**CS320 – Fall 2017**

**Homework Assignment 2**

**Due: Friday, September 15th in class**

Apply 2-level carry-lookahead addition algorithm discussed in class (logic is shown on slide 18 of arithmetic slides) to add the following two 16-bit numbers:

a: 0011010001100111

b: 0001110011001011

Show the following:

1. The values of pi and gi for each bit position [10%]. Note that gi is AND of the two inputs, and pi is the XOR of the two inputs.
2. The values of group-level Pi and Gi [20%]
3. The values of Ci and ci. First, show the logic needed to compute the carry-ins in boolean equation format. This is a two-step process: first, you compute the carry-ins to each 4-bit group (Ci), and then you compute carry-ins into the bit positions inside each group (ci). [40%]
4. Result computation in each bit position after the carries are computed. [10%]
5. Demonstrate that this result is identical to what can be achieved by ripple-carry adder. [20%]

Show all your computations in a separate page, and fill in the following table as a result:

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Bit 15** | **Bit 14** | **Bit 13** | **Bit 12** | **Bit 11** | **Bit 10** | **Bit 9** | **Bit 8** | **Bit 7** | **Bit 6** | **Bit 5** | **Bit 4** | **Bit 3** | **Bit 2** | **Bit 1** | **Bit 0** |
| **ai** | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 |
| **bi** | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 |
| **gi** | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 |
| **pi** | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 |
| **Gk** |  |  |  | 0 |  |  |  | 1 |  |  |  | 1 |  |  |  | 1 |
| **Pk** |  |  |  | 0 |  |  |  | 0 |  |  |  | 0 |  |  |  | 0 |
| **ci** | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 |
| **Ck** |  |  |  | 0 |  |  |  | 0 |  |  |  | 0 |  |  |  | 0 |
| Si Sum | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 |

a: 0011 0100 0110 0111

b: 0001 1100 1100 1011

**gi = ai AND bi (generate signal)**

g0 = a0 AND b0 = 1 AND 1 = 1

g1 = a1 AND b1 = 1 AND 1 = 1

g2 = a2 AND b2 = 1 AND 0 = 0

g3 = a3 AND b3 = 0 AND 1 = 0

g4 = 0 AND 0 = 0

g5 = 1 AND 0 = 0

g6 = 1 AND 1 = 1

g7 = 0 AND 1 = 0

g8 = 0 AND 0 = 0

g9 = 0 AND 0 = 0

g10 = 1 AND 1 = 1

g11 0 AND 1 = 0

g12 = 1 AND 1 = 1

g13 = 1 AND 0 = 0

g14 = 0 AND 0 = 0

g15 = 0 AND 0 = 0

**pi = ai XOR bi (propagate)**

p0 = a0 XOR b0 = 1 XOR 1 = 0

p1 = a1 XOR b1 = 1 XOR 1 = 0

p2 = a2 XOR b2 = 1 XOR 0 = 1

p3 = a3 XOR b3 = 0 XOR 1 = 1

p4 = 0 XOR 0 = 0

p5 = 1 XOR 0 = 1

p6 = 1 XOR 1 = 0

p7 = 0 XOR 1 = 1

p8 = 0 XOR 0 = 0

p9 = 0 XOR 0 = 0

p10 = 1 XOR 1 = 0

p11 = 0 XOR 1 = 1

p12 = 1 XOR 1 = 0

p13 = 1 XOR 0 = 1

p14 = 0 XOR 0 = 0

p15 = 0 XOR 0 = 0

**ci = gi-1 XOR (pi-1 AND ci-1)**

c0 = 0

c1 = g0 XOR (p0 AND c0) = 1 XOR (0 AND 0) = 1

c2 = g1 XOR (p1 AND c1) = 1 XOR (0 AND 1) = 1

c3 = g2 XOR (p2 AND c2) = 0 XOR (1 AND 1) = 1

c4 = 0 XOR (1 AND 1) = 1

c5 = 0 XOR (0 AND 1) = 0

c6 = 0 XOR (1 AND 0) = 0

c7 = 1 XOR (0 AND 0) = 1

c8 = 0 XOR (1 AND 1) = 1

c9 = 0 XOR (0 AND 1) = 0

c10 = 0 XOR (0 AND 0) = 0

c11 = 1 XOR (0 AND 0) = 1

c12 = 0 XOR (1 AND 1) = 1

c13 = 1 XOR (0 AND 1) = 1

c14 = 0 XOR (1 AND 1) = 1

c15 = 0 XOR (0 AND 0) = 0

P0 = p3 AND p2 AND p1 AND p0 = 1 AND 1 AND 0 AND 0 = 0

P1 = p7 AND p6 AND p5 AND p4 = 1 AND 0 AND 1 AND 0 = 0

P2 = p11 AND p10 AND p9 AND p8 = 1 AND 0 AND 0 AND 0 = 0

P3 = p15 AND p14 AND p13 AND p12 = 0 AND 0 AND 1 AND 0 = 0

G0 = g3 + p3 \* g2 + p3 \* p2 \* g1 + p3 \* p2 \* p1 \* g0

G0 = 0 + 1 \* 0 + 1 \* 1 \* 1 + 1 \* 1 \* 0 \* 0 = 1

G1 = g7 + p7 \* g6 + p7 \* p6 \* g5 + p7 \* p6 \* p5 \* g4

G1 = 0 + 1 \* 1 + 1 \* 0 \* 1 + 1 \* 0 \* 1 \* 0 = 1

G2 = g11 + p11 \* g10 + p11 \* p10 \* g9 + p11 \* p10 \* p9 \* g8

G2 = 0 + 1 \* 1 + 1 \* 0 \* 0 + 1 \* 0 \* 0 \* 0 = 1

G3 = g15 + p15 \* g14 + p15 \* p14 \* g13 + p15 \* p14 \* p13 \* g12

G3 = 0 + 0 \* 0 + 0 \* 0 \* 0 + 0 \* 0 \* 1 \* 1 = 0

Ripple Carry:

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Ci |  | 1 | 1 | 1 | 1 |  |  | 1 | 1 |  |  | 1 | 1 | 1 | 1 |  |
|  | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 |
| + | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 |
| = | **0** | **1** | **0** | **1** | **0** | **0** | **0** | **1** | **0** | **0** | **1** | **1** | **0** | **0** | **1** | **0** |