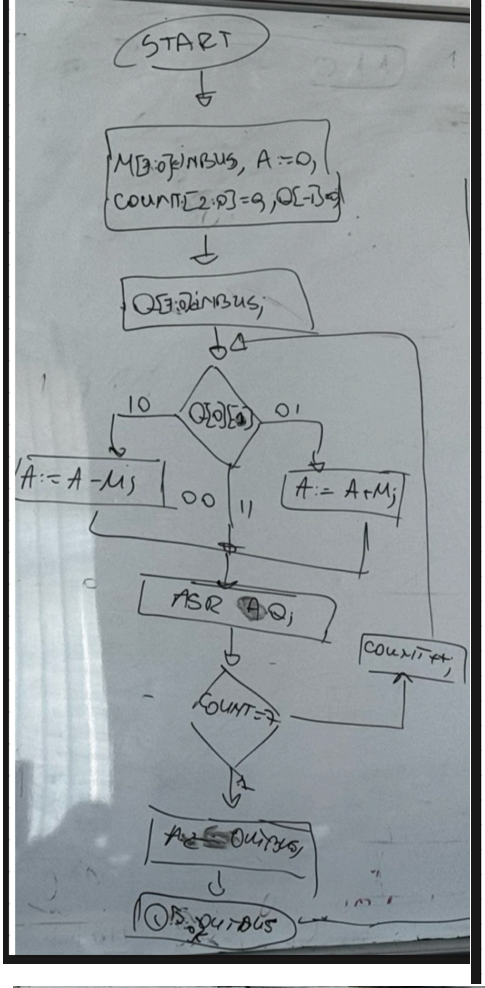
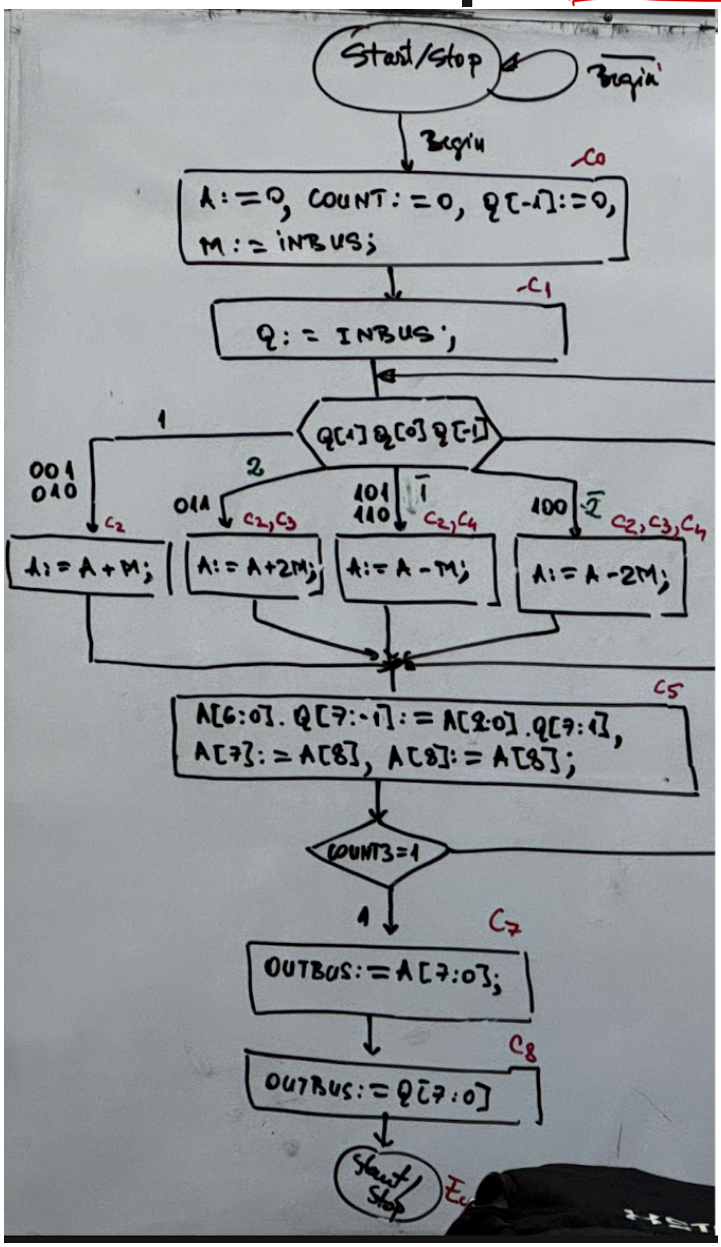


CNT	A	Q	Q-1	M
000	0000 0000	1001 0011	0	1100 1001
	+0011 0111		-M	
	0011 0111			
	0001 1011	1100 1001	1	
001	0000 1101	1110 0100	1	
	+1100 1001		+M	
	1101 0110			
	1110 1011	0111 0010	0	
011	1111 0101	1011 1001	0	
100	+0011 0111		-M	
	0010 1100			
	0001 0110	0101 1100	1	
101	+1100 1001		+M	
	1101 1111			
	1110 1111	1010 1110	0	
110	1111 0111	1101 0111	0	
111	+0011 0111		-M	
	0010 1110			
	0001 0111	0110 1011	1	→ END

00 shift
11
01 +
10 −



x_{i+1}	x_i	x_{i-1}	Operation
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	2
1	0	0	-2
1	0	1	-1
1	1	0	-1

CNT	A	Q	Q-1
00	0000 00000	1000 1011	0
	+1101 0110 1		-M
	1101 0110 1		
	1111 0101 1	0111 0010	1
01	+1101 0110 1		-M
	1100 1100 0		
	1111 0011 0	0001 1001	0
10	+0010 1001 1		+M
	0001 1100 1		
	0000 1110 0	0100 0110	0
11	+1010 1101 0		-2M
	1011 0100 0		
	1101 1010 1	0001 0001	1

$-117 * 83 = -9711$

x_{i+2}	x_{i+1}	x_i	x_{i-1}	of
0	0	0	0	0
0	0	0	1	1
0	0	1	0	1
0	0	1	1	2
0	1	0	0	2
0	1	0	1	3
0	1	1	0	3
0	1	1	1	4
1	0	0	0	-4
1	0	0	1	-3
1	0	1	0	-3
1	0	1	1	-2
1	1	0	0	-2
1	1	0	1	-1
1	1	1	0	-1
1	1	1	1	0

Above the columns: 2^{i+2}, 2^{i+1}

Radix 8

1, 2, 3, 4 M, −M

4 bits

3 shift

Radix 8

X = −104   X = −128 + 24 = −128 + 16 + 8

Y = −99 X_{C_2} = 1 0 0 1 1 0 0 0

2M = 1 1 0 0 1 1 1 0 1 0   Y = −128 + 29 = −128 + 16 + 8 + 4 + 1

−2M = 0 0 1 1 0 0 0 1 1 0

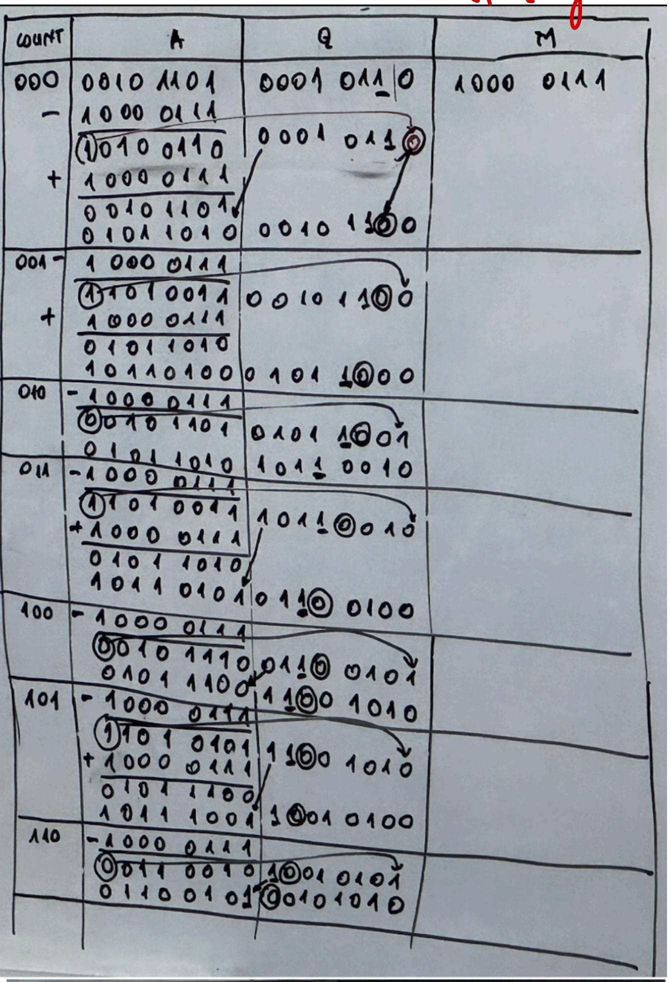
−3M = 0 1 0 0 1 0 1 0 0 1   Y = 1 1 1 0 0 1 1 1 0 1

+3M = 1 0 1 1 0 1 0 1 1 1   −Y = 0 0 0 1 1 0 0 0 1 1

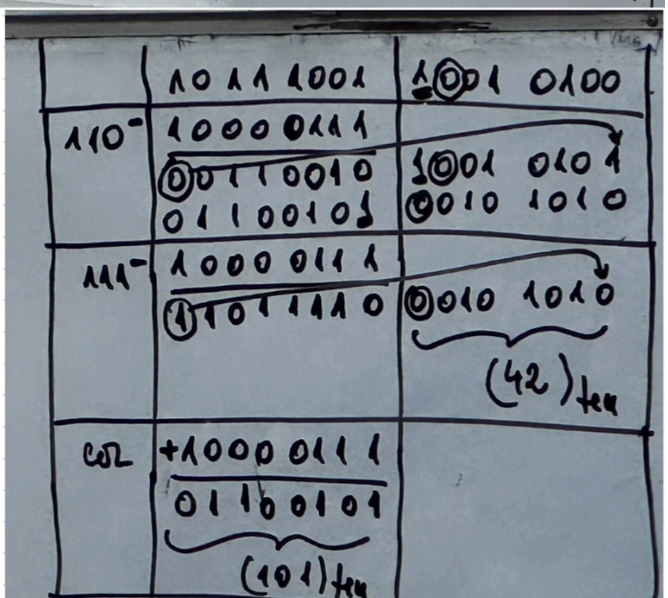
```
      1 1 1 0 0 1 1 1 0 1 +        0 0 0 1 1 0 0 0 1 1 +
+3M   1 1 0 0 1 1 1 0 1 0          0 0 1 1 0 0 0 1 1 0
      -------------------          -------------------
      1 0 1 1 0 1 0 1 1 1          0 1 0 0 1 0 1 0 0 1   −3M
```

CNT	A	Q	Q[−1]
00	00 0000 0000 00 0000 0000	1 1 0 0 1 1 1 0 0 0 0 0 0 1 1 0 0 0 1 1	0 0 (+3M)
01	+1 0 1 1 0 1 0 1 1 1 1 0 1 1 0 1 0 1 1 1 1 1 1 1 0 1 1 0 1 0	 1 1 1 0 0 0 1 1 0	 0 (−2M)
10	+0 0 1 1 0 0 0 1 1 0 0 0 1 0 1 0 0 0 0 0 0 0 0 0 0 1 0 1 0 0	 0 0 0 1 1 1 0 0 0	 1
	−104 × −99 = 10296	✓	

Restoring

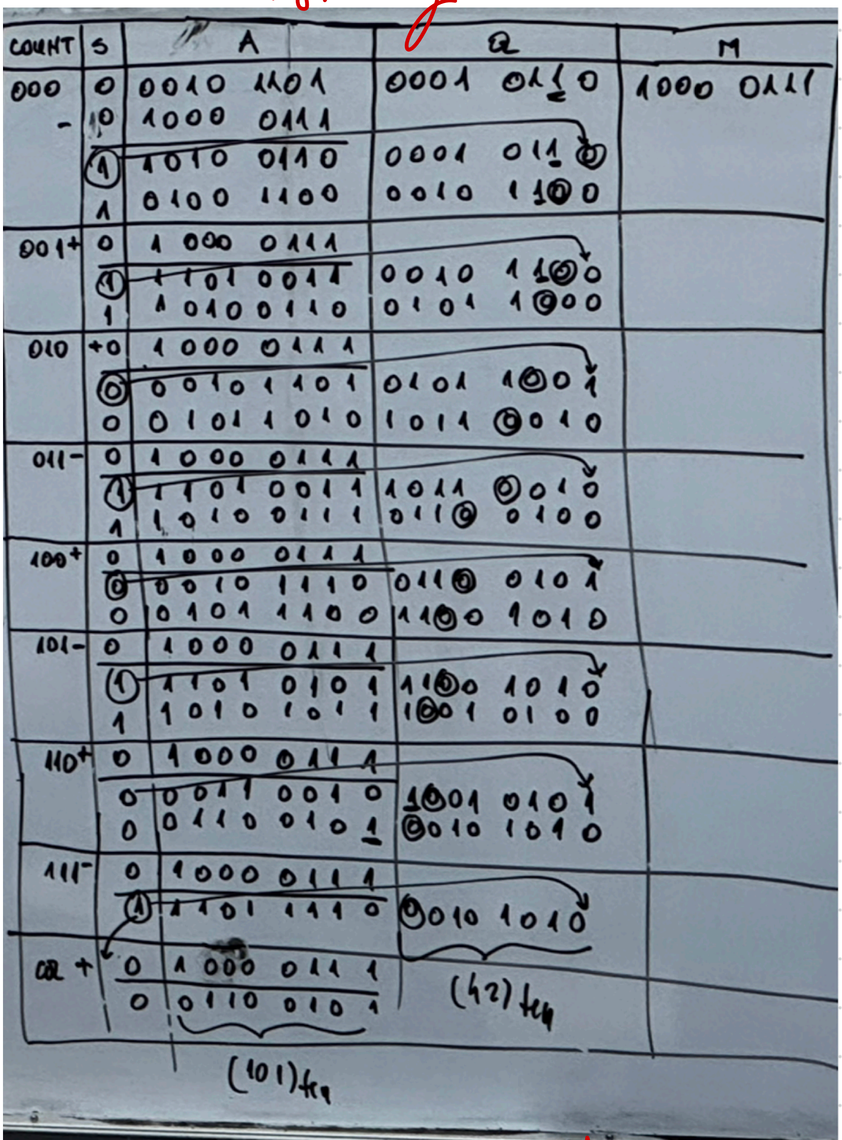


COUNT	A	Q	M
000 − +	0010 1101 1000 0111 (1)010 0110 1000 0111 0010 1101 0101 1010	0001 0110 0001 0110 0010 1100	1000 0111
001 − +	1 000 0111 (1)101 0011 1 000 0111 0101 1010 1011 0100	 0010 1100 0101 1000	
010	−1000 0111 (0)010 1101 0101 1010	 0101 1001 1011 0010	
011	−1000 0111 (1)101 0011 +1000 0111 0101 1010 1011 0101	 1011 0010 0110 0100	
100	−1000 0111 (0)010 1110 0101 1100	 0110 0101 1100 1010	
101	−1000 0111 (1)101 0101 +1000 0111 0101 1100 1011 1001	 1100 1010 1001 0100	
110	−1000 0111 (0)011 0010 0110 0101	 1001 0101 0010 1010	



	1011 1001	1001 0100
110−	1000 0111 (0)011 0010 0110 0101	 1001 0101 0010 1010
111−	1000 0111 (1)101 1110	 0010 1010 (42)ten
COR	+1000 0111 0110 0101 (101)ten	

Non Restoring

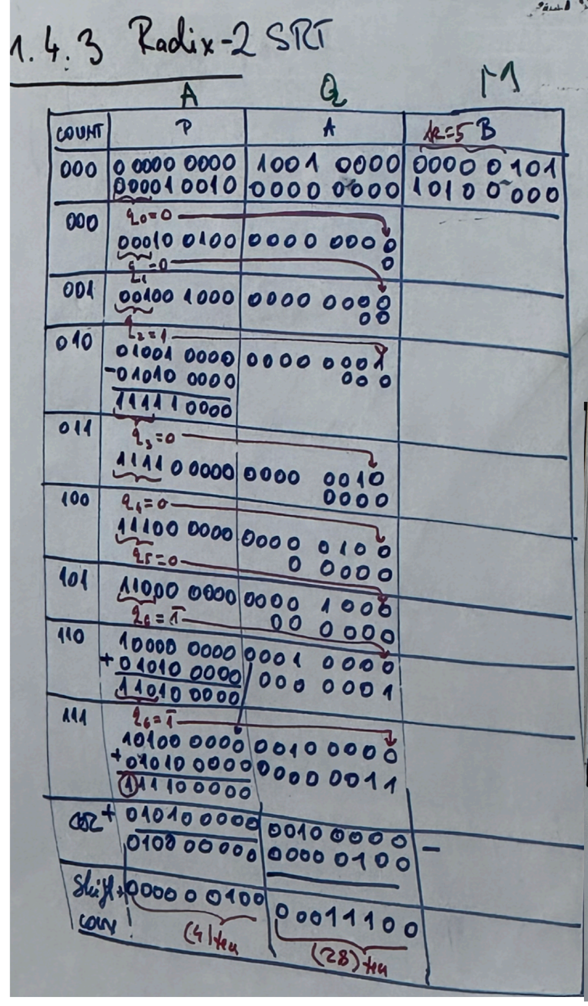


COUNT	S	A	Q	M
000 −	0 0 (1) 1	0010 1101 1000 0111 1010 0110 0100 1100	0001 0110 0001 0110 0010 1100	1000 0111
001+	0 (1) 1	1 000 0111 1101 0011 1010 0110	 0010 1100 0101 1000	
010	+0 (0) 0	1 000 0111 0010 1101 0101 1010	 0101 1001 1011 0010	
011−	0 (1) 1	1 000 0111 1101 0011 1010 0111	 1011 0010 0110 0100	
100+	0 (0) 0	1 000 0111 0010 1110 0101 1100	 0110 0101 1100 1010	
101−	0 (1) 1	1 000 0111 1101 0101 1010 1011	 1100 1010 1001 0100	
110+	0 0 0	1 000 0111 0011 0010 0110 0101	 1001 0101 0010 1010	
111−	0 (1)	1 000 0111 1101 1110	 0010 1010 (42)ten	
COR +	0 0	1 000 0111 0110 0101 (101)ten		

RA   rest − → + back, add a 0
          + → add a 1,   F sh

NRA   shift and − limit
          1 → +   1 → add a 0
          0 → −   0 add a 1

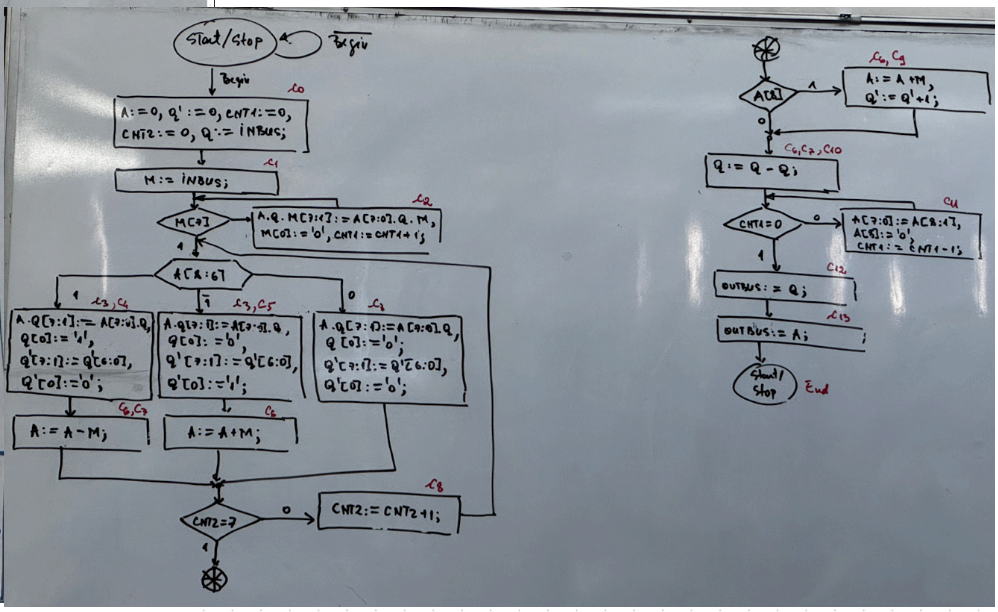
shift



$$CPU_{time} = IC \times CPI \times clk\ cycle\ time$$

$$CCT = \frac{1}{CR}$$

$$MIPS = \frac{IC}{CPU_{time} \times 10^6} = \frac{IC}{IC \times CPI \cdot CCT \cdot 10^6} = \frac{Clock\ Rate}{CPI \times 10^6}$$

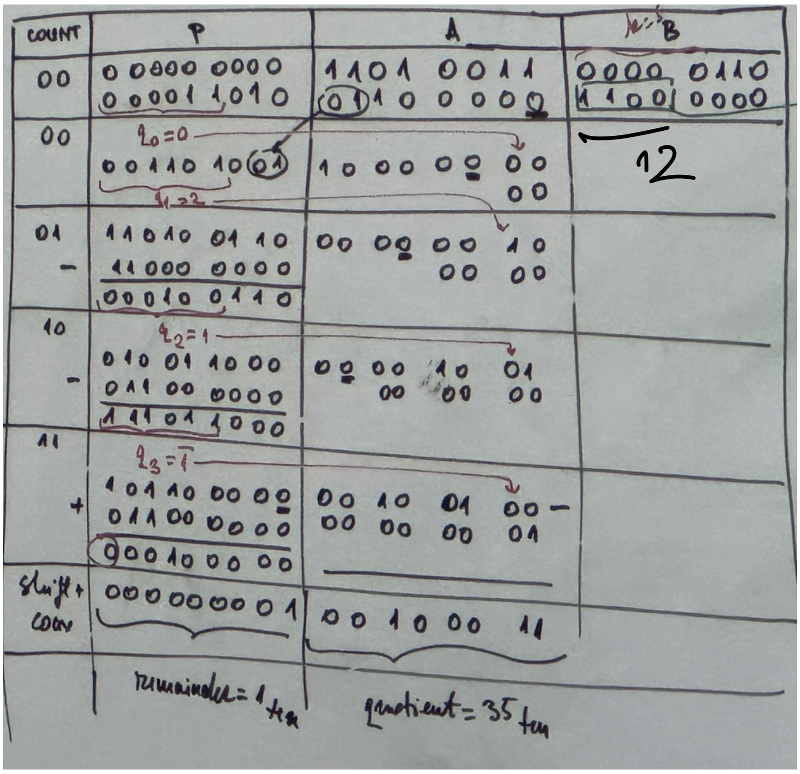


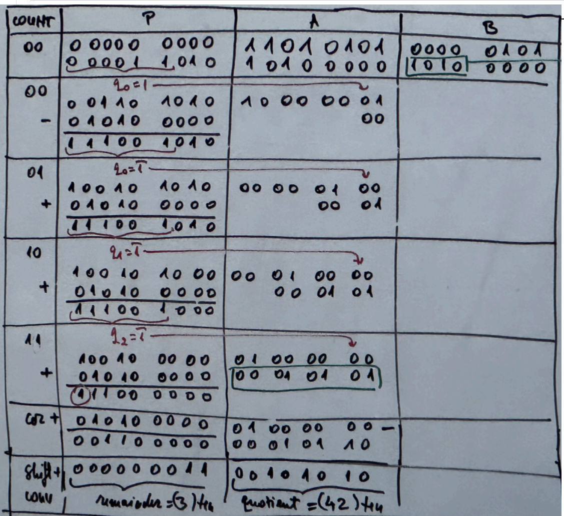
1 SRT-4

b	Range of P		q	b	Range of P		q
8	−12	−7	−2	12	−18	−10	−2
8	−6	−3	−1	12	−10	−4	−1
8	−2	1	0	12	−4	3	0
8	2	5	1	12	3	9	1
8	6	11	2	12	9	17	2
9	−14	−8	−2	13	−19	−11	−2
9	−7	−3	−1	13	−10	−4	−1
9	−3	2	0	13	−4	3	0
9	2	6	1	13	3	9	1
9	7	13	2	13	10	18	2
10	−15	−9	−2	14	−20	−11	−2
10	−8	−3	−1	14	−11	−4	−1
10	−3	2	0	14	−4	3	0
10	2	7	1	14	3	10	1
10	8	14	2	14	10	19	2
11	−16	−9	−2	15	−22	−12	−2
11	−9	−3	−1	15	−12	−4	−1
11	−3	2	0	15	−5	4	0
11	2	8	1	15	3	11	1
11	8	15	2	15	11	21	2

0 → 00 00   1 → 01 00   2 → 10 00

$\bar{1}$ → 00 01 $\bar{2}$ → 00 10





Radix 4 −37 (Q) −115 (M) −128 + 64 +

M = 1 1 0 0 0 1 1 0 1   2M = 1 0 0 0 1 1 0 1 0

−M = 0 0 1 1 1 0 0 1 1   −2M = 0 1 1 1 0 0 1 1 0

Q = 1 1 0 1 1 0 1 1 ¦ 0

CNT	A	Q	Q_{-1}
00	0 0000 0000	1 1 0 1 1 0 1 1	0
	+ 0 0111 0011		−M
	0 0111 0011		+2M
	0 0001 1100 1	1 1 1 0 1 1 0 1	1
01	+ 1 0001 1010		
	1 0101 0011		−M
	1 1010 1001	1 1 1 1 0 1 1 0	1
10	+ 0 0111 0011		
	0 0001 1100		−M
	0 0000 1110	0 1 1 1 1 0 1 1	0
11	+ 0 0111 0011		
	0 1000 0001		
	0 0100 0000	1 0 1 1 1 1 0 1	1

-117×83

$Q = -128 + 11 = -128 + 8 + 2 + 1$

$Q = 1000\ 1011$

M: $83 = 64 + 19 = 64 + 16 + 2 + 1$

$M = 00101\ 0011$ $2M = 010100110$

$-M = 11010\ 1101$ $-2M = 101\ 011010$

CNT	A	Q	Q_{-1}
00	00000 0000	1000 1011	0
	+ 11010 1101		−M
	11010 1101		+2M
	11101 0110	1100 0101	1
01	+ 01010 0110		
	00111 1100		−M
	00011 1110	0110 0010	1
10	+ 11010 1101		
	11110 1011		+M
	11111 0101	1011 0001	0
11	+ 00101 0011		
	00100 1000		
	0 00100 100	0101 1000	1

2 — 1

4 — 2

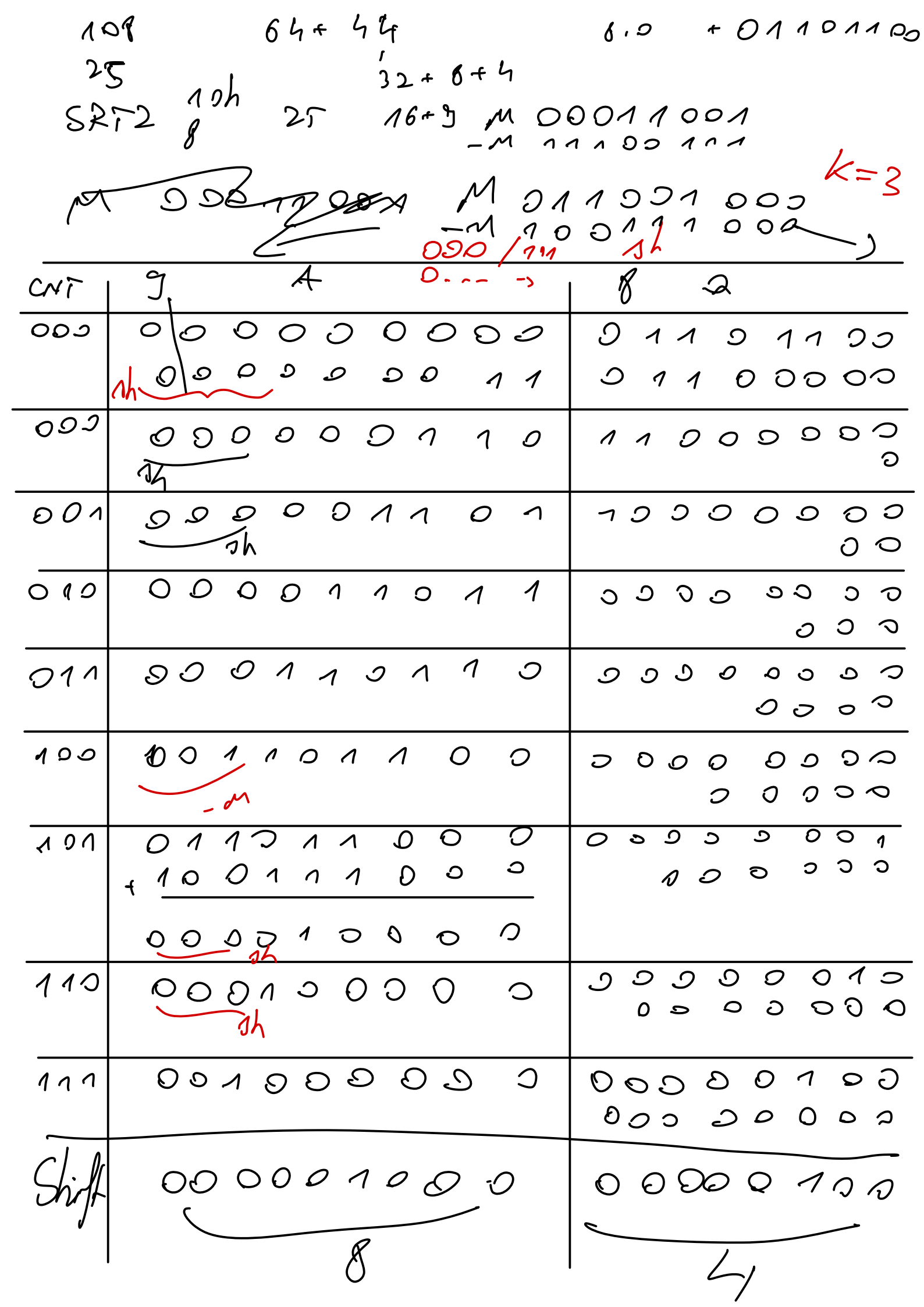
8 — 3

M 1 1 0 0 0 1 1 0 1
-M 0 0 1 1 1 0 0 1 1
2M 1 0 0 0 1 1 0 1 0
-2M 0 1 1 1 0 0 1 1 0

CNT	A	Q	Q_{-1}
00	0 0 0 0 0 0 0 0 0	1 1 0 1 1 0 1 1	0
	+ 0 0 1 1 1 0 0 1 1		−M
	0 0 1 1 1 0 0 1 1		−M
	0 0 0 0 1 1 1 0 0	1 1 1 1 0 1 1 0	1
01	+ 0 0 1 1 1 0 0 1 1		
	0 1 0 0 0 1 1 1 1		+2M
	0 0 0 1 0 0 0 1 1	1 1 1 1 1 1 0 1	1
10	+ 1 0 0 0 1 1 0 1 0		
	1 0 0 1 1 1 1 0 1		−M
	1 1 1 0 0 1 1 1 1	0 1 1 1 1 1 1 1	0
11	+ 0 0 1 1 1 0 0 1 1		

0 0 1 0 0 0 0 1 0

0 0 | 0 0 1 . 0 0 0 0 . 1 0 0 1 . 1 1 1 1 | 1


K=3
CNT
A
Q
Shift

108 / 25 M= 011001000 -M= 100111000

CNT	A	← k=3 Q
00	0 0000 0000 0 0000 0011	0 11 0 11 00 0 11 0 00 00
00	0 0000 1101 1	1 000 000 00 00
01	0 0011 0110 6 −M	0 0000 00 00 00 00
10	0 1101 1000 + 1 0011 1000 0 0001 0000 2 → sh	0 0000 00 01 00 00 00
11	0 0100 0000	00 00 01 00 00 00 00 00

shift 000~~00~~ 1000 100

228 / 13   228 = 128 + 100
64 + 36
32 + 4

13   1101

k = 4

M 0000 1101
−M 1111 0011

CNT	S	A	Q
000	0	0000 0000	1110 0100
	+(1)	1111 0011	
	1	1111 0011	1110 0100
	1	1110 0111	1100 1000
001	+ 0	0000 1101	
	(1)	1111 0100	1100 1000
	1	1110 1001	1001 0000
010	+ 0	0000 1101	
	(1)	1111 0110	
	1	1110 1101	0010 0000
011	+ 0	0000 1101	
	(1)	1111 1010	
	1	1111 0100	0100 0000
100	+ 0	0000 1101	
	(0)	0000 0001	0100 0001
	0	0000 0010	1000 0010
101	+ 1	1111 0011	
	(1)	1111 0101	0000 0100
	1	1110 1011	
110	+ 0	0000 1101	
	(1)	1111 1000	
	1	1111 0000	0000 1000
111	+ 0	0000 1101	
	1	1111 1101	
CORR	+ 0	0000 1101	
	0	0000 1010	

Type	CPI	IC
A	3	$35 \cdot 10^7$
B	2	$105 \cdot 10^6$
C	2	$400 \cdot 10^6$
Bz	3	$16 \cdot 10^7$

$CCT = 0.6\ ns$

$CR = \frac{1}{CCT}$ $\quad 0.6 \cdot 10^{-9}$

$\frac{10}{6} \cdot 10^9\ Hz$

$\frac{5}{3}\ GHz \quad 1{,}66\ GHz$

a) $CPU_{time} = CPI \times IC \times CCT$

$\frac{1}{0.6 \cdot 10^{-9}} \quad \frac{10}{6} \cdot 10^9$

$\frac{6}{10}$

~~Clk~~ / ~~I~~ · ~~I~~ · ~~I~~ / ~~Clk~~

$CC = 3 \cdot 35 \cdot 10^7 + 2 \cdot 105 \cdot 10^6 + 2 \cdot 400 \cdot 10^6 + 3 \cdot 16 \cdot 10^7$

$= (1050 + 310 + 800 + 480)\, 10^6$

$= 2540\ 10^6$

$CPU_{time} = 2540 \cdot 10^6 \cdot \frac{6}{10} \cdot 10^{-9} = 10^{-3}$

$CPU_{time} = 15240 \cdot 10^{-4} = 1{,}524\ s$

$MIPS = \frac{IC}{CPU_{time} \cdot 10^6}$

$= \frac{(350 + 105 + 400 + 160)\, 10^6}{1{,}524 \cdot 10^6} \quad \frac{1015}{1{,}524} =$

$MIPS = 666$

CPI_B new → 2× Faster

$\frac{CPU_{time\ old}}{new} = 2$ → $CPU_{time\ new} = 0{,}762$

$CC_{new} = 3.35 \cdot 10^7 + x \cdot 105 \cdot 10^6 + 2.400\ 10^6$

$+ 3.16 \cdot 10^7$

$= (1050 + 105x + 800 + 480)\ 10^6$

$(2330 + 105x)$

$0{,}762 = (2330 + 105x) \times \frac{6}{10} 10^{-6} \cdot 10^{-4}$

$\frac{7620}{6}$ $1270 = 2330 + 105x$

$x < 0$ Impossible

$\frac{2.105 \cdot 10^6}{2740 \cdot 10^6} = \frac{21}{274}$

1

$\frac{old}{new}$ 1,5

Exec Time Improved A, C ↘ 25%
B, D ↘ 40%

$CC = 3 \cdot 35 \cdot 10^7 \cdot \frac{75}{100}$

$0.5\,ns = \frac{5}{10} \cdot 10^{-9}$

$\frac{10}{5} \cdot 10^9 = 2GHz$

P1 CCT = 0.5 ns = 2GHz P2 = 3 GHz

ALU	3	1	20%
L/S	2	2	20%
Br	2	3	30%
Int	2	2	20%
FP	4	5	10%

$IC = 2.8 \cdot 10^6$

$CC_1 = 3 \cdot \frac{20}{100} + 2 \cdot \frac{20}{100} + 2 \cdot \frac{30}{100} + 2 \cdot \frac{20}{100} + 4 \cdot \frac{10}{100}$

$CPU_{time} = \frac{CC}{CR}$

$MIPS = \frac{IC}{CPU_{time} \cdot 10^6} = \frac{IC \cdot CR}{CC \cdot 10^6}$