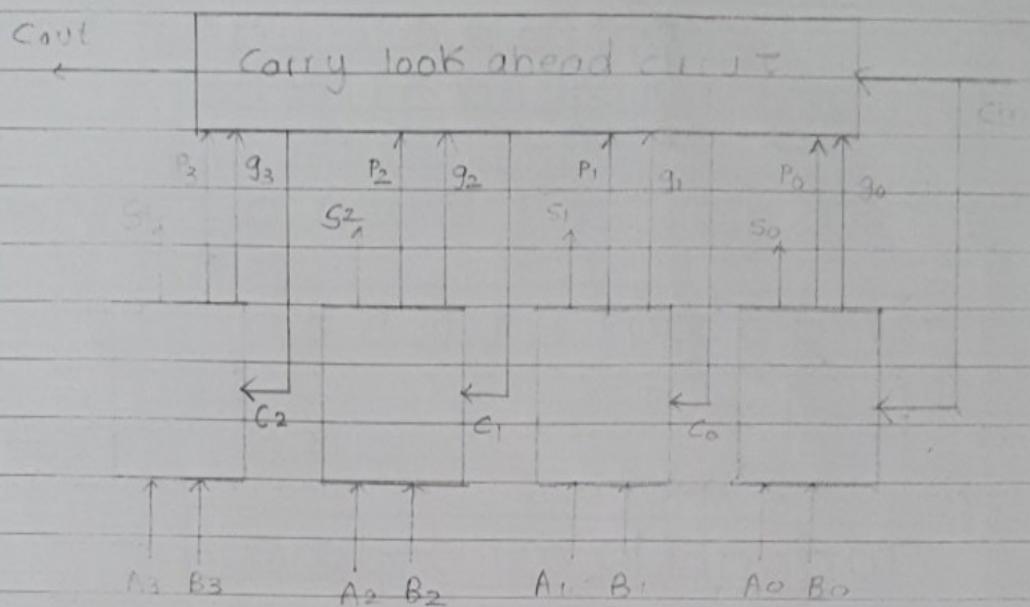
$$C^o = g_0 + p_0 C_{in}$$

$$\begin{aligned} C_1 &= g_1 + p_1 C^o \\ &= g_1 + p_1 (g_0 + p_0 C_{in}) \end{aligned}$$

$$\begin{aligned} C_2 &= g_2 + p_2 C_1 \\ &= g_2 + p_2 [g_1 + p_1 (g_0 + p_0 C_{in})] \end{aligned}$$

$$\begin{aligned}
 C_3 &= g_3 + P_3 C_2 \\
 &= g_3 + [g_2 + P_2(g_1 + P_1(g_0 + P_0 C_{in}))]
 \end{aligned}$$

Circuit diagram:-



Multiplication:-

Paper Pencil Method

$$\begin{array}{r}
 5 \times 3 \\
 0101 \times 0011
 \end{array}$$

$$\begin{array}{r}
 0 \ 1 \ 0 \ 1 \\
 \times 0 \ 0 \ 1 \ 1 \\
 \hline
 0 \ 1 \ 0 \ 1
 \end{array}$$

$$0 \ 1 \ 0 \ 1 \times$$

$$\textcircled{0} \ 0 \ 0 \ 0 \times \times$$

$$\underline{0 \ 0 \ 0 \ 0 \times \times}$$

$$(0 \ 0 \ 0 \ 1 \ 1 \ 1)_2$$

8 bit Accumulator

0000	0000
------	------

$$+ \underline{0101}$$

Add 0101

shift 00101000

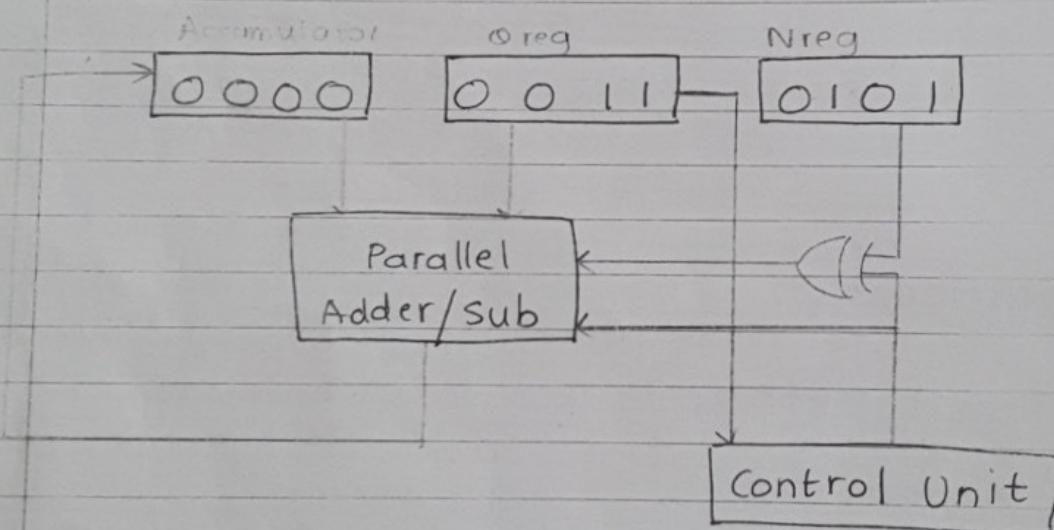
$$+ \underline{0101}$$

Add 01111000

shift 00111100

shift 00011110

shift 00001111



Step 1:- 0000

$$\begin{array}{r}
 + 0101 \\
 \hline
 0101 \\
 \boxed{0010} \quad 100\textcircled{b} \\
 \text{A} \qquad \text{Q}
 \end{array}$$

Step 2:- 0010

$$\begin{array}{r}
 + 0101 \\
 \hline
 0111 \quad 1000 \\
 \boxed{0011} \quad 1100 \\
 \text{A} \qquad \text{Q}
 \end{array}$$

Step 3:- 0011

$$\begin{array}{r}
 * \\
 0001 \quad 1110 \\
 \text{A} \qquad \text{Q}
 \end{array}$$

Step 4:- 0001

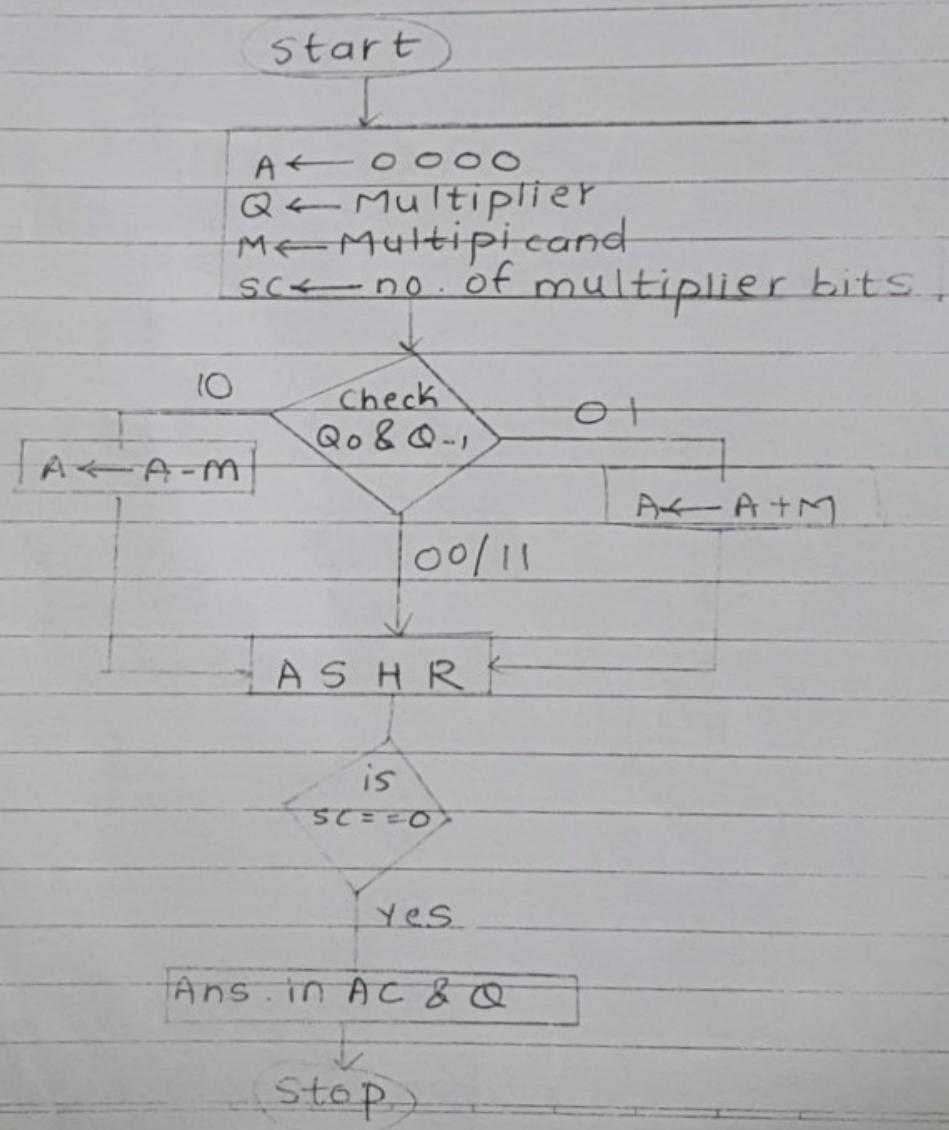
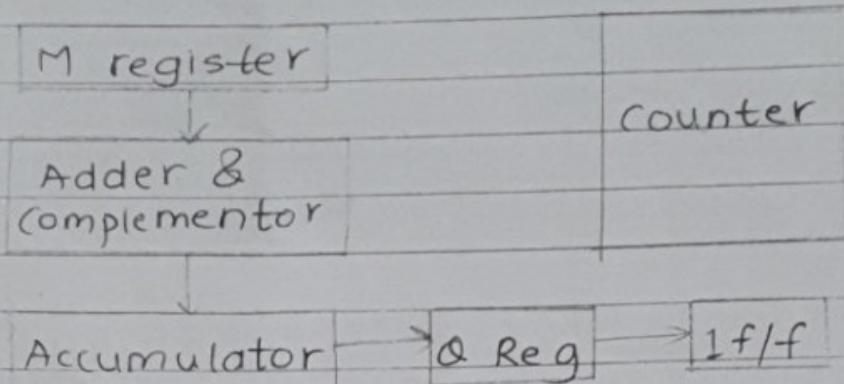
$$\begin{array}{r}
 0000 \quad 1111 \\
 \text{A} \qquad \text{Q}
 \end{array}$$

$$\begin{array}{r}
 45 \times (-3) \\
 \checkmark \quad \checkmark \\
 (0101)_2 \quad \overline{0011} = \begin{array}{r} 1100 \\ + 1 \\ \hline (1101)_2 \end{array}
 \end{array}$$

$$\begin{array}{r}
 0101 \\
 \times 1101 \\
 \hline
 0101 \\
 0000 \times \\
 0101 \times \times \\
 \hline
 10101 \times \times \times \\
 \hline
 10000001 \\
 0111110 \\
 + 1 \\
 \hline
 (0111111)_2
 \end{array}$$

Booth's Algorithm

Hardware Requirements.



5x3

$$A \rightarrow 0000, M \rightarrow 0101, -M \rightarrow 1011$$

$$Q \rightarrow 0011, SC \rightarrow 4$$

Count	Accumulator	Q Reg. Q ₃ Q ₂ Q ₁ Q ₀	Q ₋₁	Condition

4	0000	0011	0	Q ₀ , Q ₋₁ → 10 A ← A - M SC ← SC - 1 ASHR
	+ 1011			
	1011	0011	0	
	1101	1001	1	

3	1110	1100	1	Q ₀ , Q ₋₁ → 11 ASHR SC ← SC - 1

2	1110	1100	1	Q ₀ , Q ₋₁ → 01 A ← A + M ASHR SC ← SC - 1
	+ 0101			
	0011	1100	1	
	0001	1110	0	

1	0000	1111	0	Q ₀ , Q ₋₁ → 00 ASHR SC ← SC - 1 SC → 0, Stop

$$1111 \rightarrow -4 + 0 + 3$$

$$1111 \rightarrow -8 + 0 + 7$$

$$1111 \rightarrow -16 + 0 + 15$$

\rightarrow no. of bits in multiplier
 $A, C \rightarrow$ Always initialize to 0

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Date	_____

7×6

$$A \leftarrow 0000 \quad M \leftarrow 0111 \quad -M \rightarrow 1001$$

$$Q \leftarrow 0110 \quad SC \rightarrow 4$$

Count (SC)	Accumulator	Q Reg $Q_3 Q_2 Q_1 Q_0$	Q_{-1}	Condition
4	0000	0 1 1 0	0	$Q_0, Q_{-1} \rightarrow 00$
	0000	0 0 1 1	0	ASHR $SC \leftarrow SC - 1$
3	0000	0 0 1 1	0	$Q_0, Q_{-1} \rightarrow 10$
	+ 1001	0 0 1 1	0	$A \leftarrow A - M$
	1001	0 0 1 1	0	
	1100	1 0 0 1	1	ASHR $SC \leftarrow SC - 1$
2	1100	1 0 0 1	1	$Q_0, Q_{-1} \rightarrow 11$
	1110	0 1 0 0	1	ASHR $SC \leftarrow SC - 1$
1	1110	0 1 0 0	1	
	+ 0111	0 1 0 0		$A \leftarrow A + M$
1	0101	0 1 0 0		
	0010	1 0 1 0	0	ASHR
				Ans : (42) ₁₀

$$7 \times (-6)$$

$$\begin{array}{l} A \leftarrow 0000 \\ Q \leftarrow 1010 \end{array}$$

$$M \leftarrow 0111$$

$$SC \leftarrow 4$$

$$-M \leftarrow 1001$$

Unit	Accumulator	Q Reg	\oplus_1	Condition
sc)		$Q_3\ Q_2\ Q_1\ Q_0$		
4	0000	1 0 1 0	0	$Q_0, Q_1 \rightarrow 00$
	0000	0 1 0 1	0	ASHR $SC \leftarrow SC - 1$

3	0000	0 1 0 1	0	$Q_0, Q_1 \rightarrow 10$
	+ 1001			$A \leftarrow A - M$
	1001	0 1 0 1	0	
	1100	1 0 1 0	1	ASHR $SC \leftarrow SC - 1$

2	1100	1 0 1 0	1	$Q_0, Q_1 \rightarrow 01$
	+ 0111			$A \leftarrow A + M$

	0011	1 0 1 0	1	
	0001	1 1 0 1	0	ASHR $SC \leftarrow SC - 1$

1	0001	1 1 0 1	0	$Q_0, Q_1 \rightarrow 10$
	+ 1001			$A \leftarrow A - M$
	1010	1 1 0 1	0	

(1101 0110)₂ 1 ASHR

$SC \leftarrow SC - 1$

ANS = (-22)₁₀

As one of the

As multiplier is negative, ans will be in 2s complement.

$$(-7) \times 6$$

$$A \leftarrow 0000 \quad M \leftarrow 1001$$

$$Q \leftarrow 0110 \quad SC \leftarrow 4$$

$$-M \leftarrow 0111$$

Count	Accumulator	Q Reg	Q-1	Condition
		Q ₃ Q ₂ Q ₁ Q ₀		
4	0000	0 1 1 0	0	Q ₀ , Q-1 → 0, 0 ASHR SC ← SC - 1
	0000	0 0 1 1	0	
3	0000	0011	0	Q ₀ , Q-1 → 1, 0 A ← A - M
	+ 0111	0011		
	0111	1001	1	ASHR SC ← SC - 1
2	0011	1001	1	Q ₀ , Q-1 → 1, 1
	0001	1100	1	ASHR SC ← SC - 1
1	0001	1100	1	Q ₀ , Q-1 → 01
	+ 1001	1100		A ← A + M
	1010	1100		
	(1101 0110) ₂	0		ASHR SC ← SC - 1
				Ans = (-42) ₁₀

$$(-7) \times (-6)$$

$$\begin{array}{l} A \leftarrow 0000 \\ Q \leftarrow 1010 \end{array} \quad M \leftarrow 1001 \quad -M \leftarrow 0111$$

Count	Accumulator	Q Reg	Q-1	Condition
		Q ₃ Q ₂ Q ₁ Q ₀		

4	0 0 0 0	1 0 1 0	0	Q ₀ , Q-1 → 0, C
	0 0 0 0	0 1 0 1	0	ASHR
				SC ← SC - 1

3	0 0 0 0	0 1 0 1	0	Q ₀ , Q-1 → 1 0
	+ 0 1 1 1			A ← A - M
	<u>0 1 1 1</u>	0 1 0 1	0	
	0 0 1 1	1 0 1 0	1	ASHR

	0 0 1 1	1 0 1 0	1	Q ₀ , Q-1 → 0 1
	+ 1 0 0 1			A ← A + M
	<u>1 1 0 0</u>	1 0 1 0	1	
	1 1 1 0	0 1 0 1	0	ASHR

II	1 1 1 0	0 1 0 1	0	Q ₀ , Q-1 → 1 0
	+ 0 1 1 1			A ← A - M
	<u>0 1 0 1</u>	0 1 0 1	0	
	(0 0 1 0)	1 0 1 0	1	ASHR
		(4 2) ₁₀		

9×8

$$A \leftarrow 000000 \\ Q \leftarrow 010000$$

$$M \leftarrow 01001 \\ -M \leftarrow 10111$$

$$SC \leftarrow 45$$

Count	Accumulator	Q Reg	Q_1	Condition
45	0 0 0 0 0 0 0 0 0 0	0 1 0 0 0 0 0 1 0 0	0	$Q_0, Q_1 \rightarrow 00$ ASHR $SC \leftarrow SC - 1$
4	0 0 0 0 0 0 0 0	0 0 1 0 0 0 0 0 1 0	0	$Q_0, Q_1 \rightarrow 00$ ASHR $SC \leftarrow SC - 1$
3	0 0 0 0 0 0 0 0 0 0	0 0 0 1 0 0 0 0 0 1	0	$Q_0, Q_1 \rightarrow 00$ ASHR $SC \leftarrow SC - 1$
2	0 0 0 0 0 + 1 0 1 1 0 _____	0 0 0 0 1 1 0 1 1 0 1 1 0 1 1	0 0 1	$Q_0, Q_1 \rightarrow 10$ $A \leftarrow A - M$ ASHR $SC \leftarrow SC - 1$
1	1 1 0 1 1 + 0 1 0 0 1 _____	1 0 0 0 0 1 0 0 0 0 (00010 01000) ₂	1 0 0	$Q_0, Q_1 \rightarrow 01$ $A \leftarrow A + M$ ASHR $SC \leftarrow SC - 1$

$$(-5) \times (-2)$$

$$\begin{array}{l} A \leftarrow 000000 \\ M \leftarrow 11011 \\ S \leftarrow 5 \\ Q \leftarrow 111010 \\ -M \leftarrow 00101 \end{array}$$

Count Accumulator Q Reg Q-1 Condition

Q4 Q3 Q2 Q1 Q0

$$\begin{array}{rcl} 5 & \begin{array}{l} 00000 \\ + 00000 \end{array} & \begin{array}{l} | \\ 0 \end{array} \quad \begin{array}{l} | \\ | \\ | \\ | \\ 0 \end{array} \quad \begin{array}{l} 0 \\ | \\ | \\ | \\ 0 \end{array} \quad \begin{array}{l} 0 \\ | \\ | \\ | \\ 0 \end{array} \\ & \hline & \end{array} \quad \begin{array}{l} Q_0, Q_1 \rightarrow 0, 0 \\ ASHR \\ SC \leftarrow SC - 1 \end{array}$$

$$\begin{array}{rcl} 4 & \begin{array}{l} 00000001111 \\ + 00101 \\ \hline 00101011111 \\ 00010101111 \end{array} & \begin{array}{l} | \\ 0 \end{array} \quad \begin{array}{l} | \\ | \\ | \\ | \\ | \end{array} \quad \begin{array}{l} 0 \\ | \\ | \\ | \\ | \end{array} \quad \begin{array}{l} 0 \\ | \\ | \\ | \\ | \end{array} \\ & \hline & \end{array} \quad \begin{array}{l} Q_0, Q_1 \rightarrow 10 \\ A \leftarrow A - M \\ ASHR \\ SC \leftarrow SC - 1 \end{array}$$

$$\begin{array}{rcl} 3 & \begin{array}{l} 00010101111 \\ 00001010111 \end{array} & \begin{array}{l} | \\ | \end{array} \quad \begin{array}{l} | \\ | \end{array} \quad \begin{array}{l} | \\ | \end{array} \quad \begin{array}{l} | \\ | \end{array} \\ & \hline & \end{array} \quad \begin{array}{l} Q_0, Q_1 \rightarrow 11 \\ ASHR \\ SC \leftarrow SC - 1 \end{array}$$

$$\begin{array}{rcl} 2 & \begin{array}{l} 00001010111 \\ 00000101011 \end{array} & \begin{array}{l} | \\ | \end{array} \quad \begin{array}{l} | \\ | \end{array} \quad \begin{array}{l} | \\ | \end{array} \quad \begin{array}{l} | \\ | \end{array} \\ & \hline & \end{array} \quad \begin{array}{l} Q_0, Q_1 \rightarrow 11 \\ ASHR \\ SC \leftarrow SC - 1 \end{array}$$

$$\begin{array}{rcl} 1 & \begin{array}{l} 00000101011 \\ 00000010101 \end{array} & \begin{array}{l} | \\ | \end{array} \quad \begin{array}{l} | \\ | \end{array} \quad \begin{array}{l} | \\ | \end{array} \quad \begin{array}{l} | \\ | \end{array} \\ & \hline & \end{array} \quad \begin{array}{l} Q_0, Q_1 \rightarrow 11 \\ ASHR \\ SC \leftarrow SC - 1 \end{array}$$

14×3

$$A \leftarrow 00000 \quad M \leftarrow 01110 \quad SC \leftarrow 5$$

$$Q \leftarrow 00011 \quad -M \leftarrow 10010$$

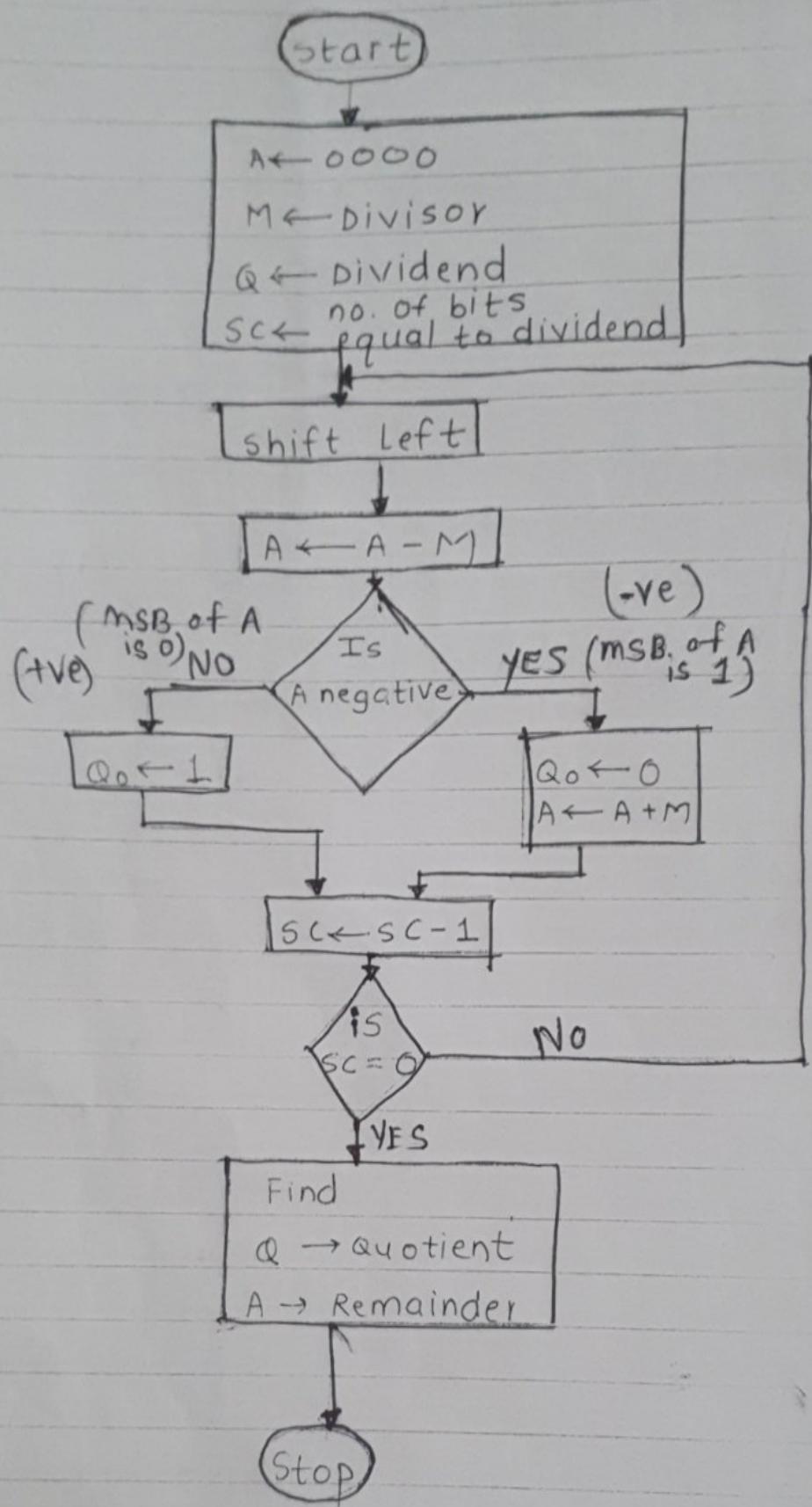
sunt	Accumulator	Q Reg	Q-1	Condition
5	00000	0 0 0 1 1	0	$Q_0, Q_{-1} \rightarrow 10$
	+10010			$A \leftarrow A - M$
	<u>10010</u>	0 0 0 1 1	0	B
	11001	0 0 0 0 1	1	ASHR $SC \leftarrow SC - 1$
4	11001	0 0 0 0 1	1	$Q_0, Q_{-1} \rightarrow 00$
	11100	1000000 0 0 0 0	1	ASHR
				$SC \leftarrow SC - 1$
3	11100	10000	1	$Q_0, Q_{-1} \rightarrow 01$
	+01110			$A \leftarrow A + M$
	<u>01010</u>	10000	1	ASHR
	00101	01000	0	$SC \leftarrow SC - 1$
2	00101	01000	0	$Q_0, Q_{-1} \rightarrow 00$
	00010	10100	0	ASHR
				$SC \leftarrow SC - 1$
1	00001	01010	0	ASHR
				$SC \leftarrow SC - 1$
		(42) ₁₀		

Restoring division Algorithm:-

$$4 \overline{)64}$$

$$\begin{array}{r} 8 \\ \hline 64 \\ -6 \\ \hline 8 \\ -8 \\ \hline 0 \end{array}$$

- In this we consider 1st digit of dividend
- We subtract divisor from the digit
- If ans is +ve \Rightarrow quotient is 1
- If ans is -ve \Rightarrow we add divisor and restore the no. and make quotient zero.
- Hence it is called as restoring division algorithm



7 ÷ 3

 $A \rightarrow 0000, Q \rightarrow 0111, M \rightarrow 0011, -M \rightarrow 1101$
 $SC \rightarrow 4$

SC	A	Q	Condition
4	0 0 0 0	0 1 1 1	LSH
	0 0 0 0	1 0 0 1 1	LSH
	+ 1 1 0 1		$A \leftarrow A - M$
	1 1 0 1	1 1 1 0	$A \leftarrow \text{negative}; Q_0 \leftarrow 0$
	+ 0 0 1 1		$A \leftarrow A + M$
	1 0 0 0 0	1 1 1 0	$SC \leftarrow SC - 1$
3	0 0 0 1	1 1 0 0	LSH
	+ 1 1 0 1		$A \leftarrow A - M$
	1 1 1 0	1 1 0 0	$A \leftarrow \text{neg}; Q_0 \leftarrow 0$
	+ 0 0 1 1		$A \leftarrow A + M$
	1 0 0 0 1	1 1 0 0	$SC \leftarrow SC - 1$
2	0 0 1 1	1 0 0 0	LSH
	+ 1 1 0 1		$A \leftarrow A - M$
	1 0 0 0 0	1 0 0 0	$A \leftarrow \text{positive}; Q_0 \leftarrow 1$
			$SC \leftarrow SC - 1$
1	0 0 0 1	0 0 1 0	LSH
	+ 1 1 0 1		$A \leftarrow A - M$
	1 1 1 0	0 0 1 0	$A \leftarrow \text{negative}; Q_0 \leftarrow 0$
	+ 0 0 1 1		$A \leftarrow A + M$
	1 0 0 0 1	0 0 1 0	$SC \leftarrow SC - 1$

6 ÷ 2

$$A \leftarrow 0000$$

$$-M \leftarrow 1110$$

$$Q \leftarrow 0110$$

$$SC \leftarrow 4$$

$$M \leftarrow 0010$$

3:

Count Accumulator Q Reg Condition

$Q_3 \ Q_2 \ Q_1 \ Q_0$

$$+ \quad 0000 \quad 0 \ | \ 1 \ | \ 0$$

$$0000 \quad | \ | \ 0 \ \square$$

$$+ \underline{1110}$$

$$1110 \quad | \ | \ 0 \ | \ 0$$

$$A \leftarrow A - M$$

$$A \leftarrow \text{neg}; Q_0 \leftarrow 0$$

$$+ \underline{0010}$$

$$10000 \quad | \ | \ 0 \ 0$$

$$A \leftarrow A + M$$

$$SC \leftarrow SC - 1$$

3

$$0000 \quad 11 \ 0 \ 0$$

$$0001 \quad 100 \ \square$$

$$+ \underline{1110}$$

$$1111 \quad 100 \ | \ 0$$

$$A \leftarrow A - M$$

$$A \leftarrow \text{neg}; Q_0 \leftarrow 0$$

$$+ \underline{0010}$$

$$10001 \quad 100 \ 0$$

$$A \leftarrow A + M$$

$$SC \leftarrow SC - 1$$

2

$$0001 \quad 100 \ 0$$

$$0011 \quad 000 \ \square$$

$$LSH$$

$$+ \underline{1110}$$

$$10001 \quad 000 \ 0 \ 1$$

$$A \leftarrow A - M$$

$$A \leftarrow \text{pos}; Q_0 \leftarrow 1$$

$$SC \leftarrow SC - 1$$

1

$$0001 \quad 000 \ 0 \ 1$$

$$0010 \quad 00 \ 1 \ \square$$

$$LSH$$

$$+ \underline{1110}$$

$$10000 \quad 00 \ 1 \ | \ 1$$

$$A \leftarrow A - M$$

$$A \leftarrow \text{pos}; Q_0 \leftarrow 1$$

$$SC \leftarrow SC - 1$$

R

O

$9 \div 4$

$$A \leftarrow 000000$$

$$Q \leftarrow 01001$$

$$M \leftarrow 00100$$

$$-M \leftarrow 11100$$

$$SC \leftarrow 5$$

Count	Accumulator	Q Reg	Condition
		$Q_4 \ Q_3 \ Q_2 \ Q_1 \ Q_0$	
5	0 0 0 0 0	0 1 0 0 1	
	0 0 0 0 0	1 0 0 1 <input type="checkbox"/>	LSH
+ 1 1 1 0 0	1 1 1 0 0	1 0 0 1 0	$A \leftarrow A - M$
	1 0 0 1 0 0	1 0 0 1 0	$A \leftarrow \text{neg}; Q_0 \leftarrow 0$
	1 0 0 0 0 0	1 0 0 1 0	$A \leftarrow A + M$
	1 0 0 0 0 0	1 0 0 1 0	$SC \leftarrow SC - 1$
4	0 0 0 0 0	1 0 0 1 0	
	0 0 0 0 1	0 0 1 0 <input type="checkbox"/>	LSH
+ 1 1 1 0 0	1 1 1 0 1	0 0 1 0 0	$A \leftarrow A - M$
	0 0 1 0 0	0 0 1 0 0	$A \leftarrow \text{neg}; Q_0 \leftarrow 0$
	0 0 0 0 1	0 0 1 0 0	$A \leftarrow A + M$
	0 0 0 0 1	0 0 1 0 0	$SC \leftarrow SC - 1$
3	0 0 0 0 1	0 0 1 0 0	
	0 0 0 1 0	0 1 0 0 <input type="checkbox"/>	LSH
+ 1 1 1 0 0	1 1 1 1 0	0 1 0 0 0	$A \leftarrow A - M$
	0 0 1 0 0	0 1 0 0 0	$A \leftarrow \text{neg}; Q_0 \leftarrow 0$
	0 0 0 1 0	0 1 0 0 0	$A \leftarrow A + M$
	0 0 0 1 0	0 1 0 0 0	$SC \leftarrow SC - 1$
2	0 0 0 1 0	0 1 0 0 0	
	0 0 1 0 0	1 0 0 0 <input type="checkbox"/>	LSH
+ 1 1 1 0 0	1 1 1 1 0	1 0 0 0 1	$A \leftarrow A - M$
	1 0 0 0 0	1 0 0 0 1	$A \leftarrow \text{pos}; Q_0 \leftarrow 1$
	1 0 0 0 0	1 0 0 0 1	$SC \leftarrow SC - 1$

1	<table border="1"> <tr><td>0 0 0 0 0 0</td><td>1 0 0 0 1</td></tr> <tr><td>0 0 0 0 1</td><td>0 0 0 1</td></tr> <tr><td>+ 1 1 1 0 0</td><td></td></tr> <tr><td>1 1 1 0 1</td><td>0 0 0 1</td></tr> <tr><td>+ 0 0 1 0 0</td><td>0 0 0 1 0</td></tr> <tr><td>1 0 0 0 0 1</td><td>0 0 0 1 0</td></tr> </table> <p>R Q</p>	0 0 0 0 0 0	1 0 0 0 1	0 0 0 0 1	0 0 0 1	+ 1 1 1 0 0		1 1 1 0 1	0 0 0 1	+ 0 0 1 0 0	0 0 0 1 0	1 0 0 0 0 1	0 0 0 1 0	LSH A \leftarrow A - M A \leftarrow neg; Q ₀ \leftarrow A \leftarrow A + M SC \leftarrow SC - 1
0 0 0 0 0 0	1 0 0 0 1													
0 0 0 0 1	0 0 0 1													
+ 1 1 1 0 0														
1 1 1 0 1	0 0 0 1													
+ 0 0 1 0 0	0 0 0 1 0													
1 0 0 0 0 1	0 0 0 1 0													

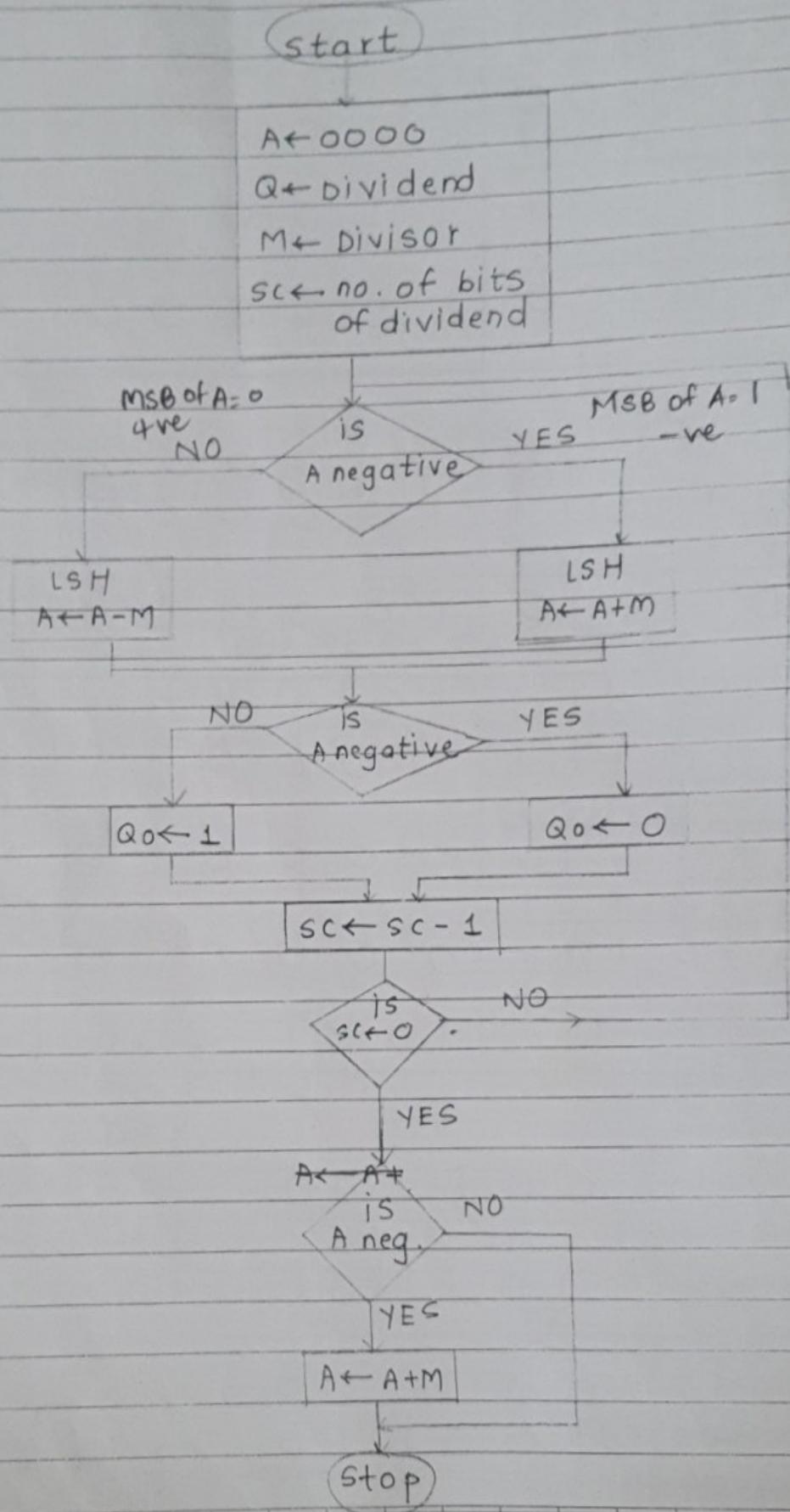
19 \div 7

$$\begin{array}{l}
A \leftarrow 000000 \quad M \leftarrow 000111 \quad SC \leftarrow 6 \\
Q \leftarrow 010011 \quad -M \leftarrow 111001
\end{array}$$

Count	Accumulator	Q Reg	Condition												
		Q ₅ Q ₄ Q ₃ Q ₂ Q ₁ Q ₀													
6	<table border="1"> <tr><td>0 0 0 0 0 0</td><td>0 1 0 0 1 1</td></tr> <tr><td>0 0 0 0 0 0</td><td>1 0 0 1 1</td></tr> <tr><td>+ 1 1 1 0 0 1</td><td></td></tr> <tr><td>1 1 1 0 0 1</td><td>1 0 0 1 1</td></tr> <tr><td>+ 0 0 0 1 1 1</td><td>0</td></tr> <tr><td>1 0 0 0 0 0</td><td>1 0 0 1 1 0</td></tr> </table>	0 0 0 0 0 0	0 1 0 0 1 1	0 0 0 0 0 0	1 0 0 1 1	+ 1 1 1 0 0 1		1 1 1 0 0 1	1 0 0 1 1	+ 0 0 0 1 1 1	0	1 0 0 0 0 0	1 0 0 1 1 0		LSH A \leftarrow A - M A \leftarrow neg; Q ₀ \leftarrow 0 A \leftarrow A + M SC \leftarrow SC - 1
0 0 0 0 0 0	0 1 0 0 1 1														
0 0 0 0 0 0	1 0 0 1 1														
+ 1 1 1 0 0 1															
1 1 1 0 0 1	1 0 0 1 1														
+ 0 0 0 1 1 1	0														
1 0 0 0 0 0	1 0 0 1 1 0														
5	<table border="1"> <tr><td>0 0 0 0 0 0</td><td>1 0 0 1 1 0</td></tr> <tr><td>0 0 0 0 0 1</td><td>0 0 1 1 0</td></tr> <tr><td>+ 1 1 1 0 0 1</td><td></td></tr> <tr><td>1 1 1 0 1 0</td><td>0 0 1 1 0 0</td></tr> <tr><td>+ 0 0 0 1 1 1</td><td></td></tr> <tr><td>1 0 0 0 0 1</td><td>0 0 1 1 0 0</td></tr> </table>	0 0 0 0 0 0	1 0 0 1 1 0	0 0 0 0 0 1	0 0 1 1 0	+ 1 1 1 0 0 1		1 1 1 0 1 0	0 0 1 1 0 0	+ 0 0 0 1 1 1		1 0 0 0 0 1	0 0 1 1 0 0		LSH A \leftarrow A - M A \leftarrow neg; Q ₀ \leftarrow 0 A \leftarrow A + M SC \leftarrow SC - 1
0 0 0 0 0 0	1 0 0 1 1 0														
0 0 0 0 0 1	0 0 1 1 0														
+ 1 1 1 0 0 1															
1 1 1 0 1 0	0 0 1 1 0 0														
+ 0 0 0 1 1 1															
1 0 0 0 0 1	0 0 1 1 0 0														
4	<table border="1"> <tr><td>0 0 0 0 0 1</td><td>0 0 1 1 0 0</td></tr> <tr><td>0 0 0 0 1 0</td><td>0 1 1 0 0</td></tr> <tr><td>+ 1 1 1 0 0 1</td><td></td></tr> </table>	0 0 0 0 0 1	0 0 1 1 0 0	0 0 0 0 1 0	0 1 1 0 0	+ 1 1 1 0 0 1			LSH A \leftarrow A - M						
0 0 0 0 0 1	0 0 1 1 0 0														
0 0 0 0 1 0	0 1 1 0 0														
+ 1 1 1 0 0 1															

	1 1 1 0 1 1 + 0 0 0 1 1 1 ----- ☒ 0 0 0 0 0 1 0	0 1 1 0 0 0 0 0 1 1 0 0 0 0	A ← neg; Q ₀ ← 0 A ← A + M sc ← sc - 1
3	0 0 0 0 1 0 0 0 0 1 0 0 + 1 1 1 0 0 1 ----- ☒ 0 0 0 1 0 0	0 1 1 0 0 0 0 1 1 0 0 0 0 0 1 1 0 0 0 0 0 1 1 0 0 0 0 0	LSH A ← A - M A ← neg; Q ₀ ← 0 A ← A + M sc ← sc - 1
2	0 0 0 1 0 0 0 0 1 0 0 1 + 1 1 1 0 0 1 ----- ☒ 0 0 0 0 1 0	1 1 0 0 0 0 0 1 0 0 0 0 0 0 1 0 0 0 0 0 0 1 0 0 0 0 0 1	LSH A ← A - M A ← pos; Q ₀ ← 1 sc ← sc - 1
1	0 0 0 0 1 0 0 0 0 1 0 1 + 1 1 1 0 0 1 ----- ☒ 0 0 0 1 0 1	1 0 0 0 0 0 1 0 0 0 0 0 1 0 0 0 0 0 0 1 0 0 0 0 0 0 1 0	LSH A ← A - M A ← neg; Q ₀ ← 0 A ← A + M sc ← sc - 1
	F 5	O 2	

Non-Restoring Algorithm:-



$7 \div 3$

$$\begin{array}{l} Q \leftarrow 0111 \\ A \leftarrow 0000 \\ M \leftarrow 0011 \end{array} \quad -M \leftarrow 1101 \quad SC \leftarrow 4$$

SC	Accumulator	Q	Condition
4	0 0 0 0	0	A is +ve
	0 0 0 0	<input type="checkbox"/>	LSH
	+ 1 1 0 1		$A \leftarrow A - M$
	1 1 0 1	<input checked="" type="checkbox"/>	$A \leftarrow -ve; Q_0 \leftarrow 0$ $SC \leftarrow SC - 1$
3	1 1 0 1	0	A is -ve
	1 0 1 1	0 <input type="checkbox"/>	LSH
	+ 0 0 1 1		$A \leftarrow A + M$
	1 1 1 0	0 <input checked="" type="checkbox"/>	$A \leftarrow -ve; Q_0 \leftarrow 0$ $SC \leftarrow SC - 1$
2	1 1 1 0	1 1 0 0	A is -ve
	+ 0 0 1 1		LSH
	0 0 0 0		$A \leftarrow A + M$
	1 1 0 1	1 0 0 <input type="checkbox"/>	
	+ 0 0 1 1		
	0 0 0 0	1 0 0 <input checked="" type="checkbox"/>	$A \leftarrow +ve; Q_0 \leftarrow 1$ $SC \leftarrow SC - 1$
1	0 0 0 0	1 0 0 1	
			$A \leftarrow +ve$
	0 0 0 1	0 0 1 <input type="checkbox"/>	LSH
	+ 1 1 0 1		$A \leftarrow A - M$
	1 1 1 0	0 0 1 0	$A \leftarrow -ve; Q_0 \leftarrow 0$ $SC \leftarrow SC - 1 = 0$
	+ 0 0 1 1		$A(-ve)$ $A \leftarrow A + M$
	0 0 0 1	0 0 1 0	

$$7 \div 5$$

$$A \leftarrow 0000$$

$$Q \leftarrow 0111$$

$$M \leftarrow 0101$$

$$-M \leftarrow 1011$$

$$Sc \leftarrow 4$$

count	Accumulator	Q	condition
4		$Q_3\ Q_2\ Q_1\ Q_0$	
	0 0 0 0	0 1 1 1	$A \leftarrow +ve$
	0 0 0 0	1 1 1 1	LSH
	+ 1 0 1 1		$A \leftarrow A - M$
	<u>1 0 1 1</u>	1 1 1 1	$A \leftarrow -ve; Q_0 \leftarrow 0$
		1 0	$Sc \leftarrow Sc - 1$
3	1 0 1 1	1 1 1 0	$A \leftarrow -ve$
	0 1 1 1	1 1 0 <input type="checkbox"/>	LSH
	+ 0 1 0 1		$A \leftarrow A + M$
	<u>1 1 0 0</u>	1 1 0 <input type="checkbox"/> 0	$A \leftarrow -ve; Q_0 \leftarrow 0$
		0	$Sc \leftarrow Sc - 1$
	1 1 0 0	1 1 0 0	$A \leftarrow -ve$
	1 0 0 1	1 0 0 <input type="checkbox"/>	LSH
	+ 0 1 0 1		$A \leftarrow A + M$
	<u>1 1 1 0</u>	1 0 0 0 <input type="checkbox"/>	$A \leftarrow -ve; Q_0 \leftarrow 0$
		0	$Sc \leftarrow Sc - 1$
	1 1 1 0	1 0 0 0	$A \leftarrow -ve$
	1 1 0 1	0 0 0 <input type="checkbox"/>	LSH
	+ 0 1 0 1		$A \leftarrow A + M$
	<u>1 0 0 1 0</u>	0 0 0 0 <input type="checkbox"/> 1	$A \leftarrow +ve; Q_0 \leftarrow 1$
		1	$Sc \leftarrow Sc - 1$
			$A \leftarrow +ve$
			stop

Q

R

$19 \div 7$

$A \leftarrow 0000000 \quad M \leftarrow 000111 \quad SC \leftarrow 6$

$Q \leftarrow 010011 \quad -M \leftarrow 111001$

Count	Accumulator	Q	Condition
		$Q_5 \ Q_4 \ Q_3 \ Q_2 \ Q_1 \ Q_0$	
6	0000000	0 1 0 0 1 1	$A \leftarrow +ve$
	0000000	1 0 0 1 1 <input type="checkbox"/>	LSH
	+ 111001		$A \leftarrow A - M$
	111001	1 0 0 1 1 0 <input checked="" type="checkbox"/>	$A \leftarrow -ve; Q_0 \leftarrow 0$ $SC \leftarrow SC - 1$
5	111001	1 0 0 1 1 0	$A \leftarrow -ve$
	110011	0 0 1 1 0 <input type="checkbox"/>	LSH
	+ 000111		$A \leftarrow A + M$
	111010	0 0 1 1 0 0 <input checked="" type="checkbox"/>	$A \leftarrow -ve; Q_0 \leftarrow 0$ $SC \leftarrow SC - 1$
4	111010	0 0 1 1 0 0	$A \leftarrow -ve$
	110100	0 1 1 0 0 <input type="checkbox"/>	LSH
	+ 000111		$A \leftarrow A + M$
	111011	0 1 1 0 0 0 <input checked="" type="checkbox"/>	$A \leftarrow -ve; Q_0 \leftarrow 0$ $SC \leftarrow SC - 1$
3	111011	0 1 1 0 0 0	$A \leftarrow -ve$
	110110	1 1 0 0 0 <input type="checkbox"/>	LSH
	+ 000111		$A \leftarrow A + M$
	111101	1 1 0 0 0 0 <input checked="" type="checkbox"/>	$A \leftarrow -ve; Q_0 \leftarrow 0$ $SC \leftarrow SC - 1$
2	111101	1 1 0 0 0 0	$A \leftarrow -ve$
	111011	1 0 0 0 0 <input type="checkbox"/>	LSH
	+ 000111		$Q_0 \leftarrow Q_1 \leftarrow A \leftarrow A + M$
	1000010	1 0 0 0 0 0 <input checked="" type="checkbox"/>	$A \leftarrow +ve; Q_0 \leftarrow 1$ $SC \leftarrow SC - 1$
1	0000010	1 0 0 0 0 1	$A \leftarrow +ve$
	000101	0 0 0 0 1 <input type="checkbox"/>	LSH
	+ 111001		$A \leftarrow A - M$
	111110	0 0 0 0 1 0 <input checked="" type="checkbox"/>	$A \leftarrow -ve; Q_0 \leftarrow 0$ $SC \leftarrow SC - 1$

111110	0000010	SC = 0
+000111		A ← -ve
1000101	0000010	A ← A + M

R Q

$$17 \div 3$$

A ← 000000

M ← 000011 SI ← 6

Q ← 010001

-M ← 111101

SC

Accumulator

Q

Condition

as Q₄ Q₃ Q₂ Q₁ Q₀

6	0000000	010001	A ← +ve
	0000000	10001□	LSH
+111101			A ← A - M
111101	10001010	A ← -ve; Q ₀ ← 0	SC ← SC - 1

5

111101 100010 A ← -ve

111011 00010□ LSH

+000011 A ← A + M

111110 0001010 A ← -ve; Q₀ ← 0
SC ← SC - 1

4

111110 0001000 A ← -ve

111100 001000□ LSH

+000011 A ← A + M

111111 0010000□ A ← -ve; Q₀ ← 0
SC ← SC - 1

3

111111 0010000 A ← +ve

+111110 010000□ LSH

+000011 A ← A + M

1000001 0100001 A ← +ve; Q₀ ← 1
SC ← SC - 1

2

0000001 0100001 A ← +ve

0000100 10001□ LSH

+111101 A ← A - M

111111 1000100 A ← -ve; Q₀ ← 0
SC ← SC - 1

1	1 1 1 1 1	1 0 0 0 1 0	A \leftarrow -ve
	1 1 1 1 1	0 0 0 1 0 □	LSH
	+ 0 0 0 0 1 1		A \leftarrow A + M
	0 0 0 0 1 0	0 0 0 1 0 1	A \leftarrow +ve ; Q ₀ \leftarrow 1 SC \leftarrow SC - 1
	0 0 0 0 1 0 R	0 0 0 1 0 1 Q	SC = 0 ; A \leftarrow +ve Stop
9 \div 2			
	A \leftarrow 0 0 0 0 0	M \leftarrow 0 0 0 1 0	SC \leftarrow 5
	Q \leftarrow 0 1 0 0 1	-M \leftarrow 1 1 1 1 0	
SC	Accumulator	Q	Condition
		Q ₄ Q ₃ Q ₂ Q ₁ Q ₀	
5 1	0 0 0 0 0	0 1 0 0 1	A \leftarrow +ve
	0 0 0 0 0	1 0 0 1 □	LSH
	+ 1 1 1 1 0		A \leftarrow A - M
	1 1 1 1 0	1 0 0 1 0 0	A \leftarrow -ve ; Q ₀ \leftarrow 0 SC \leftarrow SC - 1
4 3	1 1 1 1 0	1 0 0 1 0	A \leftarrow -ve
	1 1 1 0 1	0 0 1 0 □	LSH
	+ 0 0 0 1 0		A \leftarrow A + M
	1 1 1 1 1	0 0 1 0 0 0	A \leftarrow -ve ; Q ₀ \leftarrow 0 SC \leftarrow SC - 1
3 2	1 1 1 1 1	0 0 1 0 0	A \leftarrow -ve
	1 1 1 1 0	0 1 0 0 □	LSH
	+ 0 0 0 1 0		A \leftarrow A + M
	0 0 0 0 0	0 1 0 0 1	A \leftarrow +ve ; Q ₀ \leftarrow 1 SC \leftarrow SC - 1
2 1	0 0 0 0 0	0 1 0 0 1	A \leftarrow +ve
	0 0 0 0 0	1 0 0 1 □	LSH
	+ 1 1 1 1 0		SC A \leftarrow A - M
	1 1 1 1 0	1 0 0 1 0 0	A \leftarrow -ve ; Q ₀ \leftarrow 0

		Page No.:	Date:
1	1 1 1 1 0 + 0 0 0 1 0 ----- 0 0 0 0 0	1 0 0 1 0	$sc = 0$ $A \leftarrow -ve$ $A \leftarrow A + M$
1	1 1 1 1 0 1 1 1 0 1 + 0 0 0 1 0 -----	1 0 0 1 0 0 0 1 0 <input type="checkbox"/>	$A \leftarrow -ve$ LSH $A \leftarrow A + M$
		0 0 1 0 <input checked="" type="checkbox"/>	$A \leftarrow -ve; Q_0 \leftarrow 0$ $sc \leftarrow sc - 1$
	1 1 1 1 1 + 0 0 0 1 0 ----- R	0 0 1 0 0 0 0 1 0 0 Q	$sc = 0; A \leftarrow -ve$ $A \leftarrow A + M$

Floating point Arithematic:-

- 1] Multiplication
- 2] Division