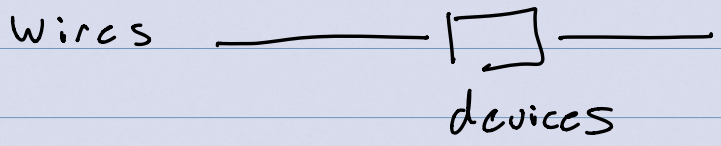
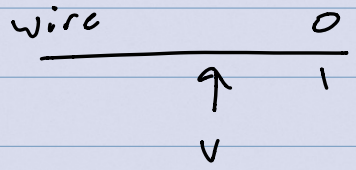
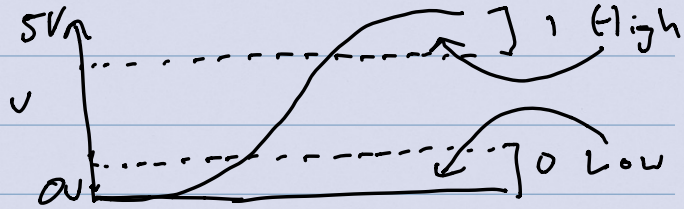
# Digital Design

## Digital Circuits - electrical

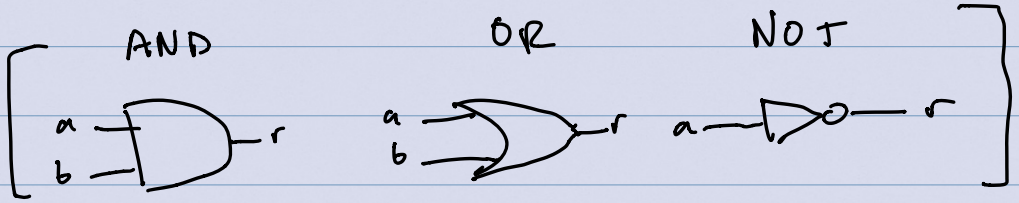



## Digital Logic




## Devices → gates

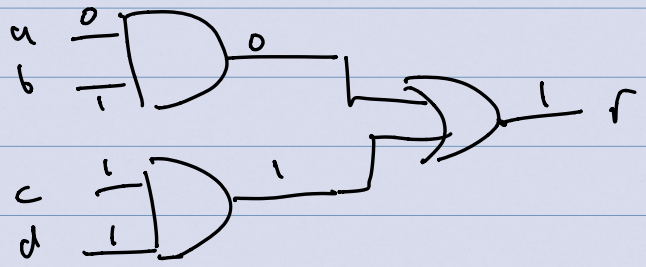



| | AND | OR | NOT |
|---|---|---|---|
| C code | r = a & b | r = a \| b | r = ~a |
| Boolean Algebra | r = a · b | r = a + b | r = $\bar{a}$ |
| Logic | r = a ∧ b | r = a ∨ b | r = ¬a |

| a | b | a · b = r |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 1 |

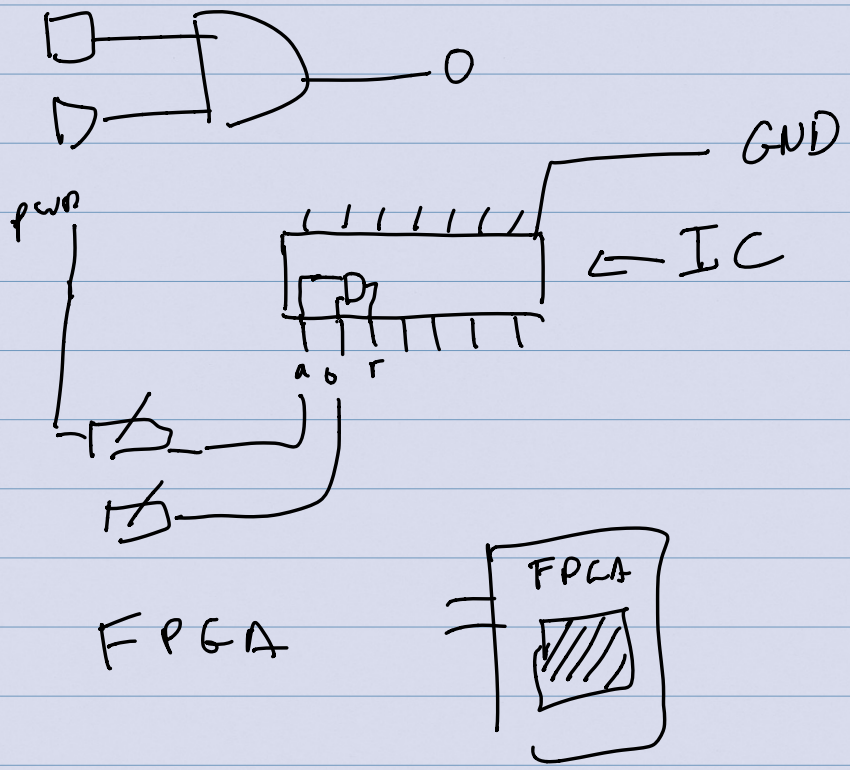
| a | b | a + b = r |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 1 |

| a | $\bar{a}$ = r |
|---|---|
| 0 | 1 |
| 1 | 0 |

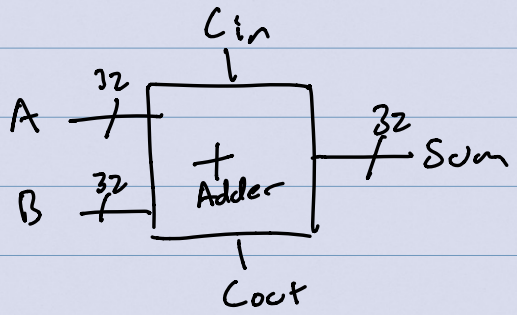



---

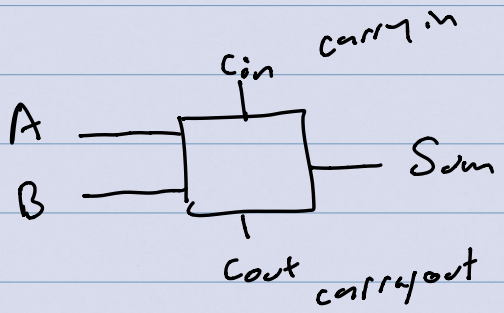
Abstraction




FPGA




32 bit adder




1-bit full adder

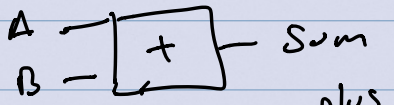
inputs

A B Cin

outputs

sum Cout

sum-of-products




plus

A + B

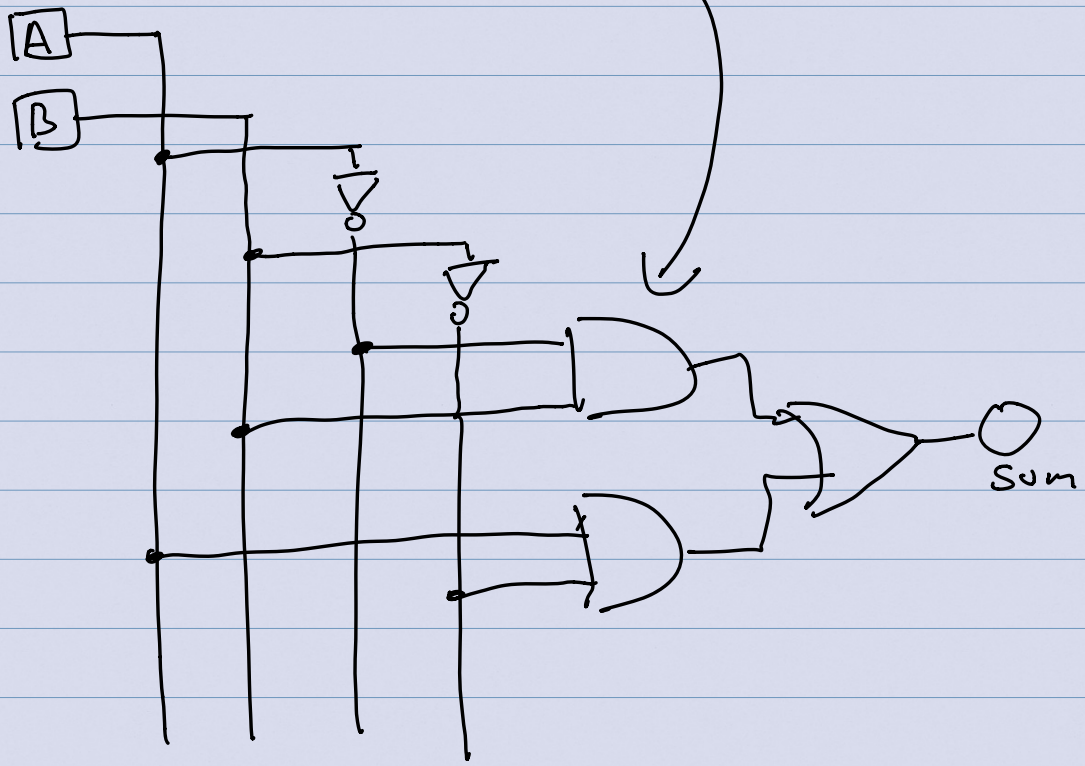
| A | B | Sum |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 0 |

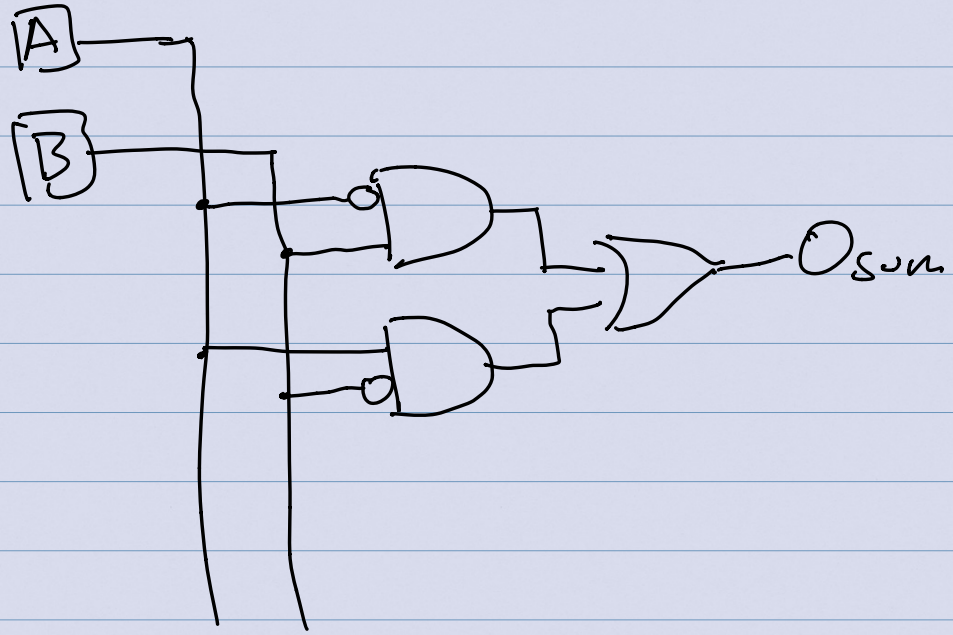
XOR

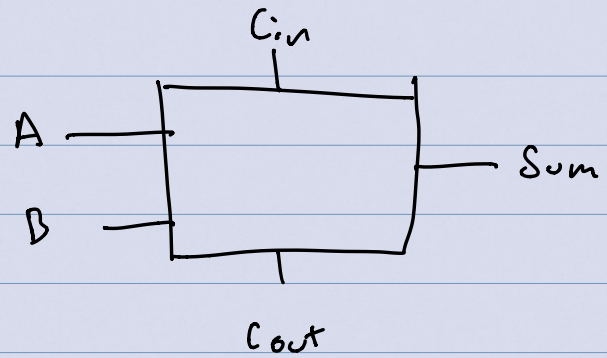
$sum = (\bar{A} \cdot B) + (A \cdot \bar{B})$

| A | B | $\bar{A} \cdot B$ | $A \cdot \bar{B}$ | $(\bar{A} \cdot B) + (A \cdot \bar{B})$ |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 0 | 1 |
| 1 | 0 | 0 | 1 | 1 |
| 1 | 1 | 0 | 0 | 0 |

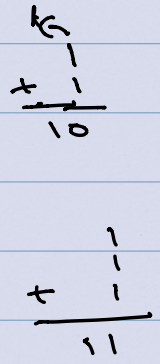
$$sum = (\bar{A} \cdot B) + (A \cdot \bar{B})$$



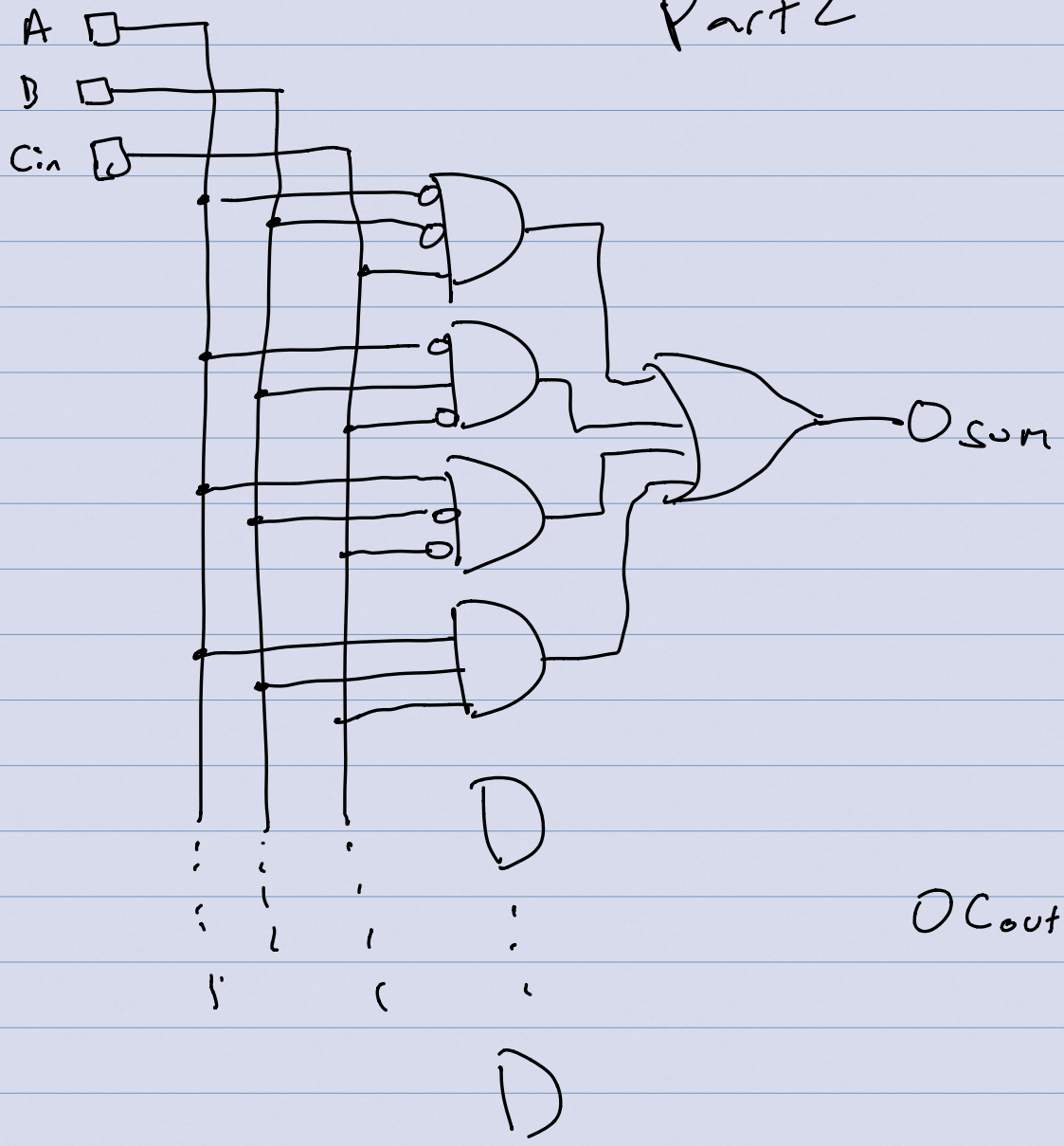



| A | B | Cin | Sum | Cout |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 | 0 |
| 0 | 1 | 0 | 1 | 0 |
| 0 | 1 | 1 | 0 | 1 |
| 1 | 0 | 0 | 1 | 0 |
| 1 | 0 | 1 | 0 | 1 |
| 1 | 1 | 0 | 0 | 1 |
| 1 | 1 | 1 | 1 | 1 |



$Sum = (\bar{A} \cdot \bar{B} \cdot C_{in}) + (\bar{A} \cdot B \cdot \bar{C_{in}}) + (A \cdot \bar{B} \cdot \bar{C_{in}}) + (A \cdot B \cdot C_{in})$

Part 2



Part 3

a, b, r are 2 bit values

0, 1, 2, 3

$2^4 = 16$

| $a_1$ | $a_0$ | $b_1$ | $b_0$ | $r_1$ | $r_0$ |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 1 |
| 0 | 0 | 1 | 0 | 1 | 0 |
| 0 | 0 | 1 | 1 | 1 | 1 |
| ⋮ | | | | | |

Sum-of-products

$r_1 =$

$r_0 =$