Carry Lookahead Adder

Ruben Van den Bossche
Sam Verboven

Universiteit Antwerpen

Addition

```
  00101110
+ 00100111
```

Addition

```
  10111100
  00101110
+ 00100111
----------
  01010101
```

Addition

- 1-bit addition
  - Sum output is 1 when exactly one input is 1 or all three inputs are 1
  - CarryOut output is 1 when at least two inputs are 1
- Carry ripples through addition
  - Hardware executes in parallel
  - Slow!

Faster addition

- Determine CarryIn's sooner
  - Faster
  - More hardware needed
- Two levels of abstraction
  - Blocks of 4-bit adder
  - Within each block the carry in's are calculated before the addition is performed

Propagate and generate

```
  00101110
+ 00100111
```

Propagate and generate

```
  0010        1110
+ 0010      + 0111
```

Propagate and generate

```
????      ????
0010      1110
+ 0010    + 0111
```

Propagate and generate

- Generate:
  $g_i = a_i \cdot b_i$
- Propagate:
  $p_i = a_i + b_i$
- CarryIn:
  $c_{i+1} = g_i + p_i \cdot c_i$

$$\begin{array}{r} c_4 c_3 c_2 c_1 c_0 \\ a_3 a_2 a_1 a_0 \\ + \quad b_3 b_2 b_1 b_0 \\ \hline s_3 s_2 s_1 s_0 \end{array}$$

Propagate and generate

- $c_1 = g_0 + (p_0 \cdot c_0)$
  $c_2 = g_1 + (p_1 \cdot g_0) + (p_1 \cdot p_0 \cdot c_0)$
  $c_3 = g_2 + (p_2 \cdot g_1) + (p_2 \cdot p_1 \cdot g_0) + (p_2 \cdot p_1 \cdot p_0 \cdot c_0)$
  $c_4 = g_3 + (p_3 \cdot g_2) + (p_3 \cdot p_2 \cdot g_1) + (p_3 \cdot p_2 \cdot p_1 \cdot g_0) + (p_3 \cdot p_2 \cdot p_1 \cdot p_0 \cdot c_0)$

$$\begin{array}{r} c_4c_3c_2c_1c_0 \\ a_3a_2a_1a_0 \\ +\ b_3b_2b_1b_0 \\ \hline s_3s_2s_1s_0 \end{array}$$

Propagate and generate

```
  0010        1110
+ 0010      + 0111
```

Propagate and generate

```
  0010        11100
+ 0010      + 0111
  0100        10011
```

Propagate and generate

```
  0010        1100
+ 0010      + 0111
------      ------
              0101
```

Propagate and generate

```
     0101  <------- (1)1100
     0010              1110
  +  0010           +  0111
  -------           -------
     0101              0101
```

Superpropagates and -generates

- Calculate c_4 of each 4-bit carry-lookahead adder
- Superpropagate P_i and supergenerate G_i
  - $P_0 = p_3 \cdot p_2 \cdot p_1 \cdot p_0$
  - $G_0 = g_3 + (p_3 \cdot g_2) + (p_3 \cdot p_2 \cdot g_1) + (p_3 \cdot p_2 \cdot p_1 \cdot g_0)$
- Calculate C_i
  - $C_1 = G_0 + (P_0 \cdot c_0)$
  - $C_2 = G_1 + (P_1 \cdot G_0) + (P_1 \cdot P_0 \cdot c_0)$
  - ...

8-bit Carry Lookahead Adder