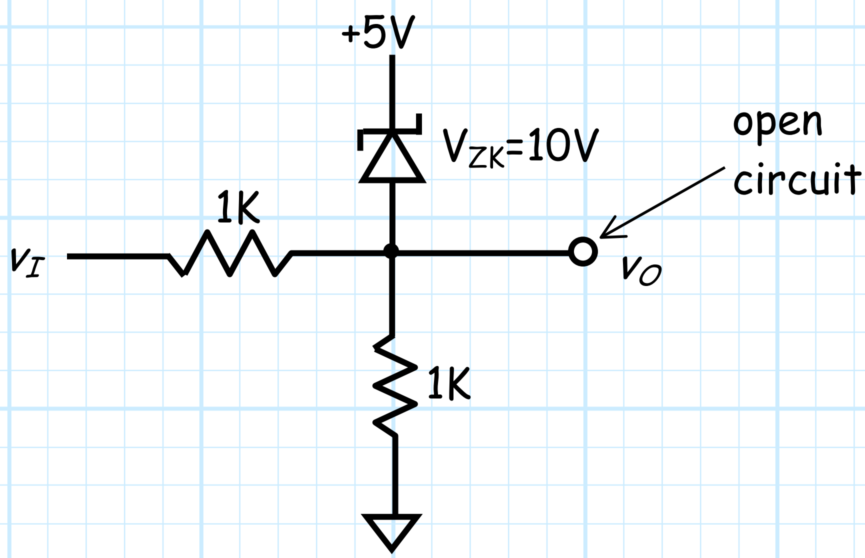
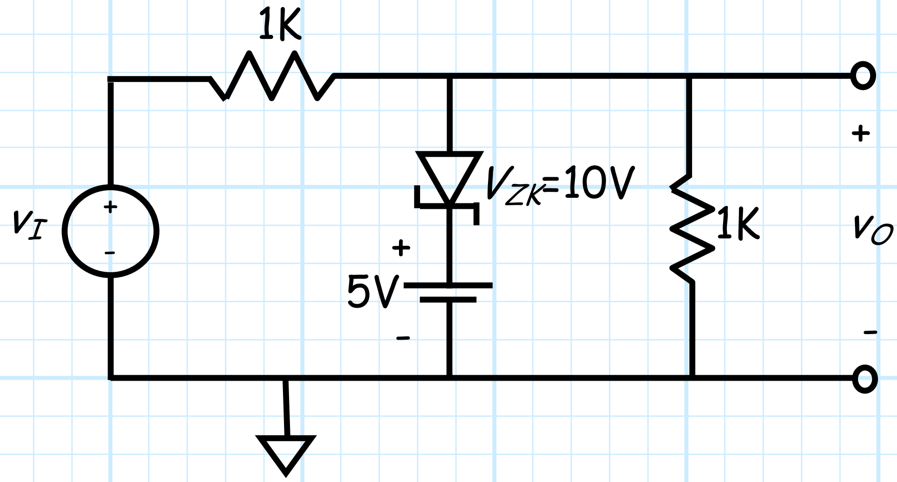
Example: A Diode Limiter

Consider the following **junction** diode circuit:



This circuit is a junction **diode limiter**!

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

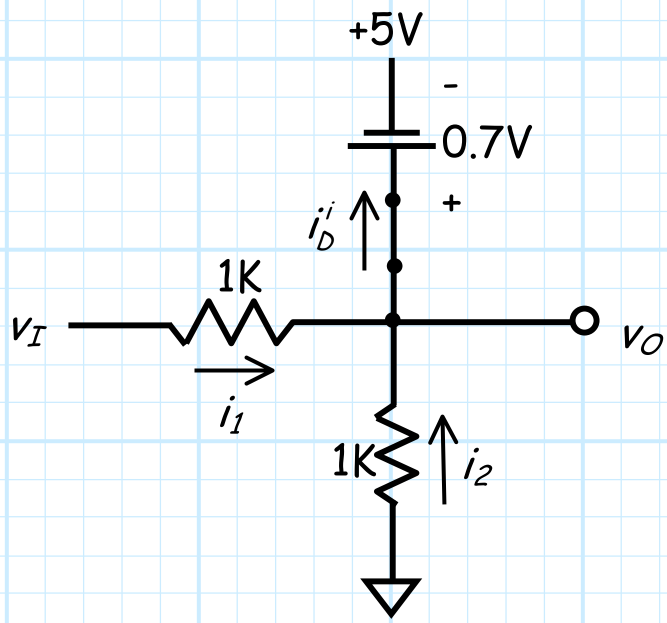


This is the **same** circuit as above!

Now, let's determine the **transfer function** of this limiter. To do this, we must follow the **4 steps** detailed in the previous handout!

Step1: Assume junction diode is **forward biased**

Replace the junction diode with a **CVD model**. ASSUME the **ideal** diode is forward biased, ENFORCE $v_D^i = 0$.



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

$$v_O = 5.0 + 0.7 = 5.7 \text{ V}$$

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

From KCL:

$$i_D^i = i_1 + i_2$$

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:

$$\begin{aligned} i_D^i &= i_1 + i_2 \\ &= v_I - 5.7 - 5.7 \\ &= v_I - 11.4 \end{aligned}$$

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:

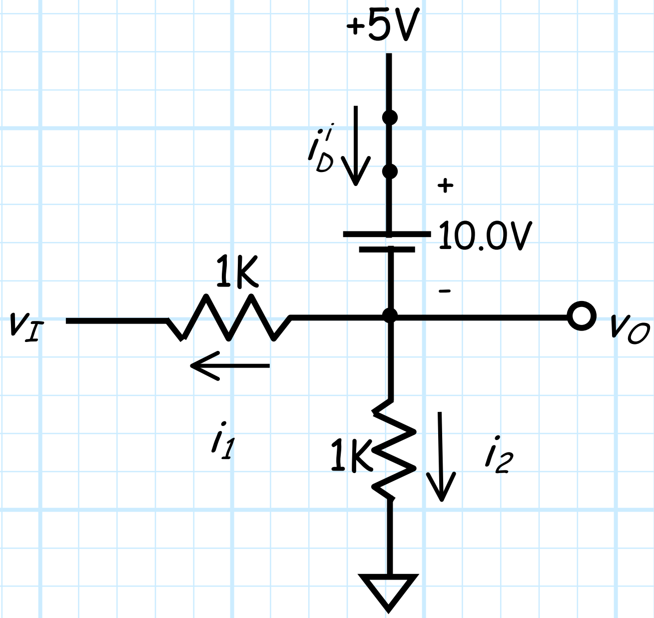
$$\begin{aligned} v_I - 11.4 &> 0 \\ v_I &> 11.4 \text{ V} \end{aligned}$$

So, from this step we find:

$$v_O = 5.7 \text{ V} \quad \textit{when} \quad v_I > 11.4 \text{ V}$$

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:

$$v_O = 5 - 10 = -5.0\,V$$

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

From KCL:

$$i_D^i = i_1 + i_2$$

where from Ohm's Law:

$$i_1 = \frac{-5 - V_I}{1} = -v_I - 5.0$$

and:

$$i_2 = \frac{0 - 5.0}{1} = -5.0\,V$$

Thus, the **ideal** diode current is:

$$
\begin{aligned}
i_D^i &= i_1 + i_2 \\
&= -v_I - 5.0 - 5.0 \\
&= -v_I - 10.0
\end{aligned}
$$

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:

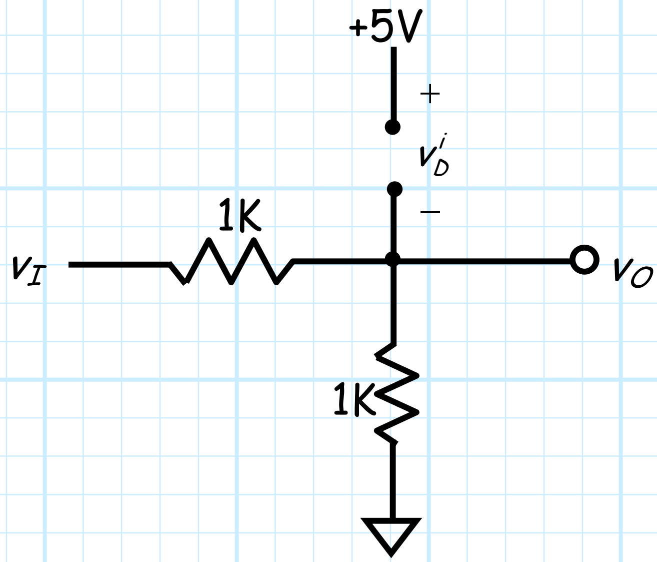
$$
\begin{aligned}
-v_I - 10.0 &> 0 \\
-v_I &> 10.0 \text{ V} \\
v_I &< -10.0 \text{ V}
\end{aligned}
$$

So, from this step we find:

$$v_O = -5.0 \text{ V} \quad \textit{when} \quad v_I < -10.0 \text{ V}$$

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:

$$v_O = \frac{v_I(1)}{1+1} = \frac{v_I}{2}$$

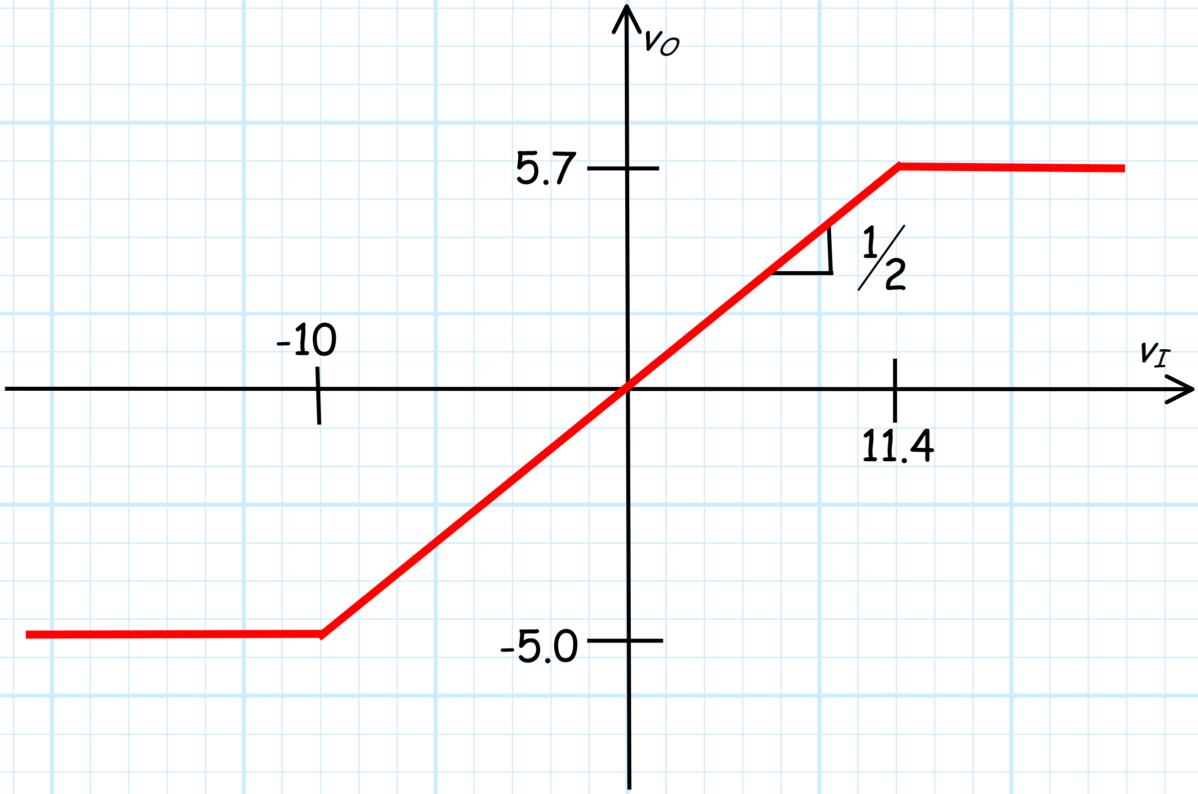
This output voltage is true **when** the junction diode is neither forward biased nor in breakdown. Thus, using the results from the first two steps, we can **infer** that it is true when:

$$-10.0 < v_I < 11.4$$

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

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

$$v_O = \begin{cases} 5.7 \text{ V} & if \quad v_I > 11.4 \text{ V} \\ v_I/2 & if \quad -10.0 < v_I < 11.4 \text{ V} \\ -5.0V & if \quad v_I < -10.0 \text{ V} \end{cases}$$



Note that at $v_I = -10$:

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

and at $v_I = 11.4$:

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

Thus, this function **is** continuous!