Topic 9: Building Blocks for Computers

Readings for this topic:

P&H, Appendix B.3 thru B.6

Goal

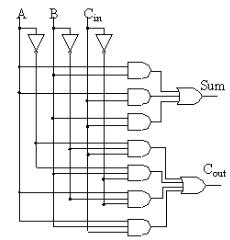
- •Summary of combinatorial and sequential components that are useful for computers.
- •Techniques for combining them

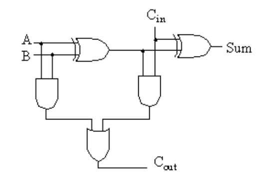
Recall: Full Adder

Boo:lean Algebra

$$Sum = \bar{A}\bar{B}C + \bar{A}B\bar{C} + A\bar{B}\bar{C} + ABC$$

$$Cout = AB + BC + AC$$





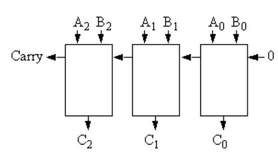
Bit Slice Adders

Problem: How to add 3 bit numbers?

- •C2C1C0 = A2A1A0+ B2B1B0
- •Redesigning circuit for 6 inputs would be messy and wouldn't scale well.

Solution: Cascade 1-bit adders

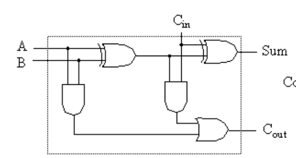
A	B	Cin	Sum	Cont
0	0	0	0	
0	0	1	1	
0	1	0	1	
0	1	1	0	1
1	0	0	1	0
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

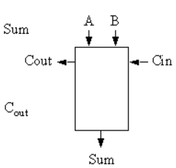


Adder bit slice

This is called a "full adder".

- •A "half adder" adds *two* bits and produces sum and carry out

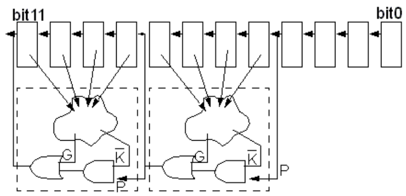




Bit-slice Adder

Problem: Time to compute carry grows with number of inputs

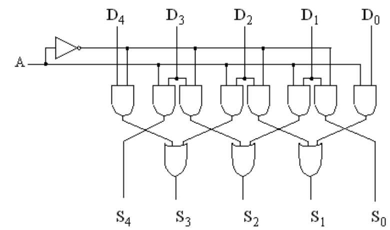
Solution: Carry look ahead adders.



•shortcut the carry from previous group of bits to following group of bits
•How: using *local* group of bits, determine:
•generate: group will always generate carry into next group
•kill: group will never generate carry into next group
•propagate: group will propagate carry from previous group into next

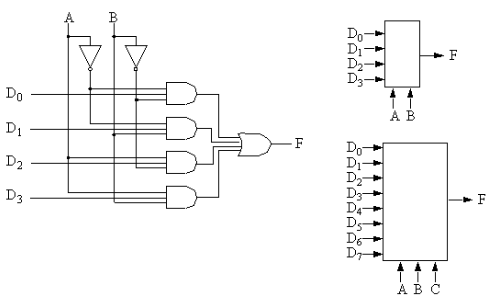
Shifters

Shifts 1 bit left/right, based on input: 1 => shift left, 0 => shift right



Multiplexer

Given an n-bit number as input, select one of 2n inputs.



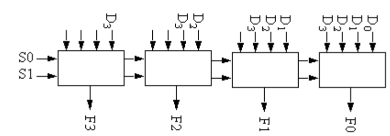
AND gate passes signal through if the control is 1

Full Shifter

Shift N-bit number N positions in one direction

Can build a shifter with multiplexors

Example: 4-bit right-shifter



Example: to make full 32-bit shifter, use 3 stages:
- •stage1: shift by 0, 8, 16, or 24
- •stage2: shift by 0, 2, 4, or 6
- •stage3: shift by 0, or 1

ALU

Summary: we can do shifters, adders, AND, OR, NOT, XOR, ...

- Arithmetic operations generate a carry
- Logic operations have no carry

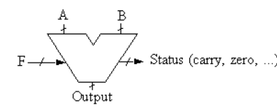
An ALU computes a function of 2 inputs O = F(A, B), where the function F is selected by other inputs (F0, F1).

- Bit Slicing: Compute function for 1 bit using carry in and carry out. This is just a generalization of cascaded adders.

An example ALU

F	Function
00	A AND B
01	A OR B
10	NOT B
11	A + B

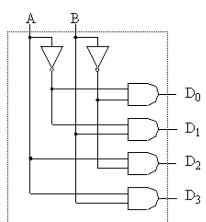
Circuit Symbol

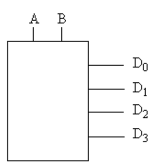


Decoders

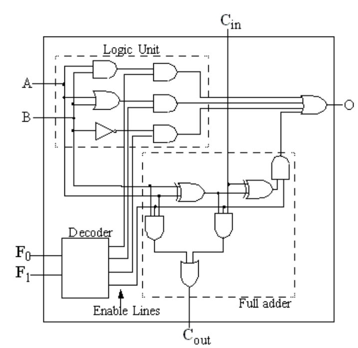
How do we *select* an operation?

Decoder: given an n-bit number as input, enables one of 2n outputs





ALU Bit Slice Schematic



ALU Schematic