Steps for Finding a Junction Diode Circuit Transfer Function

Determining the **transfer function** of a junction diode circuit is in many ways **very similar** to the analysis steps we followed when analyzing previous junction diode circuits (i.e., circuits where all sources were **explicitly known**).

However, there are also some **important differences** that we must understand completely if we wish to successfully determine the **correct transfer function**!

Step1: *Replace all junction diodes with an appropriate junction diode* ***model****.*

> **Just** like before! We will now have an **IDEAL** diode circuit.

Step 2: *ASSUME some mode for all ideal diodes.*

> **Just** like before! An IDEAL diode can be either forward or reverse biased.

Step 3: *ENFORCE the bias assumption.*

Just like before! ENFORCE the bias assumption by replacing the ideal diode with short circuit or open circuit.

Step 4: *ANALYZE the remaining circuit.*

Sort of, **kind** of, like before!

1. If we assumed an IDEAL diode was forward biased, we must determine i_D^i--**just** like before! However, **instead** of finding the numeric value of i_D^i, we determine i_D^i as a **function** of the unknown source (e.g., $i_D^i = f(v_I)$).

2. Or, if we assumed an IDEAL diode was reversed biased, we must determine v_D^i--**just** like before! However, **instead** of finding the numeric value of v_D^i, we determine v_D^i as a **function** of the unknown source (e.g., $v_D^i = f(v_I)$).

3. Finally, we must determine all the **other** voltages and/or currents we are interested in (e.g., v_O)--**just** like before! However, **instead** of finding its numeric value, we determine it as a **function** of the unknown source (e.g., $v_O = f(v_I)$).

Step 5: *Determine WHEN the assumption is valid.*

Q: *OK, we get the picture. Now we have to **CHECK** to see if our IDEAL diode assumption was correct, right?*

A: Actually, **no**! This step is **very different** from what we did before!

We **cannot** determine **IF** $i_D^i > 0$ (forward bias assumption), or **IF** $v_D^i < 0$ (reverse bias assumption), since we **cannot** say for certain what the value of i_D^i or v_D^i is!

Recall that i_D^i and v_D^i are **functions** of the unknown voltage source (e.g.,$i_D^i = f(v_I)$ and $v_D^i = f(v_I)$). Thus, the values of i_D^i or v_D^i are **dependent** on the unknown source (v_I, say). For **some** values of v_I, we will find that $i_D^i > 0$ or $v_D^i < 0$, and so our assumption (and thus our solution for $v_O = f(v_I)$) will be! **correct**

However, for **other** values of v_I, we will find that $i_D^i < 0$ or $v_D^i > 0$, and so our assumption (and thus our solution for $v_O = f(v_I)$) will be **incorrect**!

Q: *Yikes! What do we do? How can we determine the circuit transfer function if we can't determine **IF** our ideal diode assumption is correct??*

A: Instead of determining **IF** our assumption is correct, we must determine **WHEN** our assumption is correct!

In other words, we must determine for **what values** of v_I is $i_D^i > 0$ (forward bias), or for **what values** of v_I is $v_D^i < 0$ (reverse bias).

We can do this since we earlier (in step 4) determined the function $i_D^i = f(v_I)$ or the function $v_D^i = f(v_I)$.

Perhaps this step is best explained by an **example**. Let's say we assumed that our ideal diode was **forward biased** and, say we determined (in step 4) that v_O is related to v_I as:

$$\begin{aligned} v_O &= f(v_I) \\ &= 2v_I - 3 \end{aligned}$$

Likewise, say that we determined (in step 4) that our ideal diode current is related to v_I as:

$$\begin{aligned} i_D^i &= f(v_I) \\ &> \frac{v_I - 5}{4} \end{aligned}$$

Thus, in order for our forward bias assumption to be **correct**, the function $i_D^i = f(v_I)$ must be **greater than zero**:

$$i_D^i > 0$$

$$f(v_I) > 0$$

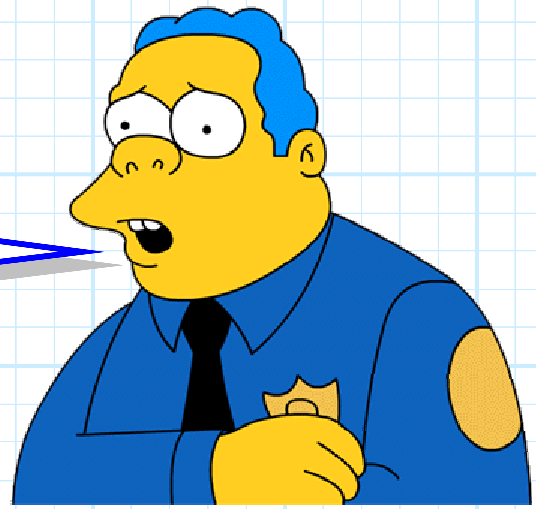
$$\frac{v_I - 5}{4} > 0$$

We can now "solve" this **inequality** for v_I:

$$\frac{v_I - 5}{4} > 0$$

$$v_I - 5 > 0$$

$$v_I > 5$$



Q: *What does **this** mean? Does it mean that v_I **is** some value **greater** than 5.0V ??*

A: **NO!** Recall that v_I can be **any** value. What the inequality above means is that $i_D^i > 0$ (i.e., the ideal diode is forward biased) **WHEN** $v_D^i > 5.0$.

Thus, we know $v_O = 2v_I - 3$ is valid **WHEN** the ideal diode is forward biased, and the ideal diode is forward biased **WHEN** (for this example) $v_D^i > 5.0$. As a result, we can mathematically state that:

$$v_O = 2v_I - 3 \quad \text{when} \quad v_I > 5.0\text{ V}$$

Conversely, this means that **if** $v_I < 5.0$ V, the **ideal** diode will be **reverse biased**—our forward bias assumption would **not** be valid, and thus our expression $v_O = 2v_I - 3$ is **not** correct ($v_O \neq 2v_I - 3$ for $v_I < 5.0\,\text{V}$)!

Q: *So how **do** we determine v_O for values of $v_I < 5.0$ V?*

A: Time to move to the **last** step !

Step 6: ***Change** assumption and **repeat** steps 2 through 5 !*

For our **example**, we would change our bias assumption and now ASSUME reverse bias. We then ENFORCE $i_D' = 0$, and then ANALYZE the circuit to find both $v_D' = f(v_I)$ and a **new** expression $v_O = f(v_I)$ (it will **no longer** be $v_O = 2v_I - 3$!).

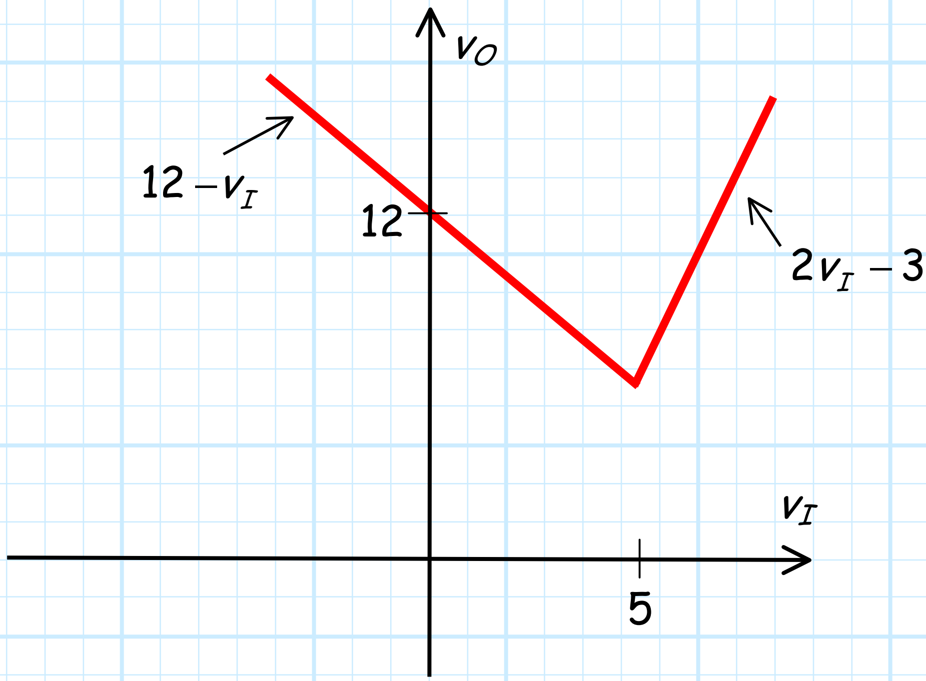
We then determine **WHEN** our reverse bias assumption is valid, by solving the **inequality** $v_D' = f(v_I) > 0$ for v_I. For the example used here, we would find that the **IDEAL** diode is reverse biased **WHEN** $v_I < 5.0$ V.

For junction diode circuits with **multiple** diodes, we may have to repeat this entire process **multiple** times, until **all possible** bias conditions are analyzed.

If we have done our analysis **properly**, the result will be a valid **continuous function**! That is, we will have an expression (but only **one** expression) relating v_O to **all** possible values of v_I.

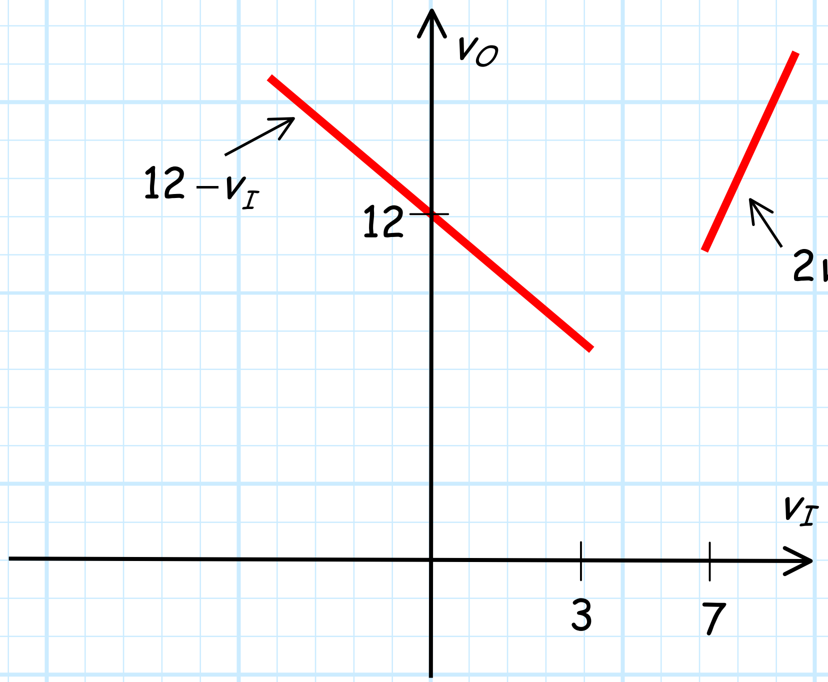
This transfer function will typically be **piecewise linear**. An **example** of a piece-wise linear transfer function is:

$$v_O = \begin{cases} 2v_I - 3 & for \quad v_I > 5.0 \\ \\ 12 - v_I & for \quad v_I < 5.0 \end{cases}$$



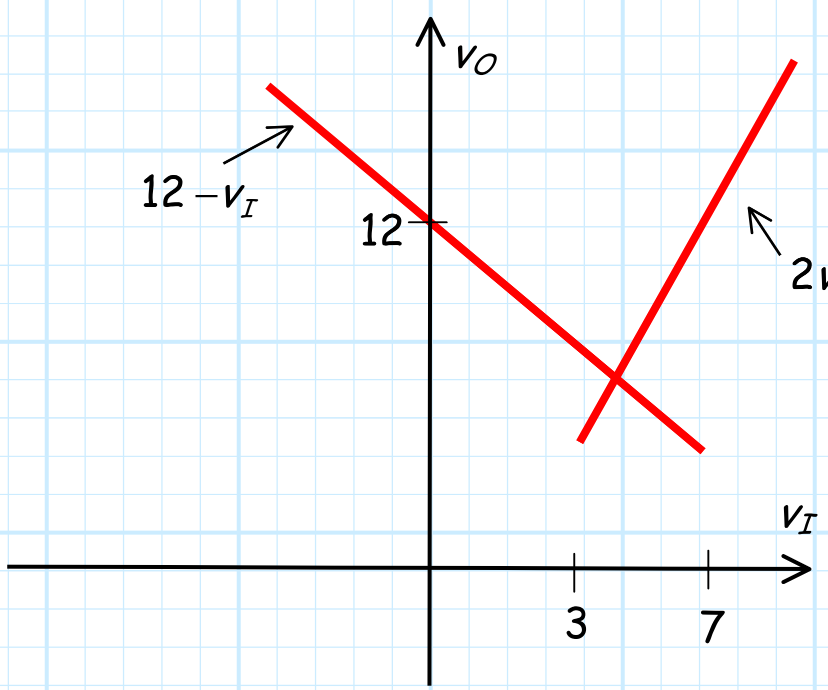
Just to make **sure** that we understand what a function is, note that the following expression is **not** a function:

$$v_O = \begin{cases} 2v_I - 3 & for \quad v_I > 7.0 \\ \\ 12 - v_I & for \quad v_I < 3.0 \end{cases}$$



Nor is this expression a function:

$$v_O = \begin{cases} 2v_I - 3 & \text{for} \quad v_I > 3.0 \\ 12 - v_I & \text{for} \quad v_I < 7.0 \end{cases}$$



Finally, note that the following expression **is** a function, but it is **not continuous**:

$$v_O = \begin{cases} 2v_I - 3 & \text{for} \quad v_I > 5.0 \\ 5 - v_I & \text{for} \quad v_I < 5.0 \end{cases}$$