Example: A Diode Limiter

Consider the following junction diode circuit:

This circuit is a junction diode limiter!

Perhaps that would be clearer if we redrew this circuit as:

This is the same circuit as above!
Now, let’s determine the **transfer function** of this limiter. To do this, we must follow the **4 steps** detailed in the previous handout!

**Step 1:** Assume junction diode is **forward biased**

Replace the junction diode with a **CVD model**. **ASSUME** the **ideal** diode is forward biased, **ENFORCE** \( V_D' = 0 \).

![Diode Limiter Diagram](image)

We find that the **output voltage** is simply:

\[
V_O = 5.0 + 0.7 = 5.7 \text{ V}
\]

while the **ideal** diode current is more difficult to determine.

From KCL:

\[
i_D' = i_1 + i_2
\]

where from Ohm’s Law:
\[ i_1 = \frac{V_I - 5.7}{1} = V_I - 5.7 \]

and:
\[ i_2 = \frac{0 - 5.7}{1} = -5.7 \]

Thus, the ideal diode current is:
\[ i_D^i = i_1 + i_2 = V_I - 5.7 - 5.7 = V_I - 11.4 \]

Now, for our assumption to be correct, this current must be positive (i.e., \( i_D^i > 0 \)). Thus, we solve this inequality to determine when our assumption is true:
\[ V_I - 11.4 > 0 \]
\[ V_I > 11.4 \text{ V} \]

So, from this step we find:
\[ V_o = 5.7 \text{ V when } V_I > 11.4 \text{ V} \]

**Step2:** Assume the junction diode is in breakdown

Replace the junction diode with a Zener CVD model. ASSUME the ideal diode is forward biased, ENFORCE \( V_D^i = 0 \).
We find that the output voltage is simply:

\[ v_o = 5 - 10 = -5.0 \text{ V} \]

while the ideal diode current is more difficult to determine.

From KCL:

\[ i_d = i_1 + i_2 \]

where from Ohm’s Law:

\[ i_1 = \frac{-5 - v_I}{1} = -v_I - 5.0 \]

and:

\[ i_2 = \frac{0 - 5.0}{1} = -5.0 \text{ V} \]

Thus, the ideal diode current is:
\[ i_D^i = i_1 + i_2 \]
\[ = -V_I - 5.0 - 5.0 \]
\[ = -V_I - 10.0 \]

Now, for our assumption to be correct, this current must be positive (i.e., \( i_D^i > 0 \)). Thus, we solve this inequality to determine when our assumption is true:

\[ -V_I - 10.0 > 0 \]
\[ -V_I > 10.0 \text{ V} \]
\[ V_I < -10.0 \text{ V} \]

So, from this step we find:

\[ V_O = -5.0 \text{ V when } V_I < -10.0 \text{ V} \]

**Step 3:** Assume the junction diode is reverse biased

Replace the junction diode with the Ideal Diode model. ASSUME the ideal diode is reverse biased, ENFORCE \( i_D^i = 0 \).

A voltage divider!
Thus the output voltage is:

\[ V_o = \frac{V_i (1)}{1+1} = \frac{V_i}{2} \]

This output voltage is true when the junction diode is neither forward biased nor in breakdown. Thus, using the results from the first two steps, we can infer that it is true when:

\[-10.0 < V_i < 11.4\]

**Step 4:** Determine the continuous transfer function

Combining the results of the previous 3 steps, we get the following piece-wise linear transfer function:

\[ V_o = \begin{cases} 
5.7 \text{ V} & \text{if } V_i > 11.4 \text{ V} \\
\frac{V_i}{2} & \text{if } -10.0 < V_i < 11.4 \text{ V} \\
-5.0 \text{ V} & \text{if } V_i < -10.0 \text{ V} 
\end{cases} \]
Note that at $v_I = -10$:

$$
\nu_o = \frac{v_I}{2} = \frac{-10}{2} = -5.0 \text{ V}
$$

and at $v_I = 11.4$:

$$
\nu_o = \frac{v_I}{2} = \frac{11.4}{2} = 5.7 \text{ V}
$$

Thus, this function is continuous!