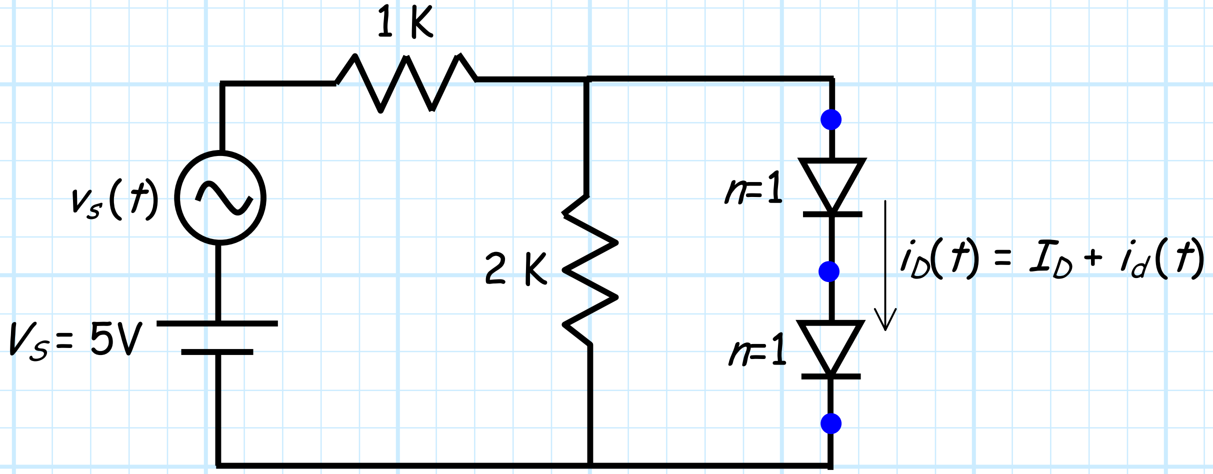
Example: Diode Small-Signal Analysis

Consider the circuit:

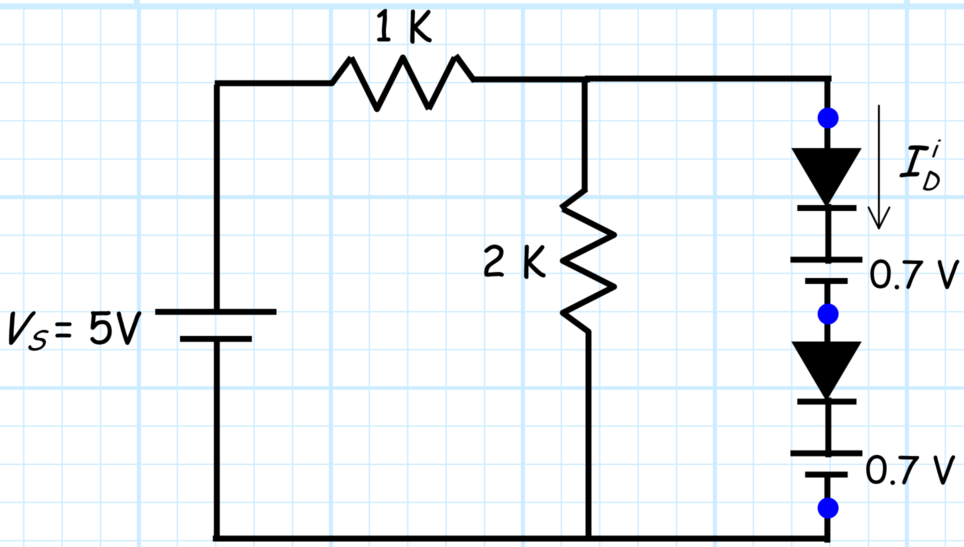


Q: *If $v_s(t) = 0.01 \sin\omega t$, what is $i_d(t)$?*

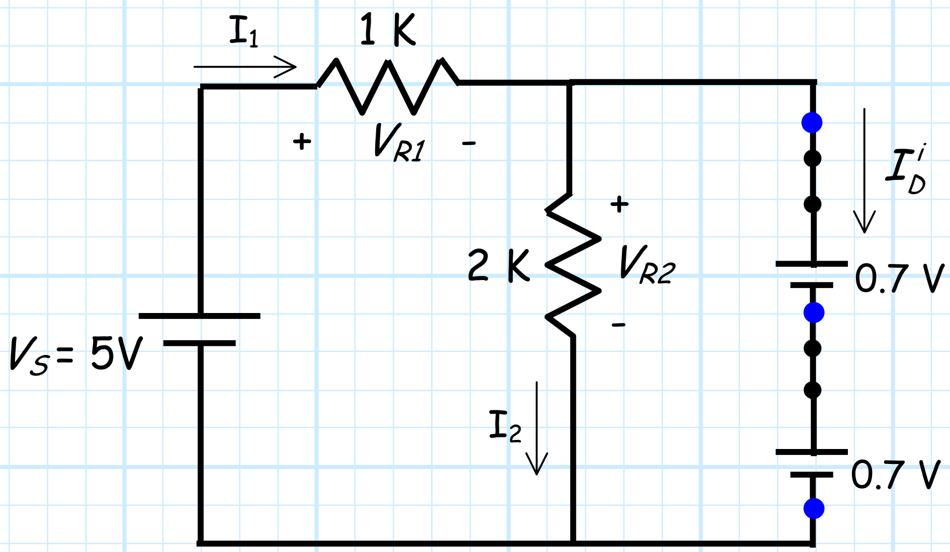
A: Follow the small-signal analysis steps!

Step 1: Complete a **D.C. Analysis**

Turn **off** the small-signal source and replace the junction diodes with the CVD model.



Assume the ideal diodes are "on", **enforce** with short circuits.



Now analyze the D.C. circuit:

From KVL $\quad V_{R2} = 0.7 + 0.7 = 1.4 \text{ V}$

$$\therefore \quad I_2 = \frac{V_{R2}}{2} = 0.7 mA$$

From KVL: $\quad V_{R1} = 5.0 - V_{R2} = 5.0 - 1.4 = 3.6 \text{ V}$

Thus from Ohm's Law: $I_1 = \frac{V_{R1}}{1} = 3.6\ mA$

And finally from KCL:

$$\begin{aligned} I_D^i &= I_1 - I_2 \\ &= 3.6 - 0.7 \\ &= 2.9\ mA \end{aligned}$$

Now **checking** our result:

$$I_D^i = 2.9\ mA > 0 \ \checkmark$$

Therefore our estimate of the D.C. diode current is:

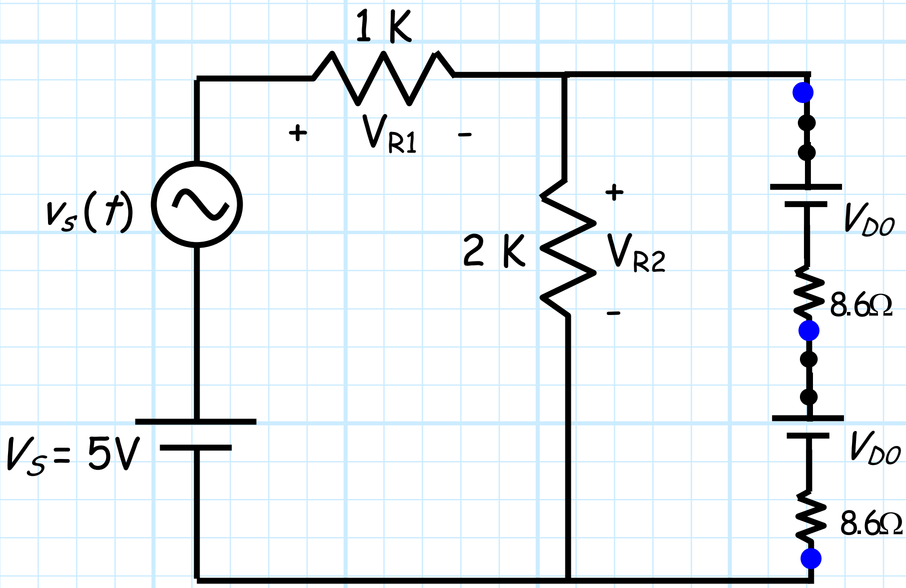
$$I_D = I_D^i = 2.9\ mA$$

Step 2: Calculate the diode small-signal resistance $\mathbf{r_d}$:

$$r_D = \frac{nV_T}{I_D} = \frac{0.025}{0.0029} = 8.6\Omega$$

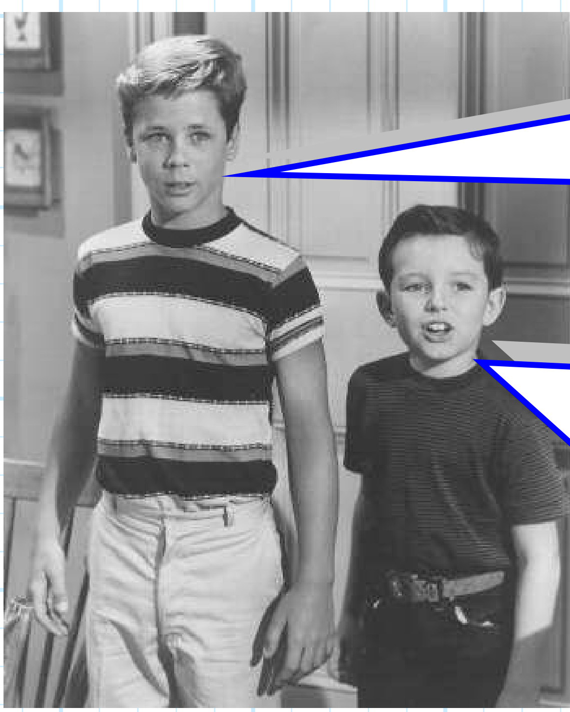
Note since the junction diodes are **identical**, and since each has the **same** current I_D =2.9 mA flowing through it, the small-signal resistance of each junction diode is the **same** (r_D=8.6Ω).

Step 3: Replace junction diodes with **small-signal PWL model**



Step 4: Determine the **small-signal circuit**.

This means turn off the 5 V source **and** the V_{D0} sources in the PWL **model** !

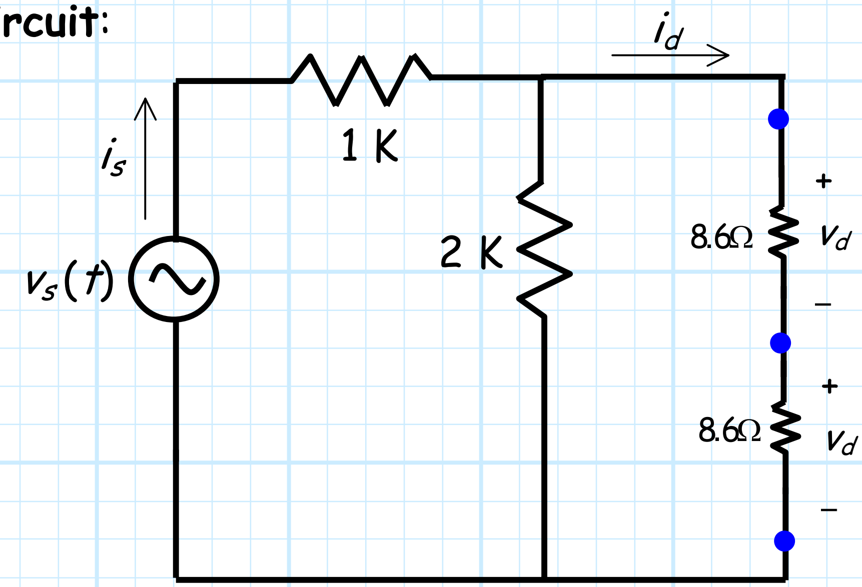


Q: *Jeepers! How can we turn off the V_{D0} sources in the PWL model? We* ***haven't*** *yet determined their* ***value!?!***

A: *Gosh Wally, don't you see! Since we're just going to set these DC sources to* ***zero*** *(i.e., $V_{D0}=0$) anyway, there is* ***no*** *reason to calculate their voltage values!*

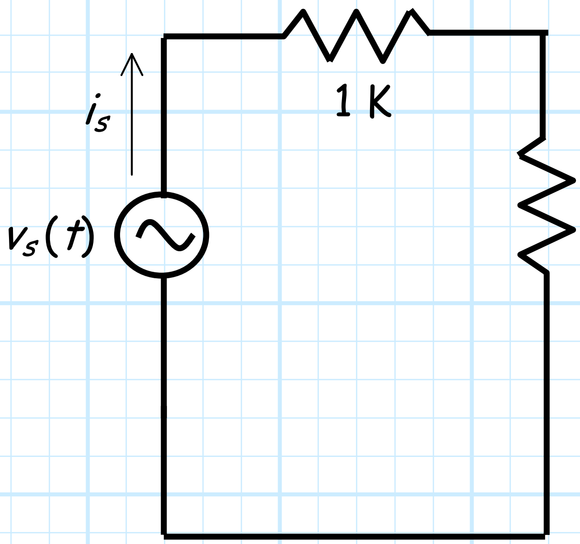
That's right! There is **no need** to determine the value of PWL model sources V_{D0}.

After turning off all DC sources, we are left with our **small-signal circuit**:



Step 5: **Analyze** the small-signal circuit.

Combining the parallel resistors, we get:

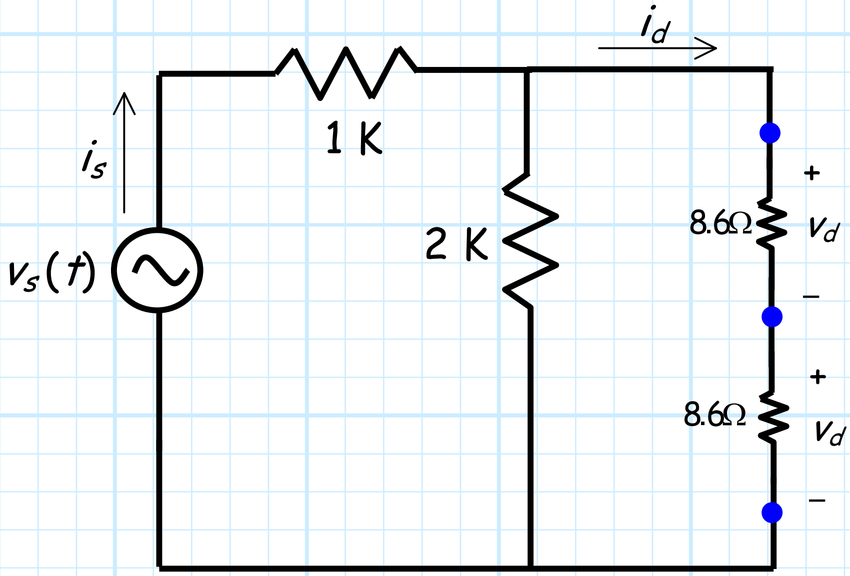


Therefore i_s is:

$$i_s(t) = \frac{v_s(t)}{1.0 + 0.0169}$$

$$= 9.83 \sin \omega t \quad \mu A$$

We can now find i_d using **current division**:



$$i_d(t) = i_s(t)\left(\frac{2}{2+0.0169}\right)$$

$$= 9.75 \sin \omega t \quad \mu A$$

And the **small signal diode voltage** is therefore:

$$\begin{aligned} v_d(t) &= i_d(t)\, r_d \\ &= 9.75(8.6) \sin \omega t \quad \mu V \\ &= 83.85 \sin \omega t \quad \mu V \end{aligned}$$