CSE 251

Electronic Devices and Circuits

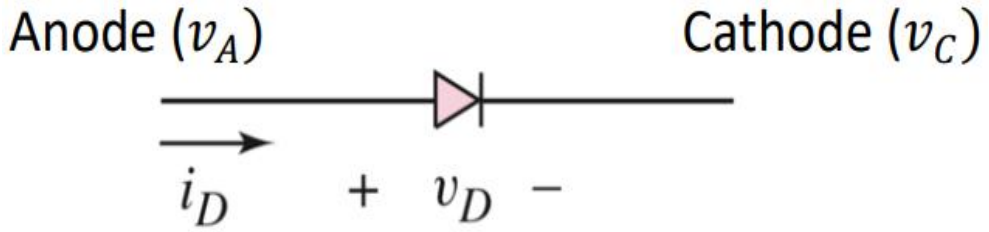
Lecture 8

Course instructor:
Mir Hamidul Hussain
Lecturer, Department of Computer Science and Engineering,
School of Data and Sciences, BRAC University
Email: ext.hamidul.hussain@bracu.ac.bd

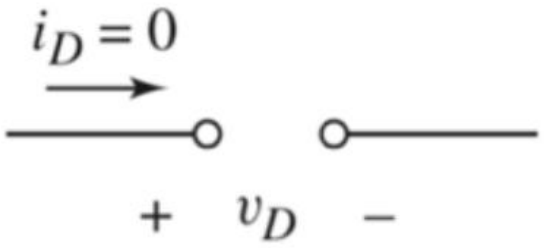
Outline

- **Diode Models and IV Characteristics: Review**
- **Diode Logic OR operation**
- **Diode Logic AND operation**

Review: Ideal Diode Model

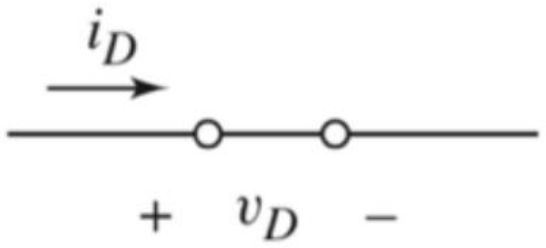


OFF State: Open circuit

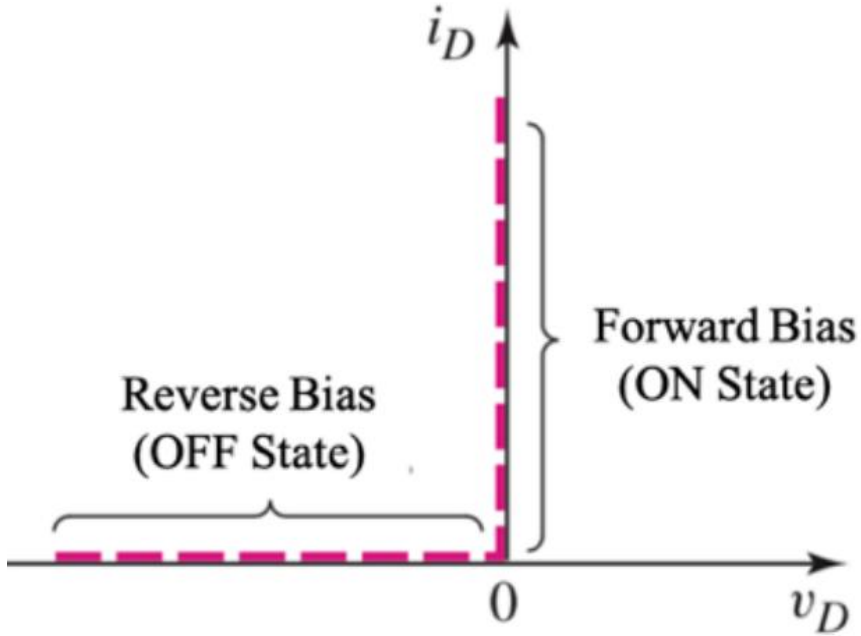


$(v_D < 0, i_D = 0)$

ON State: Short circuit



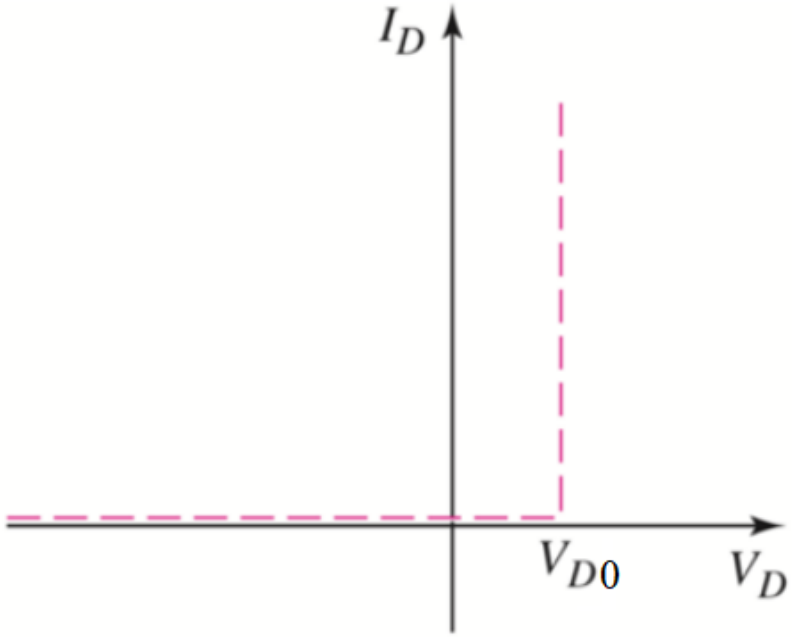
$(i_D > 0, v_D = 0)$



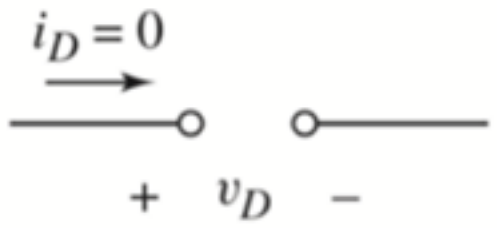
From Microelectronics: Circuit Analysis and Design by Donald A. Neamen: Chapter 2. 4th edition. Published by the McGraw-Hill Companies, Inc. Used for educational purposes only.

Modeling the real diode

1. Ideal diode model
2. **Constant voltage drop (CVD) model**
3. CVD+R model

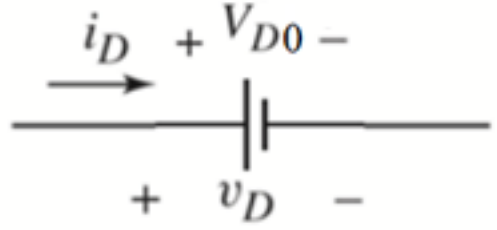


OFF State: Open circuit



$(v_D < V_{D0}, i_D = 0)$

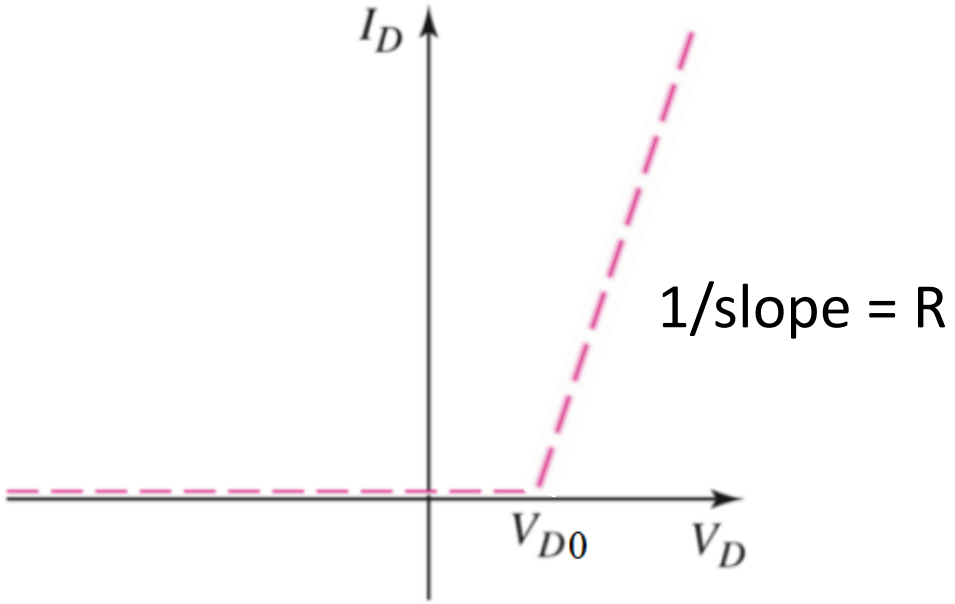
ON State: Voltage source



$(i_D > 0, v_D = V_{D0})$

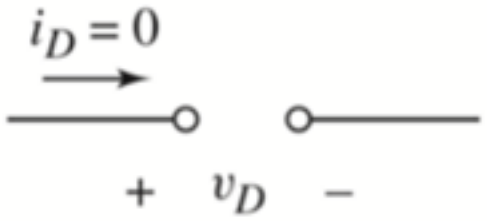
Modeling the real diode

1. Ideal diode model
2. Constant voltage drop (CVD) model
3. **CVD+R model**



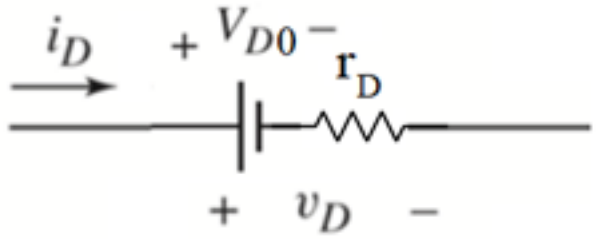
1/slope = R

OFF State: Open circuit



$(v_D < V_{D0}, i_D = 0)$

ON State: Voltage source



$(i_D > 0, v_D = V_{D0} + i_D r_D)$

Digital Representation

- Binary → Two states (0/False, 1/True)
- Binary variables in circuit, need to use two states of device/parameters

Voltage

5V → 1
0V → 0

Current

2mA → 1
3mA → 0

State

Diode

ON → 1
OFF → 0

Memristor

Low resistance → 1
High resistance → 0

Logical Operations with Diode (OR)

Logic Truth Table

INPUTS		OUTPUT
X	Y	Z
0	0	0
0	1	1
1	0	1
1	1	1

Voltage Truth Table

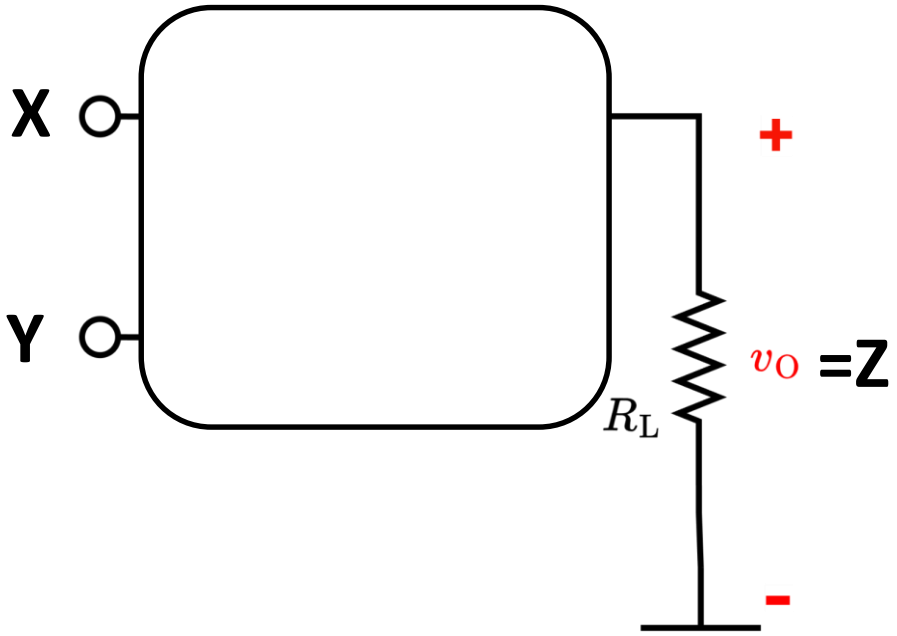
INPUTS		OUTPUT
X	Y	Z
0 V	0 V	0 V
0 V	5 V	5 V
5 V	0 V	5 V
5 V	5 V	5 V

	Low/False	High/True
Logic Levels:	0	1
Corresponding voltage levels:	0V	5V

Logical Operations with Diode (OR)

Voltage Truth Table

INPUTS		OUTPUT
X	Y	Z
0 V	0 V	0 V
0 V	5 V	5 V
5 V	0 V	5 V
5 V	5 V	5 V



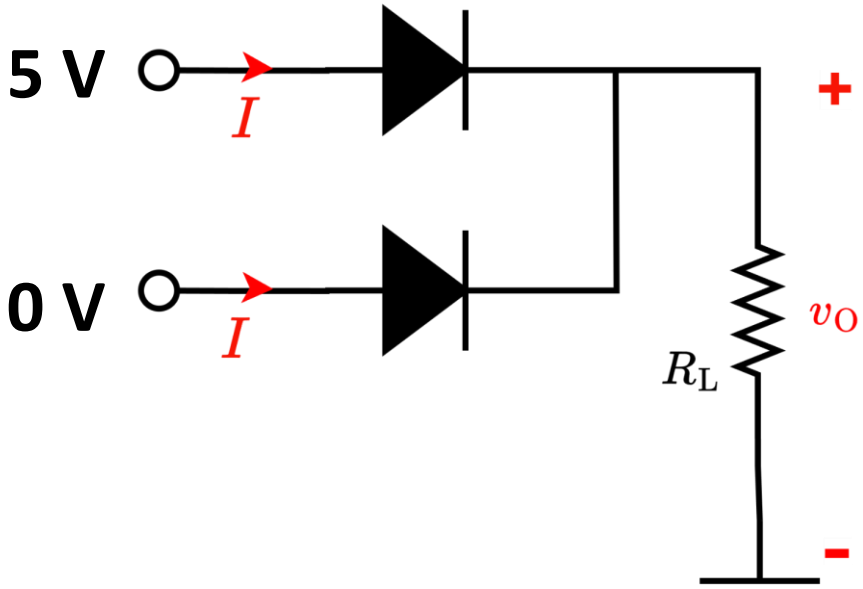
PULL DOWN NETWORK

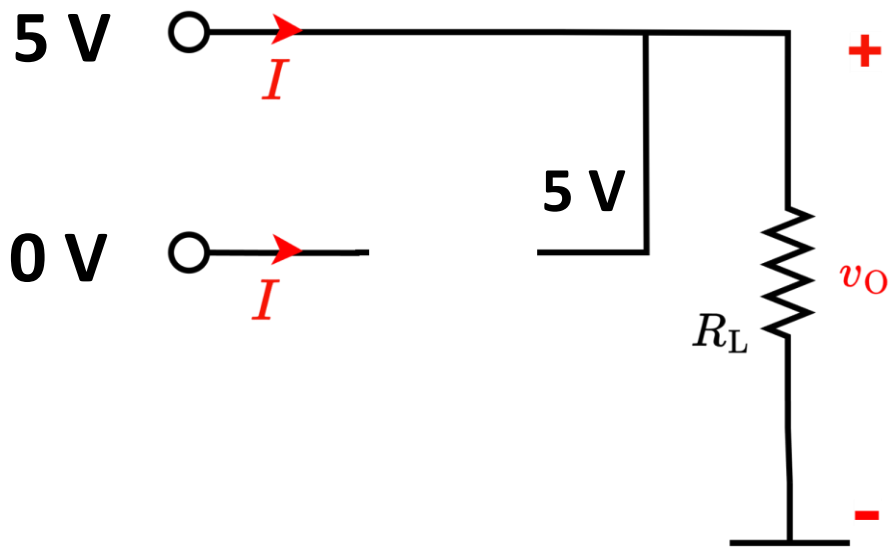
When all inputs are completely disconnected, v_O is pulled down to **GND**

Degrades the HIGHEST output voltage

Logical Operations with Diode (OR)

Ideal diode

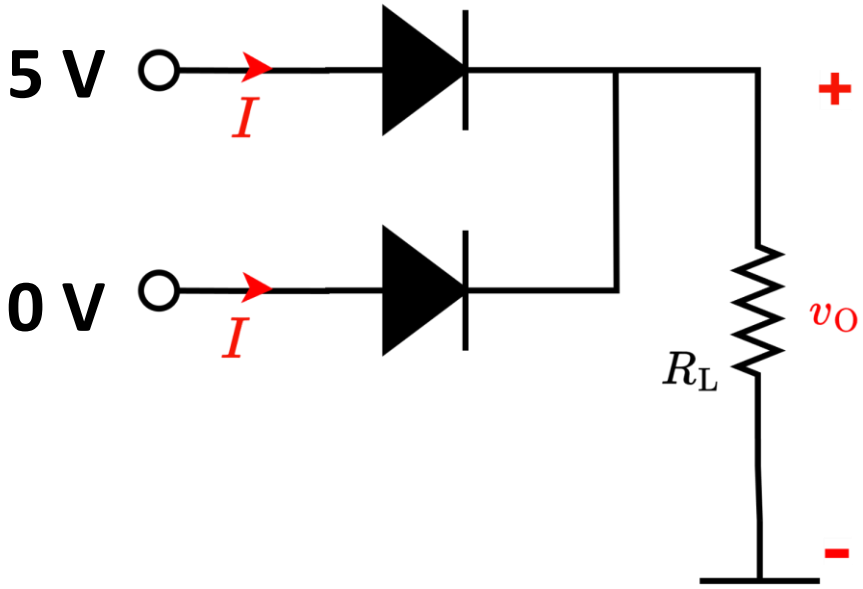


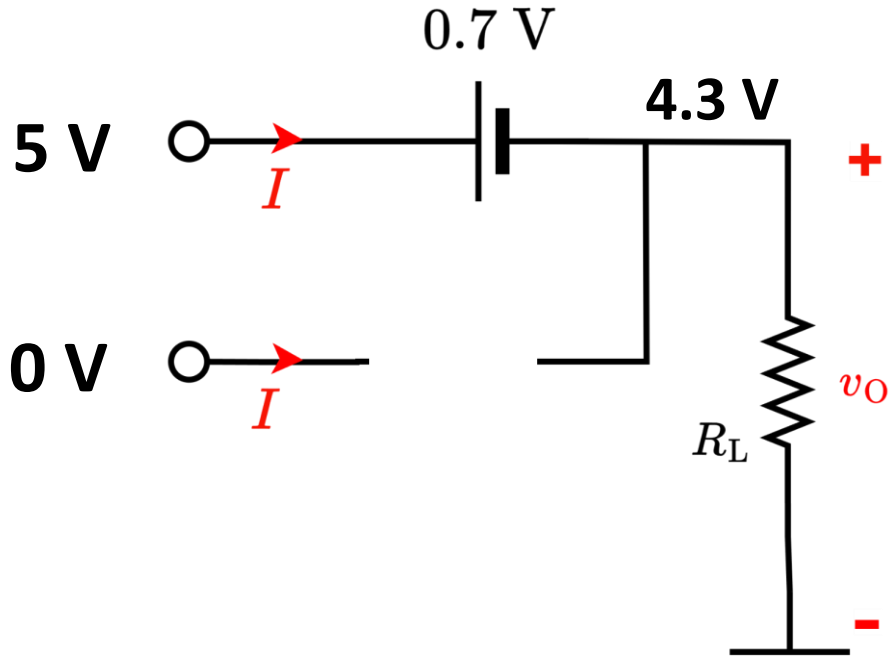


Z = 5 V

Logical Operations with Diode (OR)

CVD diode



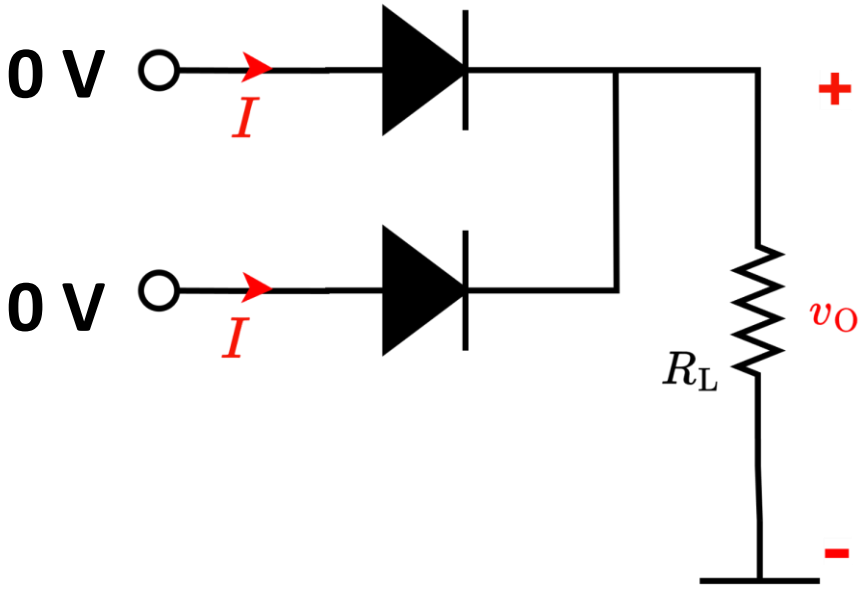


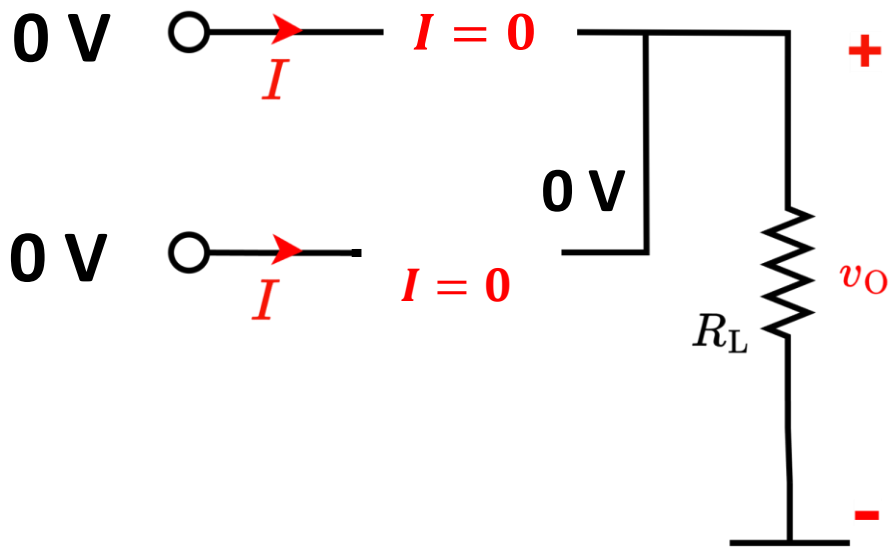
Z = 4.3 V

Degraded 5 V

Logical Operations with Diode (OR)

Ideal diode

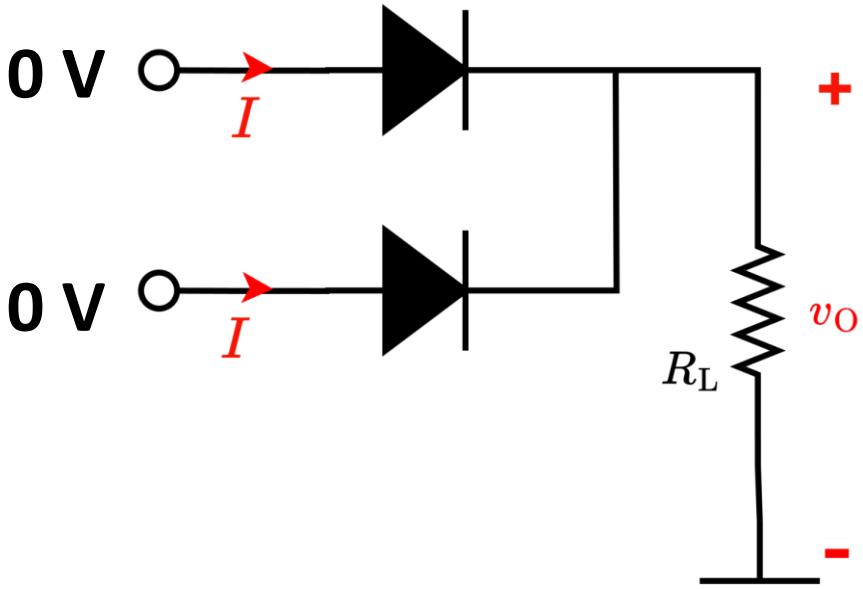


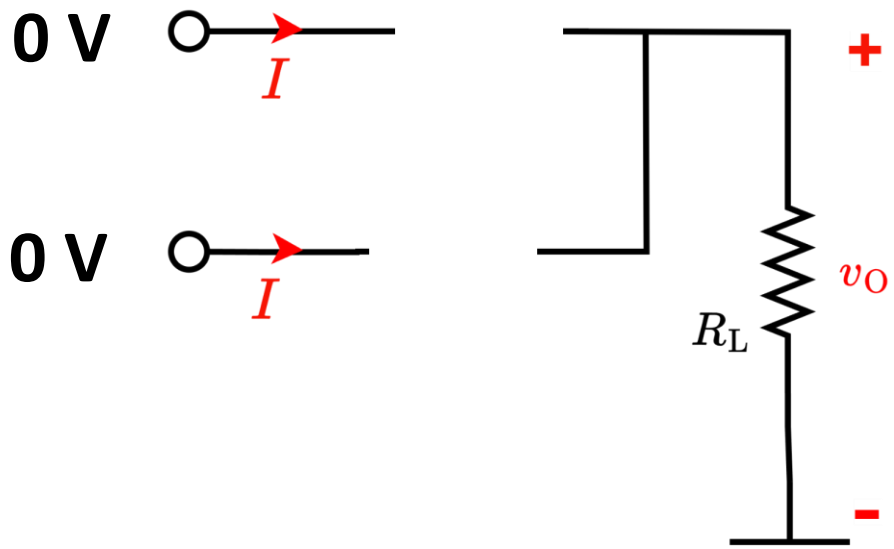


Z = 0 V

Logical Operations with Diode (OR)

CVD diode

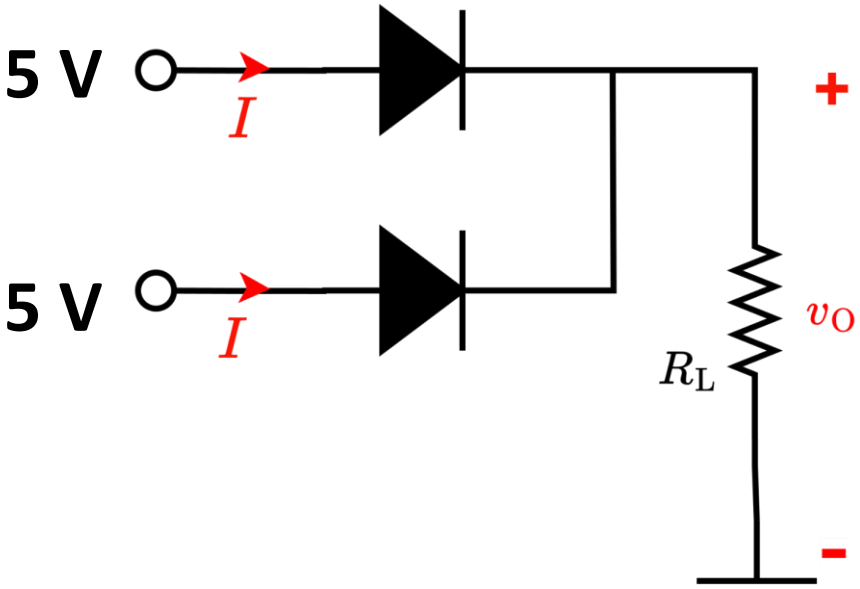


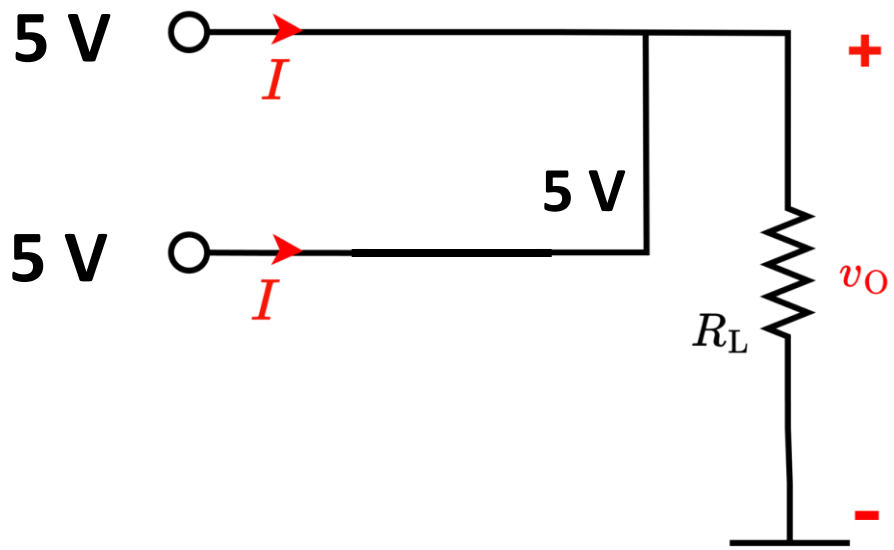


Z = 0 V

Logical Operations with Diode (OR)

Ideal diode

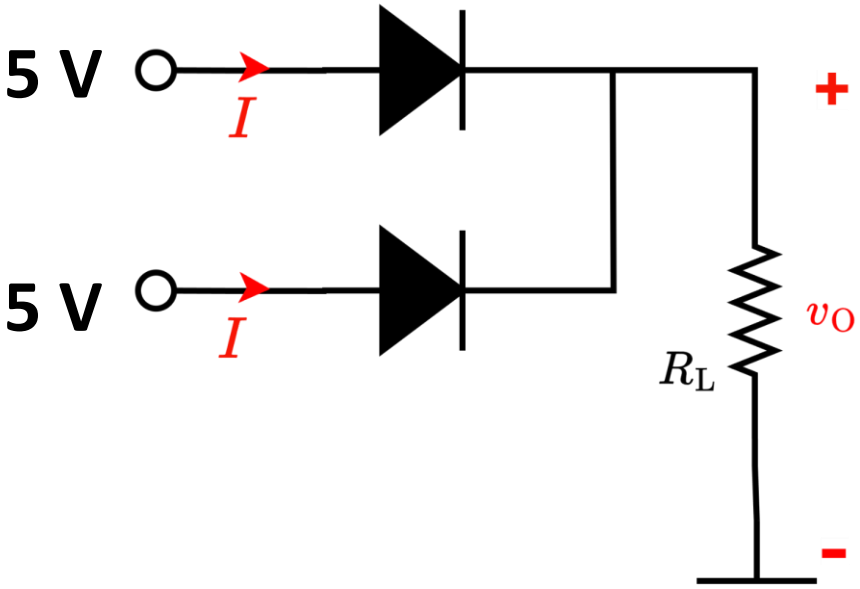


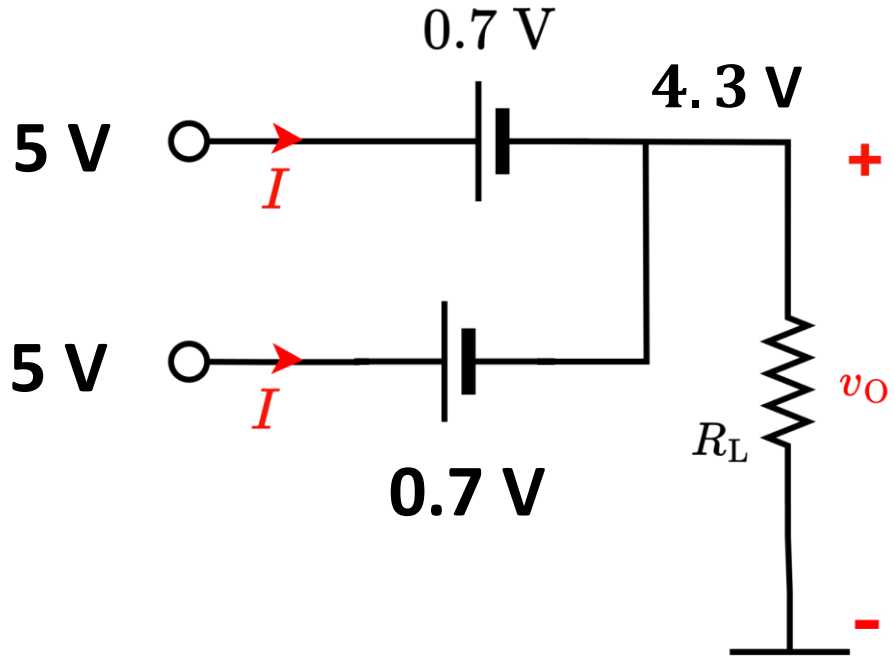


Z = 5 V

Logical Operations with Diode (OR)

CVD diode





Z = 4.3 V

Degraded 5 V

Both diodes have same V_{DO}

Logical Operations with Diode (OR)

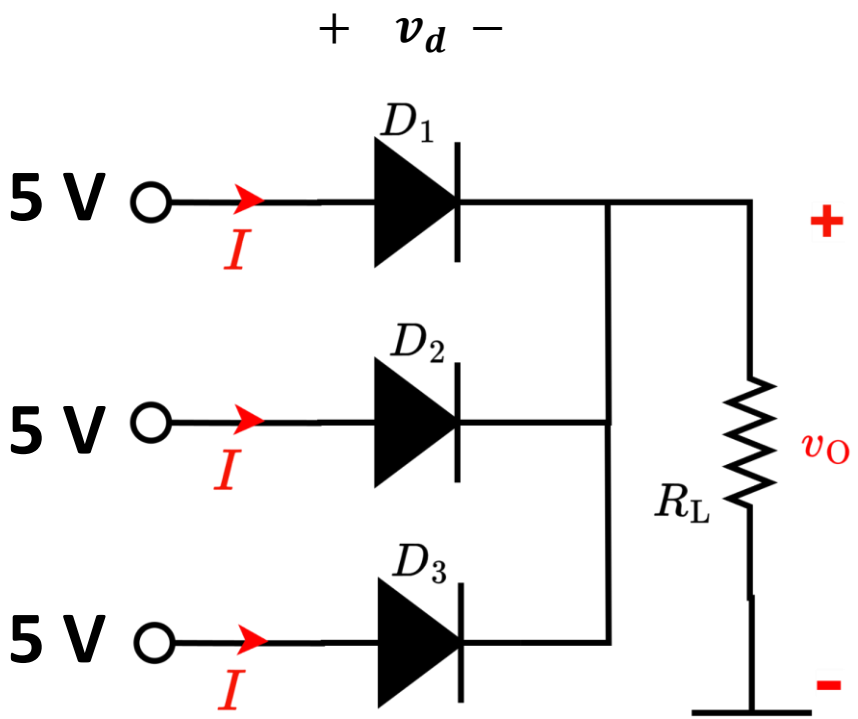
CVD diode

What if the diodes have different V_{DO}?

$V_{D1} = 1\ \mathrm{V}$

$V_{D2} = 0.7\ \mathrm{V}$

$V_{D3} = 0.5\ \mathrm{V}$



Logical Operations with Diode (OR)

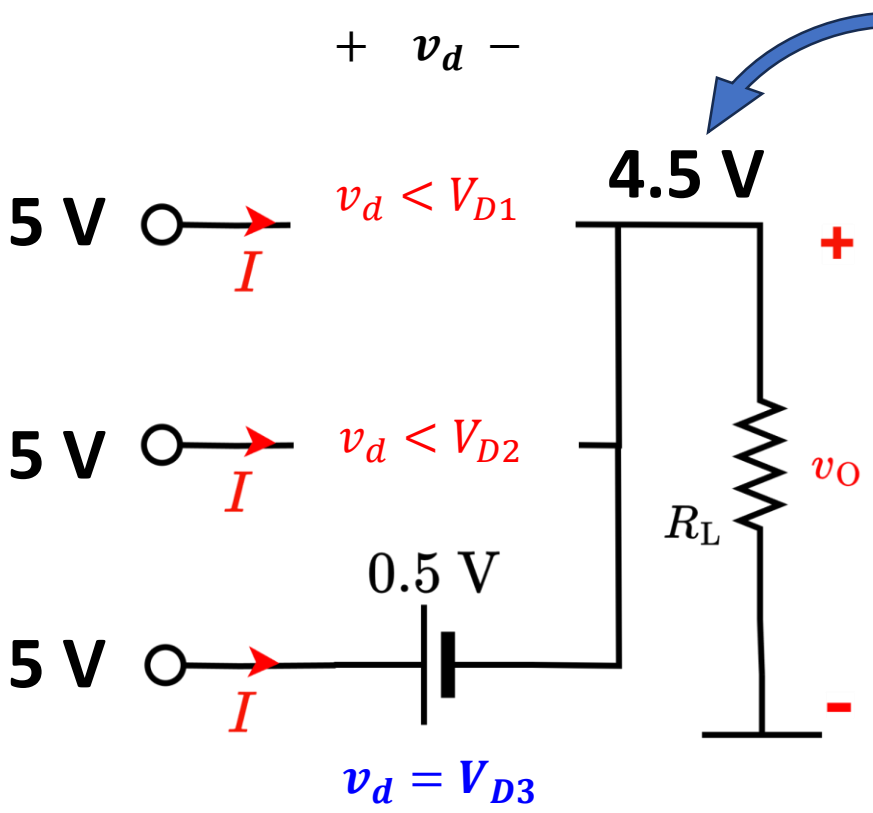
CVD diode

What if two diodes have different V_{DO}?

$V_{D1} = 1\ \text{V}$

$V_{D2} = 0.7\ \text{V}$

$V_{D3} = 0.5\ \text{V}$



Highest (possible – and consistent) voltage here!

Z = 4.5 V

Logical Operations with Diode (OR)

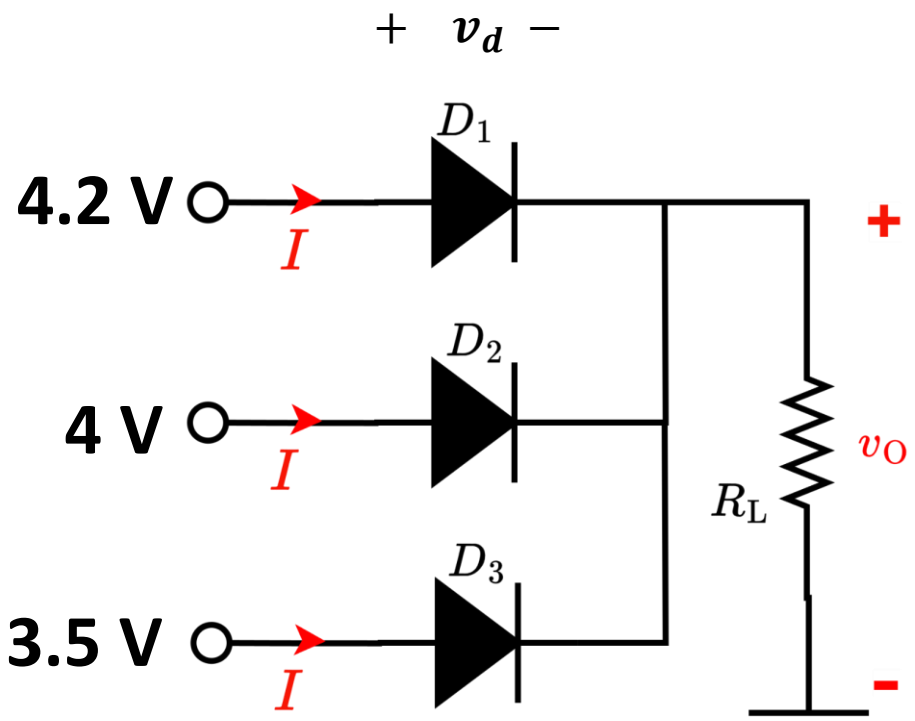
CVD diode

What if the input voltages are different?

$V_{D1} = 1\ \mathrm{V}$

$V_{D2} = 0.7\ \mathrm{V}$

$V_{D3} = 0.5\ \mathrm{V}$



Logical Operations with Diode (OR)

CVD diode

What if the input voltages are different?

Highest (possible – and consistent) voltage here!

$V_{D1} = 1\ \text{V}$

$V_{D2} = 0.7\ \text{V}$

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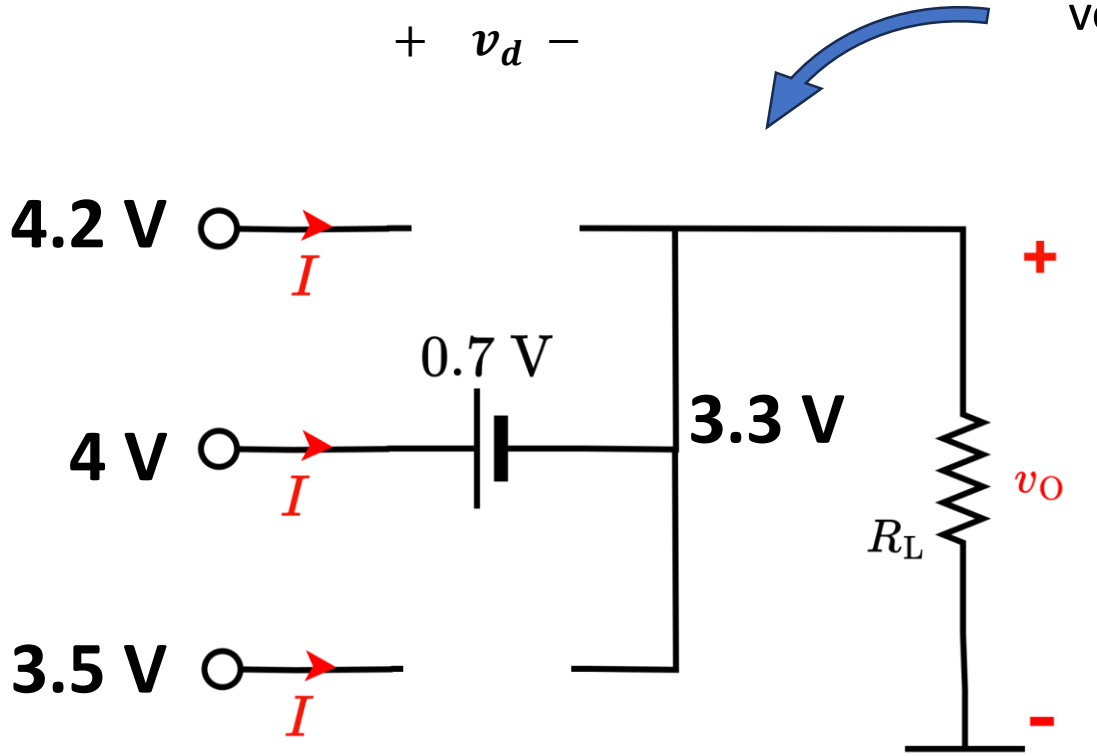


Z = 3.3 V

Logical Operations with Diode (AND)

Logic Truth Table

INPUTS		OUTPUT
X	Y	Z
0	0	0
0	1	0
1	0	0
1	1	1

Voltage Truth Table

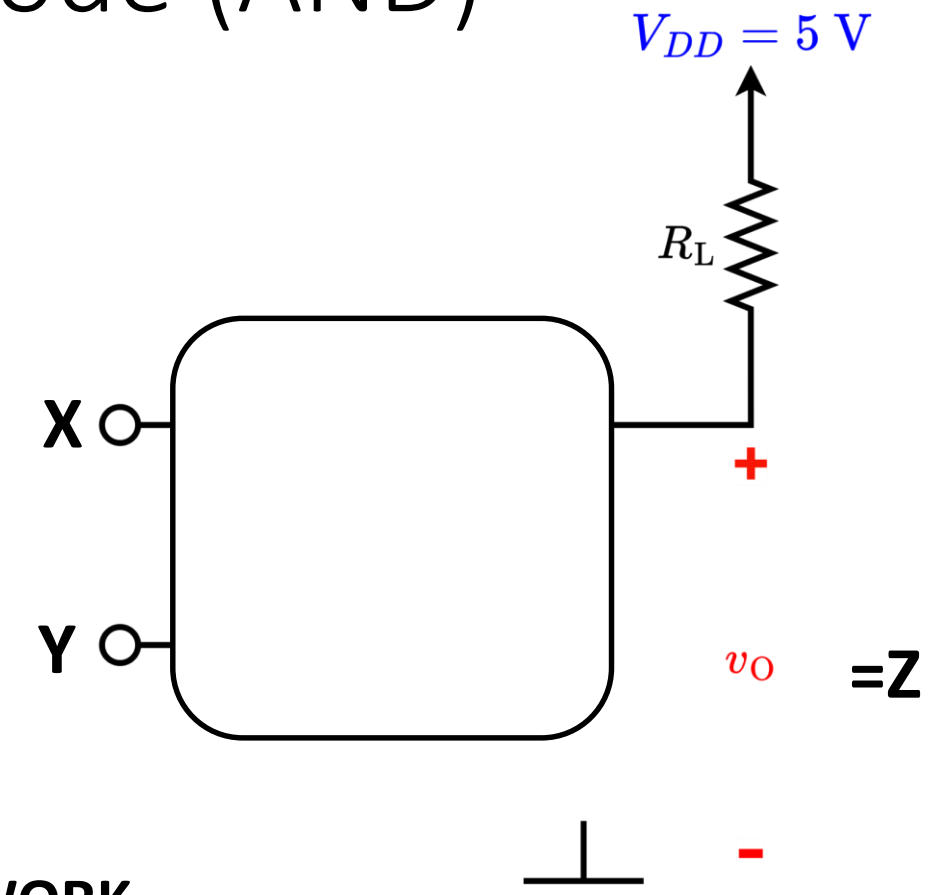
INPUTS		OUTPUT
X	Y	Z
0 V	0 V	0 V
0 V	5 V	0 V
5 V	0 V	0 V
5 V	5 V	5 V

	Low/False	High/True
Logic Levels:	0	1
Corresponding voltage levels:	0V	5V

Logical Operations with Diode (AND)

Voltage Truth Table

INPUTS		OUTPUT
X	Y	Z
0 V	0 V	0 V
0 V	5 V	0 V
5 V	0 V	0 V
5 V	5 V	5 V



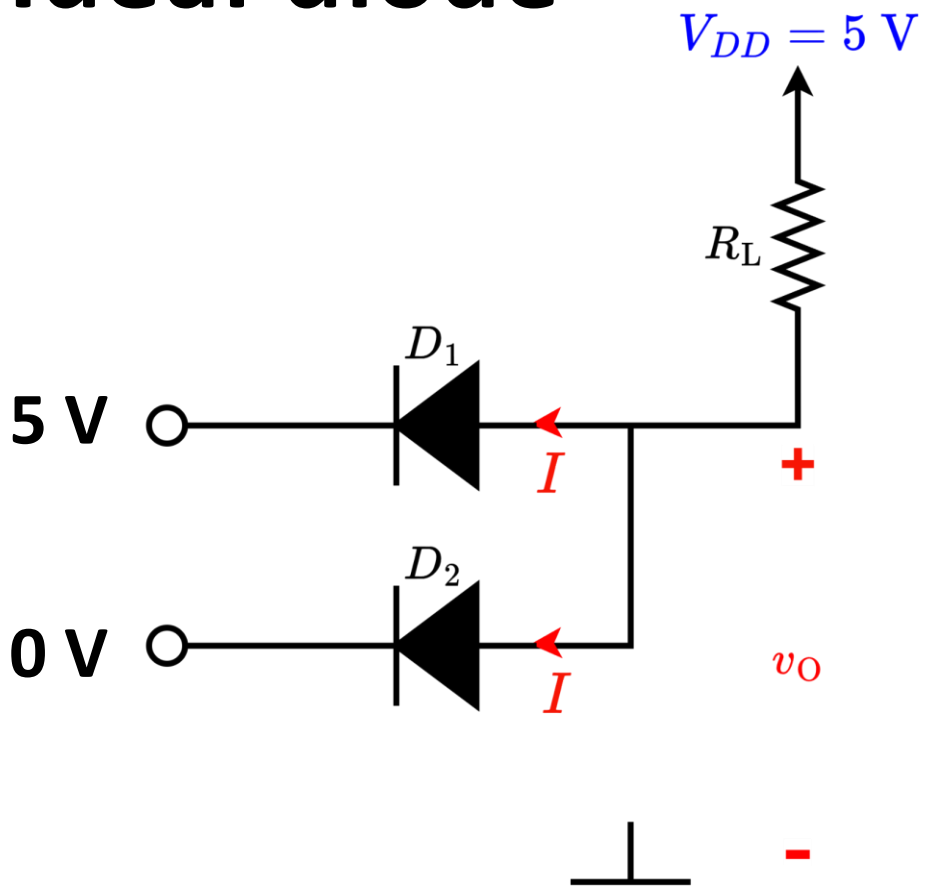
PULL UP NETWORK

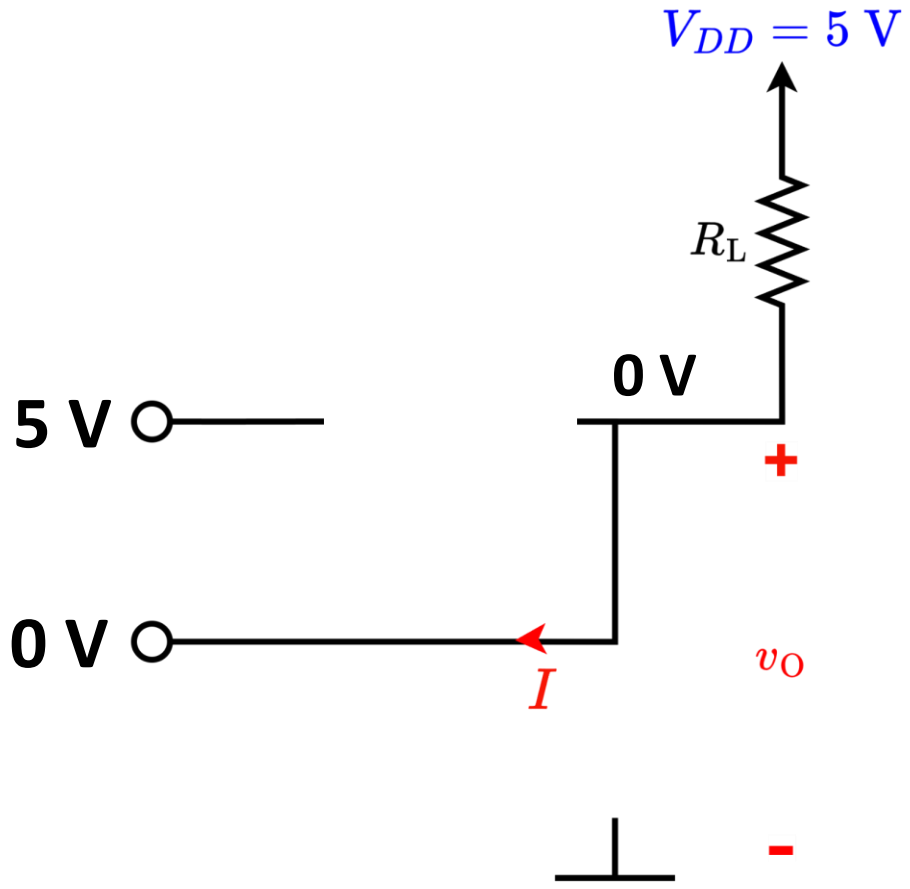
When all inputs are completely disconnected, v_O is pulled up to V_{DD}

Degrades the LOWEST output voltage

Logical Operations with Diode (AND)

Ideal diode

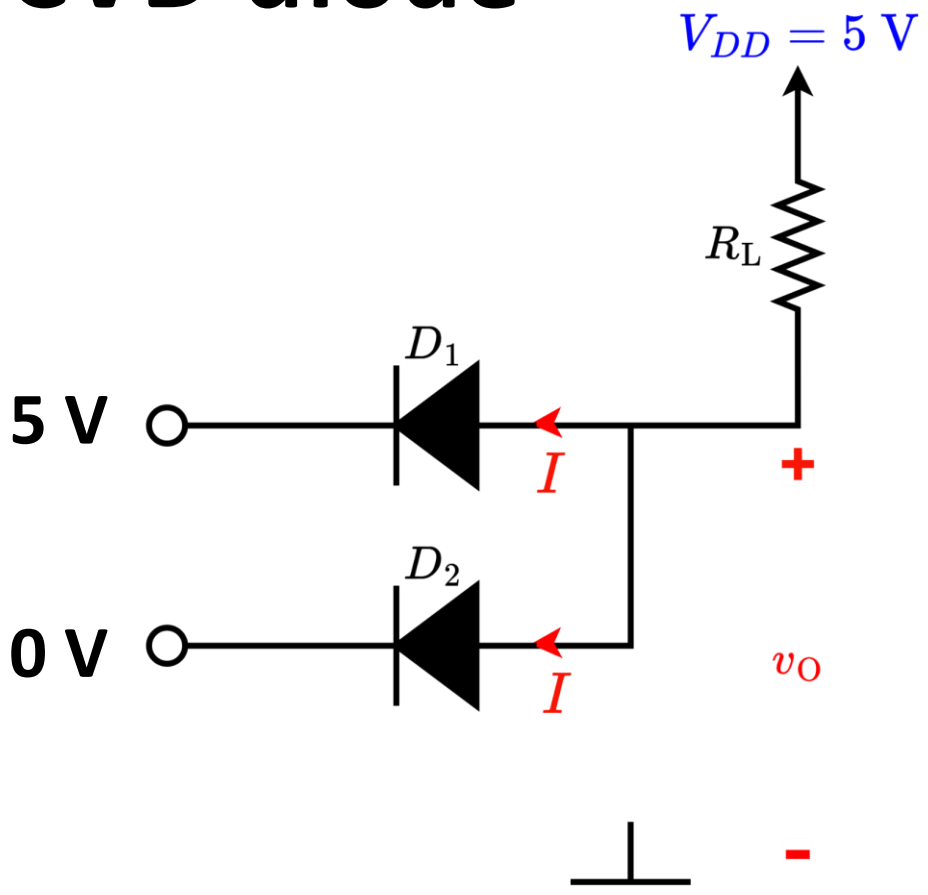


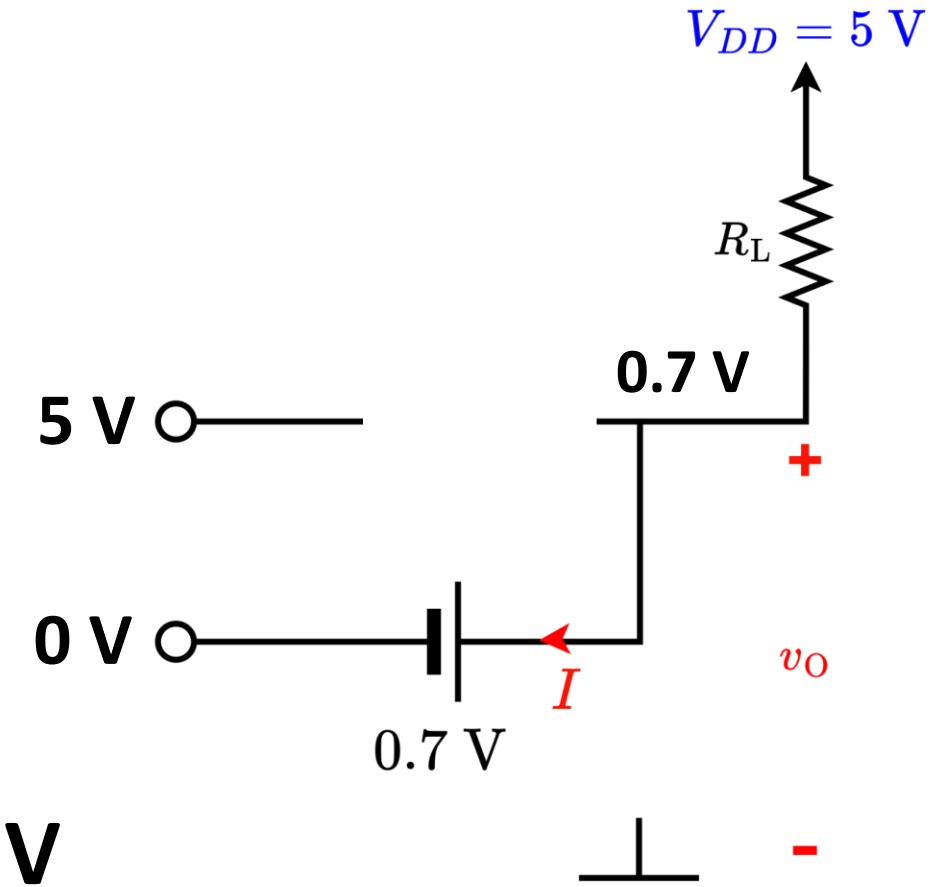


Z = 0 V

Logical Operations with Diode (AND)

CVD diode



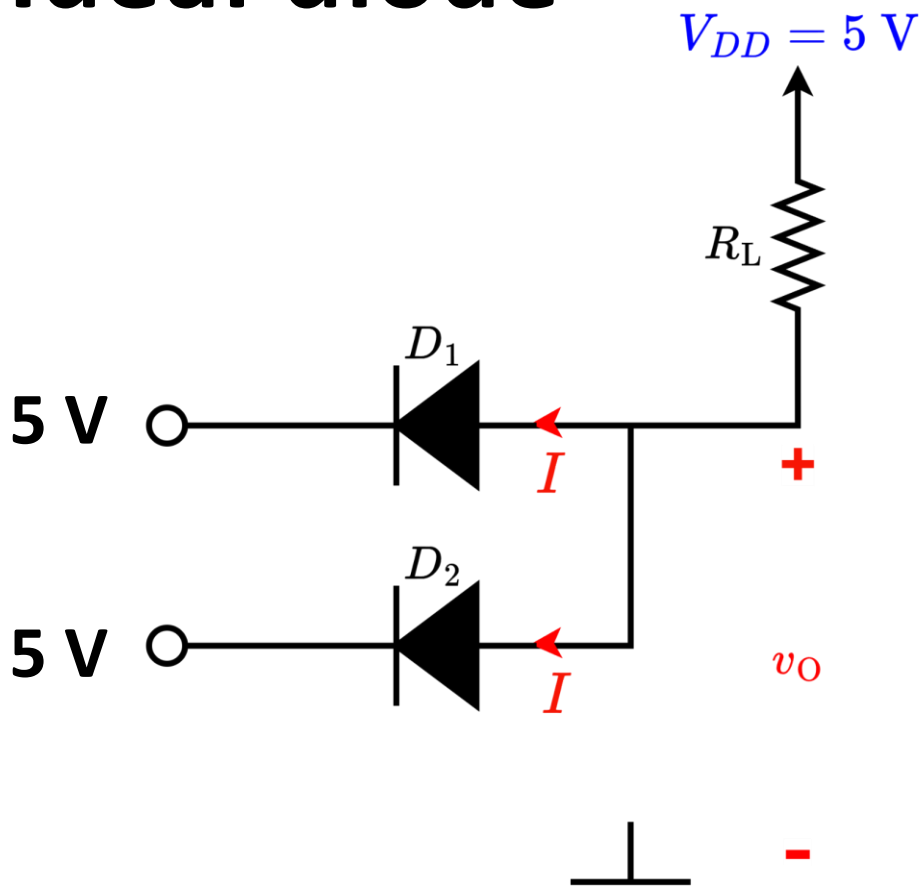


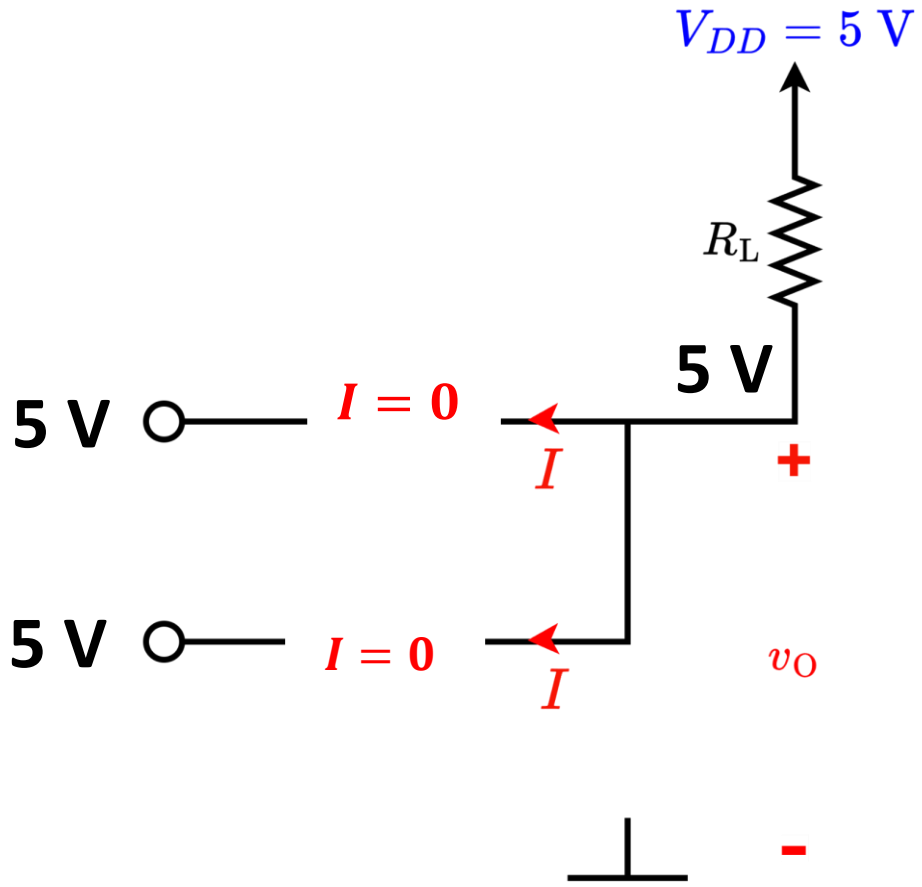
Z = 0.7 V

Degraded 0 V

Logical Operations with Diode (AND)

Ideal diode

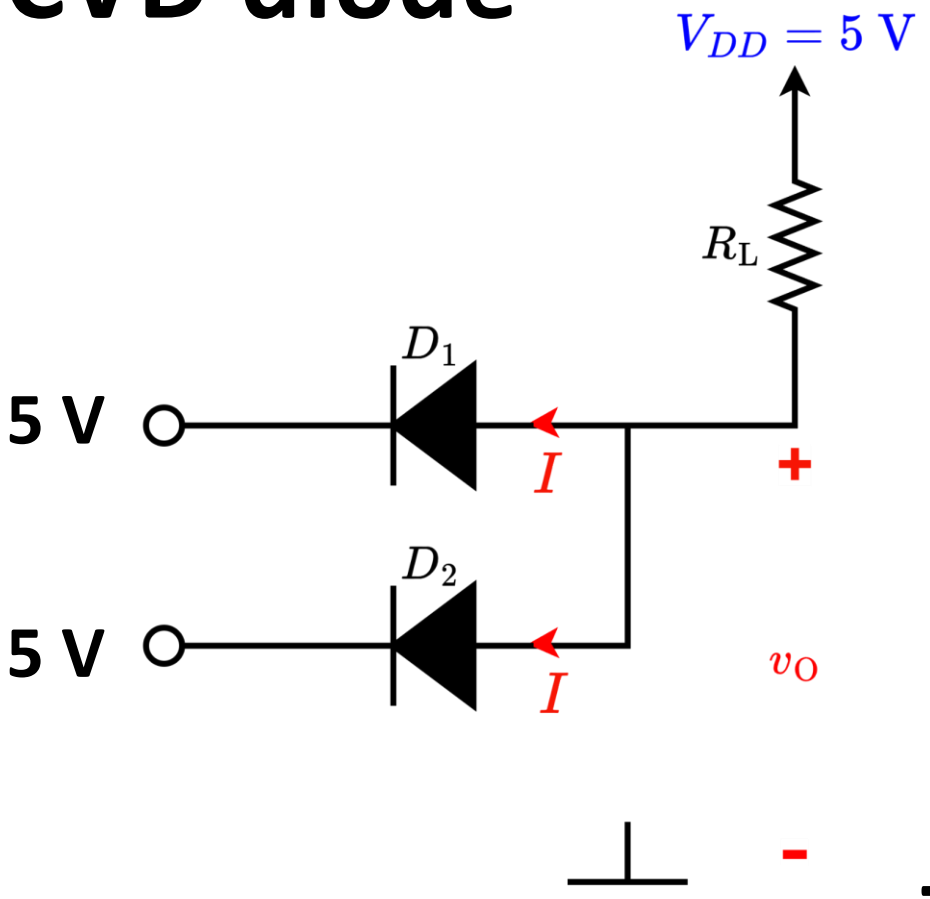


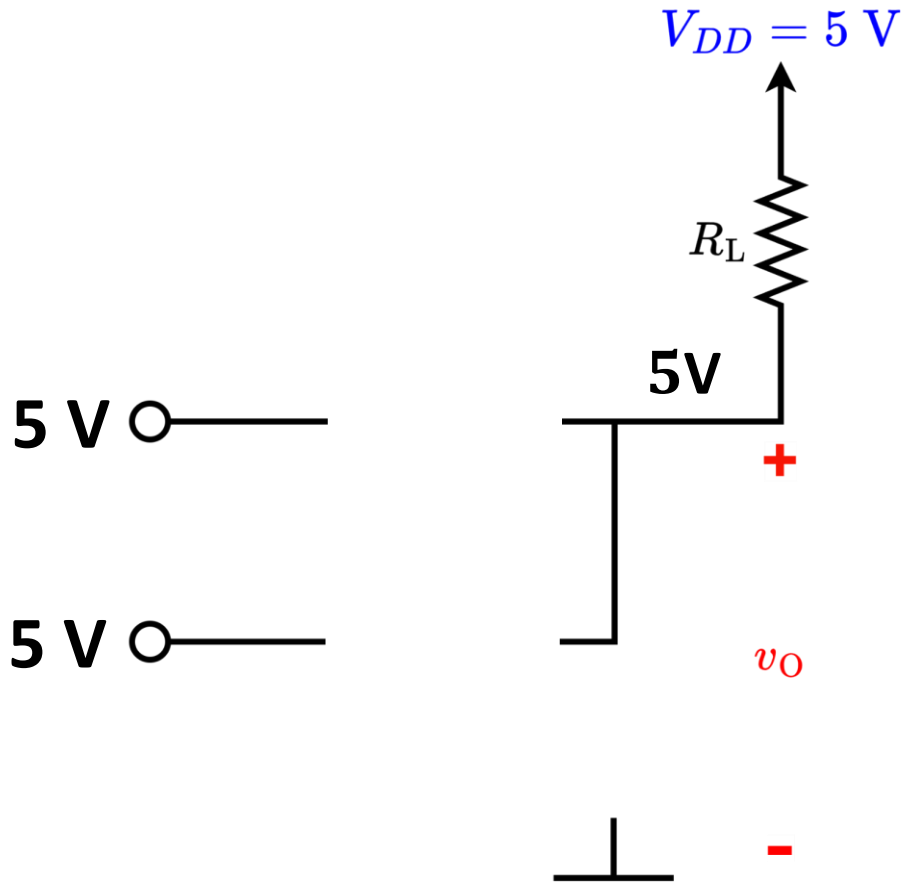


Z = 5 V

Logical Operations with Diode (AND)

CVD diode

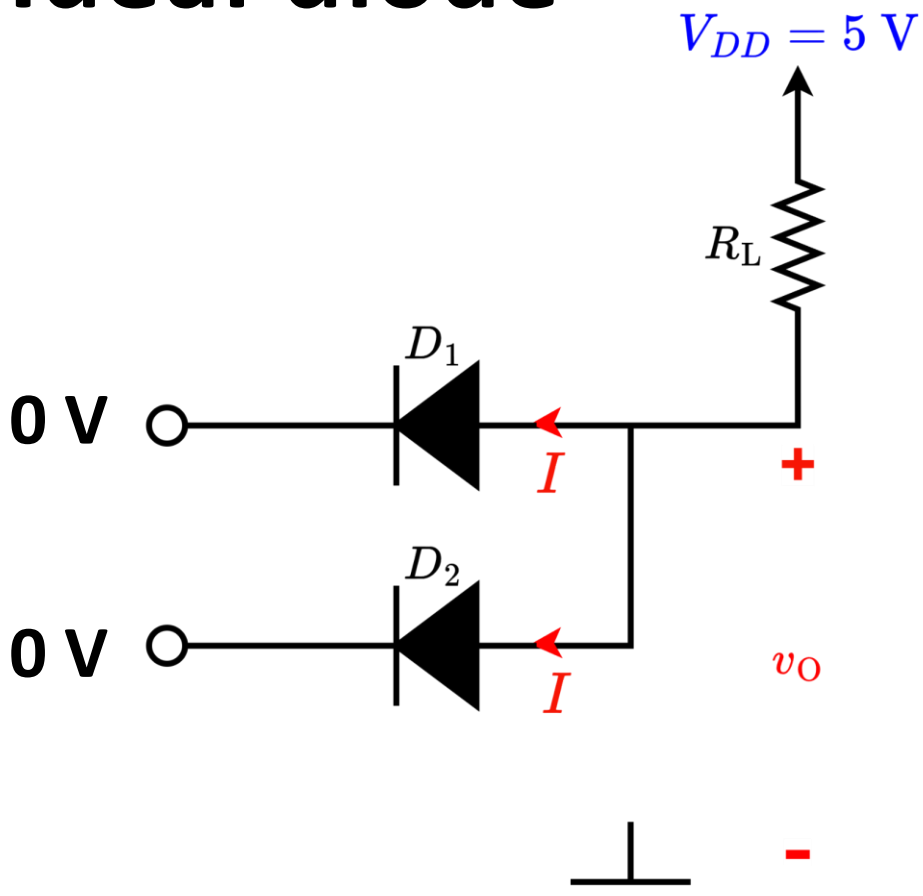




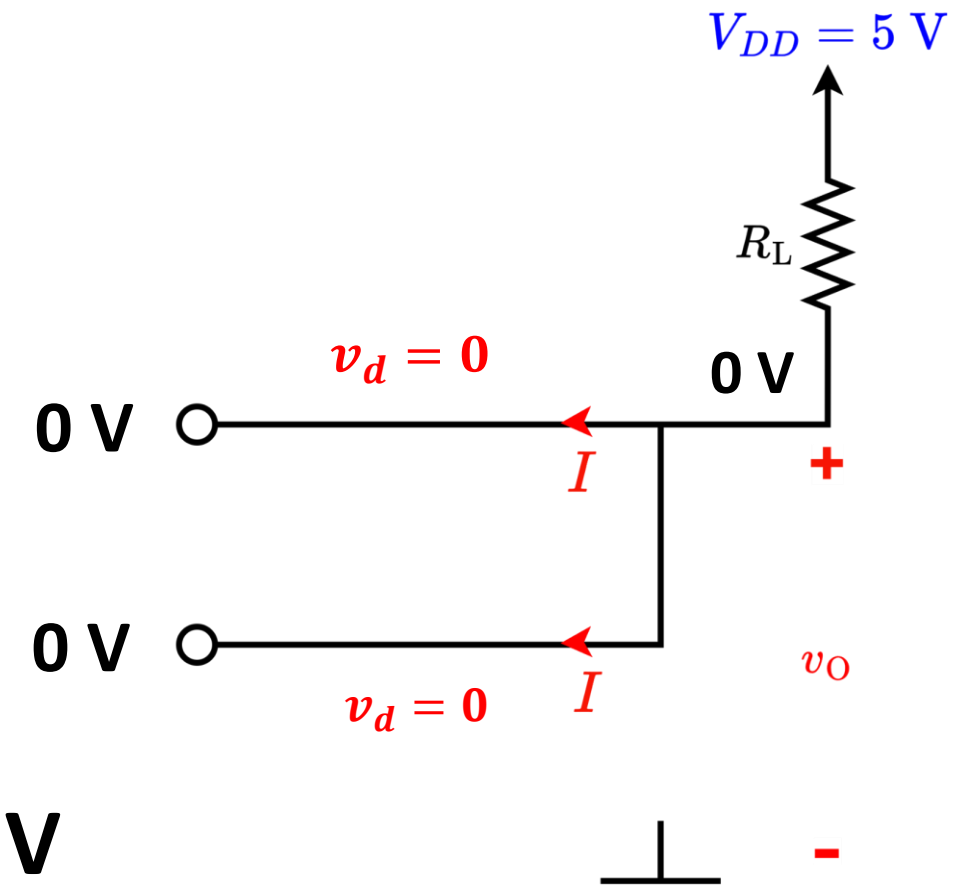
Z = 5 V

Logical Operations with Diode (AND)

Ideal diode

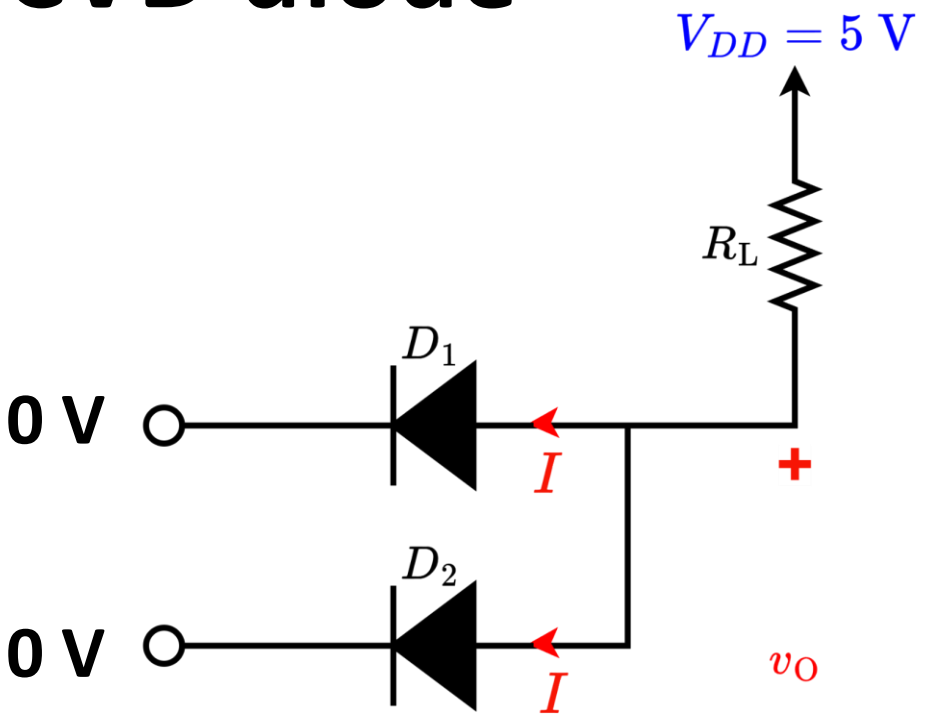


Z = 0 V



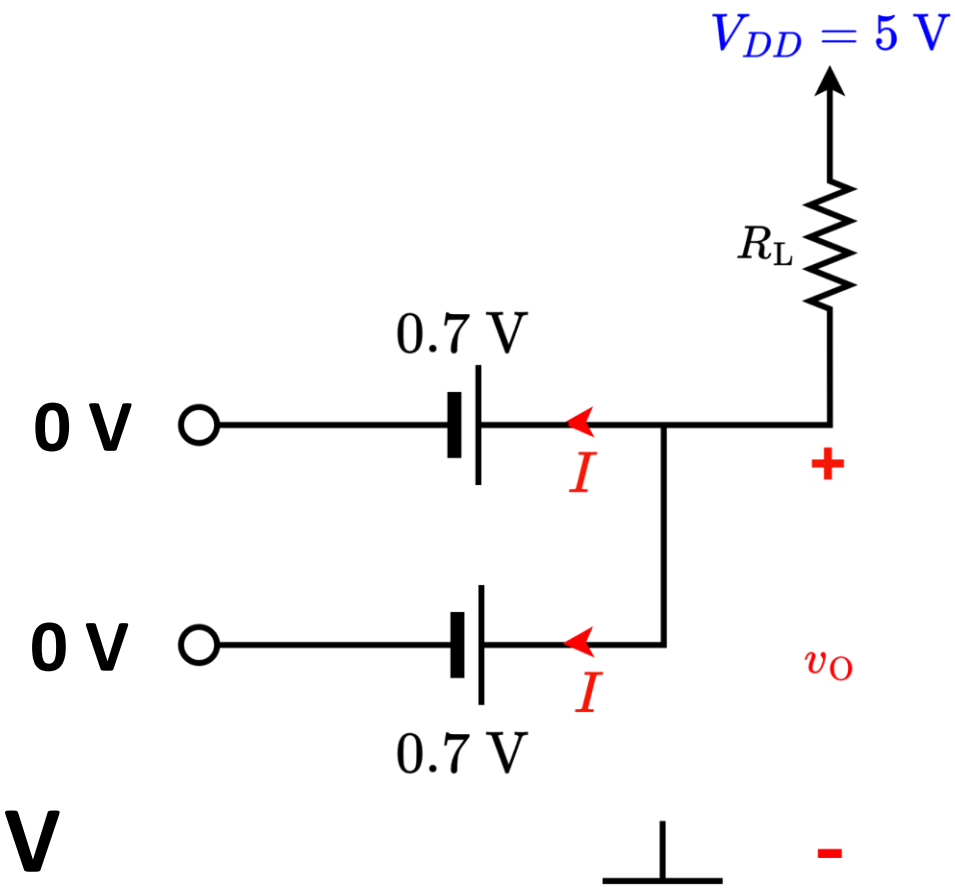
Logical Operations with Diode (AND)

CVD diode



Z = 0.7 V

Degraded 0 V



Both diodes have same V_{DO}

Logical Operations with Diode (AND)

CVD diode

What if the diodes have different V_{DO}?

$V_{D1} = 1\ \mathrm{V}$

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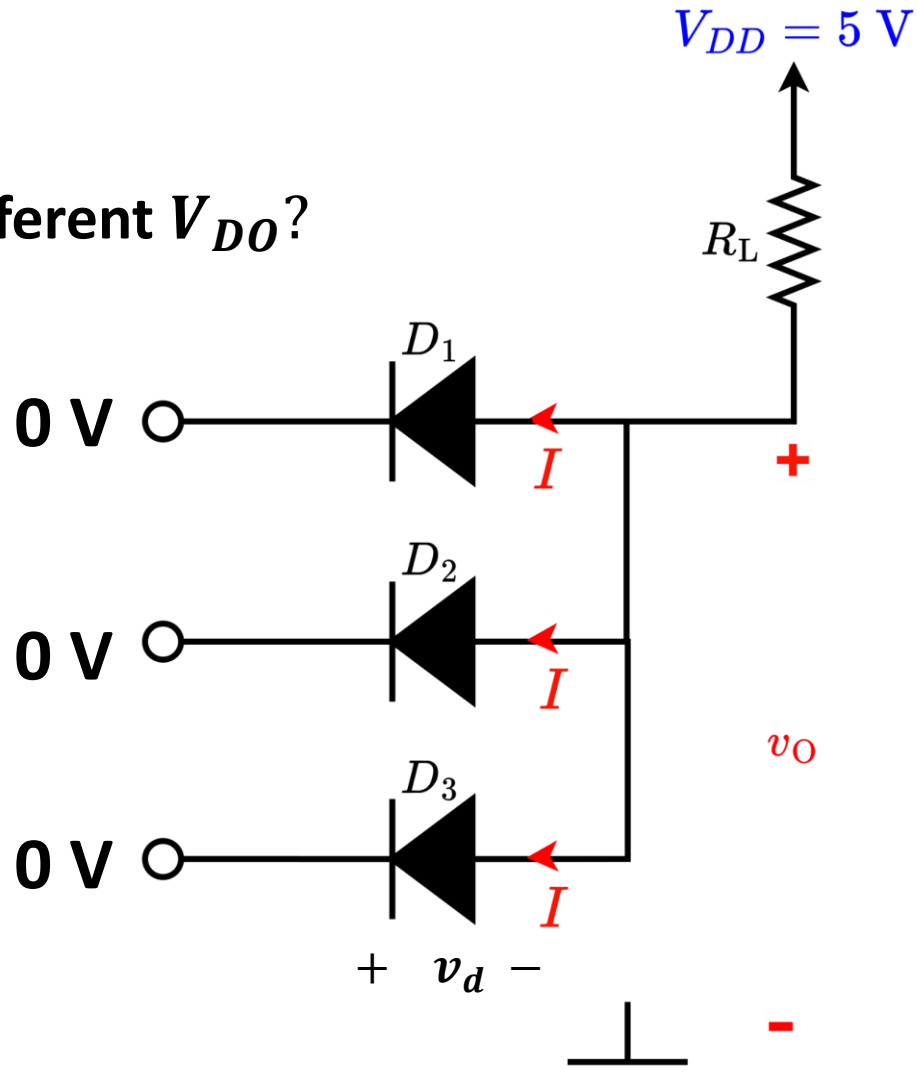
$V_{D3} = 0.5\ \mathrm{V}$



Logical Operations with Diode (AND)

CVD diode

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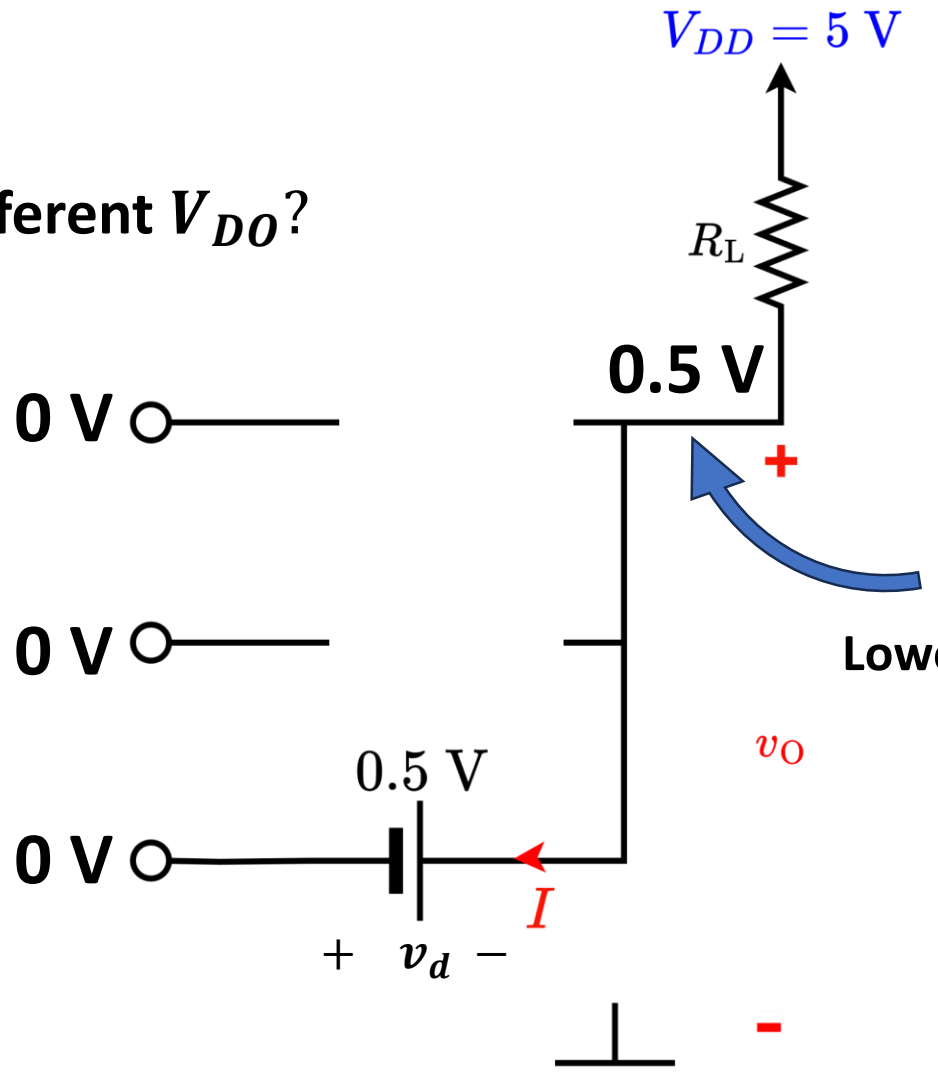
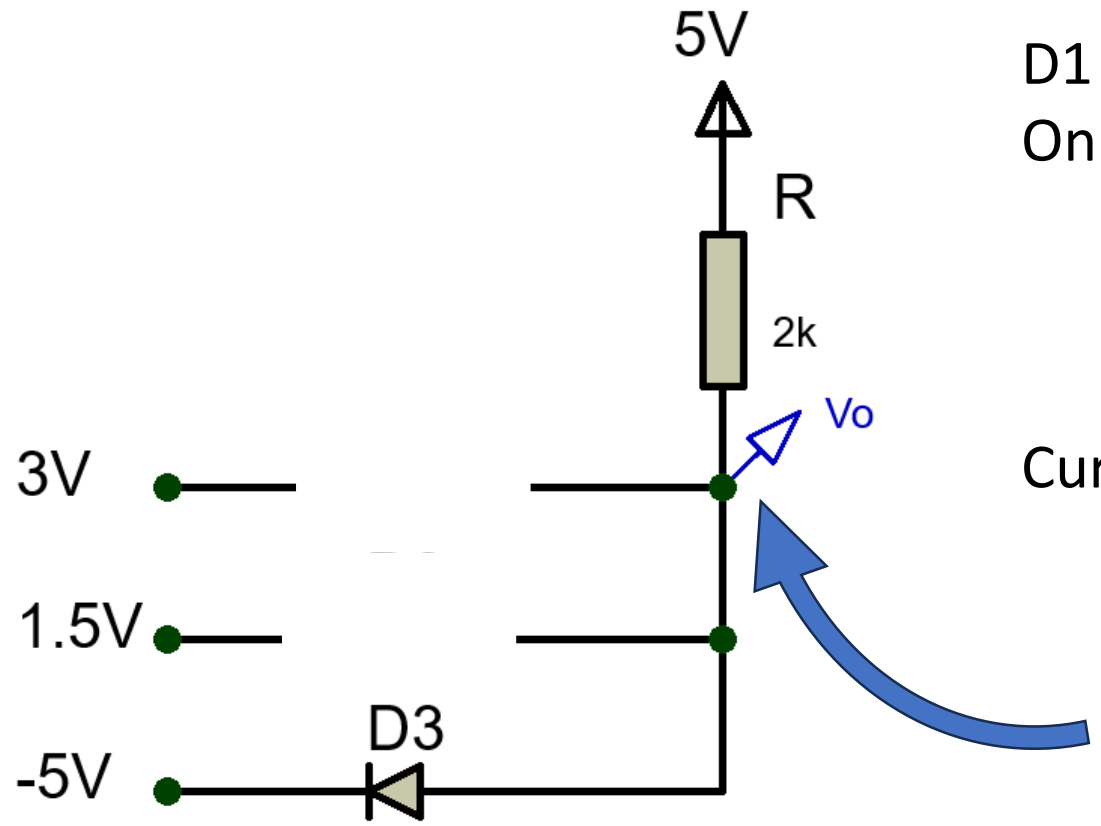


Lowest (possible – and consistent) voltage here!

Effect of input Voltage Variation in Logic Gates (AND)

Example 1: Find the value of Vo (All the diodes are ideal diodes)



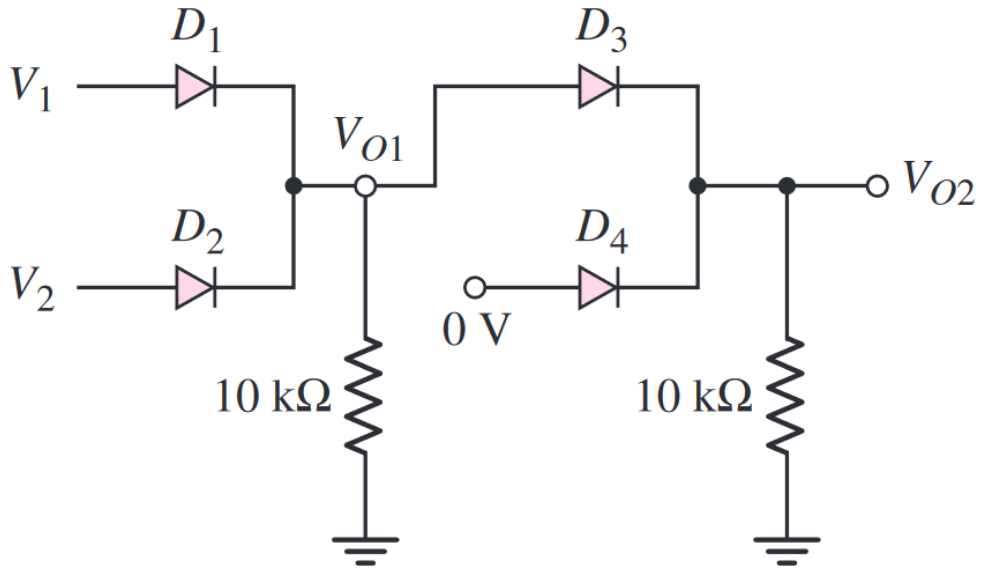
D1 and D2 are OFF → Open Circuit
Only D3 is ON → Short Circuit

$$V_O = -5 \text{ V}$$

Current, $\mathrm{I} = \frac{5\text{ V} - (-5\text{ V})}{2\text{ k}\Omega}$ = 5 mA

Lowest (possible – and consistent) voltage here!

Combined Logic Circuits

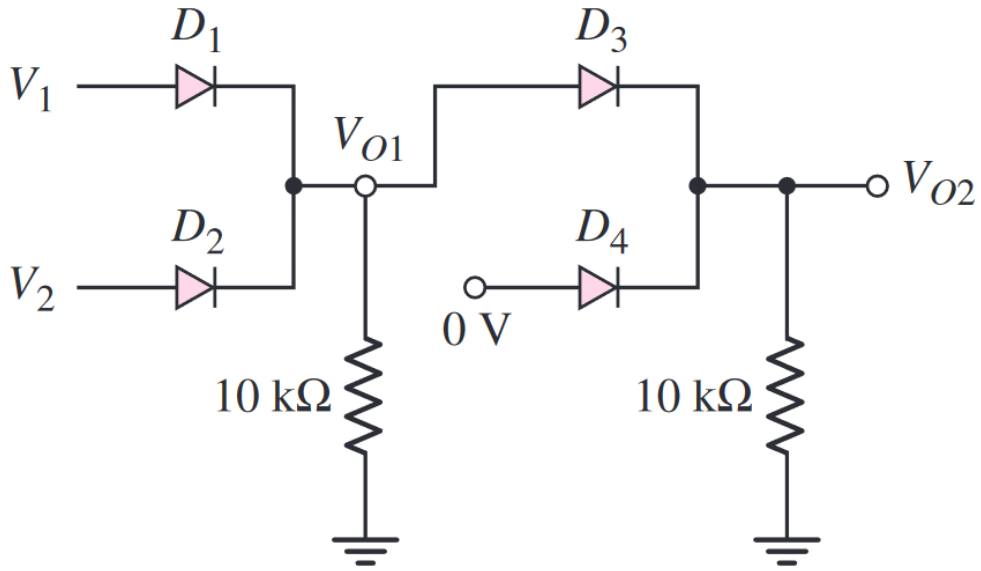


$$\boldsymbol{V_{O1} = V_1 \text{ OR } V_2 = V_1 | V_2}$$

$$\boldsymbol{V_{O2} = (V_{O1} \text{ OR } 0) = V_{O1} = V_1 | V_2}$$

Combined Logic Circuits

Example 2:



** In CVD diode models, we are assuming that all diodes have equal drop.

Suppose: $\boldsymbol{V_1 = 3\ \text{V}, V_2 = 2\ \text{V}.}$

For Ideal diodes assumption:

$V_{O1} = V_1\ \text{OR}\ V_2$ → *Largest Value of the inputs*

$$\therefore\ V_{O1} = 3\ \text{V}$$

$$\boldsymbol{V_{O2}} = (V_{O1}\ \text{OR}\ 0) = V_{O1} = \mathbf{3\ V}$$

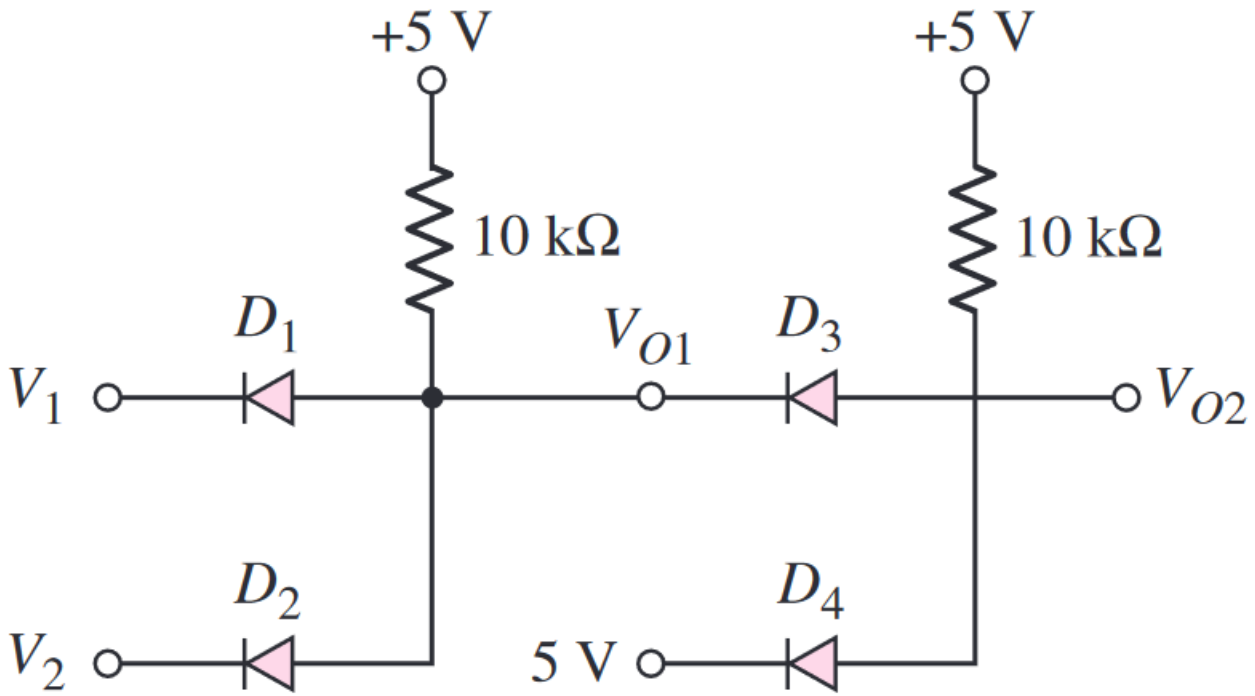
For CVD diodes assumption:

$V_{O1} = V_1\ \text{OR}\ V_2$ → *Largest Value of the inputs -* $\boldsymbol{V_{DO}}$

$$\therefore\ V_{O1} = (3\ - V_{DO})\ \text{V}$$

$$\boldsymbol{V_{O2}} = (V_{O1}\ \text{OR}\ 0) = V_{O1} - V_{DO} = (\mathbf{3 - 2\,V_{DO}})\ \mathbf{V}$$

Combined Logic Circuits

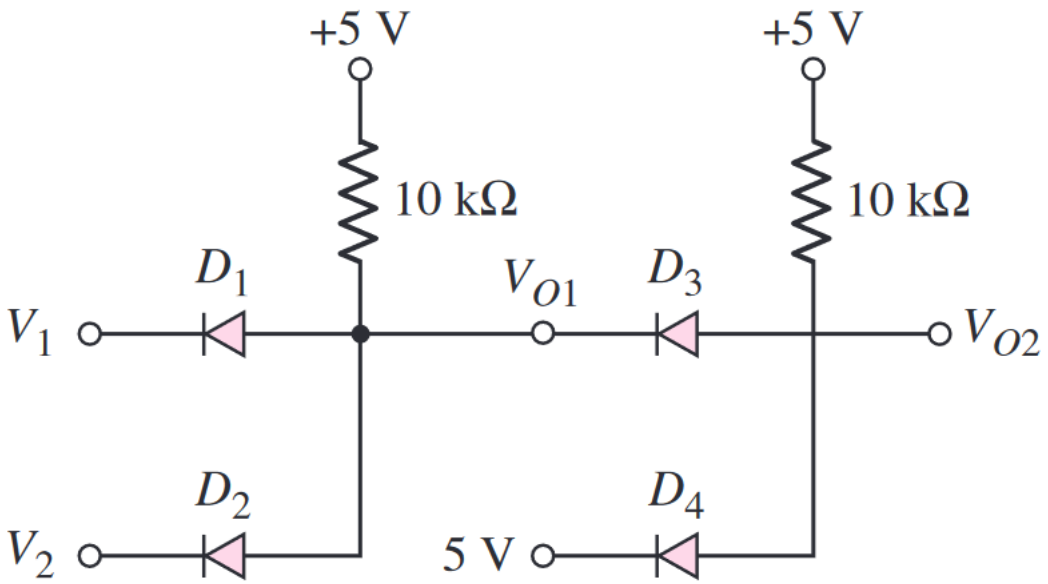


$$\boldsymbol{V_{O1} = V_1 \text{ AND } V_2 = V_1 \cdot V_2}$$

$$\boldsymbol{V_{O2} = (V_{O1} \text{ AND } 5) = V_{O1} = V_1 \cdot V_2}$$

Combined Logic Circuits

Example 3:



** In CVD diode models, we are assuming that all diodes have equal drop.

Suppose: $\boldsymbol{V_1 = 3\ \text{V}, V_2 = 1.5\ \text{V}.}$

For Ideal diodes assumption:

$V_{O1} = V_1\ \text{AND}\ V_2$ → *Smallest Value of the inputs*

$$\therefore\ V_{O1} = 1.5\ \text{V}$$

$$\boldsymbol{V_{O2}} = (V_{O1}\ \text{AND}\ 5) = V_{O1} = \boldsymbol{1.5\ \text{V}}$$

For CVD diodes assumption:

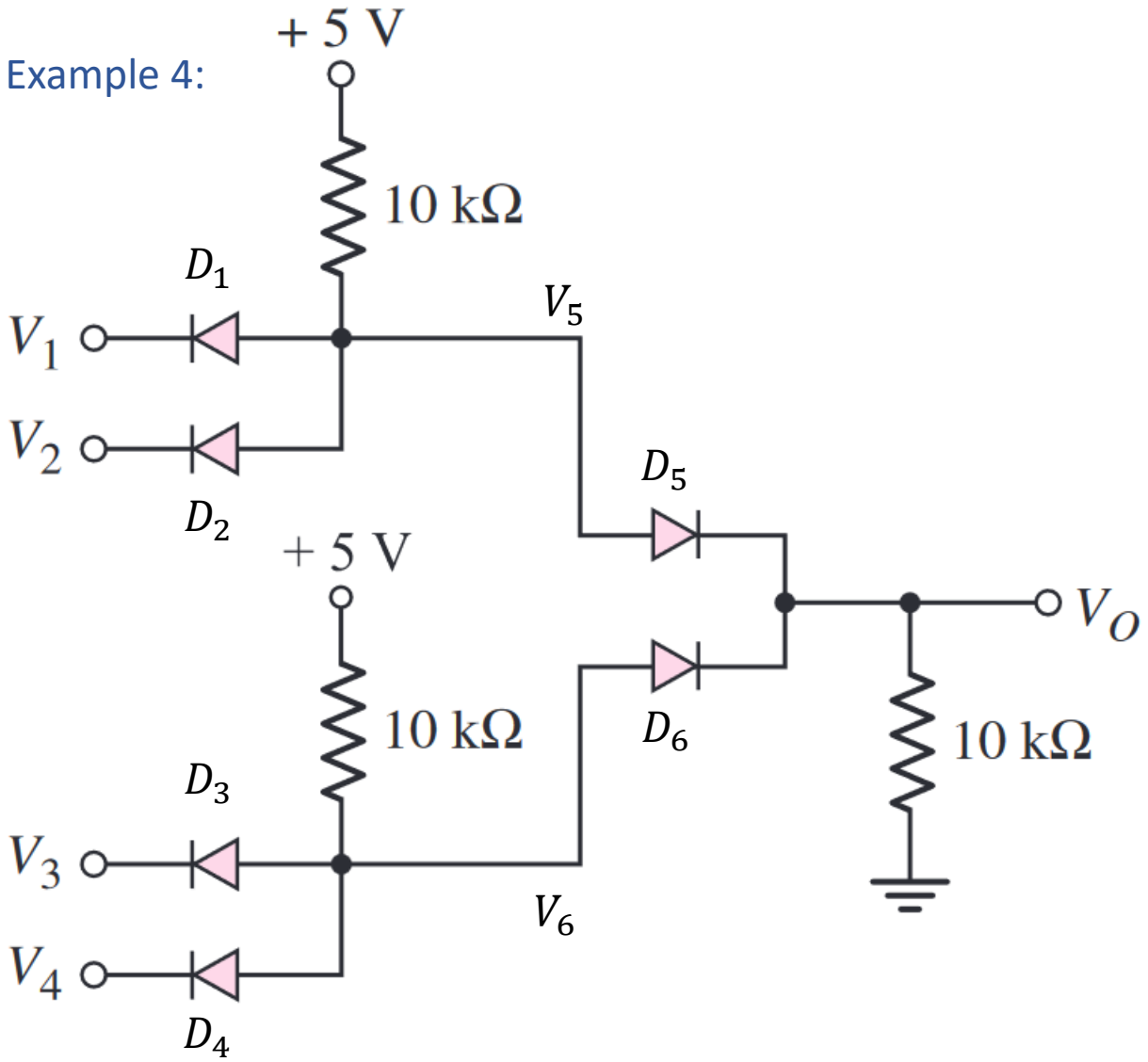
$V_{O1} = V_1\ \text{AND}\ V_2$ → *Smallest Value of the inputs* **+** $\boldsymbol{V_{DO}}$

$$\therefore\ V_{O1} = (1.5 + V_{DO})\ \text{V}$$

$$\boldsymbol{V_{O2}} = (V_{O1}\ \text{AND}\ 5) = V_{O1} + V_{DO} = (\boldsymbol{1.5 + 2\,V_{DO}})\ \text{V}$$

Combined Logic Circuits

Example 4:



1.Express V_O as a Boolean expression of V_1, V_2, V_3 and V_4

$$V_O = (V_1 \textbf{ AND } V_2) \textbf{ OR } (V_3 \textbf{ AND } V_4)$$

2. For the logic network shown, determine V_o if V1 = 2V, V2 = 2.2V, V3 = 2.4V, V4 = 2.5V

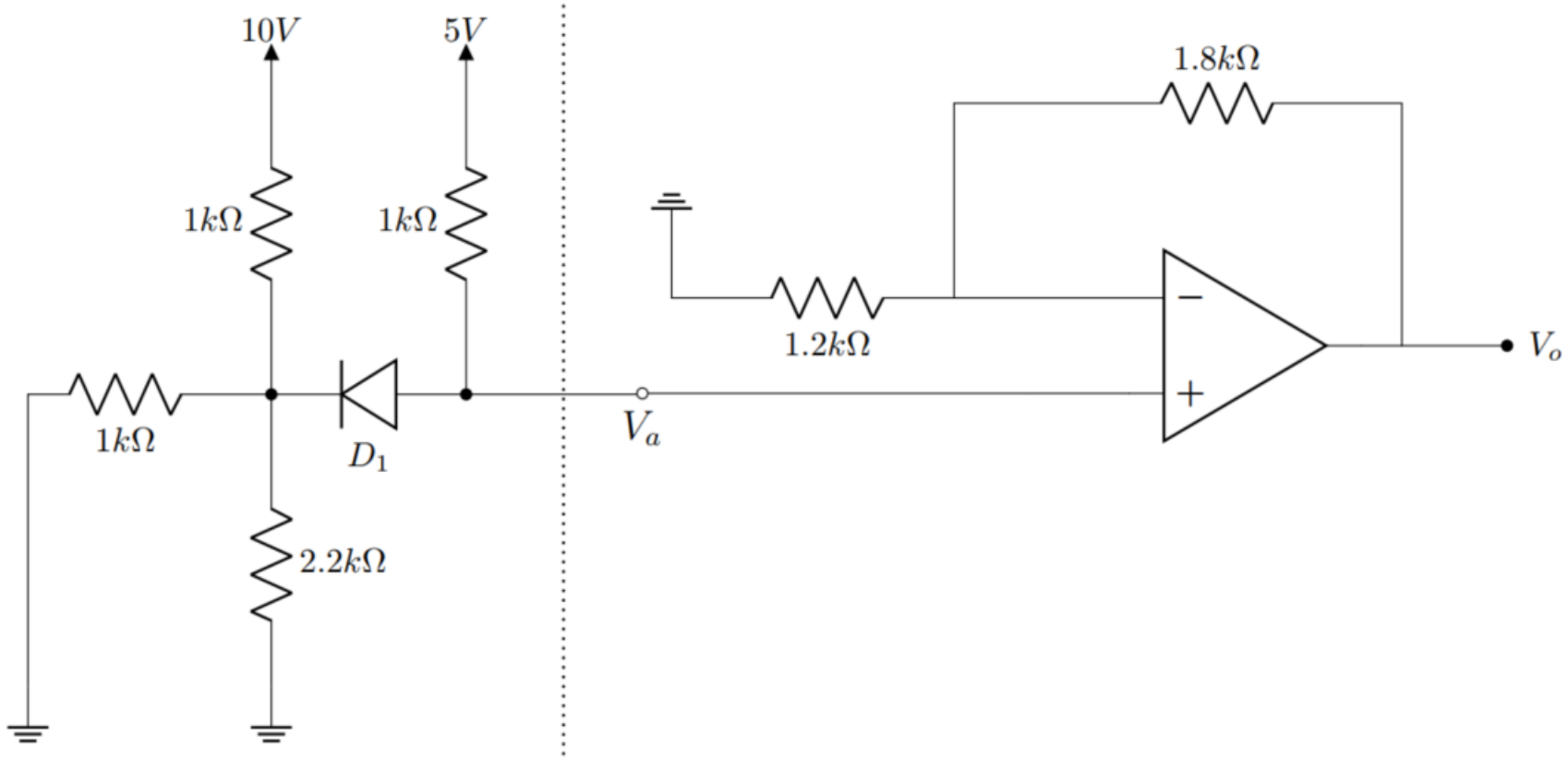
Use CVD model with

V_{DO1} = 0.3 V
V_{DO2} = 0.5 V
V_{DO3} = 0.7 V
V_{DO4} = 0.9 V
V_{DO5} = 1V
V_{DO6} = 1.5 V

V_O = 1.6V

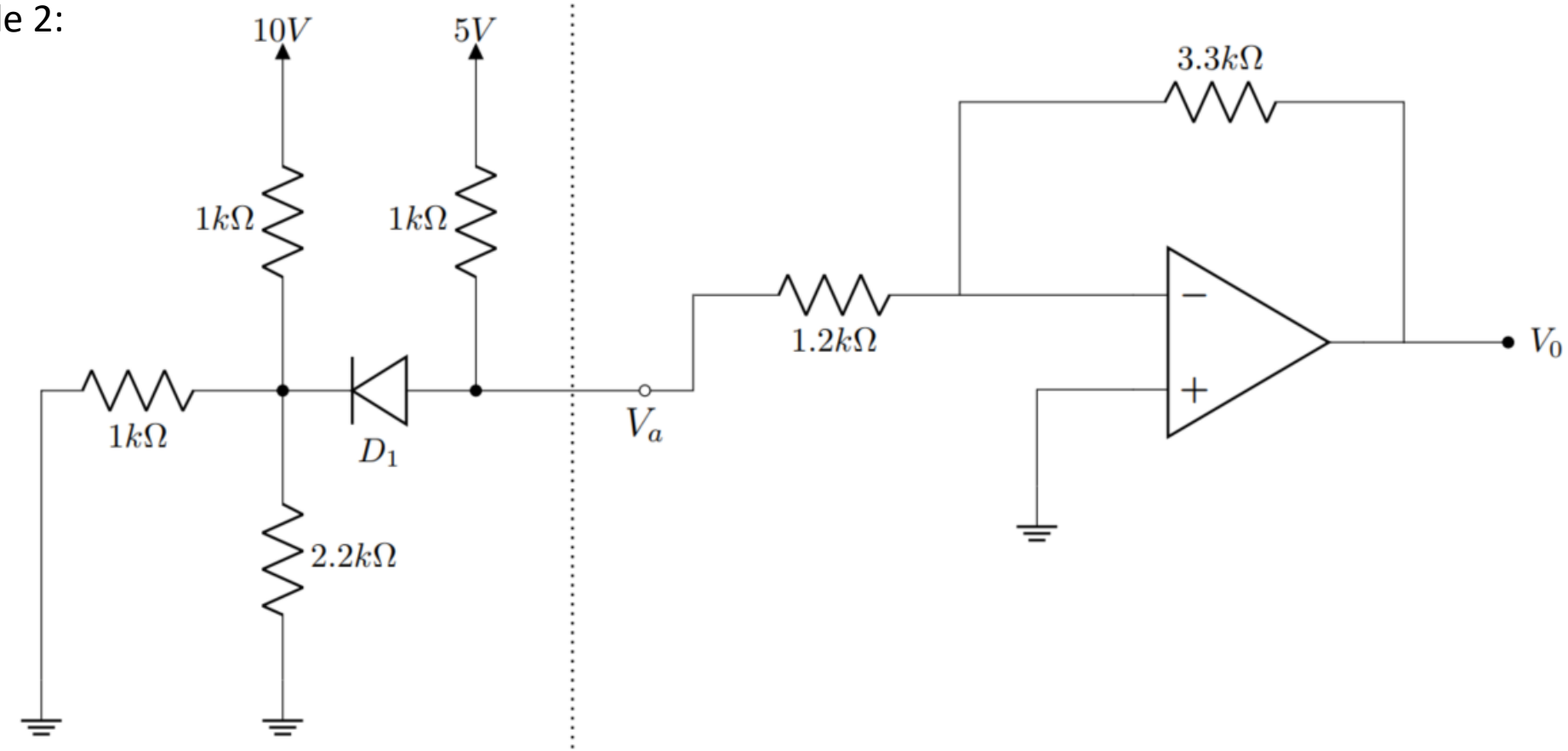
Hybrid Problems

Example 1:



Hybrid Problems

Example 2:



Thank You!