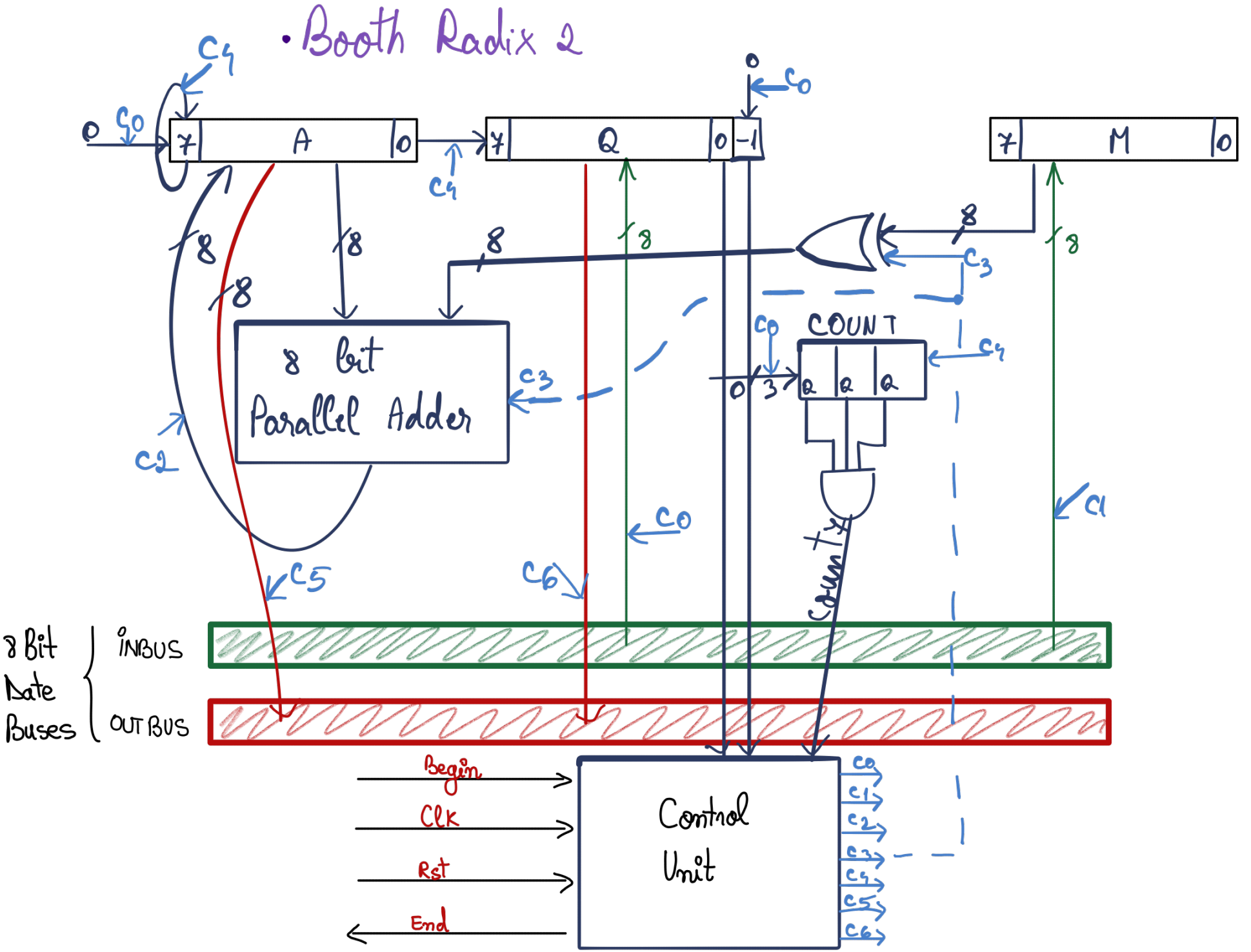

• Booth Radix 2
A
Q
-1
M
8 bit
Parallel Adder
COUNT
Q Q Q
0 3
Count
8 Bit Date Buses
INBUS
OUT BUS
Begin
Clk
Rst
End
Control Unit

FSM

- Codificăm stările

START: 0000 ← faza inițială

LOADx: 0001 ← datele sunt încărcate de pe inbus în registrul x

LOADy: 0010 ← datele sunt încărcate de pe inbus în registrul y

ADD: 0011 ← se efectuează Adunare

SUB: 0100 ← se efectuează Scădere

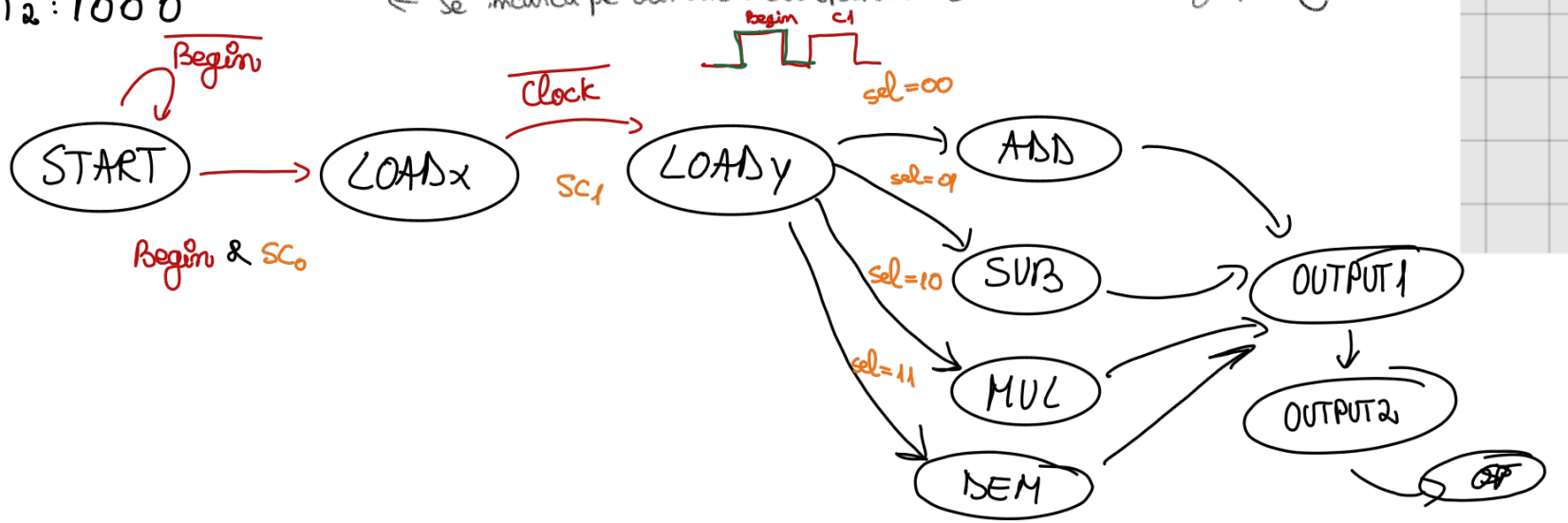
MUL: 0101 ← ...

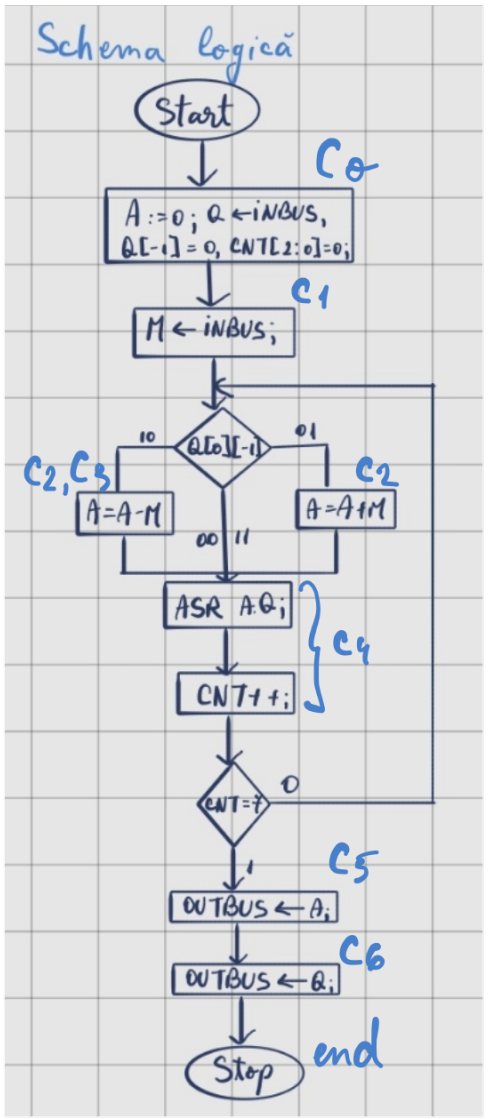
DEM: 0110 ← ...

OUTPUT1: 0111 ← Se încarcă pe outbus rezultatul

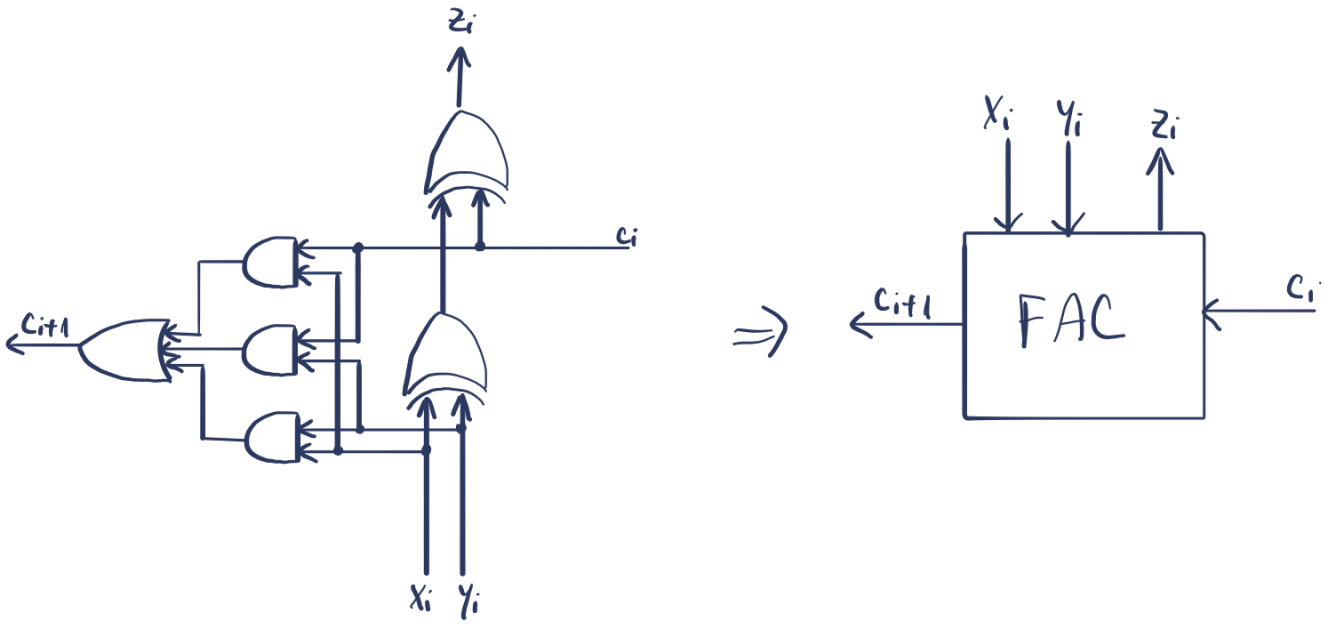
OUTPUT2: 1000 ← Se încarcă pe outbus rezultatul

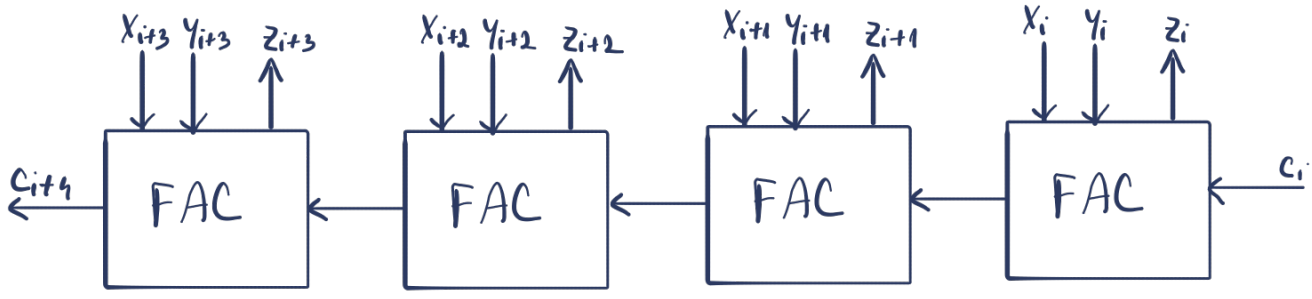
] Se încarcă pe fiare câte 8 biți pe reg de 16

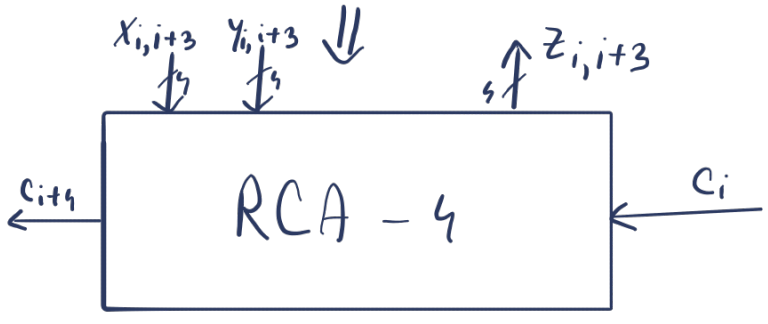


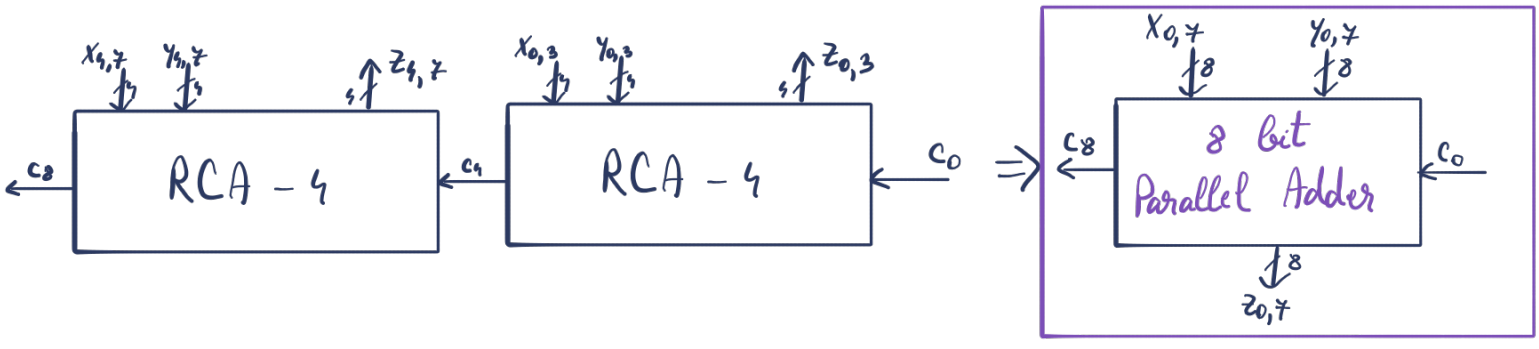


8 bit Parallel Adder

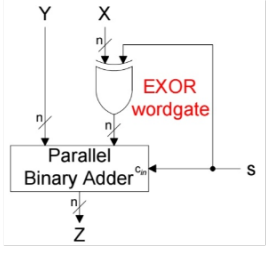








- Scădere :

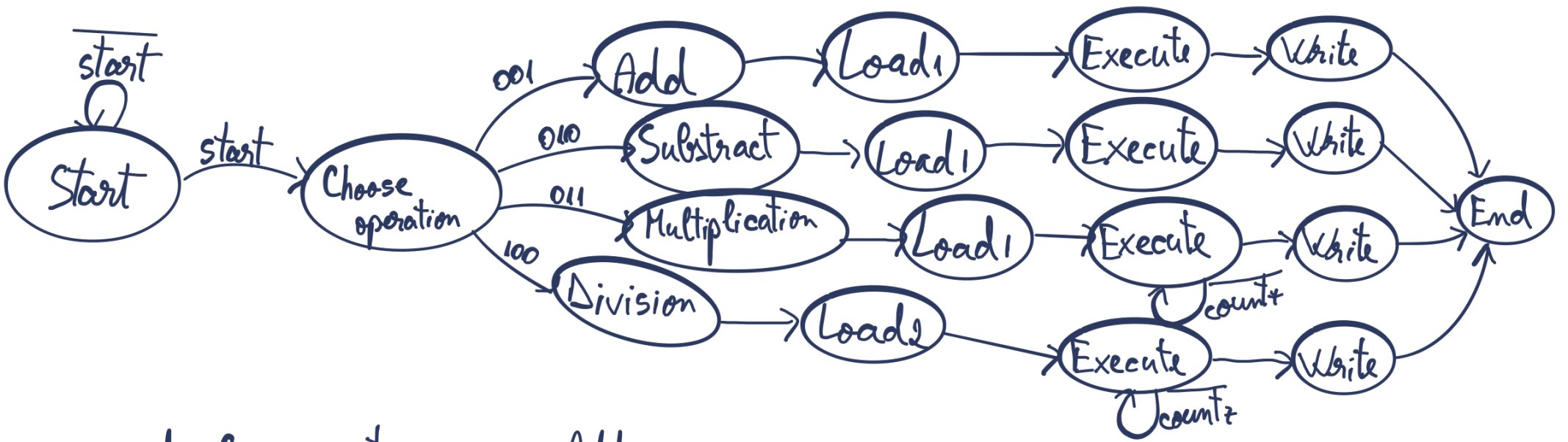


- Înmulțire : Booth Radix 2
- Împărțire : Non-Restoring

FSM (control unit)

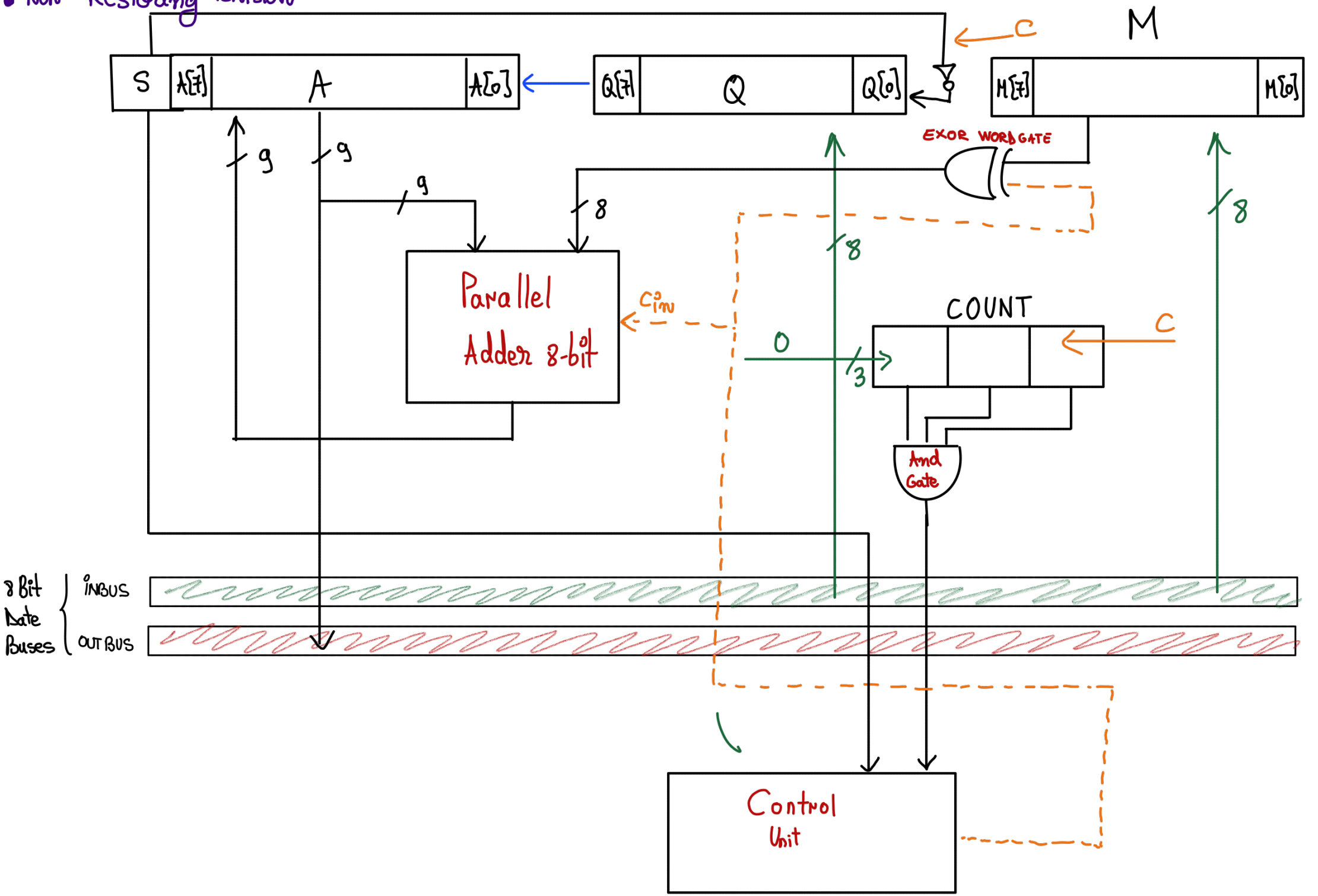
input clk, rst, start, [3:0] op
output [2:0] alu_sel, load_en, shift_en, done

Load 1 : Q , M
Load 2 : A , Q , M



code for operation : 001 Add
010 Substract
011 Multiplication
100 Division

- NoN Restoring Division



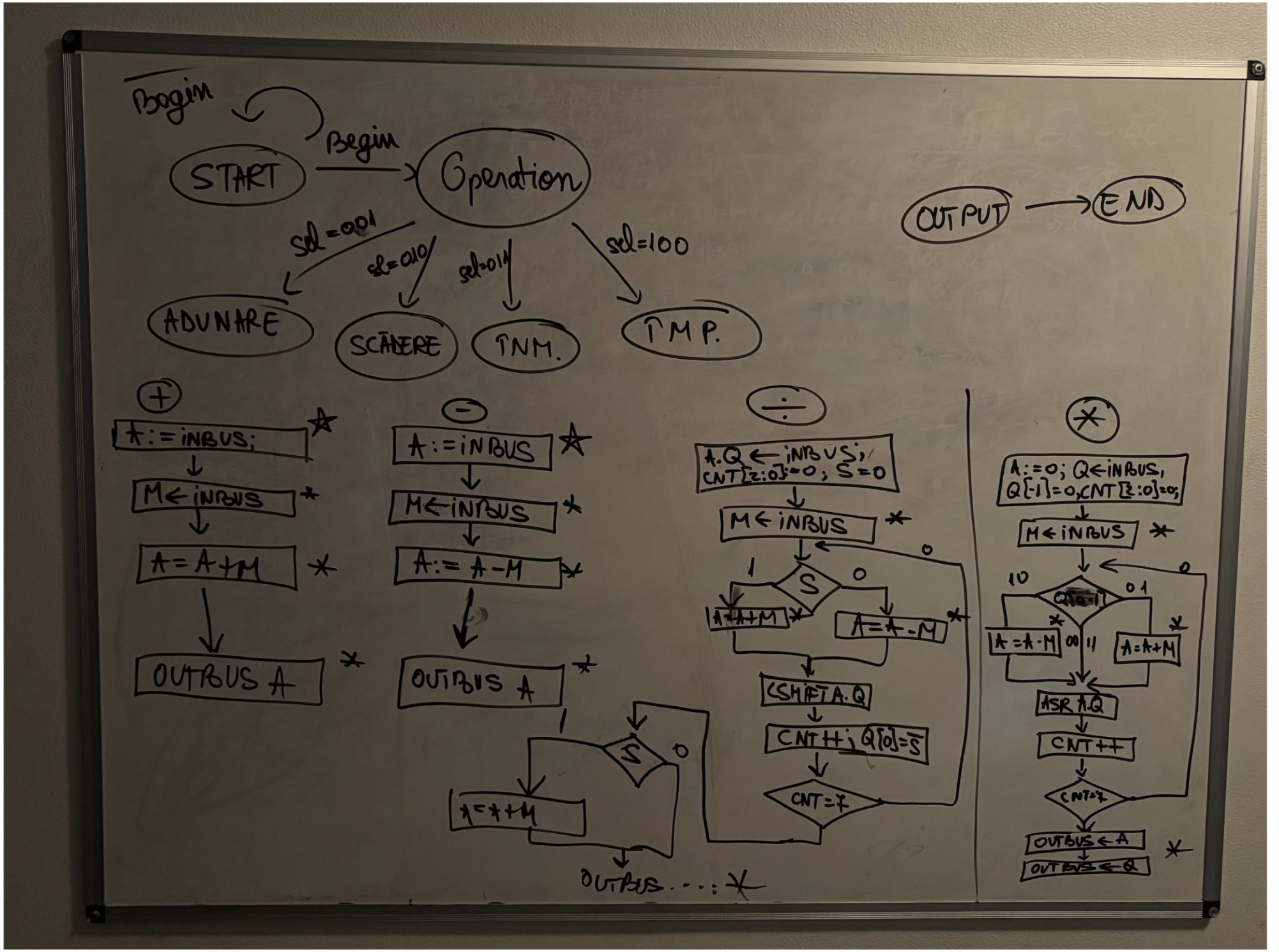
★ Questions

↳ Cum ne intră biții de pe INBUS? Începând cu LSB sau cu MSB?

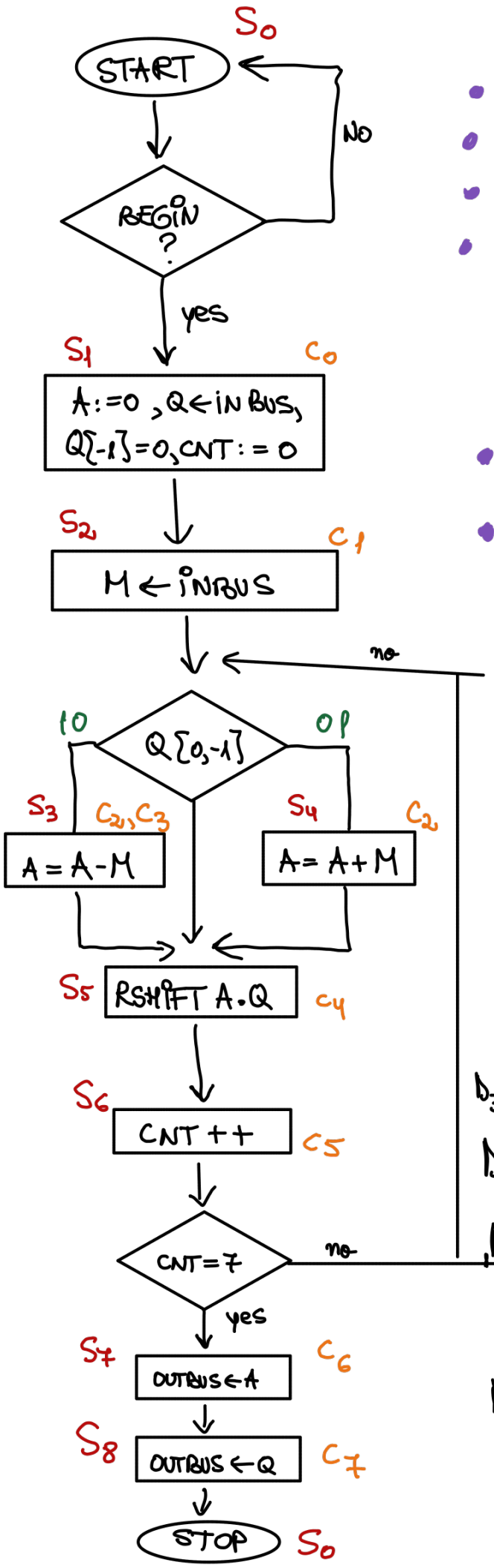
↳ La Non-Restoring Division, registrul A.Q în câți cloci se umple?

↳ cu 3 cloci sau cu 2 cloci

↳ Ce facem în caz de overflow la adunare?


Begin
START
Begin
Operation
OUTPUT
END
sel=001
sel=010
sel=011
sel=100
ADUNARE
SCĂDERE
ÎNM.
ÎMP.
+
A:=INBUS;
M←INBUS
A=A+M
OUTBUS A
-
A:=INBUS
M←INBUS
A:=A-M
OUTBUS A
÷
A.Q←INBUS;
CNT[2:0]=0; S=0
M←INBUS
S
A=A+M
A=A-M
LSHIFT A.Q
CNT++; Q[0]=S
CNT=7
OUTBUS ...;
*
A:=0; Q←INBUS;
Q[-1]=0, CNT[2:0]=0;
M←INBUS
Q[1:0]
10
01
00
11
A=A-M
A=A+M
ASR A.Q
CNT++
CNT=7
OUTBUS←A
OUTBUS←Q

- Multiplicatorul



- Codificarea stării

State	B_8	B_7	B_6	B_5	B_4	B_3	B_2	B_1	B_0
S_0	0	0	0	0	0	0	0	0	1
S_1	0	0	0	0	0	0	0	1	0
S_2	0	0	0	0	0	0	1	0	0
S_3	0	0	0	0	0	1	0	0	0
S_4	0	0	0	0	1	0	0	0	0
S_5	0	0	0	1	0	0	0	0	0
S_6	0	0	1	0	0	0	0	0	0
S_7	0	1	0	0	0	0	0	0	0
S_8	1	0	0	0	0	0	0	0	0

- Ecuații de feedback

$D_0 = B_0 \cdot \overline{BEGIN}$ or B_8

$D_1 = B_0 \cdot BEGIN$

$D_2 = B_1$

$D_3 = B_2 \cdot (Q[0] \cdot \overline{Q[-1]})$ or $B_5 \cdot B_6 \cdot \overline{CNT7} \cdot (Q[0] \cdot \overline{Q[-1]})$

$D_4 = B_2 \cdot (\overline{Q[0]} \cdot Q[-1])$ or $B_5 \cdot B_6 \cdot \overline{CNT7} \cdot (\overline{Q[0]} \cdot Q[-1])$

$D_5 = B_3$ or B_4 or $(Q[0] \cdot Q[-1])$ or $(\overline{Q[0]} \cdot \overline{Q[-1]})$

$D_6 = B_5$

$D_7 = B_6 \cdot CNT7$

$D_8 = B_7$

• Ecuații de ieșire

$c_0 = B_1$

$c_1 = B_2$

$c_2 = B_3$

$c_3 = B_4$

$c_4 = B_5$

$c_5 = B_6$

$c_6 = B_7$

$c_7 = B_8$

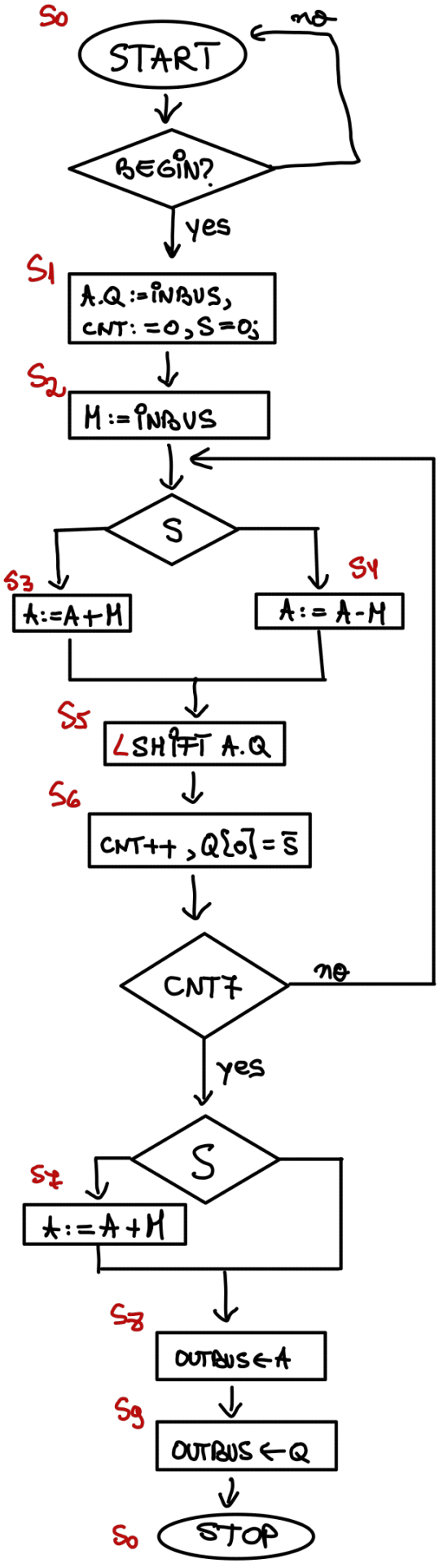
$END = B_0$

Idee: Ca să refolosim semnalele avem stări diferite pentru fiecare operație (+, −, *, /) și facem activăm $c_0, c_1 \ldots$ în mai multe cazuri.

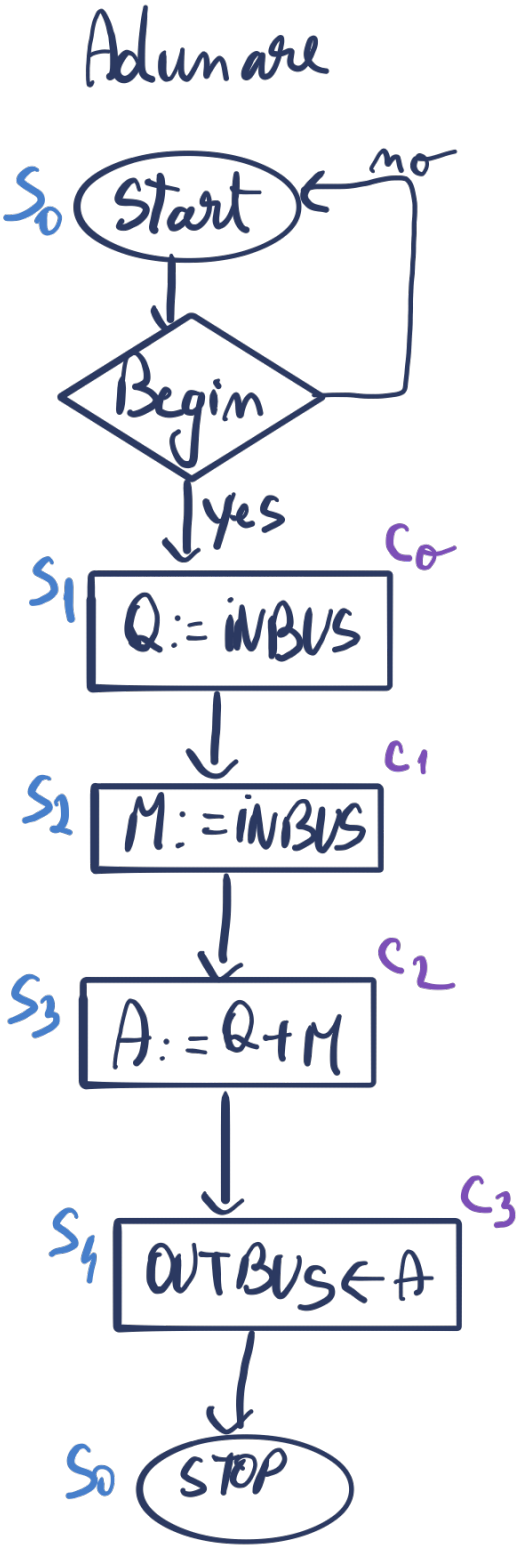
$A_1, A_2 \ldots$ adunare
$B_1, B_2 \ldots$ scădere
$C_1, C_2 \ldots$ înmulțire
$\Delta_1, \Delta_2 \ldots$ scădere

și atunci activăm $c_0 = A_1 | B_1 | C_1 | D_1$

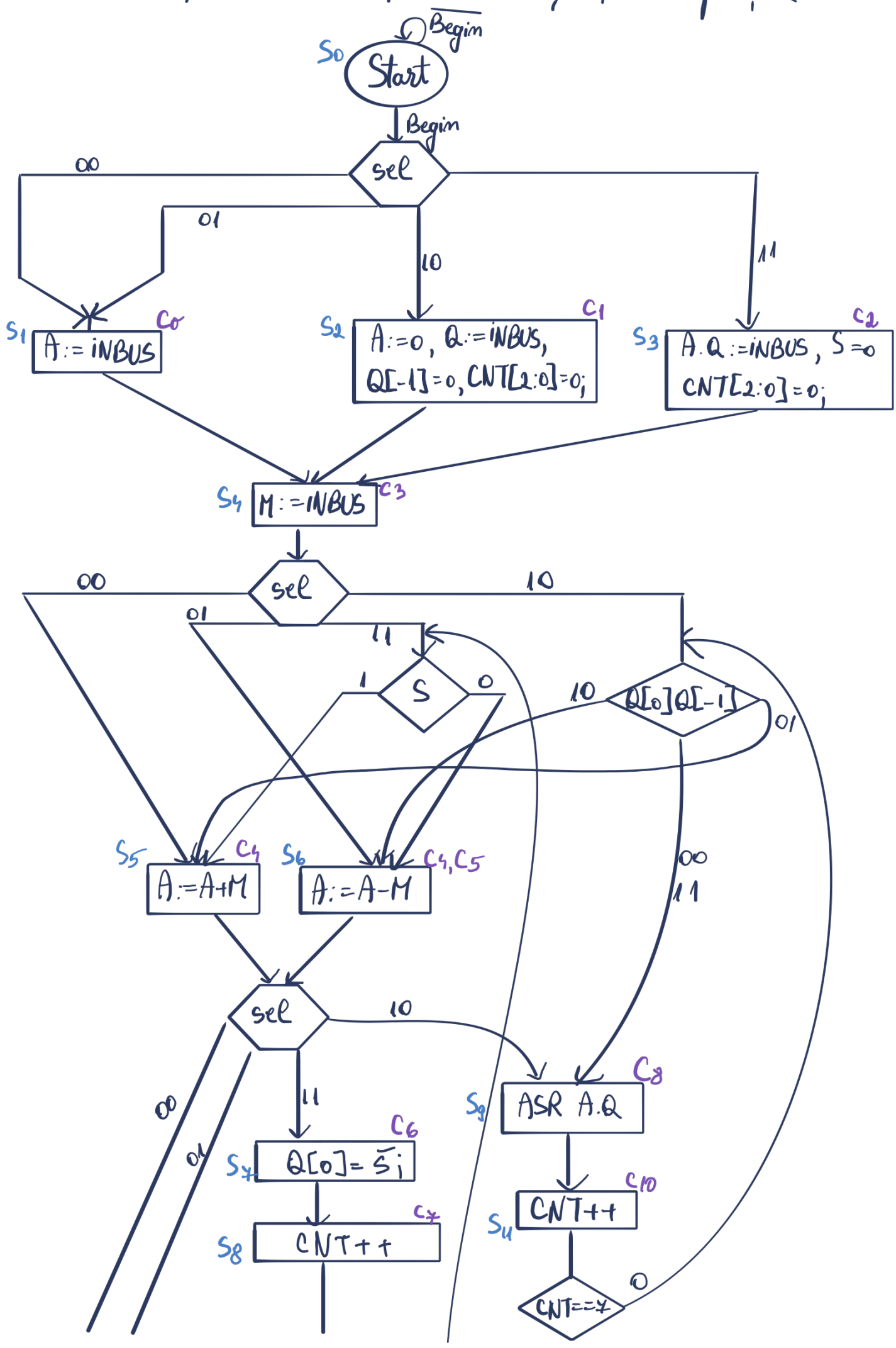
- Împărțirea

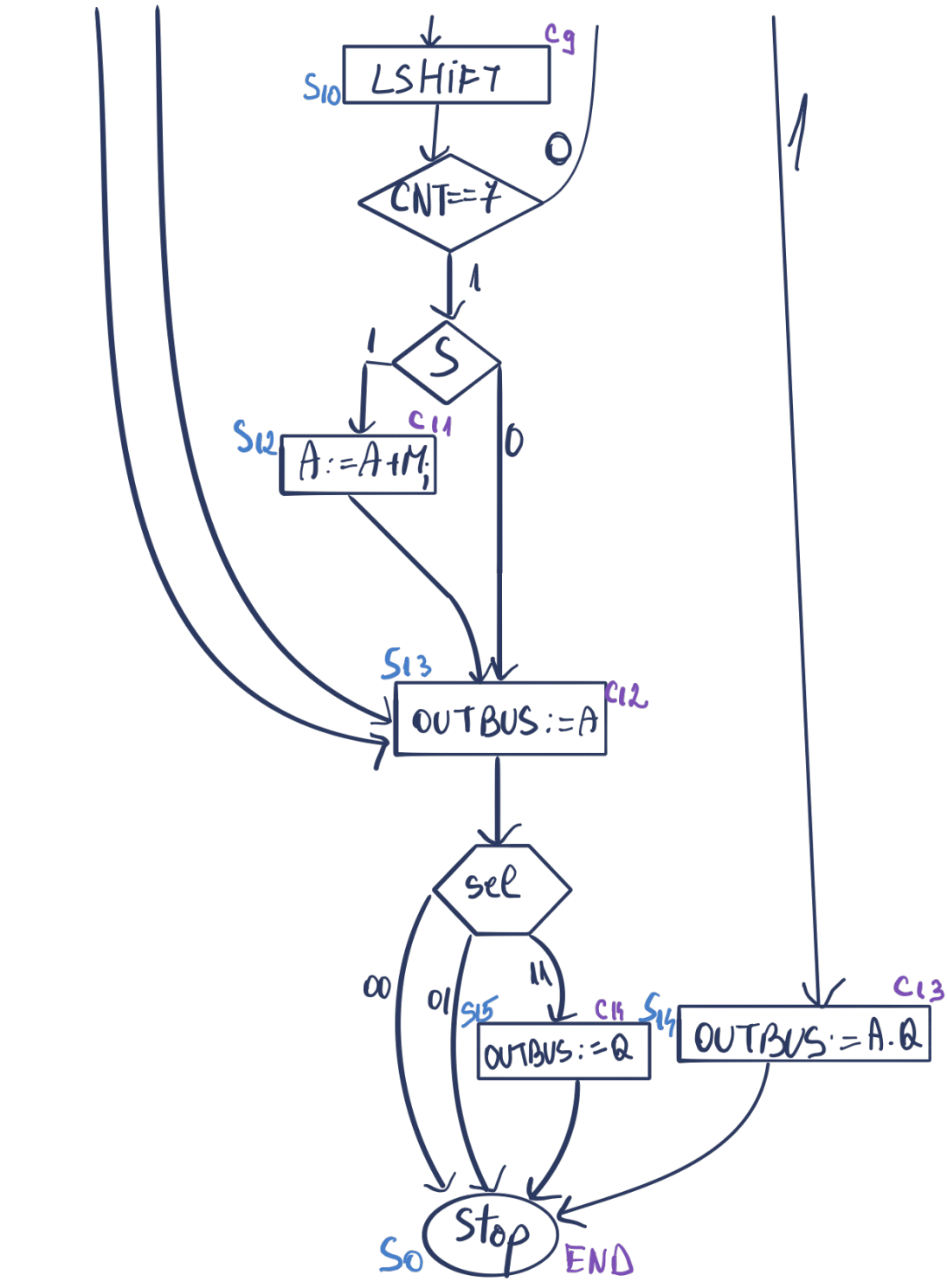


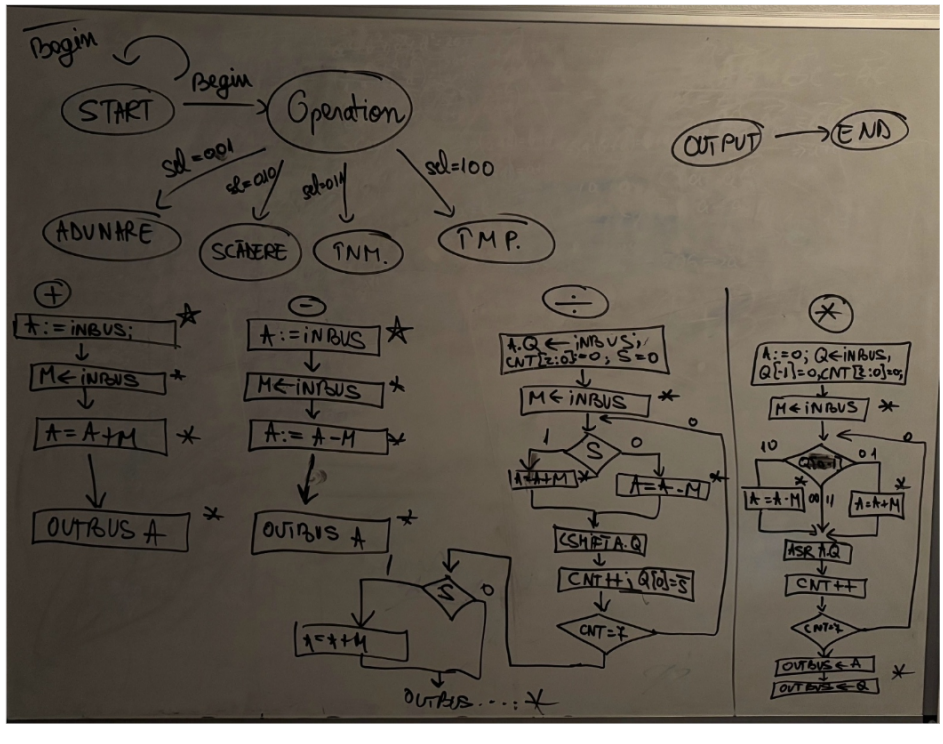
Adunare



00 - adunare, 01 - scădere, 10 - înmulțire, 11 - împărțire




C9
S10
LSHIFT
CNT==7
0
1
1
S
1
0
S12
C11
A:=A+M;
S13
C12
OUTBUS:=A
sel
00
01
11
S15
C14
S14
C13
OUTBUS:=Q
OUTBUS:=A.Q
Stop
S0
END


Begin
START
Begin
Operation
OUTPUT
END
sel=001
sel=010
sel=011
sel=100
ADUNARE
SCADERE
INM.
TMP.
A:=INBUS;
M←INBUS
A=A+M
OUTBUS A
A:=INBUS
M←INBUS
A:=A-M
OUTBUS A
A:Q←INBUS;
CNT[2:0]=0; S=0
M←INBUS
S
A=A+M
A=A-M
CSHIFT A:Q
CNT=7
A:=0; Q←INBUS;
Q[-1]=0, CNT[2:0]=0;
M←INBUS
A=A-M
A=A+M
ASR A:Q
CNT++
CNT=7
OUTBUS←A
OUTBUS←Q

Counter

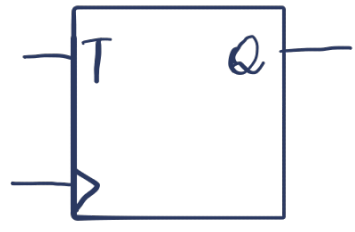
Când c_8 sau $c_9 = 0$, nu crește counter $\Rightarrow M = 0$

Când c_8 sau $c_9 = 1$, crește counter $\Rightarrow M = 1$

M	Q_3	Q_2	Q_1	Q_3^*	Q_2^*	Q_1^*	T_3	T_2	T_1
1	0	0	0	0	0	1	0	0	1
1	0	0	1	0	1	0	0	1	1
1	0	1	0	0	1	1	0	0	1
1	0	1	1	1	0	0	1	1	1
1	1	0	0	1	0	1	0	0	1
1	1	0	1	1	1	0	0	1	1
1	1	1	0	1	1	1	0	0	1
1	1	1	1	0	0	0	1	1	1

MQ_3 \ Q_2Q_1	00	01	11	10
00				
01				
11			1	
10			1	

$$T_3 = M \cdot Q_2 \cdot Q_1$$



MQ_3 \ Q_2Q_1	00	01	11	10
00				
01				
11		1	1	
10		1	1	

$$T_2 = MQ_1$$

MQ_3 \ Q_2Q_1	00	01	11	10
00				
01				
11	1	1	1	1
10	1	1	1	1

$$T_1 = M$$

• Ecuații de feedback

$$D_0 = B_0 \cdot \overline{BEGIN} + B_{13} + B_{12} \cdot \overline{sel[1]}$$

$$D_1 = \overline{sel[1]} \cdot BEGIN \cdot B_0$$

$$D_2 = sel[1] \cdot \overline{sel[0]} \cdot BEGIN \cdot B_0$$

$$D_3 = sel[1] \cdot sel[0] \cdot BEGIN \cdot B_0$$

$$D_4 = B_1 + B_2 + B_3$$

$$D_5 = B_4 \cdot \left(\overline{sel[1] \cdot sel[0]} + \overline{cnt7} \left(sel[1] \cdot sel[0] \cdot s + sel[1] \cdot \overline{sel[0]} \cdot \overline{Q[0]} \cdot Q[-1] \right) \right)$$

$$D_6 = B_4 \cdot \left(\overline{sel[1]} \cdot sel[0] + \overline{cnt7} \left(sel[1] \cdot sel[0] \cdot \overline{s} + sel[1] \cdot \overline{sel[0]} \cdot Q[0] \cdot \overline{Q[-1]} \right) \right)$$

$$D_7 = (B_5 + B_6) \cdot sel[1] \cdot sel[0]$$

$$D_8 = (B_5 + B_6) \cdot sel[1] \cdot \overline{sel[0]} +$$

$$+ \overline{Q[0] \oplus Q[1]} \left(B_4 \cdot sel[1] \cdot \overline{sel[0]} \cdot \overline{cnt7} \right)$$

$$D_9 = B_7$$

$$D_{10} = B_8$$

$$D_{11} = S \cdot CNT7 \cdot B_9$$

$$D_{12} = (B_5 + B_6) \cdot \overline{sel[1]} + B_{11} + B_9 \cdot CNT7 \cdot \overline{S} + B_{10} \cdot CNT7$$

$$D_{13} = sel[1] \cdot B_{12}$$

• Ecuații de ieșire

$$C_0 = B_1$$

$$C_1 = B_2$$

$$C_2 = B_3$$

$$C_3 = B_4$$

$$C_4 = B_5 \| B_6$$

$$C_5 = B_6$$

$$C_6 = B_7$$

$$C_7 = B_8$$

$$C_8 = B_9$$

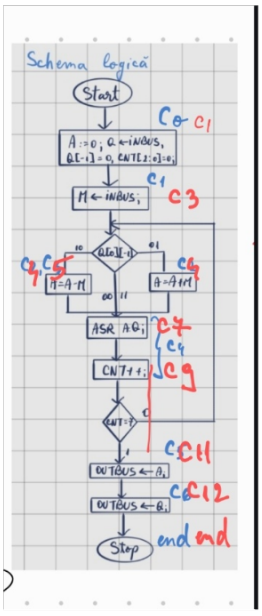
$$C_9 = B_{10}$$

$$C_{10} = B_{11}$$

$$C_{11} = B_{12}$$

$$C_{12} = B_{13}$$

$$END = B_0$$



CNTR	A	Q	Q[-1]	M
0	0000 0000	0010 1000	0	0000 1100
	0000 0000	0001 0100	0	1111 0100
1	0000 0000	0000 1010	0	
2	0000 0000	0000 0101	0	
3	+ 1111 0100			
	1111 0100			
	1111 1010	0000 0010	1	
4	+ 0000 1100			
	0000 0110			
	0000 0011	0000 0001	0	
5	+ 1111 0100			
	1111 0111			
	1111 1011	1000 0000	1	
6	+ 0000 1100			
	0000 0111			
	0000 0011	1100 0000	0	
7	0000 0001	1110 0000	0	

Q·4D = 480