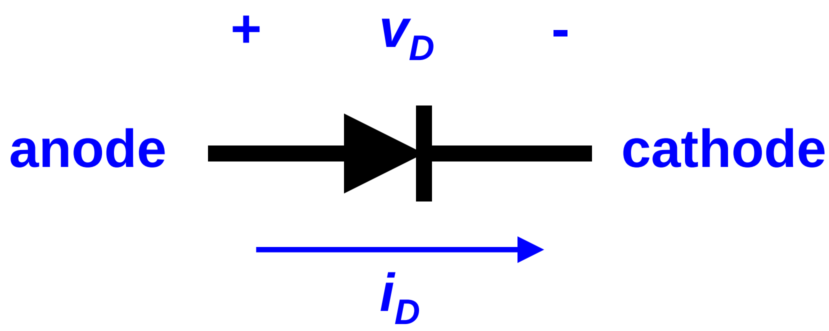
# The Ideal Diode

Diodes: A fundamental non-linear circuit element.

**A) The (Ideal) Diode Symbol**




**** The anode and cathode get their names from way back in the vacuum tube days.***

Notes:

1) The device is not symmetrical, we must specify (name) the connections: anode and cathode.
2) Positive voltage is defined from the anode to the cathode.
   - Forward Direction
3) Positive current is defined from the anode to the cathode.

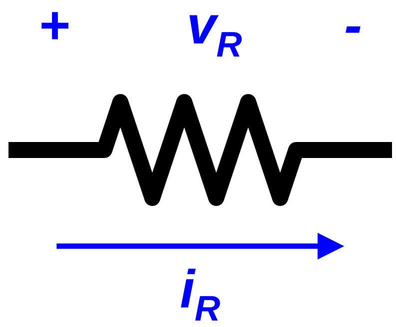
# The Ideal Diode

Why do we study the **"ideal"** diode rather than a real diode?

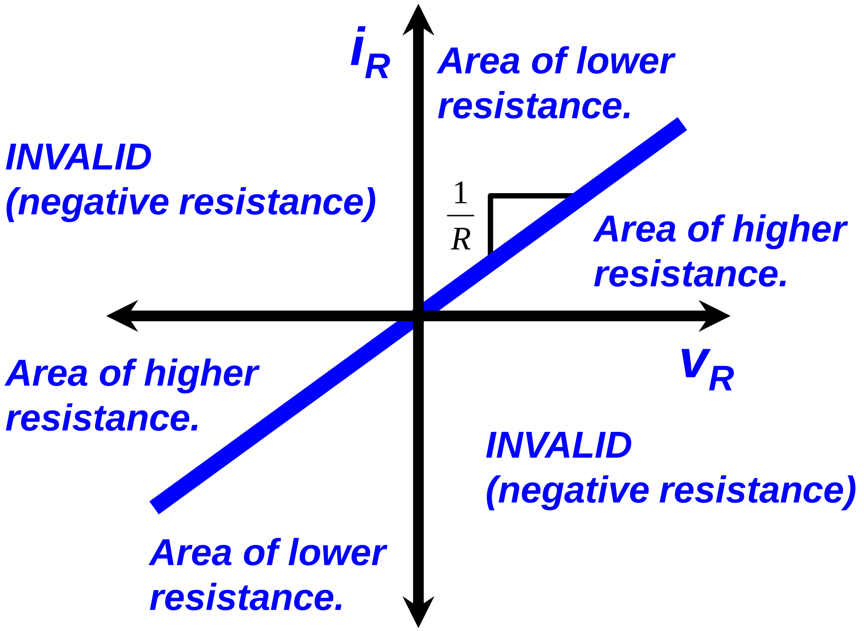
- An ideal diode is a close approximation to the real thing, and it is simplified (easy to understand).

**Resistor Extremes (a quick review)**

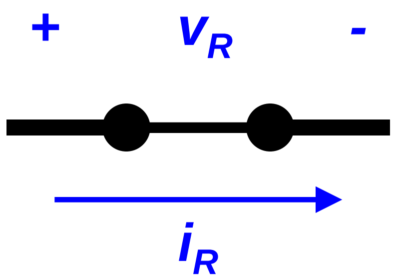
- We are going to start easy and work our way up; but first let's start really easy and review the resistor, specifically in the extreme cases when R=0 and R=∞.

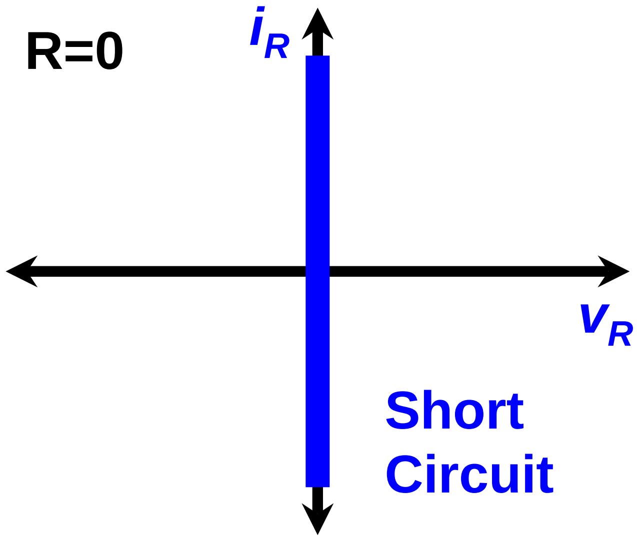



$i_R = v_R / R$

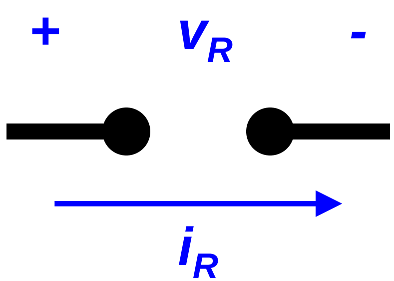


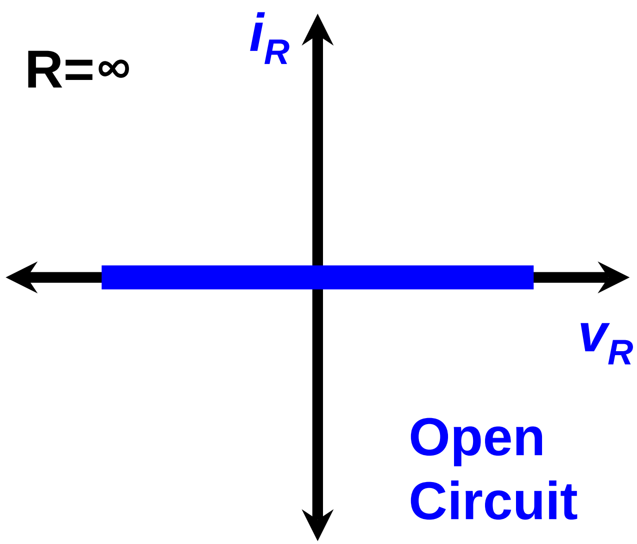
# The Ideal Diode




$i_R = v_R/0$ $\qquad$ $v_R = 0$




$i_R = v_R/\infty$ $\qquad$ $i_R = 0$

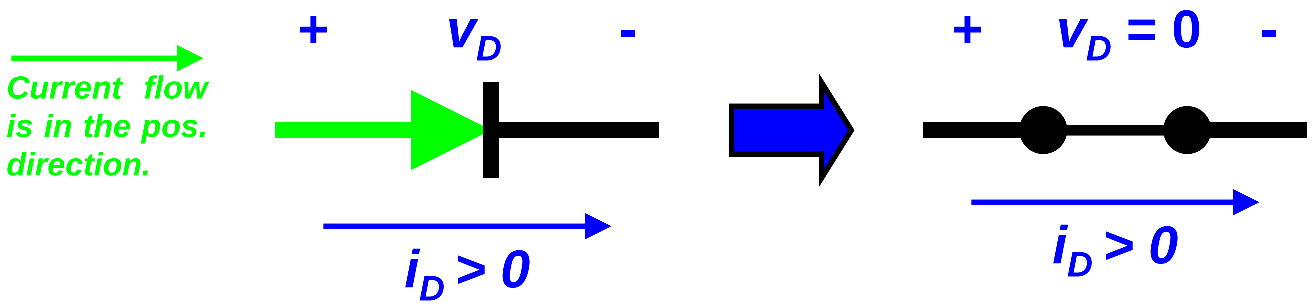
# The Ideal Diode

## C) The <u>Ideal</u> Diode Bias Regions

A resistor with R=0 is a short circuit (v=0) and a resistor with R=∞ is an open circuit (i=0), but what does this have to do with a diode?

- The ideal diode can act as a short or an open depending on what voltage or current are applied (bias).

- When current flow is in the **positve direction**, the ideal diode is a **short circuit or FORWARD BIASED**.

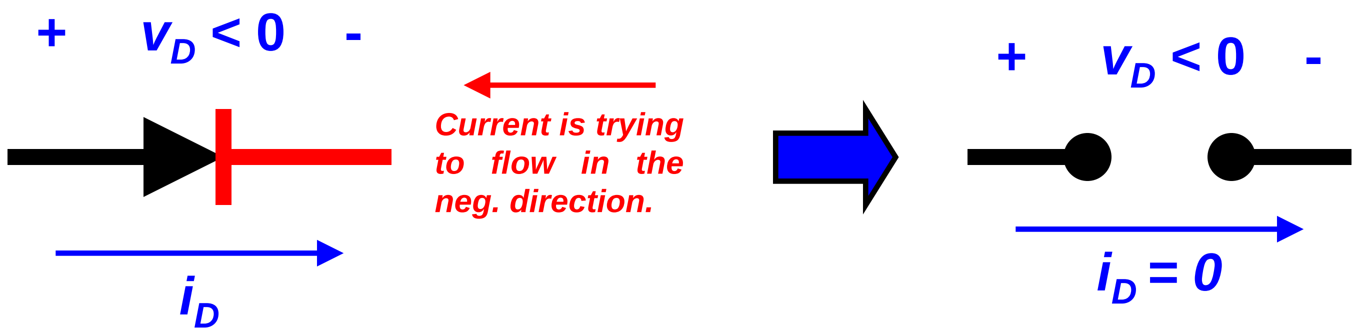



**Forward Biased: $i_D > 0$ & $v_D = 0$**
**SHORT CIRCUIT**

# The Ideal Diode

## C) The <u>Ideal</u> Diode Bias Regions (Continued)

- When current **tries** to flow in the **negative direction (negative voltage applied)**, the ideal diode is an **open circuit or REVERSE BIASED**.



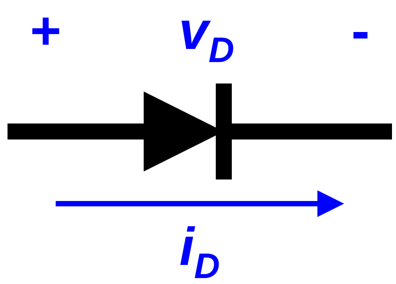

**Reverse Biased: $v_D < 0$ & $i_D = 0$**
**OPEN CIRCUIT**

- The ideal diode only lets current flow in one direction. When current is flowing in the positive direction there is no resistance **(arrow)**, and when current tries to flow in the negative direction there is infinite resistance **(wall)**.

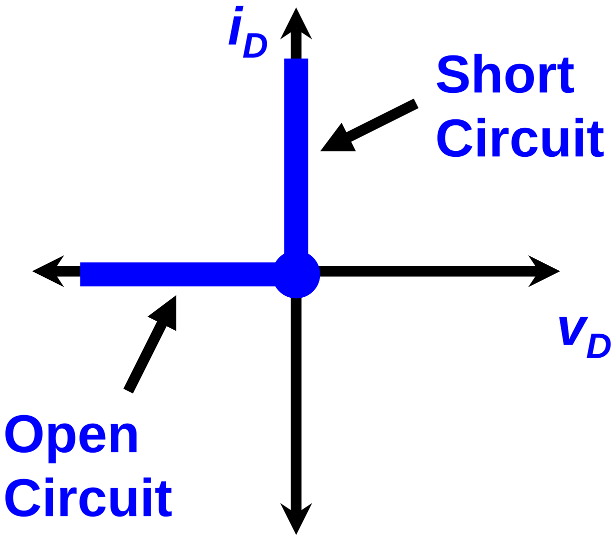
# The Ideal Diode

**D) The <u>Ideal</u> Diode *i-v* Relationship**

- Remember the ideal diode acts like a short when it is forward biased, $i_D>0$ ($v_D=0$), and like an open when it is reverse biased, $v_D<0$ ($i_D=0$).




$v_D=0$, $i_D>0$
$i_D=0$, $v_D<0$

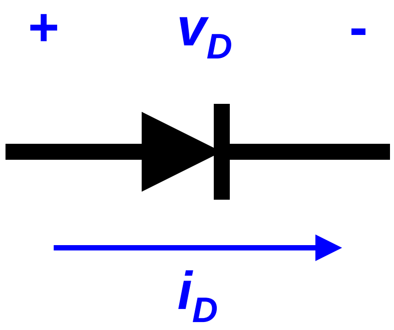


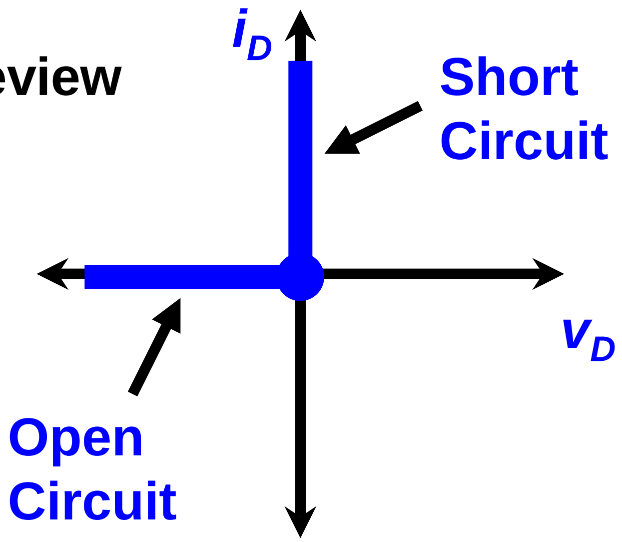

Is ideal diode is linear?

What is the power dissipated in the ideal diode?

# The Ideal Diode

## D) The Ideal Diode *i-v* Relationship Review



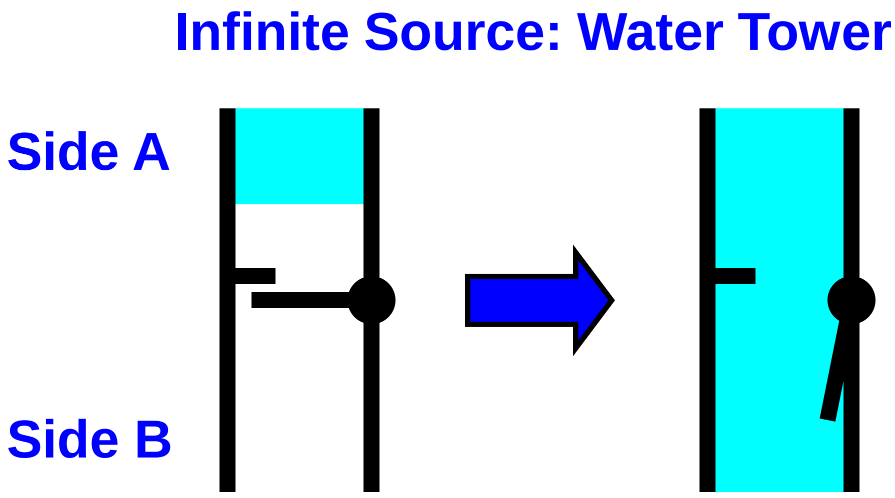

| | $v_D < 0$ | $v_D = 0$ | $v_D > 0$ |
|---|---|---|---|
| $i_D > 0$ | INVALID | **Forward Biased** **Short Circuit** | INVALID |
| $i_D = 0$ | **Reverse Biased** **Open Circuit** | **No Bias*** | INVALID |
| $i_D < 0$ | INVALID | INVALID | INVALID |

*can be included with either Forward Bias or Reverse Bias

# The Ideal Diode

**E) The <u>Ideal</u> Diode Mechanical Analog (Continued)**

- An analog for the diode is a mechanical valve to control liquid flow (another could be a ratchet).

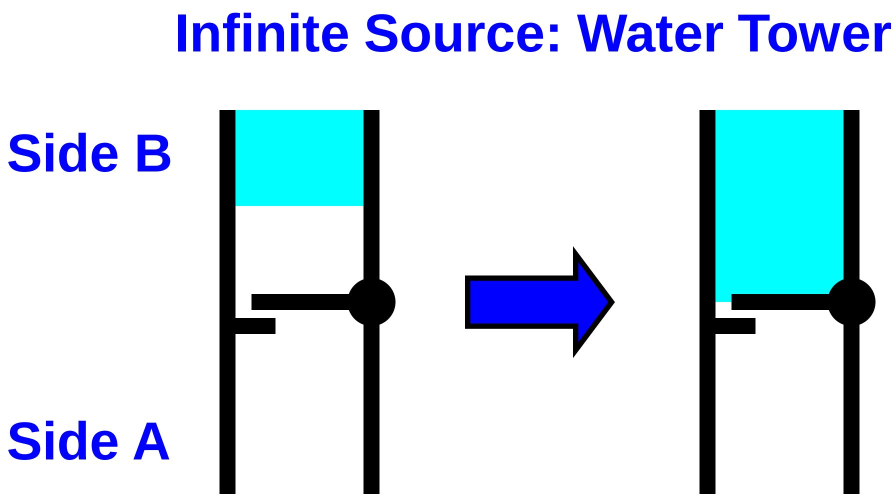



- When liquid flows in the positive direction throug the valve there is no pressure difference between the two sides.

- This is the short circuit analog.

# The Ideal Diode

**E) The <u>Ideal</u> Diode Mechanical Analog**

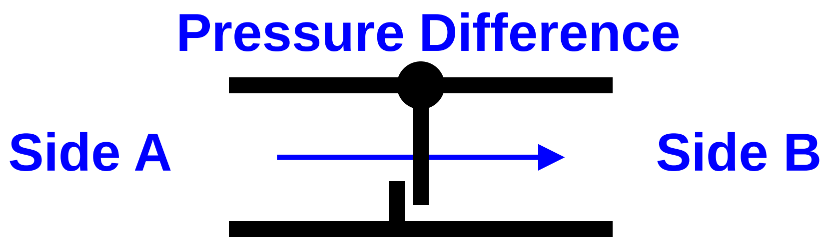


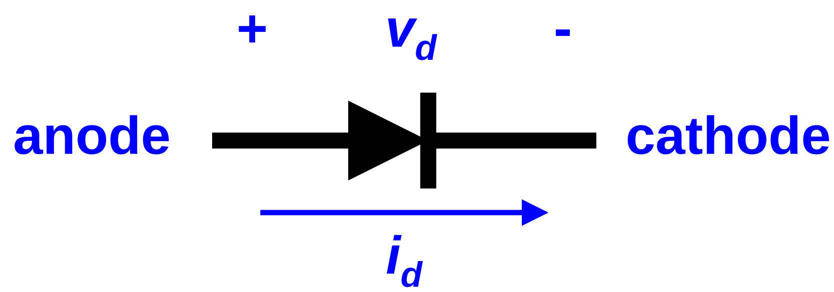

- When the valve is reversed and liquid tries to flow in the negative direction through the valve, there is no flow and a pressure difference exists between the two sides.

- This is the open circuit analog.

# The Ideal Diode

**E) The <u>Ideal</u> Diode Mechanical Analog (Continued)**




| | |
|---|---|
| **Side A** | **Anode** |
| **Side B** | **Cathode** |
| **Pressure Difference** | **Voltage** |
| **Liquid Flow** | **Current** |
| **Case 1** | **Forward Bias** |
| **Case 2** | **Reverse Bias** |

# The Ideal Diode

## F) Circuit Analysis with the Ideal Diode

- We have shown that the ideal diode can be replace by either a short circuit when it is forward biased or an open circuit when it is reverse biased.
- We also know that it is easy to analyze a circuit containing an open or a short circuit; so if we know how the diode is biased, we can replace it with an open or short and solve.

But what determines how the diode is biased?

- The circuit attached to it.

**The Chicken and the Egg Dilemma**

- We need to solve the circuit to figure out how the ideal diode is biased, but we need to know how it is biased before we can solve the circuit.
- There is a very elegant solution…First an Example.

# The Ideal Diode

**F) Circuit Analysis with the Ideal Diode**

**The Five Step Guide to Analyzing Ideal Diode Circuits**

1) Assume a bias state for each diode (In other words, just GUESS or educated GUESS).
   a) ASSUME the ideal diode is forward biased (short).
   b) ASSUME the ideal diode is reverse biased (open).

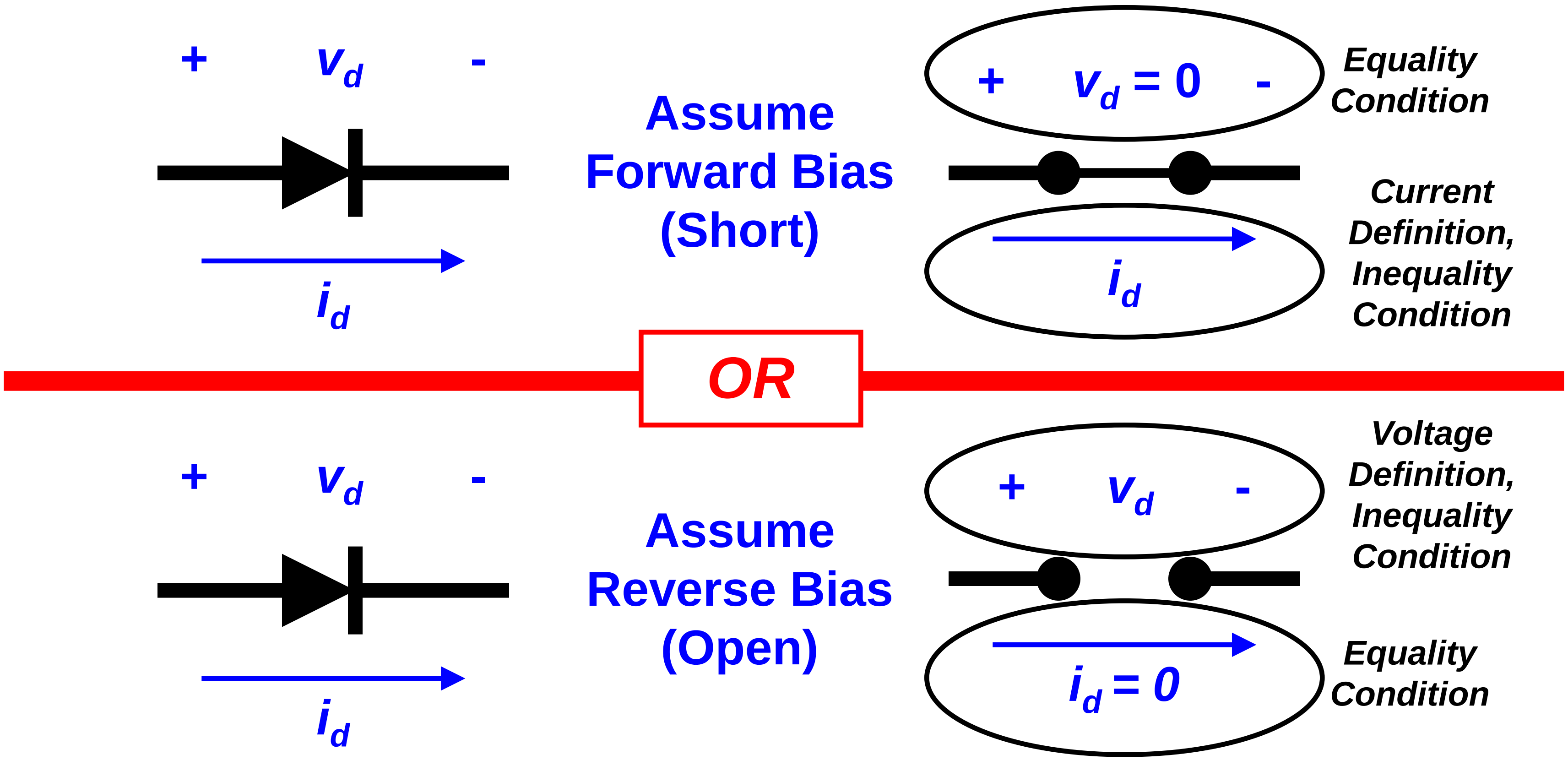
- Since each ideal diode has two possible states; there will be $n^2$ possible configurations, where n is the number of diodes.

2) Enforce the EQUALITY condition of your ASSUMPTION. (Replace the diode with the equivalent circuit)
   a) If you assumed forward bias then E.C. is $v_d$=0.
      Replace it with a short circuit.
   b) If you assumed reverse bias then E.C. is $i_d$=0.
      Replace it with an open circuit.

# The Ideal Diode

## F) Circuit Analysis with the Ideal Diode

- **IMPORTANT!! RETAIN THE SAME VOLTAGE AND CURRENT DEFINITIONS (DIRECTIONS) WHEN YOU REPLACE THE IDEAL DIODE.**



# The Ideal Diode

**F) Circuit Analysis with the Ideal Diode**

3) Analyze the circuit.

- Do this after you have replaced all the diodes with either short circuits or open circuits.

a) Determine all desired (required) circuit values.

b) Determine $i_d$ across the short circuit, and
Determine $v_d$ across the open circuit.
- You will need these to check your initial assumptions.

# The Ideal Diode

**F) Circuit Analysis with the Ideal Diode**

4) Check if the INEQUALITY Condition of your assumption is correct.

a) An ideal diode cannot have a negative current. If you assumed forward bias then the current must be non-negative (Inequality condition is $i_d \geq 0$).

b) An ideal diode cannot have a positive voltage. If you assumed reverse bias then the voltage must be non-positive (Inequality condition is $v_d \leq 0$).

- Bias, Short, Open, Equality Condition, Inequality Condition?

| Diode Bias | Equality Condition | Equivalent Circuit | Inequality Condition |
|---|---|---|---|
| Forward | $v_d = 0$ | (Short Circuit) | $i_d \geq 0$ |
| Reverse | $i_d = 0$ | (Open Circuit) | $v_d \leq 0$ |

***This chart or something similar is useful to keep track of assumption during analysis.***

# The Ideal Diode

**F) Circuit Analysis with the Ideal Diode**

5) If the inequality conditions do not match with the analysis results then change your assumption and go back to step 2.

- **Hints for ideal diode circuit analysis.**

  **1) you must check all inequality conditions.**

  $v_d = 2.2V \leq 0$ **NO … start again.**

  $i_d = 1.5A \geq 0$ **YES**

  **2) Do not check the equality conditions, check the inequality conditions.**

  **3) There is only one solution (set of assumptions) that will be correct.**

# The Ideal Diode

## F) Circuit Analysis with the Ideal Diode (Summary)

1. **Guess (Assume) a Bias for each diode. If possible make an educated guess based on your interpretation of the circuit.**
2. **Enforce the Bias for each Diode.**
   - **FB: Short Circuit, $v_D=0$**
   - **RB: Open Circuit, $i_D=0$**
3. **Solve the circuit.**
   - **The Solution of the Circuit.**
   - **The inequality variable of each diode assumption.**
     - **FB: Solve for $i_D$.**
     - **RB: Solve for $v_D$.**
4. **Compare the solutions of the inequality variables with the inequality conditions.**
   - **FB: iD>0**
   - **RB: vD<0**
5. **If correct, the problem is finished; if not, go back to step (1) and try another Guess.**

# The Ideal Diode

## G) Transfer Function with the Ideal Diode (Summary)

1. **Choose a Bias for each diode.**
2. **Enforce the Bias for each Diode.**
   - **FB: Short Circuit, $v_D$=0**
   - **RB: Open Circuit, $i_D$=0**
3. **Solve the circuit in terms of the independent variable.**
   - **The Solution of the Circuit.**
   - **The inequality variable of each diode assumption.**
     - **FB: Solve for $i_D$ in terms of the independent variable.**
     - **RB: Solve for $v_D$ in terms of the independent variable.**
4. **Compare the solutions of the inequality variables with the inequality conditions to determine the range of values that the solution is valid.**
   - **FB: iD>0**
   - **RB: vD<0**
5. **Repeat process for all possible bias combinations.**

# The Ideal Diode

- Application: Digital Logic