SUBTRACTOR CIRCUIT

COMBINATIONAL LOGIC CIRCUITS

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TOPIC OUTLINE

Signed-Magnitude Form

1's Complement Form

2's Complement Form

SUBTRACTOR CIRCUIT

SIGNED-MAGNITUDE

0101 (+5)

1101 (−5)

sign
0 - positive
1 - negative

Binary Addition

	1101	(−5)		0101	(+5)
+	0010	(+2)	+	1010	(−2)
	↓			↓	
	101	(5)		101	(5)
−	010	(2)	−	010	(2)
	1011	(−3)		0011	(+3)

Drawback

To subtract the smaller number from the larger one, logic circuits for **comparison** and **subtraction** are needed.

1's COMPLEMENT

To obtain the **1's complement** of a negative binary number, **invert each bit** – changing all 1s to 0s and all 0s to 1s.

Formula

$$K = (2^n - 1) - P$$

where:

K = negative number

P = positive number

$K = (2^{4} - 1) - 5$ 4-bit +5

$K = (16 - 1) - 5$

$K = 10$ ← Decimal

1010 ← Binary of -5

Binary Addition

	1010	(-5)
+	0010	(+2)
	1100	(-3)
	0011	(1's)

	0101	(+5)
+	1101	(-2)
	10010	
	1	adjustment
	0011	(+3)

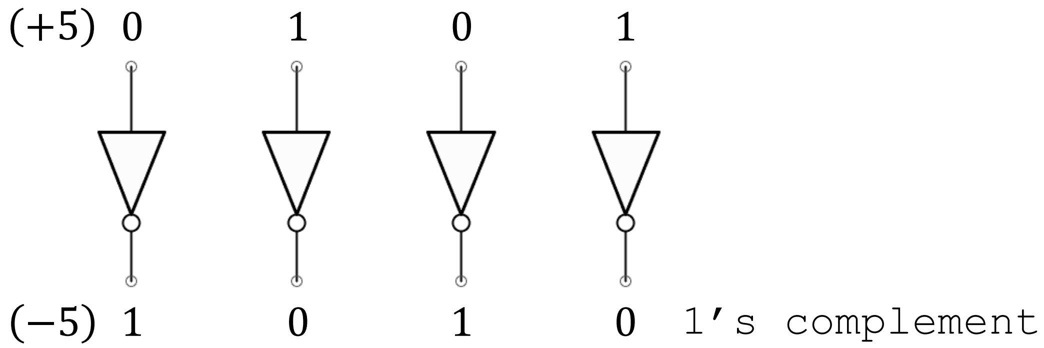
Drawback

In some cases, a correction is needed which amounts to an extra addition that must be performed.

1's COMPLEMENT

Equivalent Logic Circuit

To obtain the **1's complement** of a negative binary number, **invert each bit** – changing all 1s to 0s and all 0s to 1s.



Formula

$$K = (2^n - 1) - P$$

where:

K = negative number

P = positive number

2's COMPLEMENT

To obtain the **2's complement** of a negative number, first find its 1's complement (invert all bits), then **add 1** to the result.

Formula

$$K = 2^n - P$$

where:

K = negative number

P = positive number

$K = 2^{4} - 5$ ← +5

4-bit

$K = 11$ ← Decimal

1011 Binary of −5

Binary Addition

```
  1011   (-5)
+ 0010   (+2)
 ------
  1101   (-3)
  0011   (2's)
```

```
  0101   (+5)
+ 1110   (-2)
 ------
 10011   (+3)
 ignore
```

Range

$$-2^{n-1} \text{ to } 2^{n-1} - 1$$

$\rightarrow -2^{4-1}$ to $2^{4-1} - 1$

4-bit

$\rightarrow -8$ to 7

The addition process is the same, regardless of the signs of the operands.

2's COMPLEMENT

To obtain the **2's complement** of a negative number, first find its 1's complement (invert all bits), then **add 1** to the result.

Formula

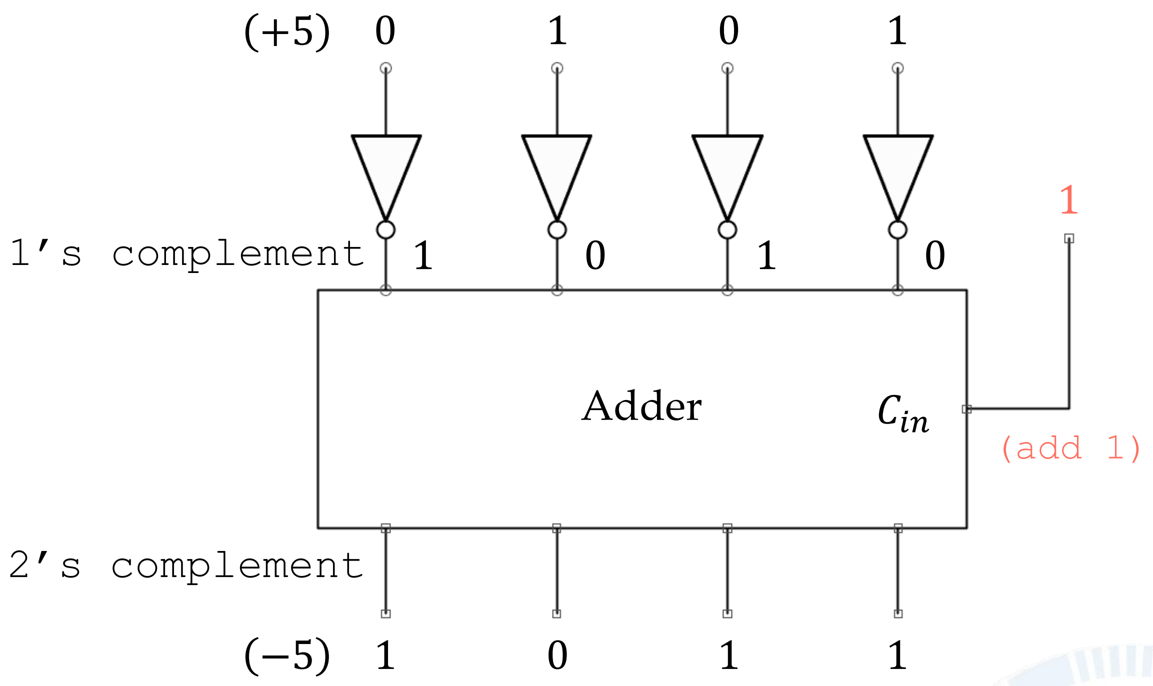
$$K = 2^n - P$$

where:

K = negative number

P = positive number

Equivalent Logic Circuit



EXERCISE

Create a block-level representation of a 2-bit binary subtractor using 2's complements method.

Range $= -2^{n-1}$ to $2^{n-1}-1$

Range $= -2^{2-1}$ to $2^{2-1}-1$

Range $= -2$ to 1

2-bit Signed Integers

$1 \rightarrow 01$

$0 \rightarrow 00$

$-1 \rightarrow 11$

$-2 \rightarrow 10$

Solution

$$\begin{array}{r} 2 \\ -\ 1 \\ \hline \end{array} \rightarrow \begin{array}{r} 2 \\ +\ (-1) \\ \hline 1 \end{array}$$

$$\begin{array}{r} 10 \\ -01 \\ \hline \end{array} \rightarrow \begin{array}{r} 10 \\ +\ 10 \\ +1 \\ \hline 101 \end{array} \rightarrow \begin{array}{rrr} C_1 & C_0 & \\ & A_1 & A_0 \\ + & \overline{B_1} & \overline{B_0} \\ & & +\ 1 \\ \hline b_2 & b_1 & b_0 \end{array}$$

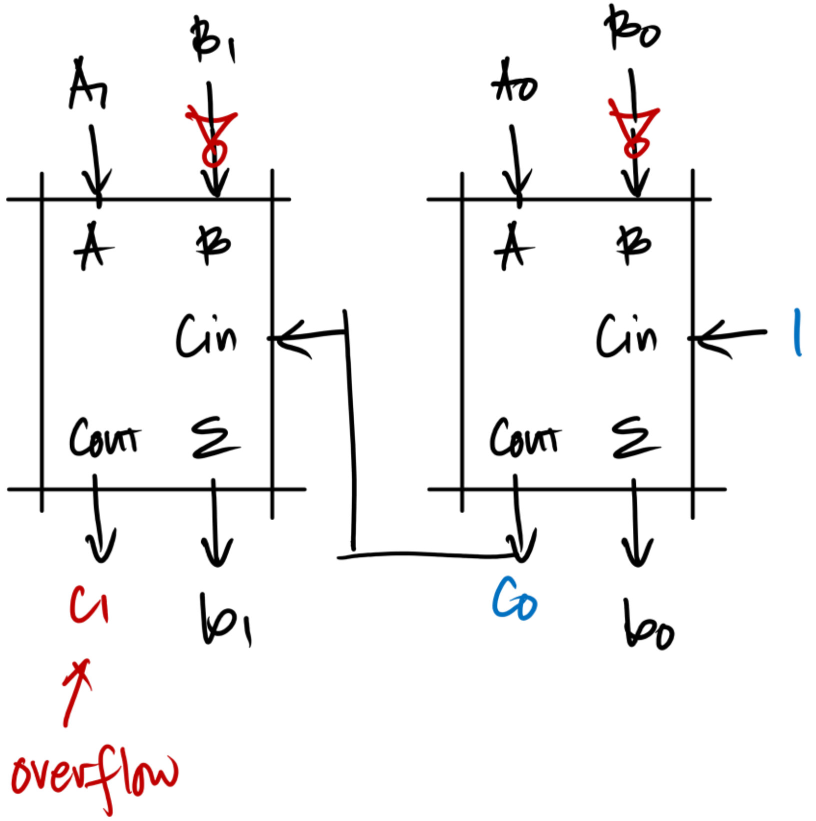
overflow

1's

2's

EXERCISE

Create a block-level representation of a 2-bit binary subtractor using 2's complements method.



Solution

$$\begin{array}{r} 2 \\ -\,1 \\ \hline \end{array} \;\longrightarrow\; \begin{array}{r} 2 \\ +\,(-1) \\ \hline 1 \end{array}$$

$$\begin{array}{r} 10 \\ -\,01 \\ \hline \end{array} \;\longrightarrow\; \begin{array}{r} 10 \\ +\,10 \\ +1 \\ \hline 101 \end{array} \;\longrightarrow\; \begin{array}{r} C_1\;C_0 \\ A_1\;A_0 \\ +\;\overline{B_1}\;\overline{B_0} \\ +\;1 \\ \hline b_2\;b_1\;b_0 \end{array}$$

overflow

1's

2's

EXERCISE

Synthesize and implement a 2-bit parallel binary subtractor using 2's complement method.

<u>note</u>

The use of XOR or XNOR gates is not allowed.

<u>Solution</u>

LABORATORY