

# Signed Binary Addition

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These slides introduce signed binary addition

# Signed Binary Addition

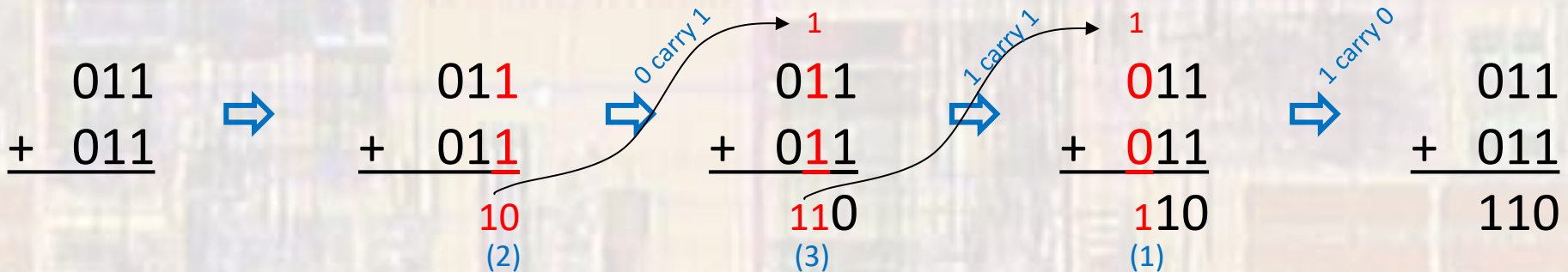
- Decimal Addition - Elementary school concepts
  - Add columns of numbers and keep track of the carry over to the next column
  - We normally use the decimal number system
    - Digits: 0-9
    - Carry over is in sets of 10

The diagram illustrates the step-by-step process of decimal addition for 245 + 189:

- Step 1:** The initial addition is shown: 
$$\begin{array}{r} 245 \\ + 189 \\ \hline \end{array}$$
- Step 2:** The units column (5 + 9) is summed, resulting in 14. A carry of 1 is shown moving to the tens column. The result is: 
$$\begin{array}{r} 245 \\ + 189 \\ \hline 14 \end{array}$$
- Step 3:** The tens column (4 + 8 + 1 carry) is summed, resulting in 13. A carry of 1 is shown moving to the hundreds column. The result is: 
$$\begin{array}{r} 245 \\ + 189 \\ \hline 134 \end{array}$$
- Step 4:** The hundreds column (2 + 1 + 1 carry) is summed, resulting in 4. The final result is: 
$$\begin{array}{r} 245 \\ + 189 \\ \hline 434 \end{array}$$

# Signed Binary Addition

- Signed Binary Addition - Extend elementary school concepts
  - Add columns of numbers and keep track of the carry over to the next column
  - Use the binary number system
    - Digits: 0-1
    - Carry over is in sets of 2



# Signed Binary Addition

- Signed Binary Addition - Examples

$$\begin{array}{r} \phantom{+} \phantom{0} \phantom{1} \phantom{0} \phantom{0} \phantom{1} \phantom{0} \phantom{1} \\ \phantom{+} \phantom{0} \phantom{1} \phantom{0} \phantom{0} \phantom{1} \phantom{0} \phantom{1} \\ \hline 100101 \\ + 011001 \\ \hline 111110 \end{array}$$

$$\begin{array}{r} \phantom{+} \phantom{0} \phantom{0} \phantom{1} \phantom{0} \phantom{0} \phantom{1} \phantom{1} \\ \phantom{+} \phantom{0} \phantom{0} \phantom{1} \phantom{0} \phantom{0} \phantom{1} \phantom{1} \\ \hline 101111 \\ + 001001 \\ \hline 111000 \end{array}$$

$$\begin{array}{r} \phantom{+} \phantom{0} \phantom{0} \phantom{1} \phantom{0} \phantom{0} \phantom{1} \phantom{1} \phantom{1} \\ \phantom{+} \phantom{0} \phantom{0} \phantom{1} \phantom{0} \phantom{0} \phantom{1} \phantom{1} \phantom{1} \\ \hline 101111 \\ + 011001 \\ \hline 1001000 \end{array}$$

Depending on the situation – this may or may not be a problem

# Signed Binary Addition

- Overflow

- In elementary school we did not care how many digits the answer required

$$\begin{array}{r} 745 \\ + 589 \\ \hline 1334 \end{array}$$

- In signed binary addition – we are generally representing something that ultimately is to be executed in hardware
  - Our hardware cannot change the number of bits (wires) it can hold
  - We must establish a maximum number size (# of bits) and create an error when the result of the addition does not fit in this size
  - Due to the unique nature of signed binary numbers, the **mathematical** addition of an extra bit may or may not indicate a problem (note: we can not physically add a bit)

# Signed Binary Addition

- Overflow – cont'd
  - The process of determining overflow in a signed binary addition is:
    - Compare the carry-in of the MSB to the carry-out of the MSB
      - If they are the same – no overflow
      - If they are different - **overflow**

1 1 1 1 1		
101111	-17	Carry-in to MSB (1)
+ 011001	25	=
<u>        </u>		Carry-out of MSB (1)
1001000	8	→ No overflow
		→ Result is correct

0 1 1 1 1		
101111	-17	Carry-in to MSB (0)
+ 101001	-23	≠
<u>        </u>		Carry-out of MSB (1)
1011000	24	→ overflow
		→ Result is wrong

# Signed Binary Addition

- Overflow – Interpretation

6 bit signed binary

	0 1 1 1 1		
	1 0 1 1 1 1	-17	Overflow
+	1 0 1 0 0 1	-23	MSB Carry-out $\neq$ carry-in
	<del>1</del> 0 1 1 0 0 0	24	Result in 6 bits is 24

