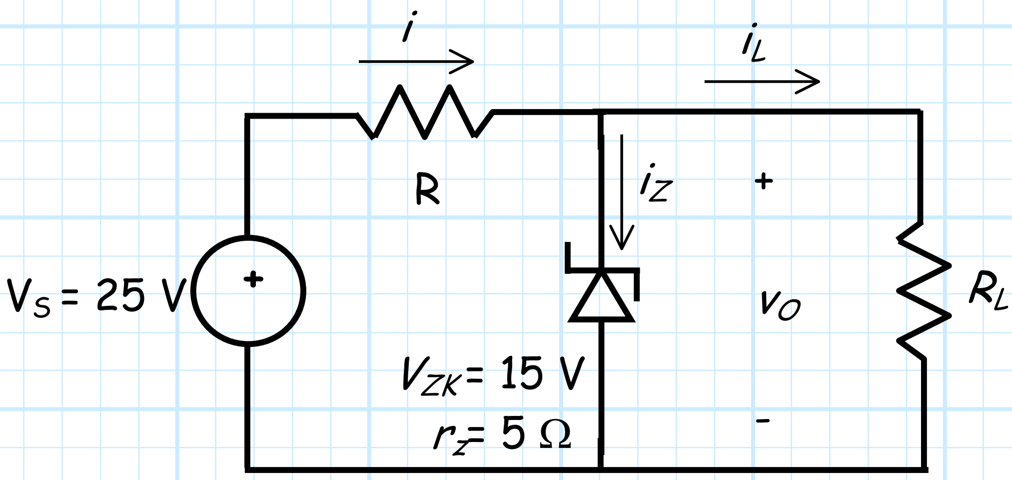
Example: The Shunt Regulator

Consider the **shunt regulator**, built using a zener diode with V_{ZK}=15.0 V and incremental resistance $r_z = 5\Omega$:



1. **Determine R** if the largest possible value of i_L is 20 mA.

2. Using the value of R found in part 1 **determine** i_Z **if** R_L=1.5 K.

3. Determine the **change in** v_O if V_S increases one volt.

4. Determine the **change in** v_O if i_L increases 1 mA.

Part 1:

From KCL we know that $i = i_Z + i_L$.

We also know that for the diode to remain in breakdown, the zener current must be **positive**.

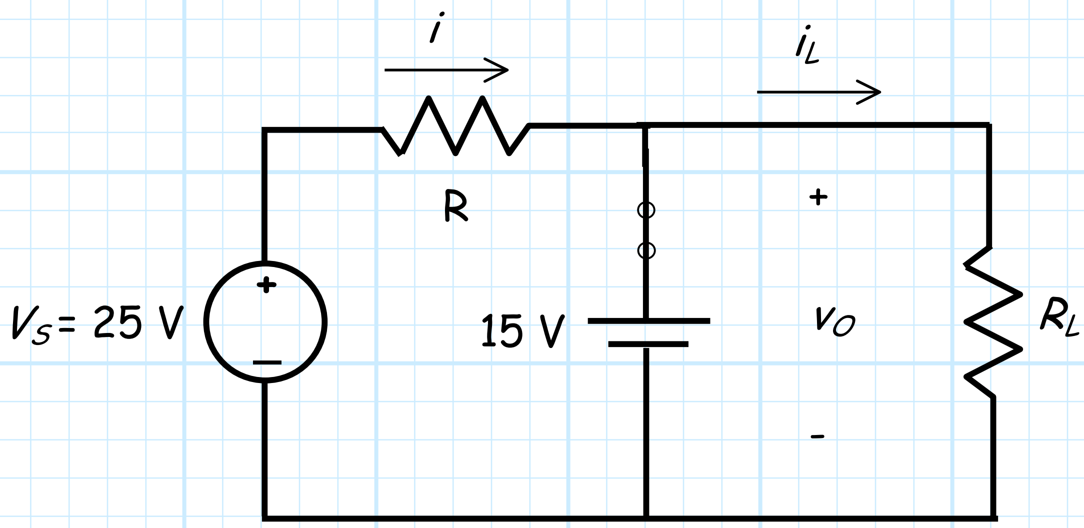
i.e., $i_Z = i - i_L > 0$

Therefore, if i_L can be as large as 20 mA, then i must be greater than 20 mA for i_Z to remain greater than zero.

i.e. $\boldsymbol{i > 20mA}$

Q: *But, what **is** i ??*

A: Use the zener CVD model to analyze the circuit.



Therefore from Ohm's Law:

$$i =$$

and thus $i > 20mA$ **if**:

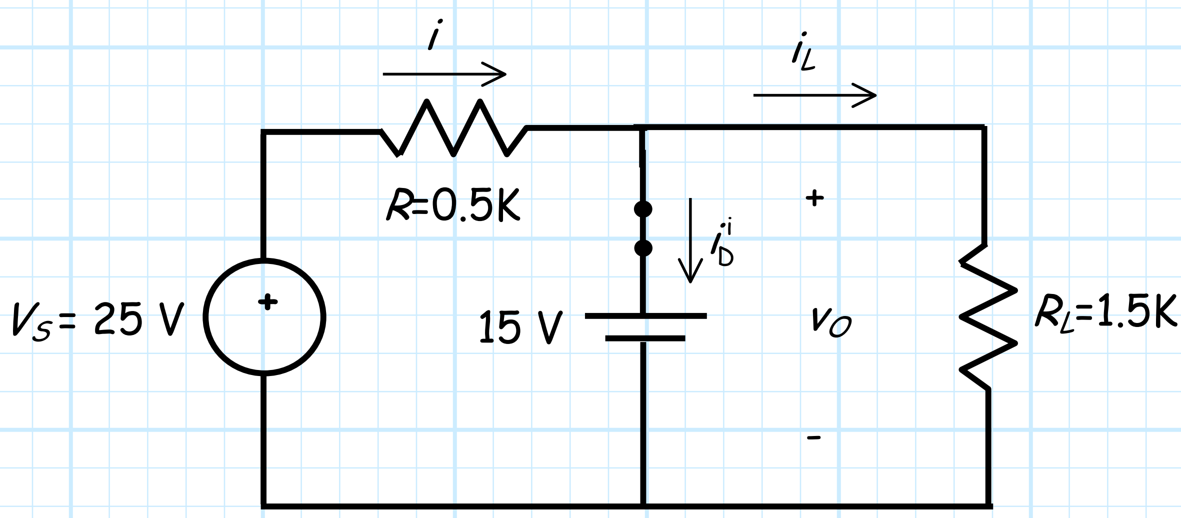
$$R <$$

Note we want R to be as large as possible, as large R improves both **line** and **load** regulation.

Therefore, set $R = 500\ \Omega = 0.5$ K

Part 2:

Again, use the zener **CVD model,** and enforce $v_D^i = 0$:



Analyzing, from KCL:

$$i_D^i =$$

and from Ohm's Law:

$$i =$$

$$i_L =$$

Therefore $i_D^i = i - i_L = 20 - 10 = 10.0 \; mA \;\; (\therefore i_D^i = 10 > 0$ ✔ $)$

And thus we **estimate** $i_Z = i_D^i = 10.0$ mA

Part 3:

The shunt regulator **line regulation** is:

$$\text{Line Regulation} \;=\; \frac{r_z}{R + r_z} =$$

Therefore if $\Delta v_s = 1$ V, then $\Delta v_o = (0.01)\,\Delta v_s =$ **0.01 V**

Part 4:

The shunt regulator **load regulation** is:

$$\text{Load Regulation} = \frac{-R\; r_z}{R + r_z} =$$

Therefore if $\Delta i_L = 1$ mA, then $\Delta v_o = -(4.95)\,\Delta i_L =$ **-4.95 mV**