EE 3613: Computer Organization

Arithmetic for Computers – 2
Carry Look Ahead Adder

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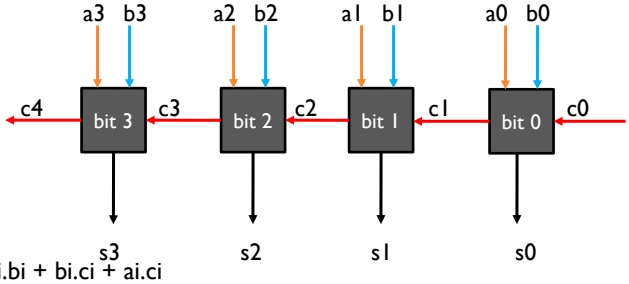
Problem: Ripple Carry Adder is Slow!

- Propagation time of the carry bit takes time – Sequential operation



- c i+1 = ai.bi + bi.ci + ai.ci
- si = ai'.bi'.ci + ai'.bi.ci' + ai.bi'.ci' + ai.bi.ci
- How many gate delays are required for a *n*-bit sum?
  - 2(n-1) + 3

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1st Try: Carry Look Ahead (CLA) Adder

- Lets start again
- ci+1 = (bi . ci) + (ai . ci) + (ai . bi)
  = (ai . bi) + (ai + bi) . ci
- c1 = (a0.b0) + (a0 + b0).c0
- c2 = (a1 . b1) + (a1 + b1) . ((a0 . b0) + (a0 +b0) . c0)
- Repeated use of (ai . bi) and (ai + bi) in the formula
- Generate (gi) and Propagate (pi)
- gi = ai . bi [a carry is always *generated*]
- pi = ai + bi [if $(i-1)^{th}$ bit has a carry, it will be *propagated* to $(i+1)^{th}$ bit]
- ci+1 = gi + pi . ci

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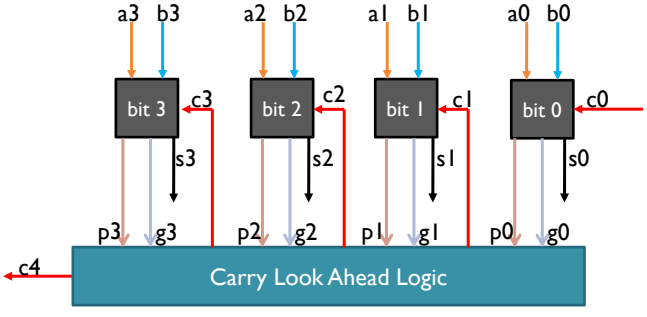
1st Try: CLA

- c1 = g0 + p0.c0
- c2 = g1 + p1.c1 = g1 + p1.(g0 + p0.c0) = g1 + p1.g0 + p1.p0.c0
- c3 = g2 + p2.c2 = g2 + p2.(g1 + p1.g0 + p1.p0.c0) = g2 + p2.g1 + p2.p1.g0 + p2.p1.p0.c0



- Number of gate delays for *n*-bit adder? (1+2+3 = 6)
- Feasible?

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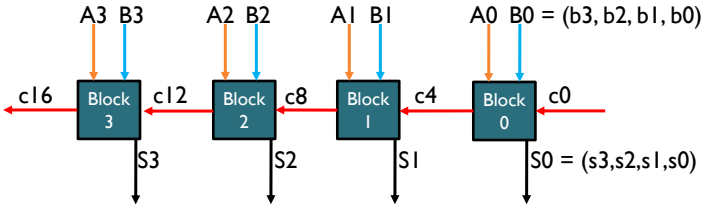
2nd Try: Two-level CLA

- Combine few bits (say 0, 1, 2 and 3) to generate c4
- Then ripple it through to the next block (4, 5, 6 and 7) to generate c8
- Total gate delay for a "n" bit adder = 1+2(n/4)+3



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3rd Try: 2nd level Generate and Propagate

- P0 = p3.p2.p1.p0
  - If all 4 bits in a block propagate, the block propagates a carry
- G0 = g3 + p3.g2 + p3.p2.g1 + p3.p2.p1.g0
  - If atleast 1 bit generates carry and is propagated, the block generates a carry
- c4 = (g3 + p3.g2 + p3.p2.g1 + p3.p2.p1.g0) + (p3.p2.p1.p0).c0
  = G0 + P0.c0
- P1 = p7.p6.p5.p4
- G1 = g7 + p7.g6 + p7.p6.g5 + p7.p6.p5.g4
- c8 = G1 + P1.c4 = G1 + P1(G0 + P0.c0)
  = G1 + P1.G0 + P1.P0.co
- c12 = G2 + P2.c8
- c16 = G3 + P3.c12
- Total gate delay for a "n" bit adder = 1 + 2 + 2(n/16) + 3

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Conclusion

- Reducing the gate delays enables faster addition
- Can recursively increase the number of levels from 2 to 3
  - Gate delay?
- Divide and conquer – break into smaller blocks and then ripple (2^{nd} try)
- Or use "SUPER" generates and propagates – (3^{rd} try)

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