# Arithmetic Division (Restoring and Non-Restoring Methods)

-Mitali Desai
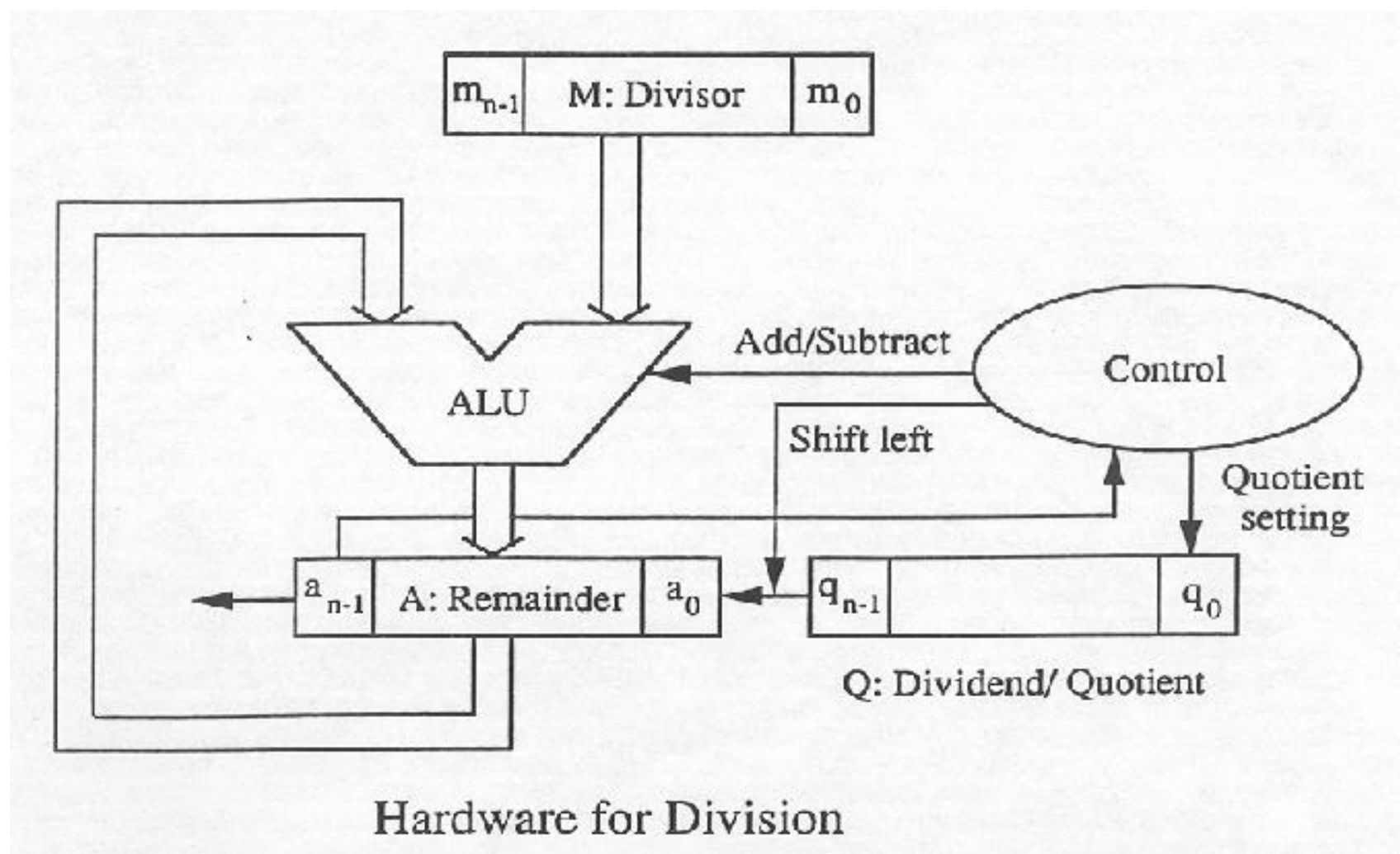
# Binary Division: Pen and Paper

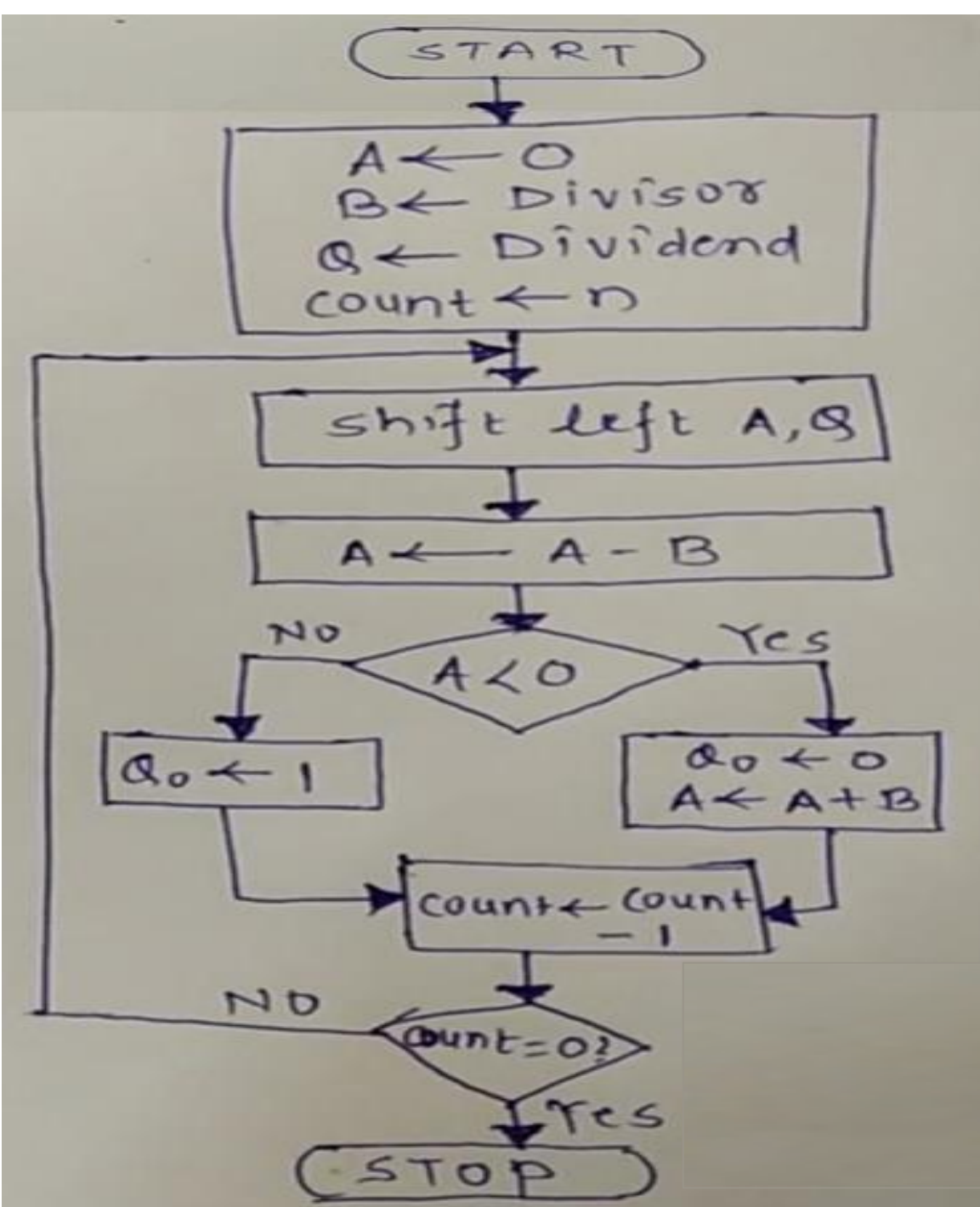**Decimal**                    **Binary**

```
                                                    Quotient
          5                                          101
      ┌──────            Divisor              ┌──────────
    3 │ 15                             11      │ 1111    Dividend
                                              -11
                                              ──────
                                               0011
                                                -11
                                              ──────
                                                 00
                                              Remainder
```

Hardware for Division

# Arithmetic Division (Restoring Method)

```
                    ( START )
                        |
                        v
        +-------------------------------+
        |  A <- O                       |
        |  B <- Divisor                 |
        |  Q <- Dividend                |
        |  count <- n                   |
        +-------------------------------+
                        |
                        v
        +-------------------------------+
        |       shift left A,Q          |
        +-------------------------------+
                        |
                        v
        +-------------------------------+
        |       A <- A - B              |
        +-------------------------------+
                        |
                        v
    NO              /  A < O  \              Yes
   +---------------<           >-------------+
   |                \         /              |
   v                                         v
+-----------+                        +-----------------+
|  Q0 <- 1  |                        |  Q0 <- 0        |
+-----------+                        |  A <- A + B     |
   |                                 +-----------------+
   |          +-------------------+       |
   +--------->| count <- count -1 |<------+
              +-------------------+
                        |
      NO                v
   +----------<  count = 0?  >
   |               \       /
   |                | Yes
   |                v
   |            ( STOP )
   |
   +-- (back to shift left A,Q)
```

Example : Dividend = 1010    $n = 4$
Divisor = 0011 $\Rightarrow B \Rightarrow 00011$
$\bar{B} + 1 = 11101$

| Operation | A | Q |
|---|---|---|
| Initially | 00000 | 1010 |

---

Example : Dividend = 1010    $n = 4$
Divisor = 0011 $\Rightarrow B \Rightarrow 00011$
$\bar{B} + 1 = 11101$

| Operation | A | Q |
|---|---|---|
| Initially | 00000 | 1010 |

$$
\begin{array}{ll}
\text{shift} & 00001\!\!\nearrow \quad\quad 010\square \\
\text{subtract} & +\,11101 \\
\hline
& 11110 \\
\text{set } Q_0 & +\,00011 \quad\quad 010\boxed{0} \\
\text{Restore A} & \otimes 0\,0000\!\downarrow
\end{array}
$$

$\Big\}$ 1st cycle

$$
\begin{array}{ll}
\text{shift} & 00010 \quad\quad 100\square \\
\text{subtract} & +\,11101 \\
\hline
& 11111 \\
\text{set } Q_0 + & 00011 \quad\quad 100\boxed{0} \\
\text{Restore} & \otimes 00010
\end{array}
$$

$\Big\}$ 2nd cycle

shift     0 0010   100☐  ⎫
subtract    1 1 1 01        ⎬ 2nd
            ――――――      ⎭ cycle
            1 1 1 11

set $Q_0$ +    0 0 0 11    100☐0☐
Restore    ⊗ 0 0 010   100☐0☐

shift       0 0 1 01   000☐ ⎫
subtract +   1 1 1 01       ⎬ 3rd
          ――――――      ⎭ cycle
set $Q_0$    ⊗ 0 0 0 10

         0 0 0 1 0   000☐1☐

operation     A         Q
            0 0 010    0 0 01  ⎫
shift       0 0 1 00    0 0 1☐ ⎬ 4th
subtract    1 1 1 01        ⎬ cycle
         ――――――      ⎭
        ⊗ 0 0 001

set $Q_0$
       0 0 0 0 1    0 0 1☐1☐
       ――――――    ――――――
           A           Q
    = Remainder   = Quotient



Flowchart:

START

A ← 0
B ← Divisor
Q ← Dividend
count ← n

shift left A, Q

A ← A − B

A < 0

NO → $Q_0$ ← 1

YES → $Q_0$ ← 0
        A ← A + B

count ← count − 1

count = 0?
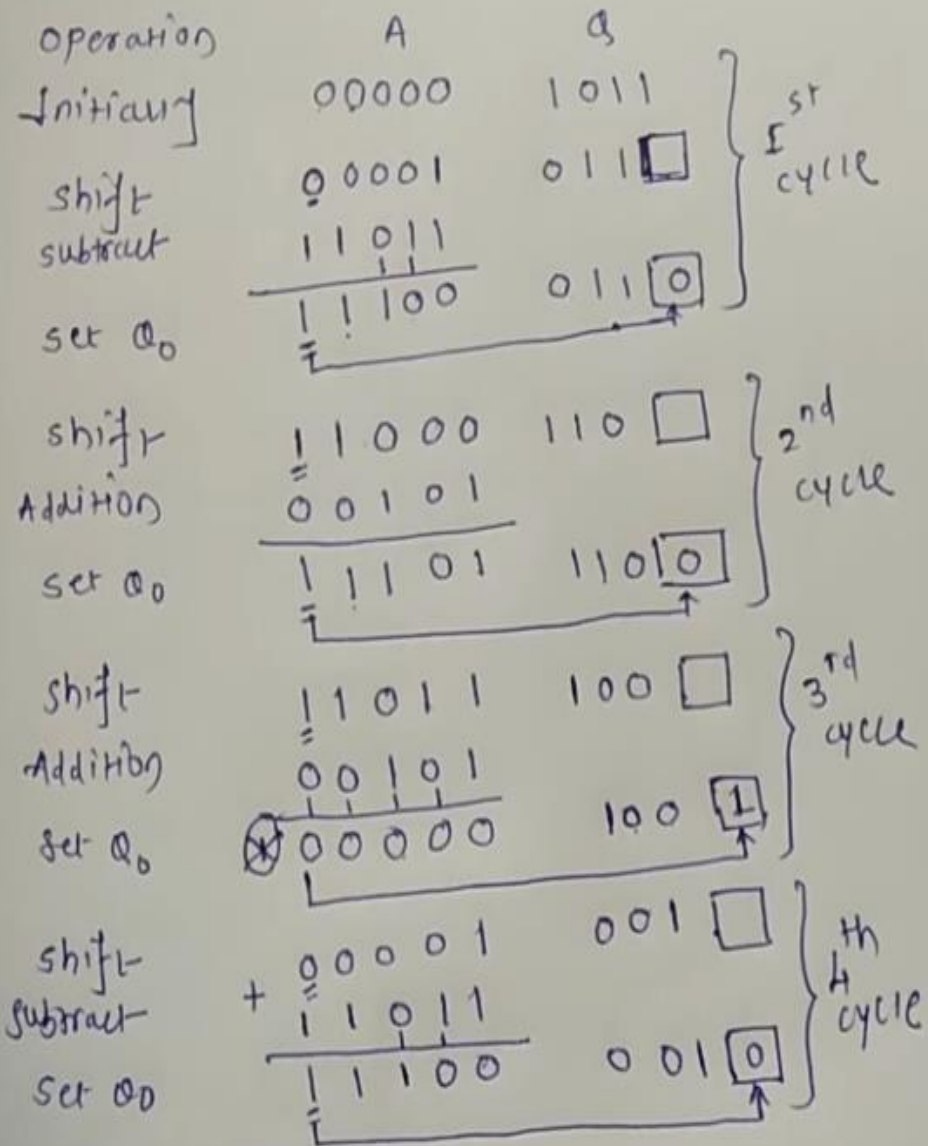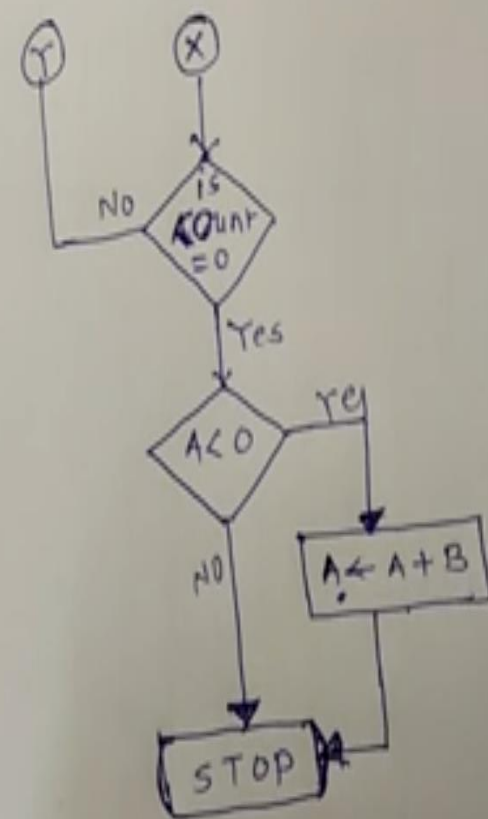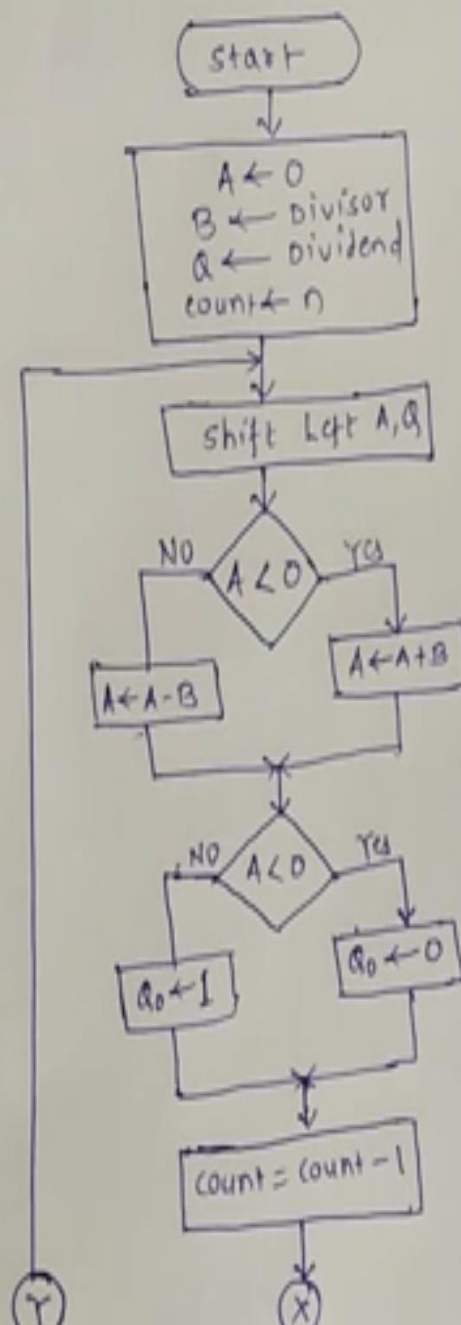
NO

YES → STOP
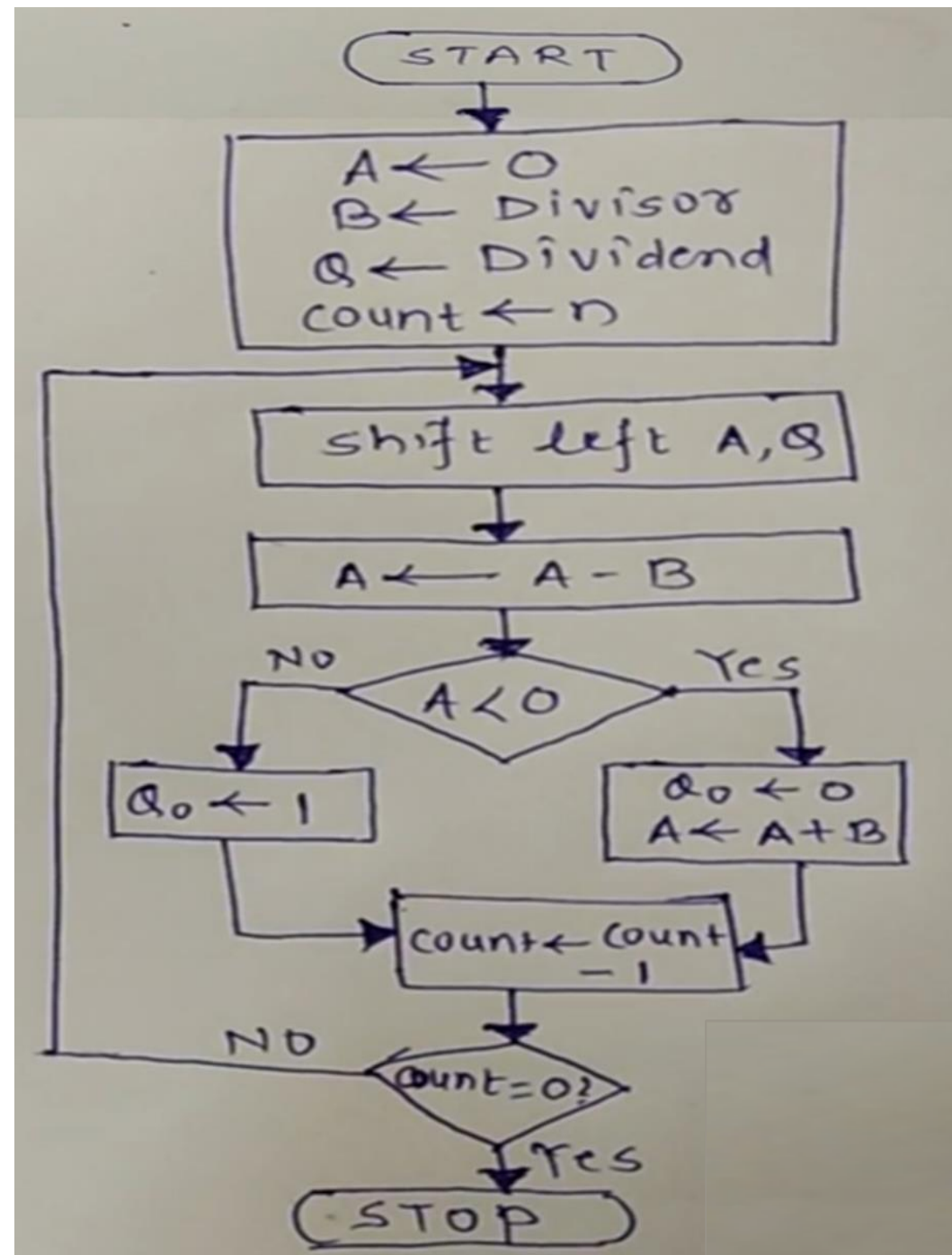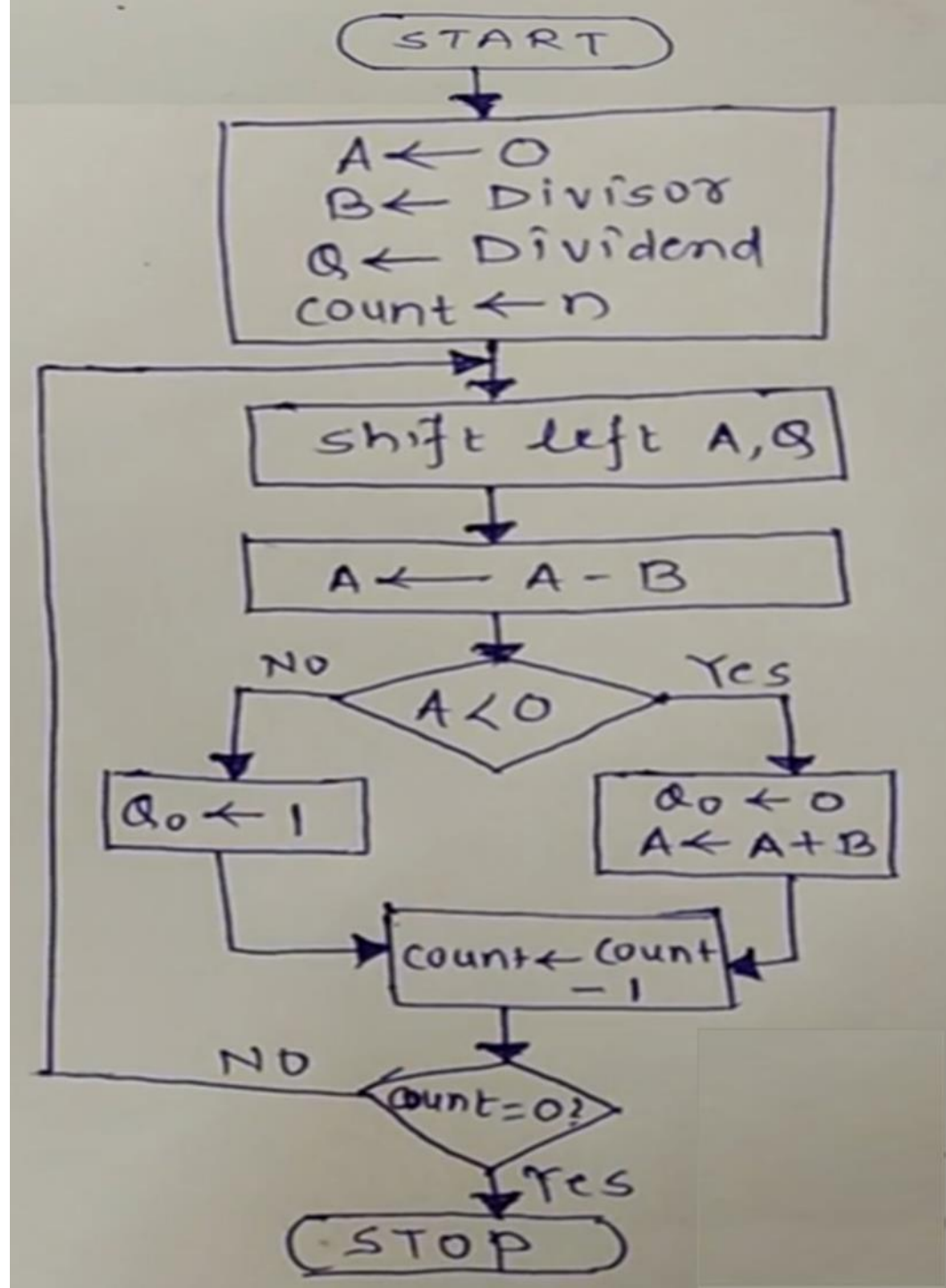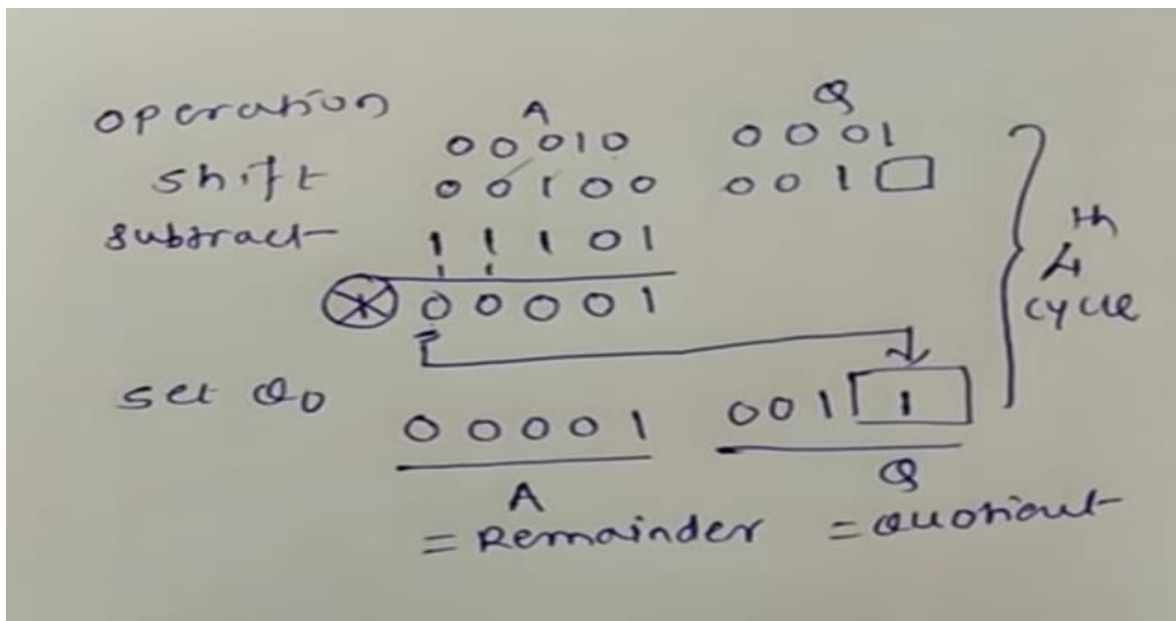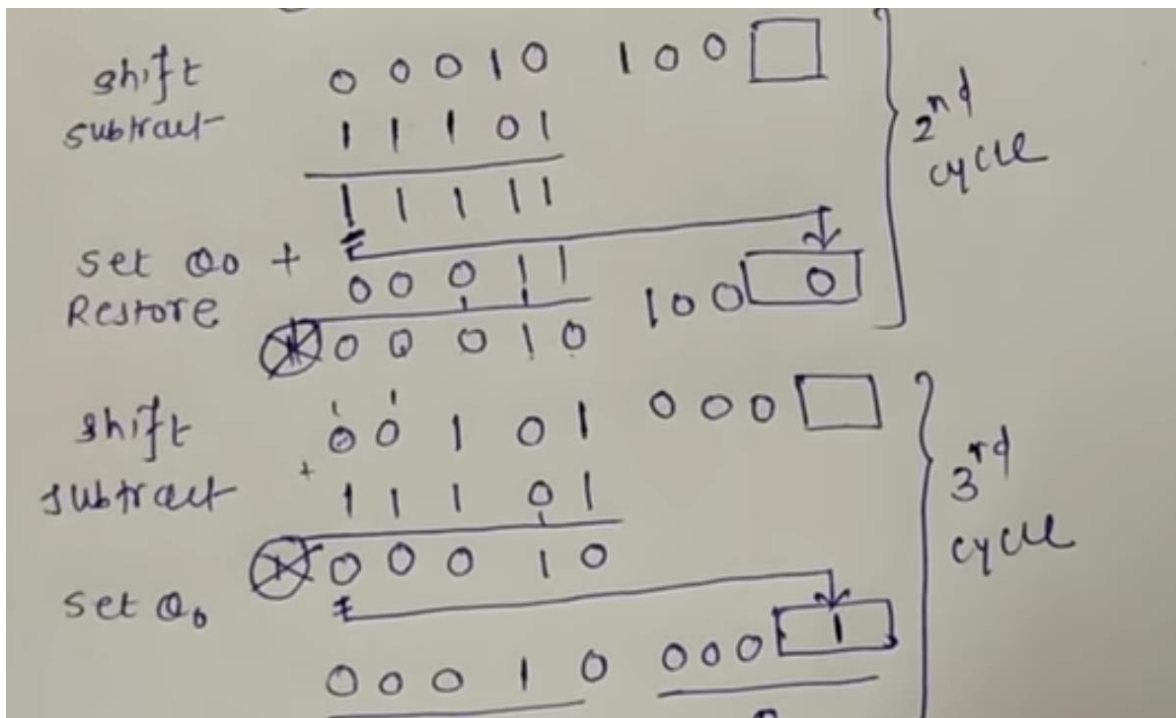
# Arithmetic Division
# (Non-Restoring Method)
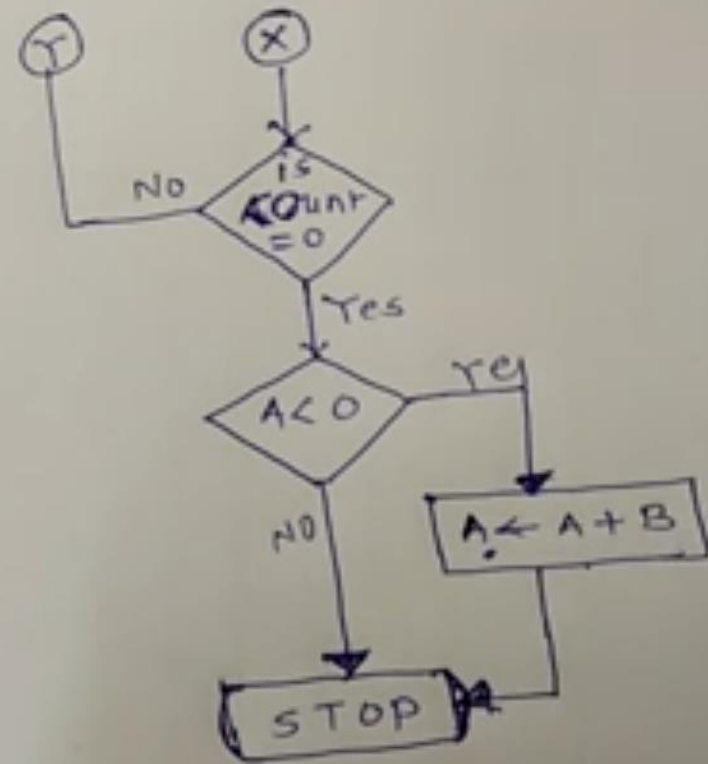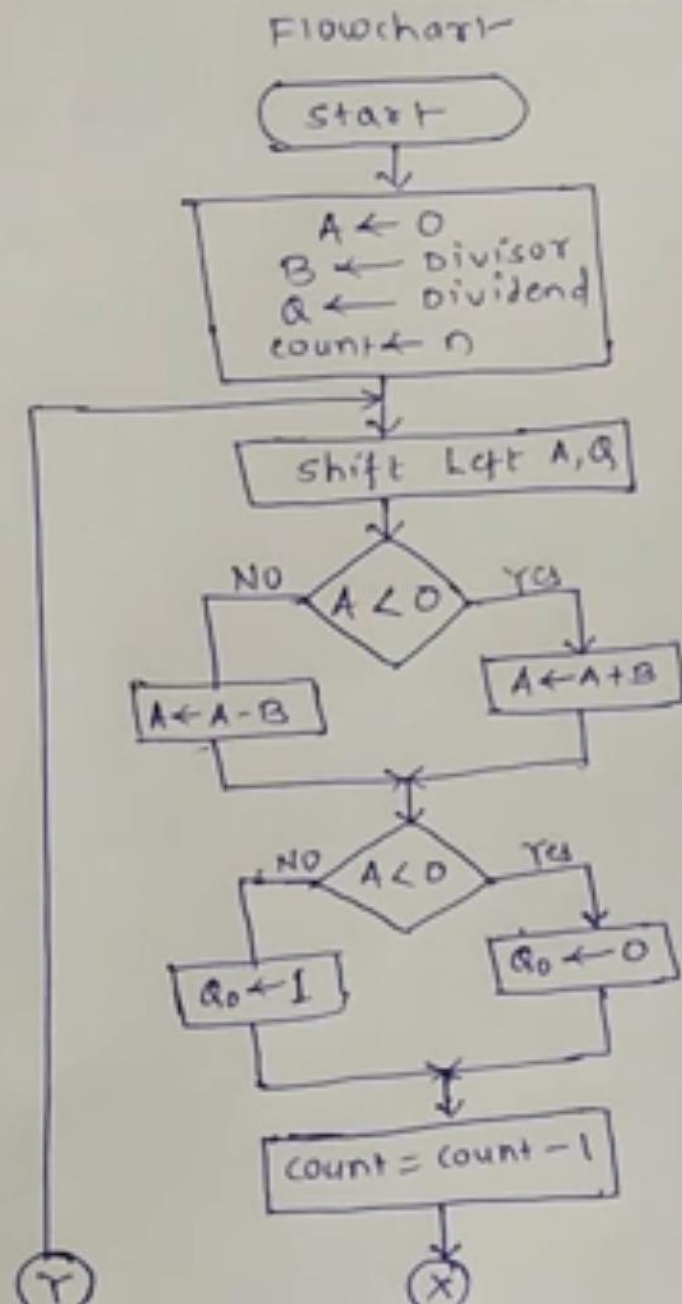
Flowchart



Fig:- Flowchart for non-restoring division operation

Example : Non-restoring Division
n=4

Dividend = 1011 ⇒ Q

Divisor = 0101 ⇒ B = 0̄0101 ⇒ B̄+1 = 11011

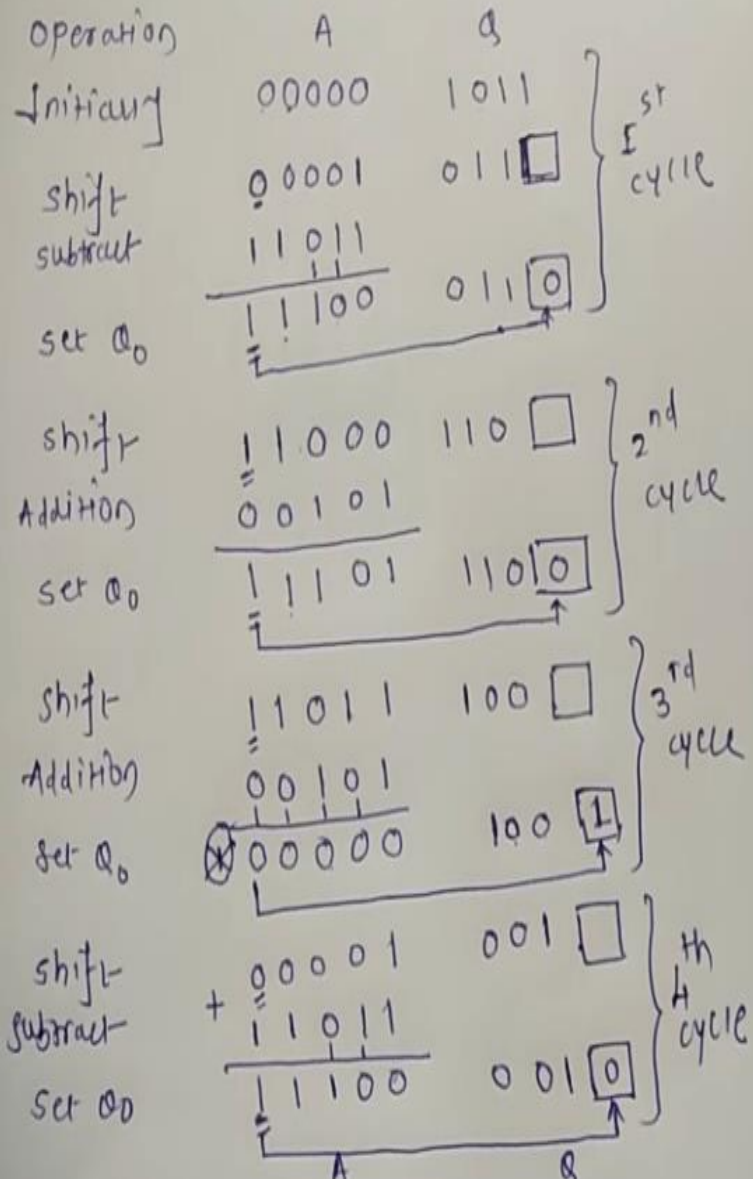| Operation | A | Q | |
|---|---|---|---|
| Initially | 00000 | 1011 | |
| shift | 00001 | 011☐ | 1st cycle |
| subtract | 11011 | | |
| | 11100 | 011[0] | |
| set Q0 | | | |
| shift | 11000 | 110☐ | 2nd cycle |
| Addition | 00101 | | |
| set Q0 | 11101 | 110[0] | |
| shift | 11011 | 100☐ | 3rd cycle |
| Addition | 00101 | | |
| set Q0 | ⊗00000 | 100[1] | |
| shift | 00001 | 001☐ | 4th cycle |
| subtract | + 11011 | | |
| set Q0 | 11100 | 001[0] | |

Flowchart



Fig:- Flowchart for non-restoring division operation

**Example : Non-restoring Division**

Dividend = 1011 ⟹ Q    n=4

Divisor = 0101 ⟹ B = 00101 ⟹ $\bar{B}$+1 = 11011

| Operation | A | Q | |
|---|---|---|---|
| Initially | 00000 | 1011 | |
| shift | 00001 | 011☐ | 1st cycle |
| subtract | 11011 | | |
| | 11100 | 0110 | |
| set $Q_0$ | | | |
| shift | 11000 | 110☐ | 2nd cycle |
| Addition | 00101 | | |
| | 11101 | 1100 | |
| set $Q_0$ | | | |
| shift | 11011 | 100☐ | 3rd cycle |
| Addition | 00101 | | |
| set $Q_0$ | ⊗00000 | 100①| |
| shift | 00001 | 001☐ | 4th cycle |
| subtract | +11011 | | |
| | 11100 | 0010 | |
| Set $Q_0$ | | | |

op.   A        Q

Addition  11100   0010

           00101   = Q
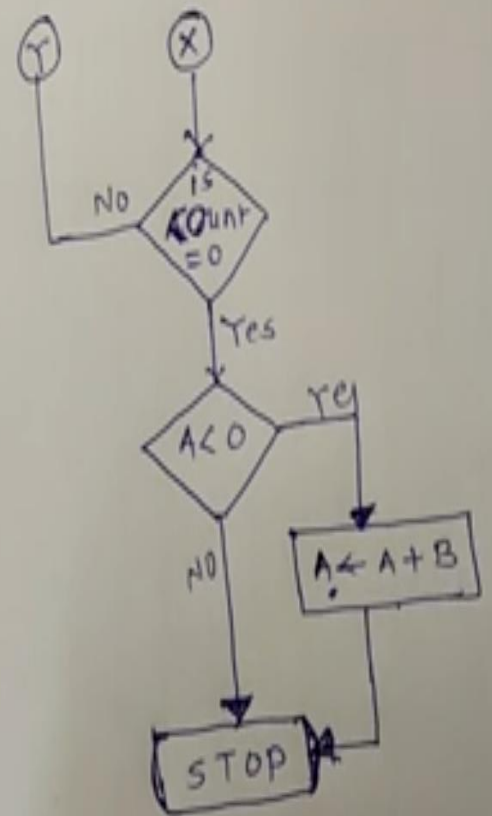
      ⊗00001

        A

    = Remainder

**Flowchart**



Fig:- Flowchart for non-restoring division operation

# Restoring Method



|  |  |  |  |
|---|---|---|---|
| Initially | 0 0 0 0 0 | 1 0 0 0 | |
| Shift | 0 0 0 0 1 | 0 0 0 ☐ | First cycle |
| Subtract | 1 1 1 0 1 | | |
| Set $q_0$ | ①1 1 1 0 | | |
| Restore | 1 1 | | |
|  | 0 0 0 0 1 | 0 0 0 ⓪ | |
| Shift | 0 0 0 1 0 | 0 0 ⓪☐ | |
| Subtract | 1 1 1 0 1 | | |
| Set $q_0$ | ①1 1 1 1 | | Second cycle |
| Restore | 1 1 | | |
|  | 0 0 0 1 0 | 0 0 ⓪⓪ | |
| Shift | 0 0 1 0 0 | 0 ⓪⓪☐ | |
| Subtract | 1 1 1 0 1 | | |
| Set $q_0$ | ⓪0 0 0 1 | | Third cycle |
| Shift | 0 0 0 1 0 | 0 ⓪⓪1 | |
| Subtract | 1 1 1 0 1 | ⓪⓪1☐ | |
| Set $q_0$ | ①1 1 1 1 | | Fourth cycle |
| Restore | 1 1 | | |
|  | 0 0 0 1 0 | ⓪⓪1⓪ | |

Remainder      Quotient

# Non-Restoring Method

|  |  |  |  |
|---|---|---|---|
| Initially | 0 0 0 0 0 | 1 0 0 0 | |
| Shift | 0 0 0 0 1 | 0 0 0 ☐ | First cycle |
| Subtract | 1 1 1 0 1 | | |
| Set $q_0$ | ①1 1 1 0 | 0 0 0 ⓪ | |
| Shift | 1 1 1 0 0 | 0 0 ⓪☐ | |
| Add | 0 0 0 1 1 | | Second cycle |
| Set $q_0$ | ①1 1 1 1 | 0 0 ⓪⓪ | |
| Shift | 1 1 1 1 0 | 0 ⓪⓪☐ | |
| Add | 0 0 0 1 1 | | Third cycle |
| Set $q_0$ | ⓪0 0 0 1 | 0 ⓪⓪1 | |
| Shift | 0 0 0 1 0 | ⓪⓪1☐ | |
| Subtract | 1 1 1 0 1 | | Fourth cycle |
| Set $q_0$ | ①1 1 1 1 | ⓪⓪1⓪ | |

Quotient

|  |  |  |
|---|---|---|
| Add | 1 1 1 1 1 | |
|  | 0 0 0 1 1 | Restore remaind |
|  | 0 0 0 1 0 | |

Remainder

4

Signed Number:

## Restoring :-

$n=4$  $\quad m = 00011$

$-7 \div 3$  $\quad Q = 0111$  $\quad m' = 11101$

$1001 \div 0011$

| A | Q |
|---|---|
| 00000 | 0111 |
| 00000 | 1110 |
| + 11101 | |
| 11101 | |
| + 00011 | |
| 00000 | 1110 |
| 00001 | 110□ |
| + 11101 | |
| 11110 | |
| + 00011 | |
| 00001 | 1100 |
| 00011 | 100□ |
| + 11101 | |
| 00000 | |
| 00000 | 1001 |
| 00001 | 0010 |
| + 11101 | |
| 11110 | |
| + 00011 | |
| 00001 | 0010 |
| R | Q |

}1  }2  }3  }4

$R = -1$
$Q = -2$

## Non-Restoring :-

$Q = 1001$  $\boxed{M = 00011}$  $\boxed{n=4}$

$1001 \div 0011$  $\boxed{m' = 11101}$

$(-7) \div (3)$  $\boxed{Q = 0111}$

| A | Q |
|---|---|
| 00000 | 0111 |
| 00000 | 1110 |
| + 11101 | |
| 11101 | |
| 11101 | 1110 |
| 11011 | 110□ |
| + 00011 | |
| 11110 | |
| 11110 | 1100 |
| 11101 | 100□ |
| + 00011 | |
| ⊗00000 | |
| 00000 | 1001 |
| 00001 | 0010 |
| + 11101 | |
| 11110 | |
| $\boxed{11110}$ | $\boxed{0010}$ |
| R | Q |

}1  }2  }3  }4

$R = 00001$
$Q = 0010$

$\boxed{R = -1 \\ Q = -2}$

$$\begin{array}{r} 11110 \\ + \; 00011 \\ \hline 00001 \end{array}$$

Dividend = Quotient x Divisor + Remainder

- To handle signed binary number division,
- first convert both the dividend and the divisor to positive numbers to perform the division
- and then correct the signs of the results as needed

➢If the dividend is positive, then the remainder will be positive.

➢If the dividend is negative, then the remainder will be negative.

➢As for the quotient, it will be positive if the divisor and the dividend have the same sign.

➢Otherwise, it will be negative.