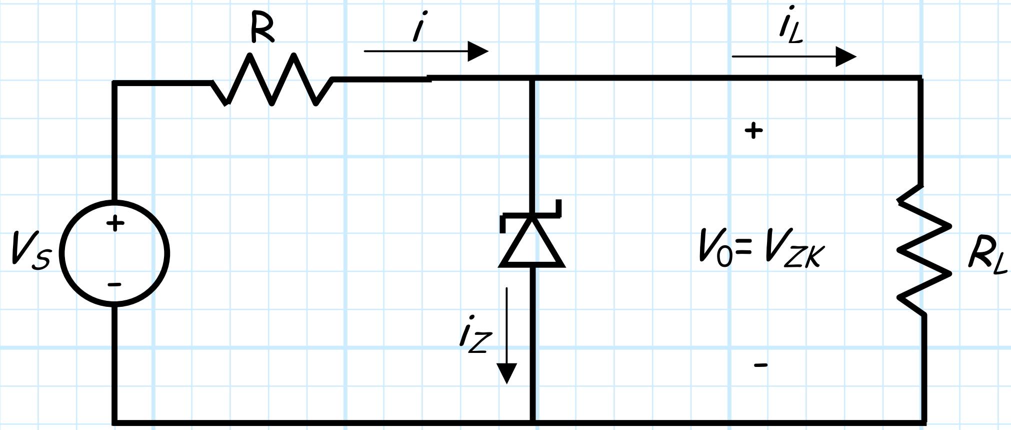
The Shunt Regulator



The shunt regulator is a ***voltage regulator***. That is, a device that keeps the voltage across some load resistor (R_L) ***constant***.

Q: *Why would this voltage **not** be a constant?*

A: Two reasons:

(1) the **source voltage** V_s may vary and **change** with time.

(2) The **load** R_L may also vary and **change** with time. In other words, the **current** i_L delivered to the load may change.

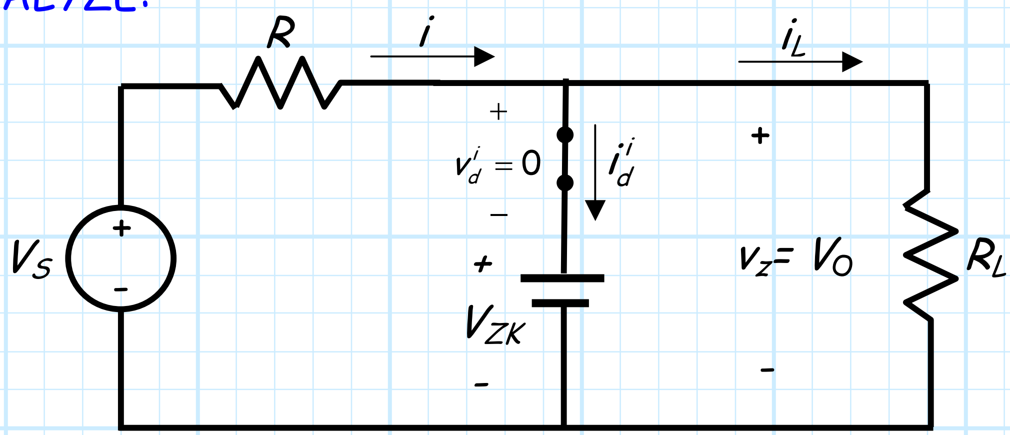
What can we do to keep load voltage V_O **constant**?

$\Rightarrow$ Employ a **Zener diode** in a **shunt regulator** circuit!

Let's **analyze** the shunt regulator circuit in terms of Zener breakdown voltage V_{ZK}, source voltage V_S , and load resistor R_L.

Replacing the Zener diode with a **Zener CVD model**, we ASSUME the ideal diode is **forward** biased, and thus ENFORCE $v_D^i = 0$.

ANALYZE:



From KVL:

$$v_Z = V_O = v_D^i + V_{ZK} = V_{ZK}$$

From KCL:

$$i = i_D^i + i_L$$

where from Ohm's Law:

$$i = \frac{V_S - V_{ZK}}{R}$$

and also :

$$i_L = \frac{V_{ZK}}{R_L}$$

Therefore:

$$\begin{aligned} i_D^i &= i - i_L \\ &= \frac{V_S - V_{ZK}}{R} - \frac{V_{ZK}}{R_L} \\ &= \frac{V_S}{R} - \frac{V_{ZK}\left(R + R_L\right)}{RR_L} \end{aligned}$$

CHECK:

Note we find that ideal diode is forward biased **if**:

$$i_D^i = \frac{V_S}{R} - \frac{V_{ZK}\left(R + R_L\right)}{RR_L} > 0$$

or therefore:

$$\frac{V_S}{R} - \frac{V_{ZK}\left(R + R_L\right)}{RR_L} > 0$$

$$\frac{V_S}{R} > \frac{V_{ZK}\left(R + R_L\right)}{RR_L}$$

$$V_S \frac{R_L}{R + R_L} > V_{ZK}$$

Hence, the Zener diode may **not** be in breakdown (i.e., the ideal diode may not be f.b.) **if** V_S or R_L are too small, or shunt resistor R is too large!

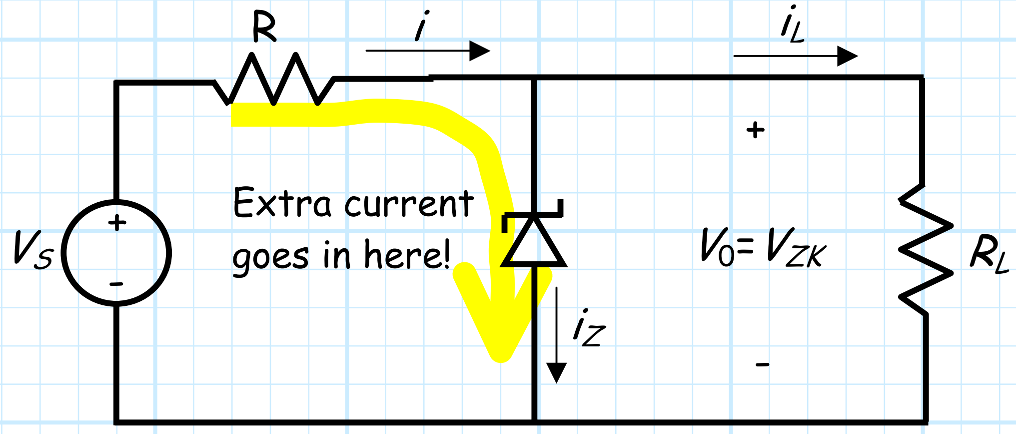
Summarizing, we find that **if**:

$$V_S \frac{R_L}{R + R_L} > V_{ZK}$$

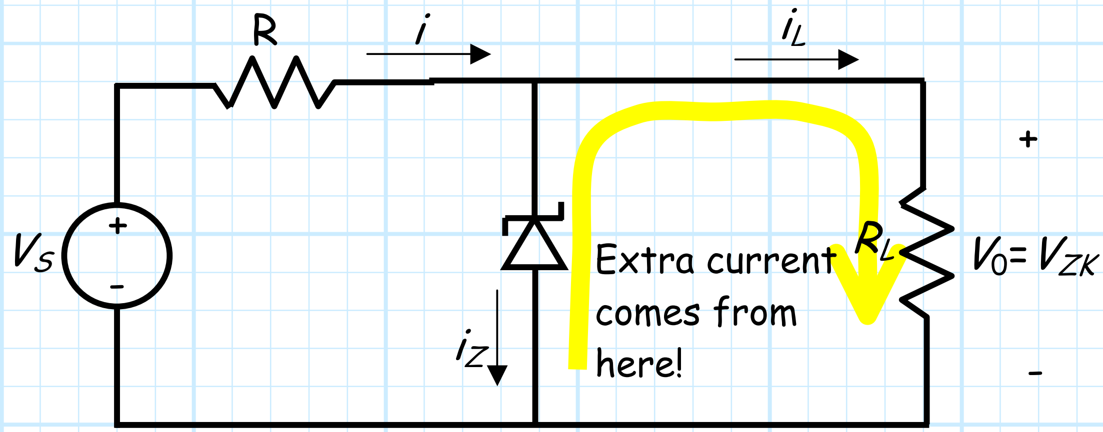
then:

1. The Zener diode is in breakdown.
2. The load voltage $V_O = V_{ZK}$.
3. The load current is $i_L = V_{ZK}/R_L$.
4. The current through the shunt resistor R is $i = (V_S - V_{ZK})/R$.
5. The current through the Zener diode is $i_Z = i - i_L > 0$.

We find then, that if the **source voltage** V_S **increases**, the current i through shunt resistor R will likewise increase. However, this extra current will result in an **equal** increase in the **Zener diode current** i_Z—thus the load current (and therefore load voltage V_O) will remain **unchanged**!



Similarly, if the **load current** i_L **increases** (i.e., R_L decreases), then the Zener current i_Z will decrease by an **equal** amount. As a result, the current through shunt resistor R (and therefore the load voltage V_O) will remain **unchanged**!



Q: *You mean that V_O stays **perfectly constant**, regardless of source voltage V_S or load current i_L??*

A: Well, V_O remains **approximately** constant, but it **will** change a **tiny** amount when V_S or i_L changes.

To determine precisely how **much** the load voltage V_O changes, we will need to use a more **precise** Zener diode model (i.e., the Zener **PWL**)!