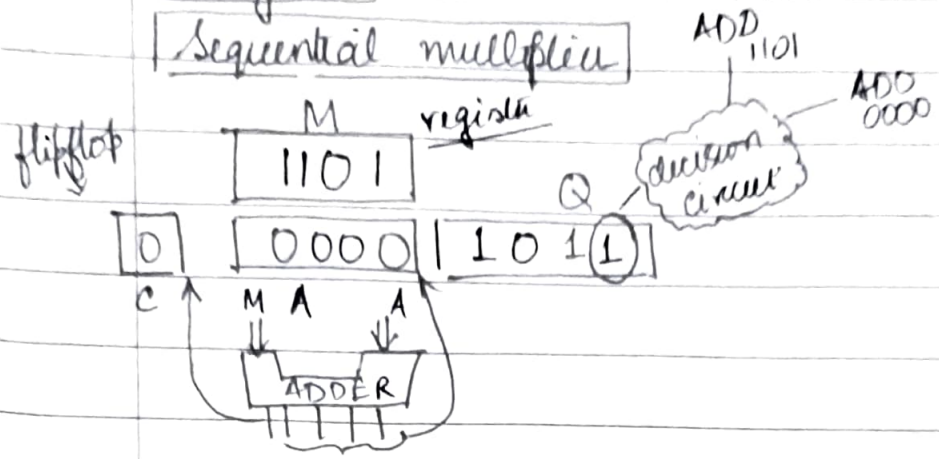
Date __/__/____

Binary multiplication

1. Unsigned

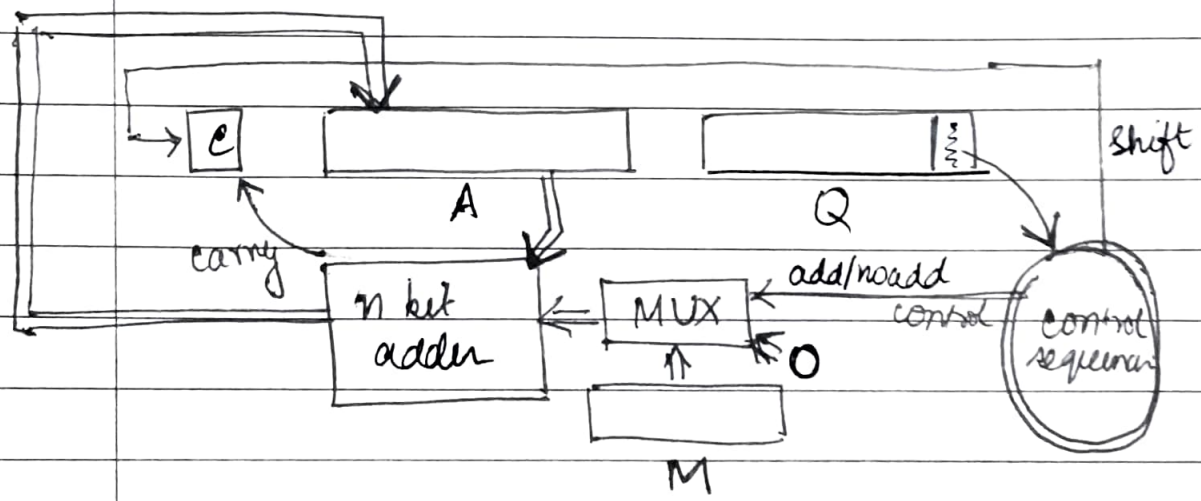
Sequential multiplier



Add	0	1101	1011	1st cycle
ShiftR	0	0110	1101	2nd cycle
Add	1	0011	1101	
Shift-R	0	1001	1110	3rd cycle
Shift-R	0	0100	1111	4th cycle
Add	1	0001	1111	
shiftR	0	1000	1111	→ result/product

```
  1101 (13)
  1011 (11)
  ------
  0000
  1101
  ------
  1101 → shift
  1101  add
  ------
  100111 → result
  0000   add
  ------
  100111 → shift
  1101   add
  ------
  10001111
  ------
```

$2^7 = 128 + 15 = 143$



(multiplicand) 11 / M X 13 / Q (multiplier)

4 bit architecture
[unsigned]

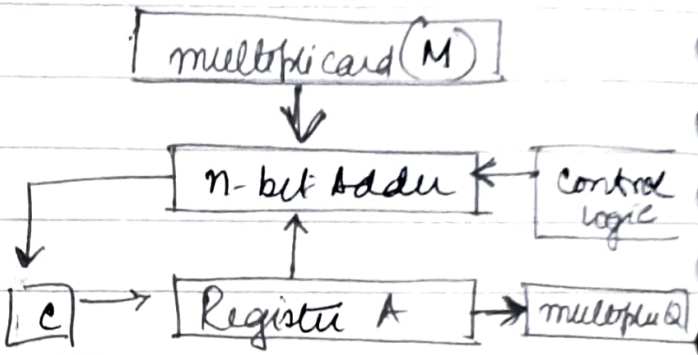
Tracing table

M	C	A	Q	operation
1011	0	0000	1101	initialization
	0	1011	1101	First cycle: add A = A+M
	0	0101	1110	shift R CAQ
	0	0010	1111	Second cycle: shift R CAQ
	0	1101	1111	Third cycle: Add A=A+M
	0	0110	1111	Shift R CAQ
	1	0001	1111	Fourth cycle Add A=A+M
	0	1000	1111	Shift R CAQ

2^7 2^3 2^1 2^0

$128 + 15 = 143$

Hardware structure



Date / /

2. **Signed number**

multiplicand 1 1 0 1 negative $-2^3+2^2+2^0 = -8+4+1$

multiplier 0 1 1 1 positive [7] [product=21] = [-3]

1 1 0 1 (-3) ✓

1 1 0 1

× 1 0 0 1 1 1 should be $-3 \times 3 = -9$ but we have

1 1 0 1 1 1 ✓

1 1 0 1

1 1 0 1 0 1 1 ✓

$-64+32+8+2+1$

$= -64+43 = -21$

sign extension

$-2^4+2^3+2^2+2^0$

$= -16+8+4+1$

$= -3$

$-2^5+2^2+2^1+2^0 = -32+7$

$= -25$ ×

$-2^5+2^4+2^2+2^1+2^0$

$= -32+16+7 = -9$ ✓

signed no.

non-neg, non-neg	neg non neg	non neg neg	neg neg
	sign extension	take 2's complement of both	take 2's complement of both
	0/1 → multiplicand positive/negative	3 × −7 → −3 × 7 = −21	−3 × −7 → 3 × 7 = 21

original 0011 × 1001

2's complement 1101 × 0111

Divisor (3) Dividend (11)

Date __/__/____

n	M	A	Q	operation
4	00011	00000	1011	Initialization
	M' 11101	00001	011?	First cycle: shift left AQ
		11110	011?	A = A − M
3		00001	0110	Q[0] ← 0, restore A
		00010	110?	SL AQ
		11111	110?	A = A − M
2		00010	1100	Q[0] ← 0, restore A
		00101	100?	SL AQ
		00010	100?	A = A − M
1		00010	1001	Q[0] ← 1
		00101	001?	SL AQ
0		00010	0010	A = A − M
		00010	0011	Q[0] ← 1

↓ remainder ↑ Quotient