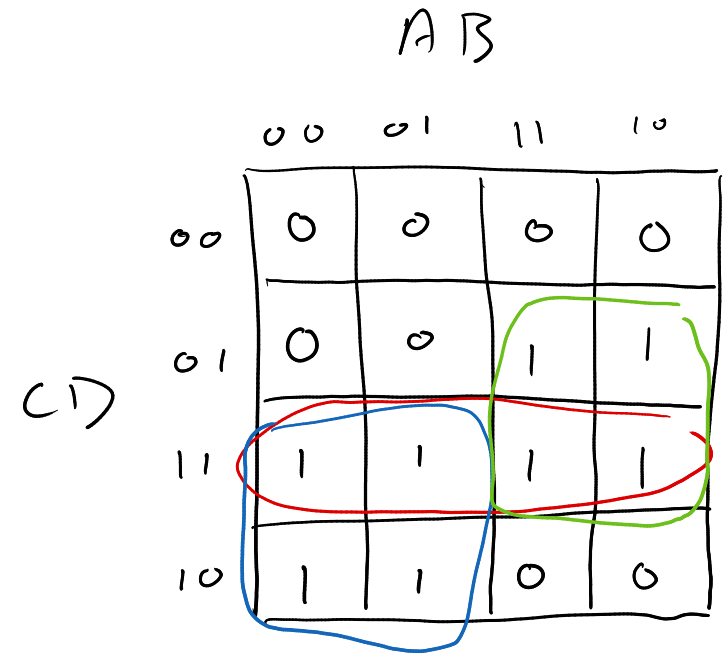


Warmup

Use a k-map to find a minimal implementation of this truth table:

A	B	C	D		Y	A	B	C	D		Y
0	0	0	0		0	1	0	0	0		0
0	0	0	1		0	1	0	0	1		1
0	0	1	0		1	1	0	1	0		0
0	0	1	1		1	1	0	1	1		1
0	1	0	0		0	1	1	0	0		0
0	1	0	1		0	1	1	0	1		1
0	1	1	0		1	1	1	1	0		0
0	1	1	1		1	1	1	1	1		1



CD

$$\bar{A}C + AD$$

redundant

ES 4: Multiplexers and FPGAs

Steven Bell

17 September 2024

Logistics

- Why self-graded homework???
 - You learn by evaluating your own work
 - You have immediate feedback and opportunities for practice
- Lab 2 this week / lab 3 next week
- You're invited for Thanksgiving




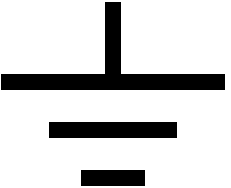
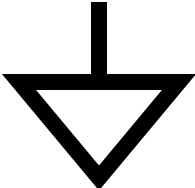
By the end of class today, you should be able to:

- Explain what a multiplexer is
- Draw a logic diagram using a 2^N -input multiplexer to implement an N-variable boolean equation
- Describe the basic structure of an FPGA

The idea of decoders and multiplexers didn't make much sense at the start, but after re-reading a couple of times, I think I'm starting to understand it.

That being said, I'm still feeling pretty unsure about what we use them for, and how they work.

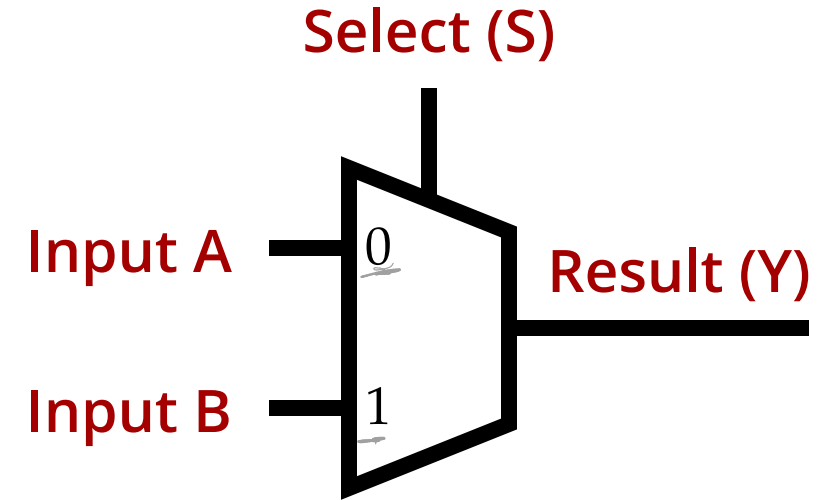
Some schematic terminology

V_{dd}						
						
		VDD	5V	HIGH	1	
<hr/>						
		Ground	0V	LOW	0	

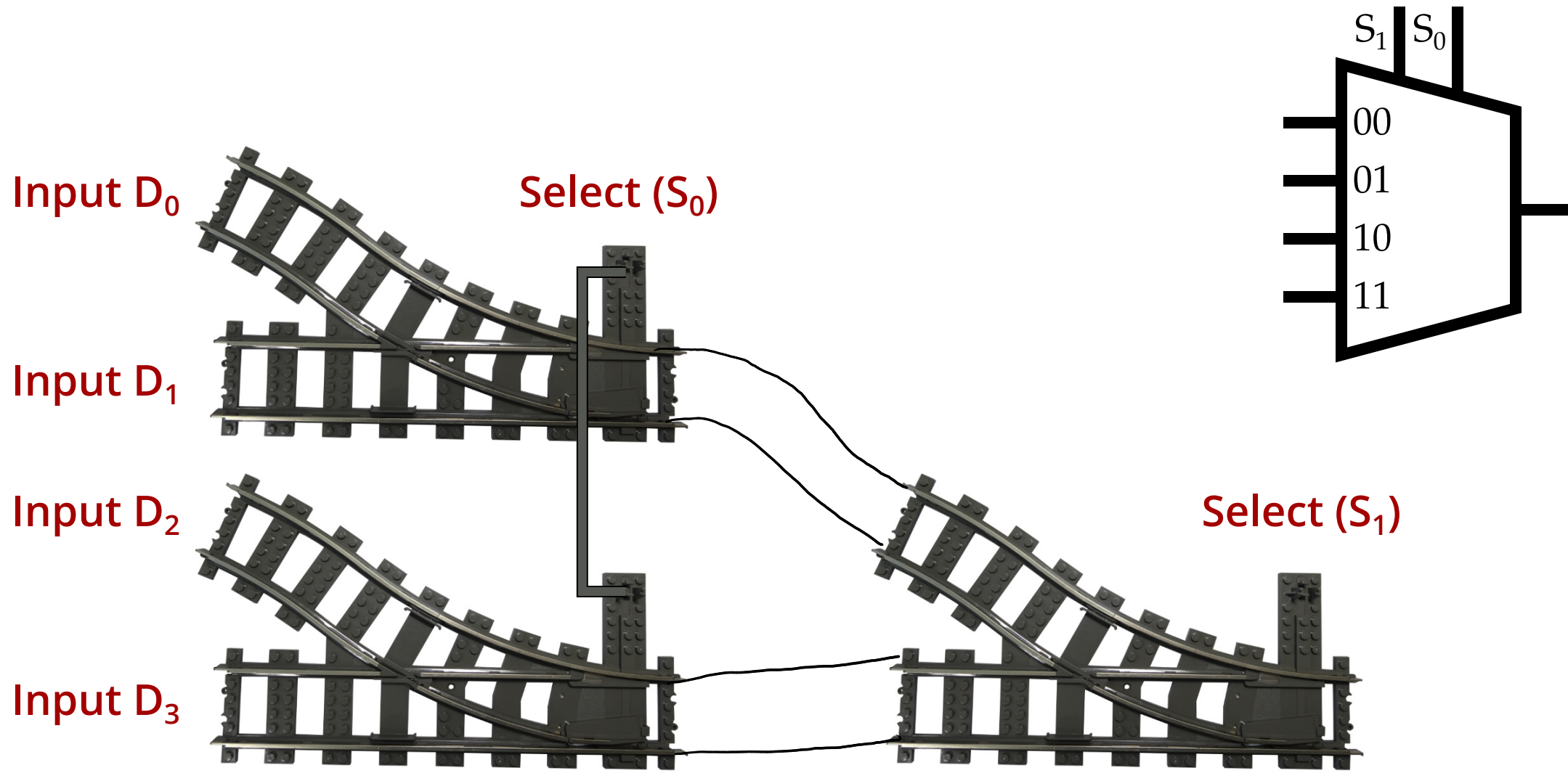
What is a multiplexer?



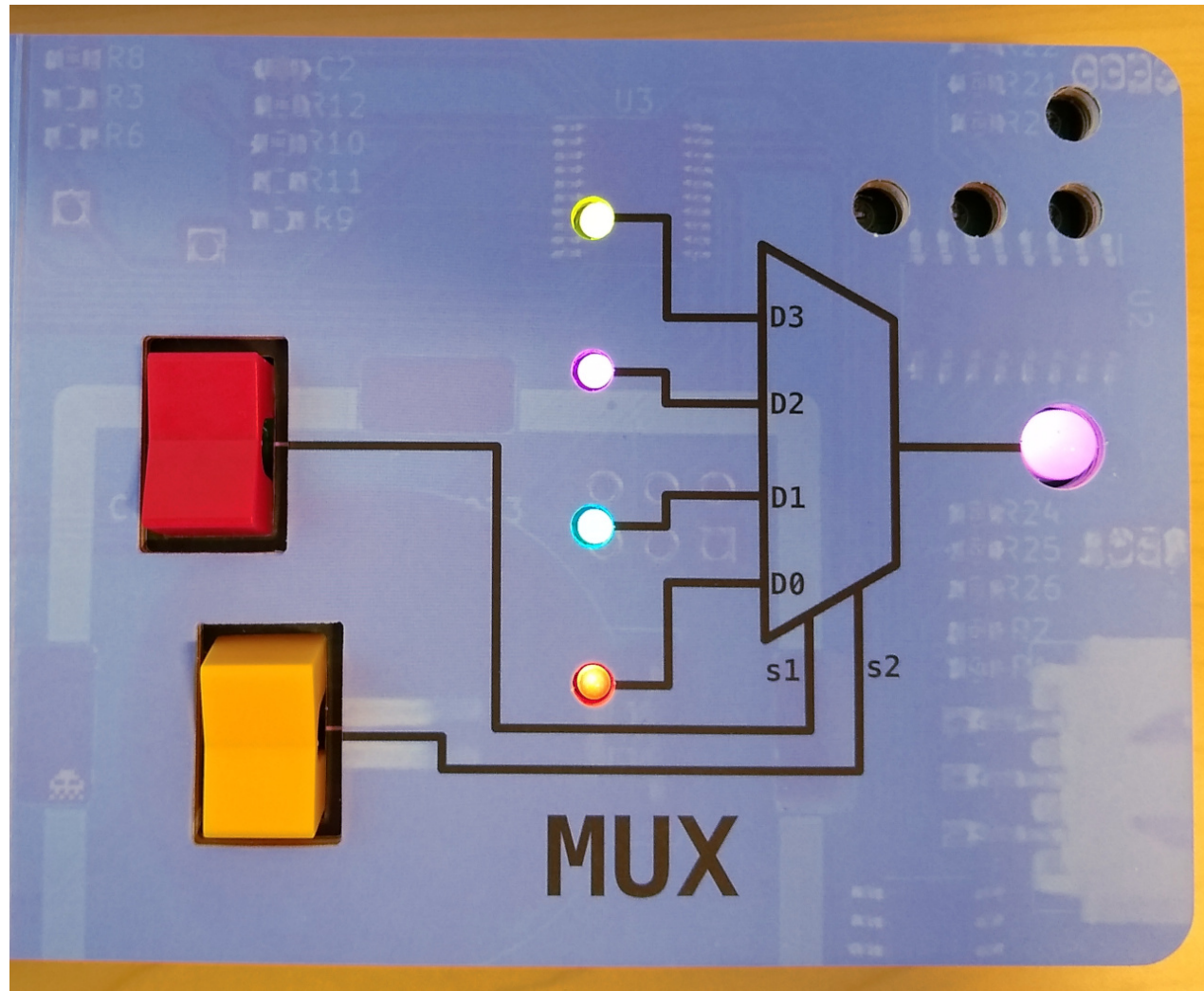
What is a multiplexer?



A 4:1 multiplexer



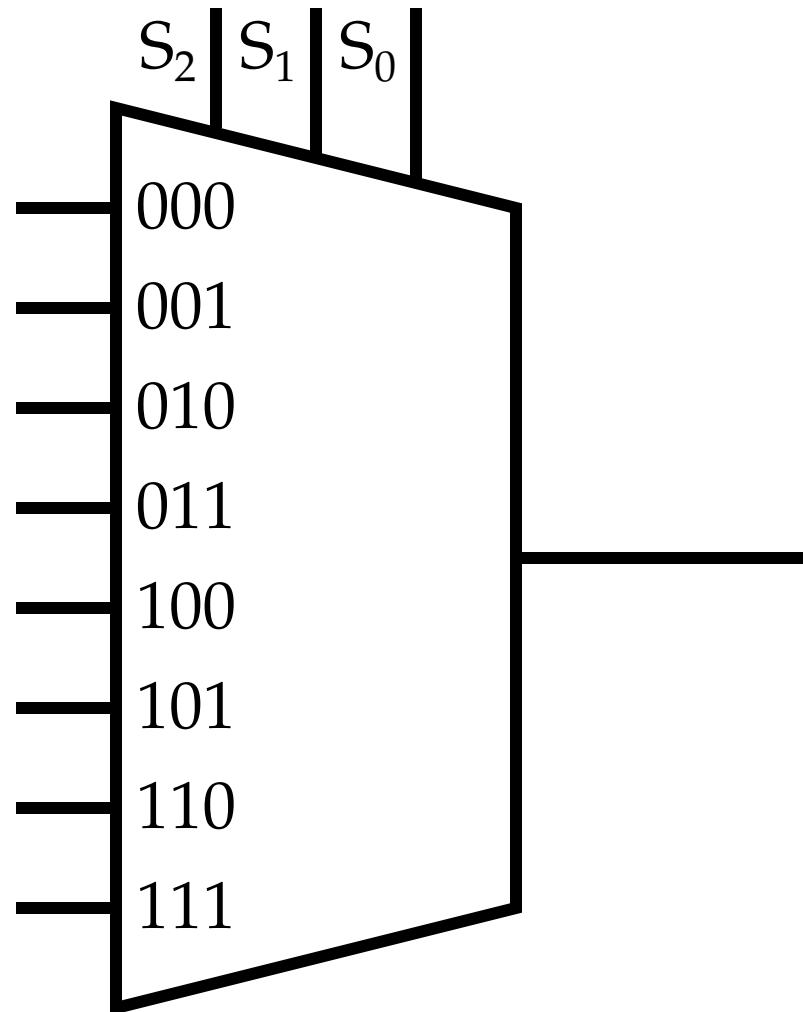
Computer Engineering for Big Babies



Come play with it outside my office!

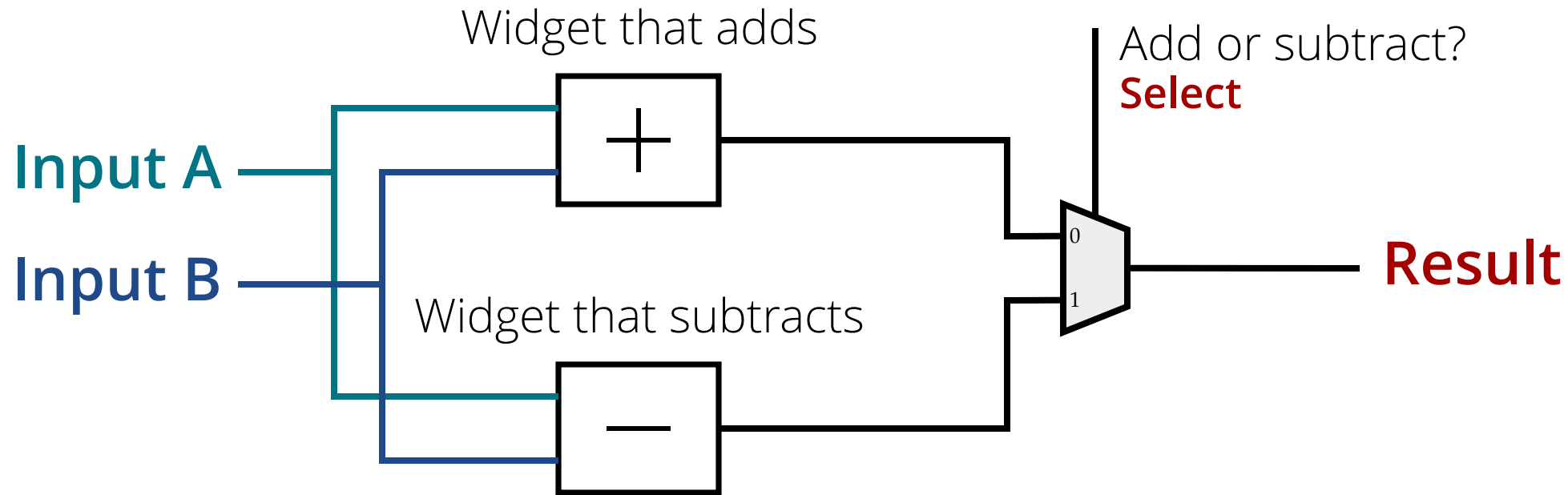
More than 4:1?

If we have N select lines, we can choose from 2^N inputs:



What good are multiplexers?

1) Allow you to select one signal out of many



What good are multiplexers?

1) Allow you to select one signal out of many

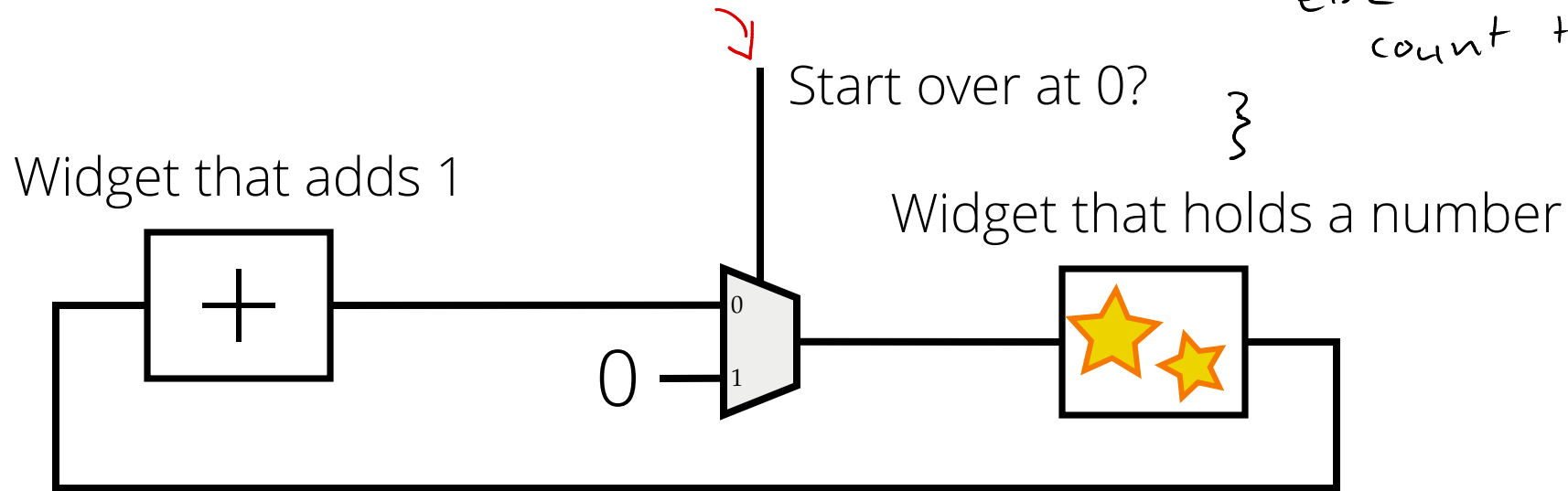
1 B) Allow you to make a choice based on a control value

It's like an **if** or **case** statement in software

Another multiplexer example

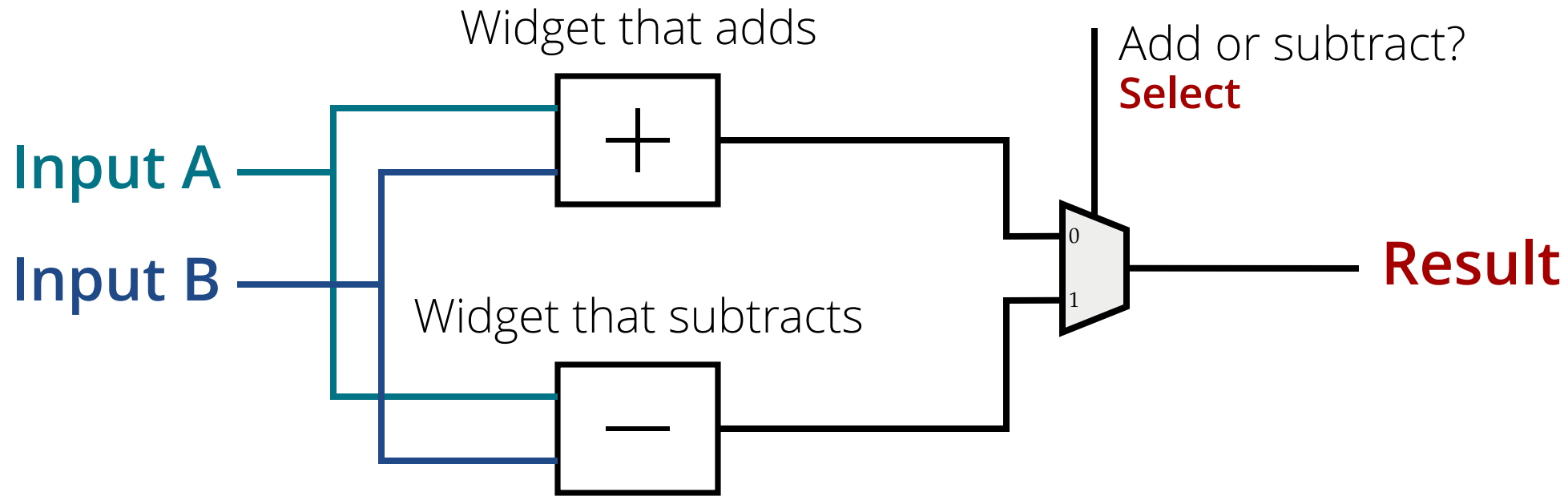
1B) Like an `if` statement in hardware

```
while (true) {  
  if (count == 0) {  
    count = 0;  
  }  
  else {  
    count += 1;  
  }  
}
```



But wait, isn't that a huge waste?

Why do both computations just to throw one away???



And back in the old days...

1) Allow you to select one signal out of many

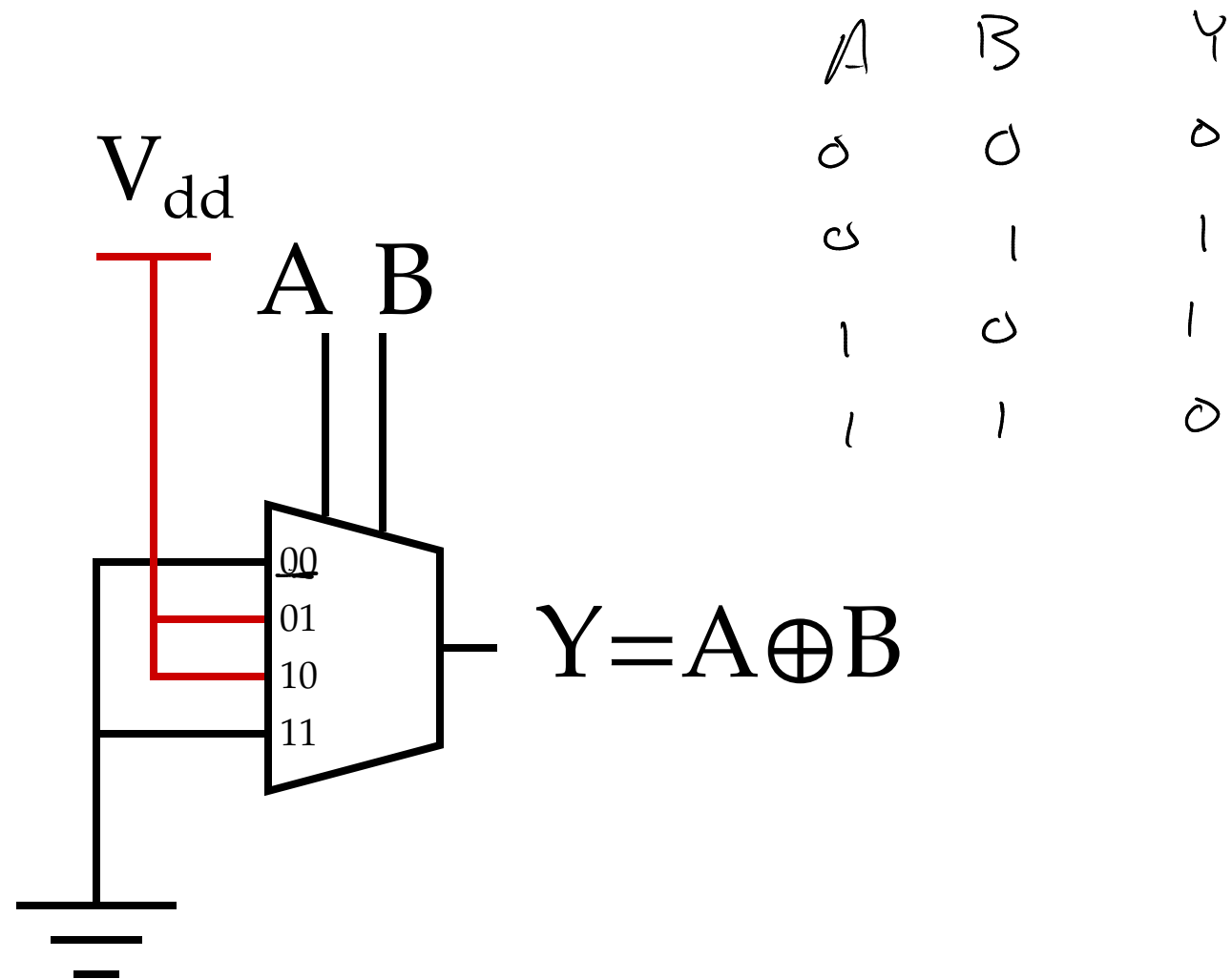
1 B) Allow you to make a choice based on a control value

It's like an **if** or **case** statement in software

2) Make it easy to implement arbitrary logic functions

Implementing XOR

Using a mux to implement a logic function



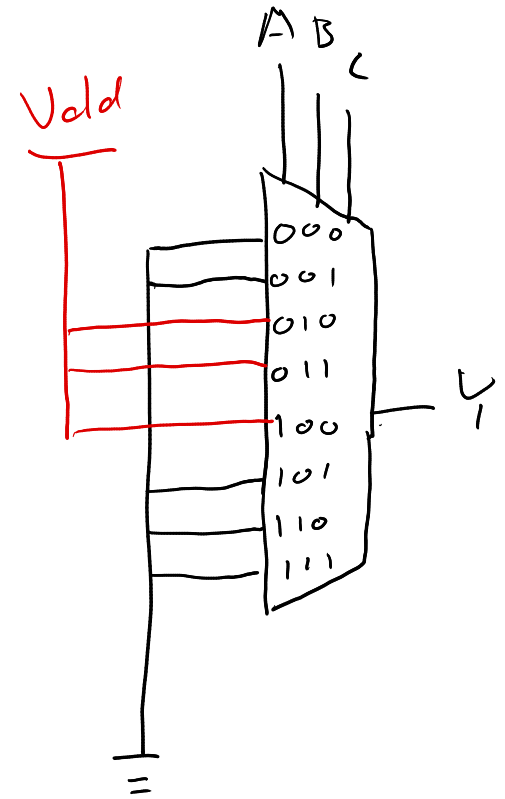
Multiplexer practice 1

Implement this logic equation using an 8:1 multiplexer

$$Y = \bar{A}B + A\bar{B}\bar{C}$$

~~$$Y = \bar{A}B + A\bar{B}\bar{C}$$~~

A	B	C	$\bar{A}B$	$A\bar{B}\bar{C}$	Y
0	0	0	0	0	0
0	0	1	0	0	0
0	1	0	1	0	1
0	1	1	1	0	1
1	0	0	0	1	1
1	0	1	0	0	0
1	1	0	0	0	0
1	1	1	0	0	0

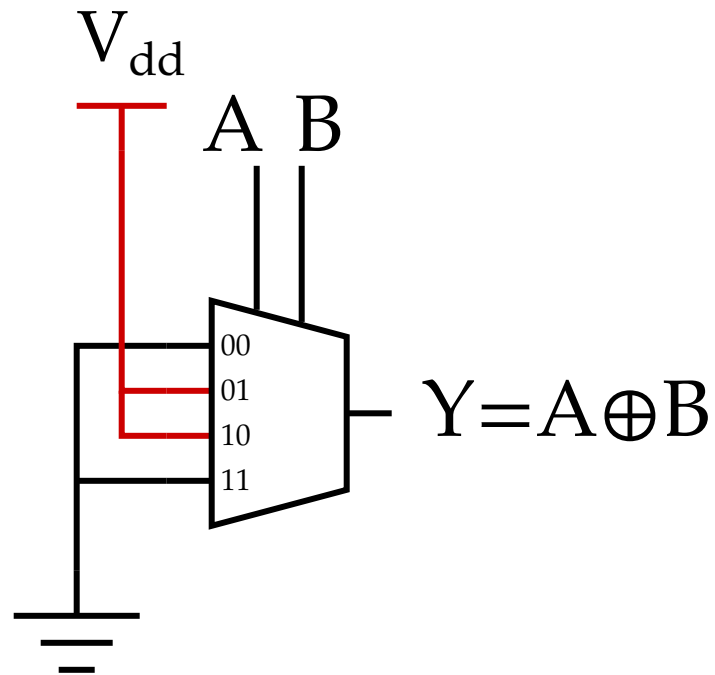


Will a time come when it's cheaper to use a microprocessor than to implement something with discrete logic gates?

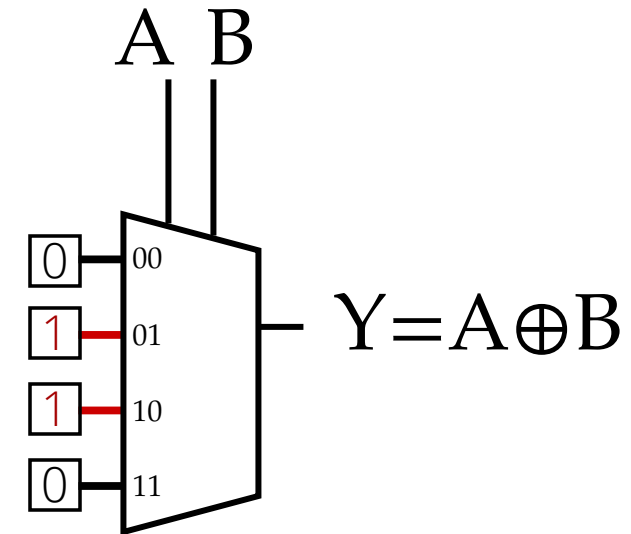
Look-up tables (LUTs)

A look-up-table is basically a mux where the inputs are little memory boxes statically configured to be 0 or 1.

With a mux



With a LUT



Introducing FPGAs

Look-up tables

have configurable connections

An FPGA is like a big chip full of ~~logic gates~~ that ~~can be wired~~ together by "~~programming~~" it.

flashing a configuration bit stream

iCE40UP block diagram (straight outta the iCE40 datasheet)

Clock stuff

Fixed-function multipliers

Memory

Logic "fabric"

Fixed-function I/O modules

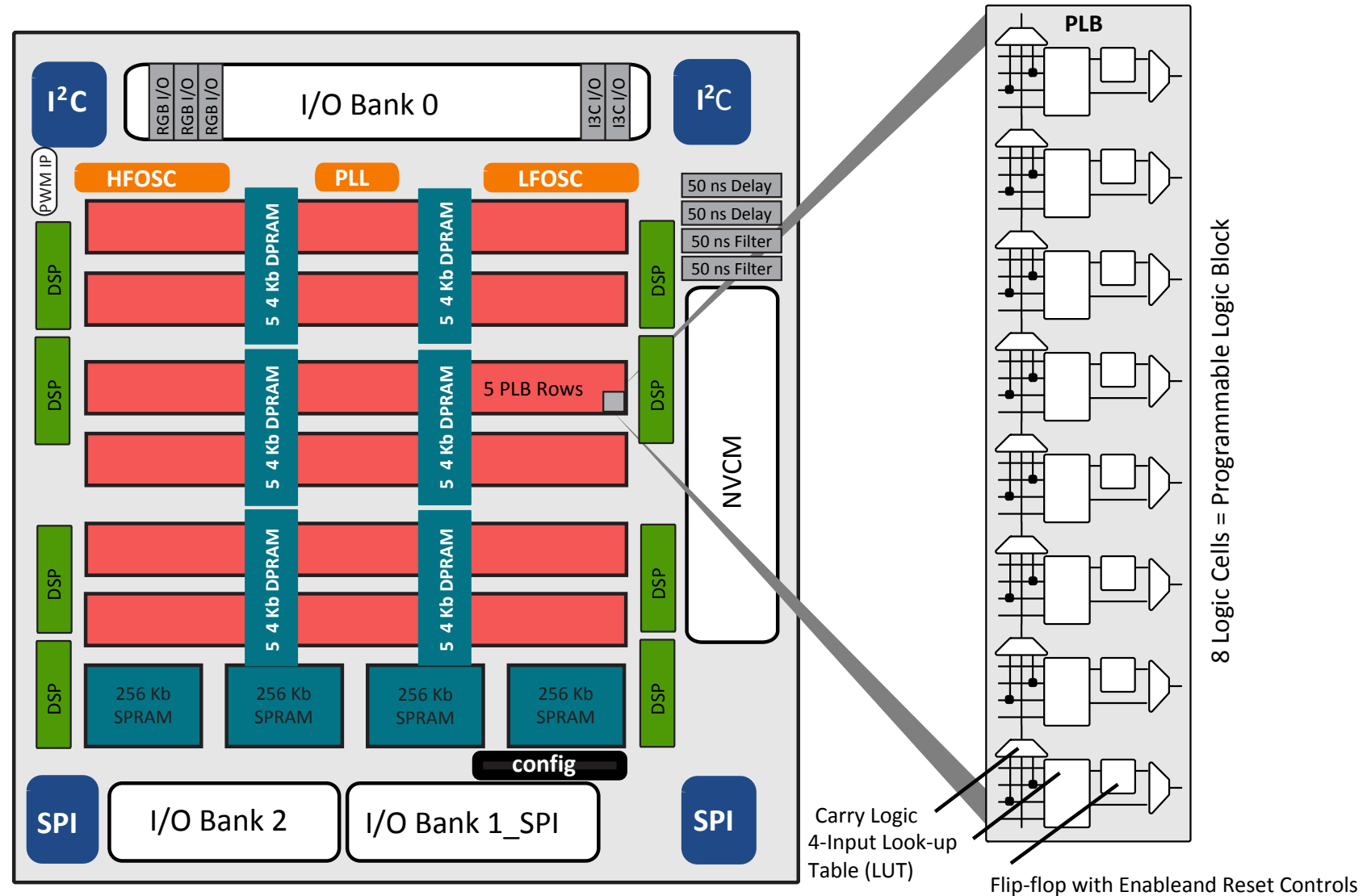


Figure 3.1. iCE40UP5K Device, Top View

iCE40UP logic element

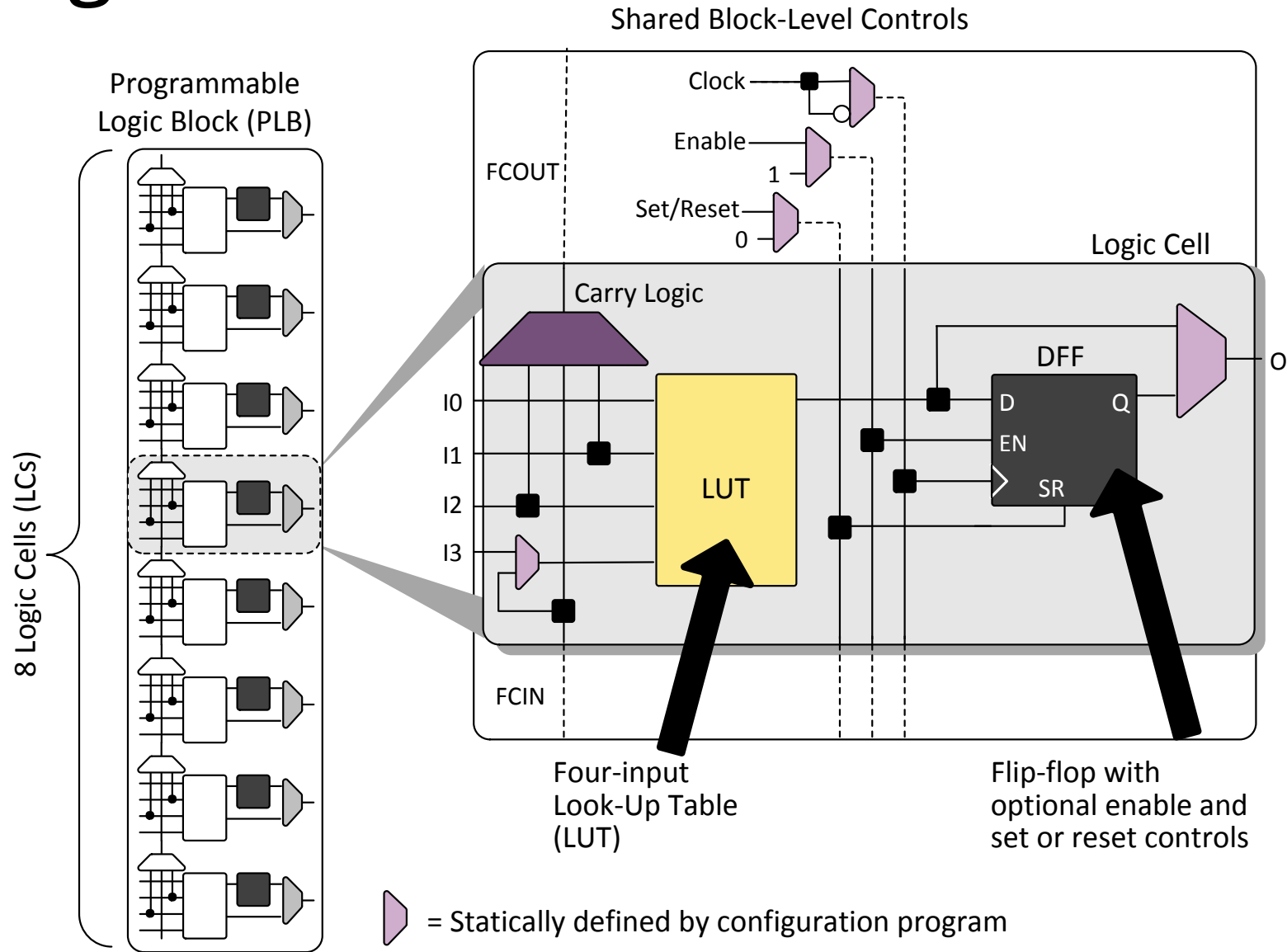
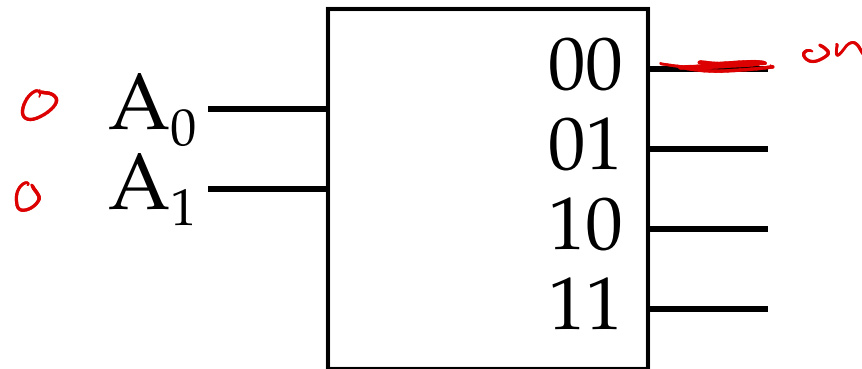


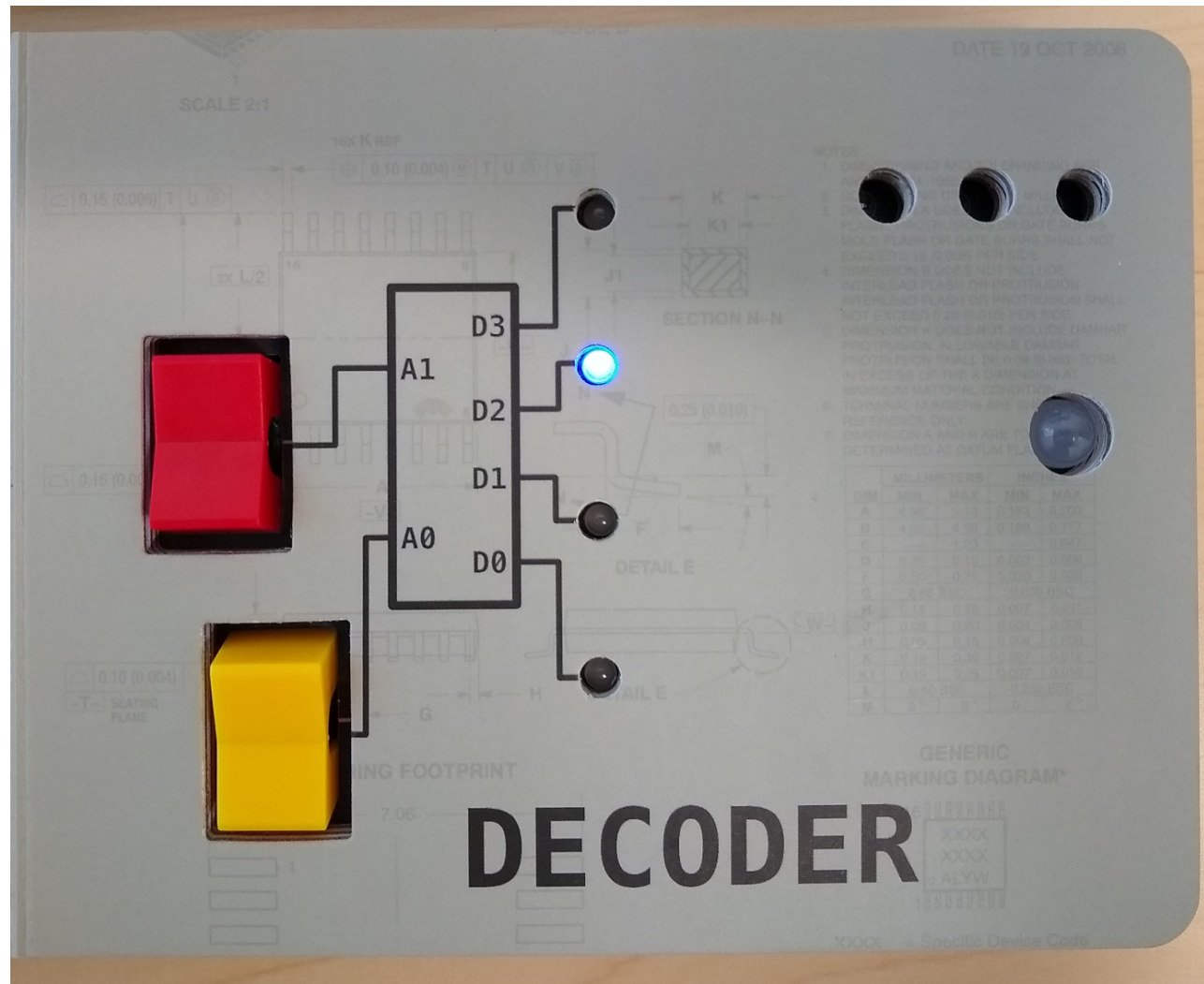
Figure 3.2. PLB Block Diagram

Decoders

Take a binary number as an input, and set the corresponding output high.



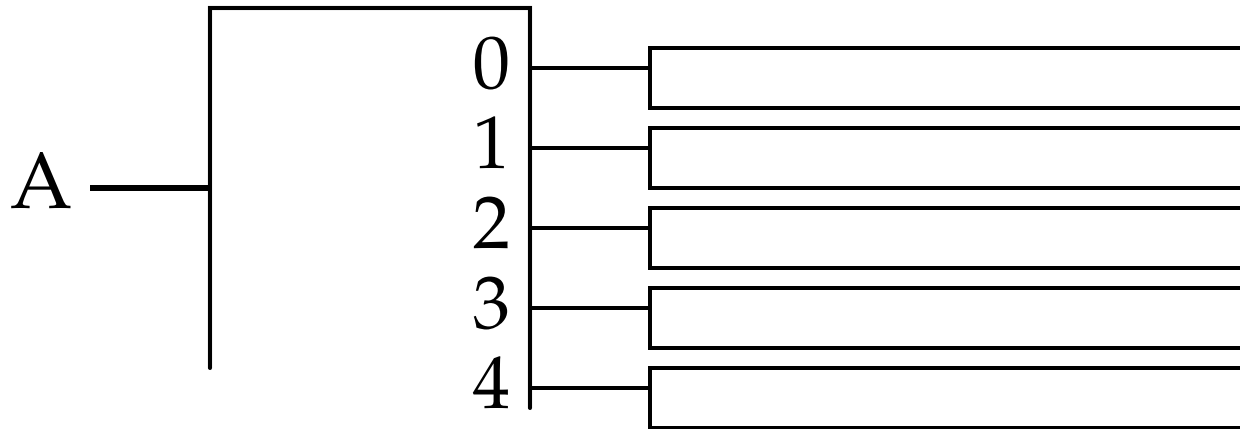
Computer Engineering for Big Babies, again



You know you want to come play with it!

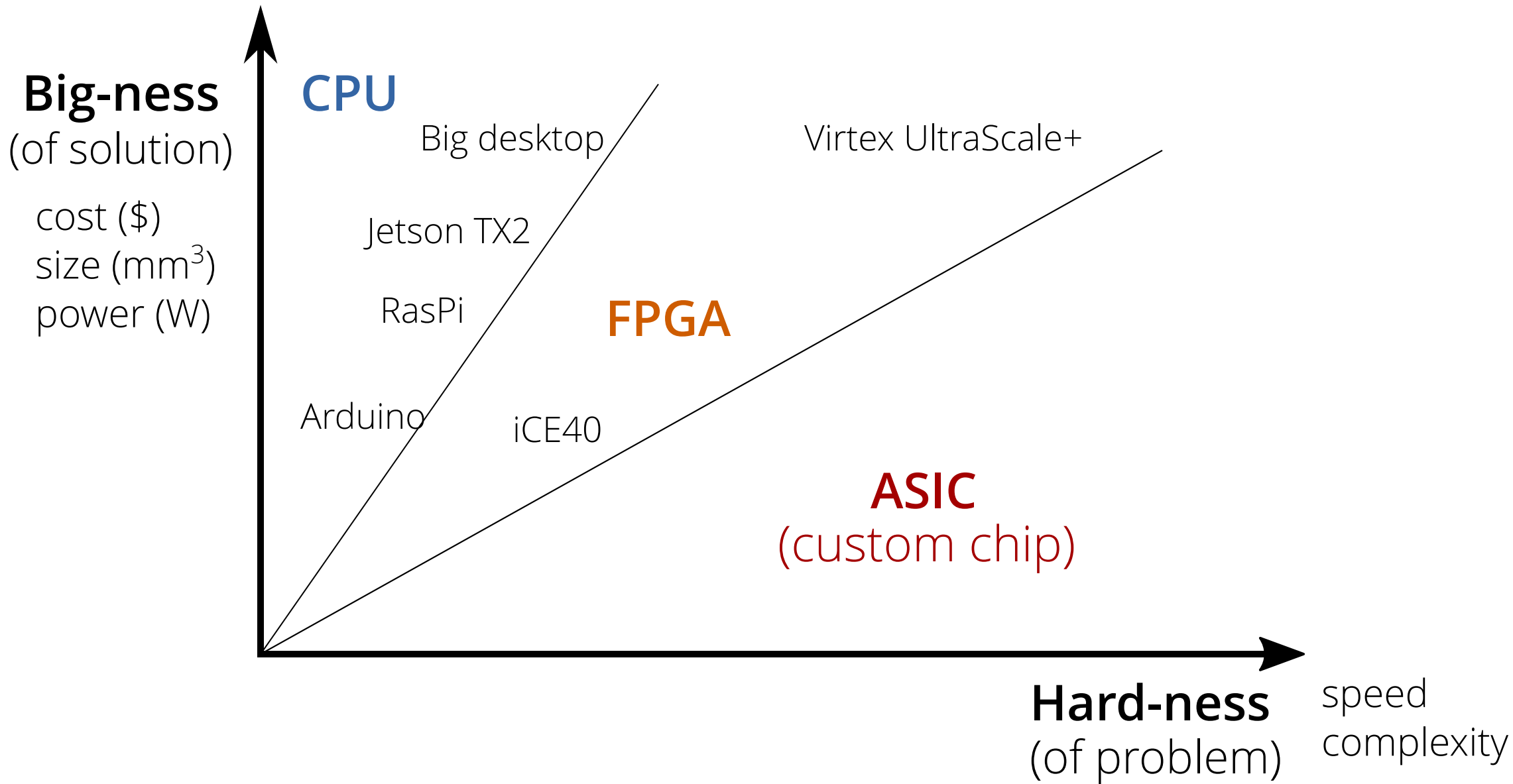
What could you use a decoder for?

You have a whole bunch of things to activate, one at a time
(say, memory cells)



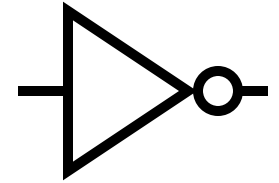
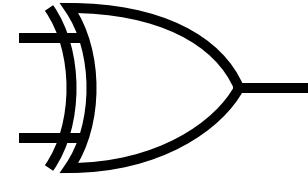
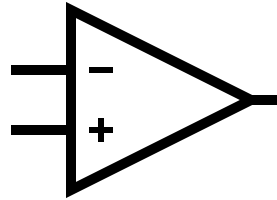
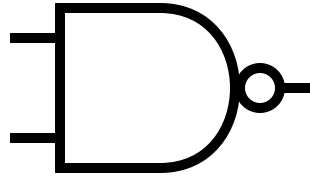
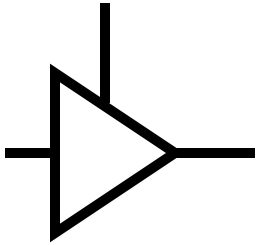
For Thursday

1. Read the book (2.9) and complete the reading check
2. Lab 2 report is due next week at your lab time
See the video and handout on the course website
3. Prelab 3 is due next week 24 hours before your lab time



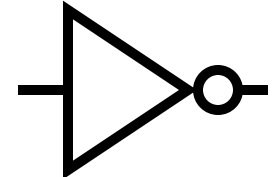
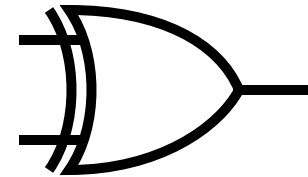
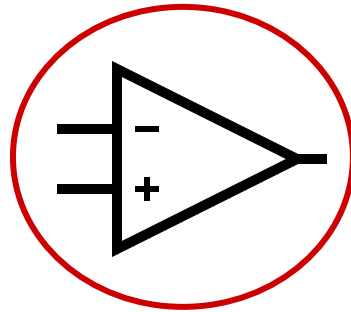
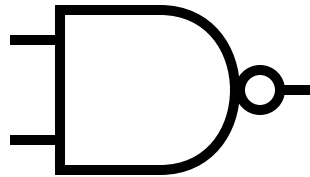
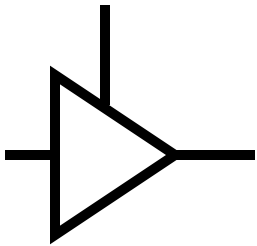
Terminology

Which of these is not a digital circuit element?



Terminology

Which of these is not a digital circuit element?



This is an op-amp!

Another mux example

Suppose you want to read 8 switches but you only have 4 inputs/outputs.

