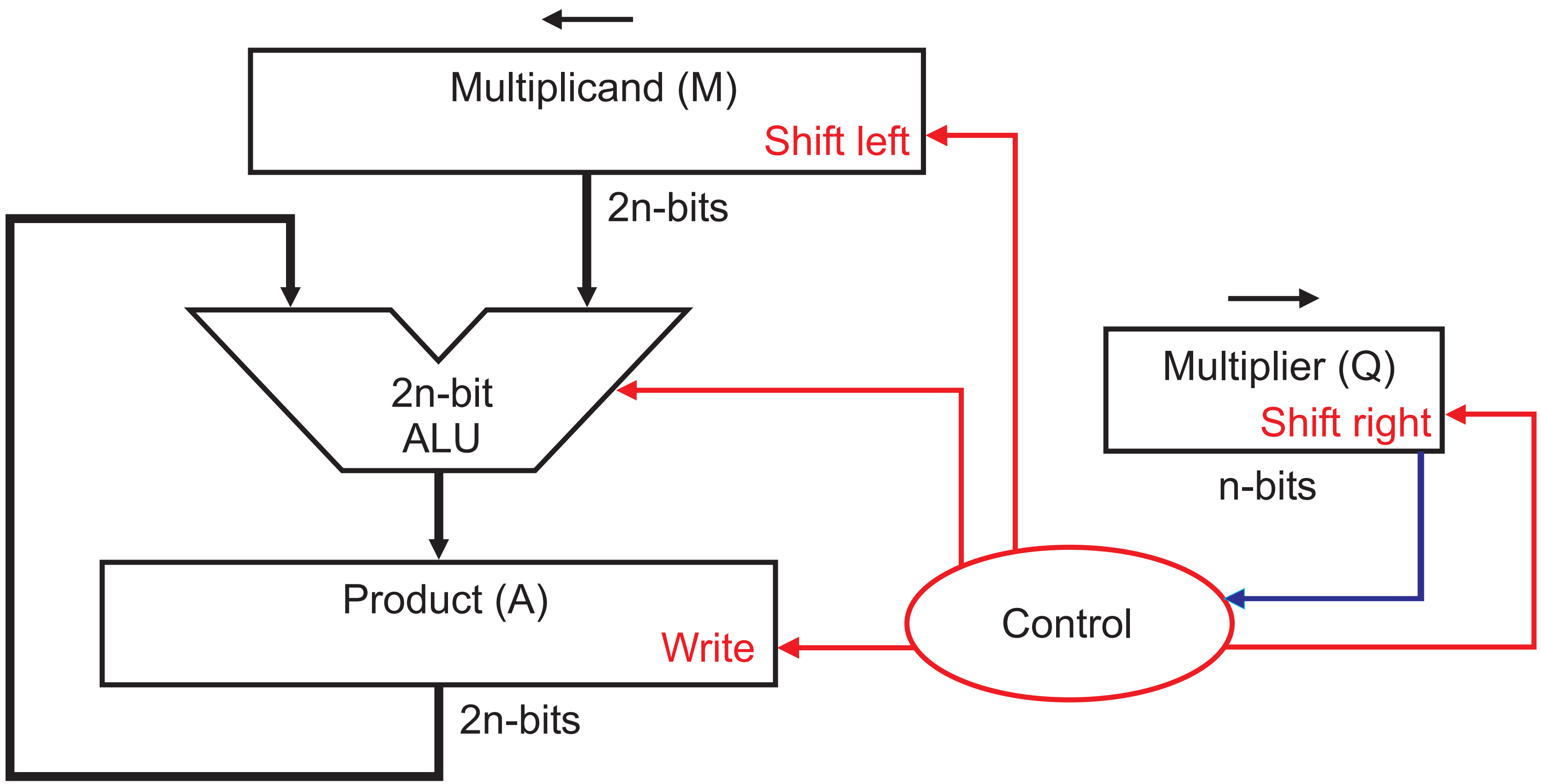
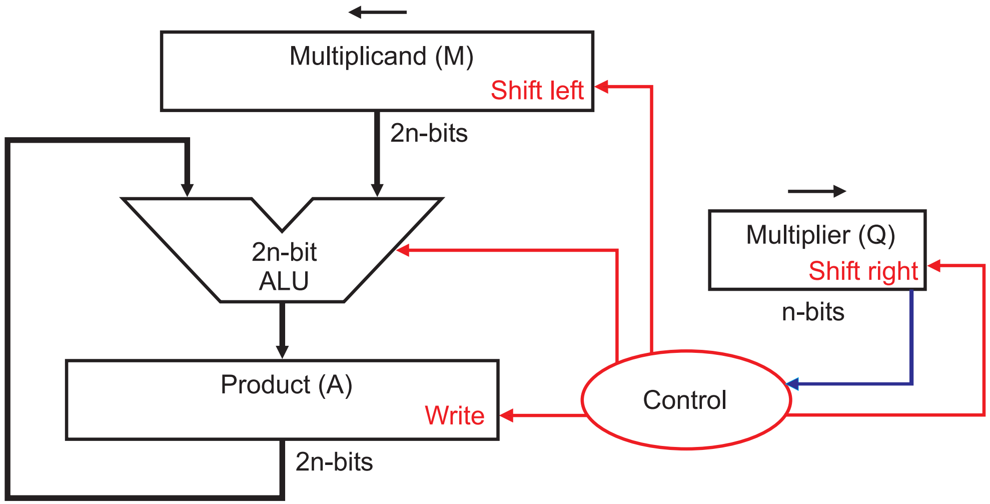
```
    1011 M (Multiplicand) 11
    1101 Q (Multiplier)   13
------------------------------
    1011
   0000
  1011
 1011    +
----------
10001111 A (Product) 143
```

Binary Integer Multiplication (unsigned)

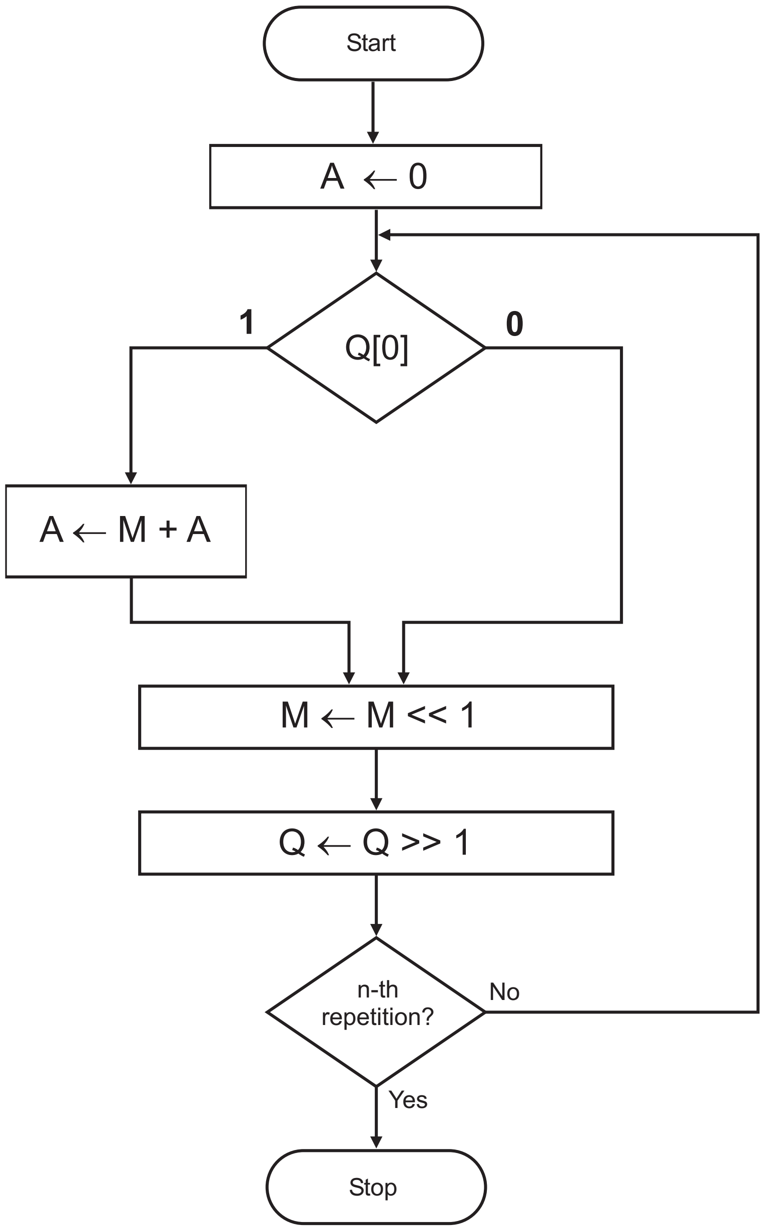


$$M*Q = A$$

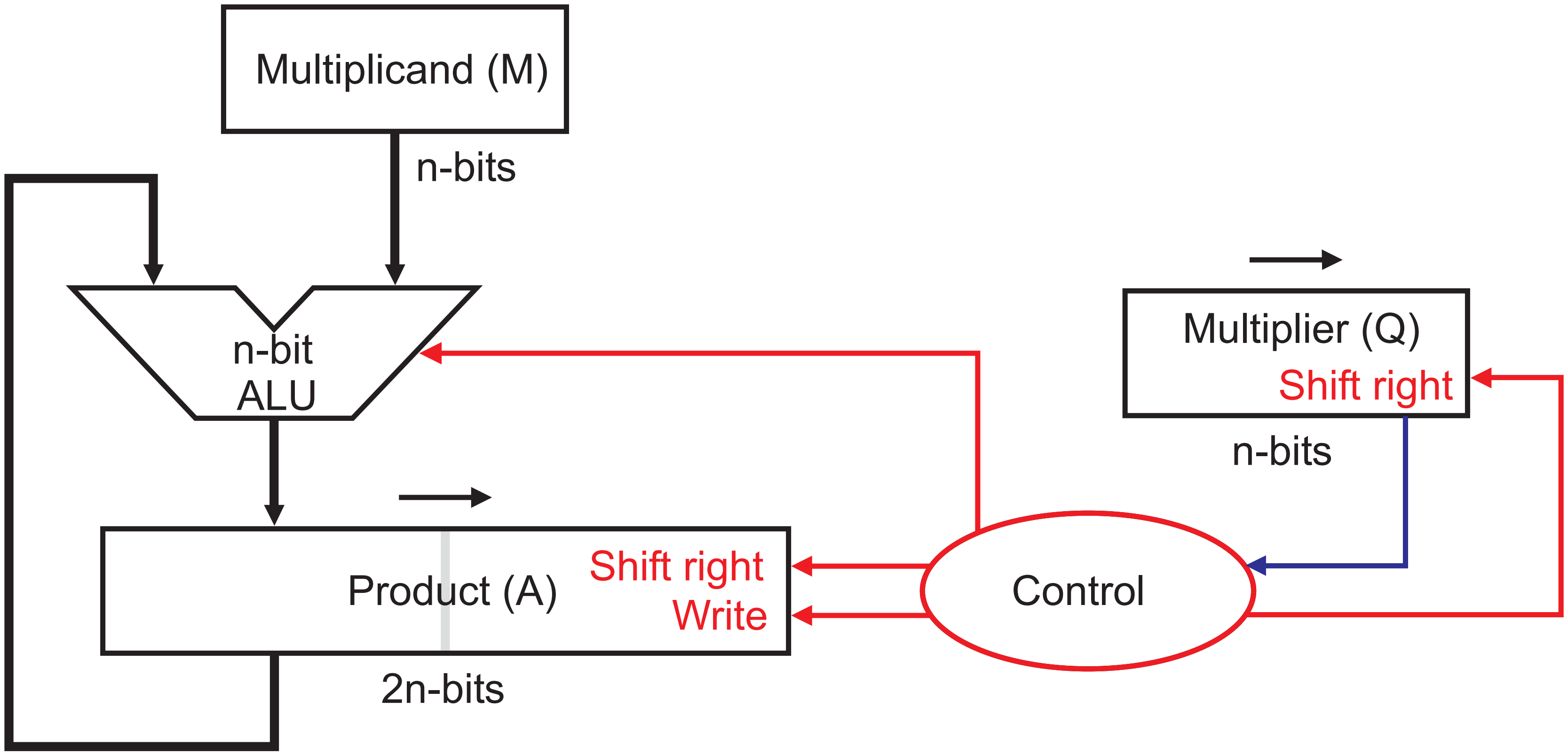
Multiplication Hardware (ver.1)



$M*Q = A$



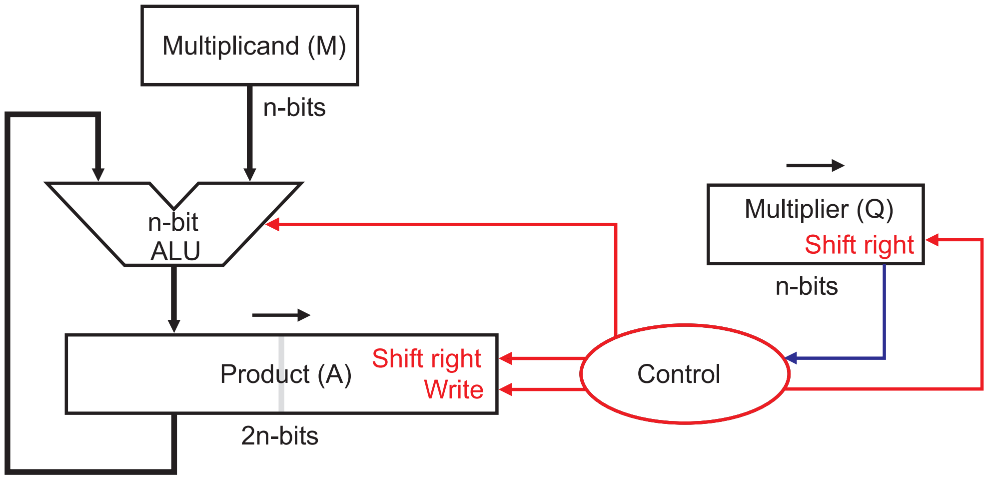
Multiplication Algorithm (ver.1)



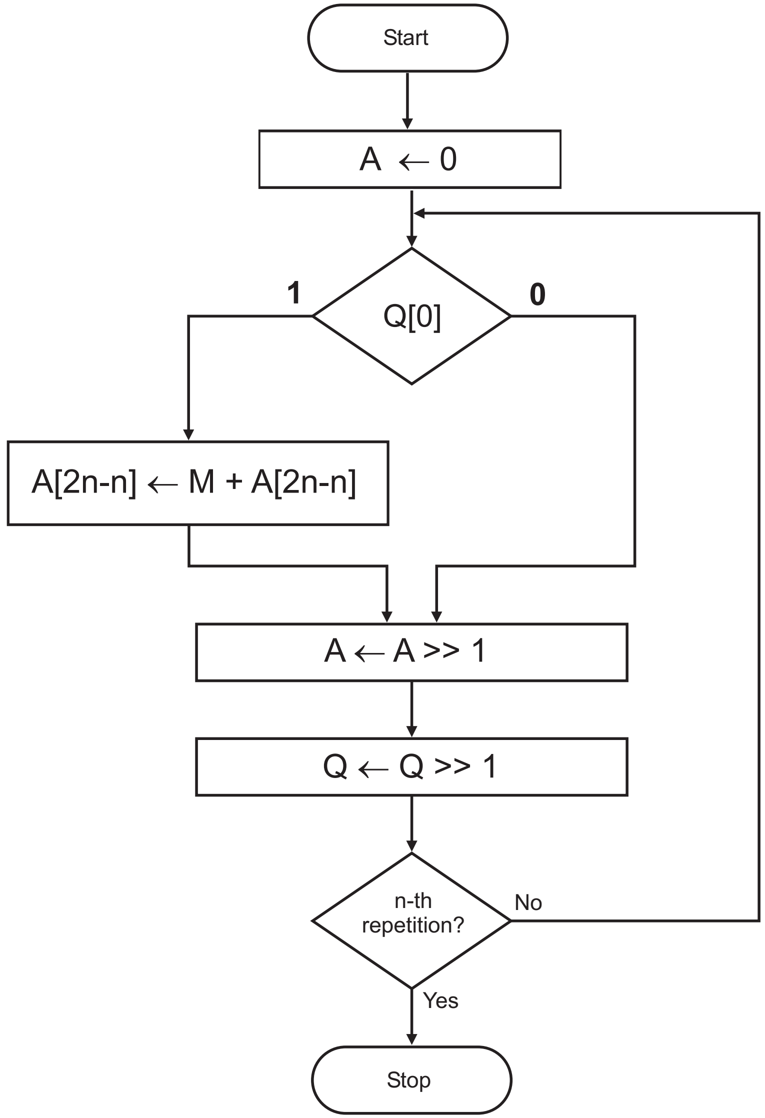
$$M*Q = A$$

Multiplication Hardware (ver.2)

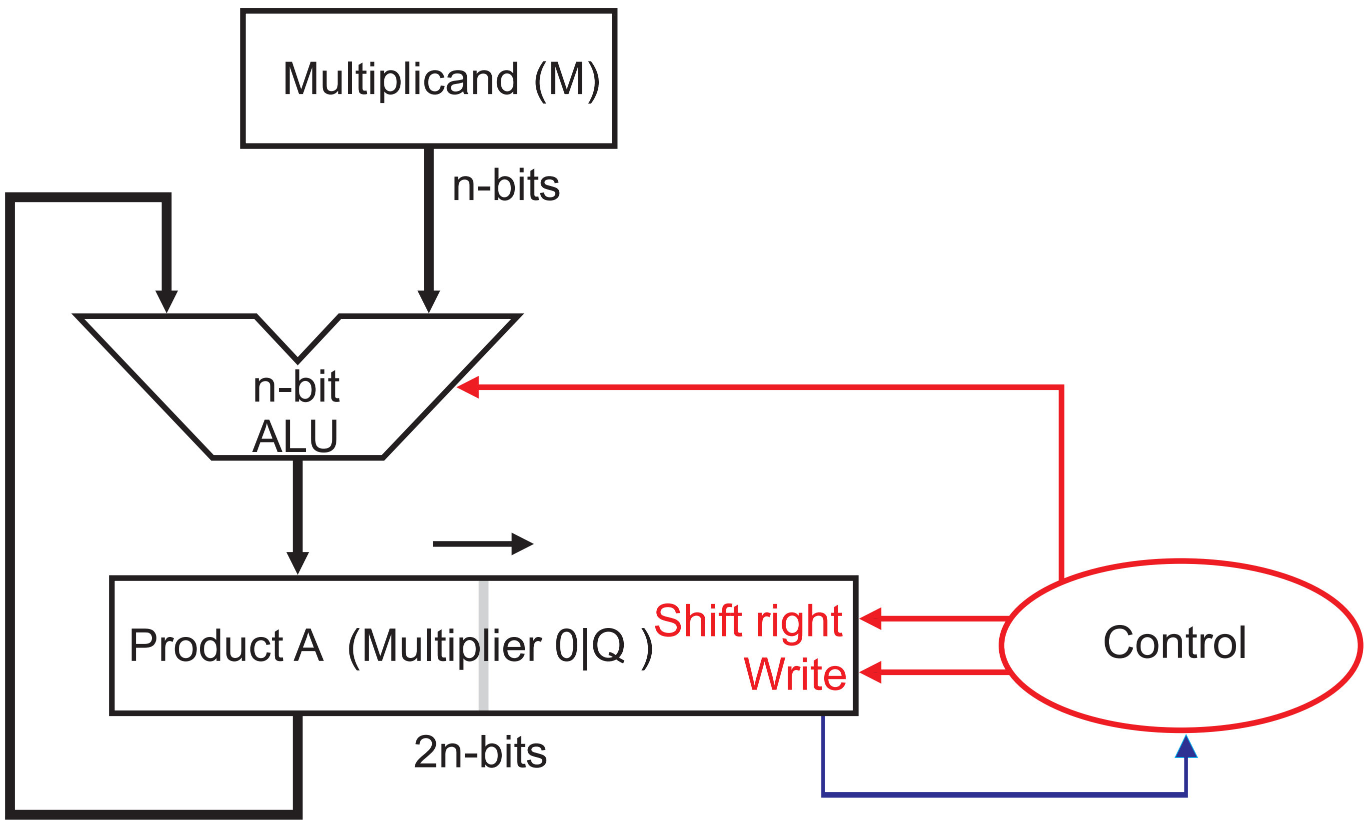
Multiplication Algorithm (ver.2)



$$M*Q = A$$

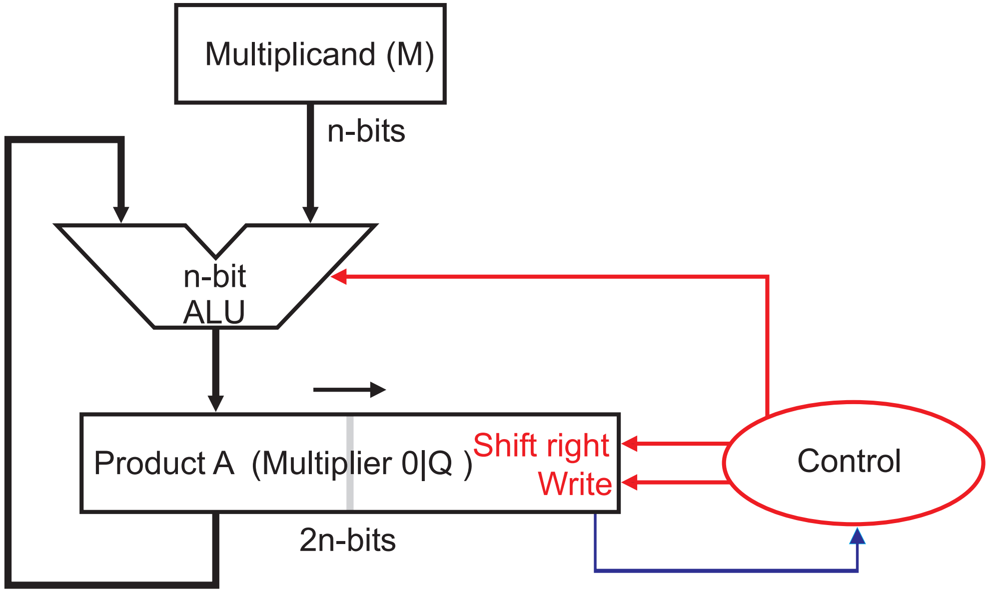


Multiplication Algorithm (ver.2)

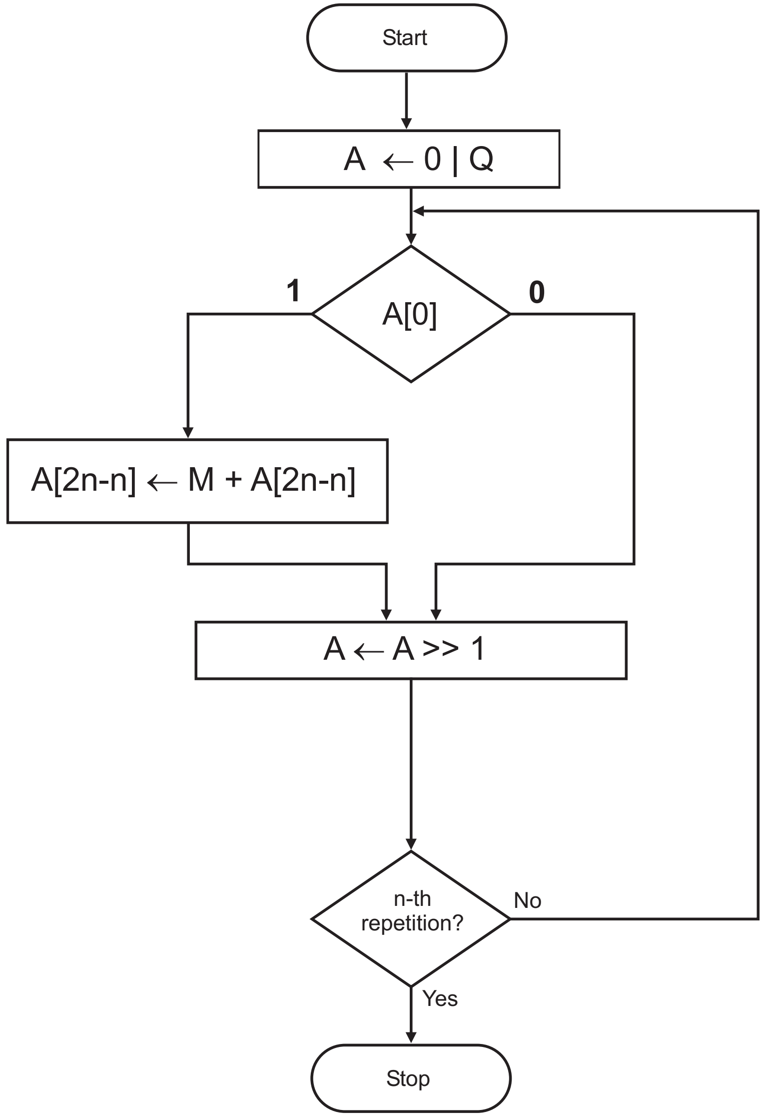


$$M*Q = A$$

Multiplication Hardware (ver.3)



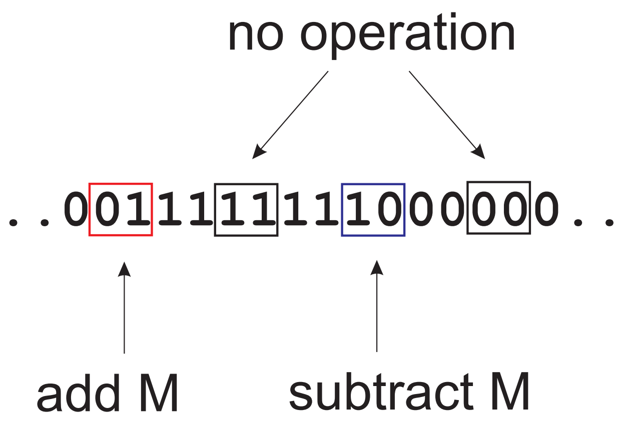
$M*Q = A$

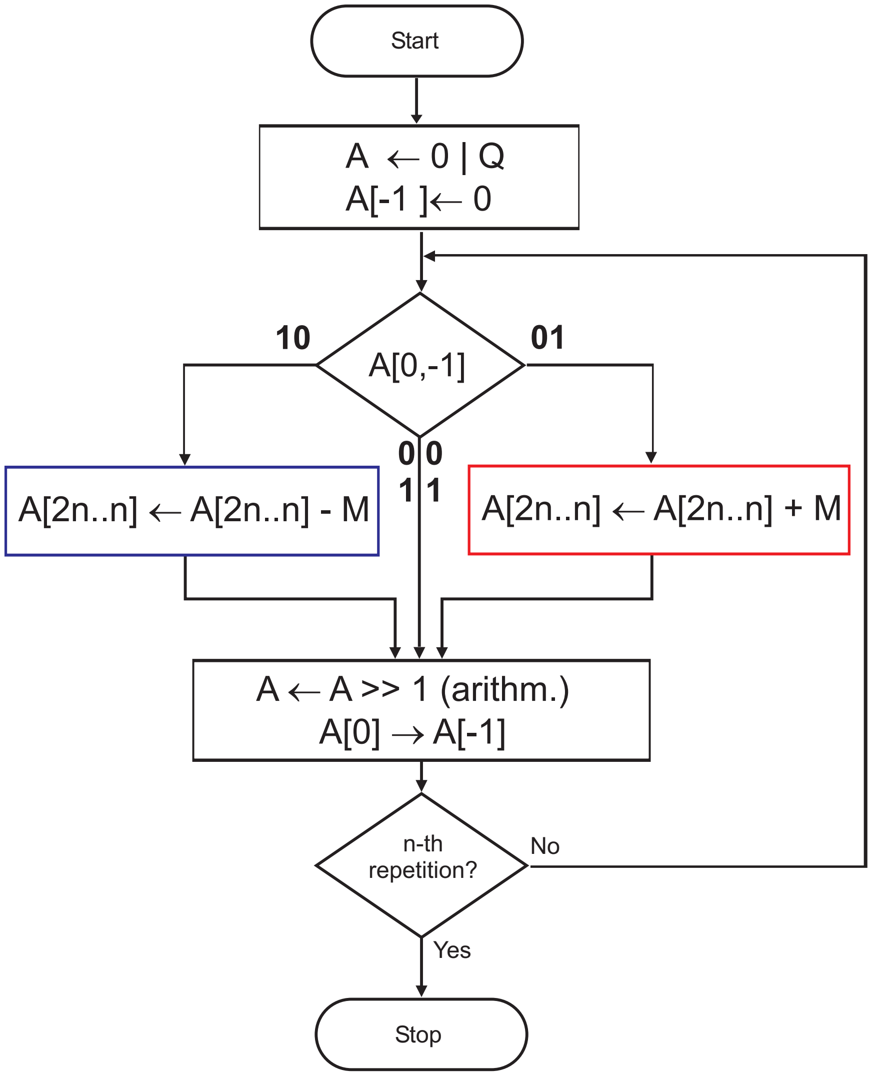


Multiplication Algorithm (ver.3)

```
        1111(15)     0011 (3)
       ---------------------------
+M      11110000
>A      01111000
+M     101101000
>A      10110100
>A      01011010
>A      00101101 (45)
```

Watch out for Carry Out during partial additions





Binary Integer Multiplication (signed) - Booth's Algorithm

$$Q = \overbrace{111\ldots111}^{n-1\ldots k+1}\overbrace{0}^{k}\overbrace{a_{k-1}a_{k-2}\ldots a_1 a_0}^{k-1\ldots 0} \quad (1)$$

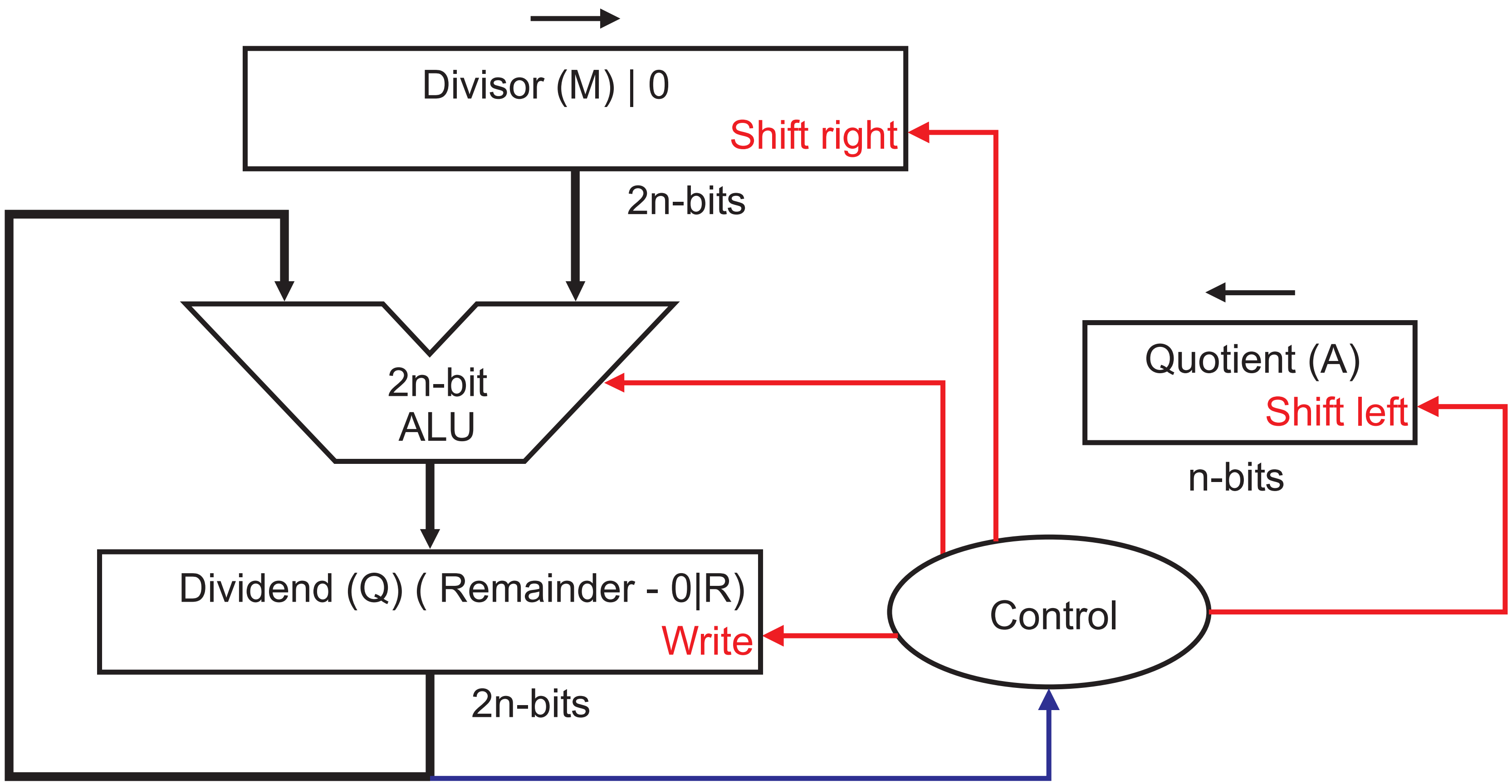
$$Q = -2^{n-1} + \underbrace{2^{n-2} + \ldots + 2^{k+1}}_{2^{n-1}-2^{k+1}} + a_{k-1}2^{k-1} + a_0 2^0 \quad (2)$$

$$Q = \underbrace{-2^{k+1}}_{\text{beginning of the last all-ones block}} + \underbrace{a_{k-1}2^{k-1} + \ldots + a_0 2^0}_{\text{part guaranteed to be expressed by additions and subtractions}} \quad (3)$$

Representation of negative multiplier Q (2's C)
by additions and subtractions for all-ones blocks

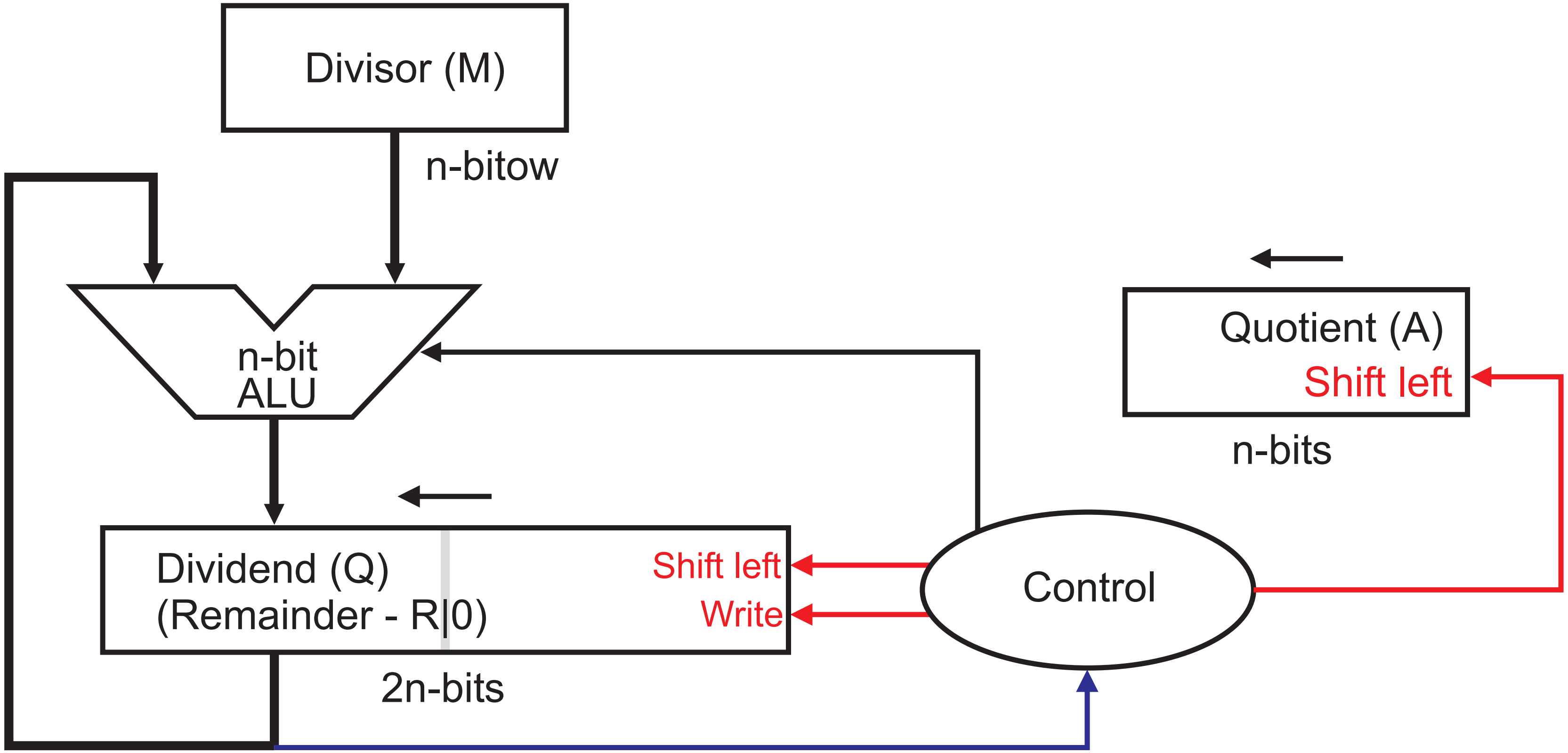
```
                      00001101 = Quotient (13)
Divisor = 1011        10010011 = Dividend
(11)                  ****          (147)
                   -   1011
                      001110
                   -    1011
                      00001111
                         ****
                   -       1011
                      00000100 = Remainder (4)
```

Binary Integer Division (unsigned)



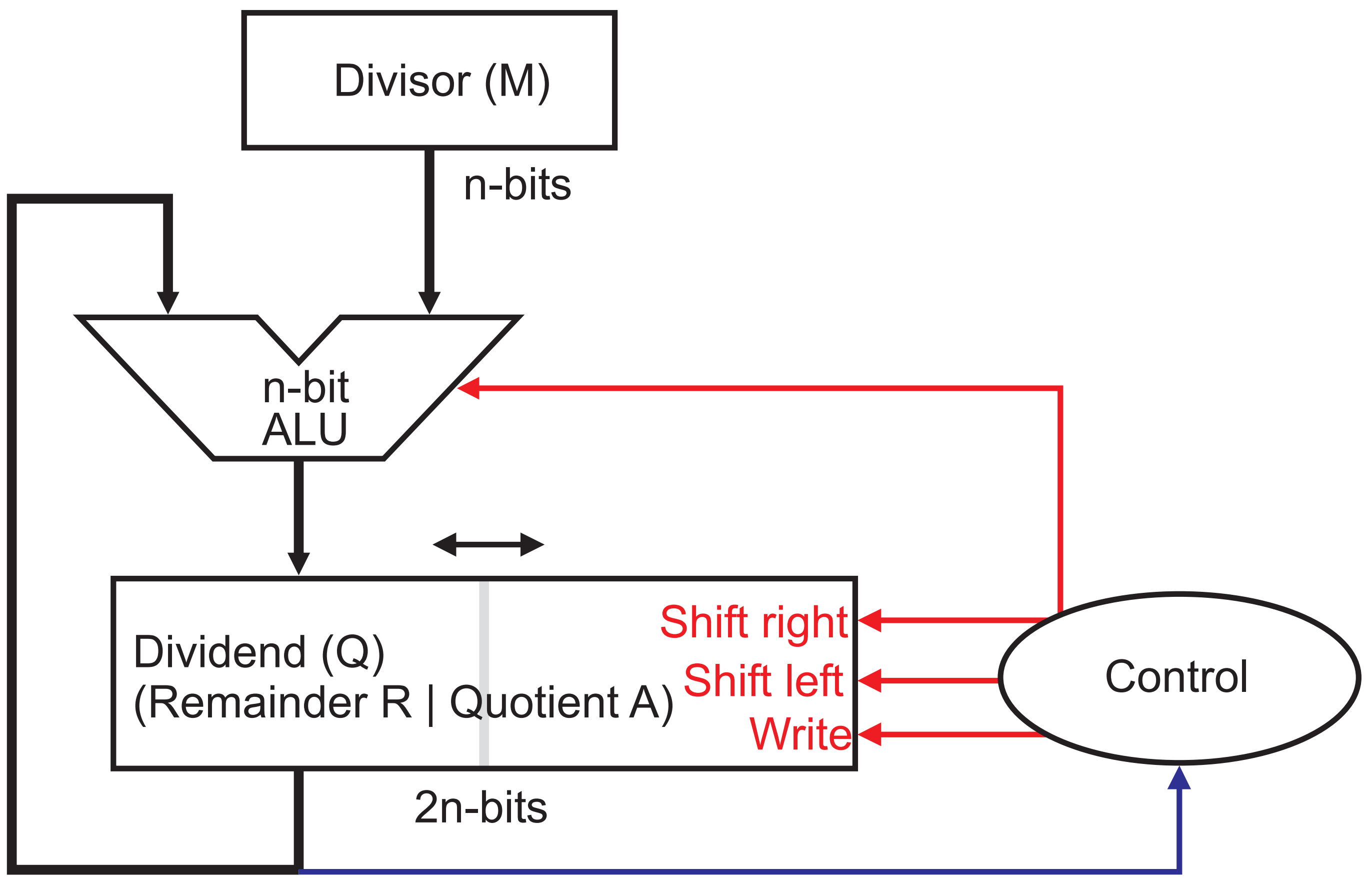
$$Q / M = A + R$$

Division Hardware (ver.1)



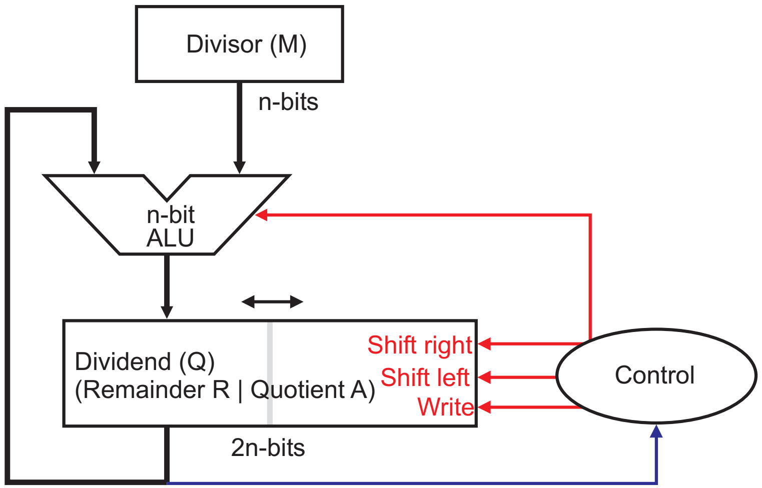
$$Q / M = A + R$$

Division Hardware (ver.2)

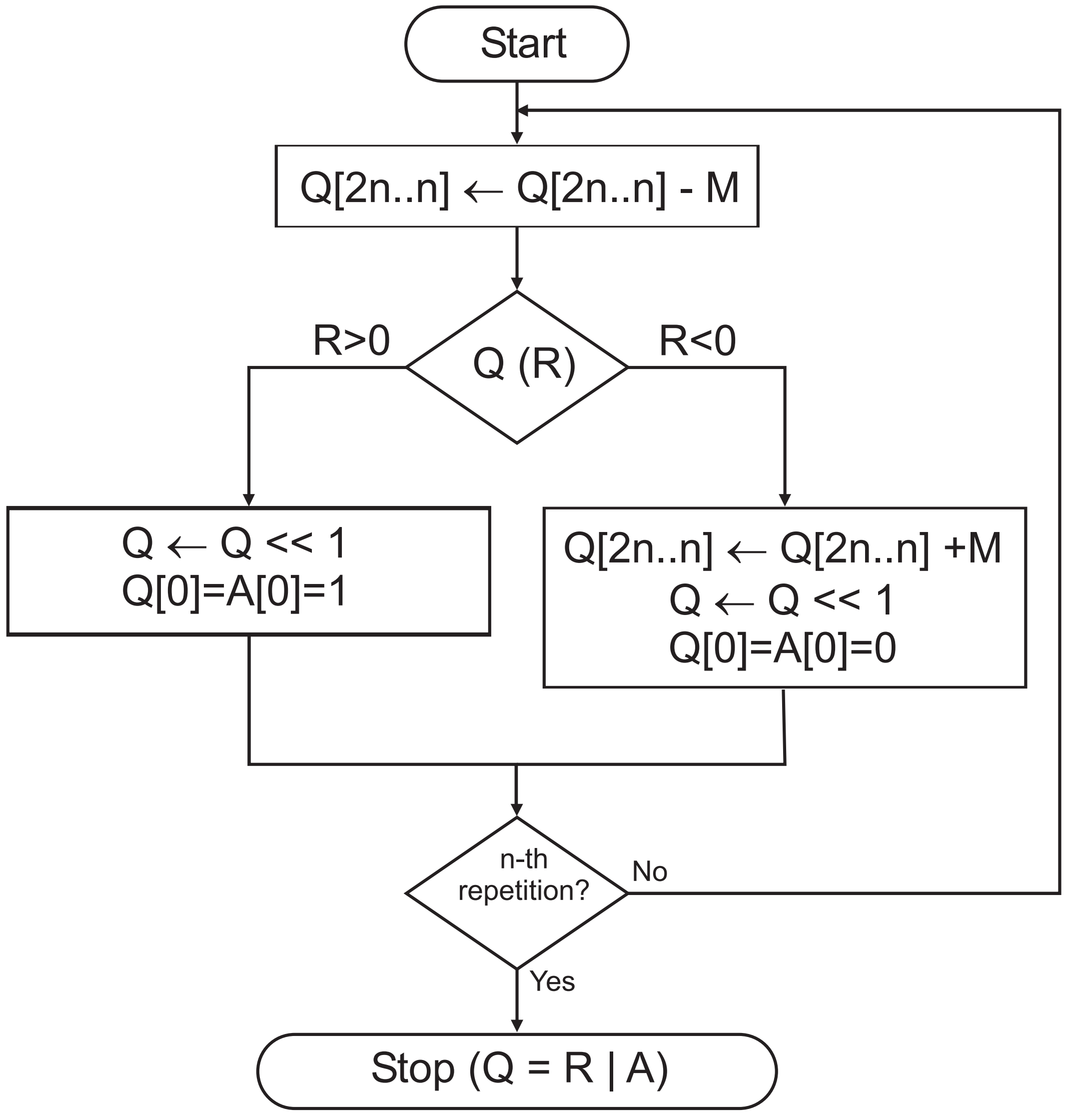


$$Q / M = A + R$$

Division Hardware (ver.3)



$$Q / M = A + R$$



Division Algorithm (ver.3)