Question 2:

⊛ 1-bit subtractor

- Half subtractor

X	Y	D	b_{out}
0	0	0	0
0	1	1	1
1	0	1	0
1	1	0	0

$b_{out} = 1$

0 → 1

~~1~~ 0

− 0 1

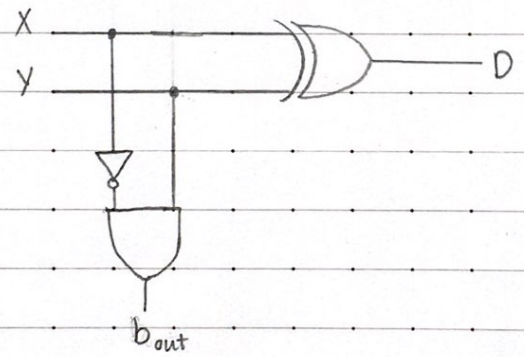
0 1

different

⇒ Expression: $D = X \oplus Y$

$b_{out} = \bar{X}Y$

Circuit:



- Full subtractor :

X	Y	b_{in}	D	b_{out}	
0	0	0	0	0	
0	0	1	1	1	
0	1	0	1	1	→ 0−1 = 1 (above), borrow 1; 1−0 = 1
0	1	1	0	1	→ 0−1 = 1 (above), borrow 1; 1−1 = 0
1	0	0	1	0	
1	0	1	0	0	
1	1	0	0	0	
1	1	1	1	1	

$(X - Y - b_{in})$

⇒ **Expression:**

$$D = x'y'b_{in} + x'yb'_{in} + xy'b'_{in} + xyb_{in}$$

$$= b'_{in}(x'y + xy') + b_{in}(x'y' + xy)$$

$$= b'_{in}\underbrace{(x \oplus y)}_{A} + b_{in}\underbrace{(x \odot y)}_{A'}$$

$$= b_{in} \oplus (x \oplus y)$$

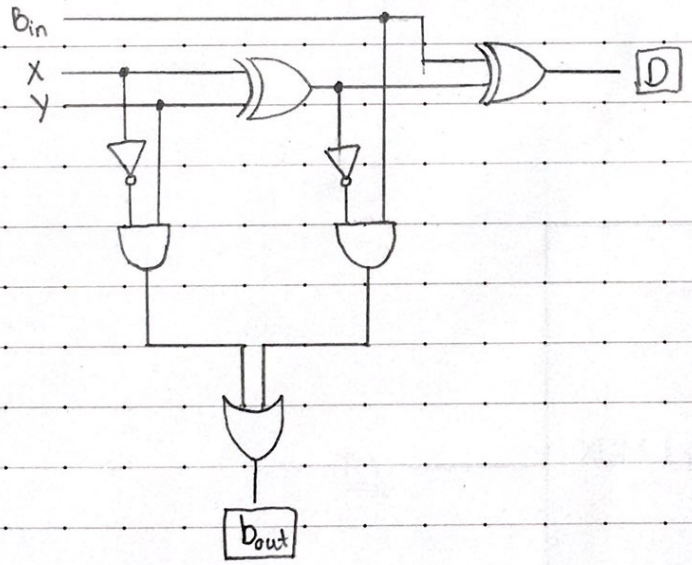
$$b_{out} = x'y'b_{in} + x'yb'_{in} + x'yb_{in} + xyb_{in}$$

$$= x'y(b'_{in} + b_{in}) + b_{in}(x'y' + xy)$$

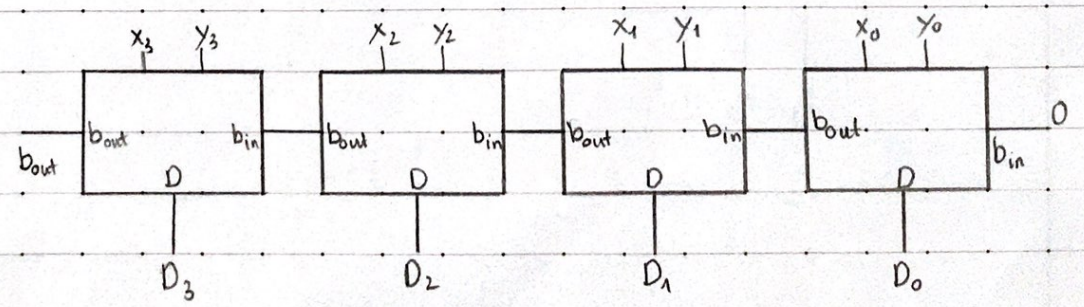
$$= x'y + b_{in}(x \odot y)$$

$$= x'y + b_{in}(x \oplus y)'$$

Circuit



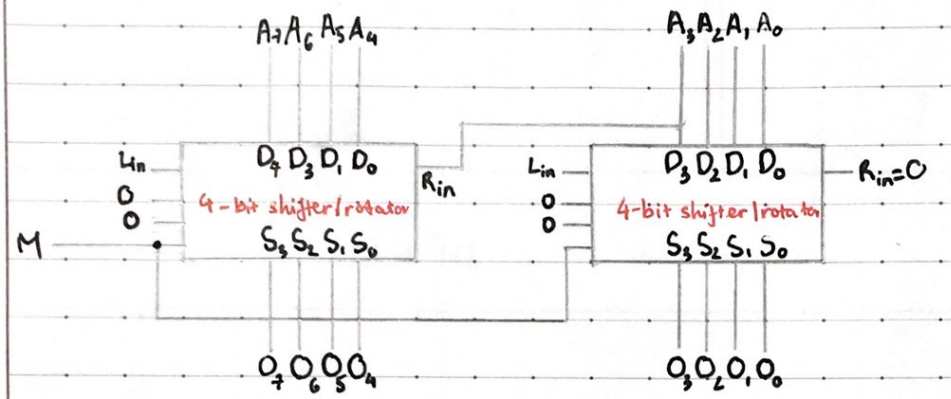
⊛ **4 bit subtractor**



Question 5:

⊛ 8-bit shifter from 4-bit shifter

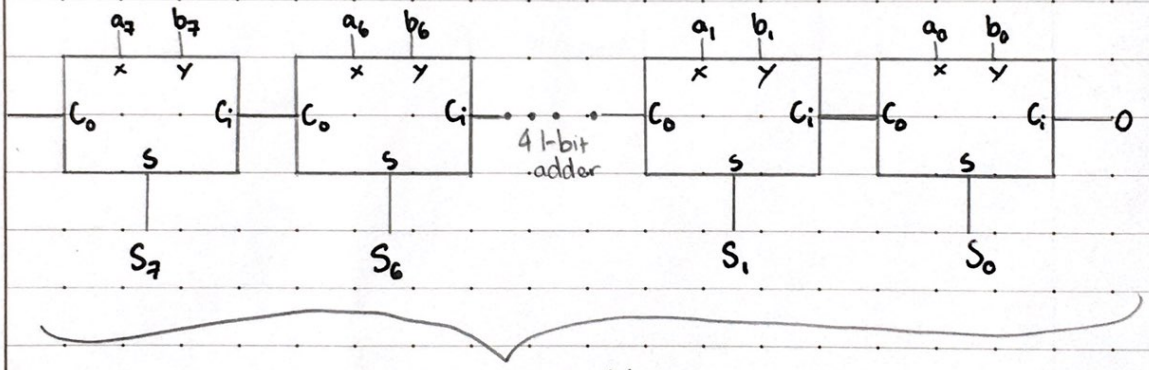
- Note: only keep left shifter and non-shift back (since we don't need other function)



M = 0 → don't shift

M = 1 → Shift left (2A)

⊛ 8-bit binary full adder.



⊛ The circuit:

- Note

+ The table shows that:

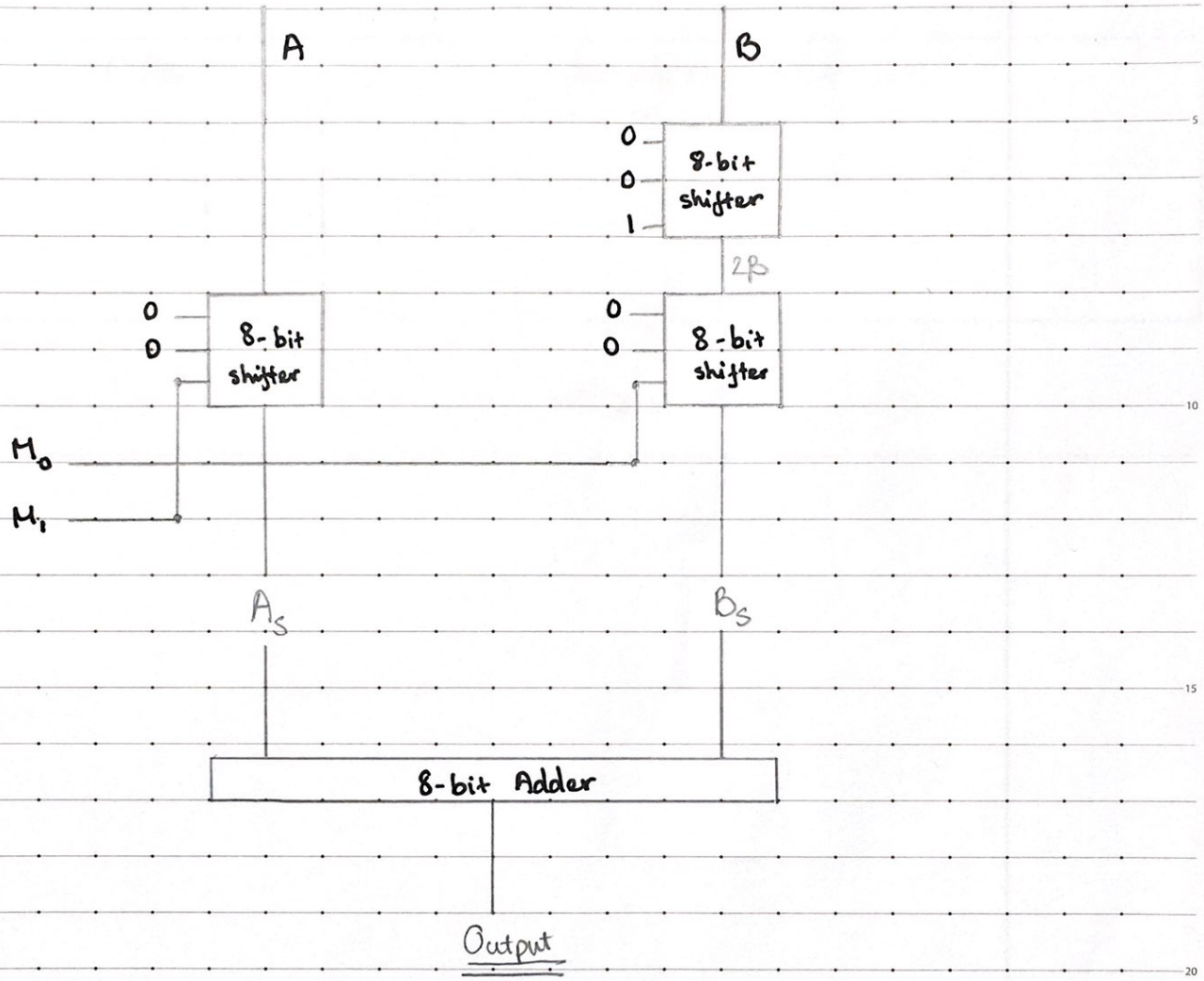
• Value of A depends on control input M_1 (A ≈ M = 0, 2A ≈ M = 1)

• Value of B depends on control input M_2 (2B ≈ M = 0, 4B ≈ M = 1)

+ Since value of B is not needed, but only 2B and 4B

→ Always shift B one time, then let it go through a shifter control by M_0, where it either shifts again (4B) or don't shift (2B)

+ 8 bit shifter & 8 bit adder has been drawn in detailed above. Below these two components are drawn in blocks.



+ $M_1 = 0$ → A don't shift → A
  $= 1$ → A shift left → 2A
+ $M_0 = 0$ → 2B don't shift → 2B
  $= 1$ → 2B shift left → 4B