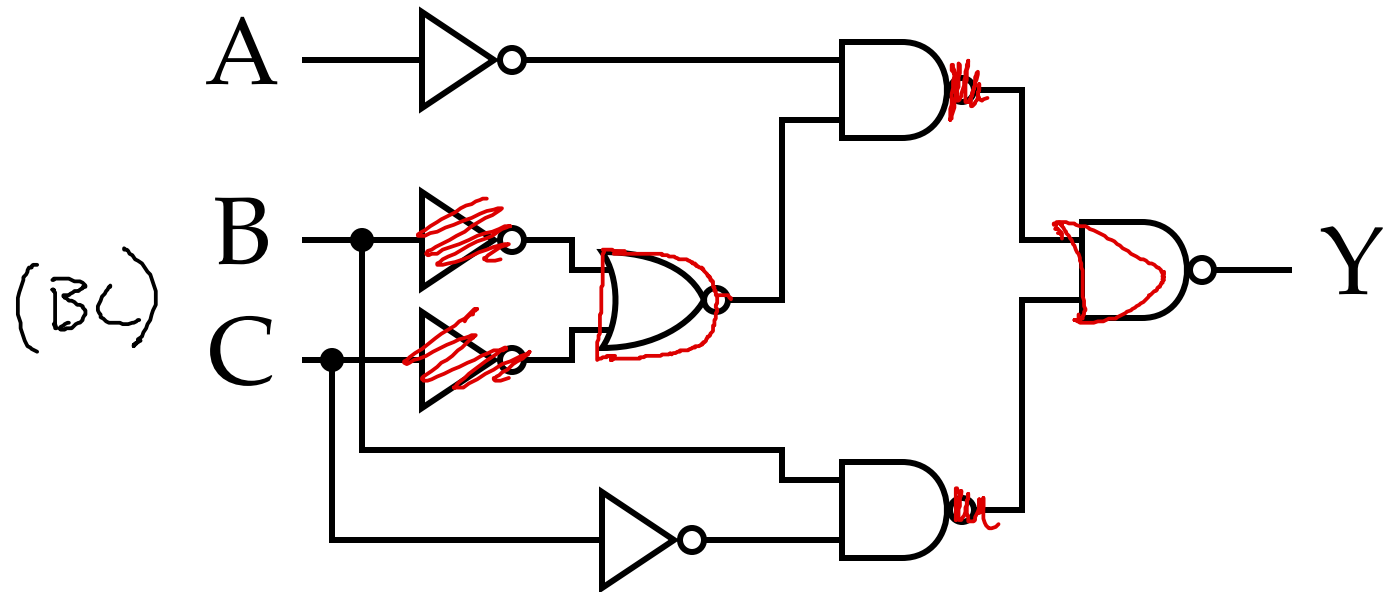


Warmup

Write a boolean equation for this circuit:

Use ! for NOT, e.g., !(AB) or !A + !B

$$\bar{A}\bar{B} = \overline{A+B}$$
$$\bar{A} + \bar{B} = \overline{AB}$$



$$\bar{A}(BC) + B\bar{C}$$

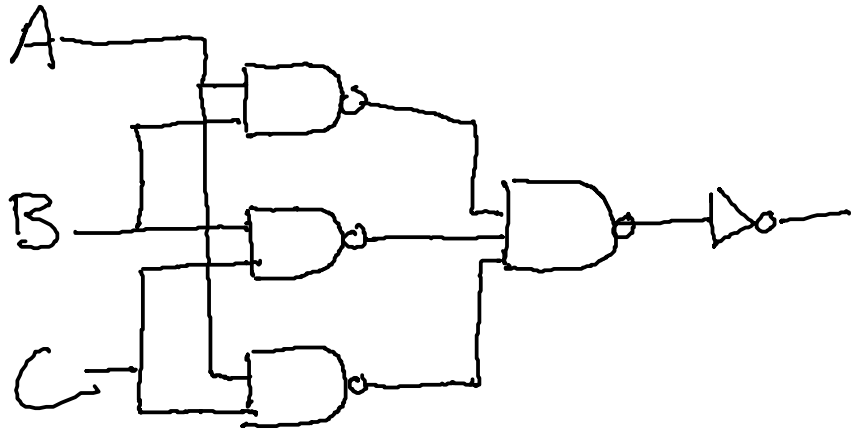
$$B(\bar{A} + \bar{C})$$

~~1. $B(\bar{A} + \bar{C})$~~ $B(\bar{A} + \bar{C}) \Rightarrow B(\overline{AC})$

Warmup #2

Implement this equation using only inverting logic:

$$\frac{(\bar{A} + \bar{B})(\bar{B} + \bar{C})(\bar{A} + \bar{C})}{(\bar{A}\bar{B})(\bar{B}\bar{C})(\bar{A}\bar{C})} \Rightarrow \overline{\overline{(\bar{A}\bar{B})} + \overline{(\bar{B}\bar{C})} + \overline{(\bar{A}\bar{C})}}$$



ES 4: Karnaugh maps

Steven Bell

20 September 2021

Logistics

- Recitation will begin this week (probably Tuesdays @ 6pm)
- Bring your lab kits to lab!

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

- Draw a k-map for a 3 or 4-input truth table, and use it to create a minimal boolean equation for the truth table.
- Find a minimal boolean equation for a truth table with "don't cares"

Key representations

Boolean equation

$$\overline{AB} + C$$

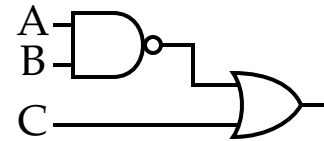
Boolean algebra

Truth table

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

Karnaugh maps

Logic diagram

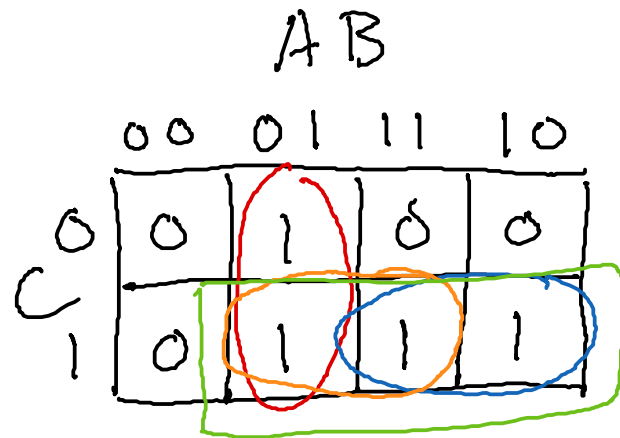


Bubble pushing

Karnaugh maps

Are just a clever way of looking at the truth table

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



$$\bar{A}B + AC + BC$$

$$(A+B)C$$

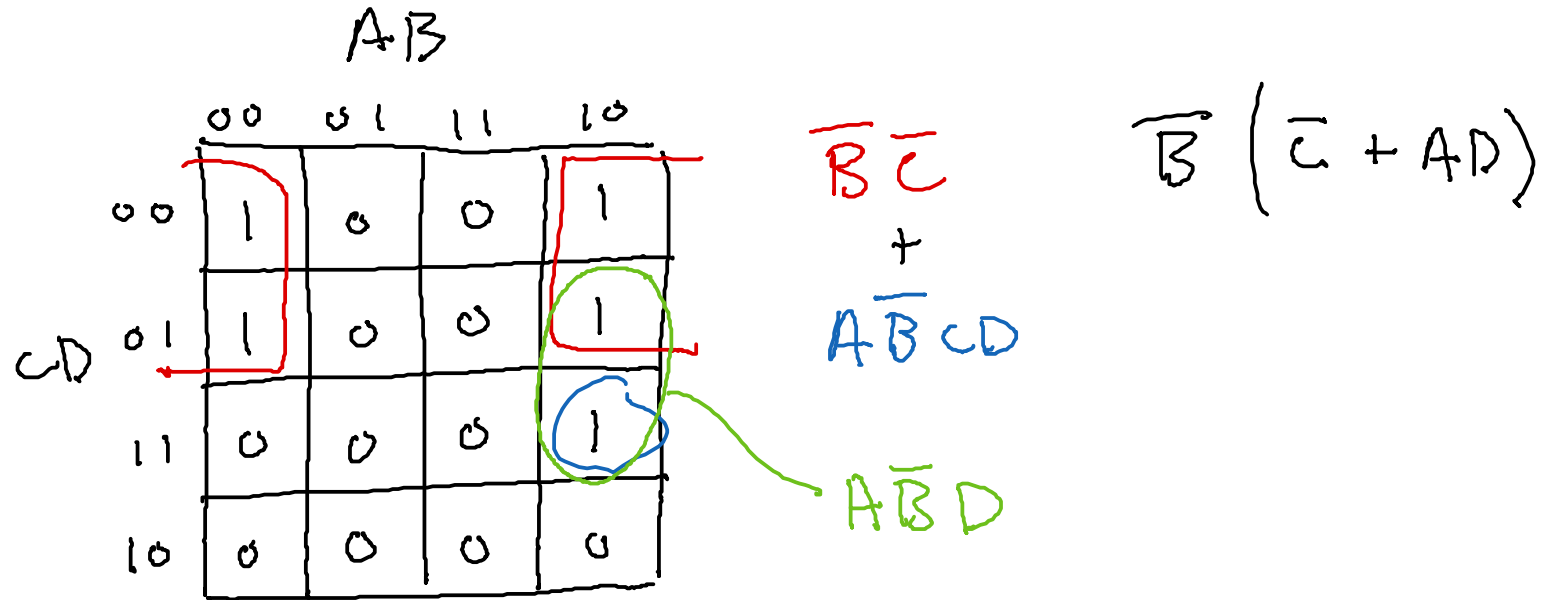
Gray code

Each subsequent number changes by only 1 bit

For 2 bits: **00** → **01** → **11** → **10**

For more than 2 bits, look up a table or equation.

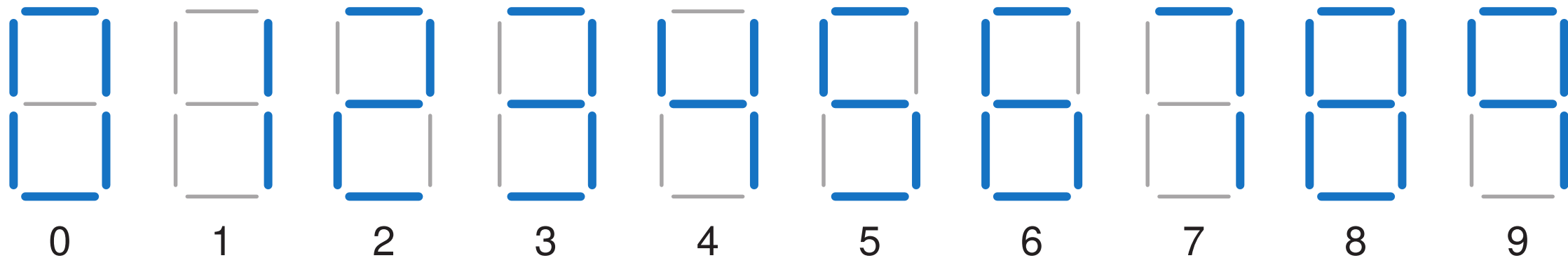
4-variable Karnaugh maps



Don't cares

Use an 'X' to represent a condition where you don't care what the output is.

When drawing boxes, you can include or ignore an X, whichever makes the logic simpler.



$N_3 N_2$

	00	01	11	10
00	1	0	x	1
01	0	1	x	1
11	1	1	x	x
10	1	1	x	x

$$N = 8N_3 + 4N_2 + 2N_1 + N_0$$

What's the point?

For Wednesday

1. Read the book (2.8) and complete the reading check

www.ece.tufts.edu/es/4/

Quiz is due at **10AM** the day of class, so I can review it

```
cp /es/4/public_html/readingchecks/readingcheck_04.txt ./
```

```
provide es4 rc4 readingcheck_04.txt
```

2. Complete **homework 1** (due Wednesday 9/22)
3. Complete **prelab 2** (due 24 hours before your lab section)
4. Submit your **lab 1 notes** (due by your lab section time)

Bonus material

What's the point of High-Z?

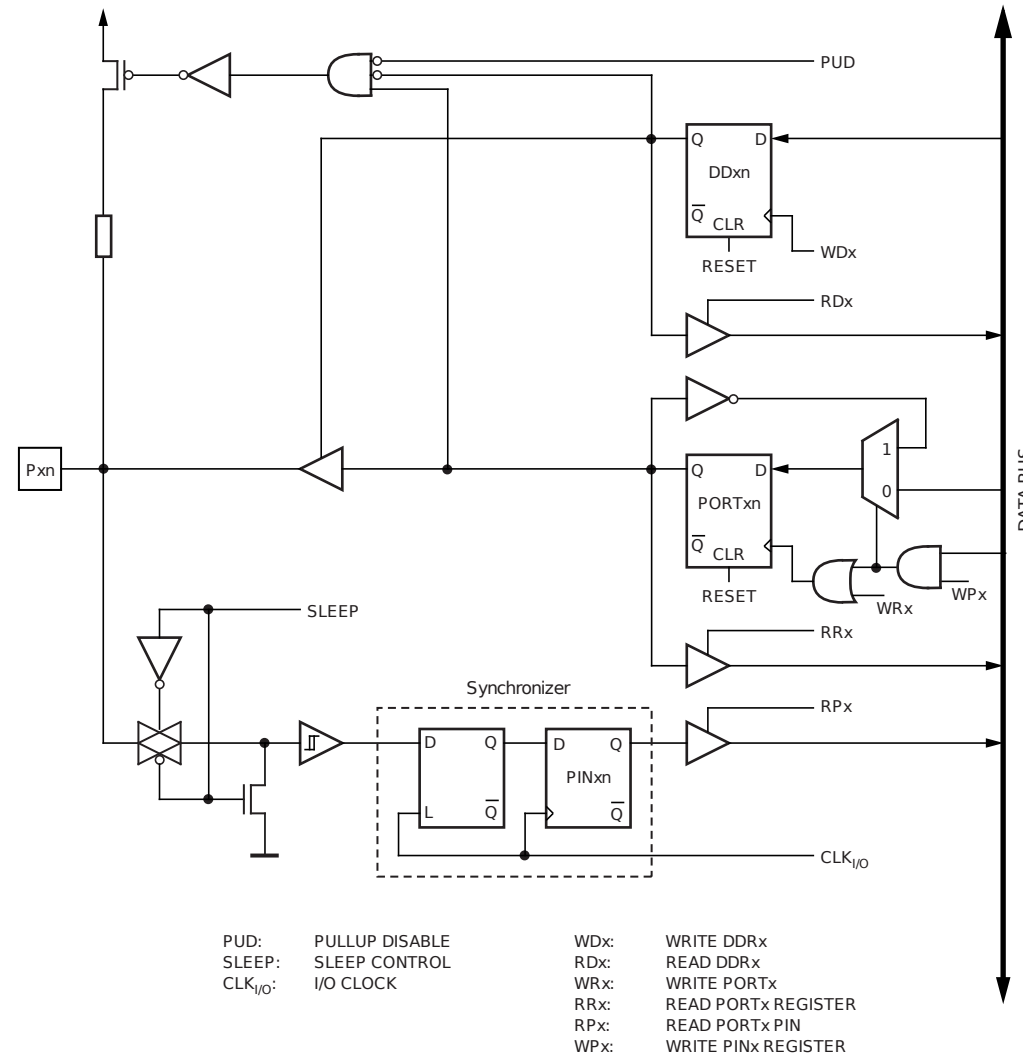
Multiple modules need to communicate on a shared bus

But this means we could have contention!

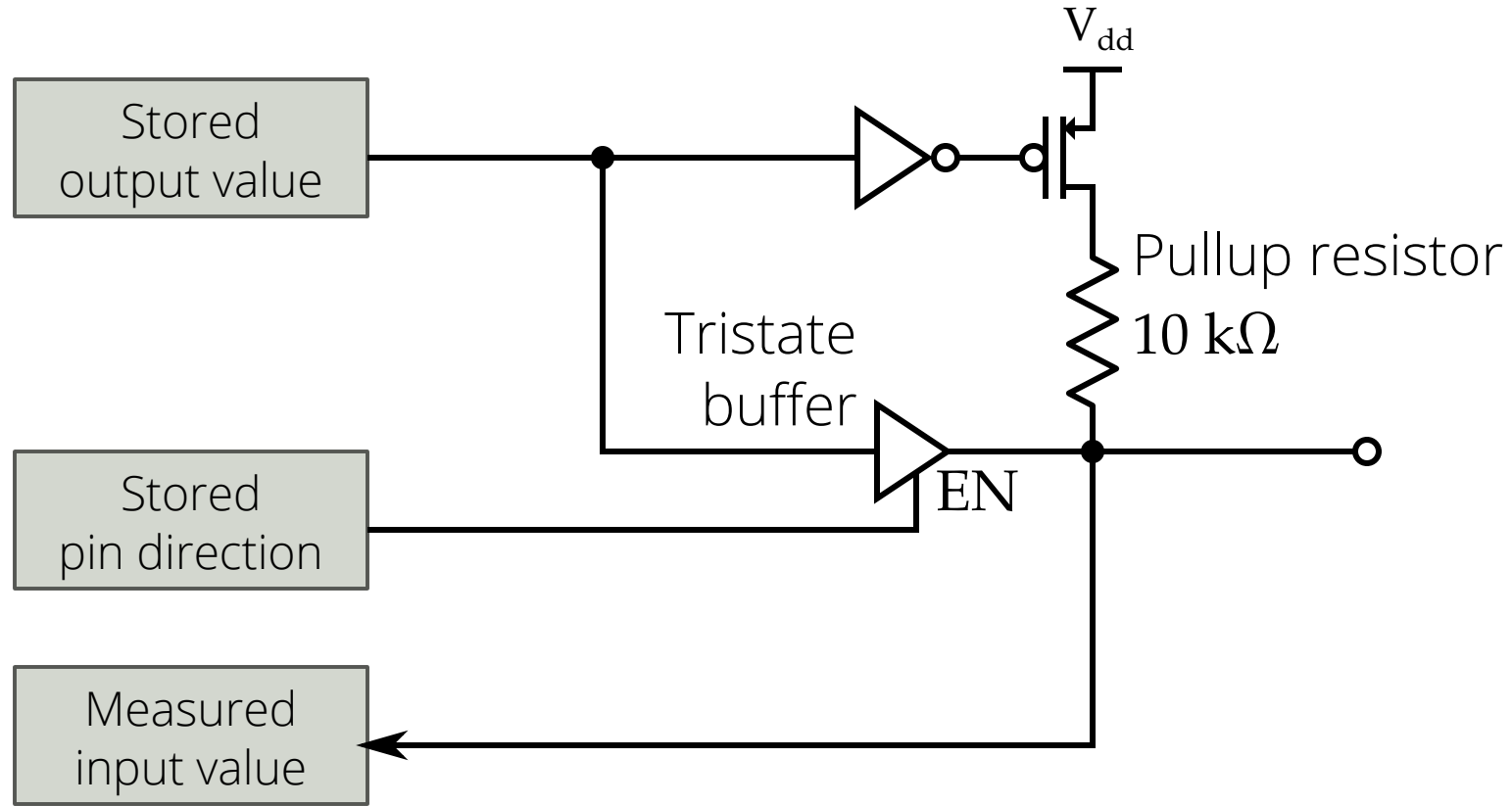
We solve this by turning off a gate completely (neither high nor low)

High-Z in practice: inside an Arduino pin

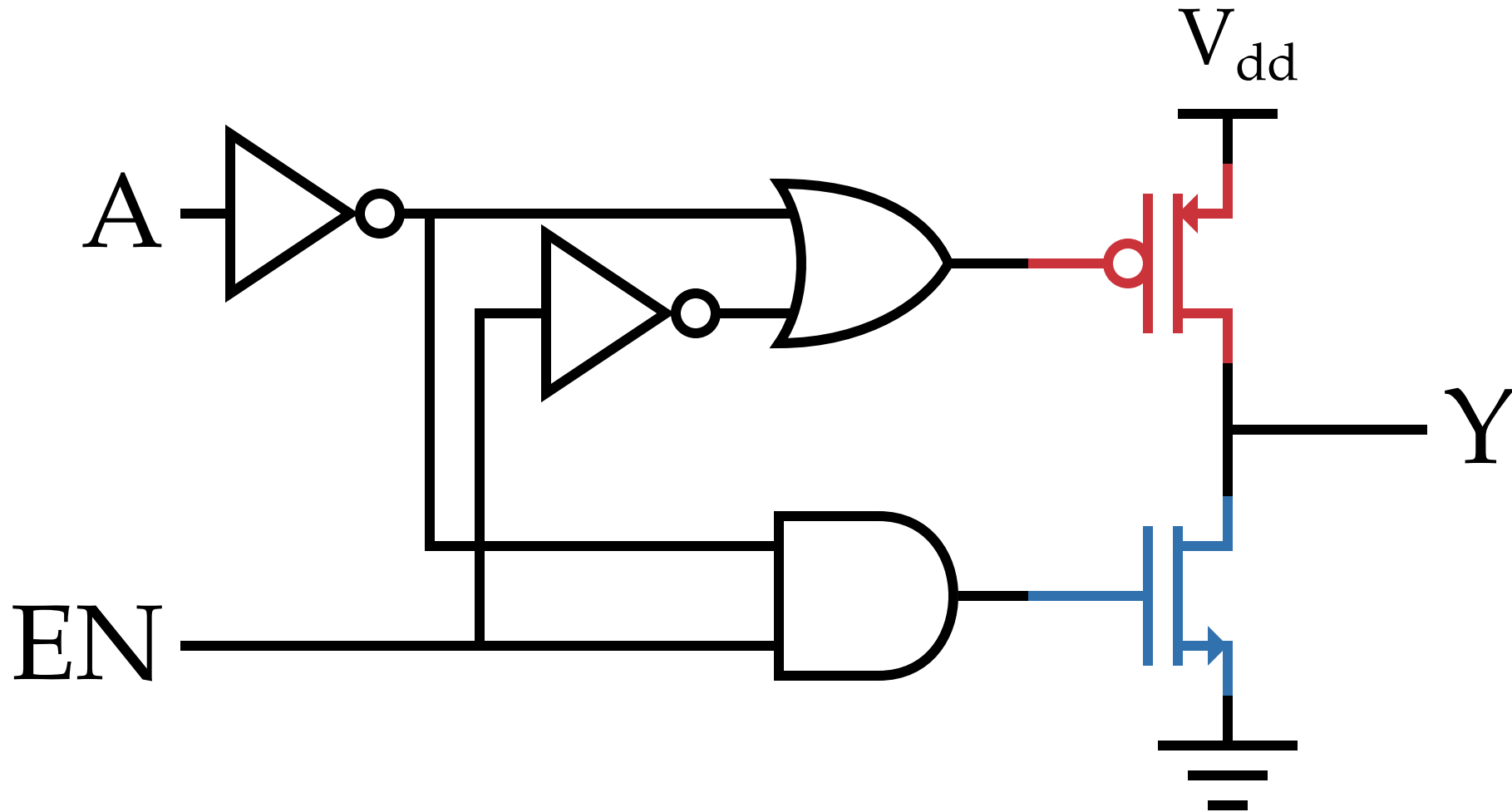
Figure 13-2. General Digital I/O⁽¹⁾



A gross simplification



A hypothetical tri-state buffer



Bonus material